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2023 KPS Spring Meeting

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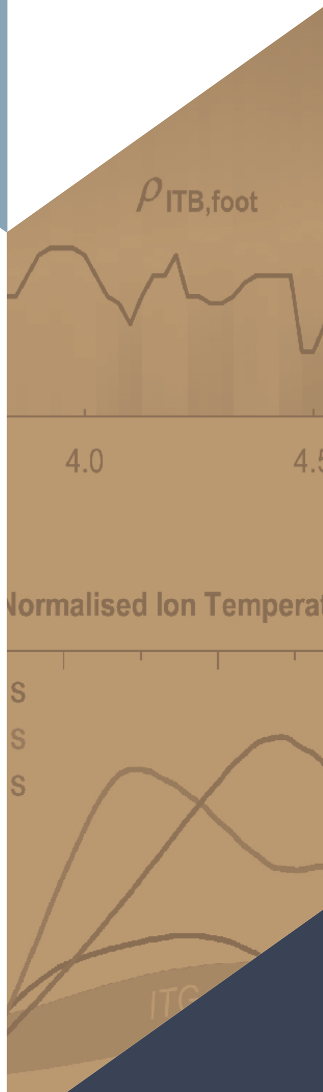

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Oral session abstract

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

A1.01

Quasiparticle-like photonic topological textures

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Abstract:

Photons can host topological textures in electromagnetic waves, which carry complex distributions of spin and orbital angular momentum of light. The excitation of those photonic topological textures has relied on structural singularities rather than underlying interactions, which restricts the dynamic and interactive characteristics. In this talk, we will discuss the quasiparticle-like excitation of photonic topological textures based on the gradient-thickness optical cavity. At the non-trivial topological phase of a given system, reflection singularities emerge in the parameter space of dielectric layer thicknesses, which induces the spiral phase distribution. Depending on the number of dielectric layers, the dimension of parameter space varies from 2-D, 3-D, and even d-D, which enables demonstrating real-space optical vortices, optical vortex ring/line, and hyper-space optical vortices. Under the external electric or magnetic bias, the optical singularities showed topology-dependent dynamics and the creation/annihilation of vortex-antivortex pairs. We expect the investigation of quasiparticle-like optical singularities will pave a way in the study of spontaneous generation of photonic skyrmion and higher-order optical vortices.

Keywords:

Topological photonics, Optical vortices, Topological phase, Quasiparticle, Synthetic dimension

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

A1.02

Scaling behavior of optical helicity of surface plasmon polariton

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Abstract:

Surface plasmon polariton is well known to support the chiral evanescent field, which has been extensively utilized for chiral light-matter interaction and spin-momentum locking. However, the degree of circular polarization of the field is not unity; rather varies depending on the system, and the governing law of the phenomena is not yet investigated. In this study, we theoretically studied the scaling behavior of the optical helicity of surface plasmon polariton in 1D (layered) and 2D (waveguide) plasmonic systems. We found that the optical helicity, normalized spin angular momentum per photon, solely depends on the effective refractive index (n_{eff}) of a given optical mode and background refractive index in a 1D system, regardless of incident frequency and structural/material parameters. For high n_{eff}, the optical helicity strictly follows power law scaling with the exponent of τ = -4. We extended this analysis into a 2D system, where the optical helicity in both out-of-plane and in-plane directions well follows the power law scaling with different exponents. Based on the reciprocal theorem, we also found out that the directional coupling efficiency of the chiral emitter also follows the power-law scaling behavior. We believe that our study opens new perspectives in spin-dependent light-matter interactions, such as valley-dependent light routing and spin-momentum locking.

Keywords:

Optical helicity, Surface plasmon polariton, Power-law scalability

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

A1.03

Universal emission characteristics of upconverting nanoparticles revealed by single-particle spectroscopy

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Abstract:

Upconverting nanoparticles (UCNPs) have been extensively studied in nanophotonics and biomedical applications due to their unique ability to absorb near-infrared photons and emit visible and/or ultraviolet light. However, due to their complex internal energy transfer and the lack of standardized single-particle spectroscopic platforms, it is a great challenge to establish a unified view of their emission properties to elucidate the underlying photophysics of these materials and expand their applications. In this presentation, using a single-particle irradiance-dependent imaging platform, we show that the emission properties of Yb^{3+}, Tm^{3+}-doped UCNPs are universal for the three emission bands, indicating that the emission characteristics can be separately described by size-dependent and concentration-dependent behavior. We also analyze the emission of UCNPs sensitive to Tm^{3+} doping concentration by comparing the critical distance of dipole-dipole interaction with the interionic distance. These findings provide insight into the interionic energy transfer between lanthanide ions, which could lead to brighter UCNPs and their broader applications.

Keywords:

rare-earth elements, lanthanides, dipole-dipole interaction, correlative light-electron microscopy

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

A1.04

All-optical control of high-purity trions in nanoscale waveguide

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Abstract:

The generation of high-purity localized trions, dynamic exciton–trion interconversion, and their spatial modulation in 2D semiconductors are building blocks for the realization of trion-based optoelectronic devices. Here, we present a method for the all-optical control of the exciton-to-trion conversion process and its spatial distributions in a MoS_2 monolayer. We induce a nanoscale strain gradient in a 2D crystal transferred on a lateral metal–insulator–metal (MIM) waveguide and exploit propagating surface plasmon polaritons (SPPs) to localize hot electrons. These significantly increase the electrons and efficiently funnel excitons in the lateral MIM waveguide, facilitating complete exciton-to-trion conversion even at ambient conditions. Additionally, we modulate the SPP mode using adaptive wavefront shaping, enabling all-optical control of the exciton-to-trion conversion rate and trion distribution in a reversible manner. Our work provides a platform for harnessing excitonic quasiparticles efficiently in the form of trions at ambient conditions, enabling high-efficiency photoconversion.

Keywords:

All-optical control, Exciton-to-trion conversion, MIM waveguide, Plasmonic waveguide

Adaptive tunable gap-enhanced Raman scattering (GERS) via 1D flexible Au nanogap

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Abstract:

Gap-enhanced Raman scattering (GERS) allows sensitive observations of chemical properties of various materials through the highly localized optical fields and gap plasmon resonance attributed to the plasmonic nano-structures. However, gap plasmon resonance excited by the static nano-gap structures has a narrow resonance band for enhancing target Raman signals. Here, we present the adaptive tunable GERS platform to selectively enhance and modulate the different vibrational modes via 1D active flexible Au nano-gap, with adaptive optical control. We demonstrate tunability of gap plasmon resonance >1,200 cm^{-1} range by engineering the gap width, facilitated by mechanical bending of the polyethylene terephthalate (PET). We confirm that the tuned GP resonance selectively enhances different Raman spectral regions of Brilliant Cresyl Blue (BCB) molecules. In addition, we dynamically control GERS intensity by manipulating the coupling efficiency of the excited photons and the electrons in nano-gap, enabled by the wavefront shaping. For these experimental results, we also demonstrate the simulation results with theoretical models, exhibiting the quantitative mechanical and optical properties of 1D flexible nano-gap, as well as the advantage in high-speed bio-medical sensing. This work provides a flexible nano-gap platform for observing and controlling the enhanced chemical responses of various materials with dynamic tunability.

Keywords:

Gap-enhanced Raman scattering, flexible device, plasmonic structure, adaptive optics

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

A1.06

Maximizing Second Harmonic Generation through simultaneous phase and mode matching in CdS nanobelts waveguides

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Abstract:

To implement photonic integrated circuits that process information using light, circuit components that control light with light, such as optical switches and optical transistors, are essential. CdS is one of the noncentrosymmetric crystalline materials with a large value of $\chi^{(2)}$ that indicates second-order nonlinear optical effect such as second harmonic generation(SHG), and it can be synthesized using CVD into nanostructures such as nanowires and nanobelts in subwavelength-scale. It is known that using very thin CdS nanowires with diameters of 80 nm or less can automatically satisfy phase matching conditions. However, in such structures, the mode overlap between the fundamental and the second harmonic is very small, leading to the problem that the second harmonic wave is not effectively generated. In this study, we investigated the effective refractive index and mode profiles of various TE and TM optical waveguide modes propagated through CdS slab waveguides composed of synthesizable CdS nanobelts with thickness near 300 nm. Based on this, we explored structures that can maximize the efficiency of nonlinear second harmonic generation through simultaneous phase and mode matching. This structure can be applied to the development of optical devices such as optical switches or nonlinear optical circuits using actual nonlinear optical processes in the future.

Keywords:

SHG, CdS nanowires and nanobelts, phase-matching, mode overlap

Metasurface-based multi-color holography using depth-division multiplexing method

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Abstract:

Metasurface-based multi-color holography has been widely studied in various ways to overcome the limitations of conventional optical holography that requires bulky and complicated setups. In this report, we propose and numerically demonstrate an efficient method to generate multi-color holograms by applying a depth-division multiplexing technique to dielectric metasurface. The designed metasurface consists of two-dimensional array of single-sized anisotropic TiO_2 meta-atoms that manipulate the phase of transmitted light by rotating the orientation of the meta-atoms based on wavelength-independent geometric phase. The structural parameters of metasurface are optimized using systematic finite-difference time-domain simulations, resulting in high cross-polarization transmission efficiency of > 82% is simultaneously achieved at all three primary colors selected as light sources. Since the positions of the multi-plane hologram images generated by the metasurface with the designed phase profile are determined by the wavelength of the plane wave light source, a multi-color image in which three component color images are superimposed can be obtained at a specific position under multi-wavelength light illumination. Both the hologram image obtained by three-dimensional finite-difference time-domain simulations and the numerically reconstructed image by Fresnel transformation agree well with the original target image, indicating that the proposed method is effectively creating multi-color hologram images. This technique can be combined with tunable/reconfigurable metasurfaces to realize dynamic color meta-holograms, and will be useful for applications such as virtual reality, flat displays, or optical communications.

Keywords:

meta-holography, metasurface, color holography

A3.01

Multi-level switching tuning of floating gate memory(FGM) based on two-dimensional materials by tunnel layer(hBN) control

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Abstract:

Today, with the evolution and development of various electronic devices, various next-generation memory devices having advantages of high density, low power consumption, and simple manufacturing are attracting much attention. In particular, a lot of research has been conducted on a memory device capable of obtaining various numbers of bits by changing a resistance value according to an input voltage in a single cell. Recently, research on a memory device based on a two-dimensional material with little electrical change in physical change is attracting attention.
In this study, a multi-level switching floating gate memory (FGM) device based on a two-dimensional material was fabricated, and a method for tuning the multi-level switching characteristics by control the tunnel layer (hBN) was further presented.

Keywords:

Two-dimensional materials, Multi-level memory, Floating gate memory, hBN thickness

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

A3.02

Realization of Noise Suppression and Signal Improvement via Separated Imprinting Process and Non-Fullerene Acceptors Design for Efficient Organic Photodetectors

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Abstract:

Organic photodetector devices (OPDs) are getting a lot of attention as a substitute for conventional PDs in image sensor markets owing to tunable properties according to their structural design. OPDs are greatly affected by both noise and signal. However, noise, such as dark current, does not discover generation source in OPD structure.
In this research, we introduce photosensitive layers composed of non-fullerene acceptors and develop newly separated imprinting process to elucidate a cause of dark current and improve the performance of OPDs.
We utilize polyurethane acylate (PUA) to the separated imprinting process, because control of the surface property of the medium is required to minimize interfacial wettability with a material. We applied the transfer process to formation of both fullerene- and non-fullerene-based sensitive layer.[1,2] The OPD with transferred sensitive layer showed a superior durability owing to the morphology stabilization. Furthermore, the morphology inversion caused by the separated imprinting contributes to suppression of dark current and enhancement photocurrent due to the favorable energy structure.
In order to investigate the difference in dark current, OPDs are compared according to the types of acceptors.[3] The non-fullerene acceptor-based OPDs show a high detectivity and a faster response time, because of the excellent dark current suppression of the carrier injection and the low trap density of non-fullerene acceptor. This work provides a strategy for promising next-generation technologies related with organic photodetector, and at the same time can make a significant contribution to increase of process yield and reduction of unit prices.

[1] W. Jang et al, Long-term-stable Transferred-organic-photoactive-layer-based Photodiode with Controlled Wetting through Interface Stabilization, ACS Appl. Mater. Interfaces 2018, 10, 38603.
[2] M.S. Kim and W. Jang et al, Morphology Inversion of a Non-Fullerene Acceptor via Adhesion Controlled Decal-Coating for Efficient Conversion and Detection in Organic Electronics, Adv. Funct. Mater. 2021, 38, 2103705.
[3] W. Jang et al, Superior Noise Suppression, Response time, and Device Stability of Non-Fullerene System over Fullerene Counterpart in Organic Photodiode, Adv. Funct. Mater. 2020, 30, 2001402.

Keywords:

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

A3.03

Electronic structure of bismuth quasicrystal grown self-assembly on 2H-MX_2 substrates

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Abstract:

Recently emergent higher-order topological insulators (HOTIs) have expanded into quasicrystal, photonic, phononic, and circuit systems (1). Here, we report that a mirror and rotational crystal symmetries combination leads to quasicrystalline Bi(110)-to-(111) structural transition. The self-assembly reconstructed six rotational Bi(110) domain boundaries exhibit the 0-dimensional (D) corner states of the Fermi surface (FS). Moreover, the layered thickness of bismuth over four layers induces the Bi(111) quasicrystalline structure transition by changing into the isotropic 12-fold 1D lines emanating from the central 2D FS. The quasi-1D helical edge states are attributed to the rotational domain boundaries, i.e., coupled hinge states (2,3).

References
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[2] F. Schindler, et al., Higher-order topology in bismuth. Nat. Phys. 14, 918-924
[3] R. Stühler, A. Kowalewski, F. Reis, D. Jungblut, F. Dominguez, B. Scharf, G. Li, J. Schäfer, E. M. Hankiewicz, R. Claessen, Effective lifting of the topological protection of quantum spin Hall edge states by edge coupling. Nat. Commun. 13, 3480

Keywords:

Higher-order topological insulator, quasictrystal, symmetry

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

A3.04

Highly efficient hybrid light-emitting transistors incorporating MoO_x/Ag/MoO_x semi-transparent electrodes

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Abstract:

Light-emitting transistors (LETs) have recently emerged as a promising type of optoelectronic device which incorporates the switching function of a transistor with a light-emitting function. Zinc oxynitride (ZnON) based organic–inorganic hybrid LETs (HLETs) have recently shown excellent characteristics in this context, including very low threshold voltage (<5 V), high mobility (up to 5.3 $cm^2V^{-1}s^{-1}$) and brightness of 1.64 × 10^4 cdm^{-2}, a significant improvement compared to organic based LETs. Despite remarkably improved performance, the external quantum efficiency (EQE) of HLETs was ~0.1%, leaving room for additional improvement. To overcome the low EQEs of HLETs, we have investigated the electrical and optical characteristics of HLETs incorporating MoO_x/Ag/MoO_x semi-transparent electrodes with variable Ag layer thickness. HLETs with the architecture MoO_x/Ag/MoO_x (8/15/15 nm) exhibited an electron mobility of 1.06 $cm^2V^{-1}s^{-1}$ with on/off ratio of 1.05 × 10^4, a maximum brightness of 2.09 × 10^4 cdm^{-2} and a greatly improved EQE of up to 3.31%. This study provides valuable information about the electrical and optical properties of HLETs with oxide/metal/oxide (OMO) semi-transparent electrodes and contributes towards a comprehensive understanding of the optoelectronic behavior of LETs.

Keywords:

Hybrid light-emitting transistors , Zinc oxynitride (ZnON), semi-transparent electrodes, oxide/metal/oxide structure

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

A4.01

2D/2D and 2D/3D Heterostack FETs for Multifunctional Electronics

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Abstract:

Applications of two dimensional (2D) semiconductors have been much oriented to various electron devices, which include multivalue field-effect transistors (FETs). The 2D channel multivalue FETs may resolve power consumption issue in modern integrated circuits. Several n-channel devices are thus reported along with few p-channel devices. Here, both n- and p-channel multivalue FETs are fabricated using p-$MoTe_2$/n-MoS_2 heterostack channel architecture, where either p- or n-channel ternary value FET is reproducible by switching the stacking order of p- and n-channel layer. Main ternary value mechanism originates from resonant tunnel injection and channel inversion which take place during device operation. For a state-of-the-art device application in 2D electronics, quaternary NAND logic circuit is first time demonstrated by integrating two ternary n-channel FETs and complementary ternary inverter is also fabricated by integrating multivalue p-channel and plain n-channel FET.

Beyond multivalue logic devices, we also demonstrate multilevel long-term memory functions operating at maximum 7 V under minimum 60 μs-short pulse, based on van der Waals heterostack n-$MoSe_2$/n-MoS_2 channel field effect transistors (FETs), to cope with the fourth industrial revolution demanding more efficient data process, memory capacity, and synaptic memory. For multilevel memory mechanism, trap density at the heterostack interface is responsible.

Other types of stack FETs with $MoSe_2$/$MoSe_2$ or $MoTe_2$/Ga_2O_3 junction are to be discussed at the presentation in detail.

Keywords:

2D/2D heterostack, multivalue and multilevel

A4.02

Non-volatile memory and switching devices with van der Waals crystals

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Abstract:

Layered van der Waals semiconductors show a wealth of exotic physical phenomena when confined into the 2D lattice, and the relevant electronic devices thus far have defined themselves as a promising building block of nanoelectronics owing to the near-atom thickness, superior electrostatic control, and adaptable device architecture. This talk will present highlights how such emerging materials can further benefit from materials processing and a new device configuration. I will first introduce a van der Waals integrated synaptic transistor combined with the multiply stacked floating gate storage nodes. It has excellent non-volatile memory performance, and this, in turn, enables highly effective modulation of trapped charge density, so it exhibits improved weight update profile in long-term potentiation/depression synaptic behavior as an electronic synapse. Next, I will talk about gas-phase synthetic strategy for wafer-scale, thickness-controlled, and low-temperature deposition techniques to bring such new electronic functionalities into device-level applications. To be specific, we demonstrate the wafer-scale growth of mono-elemental 2D tellurium (Te) thin films using an annealing-free, low-temperature ALD process. ALD-grown Te films are employed for fabricating 2D/2D and mixed-dimensional 2D/3D vertical p-n heterojunction diodes exhibiting well-defined current rectification. Additionally, we showcase an ALD-Te based selector device with fast switching time, selectivity and low Vth.

Keywords:

2D devices, vdW heterostructures, Floating gate memory, Selector

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

A4.03

Black Phosphorus Homojunction Multi-Level Transistors

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Abstract:

The multi-level logic circuit is a technology that can simultaneously reduce the area of a circuit, the complexity of circuit connection, and power consumption compared to conventional binary logic. This can amplify the amount of information that can be computed within a limited space. As interest in ultra-power-saving technology increases worldwide, the importance of designing new concept devices and system circuits, such as neuromorphic devices and architectures, is being emphasized. However, due to the difficulty of developing a fundamentally new mechanism for microcurrent control, many multilevel logic device technologies have not been reported. Most of the ternary logic transistors reported so far are NMOS, and examples of PMOS ternary transistors reported are extremely rare. In this talk, we present bipolar multi-level transistors based on black phosphorus homojunction.

Keywords:

Multi-level transistors, Bipolar transistors, 2D materials

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

A5.01

Progressive and stable synaptic plasticity with attojoule energy consumption by the interface engineering of a metal/ferroelectric

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Abstract:

In the era of “big data”, the cognitive system of the human brain is being mimicked through hardware implementation of highly accurate neuromorphic computing by progressive weight update in synaptic electronics. Low-energy synaptic operation requires both low reading current and short operation time to be applicable to large-scale neuromorphic computing systems. In this study, we implement an energy-efficient synaptic device comprising a Ni/Pb($Zr_{0.52}Ti_{0.48}$)O_3 (PZT)/0.5 wt% Nb-doped $SrTiO_3$ (Nb:STO) heterojunction with a low reading current of 10 nA and short operation time of 20–100 ns. Ultralow attojoule operation up to 5.5 aJ at a synaptic event, which is significantly lower than the energy required for synaptic events in the human brain (10 fJ), is achieved by adjusting the Schottky barrier between the top electrode and ferroelectric film. Moreover, progressive domain switching in ferroelectric PZT successfully induces both low nonlinearity/asymmetry and good stability of the weight update. The synaptic device developed here can facilitate the development of large-scale neuromorphic arrays for artificial neural networks with low energy consumption and high accuracy.

Keywords:

Energy efficiency, Low reading current, Variability, Neuromorphic computing, Ferroelectric

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

A5.02

Investigation of charge transport at the grain boundaries in alkali doped flexible Cu(In,Ga)Se_2 thin film solar cells

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Abstract:

In recent years, efficiency of flexible Cu(In,Ga)Se_2 (CIGS) thin film solar cells has been boosted over 22% by optimizing the alkali doping [1]. To maximize its performances, materials properties with incorporation of various alkali elements should be thoroughly studied. Herein, four CIGS thin film samples with various alkali post deposition treatment (PDT) including heavy alkalis (NaF, NaF+RbF, NaF+CsF) were prepared to investigate the effect of alkali doping on the surface charge transport. To characterize the formation of surface current, conductive-atomic force microscopy was conducted and CIGS with alkali PDT presented the enhanced current flow at the surface compared to the CIGS without alkali. Additionally, Kelvin probe force microscopy (KPFM) was utilized to probe the surface potential and the results showed that charge barrier formed at the grain boundaries (GBs). However, CIGS with heavy alkali did not show significantly increased or decreased formation of charge barrier indicating that the main alkali enhance the charge barrier was Na. Formation of charge barriers (i.e. surface potential bending) at the GBs mainly formed by charged defects therefore, incorporation of heavy alkali were expected not to change the charges of defects at the GBs. For the future work, stress-induced changes in charge transport will be investigated through atomic force microscopy-based measurements.

Keywords:

Cu(In,Ga)Se2 thin film solar cells, Alkali incorporation, Kelvin probe force microscopy, Conductive-atomic force microscopy, grain boundaries

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

A5.03

Study of energy storage devices: low-temperature batteries and conductive transparent films

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Abstract:

In various fields using batteries, such as electric vehicles, hybrid electric vehicles, and aerospace, batteries with exceedingly stable characteristics at low temperatures are required, but commercial lithium-ion batteries are generally unstable at low temperatures.
In this talk, we present nanomaterials for low-temperature batteries, in which $Li_3V_2(PO_4)_3/C$ was used as a cathode active material to compare lithium-ion diffusion at active electrode materials between two different electrolytes. We will discuss its significance for low-temperature Li-ion batteries.
We also present a transparent and flexible conductive film made from carbon nanotubes (CNT) and polyimide (PI) for flexible electronic applications. We demonstrated their high electrical conductivities, which could be useful for flexible electronic applications and energy storage.

Acknowledgement:
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Keywords:

low temperature battery, Li-ion battery, cathode material, polyimide film, low temperature electrolytes

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

A5.04

Optical spectroscopy study of the passivation effect by laser scribing process in the hybrid perovskite module

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Abstract:

For increasing the efficiency and attaining better chemical stability, intense research activities on perovskite solar cell materials have been performed over the last few years. In particular, the conversion efficiency of photovoltaic devices based on hybrid organic inorganic perovskites (HOIPs) have reached ~26% recently, but there is still an unresolved issue of instability in ambient conditions remaining. The purpose of this study is to identify the origin of the improved stability and efficiency induced by scribing the $Rb_{0.05}(FA_{0.95}MA_{0.05})_{0.95}Pb(I_{0.95}Br_{0.05})_3$ perovskite module with laser, we have observed improved stability and efficiency. By using micro Raman scattering spectroscopy and photoluminescence (PL) mapping, we could find local changes caused by laser irradiation. Our results strongly suggests that the improved characteristics of the module can be attributed to the passivation effect occurring as the byproduct of laser scribing process.

Keywords:

Perovskite, Raman, PL, Passivation

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2023-04-19 - 2023-04-21

A5.05

Light-driven polarity control of polar metal

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Abstract:

We investigate the light-driven functionality of the flexo-polar metal phase in $SrRuO_3$ thin film grown on $SrTiO_3$ (111) substrate via ultrafast optical techniques. By taking optical second harmonic generation (SHG), we characterize the thin film's crystal symmetry and orientation. The clear six- and three-fold patterns of azimuth-angle dependent SHG intensity are well-fitted by the tri-monoclinic domains model. We study photoinduced carrier dynamics and symmetry change by tracing the time-resolved reflectivity and SHG intensities. Transient optical reflection changes reflect that the photo-excited carrier decays through three channels, i.e., electron-electron, electron-phonon, and thermal interactions. The transient SHG intensity changes show different behaviors depending on the azimuth angle, displaying two-experimental findings; 1) Two- or three channels are involved in ultrafast symmetry dynamics depending on the pump polarization direction. 2) The six-fold symmetry is lowered to two-fold symmetry, and it can be controlled by light polarization. We discuss the photo-induced change of polarity of polar metallic phase and their functionality.

Keywords:

polar metal, light-matter interaction, oxide

A5.06

Composition induced structural phase transitions and luminescence properties of Eu^{3+}-doped A_2LaNbO_6 (A = Ca, Sr, and Ba) double perovskite

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Abstract:

We explored the relations of the luminescent properties to structural phase transitions in Eu^{3+} doped double perovskite A_2LaNbO_6 (A = Ca, Sr, and Ba). The structural phase transition according to A-site ions were clearly identified through structural analysis on X-ray diffraction by Rietveld refinement. The photoluminescence and the cathodoluminescence from Eu^{3+} were found to significantly change in relation to the structural transformation. The Eu^{3+} doping dependence of structure and emission properties on Ca_2LaNbO_6 was explored in detail. The photoluminescence quantum yield was found to be up to 83% under 465nm photoexcitation in Eu^{3+} doped Ca_2LaNbO_6. The phosphors-based white LED was demonstrated by integrating a blue LED chip, YAG:Ce, and Eu^{3+} doped Ca_2LaNbO_6.

Keywords:

Eu3+, Luminescence, Double Perovskite, Structural phase transition

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A6.01

Dielectric Constants Exceeding 25,000 in Homoepitaxial $SrTiO_3$ Films Grown by Hybrid Molecular Beam Epitaxy

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Abstract:

$SrTiO_3$ (STO) is an incipient ferroelectric perovskite oxide for which the onset of ferroelectric order is suppressed by quantum fluctuations. This property results in a very large static dielectric constant of ~20,000 at liquid He temperature in bulk single crystals. However, the low-temperature dielectric constant of epitaxial STO films is typically a few hundred to a few thousand, even though its quality is similar to that of bulk single crystals.

In this talk, we demonstrate intrinsic dielectric constants of an unstrained STO (001) film exceeding 25,000 at low temperature using a homoepitaxial capacitor structure of the form n-STO/undoped STO/n-STO (001) grown by hybrid molecular beam epitaxy method. A careful analysis of the temperature-dependent dielectric constants reveals that the n-STO/undoped STO interface plays a vital role in determining the dielectric properties. Furthermore, using different dopant types in n-STO, we reveal that it is the depleted side of the interface, i.e. n-STO that governs the overall measured dielectric constant. A detailed growth study combined with the temperature- and frequency-dependent dielectric measurement will be presented.

Keywords:

SrTiO3, Dielectric Constant, Ferroelectricity, Antiferrodistortive Transition

A6.02

Neutron Diffraction Study on Disorder Effects in Lead-free Halide Double Perovskite $Cs_2AgBiBr_6$

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Abstract:

$Cs_2AgBiBr_6$ has attracted attention as a candidate for a non-toxic photon-energy conversion material. Its crystal structure maintains a cubic (Fm-3m) structure at temperatures above ~120 K, so it is a good system to examine the delicate disorder parameters (either from thermal vibration or site disorders). We performed neutron powder diffraction on an ordered $Cs_2AgBiBr_6$ (red) and a site-disorder-induced $Cs_2AgBiBr_6$ (black). The results of the Rietveld analyses show that overall the thermal factors increase with increasing temperature above 150 K for both systems. It is also observed that the site-disordered sample has only a slightly higher degree of structural disorders. These confirm that the site disorder in the black sample did not affect the crystal structure much, implying that some charge instability of the cations in the disordered sample (rather than the structural change) might be responsible for the different optoelectronic properties in $Cs_2AgBiBr_6$.

We thank Fuxiang Ji and Feng Gao for providing the samples, and Takashi Saito and Sanghyun Lee for supporting the ND measurement and interpretation.

Keywords:

Double Perovskite, Cs2AgBiBr6, Neutron Diffraction

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A6.04

Observation of Interfacial Phonon Modes of Ferroelastic WO_3 Domain Wall by Angle-resolved Polarized Raman Spectroscopy

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Abstract:

The twin wall between two different ferroelastic orientation states in WO_3 films has a symmetric structure originating from spontaneous strains of adjacent orientation states. Here, we present the observation of domains and walls through Angle-resolved polarized Raman scattering. Remarkably, we find that a low-energy Raman mode is largely enhanced at the twin walls, of which the width can be presumed to be ~ 25 nm from a diffusive X-ray superlattice peak. The interfacial effect on the enhancement of Raman signal per unit area is estimated to be three times larger than the contribution of domains. This phenomenon is explained based on the fact that the Raman scattering tensor is slightly modified by a compatibility between the ferroelastic spontaneous strains. The finding provides a new avenue into the lattice dynamics of ferroelastic twin wall.

Keywords:

WO3, Raman, ferroelastic, domain wall, spontaneous strain

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2023-04-19 - 2023-04-21

A6.05

A-site dependent metastable polar phases from polarization-compatible octahedral rotations in perovskite $AZrO_3$ (A=Ca,Sr)

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Abstract:

We investigate the structural, electronic, and ferroelectric properties of ABO_3 perovskites using first-principles density functional theory. We focus on the effect of different atomic radii of the A-site on the metastable ferroelectric phases. The initial structures are constructed with octahedral rotation patterns commonly observed in bulk perovskite oxides where unstable phonon modes in each rotation pattern are systematically investigated to search for the metastable ferroelectric structures. We find that $CaZrO_3$ has metastable polar structures, whereas no metastable polar structures are found in $SrZrO_3$. The electronic and ferroelectric properties of the low-energy metastable polar phase of $CaZrO_3$ are further investigated, having a sizable band gap of 4.5 eV with a polarization of 53 $\mu C/cm^2$. We expect that the identified metastable polar phase can be stabilized in a thin-film/substrate geometry by utilizing the interfacial interaction.

Keywords:

first-principles calculation, ferroelectricity, dielectric properties, perovskite oxides, oxide heterostructures

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2023-04-19 - 2023-04-21

A6.06

Bidirectional Dynamic Mechanical Writing of Polar Bubbles

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Abstract:

Topological structures of ferroelectric polarization have been increasingly explored because of their novel properties for next-generation electronic applications. Recent studies have demonstrated various polar topological structures, including flux-closure, vortices, bubbles, skyrmions, and waves. However, they have been mainly discovered in superlattices, strain-relaxed geometrics, and defect-containing films driven by unscreened boundary conditions, flexoelectric effects, and strain fields. Here, we demonstrate that skyrmion-like centre-type polar bubble domains are created by dynamic mechanical forces of vibrational tapping (V-Tapping) using scanning probe microscope (SPM) tips in compressively strained $BiFeO_3$ (BFO) thin films with a morphotropic phase boundary. These domains are mechanically created with the iso-symmetric structural phase transitions between the rhombohedral-like monoclinic phase (R-phase) and the tetragonal-like monoclinic phase (T-phase) and form specific lattice structures. V-Tapping above a threshold tapping force can bidirectionally switch ferroelectric polarization, which is the first observation of bidirectional mechanical polar switching via SPM. The upward switching by V-Tapping may result from the upward quadratic second order flexoelectric effect by large strain gradients and/or phase transition-related phenomena, while the downward switching may be attributed to the downward flexoelectric effect. The polar topological states are selectively written, can be mechanically or electrically erased, and have long retention properties. Our study provides the observation of polar topological structures based on comprehensive dynamic mechanical switching mechanisms and opens a new era for bidirectional mechanical switching of ferroelectric polarization for non-volatile magnetoelectric devices.

Keywords:

Ferroelectrics, Morphotropic phase boundary, Strain gradient, Flexoelectricity, Polar topological bubble

2023 KPS Spring Meeting
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A6.07

Study on polar chiral structures of ferroelectrics using resonant elastic x-ray scattering(REXS)

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Abstract:

Recently, in the SrTiO3/PbTiO3 heterostructure, a polar chiral domain structure such as a polar vortex or skyrmion was discovered. It is highly likely to be used as an ultra-integrated memory device due to its small domain size of several tens of nanometers, and it is very important to understand its structure. To study this structure, high-resolution transmission electron microscopy (HR-TEM) has been mainly used. Although this method is a powerful method that can directly observe small domain sizes, it has two limitations: it can only measure a two-dimensional projection of atomic positions, and the sample must be destroyed. In order to sufficiently confirm the application potential of the polar chiral structure, a method to study the 3D structure non-destructively is needed. We use the resonant elastic x-ray scattering (REXS) method for this purpose. REXS is a method of tunning the energy of x-rays to the absorption edge of a specific atom and observing the change in scattering intensity according to the polarization of x-rays (x-ray circular dichroism, XCD). We measured the REXS intensity by changing the incident angle, which is the angle between the incident x-ray and the sample surface, and the sample tilt angle, and developed a theoretical framework that can quantitatively analyze the experimental data. As a result, it was shown that the detailed three-dimensional structure of the polar chiral structure and its chirality can be studied using our method.

Keywords:

ferroelectric vortex, ferroelectric skyrmions, polar chiral structure, resonant elastic x-ray scattering, REXS

A6.08

Observation of filamentary conduction in an oxide thin film by Raman microscopy

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Abstract:

Ternary oxides such as $SrTiO_3$, $(Bi,Ca)FeO_{3-d}$ show filamentary conduction where oxygen redox reactions occur in localized filament-shaped regions. In $(Bi,Ca)FeO_{3-d}$ epitaxial thin films, dark filaments are generated from positive electrode and propagate to ground electrode in lateral devices, followed by the bulk conduction where the darkening of the sample are no longer localized within the filament. Here, we track a Raman mode near 1300 cm^{-1}, which is thought to be a second-order oxygen breathing mode, to differentiate distintive phases appearing during electroforming. We discovered new intermediate phase, which has intermediate intensity and peak position between the pristine and dark phases, near the filament. This work will give an insight about the mechanism of oxygen redox reaction and inhomogeneous topotactic transformation of perovskite oxides.

Keywords:

Raman spectroscopy, Mixed-ionic-electronic conductors, Filamentary conduction, Perovskite oxide

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

A7.01

Order-disorder phase transition driven by interlayer sliding in lead iodides

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Abstract:

A variety of puzzling phase transitions has been found in two-dimensional layered materials, but some of their atomic-scale mechanisms are hard to clearly understand. Here, we report the discovery of a phase transition whose mechanism is identified as interlayer sliding in lead iodides, a layered material widely used to synthesize lead halide perovskites. The low-temperature crystal structure of lead iodides is found not 2H polytype as known before, but non-centrosymmetric 4H polytype. This undergoes the order-disorder phase transition characterized by the abrupt spectral broadening of valence bands, taken by angle-resolved photoemission, at the critical temperature of 120 K. It is accompanied by drastic changes in simultaneously taken photocurrent and photoluminescence. The transmission electron microscopy is used to reveal that lead iodide layers stacked in the form of 4H polytype at low temperatures irregularly slide over each other above 120 K, which can be explained by the low energy barrier of only 10.6 meV/atom estimated by first principles calculations. Our findings suggest that interlayer sliding is a key mechanism of the phase transitions in layered materials, which can significantly affect optoelectronic and optical characteristics.

Keywords:

ARPES, PbI2, Phase transition

A7.02

Lippmann-Schwinger final state in circular dichroism angle-resolved photoemission spectroscopy of graphene-based materials

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Abstract:

Describing the well-known wave packet property of the final state accurately is important to calculate realistic angle-resolved photoemission spectroscopy (ARPES) spectra and circular dichroism ARPES (CD-ARPES) spectra in the dipole matrix element calculation of photoemission. Here, we suggest a proper final state that is analytically driven by solving the Lippmann-Schwinger equation to the first order for a two-dimensional ionic potential with periodically arranged Yukawa-type potentials. This analytical solution provides information on the wave function profiles of the emitted electron from the solid. These profiles are indexed by a reciprocal lattice vector and offer physical insights into the emitted electron. Furthermore, we have found that the intensity of a dichroic photoemission depends on the screening constant of the Yukawa potential. We use this final state to calculate CD-ARPES spectra on graphene-based materials, including graphene, bilayer graphene with AA-stacking, and twisted bilayer graphene. In the case of twisted bilayer graphene, we demonstrate a modified electron chirality compared to that of monolayer graphene by the interlayer interaction.

Keywords:

Final state in dipole matrix element calculation, Lippmann-Schwinger equation, Circular dichroism angle-resolved photoemission spectroscopy, electron chirality in graphene based materials

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A7.03

Dirac nodal lines in puckered honeycomb crystals

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Abstract:

The topological quantum states of matter can be characterized by the geometrical form of symmetry-enforced band degeneracy in momentum space, such as nodal points, lines, and surfaces from 2-fold to 8-fold degeneracy. We report the observation of 4-fold degenerate (Dirac) nodal lines and nearly 8-fold degenerate point in puckered honeycomb crystals, black phosphorus, and germanium sulfides. By angle-resolved photoemission spectroscopy, we reveal Dirac nodal lines in the armchair zone boundary of black phosphorus, reproduced from first principles calculations and proven by our minimal model analysis to be protected by glide-mirror symmetry. The presence of multiple glide-mirror symmetries in its binary counterpart (germanium sulfides) diversifies Dirac nodal lines, two of which come closer at the zone corner to form the nearly 8-fold degenerate point. Our results demonstrate the fundamental relation between crystal symmetries and band degeneracy with puckered honeycomb systems.

Keywords:

Band degeneracy, Puckered honeycomb, ARPES

A7.04

Frequency combs generated from strong nonlinear modes in a doubly clamped nanomechanical beam

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Abstract:

Nonlinearity is a fascinating phenomenon that offers rich physics not present in linear domain and potential for a range of applications. This nonlinearity is easily visible in nanomechanical systems, especially those with high sensitivity due to their small device sizes. We investigated nonlinearity of a doubly-clamped nanobeam at low temperature by strongly driving it. Surprisingly, we were able to observe dips appeared in certain parts of the frequency-amplitude curves and, frequency combs were detected at those points simultaneously in mechanical modes and higher harmonics signals.

Keywords:

Nanoelectromechanical system(NEMS), Frequency comb, Nonlinear dynamics

A7.05

Ballistic Transport in Single-crystalline Cu Thin Film

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Abstract:

Copper (Cu) holds fundamental significance to our everyday lives due to its excellent electrical conductivity, including other outstanding physical properties such as high thermal conductivity resulting in better heat dissipation [1]. As a result, Cu has come into the spotlight as a promising metal in electronics, semiconductor interconnection technology and electro-optics. However, due to limitation of Cu thin film growth technology, the formation of grain boundary (GB) and roughening of surface occurs. This leads to increase in electron scattering rate and degrade its conductivity. Here, We report the ballistic transport of electrons in a Hall bar device made of high-quality single-crystal Cu thin films at low temperatures. 90-nm-thick ultra-flat, GB-free single-crystalline Cu(111) film was prepared by atomic sputtering epitaxy (ASE) system and additional thermal processes [2,3]. We fabricated Hall-bar devices and measured (Van der Pauw) bend resistance with different linewidths of devices at a given thickness. We observed that bend resistance becomes negative when the linewidth of the Hall bar is 150 nm below 90 K, which implies the electron mean free path exceeding 150 nm. Our results have the potential to be applied in numerous fields such as high-speed electronics, ballistic SNS Josephson interferometer and spintronics.

References

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2. S. J. Kim et al., *Nature*, **603**, 434-438 **(2022).**
3. T. W. Ha et al., *Nat. Commun*. **14**, 685 **(2023).**

Keywords:

Single-crystalline copper, Ballistic trasnport, Negative bend resistance, Grain boundary, Mean free path

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A7.07

Magnetic and electronic properties of surface-supported Nd atoms

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Abstract:

Lanthanide atoms on surfaces are unique platforms for quantum information technologies and atomic-scale information storage [1]. The most investigated systems are Ho on MgO/Ag(100) [2] and Dy atoms on graphene/Ir(111) [3], both exhibiting magnetic lifetime of more than 1000 s below 4 K. The stability of their quantum states, as well as their electronic and magnetic configuration, stems from the interaction with the substrate. For example, the *4f* occupancy of Ho atoms on MgO/Ag(100) differs from free Ho atoms in the gas phase, whereas Dy atoms on graphene/Ir(111) retain their free atom *4f* occupation. In order to understand the origin of the magnetic stability and the quantum level structure of the *4f* shells, it is crucial to understand the role played by the electrons belonging in the more delocalized *5d6s* orbitals and their interaction with the *4f* electrons. For this purpose, we investigated the behaviour of Nd atoms on Ag(100), Highly Oriented Pyrolytic Graphite (HOPG) and Graphene/Cu(111). By means of the orbital selectivity offered by X-ray absorption spectroscopy (XAS) and X-ray magnetic circular dichroism (XMCD) techniques [4], we characterize the reorganization of electrons and magnetic moments among the different shells, namely *4f* and *5d6s* orbitals, from single atoms to the clusters, by following the spectroscopic evolution of the $M_{5,4,3,2}$ absorption edges. The results show an electronic crossover from atomic-like to bulk-like configuration by increasing the coordination of Nd atoms. The electronic crossover is also observed on the *5d6s* shells which demonstrates the strong electronic correlation between the electrons of the *4f* and *5d6s* shells.

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Keywords:

Magnetism, X-ray Absorption Spectroscopy , X-ray Magnetic Circular Dichroism, Lanthanides on surface, Quantum Information

A7.08

Investigating the domain walls of the unidirectional charge density wave in $GdTe_3$

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Abstract:

$GdTe_3$, the family of RTe$_3$ (R = Rare-earth), has been of great interest due to the coexistence of different types of broken symmetry ground states such as charge-density-wave (CDW), antiferromagnetic spin ordering, and superconductivity. A unidirectional incommensurate CDW with a partially opened gap arises from the strong electron-phonon coupling and the complex interplay between the Gd 4f states and the Te p orbitals in $GdTe_3$. It becomes superconducting with an additional CDW state under high pressure. However, CDW formation and its interplay with superconductivity remain open questions. Here, we visualize two perpendicularly aligned unidirectional CDW domains with the checkerboard CDW near the domain wall using low-temperature scanning tunneling microscopy. We also perform scanning tunneling spectroscopy to reveal the correlation between the checkerboard CDW and superconductivity. Our study reveals that the CDW in $GdTe_3$ is strongly coupled to the electronic structure providing insights into the complex interplay between CDW and superconductivity.

Keywords:

Scanning tunneling microscopy, Charge density wave, Strongly correlated material, Rare-earth tritelluride

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

A7.09

Tuning Spin Screening-State of Magnetic Molecules on Au(111) by Atomic Adsorbates

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Abstract:

Detecting and controlling spin interactions of magnetic molecules have been actively studied due to possible applications in molecular spintronic and qubit devices. On metallic surfaces, exchange interactions between molecular spins and spins of conduction electrons of substrates have been detected as Kondo resonances at Fermi level. It has been demonstrated that Kondo resonances can be tuned by small molecule bindings, but not by atomic adsorbates. Here, we demonstrate that the Kondo resonances of Co-porphyrin on Au(111) can be tuned by various magnetic atomic adsorbates and be detected using scanning tunneling microscopy and spectroscopy (STM and STS). We observed several adsorbate-induced complexes in STM images, and proposed their atomic structures based on density functional theory calculation results. Our STS results were explained with the redistribution of unpaired spins of Co-porphyrin by atomic adsorbates. Our study shows the spin states and interactions of metallo-porphyrin can be tuned by magnetic atomic adsorbates.

Keywords:

scanning tunneling microscopy, scanning tunneling spectroscopy, metallo-porphyrin, density functional theory, Kondo resonance

2023 KPS Spring Meeting
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A8.01

Theories on unique phase transitions in layered materials

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Abstract:

In this talk, we will introduce our recent studies on anomalous quantum and thermal phase transitions in layered materials. First, we reveal a Metal-to-Mott insulating transition (MIT) as a function of a number of layers in 1T-$TaSe_2$. Using our newly developed first-principles calculation method for the extended Hubbard functionals, we reveal that the intricate competition between the strong screened Coulomb interaction and kinetic energy gain across the layers is a key to the MIT here. We show that our simulations of spectroscopic signals near the MIT agree with experiments from our collaborators very well. Second, we will present a new theory on anomalous charge density wave (CDW) transition in kagome metals of AV_3Sb_5 (A = K, Rb, Cs). Using our newly developed molcular dynamics simulation tools, we uncover asynchronous condensation processes to the charge density wave states in kagome metals. We demonstrate that the CDW forms first within each layer but their phases fluctuate across the kagome layers owing to unavoidable degeneracy in energetic costs for stacking CDWs. We will discuss several consequences and experimental implications for kagome metal physics based on our discoveries of condensation of preforemd CDW orders.

Keywords:

First-principles calculations, kagome metals, transition metal dichalcogenides, phase transition, molecular dynamics simulations

2023 KPS Spring Meeting
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A8.02

Twisted bilayer magnet CrI3

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Abstract:

Twist engineering of van der Waals magnets emerges as an outstanding platform for manipulating exotic magnetic states. However, the complicated form of spin interactions in the large moire superlattice obstructs the concrete understanding of such spin systems. To tackle this problem, for the first time, we develop a generic ab-initio spin Hamiltonian for twisted bilayer magnets. Our atomistic model reveals that strong AB sublattice symmetry breaking due to the twist introduces a promising route to realize the novel non-centrosymmetric magnetism. Several unprecedented features and phases are uncovered including the peculiar domain structure and skyrmion phase induced by non-centrosymmetricity. The diagram of those distinctive magnetic phases has been constructed and the detailed nature of their transitions analyzed. Further, we establish the topological band theory of moir₩'e magnons relevant to each of these phases. By respecting the full lattice structure, our theory provides the characteristic features which can be detected in experiments.

Keywords:

twistronics, two-dimensional magnetism

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A8.03

Origin of chirality in the triple-q charge density wave semimetal 1T-$TiSe_2$

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Abstract:

Chiral electronic orders provide a route to unconventional physical phenomena, but their realizations in achiral lattices pose a fundamental challenge to our current understanding of structure-property relationship in quantum matters. We investigate the case of the archetypal charge density wave (CDW) system 1T-$TiSe_2$, in which charge density modulations and atomic displacements of the same wave-vectors lead to different space group symmetries owing to the different symmetry transformation properties of the scalar (charge) and the vector (displacement) orders. Specifically, these atomic displacements alone are incapable of breaking inversion symmetry when the CDW acquires chirality. We unravel the mechanism whereby this symmetry inconsistency is resolved through an induced lattice distortion that transforms as the combined symmetry of the two orders. Using Raman spectroscopy and inelastic x-ray scattering, we show that all but translation symmetries are broken at the onset of its triple-q CDW order, at a level unresolved by state-of-the-art diffraction techniques. While this mechanism is generic for CDWs with 2x2x2 superstructures, our result points to possible violation of the Neumann's principle in the two-dimensional limit of monolayer van der Waals CDW materials in which the periodicity doubling along the third axis is absent.

Keywords:

chirality, charge density wave, inelastic x-ray scattering, Raman spectroscopy, resonant x-ray diffraction

A9.01

Spontaneous breaking of mirror symmetry beyond critical doping in Pb-Bi2212

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Abstract:

Identifying ordered phases and their underlying symmetries is the first and most important step toward understanding the mechanism of high temperature superconductivity; critical behaviors of ordered phases are expected to correlate with the superconductivity. Efforts to find such ordered phases so far have been focused on pseudogap region and only their fluctuations are expected in the doping p beyond the so-called critical doping p_c. Here, using rotational anisotropy second harmonic generation (RA-SHG) measurement, we studied point group symmetry of Pb-Bi2212 to uncover the hidden order in the regime of $p > p_c$ While the SHG response exhibits perpendicular mirror symmetries along crystal axis in the high-temperature strange metal regime, we observe that the in-plane mirror symmetries break in Fermi-liquid-like phase at low-temperature. By tracking the temperature evolution of the symmetry breaking response, we observed order-parameter-like behavior with the onset temperature at which the crossover between those two phases takes place. This ordering phenomenon at $p > p_c$ contradicts the conventional quantum critical point scenario, demanding a new perspective to fully understand the nature of overdoped cuprates.

Keywords:

High Tc superconductors, Second Harmonic generation, Quantum criticality

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2023-04-19 - 2023-04-21

A9.02

Fermi surface spin texture and topological superconductivity in kagome lattice antiferromagnet

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Abstract:

We explore the relationship between magnetic ordering in real space, the resulting spin texture on the Fermi surface, and the superconducting gap structure. Via a perturbative approach, we find that the magnetic ordering of a metal can generate momentum-dependent spin texture on its Fermi surface if the metal has more than three sublattices in its magnetic unit cell. Since pairing interaction's ability to open a gap depends on the spin texture, nodal structures in magnetic superconductors can be explained based on the spin texture originating from the magnetism. We show that this theory can be well applied to the non-collinear kagome lattice antiferromagnet with odd-parity spin-triplet pairing interaction. We also report various types of topological superconductivity that can arise from this magnetic structure, including first-order topological superconductors with non-zero Chern numbers and a second-order topological superconductor protected by inversion symmetry.

Keywords:

Non-collinear antiferromagnet, Kagome lattice, Fermi surface spin texture, Topological supercoductivity

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A9.03

Relationship between interatomic distance in YBCO and role of Ba.

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Abstract:

The mechanism of high-Tc superconductivity cuprates are still uncertain. Many studies with cuprates with CuO_2 layers are done, and several researchers found that there might be a relationship between Tc and Cu-apical oxygen distance in cuprate superconductors. We expected the correlation of Ba and CuO_2 plane in YBCO, which is a well-known cuprate superconductor, and varified it with DFT calculations. Using Vienna Ab initio Simulation Package(VASP) program, we performed DFT calculations and our result shows that Tc-distance of Ba-CuO2 plane in YBCO plot is very similar with superconducting dome of YBCO, which means that the Tc might be proportional to distance. Through this study, we expect the importance of Ba plane of YBCO, and we have studied band structure of YBCO to understand the role of Ba atom. I. S. Elfimov et al. have found that Fermi pockets from BaO contributes the most to bands defining small pocket in YBCOx(x=6, 6.5, 7). To varify this role, in future work, we will use DFT+U calculations to plot band structure of YBCO, and find out the role of Ba and other atoms contributing the change of band structure near Fermi level.

Keywords:

DFT, cuprate superconductor, superconductivity, YBCO

A9.04

Decoupling of thermal and electronic transport in high-T_c cuprate superconductors

LEE Sungwoo [1,2], CHOI Woojin [1], KIM Yeongjae [1], KWON Young-Kyun [3], SONG Dongjoon [4], KIM Miyoung [1,2], LEE Gun-Do *[1,2]
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Abstract:

Although nearly forty years have passed since the discovery of high temperature (high-T_c) superconductivity, the underlying mechanism is still unknown. The B_{1g} phonon anomaly in high-T_c cuprate superconductors has been studied for a long time. However, the correlation between the B_{1g} phonon anomaly and high-T_c superconductivity has yet to be clarified.
In the present study, we successfully reproduced the B_{1g} phonon anomaly in $YBa_2Cu_3O_7$ (YBCO) using an *ab initio* molecular dynamics (AIMD) simulation and temperature-dependent effective potential (TDEP) method. Moreover, $A_g$phonon by Ba atoms shows a more severe anomaly than the B_{1g} phonon at low temperature range. Our analysis of the phonon anomaly and the temperature-dependent phonon dispersion indicated that decoupling between thermal phenomena and electron transport at low temperature range leads to layer-by-layer thermal separation in YBCO. Electronically and thermally isolated Ba atoms in YBCO are responsible for the thermal separation and give clue to the Wiedemann-Franz law breakdown. The analytic study of the thermal separation revealed that Planckian dissipation expressing linear-T resistivity is another expression of the Fermi liquid of the CuO_2 plane. The Uemura plot of the relationship between T_c and the T_F, as well as the superconducting dome in YBCO, is explained rigorously and quantitatively. Our findings present a new perspective for understanding high-T_c superconductivity.

Keywords:

High-Tc superconductor, Cuprate, Phonon anomaly, YBCO

A9.05

Boundary obstructed topological superconductor in buckled honeycomb lattice under perpendicular electric field

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Abstract:

In this work, we show that a buckled honeycomb lattice can host a boundary-obstructed topological superconductor (BOTS) in the presence of f-wave spin-triplet pairing (fSTP). The underlying buckled structure allows for the manipulation of both chemical potential and sublattice potential using a double gate setup. Although a finite sublattice potential can stabilize the fSTP with a possible higher-order band topology, because it also breaks the relevant symmetry, the stability of the corner modes is not guaranteed. Here we show that the fSTP on the honeycomb lattice gives BOTS under nonzero sublattice potential, thus the corner modes can survive as long as the boundary is gapped. Also, by examining the large sublattice potential limit where the honeycomb lattice can be decomposed into two triangular lattices, we show that the boundary modes in the normal state are the quintessential ingredient leading to the BOTS. Thus the effective boundary Hamiltonian becomes nothing but the Hamiltonian for Kitaev chains, which eventually gives the corner modes of the BOTS.

Keywords:

HOTS, BOTS, extrinsic HOTS, f-wave pairing, Majorana fermions

2023 KPS Spring Meeting
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A9.07

Topological Quantum Dimers Emerging from Kitaev Spin Liquid Bilayer: Anyon Condensation Transition

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Abstract:

Quantum Spin Liquids (QSLs) are many-body quantum entangled states supporting anyon quasiparticles, proposed as one of the best platforms for quantum science and technology. In particular, Kitaev Spin Liquid (KSL) and Resonating Valence Bond (RVB) states are active subjects of research, stimulated by recent advances in experimental platforms including the quantum magnet RuCl3, quantum processors, and Rydberg atom arrays.

Transition mechanism between distinct QSLs is one of the outstanding problems in the field of topological quantum matter. Anyon condensation was theoretically proposed as a mechanism for such transitions, providing global insights on how a variety of topological phases can be connected via anyon condensation transitions. However, it has been elusive to confirm the mechanism in quantum spin systems because of the scarcity of appropriate microscopic models and the difficulty with defining an order parameter for anyon condensation in terms of local spin operators.

In this work, I introduce a bilayer spin model that illuminates the mechanism of anyon condensation transition. KSL bilayer state and RVB state are stabilized in different limits of the model, connected by an anyon condensation transition. By performing explicit calculations of the order parameter, this work provides numerical evidence for the anyon condensation and uncovers an intimate connection between the KSL bilayer and RVB states.

Keywords:

Quantum spin liquids, Kitaev spin liquid, Resonating valence bond state, Anyon condensation transition

2023 KPS Spring Meeting
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A9.08

Kondo screening in a Majorana metal

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Abstract:

Kondo impurities provide a nontrivial probe to reveal the underlying gauge and topological character of a quantum spin liquid. In the *S*=1/2 Kitaev model on the honeycomb lattice, Kondo impurities embedded in the spin-liquid host can be screened by binding them to gauge fluxes. Here, we present experimental signatures of metallic-like Kondo screening at intermediate temperatures in the Kitaev honeycomb material α-$RuCl_3$ with dilute Cr^{3+} (*S*=3/2) impurities. The linear temperature dependence of the magnetic specific heat shows the metallic transport of Majorana fermions. The static magnetic susceptibility, the muon Knight shift, and the muon spin-relaxation rate feature logarithmic divergence, a hallmark of the Kondo effect. These observations suggest the Kondo screening emergent from a Majorana metal, opening new avenues for unexplored Kondo physics in charge-insulating quantum magnets.

Keywords:

Kitaev honeycomb model, Kondo effect, Muon spin relaxation/rotation

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A10.01

Ferroelectric materials and devices for the next generation semiconductors

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Abstract:

Since its discovery in 2011, Hafnia-based ferroelectric material has been extensively studied for the development of next-generation semiconductors such as negative capacitance field-effect transistors (NCFETs) and non-volatile memory devices. This talk will present the material development methodology, from atomic simulation to proof-of-concept device characterization. The newly discovered domain structure between opposite polarization states, as calculated from ab-initio methods, could lower the energy barrier for domain propagation, resulting in extremely efficient switching. On the other hand, the negative differential capacitance (NDC) of ferroelectric material, when incorporated in a metal oxide semiconductor (MOS) gate stack, has been theoretically known to achieve a capacitance equivalent thickness lower than that of the underlying dielectric material. MOSCAPs made of a few nanometers-thick ferroelectric material on a SiO_2/Si substrate show exceptional dielectric performance beyond the fundamental high-k limit, as evidenced by the pulsed current voltage characteristics, demonstrating NDC experimentally in much-reduced dimensions for the first time.

Keywords:

Ferroelectric, Negative capacitance

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A10.02

원자층 증착 방법을 이용한 나노 분말 코팅 및 양산화 기술

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Abstract:

원자층 증착 방법 ALD(Atomic Layer Deposition)를 이용한 박막 증착 방법은 진공 증착 공정 중 가장 높은 step coverage와 고품질의 박막을 비교적 낮은 온도에서 증착이 가능하며 수 nm 이하로 두께 조절이 용이하여 반도체를 비롯한 다양한 분야에 적용되고 있다.
이렇게 우수한 step coverage 특성은 기존 평판형 기판 뿐만 아니라 3D 구조와 같은 복잡한 구조에도 적용이 가능하여 기존 증착 공정으로 균일한 박막 증착이 어려운 부분까지 그 활용 범위가 점차 증가하고 있다. 이러한 우수한 특성의 ALD는 나노 분말에도 균일한 코팅이 가능한데 분말의 표면에 특정 물질을 균일하게 코팅하여 분말의 전기적, 기계적, 화학적 특성을 향상시켜 응용 제품의 특성을 향상시키는데 기여하고 있다.
최근 환경 문제와 더불어 전기 자동차의 수요가 증가하고 있으며 이에 따라 배터리에 대한 수요 역시 증가하고 있다. 이러한 배터리의 경우에도 양극재와 음극재에 나노 분말을 사용하고 있으며 기술의 발전에 따라 고용량, 고안정성 배터리가 요구되고 있다. 이러한 배터리 전극에 사용되는 분말에도 ALD를 이용하여 표면을 코팅 할 경우 분말 특성을 향상시켜 배터리의 용량 증가 및 충방전에 따른 안정성을 향상시킬 수 있다. 또한 나노 분말 ALD 기술은 연료 전지 분야에도 적용이 가능한데 기존 수소 연료전지의 경우 고가의 백금이 사용되는데 연료전지 제조 비용의 대부분을 백금 촉매가 차지하고 있다. 이러한 백금 촉매 제조 시 ALD를 사용할 경우 기존 습식 방식 대비 고품질의 백금을 균일하게 코팅이 가능하고 Pt dot의 사이즈 조절이 가능하여 매우 적은 양의 백금으로 보다 향상된 성능의 연료전지 제조가 가능하다. 상기 기술 외에도 나노 분말 코팅 ALD 기술은 MLCC, 촉매, 태양전지, 디스플레이, 3D printer 등 다양한 분야에 적용이 가능하여 관련 시장이 지속적으로 증가할 것으로 예상된다.
본 발표에서는 나노 분말 코팅 ALD를 이용한 나노 분말 코팅 기술에 대해서 설명하고 나노 분말 코팅 시장 및 양산화에 대해서 소개하고자 한다. 또한 ALD를 이용한 나노 분말 코팅의 다양한 사례를 소개하고자 한다.

Keywords:

원자층 증착, 나노 분말 코팅, 코어쉘 코팅 분말, 이차전지, 연료전지, (Atomic Layer Deposition, Nano powder coating, Core-shell coated powder, Battery, Fuel cell)

A10.03

감성의 과학화, 화장품 사용감 정량화를 위한 촉각모사 센서

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Abstract:

새로운 화장품을 보면, 먼저 손 끝으로 화장품을 손등에 바르고 두들기며 느껴본다. 이러한 경험이 화장품을 사용하는 즐거움 중 하나이다. 사람의 피부는 이상적인 촉각센서라고 할 수 있다. 접촉 시 물체의 온도, 힘 분포, 미끄러짐, 진동 등에 대한 정보를 수집한다. 만약 기계에 사람의 피부와 같은 기능을 가진 촉각센서를 장착한다면 사용자와의 상호작용이 훨씬 수월해질 것이라고 유추할 수 있다. 지능형 촉각 센서는 기계학습(machine learning)을 접목한 측정 기술이다. 사람의 피부에서 느껴지는 시원함과 촉촉함의 정도, 용액의 유형까지 인식해 디지털 수치로 변환한다. 초박형으로 유연하면서 외부의 압력과 변형에도 안정적인 측정이 가능해 피부에 부착도 가능하다.
이번 세미나에서는 아모레퍼시픽에서 주관적 감각을 수치화, 정량화를 위해 개발한 지능형 촉각센서와 최근 아모레퍼시픽에서 수상한 CES 기술에 소개하고자 한다.

Keywords:

Intelligent sensor, tactile sensor, thermometer

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2023-04-19 - 2023-04-21

A10.04

Inclusive application of AI Technology in the Medical Field, Samsung Medical Center

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Abstract:

Recently, the emergence of AI medical devices that support diagnosis by learning digital images such as CT and MRI and discovering lesions is rapidly increasing. As diagnostic algorithms optimized through AI and criteria for AI medical devices that continue to learn and change are clear, non-medical device SW such as AI Assistant are also spreading. The U.S. Food and Drug Administration (FDA) defined SW for diagnosis and treatment as software as a medical device (SaMD), and classifies data-based diagnostic assistance apps acquired with an electrocardiogram attached to a smartphone as SaMD and AI medical devices. AI solutions as medical devices and non-medical devices are also being developed in various medical fields, including Samsung Medical Center, which are being fused and expanded to medical device-mounted or stand-alone precision medical device SW. In addition, life-friendly medical services such as digital treatments using life logs using various IoT sensors including wearable devices are being developed. This study introduces the cases of medical and medical studies of AI convergence applied and used by Samsung Medical Center and seeks various development directions.

Keywords:

Medical AI, Artificial Intelligence, Medical Device, SaMD

Knowing when to move can improve motor cortical decision in rodents

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Abstract:

Motor cortex prepares voluntary movement before execution. Motor cortical neurons exhibit specific firing activity in preparation of movement, often termed as preparation activity. Persistent preparatory activity sustains firing rates until a ‘go cue’ is given, usually observed in the delayed-response task with random delay lengths. Ramping preparatory activity gradually increases firing rates until go cue when delay length is fixed. Neural mechanisms underlying these distinct preparatory activities have been studied but why motor cortex generates them is less clear. We analyze the dynamics of preparatory activity of anterior lateral motor cortex (ALM) in rodents during the random delay task and the fixed-delay task. By comparing neuronal dynamics with behavior, we find that motor cortex can utilize time information (go cue timing) to shape preparatory activity so as to improve motor decision if such information is available.

Keywords:

Motor cortex, Movement preparation, Neuronal dynamics, Time information

A14.02

Insights into Brain Function and Network Connectivity of Healthy and Diseased Brains through Real-Time Optical Imaging

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Abstract:

Our brain consists of a vast number of neurons, glial cells, and circulatory systems, such as the blood and lymphatic systems. The brain requires flawless yet dynamic interaction among these components to function at a normal level. In our lab, we are utilizing real-time in vivo optical imaging, in conjunction with other neuroscience tools, to dissect the amazingly complex interactions among neurons, glia, and the vascular system. I will introduce some of our work.

Keywords:

Real-time in vivo optical imaging, Neuro-glial-vascular interaction, Neurological disease

A14.03

Metrology for brain functional activity based on electromagnetism

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Abstract:

Superconducting quantum interference devices (SQUID) and atomic magnetometers have widely been used for state-of-the-art precision measurements in various scientific research areas in range of metrology to basic physics. Beyond the fundamental applications, magnetoencephalography (MEG) based on the ultra-low magnetic field sensing technology is the most developed non-invasive brain research tool for studying neuronal dynamics. Measuring and exploring human perception with MEG could give us neurophysiologic guidelines in standardization and quantification of human sensory and cognitive functions. I introduce the various applications of ultra-sensitive magnetic field measurement technologies such as MEG and Ultra-low field MRI, and Rydberg electrometer measurements.

Keywords:

Magnetoencephalography, SQUID, Atomic magnetometer, Rydberg atom, ULFMRI

A14.04

Spontaneous emergence of cognitive functions in the brain

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Abstract:

The ability to perform various cognitive functions is often observed in naïve animals, and this raises questions about the origin of innate brain functions. Particularly, a mechanism of how visual recognition in the brain arises initially is still unclear – whether it requires supervised and unsupervised learning, as in artificial neural networks. In this talk, I will introduce our findings that early functional circuits and cognitive functions in the brain can emerge spontaneously, in the complete absence of training. First, I will show how the regularly structured cortical maps can arise spontaneously to efficiently process sensory information. Second, I will show higher cognitive functions such as number sense or object detection can emerge spontaneously in untrained neural networks. Our results imply that the random feedforward connections in early brain circuits may be sufficient for initializing primitive cognitive functions, providing new insight into the origin of innate functions in the brains.

Keywords:

cognitive function, visual recognition, spontaneous emergence, innate brain function, functional circuit, untrained neural network, cortical map, number sense, object detection

2023 KPS Spring Meeting
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A15.01

Concerted-Diffusion Enabling High Conductivity of $Li_3Y(Br_3Cl_3)$ Mixed Halide Solid Electrolytes for All-Solid-State Batteries

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Abstract:

Halide solid electrolytes for all-solid-state batteries have recently attracted great attention due to their significantly improved ion conductivity to the level of sulfide solid electrolytes. This first-principles study unveils the Li ion diffusion mechanism in $Li_3Y(Br_3Cl_3)$, which is a layered mixed-halide material. The most stable $Li_3Y(Br_3Cl_3)$ structure, which was determined from systematic and extensive investigations, delivers a conductivity of 22.3 mS cm^{-1}, which is higher than those of Li_3YCl_6 (15.8 mS cm^{-1}) and Li_3YBr_6 (3.0 mS cm^{-1}) and is comparable to approximately tens of mS cm^{-1} for sulfide solid electrolytes. Li ion transport in $Li_3Y(Br_3Cl_3)$ occurs through the interlayer concerted diffusion across the Li, halide, and Y layers, promoted by the intralayer vacancy diffusion in the Li layer. The interlayer concerted diffusion (0.23 eV) exhibits a much lower barrier than the interlayer vacancy diffusion (0.56 eV), enabling rapid Li ion transport. The lower barrier for concerted diffusion is because the diffusion of Li^+ cations continuously stabilizes the six Br^-/Cl^- anions surrounding the 4g site in the Y layer. This work suggests that mixed halides can be a promising solid electrolyte for all-solid-state batteries as an alternative to sulfides.

Keywords:

All-solid-state batteries, Solid electrolytes, Halides, First-principles calculations

Improved Energy Storage Behavior of Lithium Vanadium Oxide (Li_3VO_4)-Carbon Hybrid Materials: An Atomic-Level Insight.

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Abstract:

As electric energy transportation technologies continue to advance, researchers are focusing on various energy storage devices, including supercapacitors. Supercapacitors exhibit a high power density, yet their energy density remains comparatively low. Thus, battery electrode materials for use as a supercapacitor anode have been widely investigated.

This study explores the use of Lithium Vanadium Oxide (Li3VO4, LVO) as an anode material for supercapacitors to increase energy density. LVO has a high theoretical capacity, but its low conductivity limits its high output characteristics. To address this limitation, LVO/Carbon Nanotube (CNT) composites were synthesized and tested, resulting in significant improvements in both energy and power densities. Density-functional theory (DFT) calculations have explained the energy storage mechanism of the LVO/CNT complex, with emphasis on two crucial features: the charge reservoir behavior of CNT and the electron transfer channel at the LVO/CNT interfacial region.

Keywords:

Supercapacitor, Li3VO4, Lithium Vanadium Oxide, Carbon nanotube, density functional theory, energy storage

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

A15.03

First-principleds data driven Machine Learning approach toward designing electrochemical energy storage and conversion materials

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Abstract:

Nanoparticles play central role toward promoting various electrochemical chemical reactions or storing renewable energy. Innovative design of highly functional nanoscale materials has been, however, delayed due to several unsolved issues such as accurate performance prediction, material cost and long-term stability.
In atomic-level computational electrochemistry a new research paradigm has been established since the fourth industrial revolution featured by IT-based artificial intelligence (AI) technology and machine learning algorithm to supercomputer architectures. This presentation demonstrates new computational methodologies of high-throughput screening of promising nanoparticles candidates for electrochemical energy conversion and storage materials unlimited by the conventional problems. Using the first-principles density functional theory calculations the reliability and accuracy of materials properties are accurately collected as input to activate machine learning model. To elevate the accuracy even to higher level we incorporate active-learning methods to guide experimental measurements with frontier facilities. Using the input we apply AI-based neural-network model to identify multi-component nanoscale electrocatalysts, which are highly active and stable in electrochemical redox reactions of oxygen. Furthermore, we identify promising new additives, which substantially contributing to stabilizing the Li-ion battery systems. We show how to automate the process of materials design using computational platform

Keywords:

first principles, machine learning, electrochemical energy devices, batteries

A15.04

Relation between the Polyanion Environment and Ionic Conductivity in Amorphous Li–P–S Superionic Conductors

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Abstract:

Amorphous Li–P–S materials have been widely used as solid-state electrolytes for all-solid-state batteries because of their high ionic conductivity (10^{-4} to 10^{-3} S cm^{-1}) as well as good synthetic accessibility and processability. Despite the potential of these materials, their amorphous structures have made it challenging to quantify the relation between the structure and conductivity. In this paper, we use ab initio molecular dynamics simulations to investigate the role of the local structure and density in determining the conductivity of amorphous Li–P–S structures with different polyanion units. We observe similar rates for Li-ion hopping regardless of the local P–S polyanion environment in these amorphous materials, indicating that the path connectivity at a larger length scale may be controlling the overall Li conductivity. This finding will serve as an important guideline in the continued development of amorphous solid electrolytes for advanced all-solid-state batteries.

Keywords:

All-solid-state batteries, Solid lithium superionic conductors, Density functional theory, Ab-initio molecular dynamics, amorphous materials

A16.01

Entanglement and Bell Inequalities at the LHC with Top Quark Pair Production

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Abstract:

The Large Hadron Collider (LHC) provides a unique environment to study quantum entanglement and violation of Bell's inequality at the highest energy scales currently available. The simplest system that can display entanglement is formed by two-qubits ant the top quark pair production provides a relevant realization of such a system. In this talk, I will discuss the possible observation of entanglement and Bell-type inequalities in the top quark production at the LHC.

Keywords:

LHC, Entanglement, Bell inequality

A16.02

Entanglement Theory : Structure and Certification

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Abstract:

Entanglement is quantum correlations existing in quantum states, having no classical counterpart, and is generally a resource that enables one to achieve quantum advantages in computation and communication. In this talk, we show operational characterizations of entangled states: creation, distributions, manipulations, and distillation of entangled states. We then identify entanglement as an irreversible resource as there exist entangled states from which no entanglement can be extracted. Mathematical characterizations are also presented. We finally present a brand new technique, called entanglement witness 2.0, that can certify entangled states with local observables. In addition, experimental realizations of entangled states are reviewed.

Keywords:

Entanglement, LOCC, Entanglement Witness, Bound Entanglement

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2023-04-19 - 2023-04-21

A16.03

Quantum Machine Learning: Opportunities and Challenges

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Abstract:

Quantum computing has the potential to outperform any foreseeable classical computers in solving certain computational problems. With the increasing demand for advanced computing power and methods in big data and artificial intelligence, quantum machine learning (QML) has emerged as a highly exciting application of quantum computing. In its early development, QML gained much attention due to the quantum algorithm that can solve the system of linear equations exponentially faster than classical algorithms. However, this algorithm requires a fault-tolerant quantum computer and a quantum random access memory, which is a long-term prospect. Therefore, an important and challenging question is how we can leverage the noisy intermediate-scale quantum (NISQ) computers that are currently available to achieve QML. In this seminar, I will provide a brief introduction to quantum machine learning and then present several QML approaches that aim to fully utilize NISQ computers and achieve quantum advantages in the near future. I will also discuss some open problems associated QML, both in theory and practice, that suggest future research directions.

Keywords:

Quantum computing, quantum machine learning

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

A17.01

Relativistic mean-field models optimized for the PREX-2 and CREX experiments

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Abstract:

We construct new effective interactions using the relativistic mean-field model with the isoscalar- and isovector-meson mixing.
Under the constraints from terrestrial experiments and astrophysical observations of neutron stars, the ground-state properties of finite, closed-shell nuclei are studied to account for the recent results from the PREX-2 and CREX experiments.
We finally predict a large neutron skin thickness of ^{208}Pb and the large slope parameter of nuclear symmetry energy by means of the isoscalr, sigma-delta mixing.

Keywords:

relativistic mean-field models, PREX-2 and CREX experiments, isospin-asymmetric nuclear matter, neutron stars, nuclear symmetry energy and its slope parameter

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

A17.02

Studying 22Na destruction for Ne isotopic abundance anomaly in presolar grains

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Abstract:

Certain types of presolar grains contain anomalous isotopic abundances that are notably different from the standard solar abundance. Specifically, graphite grains carry an anomalous abundance of Neon isotopes. This is known as Ne-E(L) anomaly which means a high 22Ne abundance compared to the solar abundance. 22Ne is produced via radioactive decays of 22Na which is synthesized by the 21Ne+p capture reaction in astrophysical events such as supernovae. The abundance of 22Na will directly affect that of 22Ne and is controlled by a destructive reaction 22Na(p, g)23Mg reaction. Here, we used the previously reported measurement data of (p, d) transfer reaction on 24Mg target to determine the decay properties of several 23Mg excited states. The obtained proton branching ratios can be used to constrain the destructive reaction 22Na(p, g)23Mg for the temperature region related to supernovae. This has the potential to give different 22Na nucleosynthesis predictions, and therefore different interpretations on Ne-E(L) anomaly in graphite grains.

Keywords:

Nucleosynthesis, Presolar Grain, 22Na, Decay measurement

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

A17.03

Differential chemistry in the early universe

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Abstract:

BBN (Big Bang nucleosynthesis) 모델은 양성자와 중성자로부터 수소, 중양성자, 헬륨 등 가벼운 핵과 극미량의 리튬, 베릴륨 등이 만들어지는 핵 합성 구간을 뜻한다.

BBN 이후, 우주 팽창에 의해, 약 10^5K에 도달하게 되면, 더 이상 광해리 반응이 우세하지 않게 되어, 우주는 BBN에 의해 만들어진 수소, 중수소, 헬륨 등으로 이루어진 원시 가스의 화학 반응 및 냉각 과정이 발생하게 되며, 이를 BBC(Big Bang chemistry)라고 부른다.
이러한 원시 가스에서 만들어지는 분자들은 초기 우주의 진화에서 첫 번째 물체의 생성 시, 원시 가스의 높은 온도로 인해 중력만으로 생성되기 어렵기 때문에 냉각제의 역할을 수행 할 수 있을 것으로 여겨진다.
원시 가스들 간의 반응은 서로 독립적이지 않고 유기적으로 결합 되어 있으며, 시간에 따른 입자량을 기술하는 ODE는 경직성(Stiff)을 가지고 있다.
따라서 우리는 우주 초기 원시 가스들의 0차원 전산모사를 수행하고자, 반응의 추가, 제거가 용이한 반응 네트워크(Reaction network)로 구성하고, VODE(variable-coefficient ODE solver)를 이용하여 경직성 미분 방정식을 풀고자 하였으며, 이를 소개하고자 한다.

Keywords:

early universe, cosmology, Big Bang Chemistry

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2023-04-19 - 2023-04-21

A17.04

Revisiting the Gamow Factor of Reactions on Light Nuclei

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Abstract:

This study provides an improved understanding of the penetration probabilities (PPs) in nuclear reactions of light nuclei by correcting the assumptions used in the conventional Gamow factor. The Gamow factor effectively describes the PP in nuclear reactions based on two assumptions: low particle energy than the Coulomb barrier and neglecting the dependence of nuclear interaction potential. However, we find that the assumptions are not valid for light nuclei. As a result of a calculation that excludes the assumptions, we obtain the PP that depends on the nuclear interaction potential depth for the light nuclei. For the potential depth fitted by the experimental fusion crosssection, we present that PPs of light nuclei (D+D, D+T, D+^{3}He, p+D, p+^{6}Li, and p+^{7}Li) become higher than the conventional one near the Coulomb barrier. We also discuss the implications of the modified PP, such as changes in the Gamow peak energy, which determine the measurement of energy range of the nuclear cross-section in experiments, and the electron screening effect

Keywords:

Gamow factor, panetration probability, Gamow energy, nucleosynthesis, screening effect

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

A17.05

Progress report of the study of radiative alpha capture on carbon-12 in cluster EFT

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Abstract:

I present a progress report on studying the radiative alpha capture on carbon-12 in cluster effective field theory (EFT). The cutoff regularization method employed in the previous calculation to estimate the astronomical S factor for the E1 transition is replaced by the dimensional regularization method. In addition, we discuss the use of the asymptotic normalization coefficient (ANC) of the ground state of oxygen-16, and a remaining coupling constant can be fixed by using the radiative decay rate of the excited 1_1^- state of oxygen-16. We also discuss the model dependence of the ANCs of 0_2^+ and 2_2^+ states of oxygen-16 in potential model calculations.

Keywords:

radiative alpha capure on carbon-12, cluster effective field theory, asymptotic normalization coeffienent (ANC), ANCs of excited states of oxygen-16

A17.06

Exploring the effects of strong magnetic fields on the neutrino-process

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Abstract:

초신성 폭발 시 발생하는 대량의 중성미자는 별 내부에서 다른 입자들과 상호작용하여 초신성 밖으로 나오게 됩니다. 이때, 중성미자와 전자들의 상호작용으로 인해 중성미자 진동이 영향을 받게 됩니다. 이번 연구에서는 초신성 내부에 매우 강한 자기장이 존재할 때 중성미자와 전자들의 상호작용에 대해 논의합니다. 특히 중성미자 구의 표면으로부터 쌍극자 분포를 가지는 자기장 형태를 가정하였습니다. 강한 자기장 안에서 전자들은 자기장의 방향을 따라 정렬이 되고, 이는 중성미자의 진행 경로에서 전자와 상호작용을 바뀌게 됩니다. 이는 초신성 폭발 시 중심으로부터 나오게 되는 중성미자와 핵 사이의 열 핵반응이 자기장의 크기와 방향에 따라 위치에 따라 다르게 나타날 수 있음을 의미합니다. 이로 인해 초신성 폭발시 중성미자가 유도하는 핵 반응(neutrino-process)을 계산해서 원소들이 생성되는 양이 위치에 따라 달라질 가능성에 대해 소개를 하려고 합니다.

Keywords:

neutrino-process, neutrino in strong magnetic filed

R-matrix and Machine Learning

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Abstract:

R-matrix를 사용하는 방법에는 크게 두 가지 방법이 발전되어왔다. 첫번째 '계산 가능한' R-매트릭스 방법은, 슈뢰딩거 방정식으로부터 산란 특성을 도출하기 위한 계산 도구로, 두번째 '현상학적' R-매트릭스 방법은 다양한 형태의 cross section을 매개 변수화하는 기법으로, 주로 (또는 고유하게) 핵물리학에서 사용 되어져 왔다. 두 방법 모두 산란이라는 문제에서 시작하여, 핵 및 원자 물리학의 간단한 예들을 잘 설명해 오고 있으며, 탄성 산란 외에도, 비탄성 및 복사 포획 반응에도 이 R-매트릭스 방법이 적용되고 있다.
이 발표에서는, 이 R-matrix 방법론을 돌아보고, 최신 각광을 받고 있는 인공지능 방법론이 어떻게 이 주제에 적용가능한지에 대해 논의 해 보고자 한다.

Keywords:

R-matrix, Machine Learning, Scattering cross section

A17.08

Perspective Nuclear Astrophysics Studies using AToM-X Active Target Detectors developed at CENS

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Abstract:

One of the fundamental questions in nuclear astrphysics research is ``Where do nuclei and elements come from''. In order to address the question, experimental studies of nuclear properties with rare isotope beams(RIB) are critical. Nevertheless, most of the key nuclei providing important constraints for the nucleosynthesis models are far from stability due to limitations of beam intensity of the nuclei. Therefore, a new detector system development will provide a good opportunity to perform the nuclear physics studies with a high detection efficiency as well as a high energy and position resolution of particles.
Active Target for Multiple nuclear astrophysics eXperiments (AToM-X) at the Center for Exotic Nuclear Studies (CENS) is under development in order to perform experimental nuclear astrophysics studies. The new active target detector will provide high resolutions for charge particle tracks, energy and position of detected particles.
In this talk, possible important nuclear astrophysics studies using the AToM-X detector and radioactive ion beams will be discussed as well as the status of the detector development.

Keywords:

AToM-X, Nuclear Astrophysics, Active Target, CENS

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

A18.01

Threshold study on the irradiated ALPIDE chips

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Abstract:

The ALPIDE(ALICE PIxel DEtector) is a pixel detector for the Inner Tracking Sys- tem (ITS) recently upgraded for RUN3 of the ALICE at the LHC, and also reserved for several other experiments. The innermost ALPIDE layer is placed at the closest dis- tance(23mm) to the interaction points of the collisions and any of the radiation effects is, therefore, an essential part to be studied. The threshold study is performed using the low energy protons at the various beam facilities including the KOrean Multi-purpose Accelerator Complex (KOMAC) in Gyeongju, Korea, and the experimental results will be presented with some miscellaneous effects on the threshold unexpectedly caused by the irradiated materials in the peripherals of the chip carrier board.

Keywords:

KOMAC, ALICE, Silicon Pixel Detector, Threshold

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

A18.02

Beam test studies of silicon sensors for ALICE ITS3

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Abstract:

During the Long Shutdown 3 (2026-2028) at LHC, ALICE is planning to replace the innermost three layers of the existing inner tracking system (ITS2) with a new silicon detector (ITS3) which is under development. One main feature of the ITS3 is aiming to make truly cylindrical half barrels using wafer-scale monolithic active pixel sensors. This development reducing the material budget significantly will help to measure the trajectory of charged particles and collision vertex much more precisely. Various types of prototype silicon sensors have been produced and tested with existing APLIDE chips to evaluate their performance through test beams at PS, SPS, and DESY. In this presentation, we will introduce the test beam of prototype silicon sensors for the ITS3 and present the initial results using bent ALPIDE sensors and DPTS(Digital Pixel Test Structure) sensors.

Keywords:

ALICE, ITS3, Beam test

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

A18.03

An advanced Si pixel sensor and the Korean detector for an EIC experiment

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Abstract:

The Electron-Ion Collider(EIC) is a powerful new high-luminosity facility to be built in the United States.

The facility will deliver collisions of the polarized high-energy electrons with the polarized high-energy protons and ions, providing access to those regions in the nucleon and nuclei where their structure is dominated by gluons. The proposed Electron Ion Collider (EIC) physics program [1] initiated a few studies of the multi-purpose detector designs.

The on-going experiment ALICE at CERN is conducting research and development of a novel detector based on an advanced Si pixel sensor, a wafer-scale monolithic active pixel sensor thinned down to 30 micron [2], where Korean groups are making an active participation.

We considered a few designs of the electron-going side endap tracker for an EIC detector assuming availability of this advanced Si pixel sensor and investigated how such an advanced sensor can improve performance of the overall detector. We will describe key features of the sensor and report results of the investigation.

[1] arXiv:2209.02580v1 [physics.ins-det]
[2] Nucl. Instrum. Methods Phys. Res., A 1041 (2022) pp.167315

Keywords:

Advanced Si pixel sensor, EIC

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2023-04-19 - 2023-04-21

A18.04

Status of R&D activities of FAZIA upgrade in Korea

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Abstract:

The FAZIA (Forward A and Z Identification Array) detector system, presently at GANIL, aims to identify fragments produced in heavy-ion collisions from a few tens of MeV to about a hundred MeV per nucleon. The basic unit of FAZIA is the three-layer telescope, which consists of two silicon sensors with thicknesses of 300 and 500 um, respectively, and a CsI scintillator block. This detector configuration is ideal for clean separation of the charges and masses of the detected nuclei with Z up to about 54 and A up to about 25 with the Delta E - E and the pulse-shape analysis methods.
Recently, the FAZIA upgrade project has started to cover a larger beam-energy range. The Korean FAZIA team is the main player in the upgrade activity, developing the new silicon sensors from the chip design to the fabrication of the Si sensors with various thicknesses. It is also actively developing the front-end electronics board in collaboration with the domestic industry. Ultimately, our effort is expected to build the complete construction know-how of the Si detector array and the advanced front-end electronics board in Korea. This presentation will describe the progress of the FAZIA upgrade project, particularly focusing on the Korean team's activities.

Keywords:

FAZIA, Silicon sensor, heavy ion collision, silicon detector

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

A18.05

Production and measurement of silicon PiN sensors designed based on TCAD simulation

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Abstract:

Silicon sensors are widely used detectors in heavy ion physics experiments. Based on the intrinsic electric field structure of the semiconductor, called a depletion region, it collects electric signals generated by traversing charged particles through the detector medium. Many experimental collaborations have been using the silicon-typed detector and working on the research and development of silicon sensors to improve their efficiency and capability. The FAZIA collaboration, one of them, uses the silicon sensor to measure the energy loss of particles, and it allows them to identify particles' species with dE-E information.
We studied silicon chips from the FAZIA experiment based on Synopsys's TCAD (Technology Computer Aided Design) tool that calculates complicated physical characteristics of semiconductors, such as electric field, potential, and current density. The physical properties of different designs of the sensors depending on the reverse bias voltage were analyzed. Based on the chip designs and analysis results, our sensor fabrication proceeded with ETRI (Electronics and Telecommunications Research Institute) and was recently finished. For the quality assurance of the sensors, we measured the I-V curve of sensors and the sensor response with a radiation source in the lab. This talk presents the I-V results and performance results of produced PiN sensors.

Keywords:

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

A18.06

Development and characterization of new position-sensitive silicon strip detectors

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Abstract:

Direct reaction experiments in inverse kinematics are one of the best suited tools to probe a broad range of nuclear properties, providing great insight into the nuclear structure of exotic nuclei and allowing the measurement of reactions relevant to many astrophysical scenarios. In order to fully exploit RAON and the next generation of radioactive ion beam facilities, the CENS group has devoted a large amount of effort to develop nuclear detection instruments, such as ATOM-X Active Target TPC and STARK Silicon Telescope Array, specially designed for direct reaction experiments. An integral part of these detector devices are Micron X6 position-sensitive double sided silicon strip detector. These custom-made detectors are segmented in 4 strips on its ohmic side and 8 resistive charge-splitting strips on its junction side enabling an excellent position measurement of charged particles with a much smaller number of signals than traditional DSSSD with similar position resolution.

We will present the detailed specifications and the principle of operation, detector and instrumentation development work will be described and finally its performance will be discussed in terms of the most important parameters for direct reaction experiments: position and energy.

Keywords:

silicon detector, PSSSD, silicon telescope, nuclear instrumentation

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

A18.07

SiPM Coupled to CsI(Tl) for Low Energy γ/X-ray Spectroscopy.

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Abstract:

Silicon photomultipliers are a novel photon detection technology that works in the near ultraviolet, visible, and near-infrared spectral ranges. Their use is rapidly expanding and extending to many fields of physics, where they are replacing traditional PMTs and APDs. In this study, we coupled the (5 × 5 × 5 mm^3) CsI (Tl) crystal to a SensL J-series 60035 (6 ×6 mm^2) SiPM and detected low-energy gamma and X-rays from Cobalt, and Iron sources. A distinct and well-separated 5.90 keV peak from the background was observed from the ^{55}Fe source. The 6.4 and 14.4 keV X-ray peaks from the ^{57}Co source were measured and found to be very well separated from a background as well. Based on the mean value of the single photoelectron peak of SiPM, the absolute light yield was calculated down to 5.9 keV. Light yield for CsI(Tl) with SiPM was measured at around 60,000 ± 6000 Photons/ MeV and 413 ± 41 photons for 5.90 keV. Furthermore, measurements of energy resolution and non-proportionality have been done all the way down to the X-ray region. According to our findings, the SiPM coupled to CsI(Tl) could be an excellent detector for lower energy experiments such as dark matter searches and can be used in the study of neutrino physics as well

Keywords:

scintillator, light yield, single photoelectron, non-proportionality

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

A18.08

Alignment and Correction for Deformation of a Precision Tracker by Artificial Intelligence

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Abstract:

Precision trackers are used for the high energy and nuclear physics. The trackers measure precise positions of the hits produced by the particles and associate hits to a trajectory when the associated positions are consistent. Any small misalignment or deformation of detector caused by various factors affects the precise position measurements significantly and its correction frequently appears as a major issue in the tracker operation.
Usual correction method is to introduce parameter set relevant to likely deformation models and adjust this parameter set so that the associated hits yield ideal particle trajectory. This approach however works to the validity of the chosen deformation model while reality is always beyond the modeling.
A small but non-trivial correction function has to be associated to each position measurement for unknown deformations. Regression using neural network or artificial intelligence can approximate any multi variable functions and we performed regression fit to extract deformations for ALICE ITS detector at CERN LHC. We confirmed the consistency between the final version of the official alignment parameters determined by classical approach and constants determined by AI. Our goal is to extract sensor unit alignment parameters and to verify the stability of the alignment constants. We observed a certain level of possibility in this effort and will present results so far.

Keywords:

alignment, AI, ALICE, ITS

A18.09

CMS ETROC1 Board Test at Fermilab in 2022

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Abstract:

MIP (Minimum Ionizing Particle) Timing Detector (MTD) is a high precision time measurement detector of MIP. It is predicted that the number of pileup will be increased to 200 from 140 in the High-Luminosity LHC. Increased pileup can make hardness for analysis such as 15% of worsening resolution for missing transverse momentum and merging between low energy and high energy jets. MTD was proposed to relieve effects of pileup by providing time information of data. There was a performance test of the Endcap Timing ReadOut Chip 1 (ETROC1) board, a component of the endcap region of CMS's MTD, with 100 GeV proton beam at Fermilab in 2022. In this talk, processes of ETROC1 board test with laser and proton beam and result are reported.

Keywords:

CMS, MTD, ETROC

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A19.01

Status of COSINE-100 experiment

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Abstract:

COSINE-100 is a direct WIMP search experiment that uses 106 kg of thallium-doped sodium iodide [NaI(Tl)] as its target material. The experiment has been collecting data since September 2016 with continuous stable operation. The primary goal of the COSINE-100 is to test the dark matter signal from the DAMA/LIBRA experiment. DAMA/LIBRA has claimed the presence of an annual modulation signal, which is compatible with the nature of dark matter interaction with NaI(Tl) nuclei. However, no other experiment has succeeded in reproducing its results yet. To test DAMA/LIBRA's result directly, the COSINE-100 experiment uses the same material as its target, NaI(Tl) crystal. In this presentation, I will summarize the latest analysis outcomes of the experiment, including spectral WIMP analysis and annual modulation signal analysis.

Keywords:

WIMP , Dark matter, COSINE-100

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

A19.02

Pulse shape discrimination analysis for the COSINE-100

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Abstract:

For direct detection of WIMP dark matter particles, scintillation crystals such as NaI(Tl) are commonly used as targets/detectors. In these crystals, discrimination between WIMP-induced recoils and the background beta-gamma events can be achieved, by using a so-called pulse shape discrimination (PSD) analysis to leverage differences in their scintillation characteristics .
To perform the PSD analysis, the responses of an NaI(Tl) crystal to nuclear recoils by neutron beam and to electron recoils by a 137Cs source were measured. The target crystal was cut from the same Alpha Spectra-grown ingot as one of the large crystals for the COSINE-100 experiment. The target crystal is smaller (2cm x 2 cm x 1.5 cm) than the large crystal in order to suppress multiple scattering events in the crystal.
The PSD analysis for the COSINE-100 WIMP search data was performed with some pulse-shape dependent parameters of the nuclear and electron recoil events.

Keywords:

Dark matter, NaI(Tl), PSD, COSINE

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2023-04-19 - 2023-04-21

A19.03

Non-proportionality of the COSINE-100 Experiment

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Abstract:

The COSINE-100 experiment aims to detect the WIMP signal using NaI(Tl) crystal, with reliance on the quality of background modeling. A crucial factor in the background model is the scintillator's non-proportionality (nPR). The nPR curve for the COSINE-100 experiment was estimated by identifying internal radioactive peaks within the energy range from 0.8 keV to a few tens of keV. This talk will cover the determination method and preliminary results of the nPR curve.

Keywords:

dark matter, scintillator, nonproportionality, COSINE-100, NaI(Tl)

Dark matter search through exotic scenarios in COSINE-100 experiment

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Abstract:

Weakly Interacting Massive Particles(WIMP) is a dark matter candidate proposed as a possible explanation for the observed gravitational effects of dark matter in the universe. However, despite numerous efforts to detect WIMPs, no conclusive evidence has supported their existence. The null results in the WIMP search have motivated exploring alternative dark matter models, including exotic scenarios. In this talk, we report the status of dark matter search studies through three exotic scenarios in the COSINE-100 experiment.

Keywords:

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A19.05

Search for the Pauli Exclusion Principle violation and electron decay in a NaI(Tl) crystal

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Abstract:

The Pauli Exclusion Principle (PEP) and the stability of the electron are fundamental assumptions of quantum mechanics. However, the validity of these assumptions has not been established experimentally. The energy spectra of NaI(Tl) crystals in COSINE-100 can be used to search for the PEP violation and electron decay. As a result of searching for the X-ray signals by the PEP violation and electron decay, the most stringent limits have been obtained.

Keywords:

COSINE-100, NaI(Tl) Crystal, electron stability, The Pauli Exclusion Principle Violation

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2023-04-19 - 2023-04-21

A19.06

COSINE-100 upgrade

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Abstract:

COSINE-100 is a direct detection dark matter search experiment aiming to provide a test of annual modulation results of DAMA/LIBRA using NaI(Tl) scintillating crystal. The search for dark matter in various ways, both model-dependent and model-independent, have produced results inconsistent with those of DAMA/LIBRA but has not yet been completely rejected in the annual modulation search. The COSINE collaboration plans to upgrade detector performance by changing crystal assembly methods or the experimental environment to further investigate unresolved regions in the search for dark matter. I will present details of the plan for the next phase of the COSINE experiment.

Keywords:

COSINE, dark matter, wimp, NaI(Tl)

A19.07

Scintillation characteristics of a pure CsI crystal coupled with two SiPM photosensors at low temperature

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Abstract:

It has been reported that the high absolute light yields of pure CsI crystals at liquid nitrogen temperature (77 K) are above 80,000 photons/MeV. This makes it a good application for low-energy rare event searches, such as dark matter and neutrino coherent scattering. We characterized the scintillation properties of a pure CsI crystal coupled with a silicon photomultiplier tube (SiPM). We measured the temperature-dependent light yield and decay time from room temperature to liquid nitrogen temperature. In this presentation, I will discuss the scintillation characteristics of the pure CsI crystal.

Keywords:

Dark matter, Dark matter direct detection, CsI crystal, SiPM

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2023-04-19 - 2023-04-21

A19.08

Silicon Alpha-particle spectrometer for three-dimensional samples

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Abstract:

Alpha-particle spectrometer is an important analytical technique for alpha particle emitting radionuclides with high sensitivity. Because the emitted alpha particles from samples are mono-energetic and not emitted in a spectrum of energies like beta decays, they often have energies distinct from decays. They can be used to identify which radionuclide they originated from. Alpha particle spectroscopy is widely used in a variety of fields, such as measuring nuclear decay data, studying geology, or measuring low-level activity in the environment.
In this study, we have developed large-sized silicon sensors and silicon alpha detectors to measure emitting alpha particles from 3-dimensional samples such as crystal cylinders. We are planning to measure the alpha particle contamination level on the crystal cylinders' surface with a diameter of ~5cm that we will use for our experiments. We will present about the large-sized silicon sensor development and the performance of the detector system.

Keywords:

Alpha-particle spectrometer, alpha particle contamination level, large-sized silicon sensors

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

A19.09

Korean topographic tomography using a muon detector (HAWL)

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Abstract:

Cosmic ray muons are generated when primary cosmic rays collide with molecules in the atmosphere. These minimum ionizing muons have good penetration ability so that they can be used in the non-destructive topography application. The moveable muon detector, named Hankuk Atmospheric Weak-interaction Landscaping(HAWL), using plastic scintillator was used for scanning topography of Korea while passing through the Yangyang Highway, which has about 50 tunnels. As the world's first, HAWL detector received live data while driving. We succeeded in drawing the landscape in real time and were able to reconstruct the real landscape with high precision.

Keywords:

Muon, Topography, Plastic scintillator, Cosmic ray, Mobile

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B1.01

Semiconductor-combined nanoslot antennas for THz modulation

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Abstract:

Terahertz nanoslot antennas have been studied for various applications, such as sensing and nonlinear effect, due to the advantage of background free, field enhancement, and field confinement. Recently, we have conducted carrier dynamics of semiconductor materials using the optical pump-terahertz probe method. Combined with semiconductor materials, terahertz nanoslot antennas enable various semiconductor materials to have unique properties as ultrafast terahertz devices.
In this presentation, we will discuss the terahertz transmission modulation by the semiconductor-combined nanoslot antennas. The terahertz transmission modulation was conducted by an intense terahertz field or an optical excitation. Using a metallic nanoslot antenna accompanying strong THz field confinement, we observed the effective optical modulation due to the terahertz interaction with semiconductor nano volume. Furthermore, terahertz field-dependent modulations were observed by the field enhancement of nanoslot antenna, which induces a nonlinear response of semiconductor materials. Both modulation effects were dominantly observed as the antenna gap size decreases down to the nanoscale regime.

Keywords:

Terahertz, nanoantenna, modulation

Probing shift current dynamics via time-resolved THz pulse emission measurements in asymmetric quantum wells

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Abstract:

Ultrashort THz pulses with a duration of femtoseconds and high electric field amplitude are used in timed-resolved spectroscopy of condensed matter. Probing dynamics of novel materials in such short time scales provides valuable insight toward next generation optoelectronics, ultra-broadband communications and quantum technology. In this work, ultrafast shift current dynamics are presented by probing THz pulse emission in asymmetric quantum well structure. The center of mass position of the quantum well electronic wavefunction shifts under a resonant pulse excitation at the intersubband transition frequency, which in turn emits a monocycle THz pulse. Experiment with two pulses, i.e., 2-dimensional spectroscopy in time domain, reveals the saturation dynamics of intersubband population, and the time structure of the THz pulses can be tailored via excitation condition manipulation.

Keywords:

Shift current, THz pulse, quantum wells

Ultrafast control of topological phase by light-driven vibrational coherence

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Abstract:

Topological insulators provide excellent physical characteristics in symmetry-protected surface states with disorder-tolerant and dissipationless transport. Switching operation, a crucial component of electronics, can be achieved by reversible topological control. Although the mechanical strain has been considered as an efficient way of reversibly controlling topological invariants in Bi_2Se_3, it is accompanied by in-plane cracks and is not appropriate for time-varying applications at high-speeds.

Here, we use photoinduced stress, which can selectively excite out-of-plane strain and vibrations. Based on photoelastic effects, the changes in refractive index caused by lattice vibrations are detected with NIR probe light. THz spectroscopy is used to simultaneously capture changes in the transport properties of strained Bi_2Se_3. We found that the lifetime of surface transport is significantly disrupted by light-driven strain at the nanoscale, while the bulk conduction is enhanced across the topological phase transition. This work demonstrates ultrafast control of Bi_2Se_3 for topological switching at tens-GHz frequencies.

Keywords:

Topological insulators, Coherent phonons, THz spectroscopy

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2023-04-19 - 2023-04-21

B1.04

Optical control of on-chip Brillouin scattering

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Abstract:

Mixing telecom-band photons, GHz acoustic phonons, and RF signals via Brillouin scattering in the nanoscale has been actively studied for signal processing by employing ultra-narrow bandwidths and unique phase-matching conditions. While various Brillouin-based on-chip devices including narrowband RF filters, non-reciprocal devices, and Brillouin lasers have been demonstrated, control of on-chip Brillouin resonances and acoustic waves is still challenging because mechanical properties are constrained to material and geometric properties. Here, we introduce our novel approaches to optical control of on-chip Brillouin scattering in silicon photonic integrated circuits. We demonstrate novel photonic devices for acoustic interference control and resonance-tunable acoustic cavities. Our strategies for Brillouin scattering control open novel Brillouin-based applications and show important steps toward the implementation of on-chip optomechanical devices.

Keywords:

Optomechanics, Silicon photonics, Brillouin scattering

Multimode nonlinear optical frequency conversion in adiabatic nanofibers

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Abstract:

Multimode adiabatic optical nanofibers have recently emerged as a promising platform for efficient nonlinear optical frequency conversion. They offer a unique and powerful capability of tight confinement and adiabatic transmission of multiple spatial modes, facilitating enhanced optical nonlinearities, vast dispersion engineering, and excellent compatibility with conventional optical fiber systems. In this talk, I will present recent progress on multimode nonlinear optical frequency conversion in adiabatic nanofibers.

Keywords:

Multimode nonlinear optics, Optical nanofiber, Adiabatic transmission, Nonlinear optical frequency conversion

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

B2.01

Explaining complex interactions in socio-spatial systems with data science

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Abstract:

Complex social interactions on different spatial scales, namely socio-spatial interactions, are the fabric of human society, as exemplified by urban agglomerations, transportation, and social networks. With advances in data science providing more opportunities to demonstrate these interactions, there is a need for a holistic framework for looking at complex social phenomena as a combination of each of these interactions. In this talk, I suggest a holistic view of socio-spatial interactions composed of structural, dynamic, and emergent interactions and discuss human mobility, socio-spatial spreading, and socioeconomic correlations as an example of each category. On the structural interaction, the network structure of human mobility connecting different areas is explained with the gravity model on sociodemographic landscapes. On the dynamics, socio-spatial spreading is demonstrated by protest diffusion and epidemic spreading, with a model for simulating the spreading processes as homophilic recruitment. Lastly, on the emergence, the longitudinal and cross-sectional regularities of urban employment and urban green space are described as emergent properties from intracity interactions. This conceptual framework helps understand complex socio-spatial phenomena by decomposing interactions into elements.

Keywords:

socio-spatial interaction, urban dynamics, data science, complexity

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2023-04-19 - 2023-04-21

B2.02

Contagion dynamics on hypergraphs with nested hyperedges

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Abstract:

In many complex social systems, infectious diseases can spread through higher-order interactions, where an individual is in contact with multiple others simultaneously. The higher-order interactions in such systems have been represented as hyperedges connecting any number of nodes in hypergraphs. Hyperedges can even include other hyperedges as proper subsets of them. To address such higher-order structural features, we introduce the concept of the hyperedge-nestedness. A hyperedge, the nodes of which are connected by other smaller hyperedges, without being itself fully-included within other hyperedges in a hypergraph, is termed a facet; and a hyperedge is said to be nested, if it connects a proper subset of a facet. In this work, we investigate the effects of the hyperedge-nestedness on simplicial susceptible-infected-susceptible (SIS) model, where a susceptible node in a hyperedge of size s having n infected nodes can get infected with rate βsδs−1,n; and an infected node turns into susceptible one with rate μ. To this end we introduce and formulate an analytical framework called the facet approximation (FA) incorporating the correlation between the number of infection routes from nested hyperedges and facets. We apply the FA to the simplicial SIS dynamics on the random nested-hypergraphs with facets of size three, which is the simplest setting exhibiting the nontrivial effects of the hyperedge-nestedness on the dynamics. We compare the dynamics in the two extreme cases (i.e., non-nested vs. fully-nested cases). By obtaining the stationary-state fraction of infected nodes for the simplicial SIS model from a system of equations generated by the FA, we show how the hyperedge-nestedness changes the critical points and obtain the respective phase diagrams. Monte Carlo simulations support the FA.

Keywords:

hypergraph, contagion dynamics, epidemic, higher-order interaction

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

B2.03

Weight-dependent spread of decline in international trade hypergraph

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Abstract:

Higher-order networks such as simplicial complexes and hypergraphs can reveal the hidden features and principles of given systems that are not available in conventional pairwise networks. Here we represent by a weighted triangular hyperedge each international trade between an exporter country and an importer country with a category of products and take the collection of all such hyperedges over all countries and product categories to construct the international trade hypergraph. Individual trade volumes fluctuate from year to year to different extents for various reasons, such as a short supply of raw materials or reduced demand for products, and we investigate whether those fluctuations are independent from one another or a collective phenomenon. We consider a hyperedge h declined if its weight (trade volume) $W_h(t)$ decreases over consecutive years significantly as $r_h(t) = \log[W_h(t+1)/W_h(t)] < r_*$ with a negative constant r_*. We found that those declined hyperedges are not randomly distributed but clustered, and moreover, the probability of having declined is anti-correlated with the trade volumes of the hyperedges. By adopting the Susceptible-Infected-Recovered (SIR) model, we simulate the spread of decline over hyperedges, with the infection rate decreasing with weight, and reproduce the empirical features of the declined hyperedges. This weight-dependent SIR model is investigated with the Monte Carlo simulation and the weight-dependent mean-field approximation to demonstrate that the correlation between the degree and weight of a hyperedge, another stylized fact derived from the empirical data, significantly alters the spreading of decline.

Keywords:

International trade hypergraph, Clustering, Spread of decline, SIR model

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2023-04-19 - 2023-04-21

B2.04

Wealth coalescence in complex networks

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Abstract:

Trades on imperfect pricing drive wealth transfer from one to another, bringing the population-level wealth inequality. The yard-sale (YS) model is a kinetic model of wealth exchange that exhibits an extremely broad distribution of wealth from fair wealth exchanges: One of two randomly selected individuals gives a fraction ₩epsilon of the minimum wealth of the two to the other, the repetition of which in a population leads to the wealth distribution. While the observation is very interesting, its robustness and the dynamical properties remain to be understood. Here we study a generalized YS (gYS) model for individuals connected by a network; A connected pair can undergo the YS exchange with probability 1-p or the proportional (PR) exchange with probability p in which the sender gives ₩epsilon of its own wealth. We find that after the initial linear growth of wealth variance, the system reaches local condensate phase in which wealth can rarely be transferred any more as all the neighbors of each rich node are bankrupt. Such local condensate is resolved and relaxes towards either global condensate or a relatively uniform distribution similar to the inverse gamma distribution in scale-free networks. The scaling properties of the relaxation time and the resumed growth of the wealth variance can be understood by the degree-dependent wealth distribution and the coalescence of wealth that performs random walk on the given network, providing insight into the process of forming economic inequality.

Keywords:

Wealth exchange model, Econophysics, Yard-Sale model

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2023-04-19 - 2023-04-21

B2.05

Finite Size Scaling Approach for Revealing Inherent Scale-Freeness in Heterogeneous Networks

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Abstract:

Most systems in nature consist of interacting entities and analyzing their interaction structures can help us understand their characteristics. Most systems exhibit a scale-free distribution, where the degree distribution follows a power law, but the discussion about the "scale-freeness" of empirical networks has recently re-entered due to the inherent finiteness of real-world systems. A recent study has suggested a method to identify the true scale-freeness in networks using finite-size scaling, which can classify a network into whether it is a SF network or not. It has shown good performance about the well known model networks including the Barabási-Albert (BA) model, providing the optimal value of degree exponent. In this study, to detect the scale-freeness and find the optimal degree exponent, we apply to other heterogeneous networks such as the static-model network and the generalized BA network whose degree exponents can be freely adjusted. That is because we want to a confirm whether this method works in networks with different underlying mechanisms. Next, we extend the considered networks to the node-removed network depending on a different removal strategy. In the previous study, the regime diagram of SF-like and Poisson-like regimes is obtained by the relative entropy. To overcome the intrinsic limitation of the entropy measure, we reconfirm the boundary by this method.

Keywords:

scale-free network, fintie size scaling

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

B2.06

Cluster Formation of Free/Congested Flow in Urban Road Networks

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Abstract:

Understanding traffic behavior has been a significant concern in urban planning. There have been studies using the percolation-based approach to analyze the transitions of free-flow and traffic congestion states, but little attention has been paid to comparing the transition processes of the two states, despite their coexistence. To address this research gap, we investigate the percolating processes of the traffic jam and the free flow on the same road network using the taxi data from Chengdu in China and systemically compare the percolation patterns. We find the difference between the formation processes of the giant connected components (GCCs), clearly revealed as a gap between the GCC curves. The gap exists throughout most of the days and times, and the gap area size is more remarkable during rush hour. We suggest that the differences may be attributed to the spatial correlations in the weight (defined as the average speed of taxis) of roads with several supporting evidences. Firstly, the percolating behavior of uncorrelated weight-shuffled cases clearly differs with our empirical cases, demonstrated by the earlier onsets of the GCCs. Secondly, the weight-weight correlations are strong in human activity time when the gaps are large. The earlier onset than in the uncorrelated case is consistent with the case of the correlated percolation.

Keywords:

Percolation, Traffic flow, Complex network

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

B2.07

Hidden Directionality of Co-citation Network and Its Relation to the Impact of Scientific Papers

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Abstract:

Many scientific accomplishments result from the coevolution of knowledge. Investigating the relationships between scientific discoveries is crucial in comprehending the evolutionary paths of science and suggesting potential pathways for future scientific progress. In this study, we explore the latent directionality among scientific findings in a co-citation network while tracing the features of the papers.

Co-citation is a measure of the relationship between two documents based on the number of times they are cited together in other documents. It provides valuable insights into the interconnections between scientific discoveries. For instance, co-citation analysis is widely employed by researchers to assess the similarity between two documents, as documents that are related tend to be cited together more often. However, the level of relatedness between co-cited documents in a given document can differ, and many of them may be negligible. To better understand these relationships, it is necessary to identify essential edges, which are considered more informative connections than the others.

To accomplish this, we establish a co-citation network using the Microsoft Academic Graph dataset, one of the largest and most comprehensive databases of scientific papers. Then, we apply the information entropy approach to extract the essential edges from the co-citation network. Information entropy can be used to quantify the heterogeneity of the weight of edges attached to each node. By utilizing this property, it is possible to quantify the number of connections deemed effective in a given node.

We examined the relationship between the characteristics of papers—such as relative publication year, citation count, and novelty—and the direction of edges that arose during thenormalization process. Additionally, our investigation shows that the average similarity across the co-citation network increases during the extraction process while the average similarity of removed edges remains relatively constant.

Keywords:

Network, Co-citation, Metascience, Information theory

The core of board networks and firm value

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Abstract:

We examine the statistical and dynamic properties of board networks connected through interlocking directorates. We find that the degree distribution of a board network follows a power-law distribution. Furthermore, the evolution of the core–periphery structure of board networks over time is related to market stability. This result implies that firms, when densely connected to other boards, would like to keep their position as core groups in board networks. Firm value shows a statistically positive relationship with firms centrally positioned in a board network. Overall, we suggest that board networks can help us understand market stability and serve as an alternative information channel for increasing the firm value. These findings imply that the statistical and dynamic properties of board networks uncover
information transmission during the global financial crisis. This paper contributes to interdisciplinary applications of physics in economics and finance in terms of the dynamics of a core–periphery structure of board networks.

Keywords:

board networks, firm value, interlocking directorates, network core, network formation

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B3.01

Effective photodoping persistency of UV-doped WSe_2 on hBN

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Abstract:

UV photodoping of 2D semiconductors on hexagonal boron nitride (hBN) substrates has emerged as a powerful tool for controlling the conductivity of semiconductors and manipulating doping in optoelectronic devices. In this work, we investigate the photodoping relaxation mechanism and effective photodoping maintenance conditions in WSe_2/hBN. By monitoring the doping concentration and threshold voltage shift, we observe clear changes in photodoping relaxation time depending on the applied gate voltage. Our experimental results show that photoinduced n-type doping can be effectively maintained for over 20 hours under negative back-gate voltage, while positive back-gate voltage rapidly removes the photodoping. These findings provide insights into the underlying photodoping mechanism and offer an effective way to achieve persistent photodoping in 2D semiconductor devices.

Keywords:

UV Photodoping, TMDs, hBN, Photodoping relaxation

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

B3.02

Nanocavity-integrated van der Waals heterobilayers for nano-excitonic transistor

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Abstract:

An optical transistor is the fundamental building block for realizing optical computing, which can resolve the problem of exponentially growing computational workloads. However, direct on-and-off and in-and-out processes of light are hard to modulate due to the intrinsically non-interacting nature of photons. Furthermore, diffraction limits the minimal optical mode volume and prevents further device miniaturization.
Atomically thin transition metal dichalcogenide (TMD) heterobilayers – stacks of two different TMD monolayers are emerging as an attractive semiconductor platform. In particular, interlayer excitons (IXs) formed in heterobilayers from holes (h+) and electrons (e-) residing in different layers, show distinct photoluminescence (PL) properties compared to intralayer excitons (Xs) due to the reduced spatial overlap of h+ and e- wavefunctions. The increased out-of-plane component in the IX dipole moment enables selective manipulation of the light-matter interactions for Xs and IX via, for example, polarization-sensitive Purcell enhancement. Furthermore, both Xs and IXs can in principle be manipulated within few-nm-scale volumes. Therefore, IXs and Xs in TMD heterobilayers can act as optically controllable quasiparticles to realize nano-excitonic transistor circumventing the aforementioned limitations of optical transistors.
Here, we present a nano-optical approach for creating an ultrathin 2-bit nano-excitonic transistor using near-field PL responses of Xs and IXs in a $WSe_2/Mo_{0.5}W_{0.5}Se_2$ heterobilayer. To amplify and selectively control the near-field PL responses of intra- and inter-layer excitons in 25 nm^2 area, we employ an adaptive tip-enhanced PL (*a*-TEPL) modulation technique with the near-field wavefront shaping. We explain the underlying selective TEPL modulation mechanism with a simple theoretical model accounting for wavefront-dependent spatial distributions of exciton density and polarization-sensitive Purcell enhancement of Xs and IXs PL emission. The demonstrated concept of a 2-bit nano-excitonic transistor can be applied for further development of ultracompact devices for optical computing and communications. In addition, the ability to manipulate optical data within 25 nm^2 surface area can be useful for the development of high-density optical memory, i.e., nano-ray discs, which can improve the data capacity of blu-ray discs up to 7,200-fold.

Keywords:

nanocavity-integrated optical device, all-optical modulation, spatial light modulator (SLM), transition metal dichalcogenide (TMD) heterobilayer, interlayer exciton

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

B3.03

Chemical kinetic analysis of regioselective defect healing in WSe_2 monolayer

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Abstract:

Transition metal dichalcogenides (TMDs) have been extensively studied in electronics, optoelectronics, and catalysis, owing to their 2-dimensional (2D) layered structure and excellent electrical and optical properties. Especially, the monolayer (ML) of TMDs, which has a direct bandgap, has been widely applied for optoelectronic devices. However, 2D TMDs having a high surface-to-volume ratio would be easily reacted with surrounding molecules such as oxygen or water. The high reactivity of ML TMDs results in a degradation of their characteristics and instability, which is attributed to defects formation such as vacancies and oxidation. Besides, the inevitable structural defects of ML TMDs are generated during the transfer process, which must be solved to improve device performance. Thus, the Chemical kinetic analysis and healing of defects in TMDs are essential to fabricate cutting-edge TMDs-based applications.
In our study, we observed simultaneous vacancy healing and n-type doping effects using Trioctylphosphine Selenide (TOPSe) containing the electron-donating group of long aliphatic carbon chains. In addition, the regioselective reaction of TOPSe and WSe_2 occurs at the wrinkle. The origin of the regioselective reaction was revealed with chemical kinetics using UV-Vis absorption spectroscopy. This result indicates that the selective defect healing and doping effect at the specific positions can be controlled by the modulation of reaction kinetics, solving the problem of unstable and non-selective defect healing in TMDs.

Keywords:

healing effect, WSe2, Chemical doping effect

B3.04

Auger annihilation in anisotropic GaAs quantum rings

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Abstract:

Nonlinear photoluminescence spectrum was analyzed to investigate the localized states in anisotropic GaAs quantum rings. Time-resolved photoluminescence by TCSPC was performed in terms of excitation power dependence. At higher excitation power, nonlinear process of photoluminescence (I_{PL} ~ $I_{ex}^{0.6}$) was observed. According to increasing excitation power, photoluminescence decay time became fast, which was dominant to non-radiative decay rate at high excitation power. Fitting the decay with exciton-exciton annihilation model, we assumed that the nonlinear photoluminescence was oriented to Auger effect. To verify the Auger process, excitation correlation was performed, which showed that there was deep near zero delay time in excitation correlation signal of quantum rings. Due to exciton-exciton annihilation of Auger effect, photoluminescence intensity was decreased at overwrapped pulses. We concluded that localized states in anisotropic quantum rings gives rise to exciton-exciton annihilation of Auger effect which induces reduced photoluminescence intensity and fast decay time with nonlinear photoluminescence intensity.

Keywords:

quantum ring, Auger, exciton-exciton annihilation

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2023-04-19 - 2023-04-21

B3.05

Investigating the Impact of Surface Schottky Barriers on Two-Dimensional Material-Based Optoelectronics

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Abstract:

Ultrathin materials have emerged as a promising material type for electronics and optoelectronics due to their outstanding properties. However, their reliability is still limited due to unexpected degradation factors during device operation. In this study, we investigate the effect of Schottky barrier height (SBH) on the performance of two-dimensional (2D) material-based optoelectronics. Specifically, we demonstrate that when the SBH is formed negatively, the oppositely induced space charge region (OI-SCR) can significantly hinder the photo-generation and recombination process, leading to a degradation of the optoelectronic device performance. We investigated these effects by measuring localized photocurrents in the channel and OI-SCR regions of the device. We found that the channel region exhibited a much higher responsivity and detectivity than the OI-SCR region. We also found that depending on location, the dominant trap state can act as a recombination center or a deep-level trap. The deep trap states in the OI-SCR region increased the relaxation time, resulting in a slower optoelectronic response than in the channel region. This work provides important insights into the role of metal-semiconductor interfacial states in 2D materials-based optoelectronics. It emphasizes the need to carefully design and control these interfaces to realize high-performance devices.

Keywords:

MoS2, Schottky barrier, Shockley-Read-Hall process, optoelectronics, photocurrent

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

B3.06

Time-resolved photoemission spectroscopy simulation of black phosphorus with pseudospin

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Abstract:

Black phosphorus is the material that has the optical selection rule because of pseudospin from its high anisotropic structure with two sublattices. The optical selection rule of pseudospin is crucial because it determines allowed transitions between different pseudospin states in two-dimensional materials. Here, we study the monolayer black phosphorus with Time- and angle-resolved photoemission spectroscopy (TRPES) simulation to show its optically selective dynamics related to the pseudospin. The matrix element effects by the probe pulse polarization in the monolayer black phosphorus to observe the pseudospin of the excited electron by the pump pulse is discussed. By analyzing the pseudospin of the excited electron through our TRPES simulations, we gain a deeper understanding of the unique optical properties of black phosphorus and the implications of its pseudospin for future technological applications.

Keywords:

Black phosphorus, TRPES, optical selection rule, two-dimensional materials

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2023-04-19 - 2023-04-21

B3.07

All-Solution Synthesized High-Performance 2D Bi_2O_2Se Thin-Film Transistor

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Abstract:

Two-dimensional (2D) semiconductors have emerged as a next-generation electronic material because of their excellent electrical and mechanical properties in the atomically thin regime. These materials with a van der Waals layered structure are particularly promising for emerging electronics capable of heterogeneous integration and flexibility. For this purpose, low-temperature, and high-quality synthesis of 2D semiconductors are essential, the wet chemical synthesis has remarkable advantages in low process temperature, scalability, and cost-effectiveness compared to conventional chemical vapor deposition processes. However, it remains a considerable challenge in achieving high quality and device performance. Here, we report the wet chemical synthesis via a bottom-up process of 2D Bi_2O_2Se semiconductors showing a high mobility characteristic. The all-solution-based processes are carried out at a low temperature below 220 ℃ producing free-standing 2D flakes with a lateral size of over 10 μm and thickness down to 8 nm. In addition, the single-crystalline Bi_2O_2Se channel in a back-gated field-effect transistor geometry exhibited high mobility up to 132 $cm^2V^{-1}s^{-1}$ at room temperature. Notably, this solution can be assembled into a thin film for large-area device fabrication through a simple method such as layer-by-layer self-assembly or spin-coating. Our demonstration provides an innovative bottom-up synthesis approach to preparing high-quality semiconductors in a cost- and energy-effective manner.

Keywords:

2D materials, bismuth oxyselenide, wet-chemical synthesis, thin-film transistor

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

B3.08

Effect of Contact Engineering on $MoTe_2$/metal interface

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Abstract:

Contact Engineering plays a crucial role in the junctions formed at the contact between metal-semiconductor interfaces in electronic and optoelectronic devices. This study demonstrates a Schottky barrier photodiode (SPD) using contact engineering by designing lateral and vertical metal contacts on n-type 2H phase semiconducting molybdenum ditelluride ($MoTe_2$). The $MoTe_2$-based field-effect transistor was fabricated by depositing high-work-function palladium and low-work-function indium metals, resulting in diode characteristics. The device shows an ideality factor of 1.09 and a rectification ratio of 10^2, indicating ideal diode characteristics. In addition, the photo measurement shows a stable photodiode behavior of SPD in a wide range of light intensity. A single-channel $MoTe_2$-based study is helpful to apply in other 2D materials to achieve the possibility of designing next-generation nano-logic devices.

Keywords:

transition metal dichalcogenides, Schottky barrier diode,contact engineering,MoTe2,

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

B3.09

High-Performance and Lithography-Free WS_2-based Vertical Heterostructure Photovoltaic Devices

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Abstract:

There have been intensive research efforts to investigate intriguing physical phenomena of transition metal dichalcogenides (TMDs). TMDs have emerged as promising materials in photovoltaic-device applications due to their unique electronic and optical properties. However, TMD-based photovoltaic devices remain limited by challenges such as low-efficiency and high fabrication costs. In this work, we fabricated vertically stacked metal/semiconductor/metal heterostructures using WS_2 multilayers by a simple fabrication and studied their physical properties. The WS_2 multilayer flakes were exfoliated on template-stripped ultra-flat Ag layers, which were evaporated on SiO_2/Si wafers and then peeled off from the wafers using UV-curable epoxy. In order to investigate the transport properties of the flakes, we prepared 2-micron-sized Au top electrodes evaporated on the WS_2 flakes using a shadow mask consisting of holey carbon films. The current-voltage (*I*-*V*) characteristics of the Au/WS_2/Ag structures were obtained from current-sensing atomic force microscope measurements. Under the illumination of white LEDs, not only the V_{OC} and J_{SC} relationship, but also the polarization-dependence of the device characteristics were investigated. Optical measurements and simulations of the Au/WS_2/Ag device were also performed to understand the photocurrent characteristics. All of these results allow us to evaluate the photovoltaic performance of the Au/WS_2/Ag vertical heterostructures fabricated by the newly proposed lithography-free processes.

Keywords:

vertical heterojunction; WS2; template-strip method; current-sensing atomic force microscope

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

B4.01

Characterization of the cross-sectional doping profiling and metal contact for highly efficient TOPCon silicon solar cells

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Abstract:

Tunnel oxide passivated contact (TOPCon) structure have been attractive candidate for the high efficiency by the development of passivation layer and metal contact. TOPCon silicon solar cell has enthusiastically been investigated due to the theoretical limit of p-type passivated emitter and rear cell (p-PERC) efficiency. In particular, TOPCon cell based on n-type wafer has a great potential to realize the high efficiency through the tolerance of impurities and high temperature. In the front side of TOPCon solar cell, Ag/Al metallic paste has been usually used to contact with p+ boron emitter with SiNx and Al_2O_3 passivation layers. However, the electrical loss of front contact with the boron emitter and Ag/Al metal mainly limits the solar cell performance in the structure. Since the doping profile and formation of metal contact influence the photo-generated carrier transport, it is necessary to find the optimal doping profile and understand the formation mechanism of metal contact to improve the properties of solar cells.
In this study, we investigated the cross-sectional doping profile of front junction for TOPCon solar cells using by structural and electrical measurements. The samples with different doping profile were prepared by ion milling and focused ion beam (FIB) method. The geometric images of samples were indicated by scanning electron microscopy (SEM) and transmission electron microscopy (TEM) measurements. Through Raman mapping images, the distribution of junction including doping profile and metal contact were obtained. In particular, the carrier transport caused by the formation of metal contact was explained by the Kelvin probe force microscopy (KPFM) measurement. Finally, the solar cell performance of different doping samples was exhibited through the implied open circuit voltage (VOC), pseudo-fill factor (p-FF), and efficiency. From the comprehensive characterization, we suggested the optimal doping profile and metal contact for the enhancement of front junction properties and highly efficient TOPCon solar cells.

Keywords:

Characterization, Cross-sectional mapping, TOPCon silicon solar cells

B4.02

Functionalized Metal Oxide Catalysts for Wastewater Treatment using Electrochemical Oxygen Reduction

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Abstract:

Development of effective cathode materials is crucial for electrochemical H2O2 production and offers a promising utilization in advanced oxidation processes for wastewater treatment. In this presentation I present our studies on mesoporous sulfur-modified metal oxides coated onto stainless steel meshes as a cathode to promote in-situ generation of H2O2 for electro-Fenton processes. Sulfur doping turned out to enhance the electrocatalytic performance of metal oxide catalysts, and it was attributed to several factors such as large specific surface area, high-efficiency oxygen reduction reaction activity, and enhanced electron/charge transfer. The effect of operational parameters such as applied voltage, catalyst dosage, initial pH, initial concentration of phenol, and electrolyte concentration on the catalytic performance was investigated in terms of degradation efficiencies and rate constants. This cathode worked effectively in a wide pH range (3–10) due to its pH self-control ability and exhibited superior stability and reusability with insignificant deterioration in the catalytic activity. This study offers an alternative approach to fabricate electrocatalysts with functionalized metal oxides for wastewater treatment.

Keywords:

Advanced Oxidation Process, Electrochemical Wastewater Treatment, Electrochemical Wastewater Treatment, Hydrogen Peroxide Generation

B4.03

2D dual atom catalysts for superior hydrogen evolution reaction in wide pH media

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Abstract:

Layered two-dimensional (2D) transition metal dichalcogenides (TMDs) have been suggested as efficient substitutes for Pt-group metal electrocatalysts in the hydrogen evolution reaction (HER). However, poor catalytic activities in neutral and alkaline electrolytes considerably hinder their practical applications. Furthermore, the weak adhesion between TMDs and electrodes often impedes long-term durability and thus requires binder. Here, I present a universal platform for robust 2D dual atom electrocatalyst with superior HER performance over a wide pH range media. V-Co dual atom-doped ReS_2 on a wafer scale is directly grown on oxidized Ti foil by chemical vapor deposition and subsequently used for the highly efficient electrocatalysts. The catalytic performance surpasses that of Pt group metals in a high current regime (≥ 100 $mAcm^{-2}$) at pH ≥ 7, with a high durability of more than 70 h in all media at 200 $mAcm^{-2}$. First-principles calculations reveal that V-Co dual doping in ReS_2 significantly reduces the water dissociation barrier and simultaneously enables the material to achieve the thermoneutral Gibbs free energy for hydrogen adsorption.

Keywords:

transition metal dichalcogenides, chemical vapor deposition, dual atomic doping, water dissociation, wide-pH water splitting

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

B4.04

Novel Approaches for High Efficiency Electrochemical Energy Storage Devices Based on DNA-based nanomaterials with use of calculation methods

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Abstract:

In this talk, we present our approaches to realize high efficiency and next generation electrochemical energy storage devices based on DNAs and various nanomaterials. In one of our recent works, novel electrochemical, battery-like capacitors using DNA-wrapped multi-walled carbon nanotubs as electrode materials are demonstrated. We will be presenting subsequent works of use of DNAs and various nanomaterials for next-generation energy storage devices.
We also discuss how calculation methods such as the density functional theory (DFT) and quantum algorithms can be employed for better understanding on our experimental results. These days, the density functional theory (DFT) based simulation and quantum algorithm-based calculation methods are used to develop and design new materials for semiconductor devices and energy storage devices. In this talk, we present our recent employment of DFT calculations and quantum algorithm based calculation methods in application of next-generation nanomaterials for energy storages.

Keywords:

energy storages, DFT, quantum algorithm, VQE, , DNAs

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

B5.01

WS_2 Flakes Prepared by Au- and Ag-Mediated Exfoliation: Optical and Electrical Characterizations

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Abstract:

Layered transition metal dichalcogenides (TMDs) in the form of MX_2 (M: transition metal atoms like Mo and W; X: chalcogen atoms like S and Se) have gained increasing attention as a result of their unique physical properties. Thin TMD layers can be prepared using a new technique called metal-assisted exfoliation. It has been shown that the high binding energy at the TMD-metal interface results in a high exfoliation yield. In this work, WS_2 flakes were exfoliated on template-stripped ultra-flat metal (Au and Ag) layers, and their physical characteristics were investigated. The apparent colors of WS_2/Au and WS_2/Ag strongly depend on the underlying metal layers as well as the flake thickness. The optical phase shift at the WS_2/metal interface can significantly affect the optical reflectance spectra of the samples. Using Kelvin probe force microscopy, the contact potential difference (CPD) of the flake was investigated. We can suggest band alignment at the WS_2/Au and WS_2/Ag interfaces using thickness-dependent CPD and light-induced CPD changes. This work can provide valuable insights into the utilization of the TMD/metal structures for various optoelectronic device applications.

Keywords:

WS2, Kelvin probe force microscopy, band alignment, TMD

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

B5.02

Indium telluride grown by molecular beam epitaxy for electronic devices

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Abstract:

As promising two-dimensional layered semiconductor materials, many studies have been conducted about graphene, transition metal dichalcogenide materials (TMDc), black phosphorus, indium selenide, gallium selenide and hexagonal boron nitride(hBN). Among them, a study was conducted to confirm the suitability of the device by making a field effect transistor using a group III-VI chalcogenide material on a two-dimensional material using molecular beam epitaxy (MBE). It could be verified that the SEM and Raman spectroscopy were grown, and it could be verified that the manufactured device possessed the performance of a transistor.
Among the two-dimensional materials, chalcogenide related materials are in the spotlight for the use of next generation electronic and optoelectronic devices. Here, I conducted a study on the back-gated field effect transistor device of In_2Te_3 film on hBN

Keywords:

Group III-VI chalcogenide, Indium telluride, 2D material, Field effect transistor

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

B5.03

Partially Decorated $CrSnSe_3$ Monolayer with Alkali Metals: Mangetocrystalline Anisotropy and Curie Temperature

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Abstract:

Two-dimensional (2D) intrinsic ferromagnetic semiconductors with high Curie temperatures enable a broad range of spintronic applications. Herein we investigate the effect of partial decorating of the $CrSnSe_3$ monolayer with alkali metals Li, Na, and K on structural, electronic, and magnetic properties using first-principles total energy calculations. The decorated systems display semiconducting band features with ferromagnetic ground state. On the basis of Monte Carlo simulations, we found that Li, Na, and K decorated systems have substantially enhanced Curie temperatures of 241, 256, and 265 K. Our findings suggest that the decorated layers might be used for prospective spintronics applications.

Keywords:

2D, Curie temperature

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2023-04-19 - 2023-04-21

B5.04

Ultrafast dynamics of $IrTe_2$

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Abstract:

$IrTe_2$ exhibits a number of charge-ordered phases in different temperature ranges, and the phase transition mechanism is still under debate. Doping with various elements or decreasing the material's thickness causes $IrTe_2$ to exhibit superconductivity near 2.7 K, which develops always from one charge ordered phase (the 1/5 phase) above the superconducting transition temperature. It is crucial to understand the properties of the specific charge ordered phase in $IrTe_2$ and its superconducting phase transition.

We used near infrared pump-probe technique to investigate various charge ordered phases of $IrTe_2$. After pump excitation with an ultrashort laser pulse, coherent lattice vibration can be detected by measuring a transient reflectivity change. The Fourier transform of the oscillatory signal reveals three distinct low-temperature phases. Temperature dependent measurements allow us to identify each charge ordered phase. We find that the polarization dependence of the coherent oscillations of the 1/5 phase is different from the other phases. We will discuss the phase transition schematic diagram based on the structure of the Ir dimer. We will briefly present that the fluence dependent evolution of the ultrafast dynamics of the 1/5 phase is also distinguished from other phases.

Keywords:

Charge ordered phases, Phase transition, Superconductivity

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

B5.05

Anisotropic rippling of black phosphorus induced by van der Waals epitaxy of noble metals

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Abstract:

Black Phosphorus (BP), an emerging layered semiconducting crystal with strong in-plane anisotropy, can serve as a unique template for van der Waals epitaxy. For example, Au and Ag form single-crystalline metallic films on BP substrate with [110] surface orientation due to the BP’s template effect. These remarkable epitaxial behaviors can be attributed to the atomically puckered BP lattice structures, which lead to the strong anisotropic assembly behaviors of metals. Here, we investigate in detail the metal-BP interface and uncover an interesting interfacial reconstruction behavior. The periodic rippling of BP along its armchair lattice direction were confirmed by atomic resolution scanning transmission electron microscopy and electron diffraction analysis. The periodic rippling of BP is induced by small lattice mismatch between BP and metal along BP’s armchair direction. This study contributes to understanding the mechanisms of oriented metal epitaxy on anisotropic two-dimensional crystals.

Keywords:

black phosphorus, interfacial reconstruction, metal film epitaxy

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2023-04-19 - 2023-04-21

B5.06

Phase Transition of Graphite-Encapsulated γ-GeSe

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Abstract:

Chalcogenide phase-change materials (PCM) are promising candidates for data-storage applications. For example, Ge-Sb-Te-based PCMs utilize reversible phase transitions between the metastable crystalline phase and the amorphous phase. GeSe, one of the group-IV monochalcogenides has three types of polymorphs that are experimentally reported. Since the electrical properties of α-GeSe and γ-GeSe are extremely different, phase transition between GeSe polymorphs has great potential for memory application. In this study, the phase transition of γ-GeSe to α-GeSe by encapsulation annealing is reported. After the thermal annealing, graphite-encapsulated γ-GeSe changes into a single crystalline α-GeSe with a well-oriented crystal direction. We investigated the electrical and photoelectric properties of phase-changed α-GeSe. α-GeSe exhibits well-known p-type semiconducting behavior which is in stark contrast to those of γ-GeSe. Our works demonstrate that GeSe is a unique chalcogenide material that shows crystal-to-crystal phase transition with a great difference in resistivity.

Keywords:

γ-GeSe, phase-change material, phase transition, encapsulation

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2023-04-19 - 2023-04-21

B5.07

Fast and low-cost effective writing applicable at maskless lithography for 2D materials

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Abstract:

If the photolithography process can be carried out without a mask, it would be possible to fabricate devices quickly and effectively. Maskless lithography has the potential to simplify the fabrication process of basic devices. It is a cost-effective and efficient technique for writing patterns without using a vacuum system or the complicated procedures associated with electron beam lithography (EBL). By utilizing a 405 nm photodiode and a commercial Blu-ray1, 2 pickup, we successfully achieved pattern-writing with a minimum linewidth of 2 μm. We investigated the optimal conditions for beam intensity, scan speed, and step size experimentally and theoretically to minimize the linewidth. In this study, we applied maskless lithography to two-dimensional materials, specifically transition metal dichalcogenides (TMDCs) and graphene, and monitored their I-V curves and transport characteristics. This technology offers a fast and cost-effective fabrication process with intermediate resolution patterning.

Keywords:

Maskless lithography, light dose, fast patterning, TMDC, graphene

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2023-04-19 - 2023-04-21

B5.08

Fabrication of flexible MoS2 monolayer-based electronic devices

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Abstract:

Molybdenum disulfide MoS2 few layers is a potential two-dimensional semiconductor material due to its excellent semiconducting, mechanical, and electronic properties. In this work, we report the fabrication of CVD-grown MoS2 triangles monolayer-based electronic devices on flexible substrates. The procedure of transferring MoS2 monolayers from a silicon dioxide substrate to a transparent and flexible substrate and the method for making electrical contact will be illustrated. Then, the changes in electrical characteristics of MoS2 when applying uniaxial strain with a magnitude proportional to the bending radius of the substrate under optical microscope observation are investigated.

Keywords:

Molybdenum disulfide, electrical characteristics, flexible substrate

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2023-04-19 - 2023-04-21

B6.01

Coexistence of Tunneling and Colossal Magnetoresistance in Intrinsic Layered Antiferromangetic systems

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Abstract:

The coexistence of tunneling magnetoresistance (TMR) and colossal magnetoresistance (CMR) in certain strongly correlated electron systems with magnetic layers has attracted significant interest. TMR and CMR are two distinct quantum phenomena that arise from the complex interplay between different degrees of freedom in materials, specifically the spin, charge, and lattice degrees of freedom. In this presentation, we discuss the experimental observations of magnetoresistance with a 10,000 MR ratio in layered antiferromagnetic single crystals. This magnetoresistance has been proposed to be explained by empirical models, including the role of spin polarized states and the interplay through non-magnetic layers, as well as linear dichroism to explain the antiferromagnetic layered structure by the distortion dependent magnetic anisotropy. Overall, our results provides a comprehensive overview of the magnetoresistance in strongly correlated electron systems with magnetic layers, emphasizing the potential applications of these phenomena in the development of novel electronic devices and quantum computing.

Keywords:

Magnetoresistance, layered antiferromagnetic, tunneling magnetoresistance, single crystals, colossal magnetoresistance

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B6.02

Topological phase transition of generalized Brillouin zone in non-Hermitian electric circuits

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Abstract:

Non-Hermitian systems possess distinctive properties that are absent in Hermitian systems, such as the non-Hermitian skin effect and non-Bloch bulk-boundary correspondence (BBC). The BBC is a fundamental principle that explains the topological phases of matter, which asserts that robust boundary states are found in the nontrivial bulk topology. However, conventional BBC cannot be applied in non-Hermitian settings due to the failure of Bloch's theorem. In recent years, two modified types of BBC have been investigated in non-Hermitian systems. The first type of BBC is characterized by a line or point gap in the topology of complex eigenenergy, which results in the non-Hermitian skin effect. The second type of BBC is related to the wave function topology in the generalized Brillouin zone (GBZ), which hosts the traditional boundary state. A new type of BBC in non-Hermitian systems has recently been studied, which suggests that the BBC can arise from the intrinsic topology of GBZ. In this study, we demonstrate the new type of modified BBC experimentally using a one-dimensional non-Hermitian electric circuit network. We observe the topological phase transition accompanied by the emergence of exceptional points (EP) by manipulating the boundary couplings and potentials of the circuit. We also observe the manifestation of topological boundary modes under general boundary conditions and the merging of two GBZ during the topological phase transition. Our experimental findings are expected to facilitate further investigations into this new type of BBC in non-Hermitian systems.

Keywords:

non-Hermitian, bulk-boundary correspondence, artificial quantum matter, generalized Brillouin zone

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B6.03

Electronic origin of ferroelectricity in multiferroic Lu0.5Sc0.5FeO3

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Abstract:

Multiferroic materials have been a subject of intense study for decades due to their unique properties, particularly their ability to exhibit both ferroelectric and magnetic ordering. Despite significant advancements in the study of multiferroic materials, specific analyses for each material remain as challenges. In this study, we present the results of X-ray absorption linear dichroism and cluster calculation for hexagonal multiferroic Lu0.5Sc0.5FeO3. Large A site hybridization is observed in Oxygen K edge, which implies that strong d0 re-hybridization exists like h-YMnO3. Surprisingly, the hybridization strength of Lu is more than twice that of Sc. Ferroelectric energy gain by hybridization is calculated using cluster calculation. Using only cluster calculation result and simple phonon potential, ferroelectric double well energy landscape can be described satisfactorily. Thus, we revealed detail electronic structure and how they contributes on ferroelectricity of Lu0.5Sc0.5FeO3 with element specific manner.

Keywords:

multiferroic, ferroelectricity, XAS, cluster calculation

B6.04

Searching for Majorana bound states by Shapiro steps measurement in FeTe0.55Se0.45 Josephson junction

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Abstract:

Topological superconductors have a Majorana bound state (MBS) at their boundaries or vortices on the surface [1]. Such MBS follow non-Abelian exchange statistics, so they can be used as a fault-tolerant topological quantum computer [2], $FeTe_{0.55}Se_{0.45}$ (FTS), an iron-based superconductor, is one of the candidates for topological superconductors [3]. FTS is expected to have a topological surface state and zero-energy vortex bound state (ZVBS) under the external magnetic field [4]. To study the topological superconductivity of FTS in quantum transport experiment, we fabricated full-van der Waals vertical Josephson junction based on FTS through newly developed low-temperature micro-cleaving technique. Shapiro steps were measured upon irradiating microwave as a function of the strength of the external magnetic field. We will discuss about the progress of this research.

[1] Rev. Mod. Phys.. **82**, 4. (2010)
[2] Phys. –Usp. **44**, 131 (2001)
[3] PRL. **117**, 047001 (2016)
[4] Nature Materials. **18**, 811-815 (2019)

Keywords:

Topological superconductivity, Majorana vortex bound state

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2023-04-19 - 2023-04-21

B6.05

Introducing spin-orbit coupling in reversibly fluorinated graphene

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Abstract:

Spin-orbit coupling (SOC) which describes the coupling between spin and orbital degree of freedom of electrons is an important property in spintronics applications. Graphene is a material that has a great advantage in spintronics because it has high mobility. But graphene has very small SOC strength(~μeV) which is limitation for spintronics applications. In this work, we try to increase the SOC of graphene by attaching fluorine atoms onto graphene while minimizing the damage of graphene structure. We confirmed that the fluorinated graphene can be reserved back to pristine graphene by annealing in 500 °C for 2 hours in a vacuum, which implies that the fluorination does not damage the graphene structure. The resulting fluorinated graphene (FG) was investigated to exhibit spin Hall effect (SHE) through a nonlocal transport signal, nonlocal resistance R_{NL}, which was significantly larger than the trivial ohmic contribution. By analyzing the length dependence of R_{NL}, the spin relaxation length of FG was determined to be 0.52 μm. The strength of SOC calculated by using the Elliott-Yafet (EY) model yields 3.84 meV, three orders of magnitude larger than the SOC strength of pristine graphene and 50% larger than hydrogenated graphene [1]. These findings demonstrate the potential applications of fluorinated graphene for spintronics platforms, overcoming the limitation of low SOC intensity in pristine graphene.

[1] Balakrishnan, J., et al. (2013). "Colossal enhancement of spin-orbit coupling in weakly hydrogenated graphene." Nature Physics **9**(5): 284-287.

Keywords:

Spin orbit couplilng, Spintronics, Graphene

2023 KPS Spring Meeting
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B7.01

Hund correlations in single layer ruthenate films

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Abstract:

Hund's coupling, instead of Hubbard interaction, is a new knob to manipulate the physical properties of strongly correlated materials. For example, the role of Hund's coupling in unconventional superconductors such as Fe-pnictide or Sr 2 RuO 4 has been re-examined from the perspective of the newly proposed correlated metallic phase called Hund's metal. Among them, ruthenates have an appropriate size of Hubbard interaction and Hund's coupling, making them a suitable system for studying Hund's correlation physics. In particular, when ruthenates are grown as a single-layer thin film, bandwidth, crystal field, etc. can be effectively controlled, and various emergent phases can be observed. In this talk, we present a systematic theoretical study on the novel metallic and insulating properties of various ruthenates films by means of density functional theory plus dynamical mean-field theory (DMFT). We will discuss in detail the characteristics of the Hund correlation that emerge through thin film engineering.

Keywords:

Hund's coupling, ruthenate films, DFT+DMFT

B7.02

Strong Correlation in the Quantum Limit

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Abstract:

Quantum materials (QMs) with strong correlation and nontrivial topology are indispensable to next-generation information and computing technologies. The exploitation of topological band structure is an ideal starting point to realize correlated topological QMs. Among many classes of QMs, complex oxides offer a rich playground to exploit both correlations of Coulombic interactions between electrons often found in 3d transition metal oxides (TMOs) and SOC from heavy metal-based 5d TMOs, such as $SrIrO_3$ and Na_2IrO_3, leading to many intriguing physical properties. Hybrid materials with proper balancing of the correlation and SOC offer unique opportunities to discover new properties, and heterostructuring or combining dissimilar materials is a great approach to harnessing the complex interplay between quantum wavefunctions and various control parameters, such as proximity, dimensionality, topology, and symmetry.
Here, we report that strain-induced symmetry modification in correlated oxide $SrNbO_3$ thin films creates an emerging topological band structure. Dirac electrons in strained $SrNbO_3$ films reveal ultrahigh mobilit, exceptionally small effective mass ($m^* \sim 0.04m_e$), and nonzero Berry phase. Strained $SrNbO_3$ films reach the extreme quantum limit (XQL), exhibiting a sign of fractional occupation of Landau levels and giant mass enhancement [1]. Our results suggest that symmetry-modified SrNbO3 is a rare example of correlated oxide Dirac semimetals, in which the strong correlation of Dirac electrons leads to the realization of a novel correlated topological QM. While this is the second example of oxide-based topological quantum materials after the discovery of $CaIrO_3$ [2], we note that, when strained, much greater transport properties are discovered with the fractional occupation of Landau levels as it enters XQL at a low magnetic field.

References
[1] J. M. Ok *et al.*, *Sci. Adv.* **7**, eabf9631 (2021).
[2] J. Fujioka et al., *Nat. Commun*. 10, 362 (2019).

Keywords:

oxide thin film

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B7.03

Hund's metal perspectives on FeSe and Sr_2RuO_4

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Abstract:

We discuss electronic properties of two unconventional superconductors, FeSe and Sr_2RuO_4, in terms of characteristics of Hund's metals using DFT+DMFT calculations. First, magnetic properties of FeSe are investigated in bulk and monolayer forms. It is found that the interorbital charge fluctuations are greatly reduced between e_g and t_{2g} orbitals for bulk FeSe due to its large crystal-field splitting and the resultant strong orbital decoupling induced by the Hund's coupling. Consequently the total charge fluctuation are enhanced leading to a largely reduced ordered magnetic moment compared with LaFeAsO, consistently with the absence of magnetic order in bulk FeSe in experiments. In contrast, increased fluctuating magnetic moment and suppressed total charge fluctuation due to the increased interatomic distance and the reduced dimentionality result in a large ordered magnetic moment in expanded ML FeSe with the lattice constant of that on $SrTiO_3$. Thus, the stark contrast of the magnetic order between bulk and ML FeSe is explained in terms of Hund' metal properties within an unified framework. Small electron doping is found to effectively destroy the magnetic order in this system, implying that the superconductivity in ML FeSe/$SrTiO_3$ is in the vicinity of magnetic order.
Next, we investigate the connection between the local electron correlation and the momentum dependence of the spin susceptibility and the superconducting gap functions in Sr_2RuO_4. Adopting frequency-dependent two-particle vertex moves the zero energy spin susceptibility peaks towards the Brillouin zone center, compared with random-phase approximation which basically retains the peak positions closer to the Brillouin zone boundary as determined by the Fermi-surface nesting. We find that d_{xy} orbital plays a central role here via its enhanced correlation strength, owing to the orbital decoupling in a Hund's metal. Solving the linearized Eliashberg equation from this spin susceptibility, prime candidates of the superconducting gap symmetry are a *s*-wave, along with a nearly degenerate *d*-wave solution, all in spin singlet. Furthermore, another set of degenerate spin singlet gap functions emerges, odd with respect to k-point as well as orbital exchanges. We show that the stability of these gap functions are strongly dependent on the peak position of the spin susceptibility in the Brillouin zone.

Keywords:

Hund's coupling, DFT+DMFT, Strong electron correlation

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2023-04-19 - 2023-04-21

B8.01

Birth and future of van der Waals magnetism

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Abstract:

Symmetry and dimension are the two most essential keywords to daily physics discourse, and they pervade all corners of physics. Condensed matter physics is no exception, and there have been decades-long efforts to understand it. In particular, two-dimension has been noticed to have a very special position for many interesting reasons. Another important point to note is that most of our modern understanding is, in one way or another, related to magnetism. Hence, there have been early breakthroughs in the theory of two-dimensional magnetism, starting from the Ising solution (1943), the Mermin-Wagner theorem (1966), and then the Berezinskii–Kosterlitz–Thouless transition (1971 and 1973). Despite these glorious successes, there has been very slow progress on the experimental side. Motivated by this realization, people worked on two-dimensional magnetism since the 1970s with some, but limited, success. In 2015, my group at Seoul National University made a major breakthrough by discovering a new class of magnetic materials, now known as van der Waals magnets. In my talk, I will give an overview of how this discovery was made in Korea and how I followed this crazy idea with perseverance. And then, I will end my talk with a personal view of how van der Waals magnetism will evolve in many years to come.

Keywords:

van der Waals magnets

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B8.02

Anomalous surface states of magetic topological materials

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Abstract:

Topological crystalline insulators (TCI) can host surface states whose anomalous band structure inherits the characteristics of the crystalline symmetry that protects the bulk topology. Especially, in magnetic crystals, the diversity of magnetic crystalline symmetries indicates the potential to achieve novel magnetic TCI with distinct surface characteristics. Here, we are going to talk about the anomalous surface states of two dfiferent types of magnetic TCIs. One is a new type of magnetic TCI, coined the topological magnetic Dirac insulator (TMDI), whose two-dimensional surface hosts four-fold degenerate Dirac fermions protected by magnetic wallpaper groups. The bulk band topology of TMDIs is protected by diagonal mirror symmetries, which give the chiral dispersion of surface Dirac fermions and mirror-protected hinge modes. We also propose a class of candidate materials for TMDIs including $Nd_4Te_8Cl_4O_{20}$ and DyB_4 based on first-principle calculations, and construct a general scheme to search TMDIs using the space group symmetry of paramagnetic parent states. In the second part, we are going to discuss the anomalous intrinsic surface states of CoS_2, which is recently proposed as a ferromagnetic Weyl semimetal. Due to the interplay of the surface termination and bulk band topology, various intrinsic surface states can appear other than the Fermi arcs. We will discuss the intrinsic relation between the spin polarization of the bulk/surface and the intrinsic nature of the surface states

Keywords:

Magnetic topological crystalline insulators, anomalous surface states, Dirac fermions

B8.03

Revisiting quasi-one-dimensional systems via ARPES

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Abstract:

Discovery of graphene has greatly boosted intensive and extensive studies on various low-dimensional compounds as a platform for quantum physics based on strong electron correlation and topology. In this regard, various materials with van der Waals stacking have become a central issue of recent researches. Among a series of van der Waals materials, quasi-one-dimensional systems can emerge intriguing properties in which stronger electron correlation compared to other two- or three-dimensional materials can be expected due to its limited interaction channels. Despite the expectation, their simple but hairy structures prevent the advanced study to clarify the detailed physics of those materials.

In this talk, I will introduce recent studies of transition-metal trichalcogenides (TMTCs), which would be a novel platform to study quantum properties based on both strong electron correlation and topology. By virtue of the improved angle-resolved photoemission spectroscopy technique with external stimuli, we succeeded to identify the electronic structure of transition-metal triselenide, and revealed the complexed phase diagram of this system.

Keywords:

Quasi-one-dimensional system, ARPES, Electronic structure

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2023-04-19 - 2023-04-21

B9.01

Electronic structure study of the rotational symmetry breaking driven by three dimensional charge density wave in kagome superconductor KV_3Sb_5

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Abstract:

Vanadium based kagome superconductors AV_3Sb_5 (A = K, Rb, Cs) provide a fertile playground for studying various intriguing phenomena in kagome metal such as non-trivial band topology, superconductivity, anomalous Hall effect and charge density wave (CDW). Remarkably, the recent discovery about the C_2 symmetric nematic phase prior to the superconducting state in AV_3Sb_5 has drawn enormous attention, as the unusual superconductivity might inherit the symmetry of the nematic phase. Although many efforts have been devoted to resolve the charge orders using real-space microscopy and transport measurements, the direct evidence on the rotation symmetry breaking of the electronic structure in the CDW state from the reciprocal space have not been addressed, and the underlying mechanism remains ambiguous. Here, utilizing the angle-resolved photoemission spectroscopy, we investigate the fingerprint of band folding in the 3D CDW phase of KV_3Sb_5, which yet demonstrates the unconventional unidirectionality, and is indicative of the rotation symmetry breaking from C_6 to C_2. We pinpointed that it is the interlayer coupling between kagome planes with π-phase offset in the 2×2×2 CDW phase that would give a rise to the preferred two-fold symmetric band structure. These unique observation for the unidirectional back-folded bands in KV_3Sb_5 may provide important insights into its peculiar charge ordering and superconductivity at lower temperature.

Keywords:

KV3Sb5, Kagome metal, charge density wave, electronic structure, angle-resolved photoemission spectroscopy

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B9.02

Direct observation of hidden anisotropy of atomically thin 1T-TaS_2.

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Abstract:

Atomically thin 1*T*-TaS_2 can stabilize multiple metastable phases [1]. Such metastable phases have been regarded as nearly commensurate charge-density-wave (NCCDW) phases with varying domain sizes. Recent experimental observations of quasi-1d structure [2] and theoretical expectations of multivalley free energy [3] suggest an intrinsic anisotropy in 1*T*-TaS_2. In this study, we use scanning tunneling microscope (STM) to investigate anisotropic structures in atomically thin 1*T*-TaS_2 at room temperature. We show that reducing the thickness induces distortion of CDW domain structure [4]. An electric excitation or reducing the lateral size results in a further deviation from NCCDW phase [5]. Such a deviation leads to the emergent nanoscopic stripes and ultimately replaces the NCCDW phase with a novel 3x1 structure. Our observations provide direct evidence for the anisotropic nature of 1*T*-TaS_2 and suggest additional control parameters for hidden phases in 1*T*-TaS_2.

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[1] T. Patel, J. Okamoto, T. Dekker, B. Yang, J. Gao, X. Luo, W. Lu, Y. Sun, and A. W. Tsen, “Photocurrent Imaging of Multi-Memristive Charge Density Wave Switching in Two-Dimensional 1*T*-TaS_2”, *Nano Lett.* **20(10)**, 7200-7206 (2020).
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Keywords:

Scanning tunneling microscopy, 1T-TaS2, Charge density wave, Thickness dependence, Hidden phase

Optical transitions of a single nodal ring in $SrAs_3$: radially and axially resolved characterization

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Abstract:

Nodal semimetals are expected to display a universal power-law behavior upon light absorption, where the interband transition between the two crossing bands forming the nodal line as $E(\omega) \sim k^z$ leads to optical conductivity $\sigma_1(\omega) \sim \omega^{(d-2)/z}$. This has been experimentally verified in various topological materials. We conducted polarized optical reflection measurements on a single nodal ring in $SrAs_3$ and found that for the radial direction, the optical conductivity $\sigma_1(\omega)$ exhibited a flat absorption σ^{flat} up to $\hbar\omega$ = 130 meV ($\equiv 2\varepsilon_0$), followed by a gradual increase at higher energies. In contrast, the σ^{flat} for the axial direction was three times higher, followed by a sharp drop for energies $\omega \geq 2\varepsilon_0$. Spin-orbit coupling caused a pronounced peak at Δ_{soc} = 15 meV for both directions. Using an effective model Hamiltonian and first-principles calculations, we calculated the optical conductivity of the nodal ring, and our results were in excellent agreement with the data. We were able to determine the band overlap energy $2\varepsilon_0$ = 130 meV, average radius k_0 = 0.068 Å^{-1}, and ellipticity k_a/k_b = 1.16 of the ring. These findings establish $SrAs_3$ as an ideal platform for studying nodal rings, as optical transitions at low temperatures are exclusively determined by the single nodal ring without any interference from trivial bands at the Fermi level. As temperature increases, both the σ^{flat} and $2\varepsilon_0$ decrease significantly, indicating intriguing temperature-driven non-rigid band change.

Keywords:

Topological materials, Nodal-line semimetals, SrAs3, FT-IR spectrosocpy, Optical conductivity

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2023-04-19 - 2023-04-21

B9.04

Optical transitions of a single nodal ring in $SrAs_3$: Theoretical analysis

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Abstract:

Nodal-line semimetals (NLSMs) are a class of quantum materials where two bands cross on lines in momentum space, resulting in a characteristic frequency-independent flat conductivity. However, the complexity of the shape of the nodal line and the coexistence of trivial bands at the Fermi energy make it challenging to disentangle the optical properties of NLSMs. Recently, $SrAs_3$ has been proposed as a promising NLSM candidate. Unlike many other NLSMs, $SrAs_3$ features a single ring-shaped nodal line in momentum space and no trivial bands coexist near the Fermi energy.
In this presentation, I will discuss the optical transitions in $SrAs_3$ focusing on the theoretical side of our work. We calculate the optical conductivity using an effective model Hamiltonian with the aid of density functional theory band calculations. Our theoretical analysis reveals the effects of the nodal-line shape, spin-orbit coupling and anisotropic velocities along the radial and axial directions on the optical conductivity. Our results demonstrate excellent agreement between theory and experiment, providing new insights into the optical properties of $SrAs_3$ and other NLSMs.

Keywords:

Topological materials, Nodal-line semimetals, SrAs3, FT-IR spectroscopy, Optical conductivity

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

B9.06

Classification of Fermionic Topological Orders using Congruence Representations

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Abstract:

The fusion rules and braiding statistics of anyons in (2+1)D fermionic topological orders are characterized by the modular data of a super-modular category. On the other hand, the modular data of a super-modular category form a congruence representation of the Gamma_theta subgroup of the modular group SL_2(Z). We provide a method to classify the modular data of super-modular categories by first obtaining the congruence representations of Gamma_theta and then building candidate modular data out of those representations. We carry out this classification up to rank 10. We obtain both unitary and non-unitary modular data, including all previously known unitary modular data, and also discover new classes of modular data of rank 10. We also determine the central charges of all these modular data, without explicitly computing their modular extensions.

Keywords:

topological order, modular tensor category, topological quantum field theory, anyon, topological quantum computation

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B9.07

The Electric Field Effects on Kitaev Quantum Spin Liquids

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Abstract:

The ground state of Kitaev's honeycomb model is a non-abelian chiral spin-liquid state with Majorana fermion excitations, which has been proposed as a promising platform for fault-tolerant topological quantum computations. Here, we show that Majorana fermions can be manipulated by applying an electric field. By using a combination of exact diagonalization and parton analysis for microscopic spin Hamiltonians, it is demonstrated that the manipulation is most significant near topological phase transitions of Kitaev's quantum spin liquids. We also discuss experimental signatures to detect Kitaev quantum spin liquids in experiments, especially in connection with the candidate materials such as alpha-$RuCl_3$.

Keywords:

Quantum Spin Liquid, Kitaev's Honeycomb Model

Transparent Graphene-Amorphous Silicon Photodetectors

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Abstract:

Light field 카메라는 물체의 3차원 정보, 즉 위치와 각도 정보를 기록한다. 본 발표에서는 다층의 투명 센서를 통하여 단시간 내에 3차원 정보를 얻어내는 방식을 보인다. 다층의 투명 센서를 3차원 카메라로 활용하기 위해서는 상대적으로 높은 투과도와 높은 광센싱 효율을 요구한다. 이를 위하여, 흡수체의 두께에 따른 투명 광센서의 성능을 평가 연구하였다. 본 발표에서는, 유리 기판 위에 그래핀-실리콘 기반 투명한 센서 array 제작 및 광응답 특성과 양자 효율 특성등의 연구결과를 보인다. 광센서 구조는 유리기판 위에 증착한 ITO-Si-Graphene 적층 구조이며, 2x2, 5x5 센서 array 평면 구조이다. Si 두께에 따른 광센서 특성을 조사하기 위하여 300nm, 500nm, 700nm 두께의 실리콘을 사용하였다. 이들의 투명 센서 array의 I-V 측정과 파장별 다양한 광량에 대해 광반응 특성을 조사 연구하였다.

Keywords:

Graphene, Photodetector, Transparent Sensor, 3D Sensor, Light field

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B10.02

ZnO/NiO-Based Transparent Photovoltaic Cells: Plasmonic Effects of ZnO/Ag-Nanowire Top Electrodes

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Abstract:

Transparent photovoltaic (TPV) devices, which can be installed in windows of buildings and vehicles, enable the conversion of solar energy to electric energy and transparency of visible light. Heterostructures of wide-bandgap metal-oxides can be used as a way to fabricate TPV cells because they have a high visible transmittance and the ability to selectively absorb short-wavelength sunlight (wavelength (λ) < 435 nm). In this work, the measured and calculated optical spectra as well as the local current-voltage (*I-V*) characteristics of ZnO/NiO-heterojunction-based TPV devices have been studied. In our TPV devices, top electrodes consist of ZnO(10 nm)-coated Ag nanowires (AgNWs), which exhibit high electrical conductivity and optical transparency. The *I-V* data of the TPV devices with and without the ZnO/AgNW electrodes, obtained by conductive atomic force microscopy (C-AFM) measurements, show that the ZnO/AgNW electrodes effectively collect photo-generated charge carriers. In particular, the C-AFM studies reveal that the AgNWs significantly increase the photocurrent when illuminated by light that is polarized perpendicular to the NW axis. Such polarization-dependence suggests that the localized surface plasmon excitation in AgNW can contribute to the enhanced photocurrent. The plasmonic contribution of the AgNWs is well supported by optical calculation and measurement results. To examine light-induced changes in the surface potential distributions of the TPV devices, Kelvin probe force microscopy measurements are also carried out.

Keywords:

Transparent photovoltaic (TPV), Conductive atomic force microscopy (C-AFM), Localized surface plasmon, Kelvin probe force microscopy

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B10.03

Enhancing the Switching Speed of Vanadium Dioxide in Electrolyte-Gated Field-Effect Transistors via controlling grain size

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Abstract:

The low power consumption and great potential of synaptic devices is what makes lyte-gated field-effect transistors (EG - FETs) so important. It has been difficult to achieve remarkable performance due to the slow switch speed. Our research has improved the switching speed of the EG -FETs by controlling the grain size of the thin film used as the channel. VO2 was an ideal choice for use as a channel material because of its high on/off ratio and we controlled its grain size by various deposition conditions. Our results show that increasing the size of the grain leads to faster switch speeds, and this can be explained by scattering between and within the grains. The results open the possibility of commercializing FETs to develop other synaptic devices that contribute to artificial intelligence technology.

Keywords:

EG-FET, Switching speed, VO2, Grain size, Grain scattering

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B10.04

Dielectric constant in nanoscale bubbles on MoS_2

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Abstract:

Nanoscale bubbles spontaneously forms inevitably during a transfer process of two-dimensional (2D) materials on a target substrate due to their van der Waals interaction. Despite a large number of studies on bubble structures with localized strain, the strain induced behaviors of dielectric constant (ε) in nanobubbles of MoS_2 is poorly understood. Here, we report ε measurements for nanobubbles of MoS_2 by probing the polarization forces under an applied electric field oscillating at low frequency based on electrostatic force microscopy (EFM). Remarkably, regardless of the bubble size, such as height and radius, the higher ε are observed for the nanobubbles of MoS_2 as compared to flat regions. We find that the charge carrier increase owing to the strain-induced band gap reduction which is independent of the bubbles' height or radius is responsible for the enhanced ε of the nanobubbles of MoS_2, in agreement with our calculations based on the Clausius-Mossotti relation. Our results provide the fundamental information about the strain-induced local dielectric properties of 2D materials and guide for the design and fabrication of high performance optoelectrical devices based on 2D materials.

Keywords:

bubble, MoS2, strain, electrostatic force microscopy (EFM), dielectric constant

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B10.05

Improved performance of WS_2 field-effect transistor by h-BN tunneling contacts

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Abstract:

Transition metal dichalcogenides have attracted much attention owing to their unique properties. However, a current challenge in achieving high-quality electronic devices is contact resistance. Herein, we introduce a strategy to overcome this problem by inserting a monolayer hexagonal boron nitride (h-BN) at the chromium (Cr) and tungsten disulfide (WS_2) interface. Electrical characteristics of direct metal-semiconductor (MS) and metal-insulator-semiconductor (MIS) contacts with mono and bilayer h-BN in a four-layer WS_2 field-effect transistor are compared from 77 to 300K. Contact resistance is significantly reduced by ten times with MIS contacts. An electron mobility up to ≈115 $cm^2V^{-1}s^{-1}$ at 300K is achieved with the insertion of monolayer h-BN, which is ten times higher than that with MS contacts. These improvements are attributed to Schottky barrier reduction when monolayer h-BN is introduced between Cr and WS_2. The dependence of tunneling mechanisms on h-BN thickness is also investigated by extracting tunneling barrier parameters.

Keywords:

Transition metal dichalcogenides, mono and bilayer h-BN, tunneling barrier, contact resistance, Schottky barrier

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B10.06

Coupling Interlayer Resistance and Carrier Scattering Mechanisms in Multilayer Rhenium Disulfide for High Temperature Carrier Transport Analysis

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Abstract:

Temperature-dependent carrier density and mobility strongly influence the electrical conductivity of a materials at a given electrostatic bias condition, implying that it is possible to gain insights into carrier transport mechanisms and charge scattering phenomena by examining these temperature-dependent properties. Among numerous 2D multilayers, rhenium disulfide (ReS_2) stands out due to its high interlayer resistance (R_{IT}), which suggests the increasing significance of R_{IT} effects on carrier transport in multilayer ReS_2. In this presentation, we study the impact of interlayer resistance on carrier scattering mechanisms in 2D ReS_2 multilayers at high-temperature regimes. At room temperature, we observe a conducting channel migration along the *c*-axis of 2D ReS_2 multilayers with increasing gate and drain bias. However, at temperatures above 380 K, an anomalous peak in transconductance (g_m) driving a sudden enhancement of the carrier mobility appears clearly. The observed behavior is attributed to the rapid reduction of effective interlayer resistivity of ReS_2. Furthermore, we analyze the temperature-dependent carrier mobility using Matthiessen's rule, which enables us to separate the contributions of Coulomb impurity scattering, phonon scattering, and interlayer resistance scattering.

Keywords:

Charge scattering mechanism, interlayer resistance, carrier mobility, 2D multilayers, channel migration

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B10.07

Fabrication of Wide Band Gap of p-i-n Perovskite Solar Cell for Tandem Cell Application

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Abstract:

Perovskite solar cells (PSCs) have become a leading-edge technology in recent decades due to their remarkable power conversion efficiency (PCE), which has risen from 3.8% (n-i-p) in 2009 to 25.7% (n-i-p) in 2022. However, the Shockley-Queisser limit defines the theoretical maximum PCE that can be attained with a single junction solar cell at around 33%. Tandem solar cells, which combine narrow and wide bandgap thin-film junctions, hold great potential for surpassing this limit. The p-i-n type perovskite solar cell is the most suitable structure for this purpose. To enhance the performance of PSCs, it is critical to passivate defects on the perovskite surface and at the perovskite/ETL interface to decrease non-radiative recombination. In our study, we utilized interfacial engineering of 3D/2D perovskite through a combination of 3D perovskite with triple cation (Cs0.15Fa0.65MA0.15Pb1(I0.8Br0.2)3) and 2-thiophene ethyl ammonium chloride (TEACl). We obtained a PCE of approximately 19% with an optical bandgap of ~1.67 eV for the perovskite solar cell, which can be employed as a top junction for a highly efficient tandem solar cell.

Keywords:

wide band gap, triple cation perovskite, solar cell

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B10.08

비대칭 슈퍼커패시터 응용을 위한 $Zn_3V_2O_{10}$@rGO 물질 합성 및 특성

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Abstract:

최근 급속도로 증가하는 에너지 수요로 인해 지속 가능한 에너지 저장 기술의 개발이 가속화되고 있다. 배터리가 주로 사용되고 있지만, 충전 및 방전 속도가 느리고 전력 밀도가 낮아, 이에 대한 대안으로 슈퍼커패시터에 대한 연구가 활발히 진행되고 있다. 계층적 나노구조를 가진 새로운 전이금속 바나데이트 물질은 촉매 및 에너지 저장/변환 시스템에서 놀라운 전기화학적 특성으로 인해 엄청난 주목을 받아왔다. 본 발표에서 간단한 수열합성법으로 다양한 성장온도에서 $Zn_3V_2O_{10}$ 물질이 합성되었고, 합성된 물질의 특성이 조사되었다. 또한 환원 그래핀 옥사이드 (rGO) 시트를 도입하여 슈퍼커패시터 적용을 위한 전기화학적 특성을 개선하였다. 합성된 $Zn_3V_2O_{10}$@rGO 전극은 KOH 수용액 전해질 용액에서 높은 비용량(정전용량)과 우수한 용량 유지율을 나타냈다. 또한, $Zn_3V_2O_{10}$@rGO 전극기반의 제작된 비대칭 슈퍼커패시터 소자는 높은 최대 전력 및 에너지 밀도를 나타냈고, 우수한 사이클 안정성을 보여주었다. 이러한 유리한 특성으로 인해 $Zn_3V_2O_{10}$@rGO 전극 재료는 고성능 슈퍼커패시터 응용에 매우 유망할 것으로 사료된다.

Keywords:

전이금속산화물, 환원 그래핀 옥사이드, 전기화학적 특성, 슈퍼커패시터

B10.09

탄탈산나트륨 입자 로드된 폴리머 필름기반 나노발전소자 제작 및 특성

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Abstract:

최근 유연 및 웨어러블 휴대용 전자장치의 급속한 발전으로 인해 전원 공급 장치의 필요성이 증가하고 있고, 휴대용 전자 제품, 건강 모니터링 시스템, 무선 센서 시스템, 바이오 센서 및 기타 분야에서 널리 사용되고 있다. 따라서, 이들 휴대용 전자기기를 운용하기 위해서는 안정적이고 재생 가능한 청정에너지가 절실히 필요하다. 에너지 수확은 다양한 휴대용 및 자체 전원 전자 장치의 사용 증가로 인해 수요가 증가하고 있다. 나노 발전소자는 다양한 저전력 휴대용 전자 장치에 전원을 공급하기 위해 수확하는 생체 역학 에너지를 전기로 변환하는 잠재적인 수확 에너지 장치로 관련기술이 부상하고 있다. 따라서 본 발표에서는 탄탈산나트륨 ($NaTaO_3$) 물질을 수열합성법으로 합성한 후 polydimethylsiloane 고분자에 매립하여 유연 압전 나노발전소자를 제작하였다. 재료 농도를 최적화하고 기계적 안정성과 장기 회전 견고성 분석을 체계적으로 연구했다. 마지막으로, 제안된 압전 나노발전소자는 다양한 저전력 전자 장치에 전원공급을 시연하였고, 자체 전원 센서로도 사용되었다.

Keywords:

탄탈산나트륨, 폴리머 필름, 나노발전소자

Fusion Reactor Requirements and Discovery of “FIRE mode” in KSTAR

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Abstract:

핵융합 실현을 위해서는 핵융합반응을 일으키기 위해 넣어주는 에너지 대비 핵융합반응을 통해 얻은 에너지가 커야 한다는 기본 조건을 만족해야 한다. 이 조건은 핵융합로 내부에서 핵융합반응을 일으키는 원자핵(이온)의 밀도, 온도, 가둠효율시간의 곱이 어느 값 이상으로 유지되어야 한다는 것으로 표현된다. 원자핵은 양의 전하를 띠고 있기 때문에 원자핵들이 쿨롱반발력을 이기고 융합을 하기 위해서는 높은 운동에너지, 즉 1억도 이상의 고온이 필요하다. 이 고온의 상태에서는 원자핵과 전자가 분리된 플라즈마 상태가 된다. 최근 한국의 초전도 토카막 장치인 KSTAR에서 원자핵의 온도를 1억도 이상 30초 유지하는 기록을 달성하였다. KSTAR는 자기장을 사용하여 원자핵을 도넛 모양의 진공 용기에 가두는 방식인 토카막 방식을 이용한 핵융합 장치로 유럽, 미국, 일본, 러시아, 중국, 인도, 한국이 참여하고 있는 초대형 국제핵융합장치인 ITER와 동일한 사양의 초전도 코일로 만들어졌다. KSTAR에서는 원자핵들의 밀도가 매우 낮은 상태에서 고에너지 중성빔을 외부에서 주입하였을 때 1억도 이상의 초고온 현상이 나타남을 다양한 실험을 통해 관찰하였고, 자기장 구조를 조절함으로써 이를 장시간 유지하는데 성공하였다. 기존 장치들에서도 1억도 이상의 초고온을 얻기는 하였으나 장시간 유지가 어려웠던 점을 고려할 때 이는 이례적이며, 특히 토카막 내부 플라즈마의 가장자리에서 나타나는 치명적인 불안정성 현상이나 토카막 벽에서 유입되는 불순물이 플라즈마 중심부에 축적되는 현상도 나타나지 않아 매우 획기적인 성과로 평가된다. 다양한 다차원 모델링과 비선형 시뮬레이션을 통해, 중성빔을 통해 플라즈마에 주입되어 이온화된 ‘고속이온’이 플라즈마 내부의 난류를 안정화 시켜 초고온과 고가둠효율의 기작이 됨이 밝혀졌다. 이 기작에 따라 KSTAR에서 새롭게 발견된 플라즈마 가둠 모드는 “FIRE (Fast Ion Regulated Enhancment) 모드”라 명명하였다. [1] FIRE 모드는 비록 밀도가 낮긴 하지만 높은 온도와 가둠효율시간으로 차세대 고성능 운전모드로서 개발이 기대된다.

[1] H. Han, S.J. Park, C. Sung, and Yong-Su Na, et al. Nature 609, 269–275 (2022)

Keywords:

Fusion, FIRE mode, Fast ion, KSTAR, Tokamak

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B11.02

Experimental Approach to Establish FIRE mode

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Abstract:

KSTAR 토카막은 초전도 자석을 이용하여 핵융합 플라즈마를 발전 가능한 수준으로 생성하고 유지할 수 있는 기술을 개발하기 위한 실험용 장치로써, 2008년 첫 플라즈마를 발생한 이후로, 해마다 몇 개월간의 플라즈마 실험을 통하여 꾸준히 그 기술을 발전시켜 왔다.
핵융합 반응의 핵심조건인 1억도 이상의 이온온도에 도달하고 장시간 유지하는 실험은 2016년부터 본격적으로 시도하였는데, 그 시작은 플라즈마가 내벽에 닿아 H-모드로 천이되지 못하는 상황에서 4~5MW 이상의 중성입자빔을 주입하여 내부수송장벽(ITB)을 가지는 플라즈마를 만드는 방법이었다. 이러한 방법을 통하여 중심부에서 높은 이온온도와 전자온도를 달성할 수 있었고, 그 성능은 일반적인 H-모드 플라즈마와 비슷하였다[1].
이러한 성과를 바탕으로 ITB 형성을 더 오래 유지하기 위한 방법을 연구하였는데, 두 종류의 플라즈마 형상에서 시도하였다. 하나는 여전히 플라즈마가 내벽에 닿아 있지만 상하 비대칭적인 형상이고, 다른 하나는 플라즈마가 내벽에 닿지 않으면서, H-모드 천이에 불리한 조건인 USN(Upper Single Null) 형태를 기본으로 하였다.
첫번째의 경우, 내벽에 닿은 플라즈마의 형상조정을 통하여서 기존보다 낮은 3MW의 중성입자빔에서 ITB를 이룰 수 있었다. 이를 통하여 더욱 넓은 제어 영역을 가질 수 있었고, ITB 성능유지 시간을 늘릴 수 있었으나, 내벽과의 접촉에서 생기는 불순물로 인한 성능감소가 장시간 유지에 방해가 되었다[2]. 이에 반해 플라즈마 밀도를 낮게 유지하면서 내벽과 접촉하지 않는 USN 모양을 기반으로 하는 방법은 불순물 문제가 발생하지 않으면서, 약 4MW 미만의 NBI 만으로도 10 keV를 넘는 높은 이온 온도를 30초까지 유지할 수 있음을 확인하였으며, 이러한 상황을 만드는 데 고속 이온(Fast ion)이 중요한 역할을 하는 것을 알아내고 FIRE(Fast Ion Regulated Enhanced)모드로 명명하였다[3].

[1] J. Chung, *et al.*, *Nucl. Fusion* **58** 016019 (2018).
[2] J. Chung, *et al.*, *Nucl. Fusion* **61** 126051 (2021).
[3] H. Han , S.J. Park, C. Sung *et al. Nature* **609**, 269–275 (2022).

Keywords:

KSTAR, FIRE mode, High ion temperature, Fast ion

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B11.03

Physical mechanism of the Fast Ion Regulated Enhancement (FIRE) mode

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Abstract:

The Fast Ion Regulated Enhancement (FIRE) mode[1] is the self-organized plasma regime with promising features such as having high performance that is comparable to the high confinement mode (H-mode), but without severe instabilities. An internal transport barrier (ITB) formation through a suppression of turbulence leads to performance enhancement of the FIRE mode. The correlation between the ITB location and fast ion fraction, observed in the FIRE mode operation, implies that fast ions play an important role in ITB formation. Gyrokinetic simulation using code CGYRO[2] also reproduces a significant reduction of thermal energy flux, as fast ions are included, thereby supporting the view that fast ions contribute to ITB formation through turbulence suppression. Further gyrokinetic analysis was performed to understand the role of fast ions for turbulence suppression in the FIRE mode. We investigate multiple turbulence suppression mechanism via fast ions - increased pressure gradient, two dilution effects including both the reduced main ion fraction and changes in the main thermal ion density gradient, and an increased zonal shearing rate. We found that two dilution effects were mainly responsible for turbulence suppression in the FIRE mode. The physical mechanism of the FIRE mode identified in this study will be the basis for future study, such as expanding the operation window of the FIRE mode and optimization of its performance. This study will also provide a deeper understanding of the fast ion effects on turbulence since the FIRE mode plasma is unique in terms of a higher fraction of fast ions and a more peaked fast ion density profile than the plasmas in other operation modes. The simulation results also demonstrated that ITB can be formed solely by an inverted main thermal ion density gradient due to the high fraction of fast ions. Since manipulating the main ion density gradient can be realized using various experimental techniques, such as injecting impurity or pellets, as well as using fast ions, this new finding can become the basis for developing a new high performance operation mode.

[1] H. Han, S. J. Park, C. Sung, and Y.-S. Na, *et al.*, *Nature* **609**, 269–275 (2022)
[2] J. Candy, E. A. Belli, R. V. Bravenec, *J. Comput. Phys.* **324**, 73-93 (2016)

Keywords:

Turbulence, Fast ions, Gyrokinetic simulation, Internal transport barrier

B12.01

JKPS 발전을 위한 방안 탐색: Project JKPS2024

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Abstract:

JKPS 발전을 위한 방안 탐색: Project JKPS2024

운영자: 박지용(아주대), 남승일(부경대), 서준호(KRISS)

현재 JKPS는 낮은 인용지수, 투고수 감소 등 다양한 현안 문제들로 위기에 직면해 있습니다. 이러한 문제들을 해결하고, 보다 정상적인 학술지로서의 역할을 다하기 위해, JKPS 편집위원회에서는 2024년을 목표로 다양한 개선-발전방안을 마련하였고, 이를 학회 회원들께 설명하고 함께 논의하고자 합니다. 학회를 대표하는 물리학 전분야 SCI 학술지로서, 위기를 극복하고 제고된 위상과 보다 나은 서비스를 회원들에게 제공하는 학술지로 거듭나기 위한 노력입니다. 많은 회원님들의 관심과 참석을 부탁드립니다.

[프로그램]
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Keywords:

JKPS

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B13.01

Sizable charge transfer and correlation effects in layered heterostructures of Ta-dichalcogenide

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Abstract:

Ta-dichalcogenide heterostructures such as the bilayer 1T/1H-TaS_2 and bulk 4Hb-TaS_2 have been recently been in the limelight due to Mott physics, Kondo effect, and topological superconductivity, which arise from by coupling of a metallic 1H and a Mott-insulating 1T layers. In particular, the localized spin state in the 1T charge density wave (Star-of-David) plays an essential role. To date, however, several reports cannot seem to agree on the position of the flat band and spin occupations. Here we resolve this conundrum by demonstrating that the charge transfer between two layers is sensitive to interlayer spacings, which are variable in actual fabrications. As a result, the localized state is empty at the optimum distance but becomes partially occupied as the layer separation increases. Our findings suggest that inconsistencies in experiments may be a result of varying interlayer spacing and/or underlying substrate, and paves the road for the practical tuning of Mott physics.

Keywords:

Mott physics, charge density wave, correlation effect, layered heterostructure

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B13.02

Strain-induced bright-to-dark exciton conversion in rippled monolayer MoS_2

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Abstract:

Recently, it has been revealed that dark excitons play a significant role in optically controlled information processing due to their much longer radiative lifetimes compared to bright ones. For a realizable implementation of the features, it is important to understand and manipulate conditions in which dark excitons could exist. We adopt the strain-engineered rippling as a new parameter for a modification of the electronic structure of the monolayer MoS_2 and demonstrate an efficient conversion of bright to dark excitons through the first-principles study. For the rippled monolayer MoS_2 above the strain of ~6.8%, we show that the spin order of the conduction band is reversed and the spin forbidden dark exciton then comes to lie below the bright one.

Keywords:

Dark exciton, rippling engineering, first principles calculation

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B13.03

The Circular photo-galvanic effect in chiral Se chains

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Abstract:

Chirality, characterized by the lack of superposition with its reflection or inversion partner, has aroused intense interest as an intriguing platform hosting unconventional quantum phenomena such as Weyl semimetal, spin selection, and optical transport [1-3]. In non-centrosymmetric systems, a nonvanishing photocurrent can be generated by asymmetric distribution of excited carriers under circularly polarized light, which is so called the circular photo-galvanic effect (CPGE). Here, we demonstrate that the CPGE can occur in one-dimensional chiral selenium (Se) chains, using density functional theory (DFT) and time-dependent DFT. We find that the electronic structure is closely related to the unique geometry of Se chain, leading to a sizable helicity-tunable photocurrent. We also investigate the real-time evolution of excited carriers and its dependence on light helicity. Our results indicate that chiral structure can be a possible tool for designing an advanced optoelectronic device.

[1] Rao, Z., Li, H., Zhang, T. et al. Observation of unconventional chiral fermions with long Fermi arcs in CoSi. Nature 567, 496–499 (2019).
[2] B. Gohler et al. Spin Selectivity in Electron Transmission Through Self-Assembled Monolayers of Double-Stranded DNA. Science. 331, 6019 (2011)
[3] Liu, Y., Xiao, J., Koo, J. et al. Chirality-driven topological electronic structure of DNA-like materials. Nat. Mater. 20, 638–644 (2021).

Keywords:

DFT, Bulk photovoltaic effect, chiral material

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B13.04

Possibility of Thru-Hole Epitaxy as an Alternative of Remote Epitaxy

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Abstract:

Remote epitaxy has been developed to address issues related to the difficult separation of samples from their underlying substrates and dislocation caused by lattice mismatch during the growth of semiconductors on substrates. This technique involves adding a layer of 2D material to the surface of the substrate to enable easy separation and transfer while maintaining crystallographic alignment. Although remote epitaxy has gained attention as a useful method, it requires a perfect 2D material without defects. Previous studies utilizing first-principles calculations explained that potential changes are teleported from the substrate to the 2D layer. In this study, we re-examined the teleported potential profile to investigate the physical feasibility of remote epitaxy using different materials on sapphire substrates with an added 2D layer. By conducting first-principles calculations based on density functional theory, we examined the local potential distribution on c-, m-, and r-sapphire surfaces with a 2D material such as graphene and h-BN, while varying the number of layers from n=0n=0 up to n=3n=3. Our results indicate that when n≥2n≥2 of either h-BN or graphene, the local potential of the sapphire substrate is completely screened, regardless of the substrate's surface orientation. Even for the n=1n=1 case, where the local potential in the vicinity of the epitaxy varies depending on the stacking angles and configurations between the substrate and the 2D layer, the potential fluctuation is not only negligibly weaker than that observed on the bare sapphire substrate but also depends on the stacking configurations, not the crystallographic orientation of the substrate, indicating that the local potential profile of the substrate is not reflected over the 2D layer. We propose a new epitaxy called thru-hole epitaxy, which can equally well explain the results considered from remote epitaxy in a much more natural way, without ignoring the inevitable presence of defects in the 2D space layer.

Keywords:

size-dependent, thin film, resistivity, conductivity

B13.05

Computational insights and phase transitions of ruthenium alloy using classical molecular dynamics

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Abstract:

Evolution in melt structures with temperature during deep undercooling, forming uniform melt-free crystal sites, and the effect of the melt state on solidification behaviors by using embedded atom method (EAM) potential, all have theoretical significance for understanding the mechanism of metal solidification. This EAM potential has remarkable accuracy and a wide range of properties, including mechanical properties, lattice dynamics, the energetics of competing crystal structures, defects, deformation routes, and liquid structures. In this study, we have performed a molecular dynamics simulation to examine the impact of different cooling rates during melt Ruthenium (Ru) alloy's solidification at temperatures ranging from 3250 K to 50 K. The evolutions in local systems have been observed in an energy-temperature curve, pair-correlation functions, bond angle distribution functions, the Honeycutt-Anderson index, and visualization analysis. Upon quenching with different cooling rates, we have observed transformation to a supercooled liquid state at 1200 K and a body-centered cubic-like cluster dominated after 1200 K in a stable and supercooled liquid form. We have calculated a critical cooling rate (10^{12} *K*/s) for the crystal to amorphous transition, and the solidification under cooling increases being the superheating temperature accelerates until the maximum cooling is achieved. We have found that the maximal undercooling occurred approximately at 0.4396Tm K and the maximal superheating at 1.2893Tm K. In our simulated data, the first and second peaks of radial distribution function(RDF) at room temperature show fair accordance with the experimentally observed RDF peaks of Ru nanoparticles. These findings will provide a roadmap and a foundation for further research on the relationship between melt temperature and nucleation supercooling.

Keywords:

EAM potential, molecular dynamics , Ruthenium (Ru)

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B13.06

Unremovable linked nodal structures in stacked bilayer graphene with Kekulé texture

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Abstract:

Linking structure is a new concept characterizing topological semimetals, which indicates the interweaving of the gap closing nodes at the Fermi energy (E_F) with other nodes below E_F. As the number of linked nodes can be changed only via pair-creation or pair-annihilation, a linked node is more stable and robust than ordinary nodes without linking [1,2,3] .

We propose a new type of a linked nodal structure between a nodal line (nodal surface) at E F with another nodal line (nodal surface) below E F in two-dimensional (three-dimensional) systems with two chiral symmetries and negligible spin-orbit coupling. Contrary to the cases of linked nodes reported previously, in our system, a double band inversion creates a pair of linked nodes carrying the same topological charges, thus the pair are unremovable via a Lifshiftz transition. A realistic tight binding model and effective theory are developed for such a linking structure, and also a class of candidate materials are predicted using density functional theory (DFT) calculations. Experimental aspect of the proposed theory and predicted compounds are also discussed.

Keywords:

Linking structure, Nodal line, bilayer graphene

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B13.07

Polymorphic and dual topological insulating phases of InTe

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Abstract:

Topological insulator (TI) is characterized by its unique surface state protected by time-reversal symmetry (TRS), while topological crystalline insulator (TCI) relies on crystal symmetry such as mirror symmetry. Here, we demonstrate that InTe exhibits both TI and TCI characteristics, resulting in a dual topological insulator (DTI) with nontrivial $\mathbb{Z}_2$ invariants and mirror Chern numbers $C_M = \pm 1$. More intriguingly, InTe, which is a van der Waals layered material, can form polymorphs with a mirror plane perpendicular to the *c*-axis, possessing an additional mirror symmetry that enhances the robustness of topological surface state against perturbations. We find that the combination of TRS and the dual mirror symmetries creates a triply protected surface state. It is also revealed that broken TRS realized by an applied magnetic field cannot open a gap in the mirror symmetry-protected surface Dirac states but can only shift the Dirac point instead. Therefore, our results not only substantiate InTe to possess doubly or triply protected surface states, but also provide an exciting and unique platform to explore the Dirac states engineering physics.

Keywords:

Topological materials

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B13.08

The Origin of the Nearly Flat Band Formation in the monolayer TaS2

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Abstract:

In this work, we present a microscopic theory of the nearly flat-band formation in the monolayer TaS2 under the commensurate charge density wave (CCDW) phase, where the David-star supercell structure emerges. We construct a tight-binding model consisting of d-orbitals including crystal field effects and local potential variation due to local distortion in the David star.
By analyzing structures and energetics of the David star, we show that there is a compac localized state centered at the star, which is possibly the origin of the nearly flat band at the Fermi level. We also analyze electronic structures of TaS2 to explain that the nearly flat is isolated out of other band manifolds.

Keywords:

Two-dimensional materials, Electronic structure theory, Transition metal dichalcogenides

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B13.09

Athermal charge effect on electro-plasticity of metal

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Abstract:

Metals can stretch extensively when carrying electric current, a phenomenon known as electro-plasticity, which is commonly used in the steel industry to shape metals. It has been believed that electro-plasticity is caused by temperature rise due to the joule's heat generated by the current, but the true cause remains unknown. Recently, it was discovered that the temperature rise from the applied current is not sufficient to significantly enhance electro-plasticity. In this study, we used first-principles density functional theory to investigate the athermal effect of excess charge induced by electric current on electro-plasticity. We examined how excess charge affects deformation energy barriers and charge redistribution within deformation regions in different metals. Our findings confirm that the improvement in electro-plasticity is indeed due to the athermal effect of excess charge rather than the thermal effect caused by temperature rise.

Keywords:

charge effect, DFT, Ab initio, electro-plasticity

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B14.01

Study on DNA damage search mechanism using a novel single-molecule imaging technique

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Abstract:

DNA molecules are damaged by malfunctioning metabolism and bulky adducts, inducing genetic instability and passing it on to the next generation. DNA damage repair processes should be conducted properly. Thus, understanding the detail molecular mechanism of DNA damage repair process is important. My research focuses on DNA damage repair at the single molecular level, especially the dynamics of DNA damage recognition proteins on DNA.
Ch1.
Global genome nucleotide excision repair (GG-NER) eliminates chemical bulky adducts and UV-induced thymine dimers. This process is initiated by Xeroderma pigmentosum complementation group C protein (XPC), which detects DNA lesions by recognizing structural distortions. However, the exact mechanism for this detection and the factors affecting it are unclear.
The detailed mechanism of XPC-RAD23B was revealed by DNA curtain assay, a single-molecule imaging technique that unidirectionally aligns DNA strands. The assay uses the fluidity of the lipid bilayer to track the movement of a single protein molecule on DNA in real time. I observed XPC-RAD23B (Red) jump over the protein obstacles (EcoRI^E111Q, Green) at specific sites while diffusing. Its diffusion coefficient increases in direct proportion to the ionic strength of the environment.
These results indicate that human XPC-RAD23B uses diffusion along the DNA, especially via hopping, as a proxy for DNA lesions. This process allows it to bypass protein obstacles. Moreover, XPC-RAD23B moves along DNA strands in a heterogeneous fashion — at times immobile, diffusive, or constrained state, depending on the stability of DNA duplexes.
Taken together, these results provide insight into how hXPC-Rad23B can rapidly find DNA defects, preventing mutations and ultimately cancer in human cells.
Ch2.
R-loops(three-stranded nucleotide structures consisting of an RNA-DNA hybrid and a displaced ssDNA structure) serve as signaling molecules in various cellular processes, but they also act as DNA lesions when improperly regulated. These molecules can be recognized and eliminated by Tonicity enhancer-binding protein (TonEBP), a transcription factor for immune response and tonicity regulation. Using a DNA curtain with purified TonEBP and R-loop-containing lambda DNA, I demonstrated that TonEBP identifies R-loops via both 1D diffusion and 3D collision. In addition, TonEBP preferentially binds the displaced ssDNA in the R-loop structure, as I confirmed using electrophoretic mobility shift assay with diverse types of DNA constructs.
This study reveals that TonEBP recognizes R-loops on DNA and recruits R-loop elimination proteins such as METTL3-METTL14 to resolve the R-loops by RNase H1.

Keywords:

dna curtain, dna damage repair, single-molecule imaging, xpc, r-loop

Holotomography and artificial intelligence: label-free 3D imaging, classification, and inference

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Abstract:

Holotomography is a label-free, high-resolution, three-dimensional quantitative phase imaging technique (QPI) that uses refractive index distributions as intrinsic imaging contrast for label-free imaging. Similar to X-ray computed tomography, Holotomography measures multiple two-dimensional holograms of a sample with various illumination angles, from which a three-dimensional refractive index distribution of the sample is reconstructed by solving the wave equation. Combining the label-free and quantitative 3D imaging capability of Holotomography with machine learning approaches provides synergistic capability in bioimaging and clinical diagnosis. In this presentation, we will discuss the potentials and challenges of combining QPI and artificial intelligence for various aspects of imaging and analysis, including segmentation, classification, and imaging inference.

Keywords:

imaging, cell, microscopy, refractive index, holotomography

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B14.03

Real-time imaging of nanoscale dynamic events in single nascent adhesions using label-free interferometric scattering microscopy in living cells

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Abstract:

Focal adhesions (FAs) are dynamic protein complexes that link the actin cytoskeleton of the cell to the extracellular matrix through transmembrane integrin receptors. This study presents a characterization of the real-time dynamic behavior of nanoscopic nascent adhesions (NAs) by using the interferometric scattering (iSCAT) microscopy. iSCAT microscopy is a label-free, high-speed, and time-unlimited imaging technique that offers high sensitivity and signal stability. This enables the tracking of the entire life span of spontaneously nucleated NAs under a lamellipodium. The high-throughput and long-term image data obtained provide a unique opportunity for statistical analysis of adhesion dynamics. Furthermore, we directly show that FAs play critical roles in both the extrusion of filopodia as nucleation sites on the leading edge and the one-dimensional transport of cargos along cytoskeletal fibers as fiber docking sites. These experimental observations demonstrate that iSCAT is a sensitive tool for tracking the real-time dynamics of nanoscopic objects involved in endogenous and exogenous biological processes in living cells.

Keywords:

iSCAT, Focal adhesion, Label-free imaging

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B14.04

Long-term label-free evaluations of single bacteria with hydrogel-based immobilization for three-dimensional quantitative phase imaging

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Abstract:

Three-dimensional (3D) quantitative phase imaging (QPI) is an effective way to observe in long term and quantitatively analyze live individual bacteria without the need for labeling. However, the movement of bacteria in liquid environments including Brownian motion or motility can lead to motion artifacts that make it difficult to obtain precise images and measurements. Additionally, conventional cell immobilization techniques may produce noisy backgrounds and alter cellular physiology. This study presents an approach that utilizes hydrogels for high-quality 3D QPI of live bacteria while maintaining their physiological integrity. The proposed protocol allows for long-term high-resolution quantitative imaging and analysis of individual bacteria, including the determination of biophysical parameters of bacteria and responses to antibiotic treatments.

Keywords:

3D Quantitative phase imaging, bacteria, hydrogel, quantitative analysis

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2023-04-19 - 2023-04-21

B14.05

Translation-dependent subcellular localization of cytoplasmic mRNA in E. coli

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Abstract:

In bacteria, the functional coupling between transcription and translation is a fundamental phenomenon that regulates bacterial gene expression. However, the strong segregation between transcriptional and translational machinery found in many bacterial species, including *E. coli*, has challenged the concept of transcription-translation coupling. Here, we observed the cytoplasmic mRNA localization depending on translation to explain how transcription and translation can be spatially coupled. By visualizing different cytoplasmic mRNAs and their originated gene locus, we discovered that translation decides the specific localization pattern of cytoplasmic mRNA depending on the distance between the originated DNA and nucleoid periphery. The observed relocation of cytoplasmic mRNAs induced by translation suggests that the nucleoid periphery acts as a hub of transcription-translation coupling.

Keywords:

RNA localization of bacteria, subcellular organization, transcription-translation coupling

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2023-04-19 - 2023-04-21

B15.01

First-principles investigations on copper-based layered halide perovskites

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Abstract:

Over the past decade, halide perovskite has received a wide attention in various application fields including optoelectronics and memory due to their outstanding properties. Furthermore, due to their structural flexibility, various new materials have been proposed through atomic substitution and dimension lowering. As a result, research field based on the halide perovskite are rapidly expanding. In this study, we investigate the electronic and optical properties of copper-based layered halide perovskite by using first-principle calculations. Our study has found that the copper-based halide perovskite has spin-polarized band gap, which can effectively suppress the optical absorption of infrared light. In addition, we also identify the electronic band structure and charge density distribution of various compositional copper-based halide perovskite. Based on our findings, we have suggested a couple of different methods to modify electrical and optical properties of copper-based halide perovskite.

Keywords:

First-principles calculations, layered halide perovskite

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2023-04-19 - 2023-04-21

B15.02

Twisted boundaries for enhancing thermoelectric properties

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Abstract:

Thermoelectric materials have gained great attention owing to their capability of converting heat into electricity without mechanical movements. Identifying an ideal microstructure for efficient thermoelectric materials has been complicated by the interplay between the electrical and thermal properties. The electrical properties of thermoelectric materials are often compromised to reduce lattice thermal conductivities and increase dimensionless thermoelectric figure-of-merit (zT). Here, we utilized an unusual concept of "rotation" to effectively decouple electrical and thermal transport properties using elemental tellurium (Te) as a model system. It is found that the twisted grain in the Fe2As-doped Te crystal preserve high electrical conductivities while reducing the thermal conductivities, showing superior thermoelectric performance. We believe that the strategy described in our work is expected to provide a breakthrough for improving the thermoelectric properties of various thermoelectric materials.

Keywords:

Thermoelectric materials, Microstructure, Tellurium

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2023-04-19 - 2023-04-21

B15.03

Best Thermoelectric Efficiency Map on Ever-Explored Materials: toward Device Physics, beyond Materials

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Abstract:

Thermoelectric devices enable the direct conversion of heat into electricity through thermoelectric effects. The Seebeck effect generates electrical voltage when a temperature difference is applied across the device, while the Peltier effect couples electrical current with a reversible heat current. The efficiency of a thermoelectric device, as a heat engine, is a direct measure of its thermoelectric conversion ability. Despite the development of many high figure of merit materials, there have been limited studies on the practical implementation of thermoelectric devices for energy realization, and the achievable limit of thermoelectric efficiency remains unknown.
In this presentation, we report on the best thermoelectric efficiency of ever-explored materials [1]. By filtering the thermoelectric property data from the world's largest thermoelectric property database (Starrydata2.org) [2], we obtain a high-quality thermoelectric big data set. Using thermoelectric integral equations based on the general thermoelectric efficiency theory of three thermoelectric degrees of freedom [3], we quickly and accurately predict the thermoelectric efficiencies of devices by solving for temperature solutions in P- and N-legs. By considering P-N leg-pair combinations, interface thermal/electrical resistances, leg geometries, and thermal and electrical working conditions, we have explored the efficiencies of 100 million devices based on 13,000 materials.
Our results reveal that the best thermoelectric efficiency can reach over 17% in a single-stage P-N leg-pair device when the hot and cold side temperatures are 860 K and 300 K. With a leg-segmentation technology, this efficiency can be increased to 20% and 24% when the hot side temperature is changed to 850 K and 1100 K, respectively. In an infinite cascade model, a very high efficiency of 33% is possible with a heat source at 1400 K.
However, there is a significant discrepancy between theoretical and experimental efficiencies, which may be caused by suboptimal material selection or the presence of significant parasitic thermal/electrical resistances that have not been fully considered. This highlights the need for a careful consideration and analysis of the underlying physics of thermoelectric devices for the wider implementation of thermoelectric power generation technology in the industrial and transportation sectors.
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[2] Y. Katsura, M. Kumagai et al., Science and Technology of Advanced Materials 20, 511 (2019).
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Keywords:

thermoelectric, material, device, efficiency, data

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

B16.01

Constructing machine learning models with quantum computers

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Abstract:

Machine learning, which runs on classical computers, has made significant impacts to our daily life in recent years. On the other hand, it is well known that quantum computers can solve some types of computational problems more efficiently than classical ones. These facts motivate us to construct a "quantum" machine learning models using quantum computers, which may outperform classical ones in certain setups. In this talk, we will explore recent quantum machine learning techniques such as quantum neural networks and quantum kernel methods. Both of the approaches have potential to be implemented using near-term quantum computers. We will also discuss the current state of research in this field, including our theoretical and experimental efforts, and the challenges that remain in developing practical quantum machine learning algorithms.

Keywords:

Quantum machine learning, quantum neural network, quantum kernel method

B16.02

Theory-driven Quantum Machine Learning for HEP

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Abstract:

Machine Learning is, in most cases, powerful but a black-box application. In this talk, we will tackle this very problem from a quantum mechanics point of view, arguing that an optimisation problem, such as classification or anomaly detection, can be studied by "rephrasing" the problem as a quantum many-body system or a mixed state. Such an approach allows us to employ the entire arsenal of quantum theory for data analysis techniques while enabling exact representation for a quantum device. Hence this talk will present a small step towards fully theory-driven and interpretable quantum machine learning applications.

Keywords:

Quantum Machine Learning, Tensor Networks, Quantum Computing

Exploring quantum foundations with gauge bosons

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Abstract:

Locality, reality and measurement have been central questions in Quantum Mechanics since its first formulation. Empirical tests addressing these issues were first proposed by John Bell in 1964. Subsequent experiments in atomic and optical systems (awarded the Nobel prize for physics 2022) have been found to agree with the quantum predictions at ~eV energies, and to disagree with local hidden-variable theories. I'll discuss how, by exploiting developments from the field of quantum computing, we can now also conceive of extending these tests to high-energy systems such as in electroweak boson and Higgs boson decays.

Keywords:

Quantum physics, collider, Bell inequality, entanglement, gauge boson, LHC

B17.01

Investigation of the initial geometry description using collectivity in the AMPT model

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Abstract:

The motivation of geometry engineering with p, d, and ^{3}He projectiles at RHIC is to investigate the relation between initial geometry and final momentum anisotropy, which is thought to be strong evidence of Quark-Gluon Plasma. PHENIX results show the elliptic and triangular flow hierarchy in p/d/^{3}He+Au collisions follows the eccentricity described by the Monte-Carlo Glauber model. However, the initial geometry of small collision systems is sensitive to detailed descriptions such as sub-nucleon geometry, area of energy deposition, and elastic scattering. A multiphase transport model (AMPT) can qualitatively describe the collective behavior with scatterings at partonic and hadronic stages. We utilize the AMPT model to simulate small collision systems and investigate the correlation between initial geometry and final momentum anisotropy with different geometry descriptions. We will present the study on the relationship between the flow coefficient of produced particles and the eccentricity of initial geometry with various configurations.

Keywords:

AMPT, Initial geometry, Flow

B17.02

Elliptic flow studies of charmonium states in PbPb collisions at 5.02 TeV with CMS experiment

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Abstract:

To understand the in-medium effects of quarkonia in heavy ion collisions, it is necessary to perform differential studies of various observables to have a global picture of the quarkonium dynamics in the quark-gluon plasma (QGP). The measurement of the elliptic azimuthal anisotropy of the charmounium states has been suggested as a powerful tool to study the different in-medium effects such as dissociation and regeneration. In this presentation, we present the second-order and third-order Fourier coefficients, v_{2} and v_{3} for prompt and nonprompt J/ψ, and prompt $\psi(2S)$ mesons. The results are discussed with theoretical calculations regarding suppression and recombination effects.

Keywords:

Heavy ion collision, CMS, Charmonia

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

B17.03

Describing Ridge behavior via kinematic model

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Abstract:

The Ridge behavior in high-multiplicity proton-proton collisions has been discussed a lot since it was first reported in year. Because small systems like proton-proton collisions can not provide sufficient conditions to produce a medium called Quark-Gluon Plasma (QGP), in which the Ridge behavior is understood with high-order flows. In this work, we propose the pure kinematic mechanism between jets and medium partons as tools for describing the Ridge behavior; while jets pass through the medium, the momentum transferred from jets to medium partons is in the direction of jets' motion resulting in the collective motion of the medium.

In practical calculation, the information of the initial medium parton is necessary to describe the scattering process kinematically. In this work, we choose parton distribution functions from the hard scattering model (phPDh) close to the PYTHIA simulation. The phPDh is parameterized by a fallout parameter, *a*, a non-extensive parameter, *q*, and the temperature of the system, *T*; *a* decides the shape of rapidity distribution, and *q* affects rapidity and transverse momentum distribution. And *T* is related to transverse momentum distribution. Compared to the PYTHIA simulation, we get proper values of $a = 85$, $q = 1.15$, and $T = 145$MeV. We calculate a two-particle angular correlation using phPDh. We check the tendencies of the correlation for various energy losses of jet particles, the angle of jet particles after collisions, and so on.

Keywords:

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

B17.04

Study of characteristics of reconstructed jets using various jet resolution parameters

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Abstract:

Jets, collimated particles resulting from fragmentation of energetic partons produced in hard scatterings, are used for several purposes, such as a test of theoretical understanding of their initial production and a probe to investigate nuclear medium produced in heavy-ion collisions. In data analysis, jets are reconstructed using clustering algorithms with a selected Jet Resolution Parameter (R), which determines the size of reconstructed jets. Therefore, the characteristics of jets reconstructed with different resolution parameters can be different even in the same set of collision events. This can be due to several reasons such as measuring only a part of the jet, merging separate jets, clustering particles from the background, and others. We have performed a simulation study using the PYTHIA8 event generator to investigate how the characteristics of reconstructed jets change with different jet resolution parameters. This study will provide a guideline for a better understanding of experimental measurements of jets with selected resolution parameters.

Keywords:

Jet, Resolution parameter, PYTHIA8

B17.05

Study of jet fragmentation in ALICE

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Abstract:

Jets provide unique and powerful probes to study Quantum Chromodynamics in proton-proton collisions and the quark-gluon plasma medium in heavy-ion collisions. Among these probes, the measurement of jet substructure and the distribution of hadronic constituents within a jet provide a detailed look into the partonic shower process. ALICE has recently measured and published transverse momentum j_T distributions of the jet fragments in proton-proton and proton-lead collisions. Further follow-up analysis is done to separate two components related to jet fragments and hadronisation. The study has been extended to j_T measurements in different momentum fraction z ranges for a more detailed look. In this talk, the latest results on measurements of the transverse momentum of charged-particle jet fragments in pp collisions by the ALICE Collaboration will be presented. The results are compared with various models to test our understanding of jet fragmentation.

Keywords:

ALICE, Jet fragmentation

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

B17.06

Report about the status for heavy ion data taking in Run 3 with CMS

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Abstract:

In September 2023, heavy ion collisions will be restarted from LHC as its third period of operation (Run 3).
For the heavy ion data taking during Run 3, CMS has prepared for expected challenging issues.
In November 2022, LHC gave the Pb-ion beam the maximum collision energy for the test, and CMS tested the configuration for Run 3 with the test run.
In this presentation, the status of data taking during the heavy ion run period and prospects will be reported.

Keywords:

CMS, Run 3, heavy ion, GPU, Pb-ion

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

B17.08

B_c mesons in a hot QGP medium

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Abstract:

We study the properties of $ B_c₩, (c₩bar{b}, b₩bar{c})$ meson using a modified in-medium heavy quark potential. We have modeled the heavy quark potential for both the short as well as long distances. We have used the same screening scale for both the Coulombic as well as long distance confining term. We compute the wave functions, binding energies and decay widths of $ B_c $ mesons by using the modified heavy quark complex potential. Recently, the first $ B_c $ observation is claimed by CMS collaboration in Pb-Pb collisions. The $ B_c $ mesons are of special interest, since these are the only heavy mesons consisting of two heavy quarks with different flavors. These are intermediate in size and binding energy between $ J/₩psi $ and $ ₩Upsilon $ mesons. We compute the physical observables such as the survival probability and suppression factor of ground and excited states of B_c mesons. The survival probability with respect to centrality, rapidity and transverse momentum is one of the key signatures to quantify the properties of the medium created in heavy ion collision. We study the survival probability as a function of number of participant, which measures the centrality of the collision.We use the 1+1 dimensional viscous hydrodynamics and have included both the shear and bulk viscous effects.

Keywords:

Heavy quark potential, Bc mesons, quark gluon plasma

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

B17.09

Photo- and electroproduction of phi meson including Ps

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Abstract:

We investigate photo- and electroproduction of ϕ-mesons from a proton target, $\gamma p \to \phi p$, using an effective Lagrangian approach. To explain a bump-like structure observed in the experimental data of ϕ-meson photoproduction, we introduce a contribution of the exotic pentaquark molecular state $K^*\Sigma$, assigned as $P_s^+(2071, 3/2^-)$, for the direct ϕ-meson radiation in the s- and u-channels. In addition to P_s^+, we also consider contributions from the Pomeron exchange, pseudoscalar- and scalar-meson exchange, and axial-vector Regge in the t-channel. We will discuss the influence of P_s^+ on the total and differential cross sections, as well as the spin-density matrices, for photon virtuality Q^2 = 0, 1, and 2 GeV^2.

Keywords:

phi, Ps, photoproduction, electroproduction

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

B18.01

Carbon isotopes in Nuclear Lattice Effective Field Theory

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Abstract:

A recently developed novel Wave Function Matching method for quantum many-body problem is applied for the Carbon isotopes up to drip line in a Nuclear Lattice Effective Field Theory approach. The binding energy calculation shows very good agreement with the experimental data providing the validity of the WFM Hamiltonian for neutron rich nuclei. We discuss the implication of the dynamics of nucleons in the neutron rich nuclei.

Keywords:

Nuclear Lattice Effective Field Theory, Nuclear Structure, Carbon isotopes, dripline

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

B18.02

Shell-model calculation of the radial overlap correction to superallowed 0+→0+ nuclear beta decays

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Abstract:

The radial overlap correction, δ_{C2} is reexamined for 30 superallowed 0+→0+ nuclear β decays using the shell model with Hartree-Fock (HF) radial wave functions. Our HF calculation is based on the effective Skyrme interaction including Coulomb, an extended Charge-Symmetry Breaking (CSB) and Charge-Independence Breaking (CIB) term. The electromagnetic effects such as the finiteness of charge-density gradient, vacuum polarization, Coulomb spin-orbit and finite size of nucleons are also taken into account. In order to avoid the spurious isospin mixing, we reconstruct the actual mean field employing the HF solution for the Z=N nucleus without charge-dependent forces; then we solve it non-iteratively for the parent and daughter nuclei. It turns out that the CIB term has no significant impact on δ_{C2}. On the other hand, the CSB term makes δ_{C2} increasing systematically by 10 to 30%. Similarly, the gradient density leads to a further increase of δ_{C2} by 2 to 14%, while the other electromagnetic effects are negligible. The effect of the isospin-spuriosity suppression is somewhat complicated. Generally it produces a significantly larger δ_{C2} value, however there are a few cases for which δ_{C2} is mostly unaffected or even reduced, especially the light even-even emitters. All these improvements partly explain the long-standing discrepancy between the Woods-Saxon (WS) and HF results. Nevertheless, the remaining discrepancy is still significant except for the cases with $A \leq 26$. Furthermore, the odd-even staggering presented on the WS result is not well reproduced with the HF radial wave functions. This subsequently leads to a large difference in the predicted mirror ft ratios.

Keywords:

shell Model, Isospin-symmetry breaking correction, Low energy tests of the Standard Model, Superallowed Fermi beta decay, radial overlap correction

Coulomb Dissociation of ^{17}B

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Abstract:

^{17}B is a neutron-rich nucleus which is the second heaviest in the boron isotopes. It has structural properties such as 2-neutron halo, Borromean system, and possible for dineutron correlation. To investigate these structural properties, the Coulomb dissociation experiment for ^{17}B was performed at SAMURAI spectrometer at RIBF, RIKEN. The secondary beam produced by the fragmentation of the ^{48}Ca beam at 345MeV/nucleon was separated and identified by the BigRIPS fragment separator and was incident into a secondary Pb target where ^{17}B is dissociated into ^{15}B and two neutrons. The charged fragment ^{15}B was detected by the SAMURAI spectrometer, while the two neutrons were detected by the neutron detectors NEBULA to measure Coulomb dissociation exclusive cross section. We report the preliminary analysis results on this experiment.

Keywords:

Neutron Halo

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

B18.04

Calculation mutlipole transition and coherent scattering in neutrino-^{208}Pb

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Abstract:

We investigate neutrino-induced reactions on ^{208}Pb. We compare experimental data for Gamow-Teller strength with the results obtained using the Quasiparticle Random Phase Approximation (QRPA) model. We also calculate other multipole transitions, as well as charged current and neutral current interactions, based on our results. Furthermore, we calculate the coherent scattering that results from neutrino-induced reactions.

Keywords:

Nuclear Structure, QRPA

Rotation and Vibration in odd-odd ^{126}I and ^{128}I

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Abstract:

The excited states of the odd-odd ^{126}I and ^{128}I nuclei have been studied through the ^{124}Sn(^{7}Li, 5n)^{126}I, ^{124}Sn(^{7}Li, 3n)^{128}I fusion-evaporation reactions at E_{lab} = 50 MeV, 37 MeV respectively. The pulsed beams were produced by the 14UD pelletron accelerator at the Australian National University. The gamma-rays were detected by CAESAR array which was composed of six Compton-suppressed high-purity Ge detectors and two low-energy photon detectors. From this work, several lifetimes of the isomeric states were measured. Moreover, the collective-band structure developed on the top of the band head with the multi-particle configurations were thoroughly investigated. For instance, the negative-parity band structures were assigned to be the rotational bands based on the couplings between the proton (π) $g_{7/2}$ and/or $d_{5/2}$ and the neutron (ν) $h_{11/2}$ orbital. The excitation energies of the new levels with positive parities were also. These band structures could be interpreted by the $\pi h_{11/2} \otimes \nu h_{11/2}$ configuration and the dipole structures based on the four-quasiparticle configuration, mainly induced by the $\pi g_{7/2}$ proton coupled to the $\nu h_{11/2}$ and $\nu d_{3/2}$ orbitals.

Keywords:

Nuclear structure, Isomer, Fusion evaporation, gamma spectroscopy

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

B18.06

Investigation of single-particle states in ^{111}Sn through (d,p) reaction

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Abstract:

One of the actively researched topics in low-energy nuclear structure is shell evolution studies with radioactive nuclei. One relevant region in the chart of nuclides is the long isotopic chain of tin, where the valence neutron orbitals above the N = 50 shell closure contain knowledge of neutron-neutron interactions as well as neutron-proton interactions. Spectroscopic information on single-particle dominated states can be compared with shell model predictions based on a robust ^{100}Sn core, towards a better understanding of nucleon-nucleon interactions.

Excited states in neutron-deficient Sn isotopes have been revealed mostly through gamma-ray spectroscopy, but their spectroscopic factors have not yet been determined. To address this situation, a (d,p) transfer experiment was carried out at the HIE-ISOLDE facility of CERN. The radioactive ^{110}Sn beam was produced from proton spallation reactions on a LaC_x target, and was post-accelerated to 8 MeV per nucleon. The (d,p) reaction in inverse kinematics was induced on a thin CD_2 target, populating ^{111}Sn in various excited states. The outgoing protons were detected by the ISOLDE Solenoidal Spectrometer (ISS), where the energy resolution is improved through the use of a strong external magnetic field. Preliminary results of the experiment will be presented.

Keywords:

Nuclear structure, Nucleon transfer reaction, Shell evolution

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

B18.07

In-beam spectroscopy of ^{94}Ag

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Abstract:

The formal concept of isospin has been introduced to explain the apparent exchange symmetry between neutrons and protons. However, if the nuclear force were the same for protons and neutrons properties such as masses and excitation energies would depend only on the mass number A. Recent studies have shown that the Coulomb force cannot account for all deviations, suggesting that other isospin-symmetry-breaking components must be present. N~Z systems present the perfect testing ground to probe isospin symmetry phenomena [1-3]. In particular, pairing correlations have a significant importance in the description of the nuclear structure of N=Z nuclei, where protons and neutrons are arranged occupying the same orbits, allowing T=0 np pairing in addition to the normal T=1. It was recently suggested that spin-aligned T=0 np pairs dominate the wavefunction of the y-rast sequence in ^{92}Pd [4]. Subsequent theoretical studies were devoted to probe the contribution of np pairs in other N=Z A>90 nuclei [5-6], suggesting that a similar pairing scheme strongly influences the structure of these nuclei. In an effort to answer this question further, a recoil beta tagging experiment has been performed to try and identify the excited T=0 and T=1 states in odd-odd N=Z ^{94}Ag using the ^{40}Ca(^{58}Ni,p3n)^{94}Ag reaction. The experiment was conducted using MARA recoil separator and JUROGAM3 array at the Accelerator Laboratory of the University of Jyväskylä.

The detailed goals of the experiment and the experimental setup will be shown in this presentation. First observed γ-ray transitions from states in ^{94}Ag, identified by correlating fast, high-energy beta decays at the MARA focal plane with prompt γ-rays emitted at the reaction target, will be reported. Possible correspondence between some of these transitions and analog states in ^{94}Pd will be discussed, and shell-model calculations including multipole and monopole electromagnetic effects will be presented in order to allow a theoretical set of Coulomb Energy Differences to be calculated for the A = 94 T = 1 analog states.

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Keywords:

nuclear structure, isospin symmetry, fusion evaporation, γ-ray spectroscopy, pairing

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

B18.08

Level lifetime measurements in neutron-rich Zr isotopes around A = 110 through in-beam gamma-ray spectroscopy

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Abstract:

Isotopes of zirconium (Zr) with semi-magic atomic number 40 represent one of the most interesting cases of shape evolution in nuclei. The collective behavior of Zr nuclides is very much suppressed at neutron number 50, where ^{90}Zr exhibits properties of a doubly-magic nucleus. On the other hand, a sudden onset of nuclear deformation appears at N = 40 and 60 due to the strong proton-neutron interaction between the overlapping partner $\pi 1g_{9/2}$ and $\nu 1g_{9/2}$ ($\nu 1g_{7/2}$) intruder orbitals. The strong shape transition at N = 60 happens in Zr (Z = 40) and Sr (Z = 38) nuclei which are located at the mid-shell between N = 50 to 82. The abrupt shape transition is limited to the Sr and Zr nuclei, while the neighboring Kr (Z = 36) and Mo (Z = 42) show a smooth shape evolution pattern in terms of the quadrupole deformation.

Among Zr isotopes, ^{110}Zr with Z = 40 and N = 70 shell closures of the harmonic oscillator potential could be another quasi doubly-magic nucleus. However, a previous SEASTAR experiment at the Radioactive Isotope Beam Factory (RIBF) provided evidence for rather well-deformed nature in this isotope by measuring the energy of the first excited state through in-beam gamma-ray spectroscopy. Several questions then remain open, such as the possibility of shape coexistence or triaxial deformation in this ^{110}Zr isotope as predicted by different theoretical models.

A high-resolution in-beam gamma-ray spectroscopy study of nuclei around ^{110}Zr was performed within the HiCARI (High-resolution Cluster Array at RIBF) campaign at the RIBF to measure the level lifetimes. This large array was installed at the F8 focus which is located between the BigRIPS and Zero Degree Spectrometer at the RIBF facility. From this experiment, ^{108}Zr and ^{110}Zr were populated through one-proton one-neutron knockout and one-proton knockout reactions from ^{110}Nb and ^{111}Nb, respectively.

In this talk, preliminary experimental results will be represented. Lifetimes of specific levels in ^{108}Zr and ^{110}Zr are analyzed based on the line-shape method. These experimental results will allow to distinguish between predictions of different nuclear models concerning the shape of ^{110}Zr, the key isotope for the evolution of collective properties along the Z = 40 isotopes.

Keywords:

Nuclear structure, Nuclear shell evolution, Nuclear shape evolution, In-beam gamma-ray spectroscopy, Lifetime measurement

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2023-04-19 - 2023-04-21

B18.09

Current status of gamma-ray spectroscopy analysis using ^{56}Ti/^{58}Ti beams for the island of inversion research.

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Abstract:

While new magic numbers at neutron number 32 and 34 have been established in the Ca isotopes, signs of deformation and complex particle-hole configurations have been found in nuclei approaching the N=40 Island of Inversion. The Ti isotopes bridge this interesting region of structural changes.
The proton and neutron single-particle structure as well as the collective behavior of the neutron-rich ^{56,58}Ti isotopes was explored in an experiment performed at the RIBF, RIKEN, Japan. Exotic beam cocktails were produced by projectile fragmentation and separated and analyzed in the BigRIPS separator. Secondary reactions took place at the center of the newly designed HiCARI array for high-resolution gamma-ray detection.
In this presentation, I will give an overview of the experiment and present preliminary results for the proton knockout reactions to populate ^{55,57}Sc. While states in the former are known, the new data will shed light on the collective nature enabeling for the first time lifetime measurements. I will also present the first spectroscopic studies of ^{57}Sc.

Keywords:

HiCARI, 55,57Sc

Search for CP violation in top quark pair events in the dileptonic decaying channel at sqrt (s) = 13 TeV

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Abstract:

CP violation in ttbar events decaying into the dilepton channel (ee,mumu, and emu) is studied, collected by the CMS detector at a centre-of-mass energy of 13 TeV, corresponding to an integrated luminosity of 35.9 fb^-1. In this search, two physics observables (O1, O3), which are the Levi-Civita tensors of the four vectors of leptons, b quark jets and top quarks, are probed. These observables allow us to test the CP-odd correlation. Asymmetries of a physics observable are measured. The chromoelectric dipole moment (CEDM) of the top quark is extracted from the linear correlation between CEDM and asymmetry. Combination of three channels for the CEDM is also presented.

Keywords:

LHC , CP violation, Chromoelectric dipole moment, top quark, CMS

B19.03

Measurement of CP violation in single top t-channel production at 13 TeV

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Abstract:

CP violation is required to solve the paradox of the baryon asymmetry of the universe. A forward-backward asymmetry of an angular distribution defined in the top quark sector is highly-related to the CP violation. The asymmetry measurement is performed in the t-channel production of single top quarks in proton-proton collision at the LHC at center-of-mass energy of 13 TeV using data in full Run II (2016-2018) collected by the CMS detector.

Keywords:

CP violation, top quark, CMS

B19.04

Search for Charged Lepton Flavour Violation in top quark interaction with muon and tau in pp collisions at √s = 13 TeV

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Abstract:

Based on deviations observed in B meson decays from the Standard Model predictions, there is a proposal for the Violation of Lepton Universality. Our analysis aims to search for Charged Lepton Flavor Violation (CLFV) in the top quark interaction with a charged lepton (μ), a up-type quarks (u, c), and a tau objects. We analyze collision data collected by the CMS experiment at the LHC during the Run II period, with an integrated luminosity of 138 fb^{-1} at a center-of-mass energy of 13 TeV. To adopt a model-independent approach, we use Effective Field Theory. We enhance our sensitivity by utilizing a Deep Neural Network for signal extraction. Our analysis shows no significant excess of CLFV signals. As a result, we set expected limits of signal strength at 95% confidence levels and calculate the branching fractions for top CLFV interactions.

Keywords:

CMS, Top, CLFV, BSM, DNN

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2023-04-19 - 2023-04-21

B19.05

Measurement of the charge asymmetry in top pair production with using lepton+jets final state in CMS experiment

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Abstract:

In the Standard Model (SM), top pair production is symmetric at the leading order calculation. However, at the higher order calculation, the top quarks show direction preference by the momentum of initial quarks that contribute to the production. This asymmetry is observed as a central-forward asymmetry where top quarks have a higher rapidity than anti-top quarks in the LHC experiments. In previous measurements, no significant deviations from the SM expectations are observed within the large uncertainties of the measurement. In this study, we present a measurement of the ttbar charge asymmetry in pp collisions at 13 TeV collected by the CMS experiment. The measurement will be performed in ttbar semileptonic channel using the large-sized Run 2 dataset. The asymmetry will be measured as a function of the top pair system mass to test the SM and alternative models in the high-mass region.

Keywords:

LHC, CMS, Top

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B19.06

Measurement of V_{cb} Element of Cabibbo_Kobayashi Maskawa (CKM) Matrix Using Top Pair Production Semileptonic Channel

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Abstract:

One of the Cabibbo Kobayashi Maskawa matrix element, V_{cb}, has been only measured using the B meson decay. The existing measurements from inclusive and exclusive decay modes have some tension. Looking into the top quark decay channel (t -> bW, W ->c b) can remove non-perturbative effects of B meson and resolve this tension. This study aims to analyze full sqrt{s}= 13TeV Run 2 data collected with CMS detector at LHC. Top quarks and W bosons reconstructions are crucial in this study for signal extraction, and with machine-learning based MVA techniques, these reconstructions have improved significantly. With high jet multiplicity in signal, signal extraction relies on CMS jet flavour tagging algorithm for b and c quark jet. Furthermore, detailed study on the background sources can improve the sensitivity for our analysis method. In this presentation, we will show the analysis progress so far.

Keywords:

CKM, CMS, Vcb

B19.07

Search for monotop events in pp collisions at 13 TeV from CMS experiment

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Abstract:

A generic-purpose detector like Compact Muon Solenoid (CMS) at Large Hadron Collider (LHC) is in a restless search for any hint of new physics beyond the Standard Model (SM) as there exist a great variety of new physics models that attempt to provide answers for the open questions that cannot be addressed by the SM. Most new physics models accommodate candidates that can account for dark matter (DM), whose existence is suggested by astrophysics observations. This implies that, given a new physics signal at the LHC, we are also likely to extract some information on the nature of dark matter. Since dark matter does not leave a measurable signature in the detector, one way to observe DM is when it is produced in association with a visible SM particle (X=top, photon, etc), called MET+X where MET is the missing transverse energy. The event of monotop related to missing transverse energy is searched for hadronic and leptonic decaying channels. The signal and background study is processed using the Columnar Object Framework For Effective Analysis (COFFEA) tool, an array-based python tool for high-energy collider physics to reduce time-to-insight. In this talk, we present the selection optimization, background selection studies, signal studies, and expected limits with Full Run II for various physics scenarios for montop signature.

Keywords:

CMS, MET+X

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B19.08

Search for dark matter in association with a spin-2 mediator

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Abstract:

Sensitivity studies were performed to search for dark matter using simulated data corresponding to an integrated luminosity of 3.0 ab-1 in proton-proton collisions at a center of mass energy of 14 TeV based on the Phase-2 CMS detector at High-Luminosity LHC. This work presents a prospect of gravity-mediated dark matter search associated with the dileptonic decay of top-antitop pairs generated via spin-2 mediators using deep neural networks in machine learning. Characteristic physical observables induced by undetected dark matter are projected into a deep neural network and derived as a learning matrix that distinguishes the signal from backgrounds. The signal and background evaluated by the learning matrix are converted to the expected exclusion region and the upper limit on the mediator mass at a 95% confidence level. The expected exclusion region of 410 GeV obtained from this study using deep neural networks provides an improved prospect of about 250 GeV compared to the existing results.

Keywords:

Dark matter, HL-LHC, spin-2, Simulation

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2023-04-19 - 2023-04-21

B19.09

Updates on search for heavy Majorana neutrinos in dilepton + jets final states with CMS Run II data

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Abstract:

We present updates on search for heavy Majorana neutrinos in the dilepton + jets final states using the full Run II pp collision data from CMS detector. The total integrated luminosity is 138 fb^-1 and the center of mass energy corresponds to √s = 13 TeV. The analysis exploits three different signal processes, namely DY-like, photon-induced, and same-sign WW vector boson fusion process, allowing an extensive search range of heavy neutrino masses from 100 GeV to 30 GeV. However, this approach then also gives challenges in developing an optimal analysis strategy to utilize such various kinematic properties.
In this talk, we will present how the adoption of the BDT approach for both event selection and object reconstruction, along with the shape method, has led to a significant improvement over existing analyses. With consideration of several sources of systematic uncertainty, we set limits on the effective mixing parameter under the assumption of three flavor mixing scenarios (μ only, e only, μe mixing) as a function of the heavy neutrino mass.

Keywords:

C1.01

Colloidal chiral nanophotonics

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Abstract:

In this talk, I'll briefly introduce how colloidal nanoparticles and their assemblies can reshape chiral nanophotonics. In contrast to the lithographic method, the soft colloidal approach can unprecedentedly elaborate the chiral morphology of plasmonic nanostructure, particularly at molecular resolution. For example, DNA and protein can guide the molecular scale growth and assembly of chiral plasmonic features in a highly programmable way. Thus, this ultrasmall scale featuring of chiral morphology of metallic nanoparticles can push the working frequencies of the resonantly enhanced optical chirality into the visible or even UV regime. More importantly, various soft self-assembly methods enable the docking of the freely dispersed individual chiral nanoparticles into plasmonic superlattice, which can excite the plasmonic surface lattice resonance (SLR) or collective resonance. As the SLR mode efficiently delocalizes the resonantly boosted fields, the SLR-excited optical chirality can become highly uniform over a large area or volume. This collective chiral resonance can profoundly leverage the nanophotonic sensing of chiral molecules into the next stage.

Keywords:

colloids, optical chirality, soft photonics, self-assembly, collective mode

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2023-04-19 - 2023-04-21

C1.02

Fundamental Measures of the Radiative Optical Resonators

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Abstract:

Momentum, angular momentum, energy, and helicity are fundamental measures describing physical objects. Maxwell's equations, a set of the fundamental equation of electromagnetism, expand the concepts of fundamental measures to light. In this regard, the question arises of whether the discrete resonance modes of the optical resonators can be characterized by such fundamental measures. We prove that the optical modes of the radiative (or leaky) resonators can be described uniquely by momentum, angular momentum, energy, helicity, and their reactive counterparts. We also show that the mode volume, the quality factor (in the Purcell effect), the impurity perturbation sensitivity (in the nanosensor), and the enantioselective sensitivity (in the chiral nanosensors) are related to the fundamental measures using our theory and rigorous numerical examples. We expect that our theory on the fundamental measures of the radiative optical resonators can enable a deep understanding of resonance modes and accurate prediction of resonance-based optical device performances.

Keywords:

Optical resonators, Light-matter interaction, Purcell effect, Nanosensors

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C1.03

Coherent valley-photon coupling in transition metal dichalcogenides multilayer

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Abstract:

The emergence of transition metal dichalcogenides (TMD) layers has sparked significant research interest and led to the rapid development of valleytronics. A monolayer of TMD materials has direct bandgaps consisting of two (energy-degenerate) valleys at the corners of the Brillouin zone (K, K'), which provide an opportunity to manipulate the additional degree of freedom, so called the valley degree of freedom. And valley information can be optically addressed and detected using the spin angular momentum of light, due to their valley-dependent optical selection rule. It is generally believed that additional photonic structures such as external cavity are necessary to increase and control light-matter coupling in a TMD layer. Unfortunately, these additional structures with a linearly polarized optical mode easily spoil valley pseudospin information making it difficult to exploit the full potential of TMD layers. In this talk, the valley-selective exciton–light coupling in a TMD layer will be discussed. We investigated coherent coupling between exciton and photon in a thick TMD layer. We found out that these intrinsic exciton polariton in a TMD layer can exhibit valley polarization. Valley-dependent exciton–light coupling offers a novel platform for realization of valley transport even at room temperature without any magnetic fields. And these results pave the way for exploiting a valley pseudospin in integrated valleytronics devices using nanophotonics structures.

Keywords:

Strong coupling, Valley degree of freedom, 2D material

Issues in spin photonics

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Abstract:

Spin photonics is an emerging term describing the interaction of optical spin, either longitudinal or transverse, with nano scale materials.
We address various issues in spin photonics and the underlying physics behind them. Particularly, we explain the notion of transverse optical spin appearing in confined electromagnetic fields and their possible applications. Nonlinear optical, and extended spin structures and spin photonics for 2D materials will be also considered.

Keywords:

C2.01

Experimental realization of a Brownian gyrator powered by active noise

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Abstract:

Active baths, which are composed of active or self-propelled particles that use energy to move or exert mechanical forces, exhibit unique phenomena that differ from those of equilibrium baths. In the present work, we demonstrate the Brownian gyrator, powered by both thermal and active noise, using an optical feedback trap that applies all necessary forces to the particle. We show that the engine efficiency in the active bath can exceed that of the counter-passive engine due to an expansion in the coupling parameter space. We also discuss the effect of active noise on the thermodynamic uncertainty relation, which describes the trade-off relation between the fluctuations of the thermodynamic current and the entropy production.

Keywords:

Stochastic thermodynamics, Active noise

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2023-04-19 - 2023-04-21

C2.02

Moving towards quantum technologies: the case of quantum batteries

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Abstract:

Quantum batteries are quantum mechanical systems used as energy storage devices.
As for many other proposed quantum devices, ranging from quantum computers to quantum communication systems, they are believed to offer significant advantages over their classical counterparts.

In this talk I will first provide an overview of few tasks where quantum resources can be successfully applied.
I will then focus on the recent progresses, both at the theoretical and experimental level, in proving and understanding the sources of charging speedup that quantum batteries can have over classical batteries.
These progresses are at the core of the newly introduced notion of quantum charging advantage.

Keywords:

quantum batteries, quantum thermodynamics, quantum advantage

C2.03

New Equation of Motion for Strongly coupled systems

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Abstract:

Stochastic thermodynamics provides a framework to extend the laws of thermodynamics to stochastic systems and study the thermodynamics of nonequilibrium microscopic systems. The Langevin equation is commonly used to study stochastic thermodynamics, however, it does not fully capture the details of the coupling between the system and the bath. In general, the system-bath coupling can significantly affect the dynamics of microscopic systems, leading to strongly-coupled systems. Strongly-coupled quantum systems have been extensively studied, but the equation of motion for strongly-coupled classical systems remains unknown. In this context, we derive a new Langevin-type equation for classical diffusive dynamics that captures strong coupling effects. Our proposed equation of motion contains two coupling-dependent terms: an additional force, known as the mean force, and interaction-dependent damping coefficients. We find that the conventional Langevin equation can be restored regardless of the coupling strength when the bath is invariant under translational symmetry and separable. Our findings are validated analytically and numerically on solvable examples. This strongly-coupled Langevin equation could provide a useful tool for understanding the behaviors and thermodynamics of strongly coupled systems where traditional thermodynamics may not be applicable.

Keywords:

Stochastic dynamics, Strong coupling effects, Langevin dynamics

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2023-04-19 - 2023-04-21

C3.01

Non-Hermitian graphene metasurfaces

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Abstract:

In recent years, non-Hermitian degeneracies, also known as exceptional points, have been extensively investigated across a broad range of physical systems. Particularly in optics, where it is possible to integrate and control gain and loss structures, providing an ideal platform for exploring non-Hermitian physics. In this talk, we present the observation of exceptional points and phase singularities in a non-Hermitian metasurface. By designing a metasurface composed of hybrid meta-atoms with anisotropic radiation loss and utilizing graphene to control the intrinsic coupling between the meta-atom components, we are able to manipulate the polarization eigenstates of the metasurface through variation of radiation frequency and graphene's optical conductivity. Our findings reveal the observation of a polarization phase singularity at an exceptional point in the transmission through an anisotropic metasurface. Furthermore, we have demonstrated that the exceptional point can also be observed by combining the metasurface with single-layer graphene and varying the gate voltage to achieve an electrical tuning of the optical conductivity of graphene. Through analyzing the transmission data of the metasurface, we have observed unique phenomena associated with exceptional points, including level repulsion behavior, geometric phase under encirclement of the exceptional point, and asymmetric transmission of circularly polarized radiation.

Keywords:

Non-Hermitian photonics, Metasurfaces, Graphene, THz spectroscopy, Exceptional point

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

C3.02

Non-Hermitian and topological physics with waveguides and photonic lattices

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Abstract:

Non-Hermitian and topological physics have been developed from the quantum field theory and solid-state physics. Their key concepts are presently far-reaching to wide ranges of different physics realms as they suggest extra degrees of freedom for controlling wave phenomena in unprecedented ways. Towards this end, photonic nanostructures have provided fertile grounds because of their powerful capability to construct desired interaction potentials and possibility for practical applications as well. In this talk, we provide our recent advances in non-Hermitian and topological photonics. In particular, we focus on waveguide and diffraction grating structures where intricate non-Hermitian and topological potential distributions can be coded in remarkably simple geometric parameters. We explain mathematical methods to relate potential distributions to geometries, fundamental phenomena in binary non-Hermitian and topological systems, and their applications to practical devices such as optical isolators, intensity/phase modulators, broadband couplers, and beam shapers. We discuss remaining challenges and future directions.

Keywords:

Waveguides, Diffraction Gratings, Non-Hermitian Hamiltonians, Topological Insulators

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

C3.03

Topology of non-Hermitian systems from the exceptional point

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Abstract:

We discuss classifications of multiple arbitrary-order exceptional points by invoking the permutation group and its conjugacy classes. We classify topological structures of Riemann surfaces generated by multiple states around multiple arbitrary-order exceptional points, using the permutation properties of stroboscopic encircling exceptional points. The results are realized in non-Hermitian effective Hamiltonian based on Jordan normal forms and fully desymmetrized optical microcavities. Additionally, we reveal the relation between the spectral topology originating from complex eigenvalues in non-Hermitian systems and wavefunction topology related to the additional geometric phases. Finally, we discuss the topology of one-dimensional multi-bands systems based on exceptional points.

Keywords:

Non-Hermitian system, Exceptional point, Topology of one-dimensional systems

C3.04

Non-Hermitian physics characterized by exceptional points

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Abstract:

Non-Hermitian physics has attracted considerable attention not only as an important alternative to the Hermitian formalism of quantum mechanics in open systems with energy gain/loss and hopping non-reciprocity but also for applications in various optical and photonic systems. In a non-Hermitian system, the eigenvalues are complex values, and the eigenstates form a biorthogonal set. The complex eigenvalues have a clear physical meaning: the real and imaginary parts represent the eigenenergy of a state and its decay rate, respectively. Non-Hermitian systems have been explored in several fields, including optics, electronic circuits, atomic physics, and magnetic metamaterials. Such a topological structure has been reported in microwave experiments, optical microcavities, and a chaotic exciton-polariton billiard.

There are interesting phenomena: non-trivial winding number by exceptional points (EPs) and non-Hermitian skin effect by directional hopping. Phase transitions in these systems occur via EPs, coalescent points of eigenenergies in non-Hermitian systems. The eigenvalues generate a Möbius strip structure in parametric space. The degeneracy observed in microcavities can manifest through a subtle deformation of the cavity boundary and can be elucidated by the semiclassical theory of dynamical tunneling. The exceptional points emerge in nearly degenerate pairs and arise from different symmetry classes of modes. Furthermore, a spatially localized chirality of modes at the EP is linked to vortex structures in the Poynting vector.

Keywords:

Non-Hermitian Physics, Exceptional Points, Quantum Transport, Vortex Structure

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2023-04-19 - 2023-04-21

C4.01

Electron flying qubit in graphene

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Abstract:

Flying qubits encode quantum information in propagating modes instead of stationary discrete states. Propagation solves issues of connecting distant qubits as needed for sequential quantum operations. Although photonic flying qubits are available, the weak interaction between photons limits the efficiency of conditional quantum gates, and the extremely fast speed of photons poses a scalability problem. On the other hand, electronic flying qubits realized in semiconductors allow easy interaction and are expected to offer good scalability at the expense of weaker quantum coherence. The choice of graphene which shows enhanced coherence properties offers a unique alternative. Here, using graphene, we succeeded in the first on-demand injection of a single electronic flying qubit state and its manipulation over the Bloch sphere. The flying qubit is a Leviton generated by a voltage pulse and propagating in quantum Hall edge channels of a high mobility graphene monolayer. The Bloch sphere operation is realized using a graphene Mach-Zehnder interferometer, and the final state is read statistically by shot noise measurements. The Bloch sphere operation and the robustness to decoherence suggest that graphene is a promising platform for manipulating flying qubits.

Keywords:

flying qubit, graphene, Leviton

C4.02

A tunable electron Mach-Zehnder interferometer in quantum hall graphene

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Abstract:

The utilization of van der Waals heterostructures has enabled researchers to exploit the unique properties of 2D materials in their purest form. Recent advancements in this area have led to the development of electron quantum optics devices utilizing graphene, which rely on the wave nature of electrons in the quantum Hall regime. Previous studies had been limited to high-mobility GaAs 2D electron gas. In this study, we present the successful realization of a graphene Mach-Zehnder interferometer with fully tunable beam splitters. By manipulating the filling factors of each local section of the graphene flake in the quantum Hall regime, we are able to achieve coherent splitting and mixing of copropagating, opposite-valley channels with the same spin at the PN interface. Our experimental results demonstrate a quantum interference pattern, which is detected through the modulation of electrical current through the PN junction. These findings pave the way for the development of novel quantum electronic devices using 2D materials.

Keywords:

electron quantum optics, quantum Hall effect, van der Waals heterostructure

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C4.03

One-dimensional transport in bilayer graphene quantum point contacts

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Abstract:

In multivalley semiconductors, the valley degree of freedom can be potentially used to store, manipulate, and read quantum information, but its control remains challenging. The valleys in bilayer graphene can be addressed by a perpendicular magnetic field which couples by the valley g factor gv. However, control over gv has not been demonstrated yet. We experimentally determine the energy spectrum of a quantum point contact realized by a suitable gate geometry in bilayer graphene. Using finite bias spectroscopy, we measure the energy scales arising from the lateral confinement as well as the Zeeman splitting and find a spin g factor gs ~ 2. gv can be tuned by a factor of 3 using vertical electric fields, gv ~ 40–120. The results are quantitatively explained by a calculation considering topological magnetic moment and its dependence on confinement and the vertical displacement field.

Keywords:

Graphene, Point contact, Quantum Transport

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2023-04-19 - 2023-04-21

C4.04

Spin tunneling probability at atomic defects by Zeeman splitting

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Abstract:

Many quantum properties that vary depending on the material originate from spin, which is a fundamental physical quantity. The magnetic field causes Zeeman splitting, and the electron spin occupies the changed split energy level. We observe the level existence excitation and relaxation probability position, lifetime, and tunneling properties of the occupied electron spin in an atomic vacancy, which are important for understanding spin quantum information. We demonstrate spin tunneling probability in MoS_2, where single electron spin tunneling possibly occurs in the Zeeman splitting energy between an electron spin in single sulfur atomic vacancy and Fermi level in a magnetic field. These spin tunneling effects open new avenues for fundamental spin transport physics and applications such as spintronics and quantum information devices for developing controllable single atomic spin devices.

Keywords:

Atomic defect, quantum transport, tunneling, spin, MoS2, Zeeman energy

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C5.01

Short-wavelength infrared photodetection in MoS_2

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Abstract:

Transition metal dichalcogenide (TMD) layered semiconductors possess immense potential in the design of photonics, electronics, optoelectronics, and sensors. However, the sub-bandgap light absorption of TMD in the short-wavelength infrared (SWIR) range is insufficient to expand the applications beyond the bandgap limit. Herein, we report that the optical property of TMDs can be significantly modulated by the electrode fabrication method. Approximately 60% of near-infrared light absorption is observed in the MoS_2/Au heterostructure, which includes the hybridized interface, and the thickness of MoS_2 is in the range of 20–60 nm. The anomalously high absorption of sub-bandgap light is due to the planar cavity constructed with MoS_2 and Au. Thus, the absorption spectrum is controllable with MoS_2 thickness. Moreover, photocurrent under the SWIR wavelength range increases due to the increased SWIR absorption; thus, broad NIR wavelength detection is possible. Fast photoresponse speed (approximately 164 μs) and high responsibility (17 mA/W) are obtained in the device with a wavelength excitation of 1550 nm. Our finding here provides a facile method for optical property modulation using metal electrode engineering and for realizing SWIR photodetection in wide-bandgap 2D materials.

Keywords:

electrode fabrication, TMD/metal interface, optical property, telecommunication wavelength detection, sub-bandgap absorption, Fabry-Perot cavity

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C5.02

Moiré phonons in interlayer interaction of monolayer-WSe_2/bilayer-MoS_2 heterostructures

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Abstract:

The moiré superlattices in transition metal dichalcogenide (TMD) homo-bilayer and hetero-bilayer have been spotlighted these days for their intriguing features [1]. According to previous work on moiré phonons for TMD homo-bilayer and hetero-bilayer systems, the moiré phonons are usually observed in the high-frequency Raman region above 80 cm^{-1}, but the interlayer vibration modes are not varied with the twist angle as much as the moiré phonons [2,3]. Also, the atomic reconstruction in TMD heterostructure has become an interesting issue, which was known to occur only for small twist angles smaller than 5 ° for MoS_2 and WSe_2 homo-bilayer systems [3, 4]. In the MoS_2/WSe_2 hetero-bilayer system, torsional lattice distortion occurs for all twist angles [5]. In this work, we observed a series of moiré phonons and their dynamic behaviour in interlayer vibration modes in bilayer-MoS_2/monolayer-WSe_2 heterostructures by polarized Raman spectroscopy. In addition to 2 breathing modes and 1 shear mode of tri-layer heterostructure, several phonon modes are observed for samples with small twist angles (<10 °), and their position and intensity varied with the twist angle but not monotonically, which means they are not from the rigid moiré pattern. We did moiré supercell calculation considering atomic relaxation and compared the calculated phonon position and projection intensity with the experimental data, which agree well with each other.

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Keywords:

heterostructure, Raman spectroscopy, moiré phonon, atomic reconstruction

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C5.04

Preparation of Twisted Bilayer Graphene Trough Transfer Technique

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Abstract:

The physical properties of twisted two-dimensional (2D) material structures have garnered significant attention in recent years due to their unique electrical and optical properties. In this study, we focus on the effects of interlayer rotation on optical properties during the *in-situ* process. We discussed a novel method for manipulating and measuring the optical properties of vertically stacked two-dimensional structures. This involves the transfer method using PDMS to keep the interface clean. We fabricated the twisted bilayer graphene structure through the transfer method. Using the dry transfer method with PDMS, we were able to create bilayer graphene samples with a clean interface. We stacked graphene vertically so that the clean sides of the graphene contact with each other. Raman spectra were investigated at this interface while adjusting the twist angle between the layers. We report Raman spectra as a function of interlayer angle.

Keywords:

2Dmaterial, graphene

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C5.05

Electrical properties of Two-Dimensional Material Based Field Effect Transistor

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Abstract:

This work has studied the electrical properties of the floating-gate transistor (FET) based on two-dimensional (2D) materials such as graphene, MoS2, ReS2, and hBN. The 2D material-based FETs with floating gate channel were fabricated using the PDMS pick-up transfer method on the silicon oxide/silicon substrate. Gate voltage and voltage pulses were applied to the FETs to investigate whether the fabricated devices have characterizations like hysteresis and nonvolatile memory effects. The current-voltage characteristics were measured and based on these results, the FET and floating gate characterization was observed. Also, we confirmed that our devices can work as flash memory. The details of device fabrication and possible applications will be suggested.

Keywords:

FET, 2D material, floating gate transistor

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2023-04-19 - 2023-04-21

C5.06

Mechanical manipulation of Moire ferroelectric domain structures in twisted bilayer WSe_2

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Abstract:

Two-dimensional materials with vertical ferroelectric and piezoelectric properties are highly required for the realization of ultrathin advanced electronic devices. In this viewpoint, Moiré superlattices in van der Waals heterostructures with alternating vertical-polarization come in attractive nonvolatile memory material. Bilayer of transition metal dichalcogenides (TMD, MX_2 structure where M: transition metal and X: chalcogen) stacked with desirable angle give birth to a micro-to-nano scale of Moiré superlattices, so-called MX and XM domains. This spatially new type of ferroelectric domain changes its versatile structures by interlayer sliding, thereby enabling the manipulation of local ferroelectricity with ease.

Here, we'd like to introduce an ongoing study about the nanonewton (nN)-scale touching effect on these vertical polarization performed by local functional atomic force microscopy (AFM). Normal load of tip guides to the top layer slips relative to the bottom layer, resulting in ripple-motion-like topological rearrangement in the domain structures. We present experimental approach to the key mechanical characteristics like line tension, defect formation and switches made of bistate topological defect configuration.

Keywords:

Two-dimensional, TMD, Moiré superlattices, Ferroelectricity, Mechanical manipulation, Interlayer sliding

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2023-04-19 - 2023-04-21

C5.07

Observation of resonance mode shapes in graphene nano-electro-mechanical drums

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Abstract:

In this presentation, we report the measurement of resonance mode shapes and mechanical behavior of graphene nano-electro-mechanical drums. The graphene resonators were suspended on silicon oxide/silicon trenches using the micro-contact transfer method. The graphene resonators were actuated electrostatically via the applied gate voltage. The mechanical properties of graphene resonators were investigated by observing the resonance frequency vibration mode. The sample can be moved x-y plane using the motorized nano-positioning stage and the mechanical motion of the graphene drum was scanned with the optical interferometry system. By applying high driving voltage, we measured the multi-modes of the resonance frequency of graphene drum and observed the amplitude response while scanning the surface of the graphene in resonance. We observed up to the 4_{th} vibrational mode shapes of the graphene drum resonator. Through this work, we could examine the dynamic characteristics of graphene nano-electro-mechanical drums.

Keywords:

Graphene, Graphene Resonator, NEMS, Nano-Electro-Mechanical System, Resonance frequency

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2023-04-19 - 2023-04-21

C5.08

Low frequency Raman spectroscopy of 1T-PtX_2

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Abstract:

Two-dimensional (2D) layered materials have planar crystal structures with strong in-plane covalent bonds and weak out-of-plane van der Waals (vdW) bonds. Even if vdW bonds are weak interactions between layers, it is important to determine its physical properties. For example, electronic bands of many 2D materials strongly depend on the number of layer. The strength of vdW force in 2D materials can be estimated from rigid vibrational modes among the layers, namely shear and layer breathing modes. Since the frequencies of shear and layer breathing modes are quite lower than general atomic vibrational frequency of crystal it is necessary to use low frequency Raman measurements. PtX_2 (X=S, Se, Te) crystals are 1T phase in room temperature and have strong dependency of band structure in terms of the number of layer. However, there is not much Raman spectroscopic studies about 1T-PtX_2 because of complexity of its Raman spectra. In this work, we investigated shear and layer breathing modes of 1T-PtX_2 with polarized low frequency Raman measurements and estimated interlayer coupling strength.

Keywords:

Raman spectroscopy, 2D materials, phonon

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2023-04-19 - 2023-04-21

C5.09

Theoretical study of Raman spectroscopy in hexagonal phase $Mo_{1-x}W_xS_2$ monolayer alloy

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Abstract:

Alloying two-dimensional transition metal dichalcogenides (TMD) is an effective way to tailor the physical properties for practical applications. Raman spectroscopy is referred to as a powerful and non-destructive method to study structural characterization and composition distribution in TMD alloy. Herein, by combining factor group analysis and density functional theory calculation, we conducted the theoretical study on first-order Raman spectroscopy of the trigonal prismatic phase (1H) $Mo_{1-x}W_xS_2$ monolayer alloy. We implemented the factor analysis involving the correlation method to construct an irreducible representation of phonon modes and determine Raman-active phonon modes in the H-phase TMD monolayer. Our simulated Raman spectroscopy of 1H-$Mo_xW_{1-x}S_2$ shows the consistencies with the predicted model in Raman mode assignment and vibrational directions and captures the lattice distortion effect from the shifting and splitting of the out-of-plane A_1' mode and in-plane E' mode in monolayer alloy.

Keywords:

2D alloy, Raman, Mo1-xWxS2

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2023-04-19 - 2023-04-21

C6.01

Light-induced ferroelectricity from quantum paraelectric $SrTiO_3$

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Abstract:

Recent advancements in light-matter interactions have uncovered groundbreaking physical phenomena, offering promising implications for novel application devices. For example, recent studies revealed that ferroelectricity could be achieved by applying light on the quantum paraelectric $SrTiO_3$. Here, we investigate the microscopic mechanism of terahertz (THz) field-induced ferroelectricity in quantum paraelectric $SrTiO_3$. Our results demonstrate that a quantum description incorporating both ferroelectric soft mode and lattice strain is essential for evaluating the properties of quantum paraelectric SrTiO3. Building on this understanding, we investigate THz field-induced ferroelectricity through the resolution of the Schrödinger-Langevin equation. Our findings reveal that the microscopic mechanism driving this phenomenon is a light-mixed state between the ground and first excited states of the ferroelectric soft mode in the quantum paraelectric phase. This study contributes valuable insights into the microscopic behavior of quantum paraelectric materials and paves the way for further exploration of THz field-induced phenomena.

Keywords:

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

C6.02

Ultrafast dynamics of charge density wave (CDW) order in kagome metal, CsV3Sb5

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Abstract:

Charge Density Wave (CDW) state, broken symmetry state of electronic modulation, plays a crucial role in quantum phases within the intertwined electronic degrees of freedom on lattice playground. Conventionally, Peierls distortion model with nested Fermi surface and soften phonon mode provides a fundamental picture to describe the CDW phase transition with the structural instability driven by strong electron-phonon coupling.
New kagome metal systems (AV3Sb5, A = K, Rb, Cs), which owns exotic electronic structures simultaneously, have been attracting surging attention as an ideal system to investigate the interplay of topology, electron correlations and superconductivity.
CDW in AV3Sb5 has two type charge order. One is 2x2x1 charge order that caused by dimerization of vanadium atom and the other is 2x2x2 charge order caused by different distortion pattern in vanadium layer. Contrary to the ordinary systems, the CDW in this AV3Sb5 kagome system is not driven entirely by the electron-lattice coupling with absence of phonon softening and its origin is still ambiguous. Recently, we observed that 2x2x2 and 2x2x1 CDW state in CsV3Sb5 using time-resolved X-ray scattering at PAL-XFEL, and have found difference between two charge orders in melting and recover process on sub-picosecond regime. this non-equilibrium dynamics of CDW presents the role of interaction into c axis in CDW and maybe hints to double-dome Supserconductivity in CsV3Sb5.

Keywords:

Charge Density Wave, Kagome Lattice, X-ray scattering, Pump-probe, XFEL

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2023-04-19 - 2023-04-21

C6.03

Investigation of Ground state in VI_3 by Soft X-ray Absoprtion Spectroscopy and Cluster calculation

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Abstract:

Two-dimensional van der Waals (2D vdW) magnetic materials have attracted significant attention due to their potential applications in spintronics devices, owing to their unique layered structure that can be made into a monolayer limit. Moreover, 2D vdW magnetic materials provide a valuable platform to investigate fundamental physics related to low-dimensional magnetism. For instance, the suppressed magnetic ordering of NiPS3 in a monolayer verifies the Mermin-Wagner theorem that forbids long-range magnetic ordering in isotropic 2D systems. Additionally, a new origin of magnetic anisotropy resulting from strong ligand LS coupling was discovered in CrI3.
Recently, a new 2D vdW magnetic material, VI3, has emerged with different magnetic properties compared to CrI3 despite having the same structure. The interplay between the trigonal crystal field, spin-orbit coupling, and band effects from hopping contribute to the ground state of the V complexly, making it a challenging task to uncover the microscopic mechanism behind this puzzling magnetic behavior.
In this study, we will investigate the ground state of the recently discovered V-based 2D ferromagnet VI3. We will use a synergetic combination of X-ray absorption spectroscopy, X-ray magnetic circular dichroism, and Cluster many-body calculation to resolve the ground state of the V3+ ion. Our study aims to provide fresh insights into the microscopic origin of the magnetic properties in 3d-transition metal-based 2D magnets.

Keywords:

2d vdW magnet, X-ray Absorption Spectroscopy, VI3, Unqueched orbital moment

Femtosecond ablation and destruction of confined nanoparticles directly observed by ultrafast X-ray imaging

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Abstract:

The structural response of a metal takes into account electron-phonon coupling on the order of a few picoseconds when it is electronically excited by an fs IR laser. The sub-picosecond structural phase transitions is therefore limited. In particular, the ablation on the sub-ps scale challenges the scenario that it is achieved by thermalisation of the lattice. Here we observe ultrafast nanoparticle fission and deformation induced by strong fs-laser excitation in a confined Au system using high spatio-temporal resolution coherent x-ray imaging at the XFEL. Two-temperature molecular dynamics simulations investigated the atomic dynamics to confirm the sub-ps phase transition progression of the confined system, which corroborates the experimental results. In this presentation, we will discuss the particle distruction and fission observed in the sub ps.

Keywords:

Femtosecond ablation, Confined nanoparticle, X-ray free electron laser, Single-particle imaging, Non-equilibrium phase transition

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2023-04-19 - 2023-04-21

C7.01

Suppressed fluctuations as the origin of the static order in Sr2RuO4

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Abstract:

In this talk, we explain the recently reported counterintuitive appearance of an ordered magnetic state in uniaxially strained Sr_2RuO_4 beyond the Lifshits transition. Combining first-principles density functional theory calculations with Moriya's self-consistent renormalization approach, we show that strain weakens the quantum spin fluctuations, which destroy the static order, more strongly than the tendency to magnetism. A different rate of decrease of the spin fluctuations vs. magnetic stabilization energy promotes the onset of a static magnetic order beyond a critical strain.

Keywords:

Sr2RuO4, DFT, magnetism

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2023-04-19 - 2023-04-21

C7.02

Low-energy interband transition and charge dynamics of ultraclean $SrVO_3$

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Abstract:

Strange metallic behavior of correlated metals is one of the outstanding problems in condensed matter physics. The optical conductivities of strange metals shows characteristic spectral form composed of a zero-frequency Drude-like peak followed by a featureless midinfrared continuum. We investigated the optical response of an archetypal correlated metal $SrVO_3$ in the ultraclean and the disordered limits by using infrared spectroscopy. We observed a strong optical excitation at about 70 meV in the optical response of the ultraclean sample. The excitation was masked by the Drude-like response in the disordered sample resulting in the characteristic spectral form of the optical conductivities of strange metals. Density functional theory + dynamical mean field theory calculations revealed that the optical excitation at about 70 meV resulted from interband transition activated by the orbital-offdiagonal hoppings. The memory function analysis of the optical data showed that the interband transition led to deviations of optical self-energy from the Fermi-liquid behavior. Our work demonstrates that the effects of low-energy interband transitions should be taken into account to extract many-body effects from optical spectra.

Keywords:

Strange metal, Optical conductivity, SrVO3

C7.03

Recent Advances in the Study of the Hund Metallic Phase

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Abstract:

The on-site Hund coupling J has been a focal point of research in electron correlation for the past 15 years. It leads to the emergence of a Hund metal, a correlated metallic regime that occurs in multiorbital systems away from half-filling. This system is characterized by electron correlation promoted by J rather than proximity to a Mott insulator, resulting in a range of physical phenomena such as spin-freezing crossover, spin-orbital separation, orbital differentiation, and superconductivity.

In this talk,we will provides an overview of the Hund metallic phase and highlights our recent discoveries in the field [1,2,3]. These include the existence of Hund metals in two orbital systems, an enhancement of charge-order instability in the Hund metallic regime, and key experimental signatures of Hund metal.

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[3] S. Ryee, S. Choi, and M. J. Han, arXiv:2207.10421

Keywords:

Hund metal, Dynamical mean field theory

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2023-04-19 - 2023-04-21

C8.01

Multislice Electron Tomography using 4D-STEM: A High-Precision Approach to 3D Imaging

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Abstract:

Electron tomography offers invaluable insights into the three-dimensional structure of materials that cannot be obtained with two-dimensional imaging techniques. Recent advances have enabled atomic-level resolution using annular dark field scanning transmission electron microscopy (ADF-STEM) in combination with aberration correction. However, ADF-STEM-based tomography has limitations, including high electron dose requirements, poor contrast for light elements, and susceptibility to artifacts from nonlinear image contrast. In this talk, we introduce a novel method, called MultiSlice Electron Tomography (MSET), which utilizes 4D-STEM tilt series (referring to a collection of 2D diffraction images of a converged electron beam at each point in a 2D STEM raster). Our simulations demonstrate that MSET can effectively reduce undesirable artifacts from nonlinear contrast, enhance sensitivity for light elements, and decrease electron dose requirements. We anticipate that MSET will find widespread use in the investigation of challenging materials, such as those containing light elements or that are sensitive to radiation, where 3D atomic structures have remained unknown due to electron dose limitations or nonlinear imaging contrast.

Keywords:

4D-STEM, Multislice method, Atomic resolution electron tomography

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2023-04-19 - 2023-04-21

C8.02

Studying optical phenomena using scanning transmission electron microscopy

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Abstract:

Due to instrumental advances in electron microscopy, an electron beam became a vital probe for studying optical phenomena occurring in solid-state materials and devices. With the development of the aberration corrector, the electron beam can be focused down to the sub-angstrom resolution. The core configuration of structural defects can be identified atom-by-atom with scanning transmission electron microscopy (STEM), which is deterministic in understanding the luminescence properties of crystalline defects. With atomic-scale STEM and DFT calculations, we found that high-angle grain boundaries in GaN thin films are highly active even without additional impurities because of their unique atomic configurations. Due to the advance of the monochromator, the energy spread of the primary electron beam can be reduced to the level of 10 meV full-width half-maximum (FWHM). Accordingly, the optical modes can be directly visualized in nm scale using electron energy loss spectroscopy within STEM. With monochromated STEM-EELS, we observed strong plasmonic excitations in the slits within delafossite-oxide slabs and figured out that those are antisymmetrically-coupled hyperbolic surface plasmon polaritons. In this talk, I will present how STEM and electron-beam spectroscopies can be useful in tracking many sciences in optoelectronics and nanophotonics.

Keywords:

electron microscopy, electron-beam spectroscopy, structural defects, optical modes

Direct measurement of magnetoelastic coupling in soft ferromagnets using Lorentz 4D-STEM

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Abstract:

Soft ferromagnetic materials, e.g. Fe-based amorphous alloys, play a major role in the conversion of energy owing to their high energy efficiency.
To understand fundamental magnetism, correlative measurements of the magnetic and atomic structure of soft ferromagnetic materials are desired. Here, we have developed Lorentz 4-dimensional scanning transmission electron microscopy (Ltz-4D-STEM) for correlative mapping of the magnetic structure, strain fields, and packing structure and applied this approach to deformed Fe-based metallic glasses. Our approach considers the momentum transfer of the electron beam due to the local magnetic field, the elliptic distortion of the amorphous diffraction ring under strain, and the area encompassed by the ring to quantify the relative atomic density and reveal their spatial-correlative variance. This enables a direct pixel-level correlation of the magnetic and atomic structure and thus experimentally maps the magnetoelastic energy of soft ferromagnets. This method opens a new door to studying magnetic materials.

Keywords:

Ltz-4D-STEM, Magnetoelastic coupling, Amorphous soft ferromagnet

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2023-04-19 - 2023-04-21

C9.01

Van der Waals heterostructures for novel optoelectronic applications

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Abstract:

Polarization-sensitive photodetection has attracted considerable attention as an emerging technology for future optoelectronic applications such as three-dimensional (3D) imaging, quantum optics, and encryption. However, traditional photodetectors based on Si or III–V InGaAs semiconductors cannot directly detect polarized light without additional optical components. In this context, two-dimensional (2D) van der Waals (vdW) layered semiconductors with in-plane anisotropic properties are a promising candidate for use in polarization-sensitive photodetection.
Here, we introduce MoTe2/ReS2 and WSe2/ReSe2 van der Waals heterostructures for linear polarization photodetection. First MoTe2/ReS2 PN diode shows excellent electrical performance with ideality factor or 1.3 and high ON/OFF ratio of 10^4 and exhibit broad spectral photo response up to 1310 nm illumination. Also we demonstrate a self-powered linear-polarization-sensitive photodetector using WSe2/ReSe2 heterostructure. The WSe2/ReSe2 heterojunction exhibits excellent performance: an ideality factor of 1.67, a broad spectral photoresponse of 405–980 nm with significant photovoltaic effect, remarkable linearity with a linear dynamic range wider than 100 dB, and rapid photoswitching behavior with cutoff frequency up to 100 kHz. These two type of heterostructure shows clear linear polarization sensitive photodetection and we finally demonstration NIR digital incoherent holography.

Keywords:

Van der Waals heterostructures, ReS2, ReSe2, linear polarization sensitive photodetection

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

C9.02

Low-voltage transistors and diodes ; Extending the road beyond CMOS

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Abstract:

The continuous transistor down-scaling has been the key to the successful development of the current information technology. However, with Moore's law reaching its limits the development of alternative transistor architectures is urgently needed. Transistors require at least 60 mV switching voltage for each 10-fold current increase, i.e. subthreshold swing (SS) 60 mV/dec. Alternative tunnel field-effect transistors (TFETs) are widely studied to achieve a sub-thermionic SS and high I_{60} (current where SS becomes 60 mV/dec). Heterojunction (HJ) TFETs bear promise to deliver high I_{60}, but experimental results do not meet theoretical expectations due to interface problems in the HJs constructed from different materials. Here, we report a natural HJ-TFET with spatially varying layer thickness in black phosphorus (BP) without interface problems. We achieved record-low average SS over 4 decades of current, $SS_{ave\_4dec} \approx 22.9$ mV/dec with record-high I_{60} (= 19.5 μA/μm), paving the way for the application in low power switches. Low-power transistors, such as tunnel field-effect transistors (TFETs), negative-capacitance field-effect transistors (NC-FETs), and Dirac-source field-effect transistors (DS-FETs), have been realised to break the thermionic limit of the subthreshold swing (SS). However, a low power diode rectifier, which breaks the thermionic limit of an ideality factor (η) of 1 at room temperature, has not been proposed yet. In this study, we have realized a DS diode, which exhibits a steep slope characteristic curve, by utilising the linear density of states (DOSs) of graphene. For the developed DS diode, $\eta < 1$ for more than two decades of drain current with a minimum value of 0.76, and the rectifying ratio is large (> 10^5). The realisation of a DS diode paves the way for the development of low-power electronic circuits.

Keywords:

tunnel FET, Dirac source diode

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C9.03

Electrical manipulation of quantum light sources in 2D materials

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Abstract:

Single photon emitters are fundamental resources of quantum optics and quantum information technologies. Recently, the emergence of single photon emission in atomically thin materials such as hexagonal boron nitride (h-BN) has triggered tremendous interests in 2D material based single photon sources. For the full exploitation of 2D single photon emitters for quantum technologies, however, the ability to control each atomic defect individually is crucial. In this talk, we introduce methods to generate and manipulate quantum emitters in 2D h-BN crystals using external voltages. First, we describe the electrical tuning of quantum emitters in h-BN by fabricating van der Waals heterostructures with graphene electrodes. By applying an electric field through graphene, diverse trails of Stark shifts are observed, from which various information about the crystallographic nature of atomic defects is extracted. Second, we show the electrical switching of quantum emitters enabled by the controlled manipulation of defect’s charge state which will be beneficial for the development of chip-based 2D photonic quantum information devices.

Keywords:

Single photon sources, h-BN, van der Waals, Charge manipulation

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2023-04-19 - 2023-04-21

C10.01

Kondo cloud condensates: New coherent ground state in metal

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Abstract:

금속에 자성 불순물들이 놓이게 되면, 자성 불순물은 주변의 전자들을 포획해 온도가 임계 온도 (콘도 온도) 보다 더 내려가 절대온도 근처에서 전자들의 스핀이 자성 불순물의 스핀을 집단적으로 (양자 얽힘에 의해) 상쇄시키는 현상이 일어날 수 있고 이러한 순수 스핀이 없는 영역을 콘도 구름이라고 한다. 본 발표에서는 금속에 충분히 많은 자성 불순물이 존재할 때 극저온에서 콘도 구름들이 충분히 가까워 (응축되어) 새로운 양자역학적 바닥상태가 형성될 수 있음을 전기 전도도 및 페르미 에너지 근처에서의 터널링 상태밀도 (Density of States: DOS) 측정 결과를 가지고 설명한다. 발견된 DOS 스펙트럼은 BCS-초전도체와 매우 유사하며 콘도 구름들에 의한 응축은 BCS Cooper-pair 응축의 자성 버전과 같은 개념으로 해석할 수 있다.

Keywords:

Kondo cloud, Condensation

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C10.02

Kondo lattices in multi-orbital d-electron systems

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Abstract:

Finding d-electron heavy fermion (HF) states has been an important topic as the diversity in d-electron materials can lead to many exotic Kondo effect-related phenomena or new states of matter such as correlation-driven topological Kondo insulator. Yet, obtaining direct spectroscopic evidence for a delectron HF system has been elusive to date. Here, we report the observation of Kondo lattice behavior in an antiferromagnetic metal, FeTe, via angle-resolved photoemission spectroscopy (ARPES), scanning tunneling spectroscopy and transport property measurements. The Kondo lattice behavior is represented by the emergence of a sharp quasiparticle and Fano-type tunneling spectra at low temperatures. The transport property measurements confirm the low-temperature Fermi liquid behavior and reveal successive coherent-incoherent crossover upon increasing temperature. We interpret the
Kondo lattice behavior as a result of hybridization between localized Fe 3dxy and itinerant Te 5pz orbitals. Our observations strongly suggest unusual cooperation between Kondo lattice behavior and long-range magnetic order. If time permits, potential Kondo-hybridization with an orbital-selective Mott phase will be also discussed. Among the three t2g orbitals in 4d Ca2−xSrxRuO4, dxy is localized near the Mott phase and electrons in dxy orbital can act as localized spins, leading to the signature of Kondo-hybridization. These two examples show that Kondo phenomena may be more common than what is believed.

Keywords:

2023 KPS Spring Meeting
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C10.03

Observation of the confinement effect on a vortex-antivortex pair through an unquantized magnetic flux

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Abstract:

In geometrically confined superconductors, the quantization of magnetic flux breaks down because of the incomplete screening of the supercurrent against field penetration, although fluxoid quantization holds. In this study, we generate a vortex-antivortex pair connected to a 1D unquantized magnetic flux in ultrathin superconducting films using a vector-field magnetic force microscope. The manipulation and thermal behavior of the vortex pair exhibit a long-range interaction via the unquantized magnetic flux, thus suggesting the formation of a universal unquantized magnetic flux regardless of geometrical constriction. Our results provide an experimental route for investigating extremely low-dimensional superconductivity, such as the confinement effect on the superconducting properties and order parameters

Keywords:

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C10.04

Spin screening cloud in Pseudogap Kondo system

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Abstract:

Spin screening phenomena are central in Kondo impurity problems. We study spin screening clouds (many-electrons objects screening impurity spin) in Kondo impurity system of conduction electrons having pseudogap density of states. In both the non-Kondo and Kondo phases of the system, we analyze the spatial distribution and thermal suppression of the spin cloud. To investigate the spin cloud, we compute the entanglement between an impurity and the conduction electrons by using numerical renormalization group method. We find the spatial distribution and thermal suppression exhibit universal power-law scaling behavior in the low-energy regime. We develop fixed-point analysis method to understand the universal behavior. Our analysis provides a systematic way to study the entanglement for general impurity models which have energy dependent density of states.

Keywords:

Kondo effect, Kondo cloud, pseudogap, Quantum entanglement

C10.05

Kondo Cloud and Entanglement in Exotic Kondo Effects

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Abstract:

The quantum coherent screening of a local spin in metals is a long-standing issue in quantum many-body problems. In this work, we analyze the spatial and energy distribution of the Kondo cloud, a spatial structure screening a local impurity spin-1/2, in multichannel Kondo effects and two-impurity Kondo effects. We characterize the Kondo cloud by its quantum entanglement with the impurity spin [1,2,3]. The cloud extends over the space, having the core and the tail inside and outside the cloud length, respectively [4]. Most electrons forming the cloud lie in the core, and the tail algebraically decays, following the universal power law. We show that distinct (non-)Fermi liquids coexist in the tail, forming concentric shells centered at the impurity. Outer shells are suppressed one by one as temperature increases, and the remaining outermost shell determines the thermal non-Fermi liquid phase of the metal at that temperature. We propose how to observe the entanglement and the Kondo cloud structure, based on a charge Kondo setup [5].

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[2] J. Shim, D. Kim, and H.-S. Sim, preprint (2022).
[3] D. Kim, M. Kim, J. Shim, and H.-S. Sim, in preparation.
[4] I. V. Borzenets, J. Shim, J. C. H. Chen, A. Ludwig, A. D. Wieck, S. Tarucha, H.-S. Sim, M. Yamamoto, Nature 579, 210 (2020)
[5] Z. Iftikhar, A. Anthore, A.K. Mitchell, F.D. Parmentier, U. Gennser, A. Ouerghi, A. Cavanna, C. Mora, P. Simon, and F. Pierre, Science 360, 1315 (2018)

Keywords:

Entanglement, Kondo Cloud, Multichannel Kondo Effect, Two-Impurity Kondo Effect

2023 KPS Spring Meeting
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C11.01

Current Status of Beam Commissioning for RAON Linac

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Abstract:

Initial beam commissioning of the RAON linac facility is in progress for the low energy part of linac (SCL3) and the KoBRA beam line. At this stage of commissioning, the reference particle is argon with a mass number of 40 and a charge state of 9. The beam current for the ion source was measured to be about 30 uA. The beam pulse width and repetition rate are 100 usec and 1 Hz, respectively. This brief report summarizes the recent results of beam commissioning for the RAON linac and the beam line.

Keywords:

RAON, Linac, Beam Commissioning

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2023-04-19 - 2023-04-21

C11.02

Spinning beam effects in high-intensity linear accelerators with machine imperfections

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Abstract:

Spinning flying objects such as American football and rifled bullets are stabilized against the disturbances by maintaining the large canonical angular momentum. Motivated by this well-known principle in classical mechanics, we apply the spinning effects on the charged particle beams. It has been found that the spinning beam has an intrinsic characteristic to mitigate the space-charge-driven resonances and suppress the halo formations along the high-intensity linear accelerators. The mitigation effects of the spinning beam on the beam instabilities have been verified from the analytical calculation and multi-particle simulations. We consider stripping of H- beam at a carbon foil inside a solenoid to generate the spinning H+ beam of non-zero canonical angular momentum. Also, we have performed error studies along the periodic solenoid and quadrupole focusing lattices to investigate the spinning beam effects on the emittance growth and halo formations in more realistic operating conditions.

Keywords:

Spinning beam, High-intensity linear accelerator, Error study, Beam stripping

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2023-04-19 - 2023-04-21

C11.03

Effects of Off-Axis Beam Injection to RFQ

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Abstract:

It is observed that emittance growth and beam parameter change are induced when beam is injected to RFQ at an offset or at an angle. This shows the importance of on-axis beam injection and LEBT orbit correction. Study results are presented.

Keywords:

on-axis injection, RFQ, orbit correction

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

C11.04

Current status of pre-bunching and re-bunching systems for RAON low-energy experiments

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Abstract:

Rare Isotope Accelerator complex for ON-line experiments (RAON) is currently under construction in Korea to conduct various nuclear physics experiments using Rare Isotope (RI) and stable ion beams. The ion beams will be accelerated up to a few tens of MeV/nucleon through Radio-Frequency Quadrupole (RFQ) and Super-Conducting Linac 3 (SCL3), and be delivered to low-energy experimental facilities at RAON, including the Korea Broad Acceptance Recoil spectrometer and Apparatus (KoBRA) and the Nuclear Data Production System (NDPS).
The repetition rate of the ion beams at production targets of the low-energy experimental facilities with Continuous Wave (CW) mode operation will be 81.25 MHz, the same as the frequency of the RFQ. However, the repetition rates for Time-Of-Flight (TOF) measurements at KoBRA and NDPS are approximately 2 MHz and less than 200 kHz, respectively. Therefore, we have designed and installed a pre-bunching system, based on a fast chopper and Double Gap Buncher (DGB), upstream of the RFQ to adjust the repetition rates. Furthermore, a re-bunching system utilizing a normal conducting 5-gap Interdigital H-mode Drift Tube Linac (IH-DTL) type Radio Frequency (RF) cavity has been developed and manufactured to compress the longitudinal bunch length of the ion beams at the KoBRA production targets. We present the current status of the pre-bunching and re-bunching systems for the low-energy experimental facilities at RAON.

Keywords:

Rare Isotope Science Project, RAON, Rebuncher, IH-DTL, Double Gap Buncher

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

C11.05

Current Status of RF system for the Korea 4th Generation Light Source

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Abstract:

A new fourth-generation synchrotron radiation source (4GSR) is planned to be built in Ochang, South Korea by 2027. The technical design review for the Korea 4GSR is currently in progress and is expected to be completed in mid-2023.
The storage ring of the 4GSR will have a circumference of 800 meters and has been designed for a maximum current of 400 mA at 4 GeV electron beam energy. The target emittance is 58 pm-rad, which is 100 times less than that of the PLS-II, the third-generation light source in Korea.
The RF system for the Korea 4GSR will consist of 10 or more normal-conducting cavities, a low-level RF (LLRF) system, a high-power RF (HPRF) system, and highly HOM-damped cavities to ensure beam stability. Additionally, a longitudinal feedback system (LFS) and transverse feedback system (TFS) will be installed in the storage ring to enhance stability. Harmonic cavities will also be installed for Landau damping, and to improve beam lifetime.
For the LLRF, a new digital feedback control scheme will be implemented. As for the HPRF, a solid-state RF power amplifier will be used.
This presentation provides an overview of the current status and plans for the RF system of the Korea 4GSR.

Keywords:

4GSR, light source, RF system, HOM damped cavity, synchrotron

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

C11.06

Characterization of beam coupling via turn-by-turn beam position monitor data in circular accelerators

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Abstract:

In circular accelerators such as circular colliders and storage ring-based light sources, the skew quadrupole field errors and solenoids generate betatron coupling between the horizontal and vertical motions. Normally, the betatron coupling can affect the vertical equilibrium emittance of the electron beam, reducing the dynamic aperture and the brightness of the photon beam. On the other hand, one can introduce coupling intentionally for making a round beam in order to mitigate the space charge effect in the lower energy part of the collider or reduce the intra-beam scattering effect in the high energy part of the light source. Therefore, coupling control is crucial in the operation of modern circular accelerators. In particular, coupling parameters represent how much the horizontal and vertical motions are correlated. If the coupling parameter can be measured or controlled, we can get information on the coupling characteristics of an accelerator and may adjust them arbitrarily. In this presentation, we show how to get coupling parameters from the turn-by-turn beam position monitor (BPM) data using the Accelerate Toolbox (AT) simulation for the case of the PLS-II ring.

Keywords:

circular accelerator, beam position monitor, linear coupling

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

C11.07

Development of beam postion monitor by using SiO_2 glass insulator for Korea 4GSR project

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Abstract:

The Korea 4GSR project is a 4th generation light source storage ring construction project that aims to achieve an emittance of less than 100 pm by constructing a storage ring with a circumference of about 800 m. To achieve this, a vacuum chamber with a smaller size than the existing third-generation storage ring is adopted, which has also led to many restrictions on the design of beam position monitors. In particular, an antenna design using a glass-based insulator was considered to suppress an increase in longitudinal impedance and power dissipation. The selected material is SiO_2 glass insulator, and in this presentation, we will present the optimized antenna design and the design of the 4GSR beam position monitor.

Keywords:

beam postion monitor, BPM, 4GSR, Impedance

C12.01

새봄, 모퉁이를 돌아 길을 나서다: 새내기 여성 물리학자들의 이야기

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Abstract:

새봄, 모퉁이를 돌아 길을 나서다: 새내기 여성 물리학자들의 이야기

운영자: 조연정(경북대), 공수현(고려대)

여성위원회에서는 물리 분야에서 여성의 역할모델 부재를 부분적으로나마 해결하고, 주변 환경에서 겪는 고민이나 진로 등의 문제를 함께 고민하고 있습니다. 최근에 정규직으로 자리잡은 분들을 모시고, 어떤 연구 분야에서 일하고 있는지에 대해 듣고 소통하는 기회를 마련하고자 합니다.

[프로그램]
인사말 : 임혜인(여성위원회 위원장, 숙명여대)
강연자: 김희연(카이스트), 이연의(충북대), 이예령(건국대)

Keywords:

여성

C13.01

Neutron studies on a highly frustrated 4d pyrochlore antiferromagnet Nd2Ru2O7

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Abstract:

Pyrochlore oxides are proposed in searching for emerging quantum phases such as Weyl semimetal [1]. As a result, it has led to numerous works on 5d transition-metal-based compounds, such as iridates, for the last decade. A spin-1/2 state with a strong spin-orbit coupling interacts in a pyrochlore lattice, a source of highly frustrated magnetism. On the other hand, much less research has been done on a spin-1 counterpart. However, a fundamental distinction between the half-integer and integer magnetic moments can imply the qualitative difference in their magnetism [2]. Thus, the spin-1 pyrochlore oxide could provide a new platform to discover unprecedented electronic states.

In this talk, we will introduce the peculiar magnetism of a spin-1 pyrochlore ruthenate, Nd2Ru2O7, which belongs to the compound family of R2Ru2O7 (R = Y and rare-earth ions). To understand its magnetism, we performed elastic neutron diffraction and inelastic neutron scattering measurements using high-quality polycrystalline powder. We propose magnetic structural candidates of Ru4+ and Nd3+ ions via systematic magnetic refinements, complemented by group theory analysis. Inelastic neutron scattering measurements probe its magnetic excitations, which can be comprehended by crystalline electric field calculations. We will discuss the physical implications of our experiments related to topological magnetism.

[1] W. Witczak-Krempa et al, Annu. Rev. Condens. Matter Phys. 5, 57 (2014).
[2] F.-Y. Li and G. Chen, Physical Review B 98, 045109 (2018).

Keywords:

Quantum magnets , neutron diffraction , inelastic neutron scattering, group theory, crystalline electric field

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C13.02

Pyrochlore ruthenates - From magnon band engineering to highly coherent Higgs modes

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Abstract:

Pyrochlore ruthenates ($A_2Ru_2O_7$) are prototypical platforms for exploring the effects of frustration, spin-orbit interaction, and lattice degrees of freedom on S=1 magnetism.
We present a comprehensive spectroscopy study on a series of newly synthesized $A_2Ru_2O_7$ compounds (with A = Y, Er, Ho, Eu, Sm, Nd) and uncover an unprecedented tunability of the magnon band structure [1]. Focusing on $Nd_2Ru_2O_7$, we directly observe a highly coherent, low-energy Higgs-type amplitude mode, which arises through a competition of magnetic bond configurations within the magnetically ordered phase [2].
The low, two-fold symmetry of this amplitude mode is incompatible with the underlying crystal structure, and highlights the possibility of multiple entangled broken symmetries that can stabilize an axial Higgs mode [3].

[1] J. H. Lee, et al., in preparation (2023).
[2] D. Wulferding, et al., arXiv:2204.12124 (2022).
[3] Y. Wang, et al., Nature **606**, 896 (2022).

Keywords:

quantum criticality, spin-phonon coupling, ruthenates, Raman spectroscopy

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C13.03

First-principles investigation of the electronic and magnetic properties of quasi-one-dimensional $MoBr_3$

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Abstract:

We investigate the electronic and magnetic properties of molybdenum tribromide $MoBr_3$ using first-principles density functional theory. $MoBr_3$ consists of weakly coupled one-dimensional chains in which each Mo^{3+} ion is surrounded by a Br octahedron, face-sharing with neighboring octahedra. The ground state structure exhibits dimerization of Mo-Mo pairs with alternating short and long bonds consistent with the experimental report. We find an insulating ground state with antiferromagnetic ordering having a magnetic moment of 1.8 μ_B on each Mo atom smaller than the fully polarized value of 3 μ_B from the d^3 filling of Mo, indicating orbital-dependent hybridization which reduces the magnetic moment of Mo d_{z^2} orbitals extending along the dimer direction. A comparison of the electronic structures of dimerized and non-dimerized antiferromagnetic phases shows that the dimerized phase is preferred. Energy lowering by a bonding-antibonding splitting of the Mo d_{z^2} bands from dimerization is larger than increasing the magnetic moment without dimerization, indicating the dominant inter-orbital hopping exceeding the Hund coupling for the d_{z^2} orbitals. We identify the interplay between on-site and intersite interaction in the system with nominal Mo d 3 filling leads to orbital-dependent suppression of the magnetic moments manifested from the quasi-one-dimensional geometry.

Keywords:

Density functional theory, Quasi-one-dimensional, Dimer, Orbital selective behavior, magnetism

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

C13.04

Meron stabilization in twisted magnets

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Abstract:

Merons are topological solitons with a topological charge of one-half of skyrmions, and they have important implications for understanding chiral magnetic order and developing novel spintronic devices for information technologies. Despite their potential, the realization of merons has remained elusive compared to skyrmions. This study proposes that twisted magnets could be a promising platform for stabilizing meron-antimeron pairs. The stacking-dependent interlayer exchange coupling in a moiré superlattice generates magnetic domains that introduce an effective moiré potential to prohibit pair annihilation, which is absent in usual magnets. The results suggest a new route for achieving meron pairs in real magnetic systems, and highlight the potential of twisted magnets for exploring topological solitons.

Keywords:

moiré magnet, topological spin texture, meron

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2023-04-19 - 2023-04-21

C13.05

Strain dependent magneto-crystalline anisotropy of mono- and bilayer Fe_3GeTe_2

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Abstract:

Magneto-crystalline anisotropy (MCA) is one of important properties for spintronics application. The preference of perpendicular magnetization, perpendicular MCA, is advantageous for high bit density, low switching current, and thermal stability [1]. Here, strain dependent MCA of mono- and bilayer Fe_3GeTe_2 (FGT) is studied using density functional theory. FGT has attracted for their higher Curie temperature (130 K~) among two-dimensional magnetic materials [2-4]. For all strains (-5% ≤η≤ +5%), monolayer FGT exhibit E_{MCA} > 0 ranging from 0.85 to 4.15 meV/f.u. On the other hands, E_{MCA} of bilayer FGT varying from -0.56 to 4.82 meV/f.u. where E_{MCA} < 0 occurs when η ≤ -4%. From band analysis, at η=0%, E_{MCA} > 0 mainly comes from z|m=±1>. However, at η= -5%, m=±1 states become unoccupied, E_{MCA} < 0 emerges from X|m=±1>.

[1] Soon-Wook Jung et al., Appl. Phys. Lett. **92**, 202508 (2008).
[2] Kenneth S. Burch et al., Nature **563**, 47 (2018).
[3] M. Gibertini et al., Nat. Nanotechnol. **14**, 408 (2019).
[4] Zaiyao Fei et al., Nat. Mater. **17**, 778 (2018).

Keywords:

density functional theory calculations, magneto-crystalline anisotropy, strain

Relations between magnetism and magnetoelectricity in polar honeycomb antiferromagnets A2Mo3O8 (A=Ni, Fe, Mn)

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Abstract:

Magnetoelectric (ME) materials usually indicate compounds having magnetic and electric properties simultaneously. With the unique functionality to control magnetization and polarization by the electric and magnetic field, these materials have been studied actively as promising candidates for spintronics and magnonics applications. However, most ME materials possess multi-domains, requiring complicated electric and magnetic poling. On the other hand, polar ME compounds, where the inversion symmetry is broken in the paramagnetic state already, do not usually require poling. This makes the polar magnet technologically important. However, the microscopic mechanism for the ME property of the polar magnet, which is needed for the application, is not understood yet.

This talk introduces our recent results on neutron scattering studies on the polar ME compound family, A2Mo3O8 (A=Ni, Fe, Mn). With the summary of our experimental observations, we will discuss our understanding of the relations between magnetism and the peculiar polarization observed in these compounds. Our results provide essential information that could facilitate observing and examining novel magnetoelectric properties, such as exotic nonreciprocal, Hall, and magnonic effects characteristic to this compound family.

Keywords:

Quantum magnets , Magnetoelectricity , neutron diffraction , honeycomb lattice , polar antiferromagnet

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

C13.07

Spectroscopic evidence for spin splitting in altermagnetic MnTe

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Abstract:

The Anomalous Hall effect (AHE) has been understood in close relation to nontrivial band topology. Recently, it has been proposed that AHE can arise in compensated collinear magnets with opposite-spin sublattices connected by rotational symmetry. This distinct magnetic phase, so-called 'altermagnetism', is characterized by time-reversal symmetry (TRS) broken electronic structure with non-relativistic spin-momentum locking. We performed angle-resolved photoemission spectroscopy (ARPES) on semiconducting MnTe, an altermagnetic candidate. Spin-split electronic structure with a large splitting of ~1 eV is clearly resolved. The breaking of Kramer's degeneracy at the Neel temperature provides evidence for the spin-split ground state of altermagnetic MnTe. The compensated magnetic semiconductor with TRS-broken electonic structure opens up a new platform for novel topological spintronics.

Keywords:

Magnetism, Angle-resolved Photoemission Spectroscopy

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2023-04-19 - 2023-04-21

C13.08

Surface-induced ferromagnetism and anomalous Hall transport at $Zr_2S(001)$

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Abstract:

Translate
Two-dimensional layered electrides possessing anionic excess electrons in the interstitial spaces between cationic layers have attracted much attention due to their promising opportunities in both fundamental research and technological applications. Using first-principles calculations, we predict that the layered bulk electride Zr_2S is nonmagnetic with massive Dirac nodal-line states arising from Zr-4*d* cationic and interlayer anionic electrons. However, the $Zr_2S(001)$ surface increases the density of states at the Fermi level due to the surface potential, thereby inducing a ferromagnetic order at the outermost Zr layer via the Stoner instability. Consequently, the time-reversal symmetry breaking at the surface not only generates spin-polarized topological surface states with intricate helical spin textures but also hosts an intrinsic anomalous Hall effect originating from the Berry curvature generated by spin-orbit coupling. Our findings offer a playground to investigate the emergence of ferromagnetism and anomalous Hall transport at the surface of nonmagnetic topological electrides [1].

[1] S. Liu, Y. Luo, C. Wang, H. Jeon, Y. Jia, and J.-H. Cho, Surface-induced ferromagnetism and anomalous Hall transport at $Zr_2S(001)$, Phys. Rev. Mater. 7, 024409 (2023).

Keywords:

electride, ferromagnetism, surface

2023 KPS Spring Meeting
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C14.01

In vivo implantable strain sensor for real-time and precise pathophysiological monitoring of contractile living organs

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Abstract:

Early diagnosis based on precise monitoring of the vital organs in real-time can provide the opportunity for subsequent curative treatments and medical decisions. Here, we report the instantaneous monitoring of physiological responses in contractile living organs such as the heart, lung, and urinary bladder using a vertical graphene strain sensor (VGS), which possesses remarkable sensitivity and stability. We monitored the electrical resistance of VGS (i.e., sensitivity) corresponding to the minute contractile motion of living organs, which displacement in organs was less than a few mm in scale. For pathological diagnosis, we compared normal and damage rat models, including models of myocardial infarction, pulmonary fibrosis, and spinal cord injury, highlighting the ability of the system to discern symptoms and guide medical decisions based on the lesion. Our results suggest that the VGS could be useful in implantable biocompatible applications and may be a promising component of in vivo diagnostic platforms.

Keywords:

Vertical graphene, strain sensor, real-time pathophysiological monitoring, contractile organs

C14.02

Quantitative imaging of vesicle–protein interaction reveals molecular determinants of target binding

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Abstract:

Extracellular vesicles (EVs) are cell-derived, membrane-bound particles that enclose cellular materials. The EVs released from one cell can be taken up by other cells, thereby mediating communication among distant cells. The vesicle uptake process begins with docking of the vesicles onto cell-surface proteins, but a generalizable technique that can quantitatively observe these vesicle–protein interactions (VPIs) is lacking. Here, we introduce a simple procedure that can effectively label cell-derived vesicles without complex purification then describe a fluorescence microscopy that measures VPIs between single vesicles and cell-surface proteins, either in a surface-tethered or in a membrane-embedded state. By employing cell-derived vesicles (CDVs) and intercellular adhesion molecule-1 (ICAM-1) as a model system, we found that integrin-mediated VPIs exhibit distinct modes of affinity depending on vesicle origin. Controlling the surface density of proteins also revealed a strong support from a tetraspanin protein CD9, with a critical dependence on molecular proximity. An adsorption model accounting for multiple protein molecules was developed and captured the features of density-dependent cooperativity. We expect that VPI imaging will be a useful tool to dissect the molecular mechanisms of vesicle uptake, and to guide the development of therapeutic vesicles.

Keywords:

vesicle–protein interactions, cell-derived vesicles, ICAM-1, CD9, total internal reflection fluorescence microscopy

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

C14.03

Single-molecule imaging reveals the molecular mechanisms underlying collision between a replicating DNA polymerase and a single R-loop

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Abstract:

Phi29 DNA polymerase (Phi29 DNAp) is a bacteriophage polymerase that has high processivity and fidelity due to its unique structure. It has been applied for various biotechniques such as rolling circle amplification, multiple strand displacement amplification, and single-molecule real-time sequencing. However, the detailed mechanism underlying DNA replication by Phi29 DNAp remains poorly understood. We firstly characterize biophysical properties of phi29 DNAp using a novel single-molecule imaging technique DNA curtain, which enables real-time visualization of a replication event of individual Phi29 DNAp. The speed of Phi29 DNAp is about 130 bp/sec, and the processivity is about 23 kbp, which is different from the previous ensemble result (~ 70 kbp). However, our result is more reliable because the previous result is a multiple-turnover experiment. Our processivity indicates that Phi29 DNAp can synthesize the entire genome of bacteriophage in a single replication. In addition, we investigate the collision between replicating phi29 DNAp and a single R-loop, which is a three-stranded nucleic acid structure consisting of a DNA-RNA hybrid and a displaced single-stranded DNA. About 60% of Phi29 DNAp passes the R-loop with the DNA-hybrid on template strand during replication. By contrast, more than 60% of phi29 DNAp is stalled when Phi29 DNAp encounters the R-loop with DNA-RNA hybrid on non-template strand. We also test the collision with D-loop, which shows similar results to R-loop, suggesting that a hybridized structure on non-template strand inhibits the progression of Phi29 DNAp. In addition, shorter RNA at the R-loop and mismatch of RNA-DNA hybrid on non-template strand do not change the stalling fraction. Moreover, when G-quadruplex structure was formed on template strand, the stalling portion is increased, suggesting that G-quadruplex stabilizes R-loop structure. Taken together, we propose that a base-paired structure on the non-template strand may cause the replication stalling. This study can provide insight into how a R-loop acts as a DNA replication stress.

Keywords:

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

C14.04

Autophagy-inducing hydrogel for treatment of atopic dermatitis

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Abstract:

Alginate hydrogels are highly versatile hydrophilic polymers that form three-dimensionally cross-linked networks. These hydrogels are increasingly being used in biomedicine for wound healing, drug delivery, and tissue engineering due to their nontoxicity, high biocompatibility, and heat tolerance, as well as their ability to maintain a moist environment. Atopic dermatitis is a common chronic inflammatory skin disease characterized by dry and sensitive skin accompanied by the appearance of itching eczematous lesions. In atopic dermatitis, the phenomenon of autophagy, a major catabolic mechanism that is essential for skin homeostasis, is decreased. Therefore, improving autophagy can be a potential strategy to enhance skin regeneration and ameliorate atopic dermatitis. In addition, the growing awareness of the population of the dangers of chemicals, and increasing market demand for human-friendly products, sparks the need for a more natural method for atopic dermatitis therapy. In this work, we aimed to create a natural therapy for atopic dermatitis by fabricating an alginate hydrogel containing the natural sugar trehalose to stimulate autophagy. The alginate hydrogel is formulated and physically characterized, and its application is tested in an *in vivo* mouse model of atopic dermatitis. The results demonstrate the good potential of this substrate for skin regeneration in atopic dermatitis.

Keywords:

Hydrogel, Atopic dermatitis, Autophagy, Atopic dermatitis mouse model, Physical characterization

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

C14.05

Study on biological function of Saccharomyces cerevisiae bromodomain-containing AAA+ ATPase Yta7 using single-molecule imaging

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Abstract:

Chromatin is dynamically regulated by diverse factors such as histone chaperones, chromatin remodeling complexes, and histone modifications. The dynamic alteration of chromatin is highly associated with gene regulation, genome maintenance, and genetic inheritance. In particular, nucleosome assembly and disassembly are essential for chromatin formation. It has been reported that bromodomain-containing AAA+ ATPases serve as histone chaperones. Human ATAD2 is reported to disassemble nucleosomes from chromatin and to act as an oncogenic transcriptional co-regulator. Overexpression of ATAD2 is associated with many types of cancer with poor prognosis. By contrast, Abo1, *Schizosaccharomyces pombe* homology of ATAD2, deposits H3-H4 histones onto DNA using ATP hydrolysis. However, the biological function of Yta7, *Saccharomyces cerevisiae* homolog, is still debatable. Genetic and biochemical studies revealed that Yta7 promotes the transcription by dismantling nucleosomes through the interaction with the acetylated histone tails by ATP hydrolysis. Another study suggested that Yta7 is involved in assembly of centromere histones, Cse4. Here, using a novel high-throughput single-molecule imaging technique called DNA curtain, we purposed a model of molecular function of Yta7 as a histone chaperone. We demonstrated that wild type full-length Yta7 forms H3-H4 tetrasomes like CAF-1. However, surprisingly, when N-terminal domain is deleted (Yta7-ΔN), Yta7-ΔN dismantles organized structures such as tetrasomes and nucleosomes, oppositely to wild type full length Yta7 along with increased ATPase activity. Interestingly, the phosphorylation of N-terminus of wild type full length Yta7 reduces the loading efficiency of H3-H4 histones. Both histone loading of wild type full length and unloading of Yta7-ΔN are mediated by the interaction with histone tails and independent of ATP hydrolysis.

Keywords:

Single-molecule imaging, Histone chaperone, Bromodomain-Containing AAA+ ATPase , DNA curtain, Yta7

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

C14.06

Efforts toward building a synthetic DNA-based data storage system

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Abstract:

With the digital revolution, the gap between the data generation and its storage capabilities is broadening dramatically. Synthetic Deoxyribonucleic Acid (DNA) stands out as an attractive storage alternative due to its ultrahigh data capacity, physical storage density, and possibility of DNA storage in multiple ways over significant time periods. Although challenges remain, the active research in this field is burgeoning expeditiously. Here, we present our efforts toward building a DNA-based data storage platform. To this end, we use synthetic DNA to demonstrate experimental methods of encoding/decoding by generating randomization designs of standard and degenerate nucleotides, storage of digital data by salt and silica encapsulation of DNA and foam/powder-based DNA storage with data retrieval using digital microfluidic device. The retrieved DNA was used for PCR amplification and Sanger sequencing. Alignment of read and sequenced data and their identity percentages showed that integrity of DNA is maintained and these methods can be adopted for efficient data storage.

Keywords:

DNA data storage, randomization, salt-silica encapsulation, foam/powder, digital microfluidic device

C14.07

Study on the molecular evolution of Alcohol Dehydrogenase (ADH) enzymes employing molecular dynamics simulation

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Abstract:

Local adaptation causes genetic changes in all organisms. These genetic changes occur over a long period of time and work in a state optimized for life in the environment. Some examples of local adaptation in human life include local zone and local environments such as climate, altitude, and disease. One of the characteristic genes relating to local adaptation in Asians is alcohol dehydrogenase (ADH) genes, which are found not only in humans but also in various organisms such as bacteria, amphibians, and birds. In this study, by employing molecular dynamics simulation and network theory, we investigate the molecular evolution of ADH enzymes for *Saccharomyces Cerevisiae, Gadus Morhua*, and *Homo Sapiens*

Keywords:

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

C15.01

Ammonium-halide salts additive engineering in defect passivation of perovskite emitters for high-performance pure-blue PLED applications

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Abstract:

Recent advancements in organometallic trihalide perovskites have surprised the photovoltaics and display technology communities with their unique characteristics such as excellent color purity, color tunability, and solution processability. However, the optoelectronic properties and operational stability of pure-blue perovskite-based light emitting diodes (PLEDs) lag behind those of their green or red counterparts. The crystallographic defects present in bulk, surface, and buried interfaces of perovskite containing point defects or grain boundaries lead to severe charge carrier recombination, causing a substantial loss in quantum efficiency and luminance of blue PLEDs. This study explores a series of ammonium-halide salts additives at film surfaces, buried interfaces, and bulk perovskite films to achieve pure blue fluorescence emission with a narrow emission band. Systematic film characterizations and morphological investigations were conducted to understand the role of additives during crystallization of perovskite emitting layers. Recent achievements in pure-blue PLEDs with ammonium halide salts will be presented and discussed.

Keywords:

Perovskites, Additives, PLEDs

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

C15.02

Interface effects in hybrid lead halide perovskite solar cells: from fundamental understanding to device operation

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Abstract:

Hybrid lead halide perovskite solar cells have been remarkable progress in efficiency over the past decade. In general, the performance of solar cells is strongly affected by the interfaces between the absorber layer and charge transport layer (also electrode). Depending on interface properties, the situation of defect formation and charge carrier extraction are varied. Therefore, elucidating the role of interface properties is significant in the optimization of solar cells. In this talk, I will discuss the equilibrium space charge effects in $CH_3NH_3PbI_3$ (MAPI) and focus on the ITO/SnO_2, MAPI/TiO_2, and MAPI/Al_2O_3 contacts [1-2], which are important for charge transfer in perovskite solar cells. Here we first applied the nanoionics concept to solar cell material of MAPI and found that ionic carriers are not only relevant, they even dictate the space charge potential, which the electrons have to follow. The results give very strong indications of ionically-driven equilibrium space potentials forming at the MAPI/TiO_2 and MAPI/Al_2O_3 contacts. Also, we found the formation of a space charge layer at the ITO/SnO_2 and it leads to the suppression of electrons. This situation reduces the charge transport at the interface when the SnO_2 thickness is thinner than the width of the space-charge region.
Despite the many advantages of solar cells, degradation of perovskite materials with respect to water, oxygen, and light is inevitable. Mixing two-dimensional (2D) perovskite materials in 3D perovskite is one of the breakthroughs for improving stability owing to their hydrophobic nature [3]. However, the insulating properties of larger organic cations (2D additive) impede efficient charge transport and consequently reduce device performance. Therefore, deep studies on material properties with fine-tuning of the 2D-3D constitution to build up both stability and device performance are necessary. We demonstrated that tuning of 2D additive modifies the potential distribution near grain boundaries and work function in perovskite absorbers [4]. A small amount of 2D additive boosts the stability of the device and enhances carrier lifetime as well as charge transport by defect passivation and increasing conductivity. This work will provide a new perspective on the well-designed interface and high-performance 2D/3D-based perovskite solar cells with better stability.

[1] S. S. –O. Youn, J. Kim, J. Na, W. Jo, and G. Y. Kim, *ACS Appl. Mater. Interf.* **14** (2022) 48229-48239.
[2] G.-Y. Kim, A. Senocrate, D. Moia, and J. Maier, *Adv. Funct. Mater.* **30** (2020) 2002426.
[3] Y.-R. Wang, G.-Y. Kim, E. Kotomin, D. Moia and J. Maier, J*. Phys. Ener.* **4** (2022) 011001.
[4] B. P. Nguyen, J. Kim, H. K. Park, W. Jo, G. Y. Kim, *ACS Appl. Ener. Mater.* **5** (2022) 7965-7976.

Keywords:

Perovskite, interface, charge transport, solar cell, halide perovskite

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

C15.03

Theoretical Understanding of the Roles of Compositional Mixing in Metal Halide Perovskites: Focus on the Stability Issue

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Abstract:

Metal halide perovskites (MHPs) have gained significant attention in the field of light-absorbing and optoelectronic devices due to their exceptional performance and ease of fabrication. However, stability and toxicity are major obstacles for commercialization. To address these issues, compositional mixing has been employed to modify the electronic structures, bandgaps, and stability of MHPs. Our group has utilized density functional theory (DFT) to investigate the effects of compositional mixing in MHPs, developing computational frameworks for efficient calculations of alloyed perovskites. In this presentation, we will discuss our theoretical approaches and recent works on the enhanced stability of compositional mixing in MHPs. Firstly, we will introduce the general issue of compositional mixing. Secondly, we will comparatively discuss the intrinsic stability of A-, B-, and X-site ions and molecules. Lastly, we will present our theoretical methods for polymorph selection engineering to obtain stable and efficient perovskite solar cells. Among various phase transformations in MHPs, I will focus on the transition between g-phase to d-phase transition of $FAPbI_3$, $CsPbI_3$, and $CsSnI_3$.

Keywords:

Perovskite, Halide, Stability, Polymorph, Phase transformation

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

C15.04

Compositional Engineering on Metal Halide Perovskites for Efficient and Eco-friend Tandem Cells

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Abstract:

Perovskite-based tandem cells can reveal competitive properties of high efficiency and low cost compared to commercial silicon based cells. In addition, environmentally benign solar cells are also required to expand its penetration rate into conventional market. Hence, Pb-free perovskite tandem can be one of the crucial choices to overcome current limitations on PV field.
Sn-based perovskite PV exhibited better performances than other Pb-free analogues (Ge, Sb, Bi and etc) and pure Sn perovskites reveal rather narrow bandgap (~1.4 eV). Hence, wider bandgap absorber is also needed to construct tandem structure. In other words, wide bandgap (WBG) tin (Sn)-based perovskite solar cells (PSCs) is highly required to construct Pb-free all perovskite tandem solar cells with enhanced incident utilization of solar spectrum. However, the Sn-based perovskites typically suffer severely from technical issues such as fast crystallization, strong trap density, and Sn-oxidation. Hence, compositional and interfacial engineering on the perovskites needs to be considered to control the absorber films and charge transport at such interfaces.

First we employed hydrophobic phenylethylammonium (PEA^+) cations in WBG Sn-perovskites through compositional engineering. It was turned out that the PEA^+ substitution results in the form of 2D/3D mixed perovskites and reveals that the preferential orientation of the crystalline controlled 3D perovskite planes while the 2D perovskite phase merges the grain boundaries of the perovskite. In addition, further interfacial optimization has been made to deliver better charge transport at hole transport layer (HTL)/perovskite interface, with self- assembled monolayer (SAM). Using SAM, enhanced crystalline quality of perovskites and interfacial charge collection were found, which indicates effective strategy to further develop WBG Sn perovskites for tandem cells. Based on the works, a conversion efficiency more than 10% was attained in WBG Sn PSCs. In addition to the WBG Sn-PSCs, narrow-gap pure Sn-PSC have been also optimized to boost light absorption at bottom cells with interfacial and additive strategy, which exhibited conversion efficiency over 12%

Keywords:

Perovskites, Tandem, Pb-free, Solar Cells

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

C17.01

Introduction of the Particle Theory and Cosmology Group in the IBS Center for Theoretical Physics of the Universe

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Abstract:

I will give a brief introduction of the research activities of the Particle Theory and Cosmology Group in the IBS Center for Theoretical Physics of the Universe.

Keywords:

Theoretical particle physics, Early universe cosmology

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

C17.02

Introduction to Institute for Basic Science, Center for Theoretical Physics of the Universe (CTPU) / Cosmology, Gravity and Astoparticle physics (CGA)

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Abstract:

We are going to introduce a new center of Institute for Basic Science, Center for Theoretical Physics of the Universe (CTPU) / Cosmology, Gravity and Astoparticle physics (CGA). We are going to explain what kind of new physics we shall pursue.

Keywords:

Cosmology, Gravity, Astroparticle Physics

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

C17.03

The Status and Perspectives of the Center for Underground Physics

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Abstract:

I will review the research activities of the Center for Underground Physics. The current status and future plan of the Yangyang underground laboratory (Y2L) will be described. The status of Yemilab will be reported along with the plan for COSINE-200 and AMoRE-II experiments.

Keywords:

Yangyang underground laboratory, Underground Physics

Research activities for exotic nuclear physics in Korea

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Abstract:

The radioactive ion (RI) beam accelerator facility called RAON is under construction in Korea. It will produce RI beams by the ISOL and In-flight methods as well as stable beams. One of the experimental facilities called KoBRA is expected to carry out nuclear astrophysics and nuclear structure experiments using both stable and RI beams in the early phase of RAON. Several detector systems and experimental devices are being developed by the IBS Center for Exotic Nuclear Studies (CENS). One of the main detectors is an active target TPC detector called ATOM-X. It will be used for low energy experiments, such as alpha elastic scattering and the (a,p) reaction related to nuclear astrophysics. We are also constructing a gas target and silicon detector systems that can be used to perform reaction studies by (p,d), (p,t), (4He,3He) etc. HPGe clover detectors for studying structures of exotic nuclei are under construction. Research activities at CENS and status of the RAON accelerator will be discussed.

Keywords:

nuclear physics, exotic nuclei, RAON, CENS

C18.01

Analysis of Lambda_c^+ -> p Ks pi0 decay in the Belle experiment.

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Abstract:

We analyzed the Lc -> p Ks pi0 decay using a data sample of 980 fb^-1 collected in the Belle detector at KEK. We aim to update the relative branching ratio of Γ(Lc -> p Ks pi0)/Γ(p K- pi+) and measure sub-branching ratios. The sub-channel analysis via Dalitz amplitude analysis with helicity formalism provides good probes to test the isospin symmetry in the Lc -> pKpi decays.
In this talk, we report an updated measurement of the relative branching ratio of Γ(Lc -> p Ks pi0)/Γ(p K- pi+) and the results of amplitude analysis with sub-channel contributions and their decay parameters.

Keywords:

Amplitude analysis, Dalitz decay

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

C18.02

Pion-nucleus scattering in the Glauber model via Eikonal approximation

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Abstract:

The present study investigates the elastic pion-nucleus scattering $(₩pi^+A)$ dominated by the $₩Delta$(1232) resonance with the medium effects in the Eikonal-Glauber model. The medium effects are considered in terms of the nuclear-density ($₩rho_A$) dependent masses and strong coupling constants, which are computed and parameterized from the quark-meson coupling (QMC) model up to $₩mathcal{O}(₩rho_A^2)$. We also employ the Wood-Saxon type density profile for the bound nucleon in the finite nuclei. The element $₩pi^+N$ scattering cross section for the Glauber approach is obtained using the conventional effective Lagrangian method. We then analyze the total cross sections for the elastic scattering with the targets $^4₩mathrm{He}$ and $^{12}₩mathrm{C}$. We found that the present numerical result for the $^4₩mathrm{He}$ target reproduces the total cross-section in good agreement with the JINR data. For the $^{12}₩mathrm{C}$ target, there appear deviations $₩lesssim10₩%$ around the $₩Delta$-resonance peak in comparison to the SINR data. The medium effects on the cross-sections are discussed as well. Finally, the rescattering inside the nucleus is briefly explored.

Keywords:

Pion-nucleus scattering,, Glauber model, Eikonal approximation

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

C18.03

Spin-1 quarkonia in a rotating frame and their spin contents

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Abstract:

We propose a new way of studying the spin content of a hadron by looking at its response in a rotating frame. By collecting all responses of quarks and gluons in a rotating frame, we describe the spin-rotation coupling of spin-1 quarkonia and thereby reveal their spin contents. We demonstrate that both the perturbative and non-perturbative contributions in the operator product expansion follow a universal formula that identifies the spin-rotation coupling with unit strength. This allows us to recognize the total spin-1 of the vector quarkonia in terms of the total angular momentum of quarks and gluons. We also find that a similar behavior follows for the axial vector case but identify the different composition of the spin due to the P-wave nature of the state.

Keywords:

quarkonium, spin

Gluon distributions for the kaon and pion in the nonlocal chiral quark model

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Abstract:

In quantum chromodynamics (QCD) of the Standard Model Particle Physics, it is believed that the hadron is composed of quarks and gluons. However, It is difficult to directly compute the hadron structure from QCD. In this talk, we employ the nonlocal chiral quark model (NChQM), which mimics features of nonperturbative QCD, to compute the hadron's quark and gluon momentum distributions. Details of the calculation and our fascinating results on the quark and gluon distributions, which is relevant to the current issue in the hadronic physics community and the results of future experiments from modern facilities like the Electron-Ion Collider (EIC), electron-ion collider in China (EicC), and AMBER-COMPASS at CERN, will be discussed and presented.

Keywords:

Hadron structrure, Nonlocal chiral quark model, Quantum chromodynamic, Electron-Ion Collider, Nonperturbative QCD

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

C18.05

Energy-momentum tensor form factors of the kaon from the instanton vacuum: role of the SU(3)-flavor symmetry breaking

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Abstract:

In this presentation, we discuss the properties of the energy-momentum tensor (EMT) form-factors of the pion and kaon.
We employ the nonlocal chiral quark model, originated from the instanton vacuum of QCD at low energy,
to compute the corresponding hadronic matrix elements.
Taking into account the explicit chiral-symmetry breaking effect in the SU(3)-flavor,
we observe that strange and light quarks in the kaon show strong deviation in the pressure:
D_s(t=0)/D_u(t=0) = 1.5.

Keywords:

pion, kaon, energy-momentum tensor, instanton

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

C18.06

Exploring the Two-Pole Structure of the b_1 Axial Vector Meson

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Abstract:

During our examination of the b_1 axial vector meson within the charge exchange reaction $(\pi p \to \omega \pi n)$ using the coupled channel approach, we have uncovered the existence of a second pole of the b_1 meson, positioned below the $K\bar{K}^*$ threshold. This novel finding reveals a previously unknown two-pole structure of the b_1 meson, which has yet to be observed through experimental or theoretical means. Accordingly, in this presentation, we will investigate this two-pole structure, which shares certain resemblances to the Λ(1405) pole structure.

Keywords:

two-pole structure, axial vector meson, coupled channel

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

C18.07

The cosmological constant term, stability condition and mass decomposition of the nucleon

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Abstract:

We investigate the flavor structure of the gravitational form factors of the nucleon within the framework of the chiral quark-soliton model. While the mass and spin of the nucleon are governed by u-quark, the D-term form factor, which gives information on its internal structure, is dominated by d-quark. We also study the isovector cosmological constant term of the nucleon and its physical implications for the first time. Even though the nucleon mass is not affected by the nucleon cosmological constant term, its quark contributions reveal how the strong force fields characterize the stability of the nucleon and how the nucleon's rest energy is decomposed.

Keywords:

EMT, mass, spin, D-term

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

C18.08

Numerical calculation of meson mass using two-body Dirac equation

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Abstract:

Quark-gluon plasma is a material that is expected to be formed in early universe according to Quantum Chromodynamics, and the theoretical and experimental evidence for its existence are being discovered. Since QGP is in thermal equilibrium, the study on its thermal properties is ongoing to understand the time-evolution of QGP. As the temperature rises, mesons are separated into quark and gluons at their dissociation temperature. In this way, the amount and the types of mesons survived at the specific time can give the information on the temperature of QGP The meson masses are one of the observables, which vary in temperature and do not exist over the dissociation temperature. In this study, we solve a two-body Dirac equation with temperature-dependent potential to find a meson mass. As temperature dependent potential, we use AdS/CFT potential with 5-dimentional gravitational model which confirms the confinement within a quark-antiquark system. Relative errors are less than 1% for mesons having a mass more than 3 GeV.

Keywords:

QGP, AdS/CFT, meson

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

C18.09

Possible (inverse) catalytic phenomena in the rotating QGP

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Abstract:

In this talk, I would like to explore the possibility that the QCD critical behavior, corresponding to the (inverse) catalysis to the SBCS, at finite temperature can be modified by the rotation of the hot and dense QCD medium, such as the quark-gluon plasma (QGP). The possibility is investigated by the caloron-based nonlocal quark model at finite temperature and momentum transfers with the finite rotation, which is supposed to be generated by the peripheral collision of heavy ions, depending on the impact parameter. I also discuss possible variations of the hadron production yield due to the rotation of QGP qualitatively. Finally, the P-violating anomalous currents are briefly mentioned in the rotation of the magnetized QGP.

Keywords:

Rotating QGP, QCD phases, Critical temperature, Caloron model, Hadron production yield

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

C18.10

DVCS measurements at Jefferson Lab

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Abstract:

Many questions remain about how the partons, i.e. quarks and gluons, are distributed in space, momentum and spin inside the nucleon. Generalized parton distributions (GPDs) describe the complex internal structure of the nucleon in terms of those partons. Among other aspects, GPDs reveal the correlation between the longitudinal momentum fraction and the transverse spatial distributions of partons inside the nucleon, allowing us to perform nucleon tomography. GPDs can be studied through the measurements of exclusive reactions such as deeply virtual Compton scattering (DVCS). An overview of DVCS measurements from Jefferson Lab will be presented.

Keywords:

Nucleon structure, Deeply virtual Compton scattering, Generalized parton distributions

D1.01

Ultrasensitive and Enantioselective Sensing Using Collective Resonance on a 2D Chiral Plasmonic Lattice

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Abstract:

Currently, chiral compounds, which possess non-superimposable mirror images, constitute more than 50% of pharmaceuticals available in the market. Even though chiral molecules exhibit different physiological activities, toxicities, and metabolic processes depending on their handedness, enantioselective detection is challenging due to their identical physical, and chemical properties since chiral molecules are stereoisomers that differ only in their configuration. While general spectroscopic methods, such as circular dichroism (CD), optical rotatory dispersion (ORD), magnetic circular dichroism (MCD), and fluorescence-detected circular dichroism (FDCD) are employed to analyze the chirality of molecules but still suffer from intrinsic constraints limiting their ability to detect chiral molecules at low concentrations because of the molecule-light impedance mismatching. Recent advances in nanophotonics have led to the development of chiral plasmonic platforms[1-3] and Mie resonance[4], which utilize the superchirality concept to detect chiral molecules in strong electromagnetic helicity density[5]. However, these methods highly rely on optically localized chiral hotspots and have limitations in terms of their sensitivity and commercial viability. To address these limitations, we have proposed a new perspective based on the collective resonances (CRs) in the two-dimensional lattice structure of chiral plasmonic nanoparticles. In this work, we have demonstrated theoretically that these CRs result in collective light scattering by spinning dipoles, producing a robust optical helicity density over a large area. This approach has the potential to provide a susceptible platform for the enantioselective detection of chiral molecules. Using chiral perturbation theory, we identified enantioselective CD mode shifts and verified them experimentally using a microfluidic chamber. Our approach has exhibited ultra-high sensitivity at the pico-mole level and introduced a platform for real-time in-situ detection[6]. This research has the potential to provide significant breakthroughs in various fields, including pharmaceuticals, physiological diagnostics, pathogen detection, and beyond.

References

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5. *Phys. Rev. Lett.* **104**, 163901–163904 (2010)
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Keywords:

Chiral, Surface lattice plasmon, Plasmonics, Biosensing, Nanoparticle

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

D1.02

Flexible-type ultrathin holographic endoscope for microscopic imaging of unstained biological tissues

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Abstract:

Ultrathin lensless fibre endoscopes offer minimally invasive investigation, but they mostly operate as a rigid type due to the need for prior calibration of a fibre probe. Furthermore, most implementations work in fluorescence mode rather than label-free imaging mode, making them unsuitable for general medical diagnosis. Herein, we report a fully flexible ultrathin fibre endoscope taking 3D holographic images of unstained tissues with 0.85-μm spatial resolution. Using a bare fibre bundle as thin as 200-μm diameter, we design a lensless Fourier holographic imaging configuration to selectively detect weak reflections from biological tissues, a critical step for label-free endoscopic reflectance imaging. A unique algorithm is developed for calibration-free holographic image reconstruction, allowing us to image through a narrow and curved passage regardless of fibre bending. We demonstrate endoscopic reflectance imaging of unstained rat intestine tissues that are completely invisible to conventional endoscopes. The proposed endoscope will expedite a more accurate and earlier diagnosis than before with minimal complications.

Keywords:

Endoscopy, Phase imaging, Microscopic imaging, Holography, Label-free imaging

D1.03

High-fidelity optical diffraction tomography of live organisms via non-toxic optical clearing

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Abstract:

Optical diffraction tomography (ODT) is a computational imaging technique that visualizes a sample's three-dimensional refractive index (RI). Although widely-used reconstruction algorithms based on weak scattering approximation are suitable for transparent samples, the quality and accuracy of RI data decrease for thick or complex samples. Herein, we present a method for high-fidelity ODT by introducing a non-toxic optical clearing process. Reducing RI contrast enhances the fidelity and accuracy of 3D RI results and increases the imaging depth inside live biological samples. We validate our method using various biological organisms, including C. albicans and C. elegans.

Keywords:

optical diffraction tomography, quantitative phase imaging, bioimaging

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

D1.04

Quantitative assessments of structural heterogeneity in clear cell renal cell carcinoma using refractive index tomography

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Abstract:

Clear cell renal cell carcinoma (ccRCC) is a prevalent subtype of renal cancer known for its poor prognosis. Diagnosis by histopathology, which relies on manual microscopic inspection of stained slides, is challenging. In this study, we propose a correlative approach that combines stained images and refractive index (RI) tomography to enable quantitative assessment of ccRCC slides obtained from human patients. Using machine-learning-assisted segmentation, we quantified the structural heterogeneities at the subcellular level in both benign and malignant regions. Our results show that malignant regions exhibit a significant increase in structural heterogeneities compared to benign regions, and that RI tomography provides complementary quantitative information on the structural heterogeneities in ccRCC. These findings demonstrate the potential of our approach to improve the accuracy of ccRCC diagnosis and advance our understanding of its complex pathology.

Keywords:

renal cell carcinoma, refractive index tomography, structural heterogeneity, correlative study

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

D1.05

Common path digital holography for biodynamic imaging of living tissue

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Abstract:

Tissue-dynamics spectroscopy (TDS) is a novel imaging technique in which the properties of tissues, including their mechanical behavior and optical responses. Conventional TDS systems used dual-arm interferometers such as Mach-Zehnder configuration, which are subject to environmental influences such as mechanical vibrations and thermal drifts. Common path digital holography (CPDH) is a relatively new, advanced imaging technique in TDS that is being used to study the dynamical properties of living tissue. CPDH uses gratings and spatial filters, which provide ultra-stable interferometric fringes by isolating interferometric measurements from mechanical disturbance.

In CPDH, a high-efficiency static holographic diffraction grating acts as a beam splitter, and one of the two orders is sent through a variable aperture on the image plane to provide a spatially-coherent reference for Fourier-domain holography. The low-coherence source sets up a condition of self-coherence-gating that rejects multiply-scattered background to achieve high dynamic range Doppler spectra that are comparable to, and more stable than, spectra produced from conventional biodynamic imaging. Although CPDH has some drawbacks such as spatial resolution against holographic fringe contrast on the camera, the main advantage of CPDH is its ability to capture phase-sensitive dynamic images with enhanced interferometric stability, which enables stable TDS of living thick biological tissue for drug screening assays.

Keywords:

Digital holography, biological imaging, spectroscopy, low coherence imaging

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

D1.06

Spatially multiplexed dielectric tensor tomography

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Abstract:

Measuring optical anisotropy provides crucial information about molecular structures and properties of materials in biological and industrial fields. Recently, dielectric tensor tomography has been developed, enabling direct visualization of three-dimensional anisotropic structures. Herein, we present a robust setup for dielectric tensor tomography that uses spatially multiplexed holograms. Employing two orthogonally polarized reference beams, we multiplexed two polarization-sensitive holograms at one camera. Because of the different incident angles of the reference beams, field terms corresponding to the multiplexed holograms were simultaneously retrieved in the Fourier domain. The proposed method improved the measurement accuracy compared to the previous method by removing reconstruction artifacts.

Keywords:

Quantitative phase imaging, Optical diffraction tomography, Dielectric tensor, Optical anisotrpy, Polarization

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

D1.07

Plasma density control for highly efficient relativistic high-order harmonic generation

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Abstract:

Generating strong harmonics and extending the cutoff is the first priority to raise potential of harmonic source for advanced applications. Plasma density, in the interaction of intense laser with overdense plasmas, is the most important factor to determine both under laser intensity practically limited. Although many numerical studies have shown its importance, it has not been demonstrated that relativistic high-order harmonic generation (r-HHG) greatly depends on the plasma density. Here, we show enhancement of r-HHG by controlling the plasma density and scale length. A prepulse is used to produce the plasma before the main pulse arrives at the target. The plasma density and scale length can be controlled by adjusting the prepulse intensity and the time delay. We find that the conversion efficiency of r-HHG increases as the prepulse intensity decreases, and low prepulse intensity requires much longer time delay to maximize the conversion efficiency. Our results reveal how crucial it is to balance restoring force of plasmas with driving force of a laser pulse for highly efficient r-HHG. Plasma density control will be an indispensable prerequisite for ultra-intense laser-plasma interaction, and offers robust approach to the extreme light science.

Keywords:

Relativistic high-order harmonic generation, Ultra-high intensity laser

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

D1.08

High-dynamic range temporal characterization of femtosecond laser pulses using tunneling ionization

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Abstract:

High-power laser pulses are used in studying light-matter interactions. The high-power laser pulse has prepulses that arrive before the main pulse arrives. Although the intensity of the prepulse is much weaker than that of the main pulse, it can still be strong enough to spoil the target to be investigated. Therefore, it is important to measure the temporal contrast (the intensity ratio between the main pulse and the prepulse) precisely. A third-order autocorrelator is often used that shows an excellent dynamic range higher than 10^12. However, it only provides the intensity ratio of the prepulse. Other important information, such as the duration, wavelength, and chirp conditions of the prepulse, could not be measured. Here we demonstrate that the TIPTOE (Tunneling ionization with a perturbation for the time-domain observation of an electric field) method can be used to measure the temporal contrast of the laser pulse. We show that the laser field can be directly measured using TIPTOE in the time domain with a reasonably good dynamic range. We also show that the dynamic range of the TIPTOE measurement can be significantly improved with a differential measurement and a self-induced plasma shutter.

Keywords:

Temporal contrast of femtosecond laser pulse, plasma shutter, Temporal characterization of femtosecond laser pulse

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

D2.01

Thermalization Universality Class Transition Induced by Disorder

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Abstract:

Thermalization is characterized by time and length scales, which diverge upon tuning to an integrable limit. The corresponding slowing down shows universal features which depend on the interaction range classified into two universality classes, short and long range universality classes. We study the emergence of short-range universality from long-range universality class by computing rescaled Lyapunov spectra. For diminishing nonlinearity, translationally invariant systems fall into the long-range class. We add disorder which enforces Anderson localization with length ξ for the linear system. The gradual transition from long range to short range universality classes is observed for a system with size N as the localization length is tuned from $\xi \geq N$ to $\xi \ll N$.

Keywords:

Thermalization, universality classe

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

D2.02

Learning Langevin equation from trajectories via Bayesian neural networks

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Abstract:

Many complex systems are affected by various factors, and unresolved fast things drive their dynamics stochastically. Langevin equation is a typical mathematical model for describing such stochastic dynamics. The main advantages of the Langevin equation are that it can help predict how the system evolves in time as well as analyze its thermodynamic quantities, including absorbed heat, work done on the system, or entropy production. However, inferring the Langevin equation from observed trajectories is still challenging for nonlinear and high-dimensional systems. Here, we propose a general framework for inferring the Langevin equation from observed trajectories using Bayesian neural networks, which update the parameters of networks by Bayes' theorem and maximize the posterior distribution of the parameters. The drift force and diffusion matrix are trained separately and then combined to reconstruct the Langevin equation. Our framework provides a distribution of predictions rather than a single value. This discrepancy allows us to obtain the uncertainty of the predictions, which can be crucial in preventing misunderstandings and erroneous decisions about the system. We verify that the proposed framework can successfully infer Langevin equations for various systems, including high-dimensional, underdamped, state-dependent diffusion, and time-dependent protocol cases.

Keywords:

Stochastic inference, Langevin equation, Stochastic process, Deep learning

Anomalous Relaxation of a Brownian Particle in Active Baths

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Abstract:

We investigate a Brownian particle confined in an active heat bath and report on the non-monotonic cooling behavior while the system approaches the final steady state. This effect is especially pronounced as the correlation time of the active noise, associated with the random kicks by the active particles, becomes longer compared to the relaxation time of the damped harmonic oscillator in an otherwise thermal bath. Introducing the effective temperature scheme, where the fluctuation-to-dissipation ratio is the proxy for nonequilibrium temperature, we analyze the anomalous relaxation process in the light of stochastic thermodynamics.

Keywords:

active noise, relaxation process

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

D2.04

Thermodynamic constraint on fluctuation-response relation for nonequilibrium chemical reaction networks

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Abstract:

Fundamental relations between the response to perturbation and fluctuation in a system exist in and out of equilibrium. In this talk, I will discuss the relationship between the response of nonequilibrium chemical reaction networks to logarithmic perturbations of reaction rates and fluctuations. The response of the mean number of a chemical species is bounded by number fluctuations and the maximum thermodynamic driving force, resulting in trade-offs that can be proved for both linear and a class of nonlinear chemical reaction networks with a single chemical species. Additionally, numerical results for several model systems demonstrate that these trade-offs continue to hold for a broad class of chemical reaction networks. These results also reveal that deficiency zero chemical reaction networks share common features in the trade-offs, while deficiency nonzero ones depend more on system-specific details.

Keywords:

chemical reaction network, fluctuation-response relation, nonequilibrium

Particle smoother for calculating the reproduction number and forecasting COVID-19 cases

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Abstract:

The reproduction number is the average number of secondary cases caused by an infected individual, and is a key metric to measure the spread of infectious diseases. In this study, we used a particle smoother to calculate the reproduction number of COVID-19. This method involves using a set of particles to estimate the state of the system at each time step, and combining these estimates to obtain the reproduction number. Based on the reproduction number, we forecast new confirmed cases and admissions to the intensive care unit. We measured the accuracy of the predictions using a retrospective method.

Keywords:

reproduction number, particle smoother, COVID-19

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

D2.06

Evaluation of COVID-19 Intervention Policies in South Korea using Stochastic IndividualBased Model

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Abstract:

The COVID-19 pandemic has swept across the globe, and countries have responded with various intervention policies to prevent the spread of the virus. In this study, we focus on analyzing the effectiveness of intervention policies implemented in South Korea. We present a stochastic individual-based model (IBM) to simulate the spread of COVID-19 in South Korea. We generated a synthetic population of 51 million using the iterative proportional updating (IPU) method, matching South Korea’s population size. We assigned attributes, such as household, school, company, religion, and friends, to individuals based on statistical data provided by Korean Statistical Information Service (KOSIS). Intercity movement by Korea Transport Database (KTDB) was used to simulate the nationwide spread of infection. An uninfected person contracts the virus through contact with an infected person. We reenacted the intervention policy that was implemented in November 2020 and analyzed the effectiveness of measures such as school and workplace closure, and limiting the size of private gatherings. By applying these policies at different times, we predicted changes in the spread pattern of COVID-19 when intervention policies were implemented. Our study provides valuable insights into the effectiveness of intervention policies in South Korea, which can inform policymakers and public health officials in their decision-making process.

Keywords:

individual-based model, stochastic model, COVID-19, pendemic

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

D2.07

Alternative Strategies for Selecting Microbial Collectives to Improve their Function

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Abstract:

Microbial collectives have the ability to perform functions that individual species cannot, and these functions can be beneficial for humans such as waste degradation, vitamin production, and biofuel production. Researchers have proposed a method for improving these functions by applying artificial selection on collectives; growing low-density collectives, and selecting the best-performing collectives among them for the next generation. However, this approach is not always effective, and finding an optimal protocol for artificial selection is challenging. In our study, we explored an alternative approach for choosing collectives for the next generation. Rather than selecting the best-performing collectives, we chose collectives with a bias to counteract natural selection during maturation. Our results show that this approach leads to further improvements in the desired function by enabling the search for paths to higher-functioning collectives. Our findings suggest that incorporating a bias will be a promising strategy for enhancing collective function.

Keywords:

Microbial collective, Evolution, Artificial selection

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

D2.08

The role of self-regulation in competitive coexistence

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Abstract:

According to the competitive exclusion principle (CEP) in ecological niche theory, the number of coexisting species cannot exceed the number of available resource kinds.
While the CEP can explain many observations and experimental results, there are some exceptions.
One such exception is the "paradox of the plankton," where various plankton species coexist despite competing for a limited number of resources in the ocean.
To address this paradox, we have investigated the generalized MacArthur's consumer-resource model (GCRM) with self-regulation, using analytical and numerical methods to examine the effect of self-regulation.
We have found that the CEP holds when self-regulation is absent, but with self-regulation, it becomes possible for all species to coexist even when there are fewer available resource kinds than the number of species, which violates the CEP.
This is because the self-regulation inhibits the growth of dominant species.
Our findings explain the paradox of the plankton with the competition-based model and suggest that self-regulation is an important factor in determining competition outcomes in ecological systems.

Keywords:

Ecological Systems, Self-regulation, Paradox of the Plankton, Competitive Exclusion Principle

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

D2.09

Stability of Twisted States in Kuramoto Oscillators on a Circle with Distance-Decaying and Time-Delayed Coupling

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Abstract:

The synchronization of Kuramoto oscillators is governed by their interaction structures. While fully synchronized states are observed in dense networks of identical oscillators, sparse networks lead to the emergence of stable twisted states. However, previous research has focused on homogeneous coupling strength. In reality, the strength of interactions between oscillators can decay with distance, and the time delay between oscillators can affect the stability of synchronized states. In this study, we investigate the role of distance-decaying coupling strength and time-delayed coupling in the synchronization behavior of Kuramoto oscillators on a circle in a two-dimensional plane. Specifically, we analyze the linear stability of twisted states with respect to the power-law exponent of distance-decaying interaction and the speed at which phase information propagates. Our results indicate that stable twisted states can arise without time delay when the power-law exponent exceeds 2, and become more stable as the exponent increases. We also show that time delay can alter the stability of the fully-synchronized state.

Keywords:

Kuramoto model, Linear stability, Synchronization, Twisted state

Strain engineering of quantum emitters in van der Waals materials

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Abstract:

In this talk we will discuss our work on engineering quantum emitters in van der Waals (vdW) materials through strain engineering and coupling of these emitters to nanophotonic platforms. We will present our work on deterministic positioning of quantum emitters in hexagonal boron nitride (hBN) via strain and coupling the emission from these emitters to silicon nitride microresonators. Following this, we will discuss the brightening of defect states in 2D transition metal dichalcogenides (TMDCs) via strain and the funneling of excitons in such systems.

Keywords:

2D materials, van der Waals materials, single photon emitters, quantum emitters, strain engineering

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

D3.02

Elementary excitations of quantum emitters in hexagonal Boron Nitride

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Abstract:

The recent discovery of bright and tunable quantum emitters (QEs) in hexagonal Boron Nitride (hBN) enables the realization of novel and scalable quantum photonic platforms. While it is well accepted that QEs in hBN stem from defects, key details on their origin and on the large spectral distribution of their emission are still unknown. By interfacing resonant inelastic X-ray scattering (RIXS) and photoluminescence spectroscopy on defective hBN, we uncover an elementary excitation at 285 meV that leads to harmonics with energy ranging from the mid-IR through the UV. Our results indicate a correlation between the harmonics and the quantum emission via a donor-acceptor-pair recombination process. Due to the orbital sensitivity of RIXS, we can underscore the association of QEs with the p* antibonding orbitals. Our interpretation generalizes a large amount of data reported in the literature through a single energy scale explaining the stability and robustness of QEs in hBN.

Keywords:

Quantum emitters, hexagonal Boron Nitride, donor-acceptor-pair, RIXS

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

D3.03

What do we know about single photon emitters in hexagonal boron nitride

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Abstract:

In this presentation I will discuss the appeal of an emerging van der Waals crystal – hexagonal boron nitride (hBN). This unique system possesses a large bandgap of ~ 6 eV and can host single defects that can act as ultra-bright quantum light sources. In addition, some of these defects exhibit spin dependent fluorescence that can be initialised and coherently manipulated. I will discuss in details various methodologies to engineer these defects and show their peculiar properties. Furthermore, I will discuss how hBN crystals can be carefully sculpted into nanoscale photonic resonators to confine and guide light at the nanoscale. Taking advantage of the unique 2D nature of hBN, I will also show promising avenues to integrate hBN emitters with silicon nitride photonic crystal cavities.

Keywords:

Boron nitride, quantum, single emitters

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

D4.01

First-principles study of lattice oxygen instability in oxide-based cathode

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Abstract:

Since the discovery of a significant oxygen-redox contribution to enhancing the capacity of Li oxide-based cathodes, the oxygen release have been critical issues to increase better performance. However, despite many studies on the structural instability and degradation of cathodes, few have focused on the exclusive correlation between the oxygen release and lattice strain with completely ruling out any electrochemical influences. Here, using the first-principles density functional theory calculations, we systematically investigated the effect of oxygen vacancy on the atomic structure and oxygen release, and we found that the shear strain significantly facilitates the oxygen vacancy formation and severely disrupts the Li ordering in cathodes. Relevant structure reconstructions and underlying mechanism will be discussed in detail at the atomic scale.

Keywords:

Li-ion battery, Oxygen release, First-principles density functional therory calculations, $LiCoO_2$ cathode

D4.02

:Improvement of Speech Emotion Recognition using different type Lightweight Attentions and Augmentation Method

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Abstract:

최근 딥러닝 기술의 발전으로 컴퓨터가 사람이 가진 소통 능력을 자연스럽게 행할 수 있게 되었다. 하지만 컴퓨터가 보다 사람에 가까운 소통을 위해서는 사람의 상태를 표현하는 감정에 대해서 이해하는 능력이 필요하다. 하지만 음성 감정 인식에는 감정 특징 이해의 어려움과 학습 데이터의 부족이라는 문제가 있다. 본 연구에서는 이 두 가지 문제를 해결하기 위해 여러 방식(Spatial Gate (SG), Time Gate (TG), Frequency Gate(FG), Time and Frequency Gate (TFG))의 어텐션 모듈을 통한 감정 특징의 이해와 전처리과정을 이용한 학습 데이터 증강 방법을 제안한다

Keywords:

딥러닝, 감정인식, 어텐션

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D4.03

Molecular dynamics study of adhesion strength at Cu/a-TaN interface using neural network interatomic potentials

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Abstract:

The adhesion strength at the Cu/a-TaN interface is becoming increasingly important as semiconductor devices become smaller. In this study, molecular dynamics simulations using neural network interatomic potentials were used to investigate the adhesion strength at the Cu/TaN interface. Amorphous TaN layer is validated by uncertainty estimation method. Various methods have been attempted to physically realize the interface between amorphous TaN and Cu. Molecular dynamics simulations are conducted by varying the ratio of Ta to N in order to determine the optimal composition. This study is expected to contribute to a better understanding of the interface structure and atomistic ion-ion interactions between Cu and TaN.

Keywords:

neural network interatomic potentials, adhesion

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2023-04-19 - 2023-04-21

D4.04

AI-enabled active n-charge generation layer exploration for enhanced tandem OLED performance

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Abstract:

Tandem organic light-emitting diodes (OLEDs) are attracting significant attention as a promising technology for large displays. They consist of multiple electroluminescent units that are vertically stacked and connected through a charge generation layer (CGL). While this vertical stacking enhances the device's efficiency and durability, the driving voltage increases with the number of emission units. Therefore, improving the charge generation and transportation ability of the CGL is crucial. Among the CGL units, the n-CGL, which generates electrons, is the focus of our research. Its primary role is to easily receive electrons from adjacent layers and transfer them to the next layer through higher conductivity. Li-doped phenanthroline derivatives are considered the most effective n-CGL materials.

In this study, we utilized AI to effectively explore the vast chemical space and search for promising n-CGL materials. Firstly we tried to represent the vast n-CGL chemical space with as few molecules as we could handle through unsupervised learning. We used the Monte Carlo dropout method with the relational graph convolutional network (RGCN) to quantify the prediction uncertainty and established a scoring matrix to facilitate active discovery.

To efficiently search for molecules, we have developed an on-the-fly active exploration algorithm that utilizes data augmentation and query strategies. This algorithm generates additional promising molecules that are not currently included in our n-CGL chemical space and improves the prediction accuracy of promising molecules. The integration of these strategies provides a methodical and effective approach to exploring the chemical space beyond that captured by unsupervised learning.

Keywords:

Machine learning, Deep learning, OLED, Active learning, Electron transport layer

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2023-04-19 - 2023-04-21

D4.05

The Study of Phonon Dispersion in Defective Ferroelectric HfO_2

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Abstract:

Ferroelectric HfO_2-based materials have been considered as the promising candidates for modern electronics due to their strong compatibilities with silicon, enabling the development of low-power logic circuits and high-density nonvolatile memories. However, the orthorhombic phases of HfO_2 are dynamically unstable compared with the monoclinic phase, which hinders practical applications. For that reason, various defects such as Zr doping, and oxygen vacancies have been studied to stabilize the orthorhombic phases of HfO_2. Here, in order to understand the role of defects in phase transition at the atomic scale, we explored the phonon dispersion of defective HfO_2 by employing a combined approach of density functional theory (DFT) calculations and machine learning (ML) method. We find that the specific phonon band originated from the ferroelectric phase disappears, and imaginary modes are enhanced upon the introduction of a 10% concentration of Si dopants, which is in good agreement with experimental results. Relevant phase transition and underlying mechanism will be discussed in detail.

Keywords:

DFT, HfO2, defects, phonon

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2023-04-19 - 2023-04-21

D4.06

Finding surface reaction mechanisms with saddle point search algorithms: A TiN-ALD case study

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Abstract:

Surface reaction-based processes, such as atomic layer deposition (ALD), are widely used in the semiconductor industry. As understanding surface reaction mechanism is critical for designing such processes, many studies have been conducted using first-principles calculation methods such as density functional theory (DFT). To find the transition state of a given reaction and the corresponding activation barrier, the nudged elastic band (NEB) method can be used to find the saddle point on a potential energy surface that corresponds to the transition state. However, since this requires knowing in advance the state before and after the reaction, the double-ended saddle point search (SPS) method, such as NEB, has the disadvantage of requiring human intuition and expertise. On the other hand, there are single-ended SPS methods that search for the transition state using only the state before the reaction. Therefore, previous studies have used single-ended SPS methods to investigate mechanisms and barriers in bulk diffusion, surface diffusion, and catalysis. However, few studies have investigated the surface reaction mechanism in the presence of various types of adsorbants on the surface, as is common in ALD.
In this study, we used a single-ended saddle point search algorithm to investigate the elementary surface reactions of the TiN-ALD system using $TiCl_4$ and NH_3. Since we manually discovered several key elementary reactions in the previous study using DFT, we used the previous result to check how many elementary reactions can be found. As a result, most types of reactions were sampled, although most SPS trials did not complete in the assigned number of steps or, if completed, resulted in disconnected saddles. To increase efficiency, we examined failed cases in terms of calculation accuracy and SPS algorithms. We anticipate that this study will contribute to the understanding of surface reaction process mechanisms.

Keywords:

saddle point search, surface reaction mechanism, atomic layer deposition, density functional theory

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2023-04-19 - 2023-04-21

D4.07

Temperature Dependent simulation of 2D 2H-VSe_2 hole-doped bilayer system and rare earth free permanent magnets using Atomistic simulator VAMPIRE

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Abstract:

Two dimensional ferromagnetic materials having higher anisotropy and curie temperature plays vital role in device technological application. Therefore, its needed to study the temperature dependent properties of the 2D materials for the practical technological applications. Here we investigate the temperature dependent magnetic properties of 2H-VSe_2 bilayer system based on the first principle calculation results. We find it that the curie temperature is increasing from (600-630 K) and anisotropy is decreasing (2.01-1.95 meV) with increasing hole-doping concentration. Beside with that we also investigated the temperature dependent anisotropy and coercivity of the said material using Monte Carlo and LLG-heun methods with VAMPIRE. Our finding proposes that the 2H-VSe_2 bilayer system shows ferromagnetic ground state with hole-doping and shows ferromagnetism at room temperature make it applicable for spintronics application.

Keywords:

temperatuer dependency, 2D materials, vampire simulation

D5.01

Topological semimetals driven by strong correlations

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Abstract:

Quantum matter has traditionally been classified by (quantum) phase transitions between different ordered states [1]. The past decade, however, has seen a wealth of developments in what we now call topological quantum matter. Here, the topological nature of the state – a global characteristic (e.g. the Chern number) – takes the role of the local order parameter. Whereas much progress has been made on topological insulators and on noninteracting topological semimetals, a just emerging field are strongly correlated gapless topological phases. I will report on the recent discovery of the first such materials class, Weyl-Kondo semimetals, and the material – the heavy fermion compound $Ce_3Bi_4Pd_3$ – that coined this notion [2-4]. It exhibits giant signatures of electronic topology [2,4], which are attributed to Weyl nodes pinned to the immediate vicinity of the Fermi level, giving rise to quasiparticles with ultraslow velocity [2-4]. In this system, genuine topology control can be achieved by magnetic field tuning, leading to the annihilation of Weyl nodes at moderate fields [5]. I will also discuss design strategies for further correlation-driven topological semimetals, ranging from symmetry considerations [6] to the possible role of quantum criticality and emergence [7,8].
This work was supported by the Austrian Science Fund (I4047, I5868 - FOR 5249 QUAST, F86 - SFB Q-M&S), the European Union’s Horizon 2020 Research and Innovation Programme (824109, EMP), and the European Research Council (ERC Advanced Grant 101055088, CorMeTop).
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[8] H. Hu, L. Chen, Ch. Setty, S. E. Grefe, A. Prokofiev, S. Kirchner, S. Paschen, J. Cano, and Q. Si, arXiv:2110.06182.

Keywords:

Weyl-Kondo semimetals, heavy fermion compounds, spontaneous Hall effect, topological materials design

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2023-04-19 - 2023-04-21

D5.02

Nonlinear electrical transport phenomena in topological materials

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Abstract:

The nonlinear transport phenomena are rare in conventional metals and are not studied well. However, the situation has changed since it was recognized that nontrivial band topology could cause novel electrical responses beyond linear ones. The sensitivity of nonlinear transport to band topology allows the detection of a subtle change in band topology, which is completely hidden in linear transport coefficients. Here we achieve this by observing unexpected nonlinear transport phenomena in $ZrTe_5$, tuned at a three-dimensional (3D) Dirac metal at zero magnetic field (B = 0) and turning into a 3D Weyl metal at B ¹ 0. The nonlinear longitudinal conductivity $\Delta\sigma_L$ in a magnetic-field-aligned electric field (*E* // *B*) and the third-order nonlinear Hall (transverse) conductivity $\Delta\sigma_{xy}$ in a magnetic-field-perpendicular electric field (*E* ^ *B*) arise below a characteristic temperature T^*. While the chiral anomaly of the Weyl metal is considered the origin of $\Delta\sigma_L$, the underlying mechanism for $\Delta\sigma_{xy}$ is not well understood. Three extended scaling relations are found among linear and nonlinear conductivities, suggesting that band topology change drives $\Delta\sigma_L$ and $\Delta\sigma_{xy}$ to be finite. Topological materials need higher-order transport coefficients to fully characterize their transport and reveal its connection to nontrivial band topology.

Keywords:

topological materials, nonlinear electrical transport, topological phase transition, scaling

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2023-04-19 - 2023-04-21

D5.03

Kondo effect in Weyl semimetallic states in Mn_xVAl_3

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Abstract:

The strong correlation effect in Weyl semimetal is a critical issue in condensed matter physics. Recently, the Kondo effect in Weyl semimetal was theoretically proposed but not yet experimentally realized. Here we suggest a coexistence of the Weyl semimetal and Kondo effect in disordered Mn-doped Mn_xVAl_3. Dilute Mn-doping in type-II Dirac semimetal VAl_3 increases the chemical potential so that the Dirac point is close to the Fermi energy and lifts band degeneracy, leading to the Weyl semimetal phase transition. We observed a Kondo effect, confirmed by the resistivity minimum at T_K = 40 K, and logarithmic increase of electrical resistivity, magnetic susceptibility, and specific heat divided by temperature with a significant Sommerfeld coefficient at low temperature. The angle-resolved magnetoresistance has revealed the negative longitudinal magnetoresistance below Kondo temperature due to chiral anomaly in Mn-doped Mn_xVAl_3. At low temperature below Kondo temperature ($T \leq T_K$), the exchange interaction by RKKY interaction in MnxVAl3 breaks time-reversal symmetry even in Kondo screening, resulting in the topological phase transition from Dirac to Weyl semimetal. This research shows the coexistence of the Kondo effect and Weyl semimetallic state as well as the temperature-induced topological phase transition.

Keywords:

Kondo, Weyl semimetal, Strongly correlated system, type-II Dirac semietal, Topological phase transition

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

D6.01

First Principles Design of Defect Qubits

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Abstract:

Solid-state spin defects are promising candidates for quantum computing and communication platforms using a scalable spin-photon interface. Diamond nitrogen-vacancy (NV) center defects are representative examples that exhibit long spin coherence times and spin-selective optical transitions. However, finding a single-point defect with all the desirable traits for generating quantum entanglement networks remains elusive. The invited talk briefly explains the operation principles of defect qubits for quantum information applications and provides guides to first principles characterization of fundamental qubit properties—electronic, magnetic, vibrational, optical properties, and thermodynamic stability. The presentation then closes by discussing our recent work regarding the computational discovery of promising defect qubits in two-dimensional monolayer transition metal dichalcogenides (2D TMDs). applications As a result of the comprehensive characterization, we proposed a defect family in 2D TMDs that is a promising candidate for quantum network and sensing. In order to advance the quantum era, the theoretical characterization and design, as well as the extensive experimental efforts, enable scalable quantum information systems composed of defect qubits in solid-state hosts.

Keywords:

qubit, quantum information, sensing, first principles, defect

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

D6.02

Electronic structure and lattice reconstruction calculations in alternating twist tG-multilayer graphene, graphene on hBN and hBN-encapsulated bilayer graphene

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Abstract:

In this talk, I will discuss the lattice reconstruction and electronic properties of twist tG-multilayer graphene focusing on its magic angles, graphene on hBN focusing on its primary and secondary gap behavior in presence of a substrate, and hBN-encapsulated bilayer graphene focusing on its h-BN induced layer polarization of the graphene layers. All three systems are investigated using our multi-scale approach based on lattice relaxation calculations using a molecular dynamics code and large-scale tight-binding simulations using a reparametrized two-center (TC) model.

I first present the electronic structure of AA'AA'... stacked AT N-layer (tNG) graphene for N = 3-10, 20 layers and bulk AT graphite systems. It is found that lattice relaxation enhances electron-hole asymmetry, and leads to small reductions of the magic angle values with respect to analytical or continuum model calculations with fixed tunneling strengths that I quantify from few layers to bulk AT-graphite. The twist angle error tolerance near the magic angles obtained by maximizing the density of states of the nearly flat bands expand progressively from 0.05° for twisted bilayer graphene to up to 0.2° for AT-graphite, hence allowing a greater twist angle flexibility in multilayers.

Secondly, I illustrate the reparametrized TC-model approach to assess the impact of the substrate relaxation on the primary gap at charge neutrality and secondary valence band gap of graphene on hexagonal boron nitride (G/BN) as a function of twist angle where we observe a substrate-induced reduction of the primary gap and the closing of the primary and secondary gaps for finite angles as well as a slight initial increase for the primary gap at ~ 0.5 degree that coincides with a shallow energetic stabilization of the atomic structure away from perfect alignment.

Thirdly, I quantify through energy-resolved density of state calculations on hBN encapsulated bilayer graphene the charge transfer between layers that gives rise to layer polarization at the basis of recent experiments showing ferroelectric signals in these systems. For the four inequivalent orientations by rotating either one of the hBN layers by 60∘, we vary both the twist angle and the respective sliding between the two hBN layers and report on the ideal conditions to maximize the charge transfer, that is when the two hBN layers are rotated by exactly 60∘ with respect to each other, regardless of the specific sliding between them. I further observe that when including lattice reconstruction effects the charge transfer amplitudes are increased by factors of 2 to 3 leading to values of the order of 1e12 eV/cm2.
*Acknowledgments: Korean NRF through Grant No. 2020R1A2C3009142 and computational resources through KISTI Grant No. KSC-2022-CRE-0514

Keywords:

Graphene, h-BN, Multiscale simulation, Magic angle, Lattice reconstruction

D6.03

Pseudogap in a crystalline insulator doped by disordered metals

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Abstract:

Two-dimensional (2D) quantum materials have continued to attract broad interest in the field of condensed-matter physics. One of the exciting opportunities with these materials is the tunable band structure with surface doping. The *in situ* deposition of alkali metals can be used to tune the band gap of black phosphorus for the energy range even greater than its intrinsic band gap[1]. This can also be used not only to deliberately induce the topological phase transition to the 2D Dirac semimetal protected by spacetime inversion symmetry[2], but also to systematically trace the evolution of quantum phases (pseudospin) across the band inversion[3]. In this talk, I will introduce our most recent discovery of band renormalizations and pseudogap in a crystalline insulator (black phosphorus) doped by disordered dopants (alkali metals)[4]. Using angle-resolved photoemission spectroscopy, we found that the simple quadratic band dispersion of black phosphorus bends back towards zero wavenumber, which can be explained by the Anderson-McMillan band dispersion of liquid metals proposed in the 1960s. This is a consequence of resonance scattering by the potential of the dopant ions with only short-range order. The depth of scattering potential tuned by different kinds of alkali metal (Na, K, Rb, Cs) allows us to classify the pseudogap of *p*-wave and *d*-wave resonance.

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Keywords:

Pseudogap, Black phosphorus, ARPES, Quantum Materials

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

D6.04

Growth of highly conducting delafossite thin films

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Abstract:

ABO_2 delafossite oxides have attracted recent attention because they have a natural heterostructure of hexagonal A and BO layers that provide a diverse set of physical properties. In the delafossite oxides, A-site electrons occupy a band near the Fermi level with steep band dispersion, while B-site electrons are strongly correlated and have Mott-insulating characteristics. The diverse combination of A and B atoms provides a wide range of fascinating properties. The most notable properties found in delafossites include the highest figure of merit among the p-type transparent conducting oxides and extremely high conductivity. Layer-by-layer growth of delafossites not only provides a route to utilize their diverse properties in future devices and applications, but also enables the design of artificial delafossite heterostructures with which new physics and chemistry can be realized. Despite the efforts to grow delafossite thin films thus far, many challenges still must be solved to enable the growth of high-quality thin films.

Keywords:

Delafossite, Oxide thin film

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2023-04-19 - 2023-04-21

D7.01

Interplay between Kondo cloud metal and Cooper-pair superconductor

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Abstract:

When a magnetic moment is embedded in a metal, it captures itinerant electrons to form the Kondo cloud with a size of a few micrometres at ultralow temperatures below T_K [1]. For a metal with dense magnetic impurities such that Kondo clouds overlap with each other, correlated ground states with BCS-like DOS structures at the Fermi energy are formed [2]. On the other hand, BCS superconductors are well known to have a macroscopic ground state. Here, we fabricate a tunnel junction consisting of Kondo cloud metal and BCS superconductor, and perform tunneling DOS spectroscopy measurements. We observe the interplay between them in the tunneling DOS spectrum, providing evidence that the Kondo metal has a BCS-like macroscopic ground state. Our experimental findings confirm the Kondo condensation (the magnetic version of BCS pair condensation) in a clean metal containing magnetic impurities and will be useful for understanding complex Kondo systems.

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Keywords:

Kondo cloud, Tunneling DOS, BCS Superconductors, Condensation

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2023-04-19 - 2023-04-21

D7.02

Real Hopf insulator: Time-reversal symmetric delicate topological insulator

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Abstract:

The Hopf insulator is one of few examples of a topological insulator that can be a trivial insulator by adding trivial bands to either the valence band or the conduction band., i.e., delicate topological insulator. Here, we propose an example of the time reversal symmetric delicate topological insulator, which is obtained by applying Hopf map to time-reversal invariant systems. We show how to build these time-reversal generalized Hopf insulators mathematically and classify them using integer-valued Hopf invariants. The bulk invariants can be related to the non-trivial topological signature at the surface. Using lattice models, we demonstrate the relation between the dispersive Wannier functions and rotation symmetry of the system.

Keywords:

Bulk-boundary correspondence, Delicate topological insulator, Hopf insulator

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2023-04-19 - 2023-04-21

D7.03

Quantum volume as a probe of topology in Euler Insulators

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Abstract:

Understanding the relationship between quantum geometry and topological invariants is a crucial problem in the field of topological state research. While the relationship between the Chern class and quantum volume is well-known for two-dimensional materials, the relationship between the quantum volume and symmetry-protected topology remains an open problem. In this work, we investigate the relationship between the quantum volume and Euler class topology, which is protected by space-time inversion symmetry $I_{ST}^2 = 1$. We introduce an inequality that relates the Euler class and the quantum volume and show that the quantum volume can detect various ramifications of nontrivial Euler class topology and track the phase transition. The saturation condition of the inequality provides a definition for ideal bands under the space-time inversion symmetry, whose structure is determined by the Euler class. We propose that the difference between the quantum volume and the Euler class can be used as a measure of deviation from the ideal state, allowing for a more quantitative assessment of the extent to which chiral twisted bilayer graphene (cTBG) systems deviate from the magic angle. Our findings provide new insights into the interplay between quantum geometry and symmetry-protected topology and highlight the potential of quantum volume as a powerful tool for characterizing topological states in Euler insulators

Keywords:

Euler class topology, Quantum volume

D7.04

How to experimentally verify the locality of the Aharonov-Bohm effect

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Abstract:

In the Aharonov-Bohm (AB) effect, interference fringes are observed for a charged particle in the absence of the local overlap with the external electromagnetic field. This notion of the apparent “nonlocality” of the interaction has recently been challenged and is under debate. We show that the vacuum field plays a key role in understanding the locality problem of the Aharonov-Bohm effect. The locality addressed here is not just a theoretical problem, and we describe how it can be verified using superconducting interferometry.

Keywords:

Aharonov-Bohm effect, Locality principle, Vacuum field, Superconducting interferometry

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2023-04-19 - 2023-04-21

D7.05

Quantum geometry and Landau levels of quadratic band crossings

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Abstract:

The Landau level (LL) presents an intriguing platform for studying the geometric aspects of band crossing points. Recent studies revealed that geometric parameters, such as the maximal quantum distance give rise to nontrivial LLs even in dispersionless bands. We aim to extend the idea of relating interband coupling parameters to the wave function geometry and investigate the general quadratic band crossing points (QBCPs). Our analysis demonstrates that the coupling parameters can be determined by the projected image of the wave function on the Bloch sphere, giving two distance parameters d1, d2 and one angle parameter ϕ. These parameters in turn determine other geometric quantities such as the Berry phase. The geometric characterization of the wave function can be classified into different types, for which we provide a minimal tight-binding model realizing each geometric class. Finally, we observe the effects of the interband coupling parameters on LLs by comparing two-band models with and without interband coupling. We show that the distance parameters influence the constant shift in energy while the angle parameter governs the initial LLs.

Keywords:

Landau Level, Quantum Distance, Quadratic Band Crossing

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D7.06

Orbitally controlled quantum Hall states in decoupled two-bilayer graphene sheets

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Abstract:

We report on integer and fractional quantum Hall states in a stack of two decoupled graphene bilayers. By exploiting the momentum mismatch in reciprocal space, we suppress the single particle tunneling between both bilayers. Since the bilayers are spatially separated by only 0.34 nm, the stack benefits from strong interlayer coupling. This coupling can cause a stable Bose-Einstein condensate to form. Indeed, such a condensate is observed for half filling in each bilayer sheet when the partially filled level has orbital index 1, whereas it is absent for partially filled levels with orbital index 0. This discrepancy is tentatively attributed to the importance of skyrmion/anti-skyrmion interactions in this context. The application of asymmetric top and bottom gate voltages enables to influence the orbital nature of the electronic states of the graphene bilayers and to navigate in an orbital mixed space. The latter hosts an even denominator fractional quantum Hall state at total filling -3/2. Our observations suggest a unique edge construction involving both electrons and chiral *p*-wave composite fermions.

Keywords:

twisted double bilayer graphene, quantum Hall state, Bose-Einstein condensation, skyrmion/anti-skyrmion interaction

D7.07

Thermoelectric Measurements as a Tool for Studying Electronic Structures in Quantum Materials

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Abstract:

We investigated the magnetothermovoltage of Sb-doped Bi_2Se_3 Topological insulator (TI) nanowires (NW) with periodic magnetothermovoltage oscillations under an axial magnetic flux. The oscillation period pronounced oscillations in both magnetothermovoltage and magnetoconductance, consistent with the Aharonov-Bohm interference effect. The 180° out-of-phase change of the AB oscillation was caused by a change in the gate-voltage value, which changes the Fermi-wave vector and the density of states at the Fermi level. These results are consistent with the sub-band dispersion model for topologically protected surface states of a TI NW. We propose that thermoelectric measurements provide a tool for studying electronic structures near the Fermi level in various quantum materials.

Keywords:

Aharonov-Bohm osiilation, Topological insulator nanowire, Thermoelectric effect

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2023-04-19 - 2023-04-21

D8.01

Atomic-resolution studies of highly-conductive delafossites using STEM

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Abstract:

Pd/Pt-based delafossites are known for having the highest in-plane conductivity in the oxide family. At low temperatures, the resistivity of as-grown $PdCoO_2$ is 0.0075 μΩ, with a mean free path of 20 μm. This raises the question on the nature of the defects – is the density truly that low, or are defects present but somehow hidden from scattering channels? Here, we use scanning transmission electron microscopy (STEM) to find ribbon-like defects with 0.001% defect density. Moreover, our 4D-STEM data show that the intrinsic defects appear as satellite peaks in the diffraction pattern, from which we aim to trace back the actual crystal structure of the defects. By showing the interaction of the atomic planes with the focused electron beam, we demonstrate its capability as catalysts. Also, the defects that arise in thin film delafossites will be discussed to suggest methods to improve the film quality for future applications.

Keywords:

Delafossite, PdCoO2, 4D-STEM, Atomic-resolution, Defects

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D8.02

Operando TEM investigation of domain dynamics in 2D ferroelectric materials

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Abstract:

Control of interlayer stacking angle in two-dimensional (2-D) van der Waals (vdW) heterostructure enables one to engineer the crystal symmetry to imprint novel functionality. By stacking two layers of transition metal dichalcogenides (TMD) with designed twist angle, one can break the inversion symmetry and thereby develop vertical electric polarization. The direction of the electric polarization can be switched electrically, suggesting that the twisted bilayer TMD can host ferroelectricity. Such ferroelectricity reported in twisted bilayer vdW system is distinguished from conventional ferroelectrics in that the lateral sliding of the constituent layers induces vertical electric polarizations. Due to the reduced dimension, the ferroelectric domains do not require forward growth along the third dimension, suggesting unconventional 2-D domain dynamics under an applied electric field.
Here we employ *operando* transmission electron microscopy (TEM) to investigate the domain dynamics in 2-D vdW ferroelectrics. Operando TEM technique enables one to examine the structural change in the environment that mimics the device operating condition. On a thin SiN based TEM compatible platform, we fabricated double capacitor structure on 2D vdW ferroelectrics. Electrical gating in double capacitor structure and real time observation of structural change in a simultaneous manner provides an insight onto the switching mechanism of the 2-D vdW ferroelectrics.

Keywords:

operando TEM, 2-D vdW ferroelectrics, domain dynamics

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D8.03

Cross-sectional transmission electron microscopy study of 2D-3D interfaces

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Abstract:

Transmission Electron Microscopy (TEM) has been considered as a useful technique to investigate the structural and chemical properties of various semiconductor interfaces. Generally, interfaces are inevitably formed between two dimensional transition metal dichalcogenides (TMDCs) and 3D materials (such as metal and substrate) during the synthesis of 2D materials and electronic device fabrication. To atomically reveal the interface structures, the cross-sectional TEM analysis combined well-prepared TEM samples is needed. In this presentation, I will present various cross-sectional (S)TEM works which were performed using a Cs corrected (S)TEM combined with a focused ion beam (FIB) sample preparation technique. Firstly, I will show the unique interface analysis which is important for characterizing the fundamental phenomena found at the interface between 3D metals and 2D monolayer MoS_2 for field-effect transistors. In addition, tellurium oxide buffer layer at the interface between 2D $PtTe_2$ and 3D Al_2O_3 substrates is clearly visualized via cross-sectional TEM (STEM) images.

Keywords:

two-dimensional semiconductors, interface analysis, cross-sectional TEM

Understanding Nucleation Dynamics via High-Speed Atomic-Resolution TEM

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Abstract:

Nucleation in atomic crystallization remains poorly understood despite advances in classical nucleation theory. The nucleation process has been described to involve a non-classical mechanism including a spontaneous transition from disordered to crystalline states, but a detailed understanding of dynamics requires further investigation. Here, using in-situ transmission electron microscopy of heterogenous nucleation of individual gold nanocrystals with millisecond temporal resolution, we show that the early stage of atomic crystallization proceeds through dynamic structural fluctuations between disordered and crystalline states, rather than through a single irreversible transition. Our experimental and theoretical analyses support that structural fluctuations originate from size-dependent thermodynamic stability of the two states in atomic clusters. These findings, based on dynamics in a real atomic system, reshape and improve our understanding of nucleation mechanisms in atomic crystallization.

Keywords:

crystal nucleation, in situ TEM, high-speed TEM, reversible transition, non-classical nucleation

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D9.01

First-Principles based Modelling of Electrocatalysis Beyond the Potential of Zero Charge

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Abstract:

In recent years, implicit solvation approaches have experienced a renaissance in the context of interfacial electrochemistry, not least because in conjunction with ab initio thermodynamics they allow to mimic the polarization of the electrode at potentials beyond the PZC. In this talk, I will survey this context and corresponding fully-grand canonical (FGC) calculations. Specifically, I will discuss the application to compute thermodynamic cyclic voltammograms (CVs) and demonstrate that only FGC calculations are able to capture non-Nernstian peak shifts and other double layer-effects on the CV shape. Relevant for catalysis is in particular the ability to predict potential-induced variations of adsorption energies and concomitant effects on detailed reaction mechanisms. The use of machine-learned potentials finally opens the door toward predictive-quality explicit solvation simulations and global geometry optimization to address a potential operando evolution of the electrode.

Keywords:

First-Principles Modelling, Electrocatalysis, Solvation, Density-Functional Theory

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D9.02

Fully ab initio modeling of electrocatalytic and corrosion phenomena

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Abstract:

Direct experimental measurements of the atomistic mechanisms underlying electrocatalysis or causing wet corrosion at the solid-liquid interface have been notoriously challenging and are often lacking. Fully parameter-free ab initio calculations have the potential to accurately describe and explore such mechanisms but face many conceptual challenges due to the complexity of such interfaces: large electric fields, control of the applied external potential, computing thermal averages over large timescales, metal-insulator transitions, etc. Recent methodological breakthroughs such as the availability of efficient computational electrodes or the development of efficient thermopotentiostats allow us to overcome these limitations and open new routes to study the structure and chemical reactions at electrified solid-water interfaces. The talk will give a brief overview of the key concepts of these new methodologies and show applications related to electrocatalytic reactions with a focus on the hydrogen evolution reaction (HER) and corrosion.

Keywords:

Electrocatalysis, corrosion, ab initio molecular dynamics, solid-water interfaces, structure, reactions, electrochemical cell, applied potential, thermopotentiostat

2023 KPS Spring Meeting
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D9.03

Tracing the structural evolution of ultrathin surface oxides in vacuum and under an aqueous environment

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Abstract:

Ultrathin surface oxides are commonly formed on many technologically-important metal surfaces (e.g. under passive oxidative corrosion). The use of these metals can range from industrial metallurgy to heterogeneous catalysis under either ambient or extreme conditions (such as high temperatures/pressures and humid environments). There have been quite a few studies highlighting the conversion of these ultra-high vacuum (UHV) characterized ultrathin oxide layers to surface hydroxide layers. However, these studies are not comprehensive and cannot account for the rich and diverse (transition) metal chemistry in solution. Many of these surface-dominated physiochemical processes are usually difficult to probe in-situ and thus a complete understanding of the actual surface layer of metals under an aqueous environment is still very much lacking to date. Using state-of-the-art electronic structure theory calculations, we investigate and characterize various known surface oxides on Cu(111) (using tip-inclusive scanning tunneling microscope simulations) and also addressing the survival of these UHV-observed surface oxides under an aqueous environment. Specifically, using ab initio molecular dynamics, we provide some preliminary structural results for the common "29" O/Cu(111) under mildly and strongly acidic conditions.

Keywords:

Copper surfaces, Oxidation, DFT, STM, Aqueous environment

D9.04

Structures and processes in interfacial electrocatalysis from first principles

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Abstract:

Interfacial catalysis and electrochemistry is concerned with structures and processes at the interface between an electron conductor, the electrode, and an ion conductor, the electrolyte. In the atomistic description of electrocatalytic processes under operating conditions, the environment and the electrochemical control parameters need to be appropriately taken into account which is hampered by the complexity of these interfaces. In this talk, a variety of different theoretical and computational techniques such as grand-canonical approaches or ab initio molecular dynamics simulations will be presented. Their applicability will be discussed using several examples such as coadsorption effects at metal electrodes and the dependence of water structures at metal electrodes on the electrode potential. Furthermore, degradadation effects at the cathode of metal-air batteries will be addressed. This type of batteries promise very high energy densities but their their poor cyclability prohibits their commercialization as rechargeable batteries.

Keywords:

Electrocatalysis, electric double layer, grand-canonical approaches, ab initio molecular dynamics simulations, electrolyte, electrode potential, degradation, Pourbaix diagrams

D10.01

Layered semiconductor materials interact with structured light

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Abstract:

Recent studies on controlling valley polarization in layered transition metal dichalcogenide (TMD) materials have gained significant attention due to the potential applications of valleytronics devices. The tunable bandgap of layered TMD materials, along with their distinctive electronic, optical, and mechanical properties, make them highly promising for a wide range of applications, including transistors, sensors, and photovoltaics. Monolayer molybdenum disulfide (MoS2) exhibits an optical bandgap of 1.8eV and a valley degree of freedom that can be modulated through circularly polarized light or strain engineering, making it a material with distinctive characteristics. While circularly polarized light or strain engineering can alter the valley degree of freedom in monolayer MoS2, it remains difficult to achieve precise control over its spin behavior via these approaches. To address this challenge, researchers are exploring new techniques to manipulate the spin properties of MoS2, such as using magnetic fields, electrical gating, or hybridizing with other materials.
Our study aims to examine the captivating phenomenon that arises when the structured light possessing orbital angular momentum (OAM), a previously unexplored degree of freedom, interacts with layered MoS2. The establishment of the orbital angular momentum of light as light sources for excitation was made possible by using a spatial light modulator in combination with an optical measurement system, which allowed for the measurement of optical and electrical properties for TMD materials. The interaction between OAM light and MoS2 materials will be discussed with regards to the responses observed in photoluminescence and Raman spectroscopy, as well as electric measurements. Insights gained from this study can enhance the capability to manipulate spin properties of TMD materials, thereby opening new possibilities for spin-based optoelectronics.

Keywords:

Transition metal dichalcogenide, orbital angular momentum of light, photoluminescence, Raman spectroscopy

2023 KPS Spring Meeting
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D10.02

Sub-thermionic subthreshold swing tunnel field-effect transistor with gate-controlled $MoTe_2$ homojunction

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Abstract:

A tunnel field-effect transistor (TFET) activated by a quantum band-to-band tunneling mechanism has encouraged the acceleration of nanodevices owing to its capability to beat the thermionic emission limit of a subthreshold swing (SS) (60 mV dec^{-1}) in conventional metal-oxide-semiconductor FETs. Despite numerous studies, fabricating a TFET based on two-dimensional materials remain several major concerns due to factors such as a low on–off current ratio, weak air stability, and large hysteresis. Herein, we developed a $MoTe_2$ homojunction-based TFET with bottom metal contacts and a defect-free polymer substrate. The transfer characteristic shows a sub-thermionic minimum SS of 36.4 mV dec^{-1} and SS average over four decades of 46 mV dec^{-1} at 300 K, with negligible hysteresis. In particular, a smaller supply voltage of 0.6 V (vs. 0.7 V for Silicon technology) is realized in the TFET. Furthermore, our device exhibits an excellent on/off current ratio of ~10^8, strong air stability for a period of over several months and a sub-Boltzmann limit, body factor of m = 0.21. This study demonstrates a strategy for a van der Waals heterostructure assembly and describes the considerable progress in TFET research.

Keywords:

Tunnel Field-effect Transistor, van der waals heterostructure, sub-thermionic subthreshold swing

D10.03

Applications of perovskite quantum dots for light-emitting memory and exciton-polariton condensation

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Abstract:

All-inorganic metal halide perovskite materials, usually expressed as the chemical formula of ABX3, where A and B are metal cations with different sizes and X being a halide anion, have been intensively investigated due to their unique photophysical characteristics and high stability in the ambient environment. They can be easily processed by solution methods and be implemented in low-cost, mass-production of optoelectronic devices for high-scalable applications. Furthermore, all-inorganic perovskite halides have low activation energies for the migration of halide-ion vacancies under an applied bias, which enables the drifts of charged cations and anions per the poling direction and is believed to be the cause of several intriguing phenomena observed in the perovskite optoelectronic devices.

In this talk, we will introduce our recent work in which a novel all-inorganic perovskite CsPbBr3 light-emitting memory (LEM) is demonstrated by monolithically integrating a perovskite light-emitting electrochemical cell with a perovskite nonvolatile resistive random-access memory. A physical picture, outlining the movements of each ion in the perovskite LEM and their reduction and oxidation processes under different bias scenarios by carefully investigating its intriguing electronic and optical characteristics, will be discussed. On the other hand, to achieve a strong exciton-photon coupling regime and observe the exciton-polariton condensation, we have embedded the single-monolayered perovskite quantum dots into a Tamm-plasmon (TP) photonic microcavity made of a dielectric bottom DBR, a polymethyl methacrylate layer, and a thin silver capping layer. A room temperature macroscopic condensation of polaritonic emissions is hence observed in the TP polaritonic device by mapping out its energy-momentum dispersion relation through angle-resolved photoluminescent measurements. We believe these findings could serve as a new paradigm for generating more advanced all-inorganic perovskite optoelectronics and new applications through the synergy of electronics and photonics.

Keywords:

Perovskite quantum dots, light-emitting memory, Tamm-plasmon, exciton-polariton condensation, CsPbBr3

2023 KPS Spring Meeting
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D10.04

Thin film transistors for synaptic transistor appications

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Abstract:

Neuromorphic devices are receiving more interest as a potential solution for energy-efficient artificial intelligence (AI) technology. While AI is becoming more widespread in our daily life, from suggesting a relevant product to even creative tasks such as automatically-generated writing, its vast energy consumption for processing a large amount of data limits its sustainable usage. Neuromorphic devices are a sort of electronic device that mimics the operation principle of the biological synapse. They utilize pulse-induced conductivity modulation through various mechanisms that can serve as a single synapse in the hardware-implemented artificial neural network to achieve energy-efficient neural network processing. Among various types of neuromorphic devices, synaptic transistors are considered as good candidates for future scalable array integration thanks to their three-terminal configuration, which allows us to perform programming and reading processes separately. For constructing synaptic transistors, thin film transistors (TFT) are widely utilized for easy fabrication, process modification, and compatibility with silicon devices.
In this presentation, we will discuss the fabrication of amorphous oxide semiconductor (AOS) based TFTs and their synaptic transistor applications and future plans for array integration. At first, IGZO-based TFTs with embedded AlOx charge trap layer will be discussed as a scalable way to produce synaptic transistors with an all-sputtering-based fabrication process. Next, ZnO TFTs will be discussed as a device that responds to both optical and electrical pulses simultaneously, hence advantageous for achieving highly-linear activation functions or global modulation in array applications. Future plans for integration strategy and readout electronics of large-scale synaptic TFTs will be discussed as well.

Keywords:

Neuromorphic device, Synaptic transistors, Optoelectric devices

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2023-04-19 - 2023-04-21

D11.01

Initial ELM suppression by ML-based 3D field control without increasing of P_{TH} in KSTAR

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Abstract:

KSTAR focused on exploring the key physics and engineering issues of the high beta steady-state operation for ITER and future fusion reactors utilizing unique capabilities of KSTAR with low intrinsic error field and magnetic ripple [1, 2]. Most of all, a scenario was developed targeting steady-state ELM-suppressed operation and significant progress has been made in ELM suppression and ELM control to address the stationary scenario.
Multiple low-n non-axisymmetric fields have been systematically scanned to determine the influences on H-mode power thresholds. As expected, the increase of non-axisymmetric fields has led to a higher power threshold. It strongly suggests that intrinsic error fields as well as non-axisymmetric fields for initial ELM suppession should be minimized to economically secure the access to H-mode in ITER.
In recent KSTAR 3D magnetic field experiments, ELM optimization and automatic control techniques such as Machine Learning (ML) algorithm [3] in order to suppress ELM successfully implemented in KSTAR PCS. Machine learning algorithm successfully suppressed nearly complete ELM-crash including initial ELM without increasing of the H-mode power threshold in KSTAR. The Machine learning algorithm applied to RMP-driven ELM suppression experiments can suppress all ELMs, including initial ELMs, without raising of the H-mode threshold power in ITER.
This research was supported by R&D Program of "KSTAR Experimental Collaboration and Fusion Plasma Research (EN2301-12)" through the Korea Institute of Fusion Energy (KFE) funded by Korea Ministry of Science and ICT (MSIT).

[1] Y. In et al, Nucl. Fusion 55 043004 (2015).
[2] S.W. Yoon et al, IAEA-FEC (2014).
[3] Giwook Shin et al, Nucl. Fusion 62 (2022) 026035

Keywords:

Machine Learning, KSTAR, ELM suppression, 3D magnetic field, H-mode power thresholds

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

D11.02

Recent developments in laser systems at PAL-XFEL

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Abstract:

The Pohang Accelerator Laboratory X-ray Free Electron Laser (PAL-XFEL) facility offers reliable x-ray radiation with photon energy ranging from soft X-ray (0.2-1 keV) to hard X-ray (2.4-20 keV), and pulse durations on the order of a few hundred femtoseconds, catering to various users from diverse fields such as materials, biology, chemistry, and physics. With the growing demand for new scientific discoveries such as quantum materials and new drug development, new XFEL operation modes such as attosecond XFEL and terawatt-scale XFEL are required. Therefore, we are developing novel operation modes to meet the users' demanding requirements. At PAL-XFEL, we have developed various XFEL operation modes for attosecond soft X-ray FEL in the soft X-ray regime and terawatt-scale XFEL for hard X-ray HX2. To enable such new operation modes for XFEL, laser-electron beam modulation is essential, and thus, we are currently developing laser systems including the oscillator, high-power laser amplifiers, and wavelength conversion devices. Specifically, we have adopted a laser diode pump for the home-built oscillator to achieve easy maintenance and cost-effectiveness. In this presentation, we will present the on-going laser developments for PAL-XFEL.

Keywords:

PAL-XFEL, Laser sysem, LD pumped oscillator

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2023-04-19 - 2023-04-21

D11.03

Generation of isolated terawatt sub-attosecond high-energy X-ray pulses from a free-electron laser

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Abstract:

The endless quest for dynamics in natural phenomena has resulted in the generation and application of attosecond pulses to trace electron dynamics in atomic and molecular systems. The next challenge is to generate powerful pulses on the zeptosecond time scale, which is currently inaccessible. Through a simulation study, a new type of x-ray source that can generate an isolated terawatt sub-attosecond pulse at high-energy x rays by combining attosecond pulse technology with free-electron laser technology is proposed. The successful generation of a sub-attosecond pulse necessitates the consideration of nanometer-wide current-spikes, the sub-attosecond pulse amplification, and pulse duration and background noise control. The underlying interaction mechanism between a sub-attosecond pulse and a current-spike is closely investigated using the simulation results. The proposed method is expected to produce an isolated ~700 zs pulse with a peak output of 2.9 TW at a photon energy of 247.5 keV.

Keywords:

free-electron laser, attosecond, terawatt

2023 KPS Spring Meeting
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D11.04

Characterization of strongly coupled plasmas generated by a femtosecond pulse laser within a phase coexisting supercritical fluid

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Abstract:

Strongly coupled plasmas (SCPs) are a promising research area, drawing interest in EUV light generation for the semiconductor manufacturing and inertial confinement fusion experiments. Many celestial bodies in our universe, such as the Jovian planet's core, white dwarfs, and neutron stars, exist in the SCP state. Despite their ubiquity, SCPs remain an understudied research area due to their collisions and complex collective motion. Achieving high density states requires a large amount of energy, and their transient nature makes the experimental data insufficient. Thus, developing new experimental approaches to effectively create and extend the lifetime of SCPs is crucial for a better understanding. Recently, we demonstrated that the opaque supercritical fluids by nanometer-sized clusters and micrometer-sized droplets prolong the lifetime of the laser-produced SCPs by enhancing photon confinement [1, 2]. In this study, we established an experimental design using a femtosecond pulse laser to scrutinize the SCPs generated in supercritical fluids instead of nanosecond pulses. The femtosecond pulse laser offers advantages for generating high-density plasma due to its different ionization mechanism compared to nanosecond pulse lasers. In the nanosecond pulse lasers, the field absorption process is essential to accelerate free electrons and induce energetic collisions, whereas direct photon interaction with matter is more probable in the femtosecond pulse, such as multi-photon ionization or tunneling ionization. These different mechanisms will induce distinct characteristics of SCPs generated in the argon supercritical fluids. Here, we discuss the characteristics of the SCP generated by the femtosecond pulse laser inside the supercritical fluids and how the clusters and droplets interact with the femtosecond pulse laser.

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Keywords:

Strongly Coupled Plasma, Supercritical Fluid, Laser Produced Plasma, Femtosecond Pulse Laser, Dusty Plasma

2023 KPS Spring Meeting
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D11.05

Numerical study on the Wave instability by the Runaway Electron Beam

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Abstract:

Mitigating the average kinetic energy or defocusing the runaway electron (RE) beam is one of the significant objectives for the safe operation of fusion devices. It is essential to understand the dynamic features of the RE beam in the tokamak plasma to establish strategies to mitigate the growth of RE beams. It is known that the RE beam can generate electrostatic waves [1] or whistler waves [1, 2, 3]. To understand the detailed interplay between the RE beam and the plasma waves, we have conducted a numerical study using a 2-dimensional electromagnetic particle-in-cell (PIC) simulation. More specifically, the connection among the dispersion properties of the plasma wave generated by the RE beam, temporal evolutions of the energy in the system, and the momentum distribution of the plasma and RE beam are studied with linear analysis. As a result, we observed that the Cherenkov resonance accompanies the electrostatic wave and the diffusion of the RE beam distribution function in the parallel direction, and anomalous Doppler resonance evokes the whistler wave and the diffusion of the RE beam in the perpendicular direction. The condition of whether the Cherenkov resonance or the anomalous Doppler resonance occurs depends on the beam energy. Further study for the features of the distribution will be done in the future.

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[2] D. A. Spong et al., Phys. Rev. Lett. 120, 155002 (2018)
[3] M. H. Kim et al., Nucl. Fusion 60, 126021 (2020)

Keywords:

Tokamak, Runaway electron (RE) beam, Doppler resonances, Particle-in-cell (PIC) simulation

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D11.06

Turbulent Magnetic Diffusivity β Effect in a Magnetically Forced System

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Abstract:

이 발표는 자기장 에너지 또는 전류가 역학 에너지보다 큰 플라즈마 시스템에서 자기장이 증폭되는 현상에 관한 내용을 다룬다.
플라즈마 시스템 내의 자기장 구동 방식의 다이나모는 역학적 구동 과정에 비해 직접적으로 관찰되는 현상이라고 볼 수는 없다. 그러나 뚜렷한 운동 효과가 관측되지 않는 항성 코로나, 강착 디스크, 플라즈마 실험실 또는 기타 자기화된 플라즈마 시스템에서 주된 메커니즘으로 존재하는 것으로 파악된다. 플라즈마-자기장 상호 작용은 본질적으로 비선형적 커플링 현상이어서 직관적인 이해나 이론적인 계산이 쉽지는 않지만, 플라즈마 시스템이 헬리컬 에너지에 의해 구동되는 경우 비선형 프로세스는 의사 텐서 α, β와 자기장 자체로 선형화가 가능하다. 또 이로부터 태양 자기장의 11년 주기의 N-S극 역전 현상을 설명할 수 있으며, 원칙적으로 완전한 α & β 계수는 비정상적인 태양 자기장 활동도 설명 및 예측이 가능하다.

현재까지 많은 이론석 수치적 연구에도 불구하고 정확한 α, β 텐서를 찾아내지 못했고, 오직 수치적이고 정성적인 이론 접근만이 가능했다.
비선형 자기장 증폭은 그러한 불완전한 이해를 바탕으로 연구가 진행돼 왔는데, 한 예로 종래의 α효과는 운동에너지를 자기에너지로 변환하고 전이시키는 주된 다이나모 효과로 생각돼 왔으며, 대조적으로 자기확산 β 효과는 자기 에너지를 확산시키는 것으로만 생각되었다. 또 대부분의 이론적인 접근은 (MFT, DIA, EDQNM) 이러한 개념을 추종하는 방향으로 진행돼 온 것이 사실이다.

그러나 본 논문에서는 α와 β의 완전한 해석적 정의를 나열하는 대신, 컴퓨터 시뮬레이션 (DNS) 데이터를 기반으로 하고, 자기장 에너지 및 자기 헬리시티를 사용하는 반해석식을 유도하여 시뮬레이션 데이터에 적용, 각 계수들의 시간적 변화를 찾아냈다. 연구결과 평균적인 α 효과가 자기장을 증폭하는 데 그다지 중요하지 않음이 확인됐으며, 오히려 다이나모 프로세스에서 핵심적인 역할을 하는 것은 라플라시안과 ($\bigtriangledown^2 \rightarrow -k^2$) 결합된 "마이너스 자기 확산 β 효과"임이 확인됐다. 동시에 마이너스 β 확산은 플라즈마 운동에너지를 억제하는 것으로 확인됐다. 이는 플라즈마의 열 역학적 에너지가 전자기장 에너지로 전환됨을 의미하는데, 이 과정을 수치적, 이론적 방법과 난류 이론 및 전자기적 필드 구조 모델을 사용하여 프로세스를 설명한다 (Park 2020, Park et al 2023, ApJ).

Keywords:

플라즈마, 자기 유체 난류 다이나모, α & β 효과, 태양 자기장

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D11.07

이중 표면 유전장벽 플라즈마 유동 발생기의 전기풍 발생 성능

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Abstract:

대기압 상태의 약전리 플라즈마에서 전기장에 의해 가속된 하전입자는 충돌을 통해 중성기체 입자에 운동량을 전달하여 전기유체역학적(Electrohydrodynamic: EHD) 힘을 가하게 된다. 이로 인해 발생하는 중성기체의 유동인 전기풍은 별도의 기계적인 부분이나 연소과정 없이 단순한 구조에서 짧은 반응시간으로 기체 흐름을 발생시킬 수 있다는 장점을 지닌다. 이러한 전기풍을 생성하는 플라즈마 유동 발생기는 냉각이나 유동제어 등의 분야에서 활용 가능성에 대한 연구가 활발히 진행되고 있으며, 실제 분야에 적절히 활용하기 위해서는 발생하는 전기풍의 유속과 효율에 대한 조사가 필요하다. 본 연구에서는 표면 유전장벽방전(Dielectric barrier discharge: DBD)을 직렬로 여러 개 배치한 이중 표면유전장벽 플라즈마 유동 발생기를 제시하고 얻을 수 있는 전기풍의 유속과 소모전력 등의 성능을 조사하고자 한다. 실험 결과 플라즈마 유동 발생기의 배치와 구동조건을 조정함으로써 단일 유전장벽방전에서 발생하는 1.3 $m\cdot s^{-1}$ 보다 최대 3배 가량 증가한 4.2 $m\cdot s^{-1}$의 전기풍을 측정하였다. 최대 유속의 전기풍이 발생할 때 방전길이당 111 W/m의 전력이 소모되었으며, 플라즈마 유동 발생기의 배치에 따라 방전길이당 동일 소모전력에서 전기풍 유속이 증가함을 확인하였다. 본 연구를 통해 조사한 유전장벽방전의 배치 조건을 토대로 향후 표면 유전장벽방전을 적층한 조건과 타 연구들의 플라즈마 유동 발생기 구동 조건 등을 적용하여 플라즈마 유동발생기 성능 향상에 대해 조사할 예정이다. 이와 동시에 전기풍의 유속 분포와 플라즈마 특성에 대한 추가적인 연구가 필요하며, 이를 예측할 수 있는 전산모델을 개발한다면 각 적용분야에 대해 적절한 전기풍을 얻을 수 있는 플라즈마 유동 발생기를 제시할 수 있을 것으로 기대된다.

Keywords:

대기압 플라즈마, 표면 유전장벽방전, 플라즈마 유동 발생기, 전기풍

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2023-04-19 - 2023-04-21

D13.01

Thickness dependence of creep-scaling behavior in Pt/Co single interface films

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Abstract:

The dynamics of the magnetic domain walls has been widely studied in recent days because of its possibility related to the next-generation devices such as magnetic racetrack. Moreover, it is actively used as a useful tool for determining magnetic properties such as the exchange stiffness, spin-orbit torque efficiency, Dzyaloshinskii-Moriya interaction (DMI) energy and so on. Such experiments have been carried out under well-controlled applied field and current because of its accessibility and accuracy. These interfacial phenomena are attributed to the SOC inevitably at two interfaces and it is not easy to resolve the contributions from each interface. In this study, we investigated the domain-wall dynamics from single interface film by means of in-vacuum magneto-optical Kerr effect (MOKE) microscopy. The experiments of the domain-wall creep-scaling behavior quantify the dead-layer thickness at the single interface. Then, the scaling law between the creep- scaling constant and the effective magnetic layer thickness was experimentally confirmed.

Keywords:

Domain Wall, Creep, Interface

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D13.02

Controlling the magnetic properties of layered Cr_2Te_3 ultra-thin film via ex-situ annealing

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Abstract:

Chromium telluride ($Cr_{1+x}Te_2$) family has been known as a layered itinerant ferromagnet with self-intercalated Cr inside the Van der Waals gap based on 1T $CrTe_2$. Recently Chromium telluride ($Cr_{1+x}Te_2$) family draw a huge attention due to their unique physical properties such as Skyrmions (Nature Communications, 13, 3965 (2022)) and topological Hall effect (ACS Nano, 16, 8974 (2022)) etc. As strong potential candidate to realize 2D-spintronics, numerous researches had done to understand the physical properties of Chromium telluride ($Cr_{1+x}Te_2$). However, manipulation of magnetic properties of Chromium telluride ($Cr_{1+x}Te_2$) had not been performed yet. Here, we investigate the controlling of the magnetic properties of Cr_2Te_3 ultra-thin films with ex-situ annealing method. With complementary microscopic and spectroscopic evidence, we will address the origin of observed manipulation of magnetic properties of ultra-thin film system.

Keywords:

Magnetic anisotropy energy, Curie temperature, ex-situ annealing

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D13.03

Terahertz polarimetric imaging for spin dynamics

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Abstract:

So far, various tools have been developed for measuring of how spins move for practical application of data processing and data storage. Especially, THz time-domain spectroscopy is promising method for spin dynamics in energy range of few meV and response time of picosecond. Although far-field THz spectroscopy has been used to observe spin dynamics in magnetic system, its microscopic imaging has been difficult because of long wavelength of THz waves. Here, we introduce the near-field THz method for visualizing spin dynamics in planar spin Hall effect and spin precessing motion in real space.

Keywords:

Planar spin Hall effect, spin dynamics, near-field THz imaging

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D13.04

Direct observation of quantum tunneling of magnetization of single nuclear spin

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Abstract:

We study a quantum tunneling of magnetization (QTM) of Ho atom on MgO using scanning tunneling microscopy with fast ramping superconducting magnet. Due to the large spin-orbit coupling and hyperfine interaction, Ho atom on MgO has eight avoided level crossings representing Landau-Zener tunneling. The probability of QTM through each avoided level crossing shows the magnetic field ramping speed dependence. We found the effective magnetic field range for Landau-Zener tunneling by the controlling magnetic field sweeping speed and range. The quantum tunneling between electron spin states through the specific avoided level crossing has been directly observed in the tunneling current. The qubit operation method using the nuclear spin of Ho atom will be also discussed.

Keywords:

STM, Landau-Zener Tunneling, Quantum tunneling of magnetization, Rare earth atom

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D13.05

Ferromagnetic Resonance spectroscopy in Ion beam-Irradiated Metallic Thin Films

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Abstract:

Novel iron-based magnetic thin films have been attracting substantial interest due to their potential applications in various technologies as well as fundamentals of magnetic and electronic properties, unlike bulk counterparts. Ferromagnetic resonance (FMR) spectroscopy is one of the most important tools to determine the magnetic anisotropy of thin films and thus has been used widely used for a long time. Here, we have investigated the FMR data as a function of a rotating angle with respect to the film plane of $CeFe_{12}$ and FeNi. Intriguingly, N^+ ion beam implantation may increase the saturation magnetization in $CeFe_{12}$ thin films, which may be ascribed to an increase in magnetocrystalline anisotropy as revealed by the ferromagnetic resonance spectroscopy. For FeNi, we implanted a 20 keV Cu^+ ion beam with a dose of 1×10^{15} cm^{-2} in the sample. We find that the saturation magnetization increases and the FMR signals exhibit a shoulder peak which may arise from some different magnetic ordering.

Keywords:

Ion beam implantation, ferromagnetic resonance spectroscopy, CeFe12, FeNi

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D13.06

Phase transition variation of FeRh with local defects

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Abstract:

FeRh exhibits a first-order phase transition from an antiferromagnetic state to a ferromagnetic state around 370 K. This phase transition is accompanied by a significant change in the structural and electrical properties of the material. It is of great interest to both fundamental research and potential technological applications. Interestingly, the phase transition characteristics of FeRh can be affected by local atomic defects. Therefore, understanding these effects is essential for the development of new FeRh-based materials with tailored magnetic properties for various applications

In this presentation, the focus was on studying the effects of hydrogen ion irradiation on FeRh films and how it can modify the phase transition characteristics of the film. We found the irradiation-induced selective Fe-Frenkel defects formation in the film, resulting in a decrease in the transition temperature and an increase in the initial residual ferromagnetic state within the antiferromagnetic region. To understand the mechanism behind this phenomenon, we used density functional theory calculation, which showed that the formed Fe-Frenkel defect broke the hybridization between Fe and Rh, leading to a polarized Rh spin. This polarization increased the residual ferromagnetic state below the transition temperature and decreased the transition temperature. Additionally, we observed a double-step phase transition in an H-FeRh/FeRh lateral superlattice structure. This observation suggests the potential use of the structure for a lateral spintronic device.

This work is supported in part by NRF-2023R1A2C1005252, NRF-2022M3H4A1A04071154, and NRF-2022M3H4A1A04085306.

Keywords:

FeRh film, Antiferromagnetism, Phase transition, Hydrogen irradiation, Frenkel defects

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D13.07

Role of pressure on Anomalous Hall and Nernst effect of compensated ferrimagnet Mn_3Al

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Abstract:

Role of pressure on anomalous Hall and Nernst effect is studied in Mn_3Al using first-principles calculations. Recent work [1] has shown that compensated ferrimagnet Mn_3Al exhibits anomalous Hall and Nernst effect even with vanishing net magnetization owing to non-vanishing Berry curvatures. As an extension, evolution of bands and consequent Berry curvature upon pressure are explored with two chemical potentials $\mu = 0\ \mathrm{eV}$ and $\mu = -0.3\ \mathrm{eV}$. The evolution of Fermi surface, anomalous Hall and Nernst conductivity with respect to pressure is revealed for two distinct chemical potentials. Occupations changes of bands near the Fermi level are evident upon pressure. On the other hand, nodal lines are robust for $\mu = -0.3\ \mathrm{eV}$.

[1] Minkyu Park, Guihyun Han, and S.H. Rhim, Phys. Rev. Res. **4,** 013215 (2022).

Keywords:

Anomalous Hal effect, Anomalous Nernst effect, Spin Hall effect, Density functional theory, Berry curvature

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D13.08

Mapping Orbital-Resolved Magnetism in Single Lanthanide Atoms

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Abstract:

Single lanthanide atoms and molecules are promising candidates for atomic data storage [Donati et al., App. Phys. Lett **119**,160503 (2021)] and quantum logic [Reale et al., Phys. Rev. B **107**, 045427 (2023)] due to the long lifetime of their magnetic quantum states. Accessing and controlling these states through electrical transport requires precise knowledge of their electronic configuration at the level of individual atomic orbitals, especially of the outer shells involved in transport. However, no experimental techniques have so far shown the required sensitivity to probe single atoms with orbital selectivity. Here we resolve the magnetism of individual orbitals in Gd and Ho single atoms on MgO/Ag(100) by combining X-ray magnetic circular dichroism with multiplet calculations and density functional theory. In contrast to the usual assumption of bulk like occupation of the different electronic shells, we establish a charge transfer mechanism leading to an unconventional singly ionized configuration [Singha et al., ACS Nano **15**, 16162 (2021)]. This charge transfer mehcanism can be used to control the magnetic stability of lanthanide atoms, as it was also observed for Dy atom on MgO/Ag(100) [Donati et al., Nano Lett. **21**, 8266 (2021)]. Our work identifies the role of the valence electrons in determining the quantum level structure and spin-dependent transport properties of lanthanide-based nanomagnets.

Keywords:

Lanthanides, Single atom magnets, Charge trasfer, Surface spins

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D14.01

Bridging-induced phase separation by SMC complexes

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Abstract:

Structural maintenance of chromosome (SMC) protein complexes are able to extrude DNA loops. While loop extrusion constitutes a fundamental building block of chromosomes, other factors may be equally important. Here, we show that yeast cohesin, but also human cohesin and yeast condensin exhibit pronounced clustering on DNA, with all the hallmarks of biomolecular condensation (*1*). DNA-SMC clusters exhibit liquid-like behavior, showing fusion of clusters, rapid fluorescence recovery after photobleaching and exchange of SMC complexes with the environment. Strikingly, the *in vitro* clustering is DNA length dependent, as both yeast cohesin and human cohesin form clusters only on DNA exceeding 3 kilo–base pairs. We discuss how bridging-induced phase separation (BIPS), a previously unobserved type of biological condensation, can explain the DNA-protein clustering through DNA-protein-DNA bridges. We confirm that, in yeast cells *in vivo*, a fraction of cohesin associates with chromatin in a manner consistent with BIPS. BIPS likely is a universal phenomenon among SMC proteins. Biomolecular condensation by SMC proteins constitutes a new basic principle by which SMC complexes direct genome organization.

Keywords:

SMC protein, Cohesin, condensin, Bridging-induced phase separation

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D14.02

Accurate prediction of protein-ligand interactions by combining physical energy functions and graph-neural networks

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Abstract:

Accurate prediction of protein-ligand interaction plays a critical role in understanding biological processes and drug discovery. Recently, various structure-based deep-learning-based protein-ligand affinity prediction methods have been suggested. However, it has been shown that ligand screening using predicted affinity is not accurate enough due to the limited size of the complex dataset. This work presents a new hybrid model that combines graph-neural networks using docked conformations and physics-based scoring functions. Our model consists of three separate graph-neural networks to predict protein-ligand interactions. The first network is a binary classifier that predicts whether a protein-ligand pair is active without using docked conformations. The second and third graph-neural networks are regression models predicting both binding affinities and RMSDs from the native conformation. In addition to the results from these three graph-neural networks, information from physics-based scoring functions is considered. We show that considering both graph-neural network predictions and physics-based estimates is critical in improving prediction accuracy. The test results using the PDBBind set show that our model outperforms other deep-learning-based approaches in screening power.

Keywords:

Graph-neural-network, protein-ligand binding affinity, drug discovery

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D14.03

Single cell profiling in intact biological systems using 3D histological techniques

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Abstract:

Brain function majorly emerges from communication network among neurons. Thus, mapping brain network with cellular resolution is necessary for in-depth understanding of brain functions and dysfunctions. In this talk, I will introduce techniques we developed for single-cell profiling of brain: organ-scale visualization technique (SHIELD) and ultrafast organ-scale immunolabeling technique (eFLASH). I will also present biological findings enabled by the techniques with high-throughput imaging and image analysis pipeline.

Keywords:

3D histology techniques, Light-sheet microscopy, Brain mapping

Biohybrid Muscular Systems and Path Towards Translation

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Abstract:

Biohybrid muscular systems, which are models containing cardiac muscles as building blocks, are emerging platforms to offer new strategies for bioengineering fields. These systems typically involve using living cells, such as cardiac muscle cells, to provide the biological component of the hybrid system, while synthetic materials are used to provide structural support or control the movement of the cells. By leveraging unique features that living cells can offer, biohybrid system has the potential to revolutionize the field of robotics and automation, to create new types of soft robots and actuators that are powered by living cells. By exploiting the dual functionality of cardiac cells, we recreated reciprocal contraction and relaxation in a muscular bilayer construct where each contraction occurs automatically as a response to the stretching of an antagonistic muscle pair. Additionally, we engineered an electrically autonomous pacing node, which enhanced spontaneous contraction. The construct equipped with intrinsic control strategies demonstrated self-sustained swimming, highlighting the role of feedback mechanisms in muscular pumps such as the heart and muscles. Also, our biohybrid muscular systems are used to develop new types of drug delivery systems or diagnostic tools for cardiomyopathies. We develop biological models that are tools for advancing our understanding of complex biological systems and for developing new translational applications in a variety of fields.

Keywords:

Tissue engineering, Cardiac Biophysics

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D15.01

Engineering Quantum Hall States through Interfacial Interactions

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Abstract:

In this talk, we discuss the experimental observation of quantum Hall states in graphene. The quantum Hall effect is a fascinating phenomenon that arises in two-dimensional electron systems in the presence of a strong magnetic field. The resulting quantum Hall states are characterized by a quantized Hall conductance, and they exhibit striking topological properties. By stacking graphene with other materials such as graphene, Kitaev quantum spin liquid, and 2D anti-ferrmagnetic material, we engineer the graphene system and observe new quantum Hall states. We will present our recent experimental results, highlighting the interfacial interactions that are responsible for the emergence of new phenomena in the system. Our work provides a deeper understanding of the interplay between electronic properties of materials and their interfaces, and opens up new possibilities for engineering and controlling quantum Hall states in two-dimensional systems.

Keywords:

graphene, quantum Hall effect, twisted bilayer graphene

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2023-04-19 - 2023-04-21

D15.02

Probing deep-ultraviolet optoelectronic processes in hexagonal boron nitride

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Abstract:

Hexagonal boron nitride (hBN) is a van der Waals (vdW) semiconductor with a wide bandgap of ~ 5.96 eV. Despite the indirect bandgap characteristics of hBN, charge carriers excited by high energy electrons or photons efficiently emit luminescence at deep-ultraviolet (DUV) frequencies via strong electron-phonon interaction. In this work, we probe optoelectronic processes at a band edge in hBN by means of optical imaging and spectroscopy at deep ultraviolet frequencies. Our laser excitation spectroscopy shows that strong radiative recombination and carrier excitation processes originate from the pristine structure and the stacking faults in hBN. We further demonstrate prominent electroluminescence and photocurrent generation from hBN by fabricating vdW heterostructures with graphene electrodes. Our work provides a pathway toward efficient DUV light emitting and detection devices based on hBN.

Keywords:

hBN, exciton, deep-uv laser spectroscopy

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D15.03

Direct probing of crystal-momentum selected electron-phonon scattering processes in vertical van der Waals heterostructures

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Abstract:

In solid-state systems, electron-phonon scatterings play a pivotal role in determining physical quantities such as charge carrier mobilities and thermal conductivities. Here, we discuss direct probing of crystal-momentum selected electron-phonon scattering processes in vertical van der Waals heterostructures composed of graphite and monolayer WSe2. By experimentally controlling the twist angle of the top and bottom graphite layers, we can specify the crystal momentums of phonon excitations that contribute to vertical quantum charge flows, as well as how much inelastic electron-phonon scattering is required in electron tunneling processes.

Keywords:

van der Waals heterostructure, electron tunneling, electron-phonon scattering

D15.04

Edge dependence of supercurrent in the quantum Hall regime

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Abstract:

The observation of the supercurrent in a graphene Josephson junction in the quantum Hall regime has attracted considerable attention, as it demonstrated the hybridization of two seemingly incompatible phases: the quantum Hall state and the superconducting state. However, the mechanism of the quantum Hall supercurrent is still controversial due to the resistance at the quantum Hall plateau not being well-quantized. This suggests that the supercurrent may flow through the bulk state instead of the quantum Hall edge states. To clarify this issue, we fabricated and measured graphene Josephson junctions in both a conventional rectangular geometry with edges and a Corbino-like geometry without any edges. We observed that the supercurrent in the quantum Hall regime only exists in the conventional rectangular geometry. The supercurrent appeared when we etched the Corbino-like geometry device into the conventional geometry with an edge. We also investigated the effect of impurity scatterings between counter-propagating channels by comparing graphene Josephson junctions with native edges and etched edges. The addition of impurities near the graphene edge by plasma etching reduced the appearance and magnitude of the supercurrent in the quantum Hall regime. Our work provides a thorough study of the edge dependence - edge-free, native edge, and etched edge - of the supercurrent in the quantum Hall regime.

Keywords:

Quantum Hall, Superconductivity, Josephson Junction, Graphene

D16.01

Search for excited leptons in llγ final states at 13 TeV

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Abstract:

A search for excited leptons (electrons and muons) is presented using 2017+2018 data collected by the CMS experiment at a center-of-mass energy of 13 TeV and corresponding to an integrated luminosity of 101 /fb. Excited leptons are predicted by various theoretical models beyond the standard model (SM) that quarks and leptons are made of unknown fundamental constituents never observed yet. Excited leptons ($l^* = e^*, \mu^*$) in $ll\gamma$ ($l = e, \mu$) final states where the excited lepton decays to a SM lepton and a photon ($l^* \rightarrow l\gamma$) are studied. We select events which have two same-flavor leptons and one photon and we apply Z-veto which dilepton mass should be larger than 116 GeV due to $Z\gamma$ process. Background is estimated directly from fits to data and signal extraction using unbinned maximum-likelihood fits on 3-body invariant mass is used. Before unblinding, fits on the MC spectra each channels and years instead of data are performed. The possible bias introduced by the choice of the fitting function is evaluated by bias study with RooMultiPdf. Several systematic studies including bias study are updated and preliminary limit will be presented.

Keywords:

cms

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D16.02

Search for new physics using non-isolated leptons in the CMS experiment

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Abstract:

Physicists have been searching for evidence of BSM physics for a decade, but so far no direct evidence has been found. This may be because a proper phase space where the new phsyics is hidding has not yet been explored. However, the muon g-2 result shows a possibility that the new physics has a connection with muons. Therefore, this study focuses on a new phase space related to muons, namely non-isolated muons located within a jet. This analysis uses 2016 CMS datasets which is a 13 TeV proton-proton collision data corresponding to 무 integrated luminosity of 35.9 fb-1. This talk will present the first expected limit assuming Z' radiations.

Keywords:

non-isolated lepton, Beyond the Standard Model(BSM), CMS

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2023-04-19 - 2023-04-21

D16.03

Search for new physics in dilepton events using asymmetry

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Abstract:

We report a noble way to search for new physics in dilepton events using asymmetry at the LHC. Since the discovery of the Higgs particle, we have not observed any new physics signal yet in bump hunting. A tantalizing new physics signature can be hidden in the corners of kinematic phase space of the dilepton events. We categorize events depending on the number of b-jets, and measure differential asymmetry as functions of various kinematic variables to search for hints of new physics.

Keywords:

LHC, CMS, 13TeV, asymmetry, AFB

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2023-04-19 - 2023-04-21

D16.04

Strange Jet Tagging for Measuring |Vts| Using Machine Learning

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Abstract:

The CKM matrix describes flavor-changing interaction between quarks and is unitary in the Standard Model. Vts is one such matrix element that shows the coupling between the top and strange quark. The decay of the top quark to a strange quark has yet to be observed. A significant component of the measurement of the |Vts| matrix element at the LHC is tagging the strange jet from top decays. This study uses a machine learning method based on the self-attention mechanism for tagging the jets from top decays in top quark pair production with dileptonic final state events. These events consist of several types of objects such as jets, leptons, and missing energy, all of which are included as inputs to the machine learning model. We use this technique to improve the ability to identify events with top decaying to the strange quark, for the Vts measurement.

Keywords:

s-tagging, machine learning, top, CKM

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2023-04-19 - 2023-04-21

D16.05

Multi-photon decays of the Higgs boson at the LHC

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Abstract:

Many new physics scenarios predict multi-photon Higgs resonances. This work focuses on the multi-photon Higgs boson resonances, which may arise via portals to the dark sector. The primary decay chain is the Higgs to dark photon pairs that subsequently decay into photons and axion-like particles. The axion-like particles then decay into photon pairs. The primary signal is a six-photon Higgs resonance. However, depending on the relevant kinematics, the photons can become well-collimated and appear as photon-jets (multiple photons that appear as a single photon in the detector) or $₩xi$-jets (non-isolated multi-photon signals that do not pass the isolation criterion). These effects cause the true six-photon resonance to appear as other multi-photon signals, e.g., four or two photons. We explore and examine the multi-photon signals that could appear at the Large Hadron Collider (LHC). The mass regions where two, four, and six-photon resonances dominate are determined. Some additional signal categories involving $₩xi$-jets are considered. All of these multi-photon signals provide excellent footing to explore new physics at the LHC and beyond.

Keywords:

Higgs, BSM, exotic decays, LHC

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

D16.06

The CMS Muon High Level Trigger Efficiency SF for Run3 with systematic uncertainty

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Abstract:

The LHC starts Run3 in 2022 with a center of mass energy of 13.6 TeV. During data acquisition, the Muon High-Level Trigger (HLT) plays a crucial role, and its efficiency is used to monitor the quality of the Muon data. To estimate this efficiency, the Tag and Probe method is utilized. Systematic uncertainty is determined by comparing the efficiency to another Monte Carlo (MC) model and by varying the mass range bins. This presentation will focus on the results of Muon HLT efficiency and SF using the Run3 data.

Keywords:

CMS, HLT

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D16.07

A study of non-isolated muons and MET from b-jets in the CMS experiment

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Abstract:

Muons originated from b-jets are mostly used for studying QCD backgrounds in searching for new physics. Despite this importance, the properties of non-isolated muons from b-jets have not studied detailedly so far. Thus, we present kinematic features of non-isolated muons from b-jets. Moreover, the relationship between muonic neutrinos and b-jets is presented for studying the transverse missing energy. The presented result is from proton-proton collision data in the CMS experiment, collected in 2016 at centre-of-mass energy of 13 TeV with integrated luminosity of 36 fb-1.

Keywords:

CMS, muon, MET, b-jet, LHC

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

D16.08

Measurement of Noise term in JER using random cones method at CMS detector

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Abstract:

Jet energy resolution(JER) can be parameterized with the NSC fit for calorimeter resolutions. The noise term of JER is obtained by measuring the fluctuations in the energy deposits due to pile-up using data samples that are collected by zero bias triggers. In this analysis, the random cones method is used for these measurements. Two random cones are produced by random ϕ values and within opposite η regions. Energy deposits in each random cone which has a 0.4 cone size are summed. Noise term can be obtained from the difference of p_T of two random cones ($p_T^{R.C.1} - p_T^{R.C.2}$). Through this approach, the contribution to the resolution from the noise term due to pile-up can be directly estimated. In addition, noise terms can be obtained from single cone method with the pileup offset corrections determined from the data. Thus, the pileup offset corrections can be validated by comparison with results measured from two different methods. In this talk, the extracted noise terms in the random cone, based on the full 13 TeV Run 2 data samples collected by the CMS experiment, and the current status of comparison with the single cone are presented.

Keywords:

cms, LHC, noise term, JER

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

D16.09

Study of high-energy electron identification for heavy gauge boson search at CMS

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Abstract:

The Compact Muon Solenoid (CMS) detector is one of two multi-purpose experiments at the Large Hadron Collider (LHC) with a broad physics program. Many important physics programs depend on trigger performance, physics object reconstruction, and identification of electrons and positrons with excellent efficiency and resolution. High-energy electrons are particularly important signatures in Beyond Standard Model (BSM) searches, such as heavy gauge boson (W' and Z') searches. To select high-ET electrons, the CMS experiment utilizes a dedicated cut-based identification method called high-energy electron pairs (HEEP). In this talk, we present an overview of the HEEP identification strategy for discriminating prompt electrons from backgrounds in the CMS detector. Furthermore, performance and validation studies of the HEEP criteria with CMS Run-3 Monte Carlo simulation samples for W'/Z' signal events at a center-of-mass energy of 13.6 TeV were reported.

Keywords:

BSM, HEEP, Identification, New heavy gauge boson, Egamma

K*(892) Production in ^{12}C(K-,p) Reaction at 1.8 GeV/c

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Abstract:

We present preliminary results of mesuring K*(892) production in ^{12}C(K^-,p) reactions with a beam momentum of 1.8 GeV/c at J-PARC.
The E42 experiment, dedicated to the H-dibaryon search, collected millions of (K^-,p) reaction events with a ^{12}C target. The outstanding performance of the E42 detector enables us to reconstruct $K^-p \rightarrow$ K*(892)p reaction and K*(892) $\rightarrow K_S^0\pi^-$ decay, which lead us us to investigate the in-medium properties of the K*(892). Furthermore, we can also explore hyperon resonances in $K^-p \rightarrow K_S^0 p\pi^-$ and $K^-n \rightarrow K^-p\pi^-$ quasi-free scattering processes.

Keywords:

J-PARC, E42, K*(892), Vector meson

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2023-04-19 - 2023-04-21

D17.02

Measurement of K-p -> K+Xi- and K-p -> K+Xi(1535)- reactions at 1.8 GeV/c

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Abstract:

We report preliminary results on measuring Xi- and Xi(1535)- production in K-p reactions at 1.8 GeV/c with the J-PARC E42 detector. We collected approximately seven thousand (K-, K+) reaction events with a polyethylene (CH2) target. A forward dipole spectrometer tagged outgoing K+ particles in the angular region from 0 to 20 degrees. In contrast, a superconducting dipole spectrometer enables us to reconstruct Xi- and Xi(1535)- decays in the HypTPC. We analyzed Xi- and Xi(1535)- production events using the CH2-target dataset. In addition, we developed a tracking algorithm to remove accidental beam trajectories overlapped in the same event because of the high-intensity beam exposure. This talk will present the improvement in tracking software and preliminary results on reconstructing K-p->K+Xi- and K-p->K+Xi(1535)- reactions.

Keywords:

E42, TPC, J-PARC, Lambda, Xi

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2023-04-19 - 2023-04-21

D17.03

Measurement of the Ξ(1820) at the LHC energies

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Abstract:

Measurements of the Ξ(1820) resonances in high-energy heavy-ion collisions allow for the study of the fundamental properties of chirality and its effect on the mass of particles. Modifications to the width and mean of the Ξ(1820) and changes in its yield in comparison to the Ξ(1530) resonance could be a sign of the chiral symmetry restoration. Furthermore, the lifetime of Ξ(1820) is short enough that it is comparable to the duration of the hadronic phase, so it may allow us to investigate the particle re-scattering and regeneration in the hadronic phase. We will report on the measurement of Ξ(1820) baryon at the LHC energies by reconstructing its decay to Λ-K in pp collisions and the plan for further study with p-Pb and Pb-Pb data.

Keywords:

LHC, ALICE, multi-strangeness baryon, Ξ(1820)

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

D17.04

Search for Double-strangeness Nuclei using Nuclear Emulsion

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Abstract:

Since the 1980s, several emulsion-counter hybrid experiments have been carried out for double-strangeness (S=-2) nuclei search at KEK and J-PARC Proton Synchrotrons. The S=-2 nuclei, such as double-Λ hypernucleus, twin-Λ hypernucleus and Ξ^- hypernucleus, can give us information on Λ-Λ interaction and Ξ^--N interaction in the nuclei. The Ξ^- hyperons are produced from quasi-free (K^-, K^+) reactions and the S=-2 nuclei can be formed at the nuclear captures at rest of Ξ^- hyperons in the emulsion, where $\Xi^- p \rightarrow \Lambda\Lambda$ occured. Due to its submicron spatial resolution, the nuclear emulsion detector is very suitable to identify the S=-2 nuclei. By following Ξ^- tracks and observing the Ξ^- capture points carefully in the emulsion, we can see the 3D images of very short tracks (~several μm) of the S=-2 nuclei and the complex event structure around the points. In this talk, we will introduce the experimental methods and physics results of KEK E176, KEK E373 and J-PARC E07 for the S=-2 nuclei search.

Keywords:

Nuclear emulsion, S=-2 nuclei, Double-Λ hypernucleus, Twin-Λ hypernucleus, Ξ- hypernucleus

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2023-04-19 - 2023-04-21

D17.05

Current Status of E42 Data Analysis for the H-dibaryon Search

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Abstract:

We report recent progress in data analysis for double-strangeness production in 12C(K^-, K^+) reactions at 1.8 GeV/c. We collected approximately $3x10^5$ $^{12}C(K^-, K^+)$ events with the J-PARC E42 detector.
The Hyperon Spectrometer highlighted the E42, which comprises a time projection chamber (HypTPC) and time-of-flight detectors (HTOF), enables us to detect the H-dibaryon decays to ΛΛ, Ξ^-p, and $\Lambda p\pi^-$. This talk will present preliminary results on the E42 detector performance, such as the momentum, spatial resolutions, and particle identification.
We will also discuss the mass reconstruction of Λ and Ξ^- decays.

Keywords:

E42, TPC, Particle Identification, H-dibaryon

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

D17.06

Diquarkyonic matter: quarks, diquarks and baryons

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Abstract:

In this work, we investigate the color-spin interaction of a quark, a diquark and a baryon with their surrounding baryons and/or quark matter. We extend our previous work by increasing the maximum number of surrounding baryons to 5 and additionally consider all possible diquark probes that are immersed in such surroundings. This is accomplished by classifying all possible flavor and spin states of the resulting multiquark configuration in both the flavor SU(2) and SU(3) symmetric cases. We find that a quark becomes more stable than a baryon when the number of surrounding baryons is three or more. Finally, when we consider the internal color-spin factor of a probe, our results show that the effects of the color-spin interaction of a multiquark configuration is consistent with the so-called diquarkyonic configuration.

Keywords:

color-spin interaction, diquarkyonic matter, multiquark configuration

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

D17.07

D_{s0}^* (2317) as a DK molecular state

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Abstract:

In the present talk, we present a molecular nature of the charmed strange $D_{s0}^*(2317)$ state. The $D_{s0}^*(2317)$ state has a mass approximately 40 MeV below the D^0K^+ threshold and the upper limit of the width is known as 3.8 MeV. The favorable spin-parity quantum number $J^P = 0^+$ is derived from the fact that the branching ratio of radiative decay is 5 % of the $\Gamma_{D_{s0}^*(2317)\to D_s\pi^0}$. Since $D_{s0}^*(2317)$ only decays into the isospin breaking process, the $\pi^0 - \eta$ mixing for the $D_s\pi^0$ channel is considered. The study revealed that the attractive interactions of the u-channel exchange amplitudes in DK channels are strong enough to generate DK bound states. The $D_{s0}^*(2317)$ state is identified as a resonance on the second Riemann sheet in the $D_s\pi^0$ complex energy plane, with $\sqrt{s}_R = 2317.343 - i0.0138$ MeV.

Keywords:

DsJ, Meson molecule

2023 KPS Spring Meeting
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D17.08

New vector meson-baryon states

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Abstract:

We study a new vector meson-baryon bound state (ΣK^*), such as the heavy pentaquark states P_c^+ $(4440, 4457)$, in terms of molecular states consisting of a charmed vector meson and a singly charmed baryons ($\Sigma_c^+ \overline{D}^{*0}$). Taking the excited nucleon state $N^*(2080)D_{13}$ as one of the candidates to describe a ΣK^* weakly bound molecular state, the mass spectra for other members of the corresponding multiplet and possible final states are studied.

Keywords:

Chiral soliton model, vector meson-baryon state, molecular states, excited baryons

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

D17.09

Exploring hadronic rescattering effects on resonance productions in pp and pA collisions

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Abstract:

The production of short-lived hadronic resonances can be affected by several effects until the chemical freeze-out as well as rescattering effects at the hadronic phase. The rescattering effects have been studied in experiments by comparing yields of hadronic resonances of a different lifetime such as ρ, K^{*0}, and ϕ. ALICE results show that the $\mathrm{K}^{*0}/\mathrm{K}^{\pm}$ ratio decreases as charged particle multiplicity increases. On the other hand, there is no strong multiplicity dependence on the $\phi/\mathrm{K}^{\pm}$ ratio. The results in heavy-ion collisions can be described by the EPOS+UrQMD model, and the UrQMD model for hadronic interactions is essential to reproduce the decreasing trend of $\mathrm{K}^{*0}/\mathrm{K}^{\pm}$. Recently, a framework for hadronic rescattering has been implemented in the PYTHIA8 event generator. In this study, we explored hadronic rescattering effects on resonance production in pp and pA collisions with PYTHIA8 to compare with the experimental data and other models.

Keywords:

Hadronic rescattering, Resonance, PYTHIA

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D17.10

Subthreshold Pion Production Experiment (SUPER) at RAON

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Abstract:

Subthreshold pion production in heavy-ion reactions leads to a low-lying nuclear state so that it involves large momentum transfer even close to the threshold. Therefore, this reaction is senstive to nuclear dynamics at short distances. However, the existing experimental data sets on the excitation function near 20 MeV are not consistent. An improved excitation function would allow the study of the threshold behavior in more detail, particularly for nuclear structure and the transition from a coherent to an incoherent production mechanism. In heavy-ion collisions, pion production at energy per nucleon below the NN threshold is also still a puzzling process. Despite a substantial theoretical effort, no model has globally treated all the involved aspects. The observed cross sections are much larger than predicted by NN collision or statistical models, indicating the presence of a collective production mechanism. We propose a new experimental program on subthreshold pion production envisioned at an early stage of RAON. The KOBRA beam line can deliver $^{14}N^{6+}$ in energies up to 43 MeV/nucleon and $^{16}O^{6+}$ in energies up to 41 MeV/nucleon. The beam intensity will be the order of 10^{12} pps. Therefore, we can study neutral pion production from threshold (<20 MeV/nucleon) to 40 MeV/nucleon with$^{16}O^{6+}$ projectiles and various nuclear targets. The new program includes the construction of a neutral-pion spectrometer based on the KEK CsI(Tl) array. We will report preliminary simulation results on subthreshold pion production at RAON.

Keywords:

Subthreshold pion production, RAON

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D18.01

Consistent analyses of nuclear structures and reactions using the Gamow Shell Model

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Abstract:

The nuclear shell model is a traditional approach for describing and predicting the nuclear properties. It is based on the idea that nucleons occupy shells in the nucleus and interact with each other through a residual two-body interaction. The Gamow Shell Model (GSM) is an extension of the conventional shell model that incorporates Gamow-style many-body wavefunctions. GSM allows for a unified treatment of structure, reactions, and decays. GSM opens possibilities for describing nuclear phenomena in neutron-rich nuclei and superheavy nuclei. Calculated results using the GSM will be presented along with the description of the GSM.

Keywords:

Gamow Shell Model

Optical potential for low-energy nucleon-nucleus elastic scattering

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Abstract:

In this talk, we provide a detailed explanation of the excitation functions related to proton elastic scattering for ^{12}C and $^{14,15}O$ nuclei, with a high degree of accuracy. The first resonance in each excitation function is identified as the *s*-state resonance of the mean-field theory. The role of the spin-spin component of the optical potential is discussed. The framework offers an effective approach to understanding nuclear scattering for energies that are near the emission threshold, making it a practical and useful method for future studies.

Keywords:

Elastic scattering, Resonance, Optical potential

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D18.03

Evaluation of neutron induced nuclear reaction cross section for plutonium isotopes

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Abstract:

The evaluation of neutron-induced reaction cross sections for plutonium isotopes is an active area of nuclear data research, and significant progress has been made in recent years. However, there are still some uncertainties in the cross section data for high energy neutrons.
Especially, there are large discrepancies among the current available libraries, such as ENDF/B-VIII.0, JEFF-3.3 and JENDL-5.0, for cross section and fission neutron spectra .
In this study, a new evaluation file with the ENDF-6 format including the optimal fission cross-section and spectrum was produced by utilizing several fission models implemented in the Hauser-Feshbach model codes, EMPIRE and CoH_3. The results of this study were compared with the latest nuclear reaction libraries ENDF/B-VIII.0, JEFF-3.3 and JENDL-5.0.

This work was supported by the KAERI Institutional Program.

Keywords:

nuclear reaction, nuclear data, nuclear evaluation, nuclear fission

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2023-04-19 - 2023-04-21

D18.04

Calculation of Fission Product Yield Using Semi-empirical Model

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Abstract:

Fission product yields (FPY) of neutron induced fission of Uranium are calculated using a semi-empirical model recently developed. FPYs are assumed to be proportional to the number of configuration at excitation energy of a compound nucleus. Excitation energies are calculated as the difference between the incident energy and a modified fission barrier height in which the macropotential correction and shell effect correction are added to liquid-drop model's fission barrier height. A previous model recently developed has ten parameters in which 6 parameters are adjustable. In our model, the previous model is modified by using an experimental energy level density parameter. Therefore, the number of adjustable parameters are reduced to five. Five adjustable parameters are then calculated by fitting to ENDF/B-VIII.0 fission yield data of Uranium 232 to 238. These calculated parameters are used to calculate FPYs. Calculated FPYs are compared with experimental data and evaluated data and are found to be in a good agreement.

Keywords:

Nuclear Fission, Fission Product Yield

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D18.05

모니터핵반응을 이용한 양성자 빔 플럭스 측정

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Abstract:

양성자 유도 핵반응으로부터 생성되는 방사성핵종의 단면적을 결정하기 위해서는 정확한 양성자 빔 플럭스 측정이 필요하다. 양성자 방사화 실험에서 빔의 플럭스 측정은 흔히 패러데이컵을 이용하거나 잘 알려진 모니터 핵반응을 사용한다. IAEA에서 권고하는 모니터 핵반응은 양성자의 경우 총 11개의 핵반응이 있으며, 우리는 Ai, Ti, Ni을 사용하여 양성자 빔의 플럭스를 결정하였다. 실험은 경주 양성자가속기에서 수행되었으며, Al, Ti와 Ni을 적층한 시료에 57 MeV 양성자 빔을 20분 조사하였다. 양성자방사화에 의해 방출되는 붕괴감마선은 고분해능 감마선 검출기를 사용하여 관심있는 핵종의 반감기를 고려하여 반복 측정되었다. IAEA에서 권고하는 모니터 핵반응으로 구한 양성자 빔 플럭스는 자체 제작한 샘플 홀더가 장착된 패러데이컵에 의해 얻어진 결과와 비교하였다.

Keywords:

모니터핵반응

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D19.01

AMoRE-I alpha background analysis

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Abstract:

AMoRE experiments are searching for the neutrinoless double-beta decay of Mo-100 with the molybdenum-based bolometric scintillation detectors operating at a few tens milli-kelvin temperatures. It is necessary to analyze the alpha events to estimate the internal background of the crystals. The backgrounds of concern arise from beta and gamma decays. Most of these decays occur in one of a few sub-chain decay sequences within longer decay chains, with the sub-chain equilibriums supported by long-lived isotopes at the start of each sub-chain. The most relevant sub-chains include sequences of multiple alpha decays. Using appropriate coincidence criteria, alpha decay events specific to a particular sub-chain can be identified and separated from other alpha events that have overlapping energy distributions.
An analysis method using this concept and ana estimated value of the internal alpha background of the crystal are presented.

Keywords:

double beta decay, scintillation crystal, radioactive background, alpha decay

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2023-04-19 - 2023-04-21

D19.02

Status of AMoRE-I Analysis Results

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Abstract:

AMoRE is an international project to search for the neutrinoless double beta decay of ^{100}Mo in enriched Mo-based scintillating crystals read-out by metallic magnetic calorimeters (MMCs) in a mK-scale cryogenic system. The project aims for zero background in the region of interest near 3.034 MeV. Simultaneous measurements of phonon and photon signals from the MMC are performed to achieve high energy resolution and good rejection of alpha-induced backgrounds. AMoRE-I, a phase following the completed AMoRE-pilot, operates with thirteen $^{48depleted}Ca^{100}MoO_4$ and five $Li_2{}^{100}MoO_4$ crystals in the Yangyang underground laboratory. Since the beginning of the AMoRE-I in Sep. 2020, we have accumulated more than 500 days of stable physics data. As a result of more prolonged exposure and enhanced noise suppression, we have achieved a lower background level. Also, the more improved analysis method of ROI estimation and the fine calculation and cut efficiency allow us a new higher half-life limit. We will report a new result from the data of the AMoRE-I operation period and present the current status of the experiment together with recently improved analysis techniques.

Keywords:

AMoRE, Underground Experiment, Neutrinoless Double Beta Decay

D19.03

Multi-crystal-hit study for the 2νββ decay of ^{100}Mo to the exited state of ^{100}Ru at AMoRE-I

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Abstract:

Studying the *2νββ* decay to excited states can have strengths in the research of bosonic neutrino and contribute to the studies of SSD and HSD models. The AMoRE-I, located at Yangyang underground laboratory(Korea), is the first phase of AMoRE (Advanced Molybdenum-based Rare process Experiment). It comprises four towers with thirteen $Ca^{100}MoO_4$ crystals and five $Li_2{}^{100}MoO_4$ crystals in total. This multi-channel structure has the advantage of studying the *2νββ* decay of ^{100}Mo to excited states.
In this study, a data set of 2.93 kg · year ^{100}Mo exposure time is used, and the preliminary measured value of the ^{100}Mo half-life for the *2νββ* decay to the 0_1^+ state is $7.24 \pm 0.93 \times 10^{20}$ years.

Keywords:

AMoRE, bosonic neutrino, 2νββ decay to excited state, 100Mo

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2023-04-19 - 2023-04-21

D19.04

An experimental search for keV sterile neutrinos

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Abstract:

We developed a simple small-scale experiment to measure the beta decay spectrum of ^{3}H. This research investigates the presence of sterile neutrinos in the keV region. Tritium nuclei were embedded in a 1$\times$1$\times$1 cm^3 LiF crystal from the ^{6}Li(n,α)^{3}H reaction. The energy of the beta electrons absorbed in the LiF crystal was measured with a magnetic micro-calorimeter at mK temperatures. We present a current status for energy calibration study, in particular, the position-dependence in the crystal for collimated events from a low-energy x-ray source. Moreover, we present the respective sensitivity for keV search in a future experiment.

Keywords:

tritium, sterile neutrino, MMC

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2023-04-19 - 2023-04-21

D19.05

Preliminary Performance of AMoRE-II muon detector

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Abstract:

AMoRE-II is an experiment to search for the neutrinoless double beta decay of ^{100}Mo in molybdate crystal (Li_2MoO_4 - LMO) with a cryogenic setup. It will be conducted in an underground laboratory Yemilab in Jeongseon. To achieve the desired sensitivity of AMoRE-II, the muon- induced background should be below 10^{-5} counts/keV/kg/year. Two types of muon veto detectors, plastic scintillators and water Cherenkov detector have been installed at Yemilab. The result of the preliminary performance test will be presented.

Keywords:

Muon veto, double beta decay

D19.06

Extended search result of the CAPP18T haloscope

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Abstract:

We report an extended search for the axion dark matter using the CAPP18T haloscope. The CAPP18T experiment adopts innovative technologies of a High-Temperature Superconducting (HTS) magnet and a Josephson Parametric Converter. We experienced a magnet quench during ramp down just after run-1. The inspection of the system revealed that the magnet and the cavity got damaged. After run-1, the CAPP18T system was moved to KAIST Munji campus and reconstructed. The manufacturer repaired the 18T magnet. The system reconstruction also included rebuilding a new cavity, improving the impedance matching of the RF chain, and readjusting the tuning rod to the cavity for improved thermal contact. The total system noise temperature became lower than run-1. The coupling between the cavity and the strong antenna β was set to be ~ 2 for run-2, to enhance the axion search scanning speed. In this talk, we will report the run-2 results.

Keywords:

Dark Matter, Axion, Axion Haloscope, HTS Magnet

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2023-04-19 - 2023-04-21

D19.07

High-frequency axion search with a novel multiple-cell cavity and a Josephson parametric amplifier

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Abstract:

Axions are hypothetical particles proposed to resolve the strong CP problem, and their invisible properties make them a compelling candidate for cold dark matter. The cavity haloscope is widely used for direct detection of microwave photons converted from dark matter axions. For high-frequency axion searches, a large cavity volume and low detector noise are crucial to improve experimental performance. In this talk, we discuss an axion experiment designed for a search in the frequency range of above 5 GHz. Featuring a novel multiple cell cavity and a high-performance Josephson parametric amplifier, the experiment will be sensitive to the KSVZ model.

Keywords:

Axion, Haloscope, Dark Matter, JPA, Multiple cell cavity

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

D19.08

Tunable photonic crystal haloscope for high-mass axion searches

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Abstract:

The axion is a theoretically well-motivated particle that could address both the strong CP problem and the dark matter mystery. The cavity haloscope offers the most sensitive experimental method, but detection efficiency is sacrificed at high frequencies (masses) mainly due to volume loss and low quality factors. Recently IBS-CAPP has developed a photonic crystal haloscope that can extend the search frequency beyond 10 GHz (40 ueV in mass) while addressing these issues. It features an array of periodically deployed dielectric rods in an ordinary cavity, with a kirigami auxetic structure implemented for frequency tuning. Here, we present the characteristics of this novel cavity design and demonstrate the experimental feasibility.

Keywords:

Axion, Dark matter, Haloscope, Photonic crystal

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

D19.09

New detection method for axion dark matter using interference-based variance amplification

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Abstract:

In searches for dark matter axions, quantum noise limited amplifiers and/or photon counters have been developed to minimize the system noise. Among those, bolometer-based photon counters are sensitive detectors of millimeter waves while offering a wide bandwidth. However, their noise equivalent powers are relatively too large to apply to axion searches in practice. In this talk, we propose a new detection method that effectively lowers the noise level to near the standard quantum limit. This scheme utilizes the interference of the axion signal photons with injected probe photons in order to amplify the variance of the output power. We introduce the basic concept of the method and compare its performance (scan rate) with that of an ordinary detection scheme.

Keywords:

axion, microwave, haloscope

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

Solid and liquid saturable absorbers for tunable pulsed fiber laser

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Abstract:

The saturable absorber(SA) is essential in passively generating laser pulses. In recent decades, there has been an extensive research effort to develop ultrafast pulsed fiber lasers that exploit nonlinear optical interactions in novel materials using various deposition methods. In particular, a variety of solid materials, including two-dimensional materials, carbon materials, and topological insulators, have been intensively studied to find their nonlinear optical applications in SAs. Recently, liquid SAs based on deionized water and alcohol are investigated for their clear advantages, simplicity of fabrication, high optical damage threshold, efficient thermal diffusion, and broad bandwidth of operation. Despite these advantages, spectrally tunable Q-switching pulse has not been implemented in fiber ring laser configurations using liquid SAs.

In this talk, I will present new fabrication methods for solid and liquid saturable absorbers. Then, I demonstrate a tunable wavelength microsecond Q-switching erbium-doped fiber laser based on the proposed SAs with a Fabry-Perot interferometer tunable filter.

Keywords:

Fiber laser, Saturable absorber,Graphene oxide, Deionized water, Fabry-Perot interferometer filter

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

E1.02

Development of ultrafast laser system for dermatology based on Yb-fiber/Yb:YAG thin-rod

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Abstract:

The purpose of laser treatment for skin is delivering energy to target tissues without surrounding damages. Mechanisms of the laser treatment is based on a selective photothermolysis and it demands short pulse durations below thermal relaxation time(TRT) and stress relaxation time(SRT). Among laser tissue interactions, plasma induced ablation, which requires high peak intensity and low pulse energy simultaneously, is considered as an ideal phenomenom for selective photothermolysis because it is suitable for minimizing damages of adjacent tissues. In case of 15-nm-size melanin granule, SRT is about 10 ps, and it means that ultrafast laser with pulse duration below 10 ps will be effective to the laser treatment of melanin.
In this research, ultrafast laser system consists of Yb fiber oscillator, Yb-fiber amplifier, and Yb:YAG thin-rod amplifier is developed. The laser exhibits output power of 30.5 W, center wavelength of 1030.4 nm, repetition rate of 495 kHz, pulse energy of 61.6 μJ, pulse duration of 721 fs, respectively.

Keywords:

Ultrafast laser, dissipative soliton, fiber amplifier, Yb:YAG thin-rod

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

E1.03

Non-resonant lasing in a deep-hole scattering cavity

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Abstract:

Random lasers have not been widely used because of the low pumping efficiency and omnidirectionality of laser emission. To mitigate these problems, we propose a deep hole made of scattering gain material as a cavity for a power-efficient and easy-to-fabricate random laser. Owing to strong diffuse reflections on the inner surface of the cavity, light is efficiently trapped inside the cavity. In addition, lasing characteristics including directionality can be easily tuned by adjusting the diameter and depth of the hole. Compared to our previous spherical design, the new design provides much lower threshold power and higher efficiency due to efficient coupling and scalable cavity design. Our new laser is readily realized by drilling a small hole on diffusive gain media and placing a coupling lens in front of the hole which focuses pump light into the hole and collimates the laser beam emitting from the hole at the same time.

Keywords:

Random laser, Non-resonant feedback, Scattering cavity

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2023-04-19 - 2023-04-21

E4.01

Contrast enhanced STED optical nanoscopy

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Abstract:

Stimulated emission depletion (STED) super-resolution microscopy (or optical nanoscopy) offers significant enhancement of optical resolution compared to conventional microscopy. To achieve resolution beyond the diffraction-limit, STED nanoscopy uses orders of magnitude (roughly ~10^5) more photons than the conventional confocal microscopy. Those additional 'STED' photons, which are designed to deplete the fluorescence at the periphery of focus, can induce unintended background noise. Increased low spatial frequency background noise decreases the signal-to-background ratio (SBR) and deteriorates the image quality by masking the high spatial frequency, super-resolved signal. Here, we report a simple and easy-to-implement method, which we call polarization switching STED (psSTED), that can efficiently suppress the low spatial frequency background appearing in STED images. In psSTED, we switch the STED beam polarization between two different circularly polarized states to record a regular STED image and a background noise image. A simple, unambiguous subtraction process between these two images accomplishes a background-free super-resolved image. With both simulation and experimentation, we demonstrate psSTED works universally for different STED conditions. Finally, we compare the performance of psSTED with other state-of-the-art background subtraction methods and highlight its capability of efficient background suppression with a much simpler hardware implementation.

Keywords:

Super-resolution microscopy, STED, Background noise

E4.02

Mass Photometry: probing the mass of single molecules from images

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Abstract:

A coherent light source illuminates a solution of single molecules through a simple wide-field microscopy setup. While the vast majority of the light is transmitted forward, a small portion is reflected back to the objective lens, and an even tinier fraction resulting from the back-scattering of the molecules is collected. Resulting from the interaction of the latter two, a faint interference pattern is captured live on camera: be it nucleic acid, single proteins, or a duo of interacting proteins, their mass can be assessed directly from the contrast of those interference rings. Such is the concept of mass photometry.
iSCAT microscopy phase masks and video processing are part of the arsenal of clever techniques used to then extract this barely detectable signal from the noisy, speckle-ridden image.
Despite being recent, mass photometry has already been widely adopted as a new, complementary tool for the study of single molecules.

Keywords:

Mass photometry, light scattering, iSCAT, microscopy, interferometry, protein-protein interaction, single molecules, membrane proteins, nucleic acids

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

E5.01

The Role of Symmetry on Spin Hall Conductivity of W-N alloys

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Abstract:

W alloys have attracted attention due to their large spin Hall angle (θ_{SH}), which is promising for spin-orbit torque devices [1,2]. Recently, efforts have been devoted to increase θ_{SH} in b-W by doping and alloying [3,4]. Inspired by a recent experimental study of W-N alloys [5], we investigate spin Hall conductivities (σ_{xy}) of W-N alloys using first-principles calculations. Particularly, W_2N shows the largest σ_{xy} of -966, enhanced by 18 % over b-W. The large σ_{xy} of W_2N is elucidated by large spin Berry curvature from an anti-crossing point around 2/3MΓ. Furthermore, the lifted degeneracy is examined using group theory, which involves the Fermi level crossing the gap. This allows only the negative spin Berry curvature to persist, which leads to a large σ_{xy} value.

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Keywords:

spin Hall angle, Spin Hall conductivity, first-principles calculations, spin Berry curvature

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2023-04-19 - 2023-04-21

E5.02

Enhancement of the Rashba Effect in a Conducting $SrTiO_3$ Surface by Capping Layer

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Abstract:

The Rashba spin-orbit interaction is a physical phenomenon observed in condensed matter systems. It is a result of the inherent structural asymmetry of materials and leads to a coupling between the spin and momentum of electrons in the band structure, which can lead to various electrical properties. One of the electrical manifestations is nonreciprocal charge transport, which manifests a directional electron flow under broken time-reversal and inversion symmetry. This phenomenon has potential applications in the development of various electronic devices, including rectifying devices and spin-based logic devices. Here, we present the nonreciprocal charge transport in conducting $SrTiO_3$ (001) surface due to the Rashba-type spin-orbit interaction. We generated a conductive STO (001) surface by introducing oxygen vacancies through Ar^+ irradiation and probed the nonreciprocal charge transport signal using second harmonic voltage measurement with AC current. The results demonstrate clear nonreciprocal charge transport at low temperature in the Ar^+ irradiated sample, with the strength of the nonreciprocal signal being highly dependent on the irradiation time. Additionally, the nonreciprocal signal was significantly enhanced by adding a MoO_3 capping layer on the conductive STO surface. Our work presents controlling the Rashba spin-orbit interaction by external factor, which is desirable in applications of oxide spin-orbitronics.

Keywords:

Rashba effect, nonreciprocal charge transport, spin—orbit coupling, SrTiO3, oxide surface

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

E5.03

Unraveling the magnetic properties governing domain-wall dynamics in ferromagnets: a peculiar reversal phenomenon

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Abstract:

The dynamic behavior of elastic interfaces in ferromagnets under driving forces has been extensively studied for fundamental understanding of physics and as a promising candidate for next-generation spin memory and logic devices [1, 2]. There are two distinct dynamic regimes for domain walls (DWs): thermally activated DW creep motion and dissipative viscous DW flow motion [3]. Despite remarkable efforts to understand how DW motion depends on external driving forces, the role of magnetic properties on DW motion for the different dynamic regimes remains elusive. In this study, we experimentally observed that the dynamics of magnetic DWs are governed by distinct key factors for different dynamic regimes, resulting in a peculiar phenomenon of reversal in the speed of DWs with respect to ferromagnetic thickness between the two dynamic regimes. Our findings provide a better understanding of how magnetic properties and volume influence DW dynamics and offer a simple rule for controlling DW motion. Details will be discussed in the presentation.

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Keywords:

Magnetic Domain-Wall, dynamic regime

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E5.04

Pt/Co/W 비대칭 인공초격자의 라쉬바 효과와 그에 기인한 스핀 전류 발생 연구

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Abstract:

스핀-궤도 상호작용이 큰 비자성체 물질과 강자성체 물질의 이종접합구조는 스핀 전류에 의한 자화 (magnetization) 제어 연구에 중요한 단위구조체이다. 주기율표 상의 원소 중에는 원자 번호가 큰 Pt, W와 같은 5d 금속에서 자화 제어가 가능한 수준의 스핀 전류가 보고되어 왔다. 또한, Bi2Se3와 같은 위상절연체, WTe_2와 같은 저차원 반데르발스 물질들에서도 자화제어가 가능한 스핀 전류 발생이 보고되는 등, 자화를 효율적으로 제어하기 위해 10^{10} A/m^2 이하의 스위칭 전류밀도를 달성하기 위한 노력이 이어지고 있다. 여기서 중요한 점은 개발되는 이종접합구조가 Spin-orbit torque (SOT) magnetic random access memory (MRAM)의 단위 구조인 자기 터널 접합 소자 구조에 적합해야 한다는 것이며, 응용을 위해서는 CMOS 공정에도 적합해야한다. 즉, 대면적 공정이 가능한 물질이어야 한다. 이러한 관점에서 위상절연체, 반데르발스 물질들은 MRAM 개발에 활용되기 어렵다고 할 수 있다.
본 연구에서는 원자수준의 박막 증착 기술을 이용하여 제작된 W/Co/Pt 비대칭 인공 초격자에서 스핀 전류가 기존 SOT-MRAM에서 가장 중요하게 활용될 Pt 대비 300% 이상 향상된 스핀-전류가 발생함을 보이고 그 원인에 대하여 논의하고자 한다.

Keywords:

스핀 전류, 라쉬바 효과, 비대칭 인공초격자

2023 KPS Spring Meeting
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E6.01

Delocalization transition in non-Hermitian quasicrystals

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Abstract:

The quasicrystals with exotic ordered tiling patterns without periodic length scales have been actively studied for their abundant localization properties of the quantum states. One of the famous results which have been discovered are critical states showing novel scaling behaviors, neither exponential decay nor sinusoidal oscillation. Such unique wave localization characteristics which are not emergent in the conventional periodic systems have potentials to open various experimental applications such as quantum transports. However, since the systematic way to control the localization characteristics of the quantum states in the quasicrystals has been barely understood, the experimental utilities of the quasicrystal have been limited. In this work, we focus on a non-Hermitian quasicrystals where the hopping phase exists non-reciprocally and discuss the evolution of localization characteristics of the quantum states. Importantly, in contrast to the non-Hermitian skin effect, the non-Hermiticity encoded in the hopping phase factor gives rise to the delocalization of the states. Furthermore, by quantifying the localization in the spectrum via inverse participation ratio and fractal dimension, we demonstrate that the non-Hermitian hopping phase results in delicate controllability of the localization characteristics of quantum states. Our work offers novel utility of non-Hermiticity for controlling wave localization, and finally we also discuss the relevant experimental applications.

Keywords:

Delocalization, non-Hermitian system, Quasicrystal

E6.02

Detecting the amplitude squared signal for dynamic mode imaging in atomic force microscopes

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Abstract:

Dynamic mode imaging with high-speed atomic force microscopes (HS-AFMs) faces speed limitations due to the need for accurate cantilever oscillation amplitude estimation. Recent advances using the derivative and square of the oscillation signal have led to large-bandwidth detectors with no latency in theory. In the presence of noise and output-of-band signals, the performance of these methods is likely to deteriorate. Lock-in detectors are commonly used for signal estimation in noisy backgrounds, but their bandwidth is limited, resulting in significant latency. To overcome these limitations, we propose using the squared amplitude signal and signal derivatives instead of phase shifters in the detection path to extend the bandwidth of lock-in detectors and reduce latency. We evaluate our method's performance against conventional lock-in architectures in terms of bandwidth and noise performance.

Keywords:

high-speed atomic force microscopy, lock-in detection, cantilever amplitude detection

Infrared Spectroscopic Study of Semimetal LaSb: Coexistence of Two Carriers with Ultrahigh- and Moderate-Mobility.

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Abstract:

우리는 LaSb라는 단순 입방 구조의 준금속 물질에 대해 10 K 온도에서 광 반사율 측정 실험을 진행했다. 이 광 실험에서 두 개의 명확한 Drude 피크가 관측되었다. D1 피크는 130 cm^{-1}의 적당한 산란율을 가졌지만, D2 피크는 0.116 cm^{-1}의 매우 낮은 산란율을 보였다. D2 피크는 4.02×10^5 cm^2 V^{-1} s^{-1} 의 매우 높은 이동도와 0.2 의 유효 질량을 가지며, D1 피크의 이동도인 1.59×10^2 cm^2 V^{-1} s^{-1} 와 대조적이다.
이 물질의 특징 중 하나는 이동 속도가 현저하게 다른 두 캐리어가 공존한다는 것이다. 이 두 캐리어의 기원을 알아보기 위해, 우리는 광 실험을 통해 얻어낸 각 Drude 피크의 광학적 스펙트럼 가중치를 계산했다. 그리고 앞서 계산한 가중치 값과 LaSb에서 이미 알려진 운반자들인 덩어리 전자 밴드, 홀 밴드, 선형 전자 밴드, 그리고 표면의 Dirac-like 밴드의 광학적 스펙트럼 가중치와 비교했다.
우리의 계산은 완벽하지는 않았지만, D1 피크를 적당한 전하 이동도를 가진 덩어리 전자 밴드에 할당하고, D2 피크를 초고 이동도를 가진 덩어리 홀 밴드에 할당함으로써 스펙트럼 가중치에서 최적의 일치를 얻어냈다. 전하 이동도가 현저하게 다른 두 캐리어의 공존은 LaSb의 전기, 자기 수송 및 열전도 특성에 중요한 영향을 미칠 수 있다. 그러나 이러한 현상을 완전히 이해하려면 더 많은 연구가 필요하다.

Keywords:

Semimetal, Optical conductivity, LaSb, Two band model, Ultrahigh mobility

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E7.01

Hund Metallic Behavior in Cubic $BaRuO_3$ Thin Film

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Abstract:

Strongly correlated system has been actively studied due to its distinctive emergent properties. In such system, combination between several degrees of freedom realizes novel quantum phenomena. For instance, parameters such as bandwidth, *W*, band filling, *n*, and on-site Coulomb repulsion, *U* are well known to be origins of anomalies in physical behavior like Mott transition, heavy fermion behavior, quantum Hall effect, and High T_C superconductivity. Recently, there is increasing effort to realize Hund metal, in which Hund's coupling *J* significantly affects the metallic properties. Hund metal signifies the role of *J*, in addition to *W*, *n*, *U*, in characterizing the metallic state. Cubic $BaRuO_3$ is theoretically proposed to be a Hund metal, yet, the structural symmetry of natural $BaRuO_3$ crystals are all hexagonal.[1,2] In this presentation, we show the stabilization of metastable cubic phase of $BaRuO_3$ epitaxial thin film by pulsed laser epitaxy. The 4-fold symmetry of the system was confirmed through synchrotron X-ray diffraction. To understand the Hund metallic behavior, we measured temperature dependent optical spectra. We deduce essential information of interacting metallic system including self-energy, quasiparticle weight, as functions of excitation energy. Our experimental proposal of the new Hund metal can provide deeper understanding on the strongly correlated Ruthenates.

[1] S. A. Lee *et al., Adv. Electron. Mater*, **7**, 4, (2021)
[2] N. Dasari *et al.*, *Phys. Rev. B,* **94**, 085143, (2016)

Keywords:

Strongly correlated oxide, Hund coupling, Thin film, Ruthenates

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E7.02

Raman spectroscopy of the magnetic excitations in NiO nanoparticles

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Abstract:

Understanding the magnetic excitations is of great significance in NiO applications from both the fundamental and applied perspectives. We investigate the Raman spectra of the antiferromagnetically ordered states of NiO nanoparticles of varied oxygen contents. The two-magnon (2M) peak intensity increases as the oxygen concentration decreases in NiO nanoparticles. Raman spectroscopy reveals the change of the splitting of anisotropic transverse optical (TO) phonon with different oxygen contents. We have shown that the varied oxygen contents underlie both the change in the 2M intensity and the splitting of TO phonon in the NiO nanoparticles.
Two-dimensional correlation spectroscopy (2D-COS) analyses of the temperature-dependent Raman spectra of NiO nanoparticles are also performed. The analyses show that the TO phonon anisotropy is induced by the magnetic ordering. The spin-phonon coupling in NiO nanoparticles is clearly visualized by the 2D-COS analyses. Our work gains detailed insights into the antiferromagnetic (AFM) ordering states in NiO nanoparticles.

Keywords:

NiO nanoparticles, Raman Spectroscopy, two-magnon, Two-dimensional correlation spectroscopy, oxygen contents

2023 KPS Spring Meeting
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E7.03

Glassy Behaviors of Mixed Hybrid Lead Halide Perovskites Probed by Brillouin Spectroscopy

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Abstract:

The past few years have observed a significant rise in curiosity in mixed hybrid lead halide perovskites as potential materials for various optoelectronic applications due to their tunable properties resulting from the hybridization of inorganic and organic elements [1]. Nevertheless, the crystal structure and phase behavior of mixed hybrid lead halide perovskites—which may be influenced by a number of variables, including temperature, pressure, and structural disorder—strongly influence their characteristics. In this study, we created two mixed hybrid lead halide perovskites, $MAPbBr_{0.5}Cl_{2.5}$ and $MAPbBr_{1.5}Cl_{1.5}$ and used Brillouin spectroscopy—a non-destructive method that reveals a material's elastic properties—to examine their phase transitions.
We found that the $MAPbBr_{0.5}Cl_{2.5}$ sample showed distinct acoustic anomalies in the Brillouin spectra at temperatures around -90°C and -125°C, indicating the presence of phase transitions. In contrast, the $MAPbBr_{1.5}Cl_{1.5}$ sample showed diffusive phase transitions, characterized by the gradual broadening, and shifting of the Brillouin peaks. Contrary to that, pure halide components such as $MAPbCl_3$ show distinct phase transitions [3]. It is noteworthy that the degree of substitutional disorder exerts a notable influence on phase behavior. As an instance, in the case of the composition $MAPbBr_{0.5}Cl_{2.5}$, which is in proximity to the chloride end members within this system, distinct phase transitions are observed at slightly lower temperatures compared to $MAPbCl_3$. Conversely, the intermediate composition exhibits a diffusive glassy behavior without discontinuous anomalies [4]. The smearing out of phase transition might be due to increased structural or chemical disorder in this mixed hybrid perovskite. Altogether, our work offers insightful information about the phase behavior of mixed hybrid lead halide perovskites.

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[2] Jeon NJ, Noh JH, Kim YC, Yang WS, Ryu S, Seok SI. Solvent engineering for high-performance inorganic–organic hybrid perovskite solar cells. Nature materials. 2014 Sep;13(9):897-903.
[3] Naqvi FH, Ko JH. Structural Phase Transitions and Thermal Degradation Process of $MAPbCl_3$ Single Crystals Studied by Raman and Brillouin Scattering. Materials. 2022 Nov 17;15(22):8151.
[4] Shahrokhi S, Dubajic M, Dai ZZ, Bhattacharyya S, Mole RA, Rule KC, Bhadbhade M, Tian R, Mussakhanuly N, Guan X, Yin Y. Anomalous Structural Evolution and Glassy Lattice in Mixed-Halide Hybrid Perovskites. Small. 2022 May;18(21):2200847.

Keywords:

Mixed hybrid halides, Brillouin spectroscopy, Phase transitions, Glassy lattice

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E7.04

Investigation of Work Function Variation in Vanadium Dioxide Insulating Phases Grown on GaN Substrates

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Abstract:

Vanadium dioxide has great potential for electronic and optoelectronic applications, such as smart windows, memory devices, sensors, and photodetectors. The work function of VO_2 thin films is an important factor that can affect the performance of these devices. There is still a lack of understanding about the work function of VO_2 thin films. We used the Kelvin probe force microscopy to investigate the work function of diverse phases of VO_2 thin films. The films were characterized by X-ray diffraction and were fabricated using an RF sputtering system. The work function of VO_2 thin films varies depending on their insulating phase, with the highest work function observed in the monoclinic (M2) phase, followed by the triclinic (T) phase and the monoclinic (M1) phase. Variations in oxygen dioxide levels are to blame for the observed differences in work function among the M1, T, and M2 phases. The utility of the study of VO_2 thin films and the insights into the development of VO_2 based electronic devices were demonstrated by our findings.

Keywords:

Vanadium Dioxide, Thin Films, M2 phase, Work function, Strain

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E8.01

Magnetic wallpaper Dirac fermions and topological magnetic Dirac insulators

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Abstract:

Topological crystalline insulators (TCIs) can host surface states whose anomalous band structure inherits the characteristics of the crystalline symmetry that protects the bulk topology. Especially in magnetic crystals, the diversity of magnetic crystalline symmetries indicates the potential to achieve novel magnetic TCIs with distinct surface characteristics. Here, we propose a topological magnetic Dirac insulator (TMDI), whose two-dimensional (2D) surface hosts fourfold-degenerate Dirac fermions protected by either the $p^{'}_{c}4mm$ or $p4^{'}g^{'}m$ magnetic wallpaper group (MWG). The bulk band topology of TMDIs is protected by diagonal mirror symmetries, which give chiral dispersion of surface Dirac fermions and mirror-protected hinge modes. We also propose a class of candidate materials for TMDIs, including $Nd_4Te_8Cl_4O_{20}$ and DyB_4, based on first-principles calculations and construct a general scheme to search for TMDIs using the space group symmetry of paramagnetic parent states. We believe that our theoretical discovery of TMDIs and their anomalous surface Dirac fermions will facilitate future research on new magnetic TCIs and illustrate a distinct way to achieve anomalous surface states in magnetic crystals.

Keywords:

topological magnetic Dirac insulator, fourfold-degenerate Dirac fermions, chiral surface state, mirror Chern number

E8.02

Tunable magnetic ordering at the interface of all-van der Waals layered heterostructures

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Abstract:

Spin-orbit coupling (SOC) is core to control the conversion efficiency, complex magnetic spin structures, and spin torque. Heterostructures of inherently large SOC van der Waals (vdW)-transition metal dichalcogenides (TMDs)and magnetic materials possessing spin textures have attracted huge interest. In this study, we use all-van der Waals-layered heterostructure, Fe_3GeTe_2 (FGT)/monolayer $W_{1-x}V_xSe_2$, (x = 0, 0.05 and 0.15), for SOC strength effect on the magnetic ordering of FGT. We found that various magnetic ordering such as spin-flop, spin-flip and inverted magnetization is induced as varying V-doping concentration. We further demonstrate a sharp magnetic switching from antiferromagnetic to ferromagnetic in FGT/$W_{0.95}V_{0.05}Se_2$, which is characteristic of the synthetic antiferromagnetic structure. Our proof-of-concept result offers the possibility of interface-tailoring spintronics including two-dimensional magnetoresistive random access memory toggle switching.

Keywords:

Two-dimensional vdW heterostructure, Tunable magnetic order, Proximity effect, Spin-orbit coupling, Spintronics

2023 KPS Spring Meeting
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E8.03

Direct correlation between spin states and magnetic torques in a room-temperature van der Waals antiferromagnet

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Abstract:

Explorations of van der Waals (vdW) antiferromagnets have revealed new avenues for understanding fundamentals of highly anisotropic magnetism and realizing spin-based functional properties. However, there is a serious limitation to the feasibility of spintronic applications at room temperature due to the lack of suitable materials. In this work, we have examined anisotropic magnetic characteristics of Co-doped Fe_5GeTe_2, a high-T_N antiferromagnet with T_N = 350 K, where magnetic multilayers are intrinsically formed. Our spin-model calculations with uniaxial anisotropy quantified magneto-crystalline anisotropy energy and visualized the specific spin arrangements varying in the presence of rotating magnetic fields at room temperature. We further show that the spin configurations can be profoundly relevant to the distinctive evolution of magnetic torques in different magnetic phases. Our progressed approach offers the high-T_N vdW antiferromagnet as a magnetic platform to establish room-temperature spin-processing functionalities.

Keywords:

van der Waals, Spintronics, Antiferromagnet, Single crystal

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E8.04

Ca_2RuO_4의 전자 여기에 대한 편광각 의존 라만 연구

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Abstract:

스핀 강상관계가 있는 대부분의 물질들은 하이젠베르크 모델(Heisenberg model)을 사용하여 자성을 설명합니다. 하지만 이 모델과 맞지 않는, 바닥 상태와 스핀 정렬 여부 사이에 불일치가 있는 물질들의 경우 추가적인 접근과 연구가 필요합니다. 4d 오비탈의 전자를 가진 자성 물질들은 스핀-궤도 결합(SOC)과 반자성(AFM) 간의 관계를 연구하기에 좋은 환경을 제공합니다. 현재 Ca_2RuO_4는 SOC와 자성에 대한 연구 물질들 중 하나입니다. Ru^{4+} 이온은 주위 원소와 공유 결합 후 4d 오비탈에 4개의 전자를 제공하며 Ca_2RuO_4 결정 내에서 자성을 결정하는데 주요한 역할을 합니다. 또한 Ru^{4+} 이온의 스핀은 자성 외에도 마그논(Magnon)을 형성하며, 이는 스핀 강상관계 이해에 중요합니다. 이 시점에서, 라만 분광법은 마그논과 같은 준입자(quasi-particles)를 탐지하는 데 효과적인 도구입니다. 각도 의존 라만 분광법을 사용한 실험에서, Ca_2RuO_4의 마그논 이방성은 레이저 에너지에 따라 달라짐을 발견했습니다. 2.33, 2.21 및 1.88 eV 레이저 사이에서 나타나는 이방성은 아직 명확히 설명되지 않았지만, d_{yz}와 d_{zx}에서 유도된 에너지 준위가 레이저의 에너지와 공진하여 반대칭 라만 과정(Anti-symmetric Raman process)을 일으켜 발생한 것으로 보입니다.

Keywords:

Ca2RuO4, 마그논(Magnon), 라만 분광법(Raman spectroscopy), 반대칭 라만 텐서(Anti-symmetric Raman tensor)

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E9.01

Data-driven multiscale models to understand and design electrocatalysts

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Abstract:

Understanding chemical reactions at the electrochemical interfaces is challenging due to the multiscale nature of the phenomena, theoretical descriptions of which would require the prediction of adsorbate binding, effects of potential, solvation, kinetics, and etc. In this talk, I will present some of our recent efforts to understand electrochemical reactions such as nitrogen reduction and hydrogen evolution reactions, by combining machine learning and multiscale strategies. We present a simple and versatile representation, applicable to any deep-learning models, to predict the binding energy of small molecules, and apply the model to study the extraordinary mass activity of jagged Pt nanowires toward hydrogen evolution reaction. Effect of potential is demonstrated to be critical to properly understand several electrochemical reactions. I will close my talk with some discussions on the synthesizability of inorganic materials to bridge the gap between computationally designed catalysts and their actual synthetic feasibility in the laboratory.

Keywords:

Electrocatalysis, machine learning

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E9.02

Electrochemical stability of metal oxides from first-principles

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Abstract:

In electrochemistry, the stability of solid electrode materials depends critically on the applied electrode potential and pH. Metal oxides, for example, are partially or fully reduced under cathodic conditions which determines the bulk and surface composition, and thus the ensemble of active sites. In this work, we first present a screening of DFT functionals for the prediction of metal oxide formation energies and suggest the most promising candidate. Then we move our focus to copper and ceria, as well as copper-ceria interfaces which have been recently presented as promising electrocatalysts. We investigate their thermodynamic stability under electrochemical conditions while utilizing state-of-the-art machine learning tools in combination with global geometry optimization to screen the wide material phase space. From this, we compare to experimental *in situ* X-ray data and explain product selectivity of electrochemical CO_2 reduction.

Keywords:

Electrochemical stability, metal oxides, Pourbaix diagram, machine learning, structure prediction

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E10.01

Flexible piezoelectric generator based on conductivity-controlled GaN nanowires and its application to self-powered rapid- and slow-adapting mechanoreceptors

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Abstract:

Human skin contains slowly adaptive (SA) and rapidly adaptive (RA) mechanoreceptors, which respond differently to various external stimuli. Based on human tactile perception principles, the fabrication of a self-powered electronic skin (e-skin) that simultaneously mimics SA- and RA-mechanoreceptors is a prime need that can enable robots and artificial prosthetics to interact with the surrounding environment. However, the complex process of merging multimode sensors to mimic SA- and RA-mechanoreceptors hinders their utilization in e-skins. Here, we proposed state-of-the-art SA- and RA-mechanoreceptors based on n-type and semi-insulating GaN nanowire (NW) arrays, respectively. The SA- and RA-mechanoreceptors demonstrated distinguished features such as grasping of an object and detection of surface textures of different objects, after being affixed on an index fingertip. The proposed e-skin comprises SA- and RA-mechanoreceptors and can simultaneously mimic static and dynamic pressure signals using piezoelectric sensing principles. The mechanoreceptors further detected several stimuli of various pressures with low and high frequencies. The response and reset times showed by the GaN NW-based SA-mechanoreceptors were reported for the first time as 11 ms and 18 ms under 1-Hz frequency, which are rapid enough for practical e-skin applications.

Keywords:

piezoelectric, generator, GaN, nanowire, mechanoreceptor

2023 KPS Spring Meeting
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E10.02

Theoretical spectroscopy of quasi-2D quantum materials

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Abstract:

Spectroscopy, by probing the response of materials to those perturbations, allows the analysis of the induced elementary excitations and hence the characterization of the material properties. Theoretically, the many-body quantum theory with quantitative calculations can explain the origin of experimental spectroscopy and make predictions that suggest new experiment and provide insight information that may be difficult or not yet possible to measure experimentally. Indeed, recent breakthroughs in the emergent 2D quantum materials thanks to the paradigm of collaboration between modern electronic structure theory and advanced techniques.

Beyond mean-fields models of independent electrons, such as density functional theory (DFT), we perform the density functional perturbation theory (DFPT) and/or GW+BSE calculations within the many-body perturbation theory (MBPT) to tackle following interesting and novel phenomena of low-dimensional quasi-2D quantum materials:

1. In-plane anisotropy of layered compounds SnS1-xSex
2. The mechanism of growing 2D *h*-BN layers on graphene substrate
3. The possible Peierls-instability-driven CDW state in 2D NbSe2

In an excellent agreement with recently available experiments, our calculated spectra not only provide insights into underlying mechanisms of electronic excitations but pave a path to rational design of materials for novel optoelectronic applications.

Keywords:

2D quantum materials, DFPT, MBPT, GW+BSE, SnSxSe1-x, h-BN, CDW, NbSe2

2023 KPS Spring Meeting
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E12.01

예비교사를 위한 physical computing 교육과정 제안

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Abstract:

최근 마이크로프로세서 보드의 활발한 보급을 통하여 이를 기반으로 다양한 과학 실험, 로봇제어, AI 개발 등의 활용이 두드러지고 있다. 일선 초중등학교에서도 4차 산업혁명에 따른 로봇, AI의 활용 등의 확대에 따른 사회적 상황에 맞추어 이에 대한 교육의 도입이 빠르게 이루어지고 있다. 이에 비하여 아직도 대학의 예비 물리교사 교육에서는 물리교육에 이를 도입하여 활용하는 역량을 갖춘 교사양성을 위한 physical computing 교육의 도입이 충분하지 못한 상황이다. physical computing은 단지 컴퓨터 프로그래밍 능력만 향상시키는 것이 아니라, 자연현상의 여러 물리적 신호를 감지하는 과정에 대한 물리학의 이해를 높이고, 전기 회로의 다양한 구성을 통하여 전기소자의 이해, 전자기학의 이해 등 물리학의 개념적 이해를 높일 뿐 아니라, 실제 자연 현상을 측정하고 물리법칙을 이해하기 위한 실험 설계 및 수행 능력을 형성하는 데에도 크게 기여할 수 있다. 따라서 본 연구에서는 이러한 교육목적을를 바탕으로 15주 2학점 정도의 과정을 기반으로 마이크로프로세서 보드를 활용한 physical computing의 교육과정 모형을 제시하고, 이를 바탕으로 예비물리교사 교육과정에서 활용하는 방안에 대하여 제안하고자 한다.

Keywords:

physical computing, 마이크로프로세서 보드, 로봇 제어 및 AI, 실험 교육

2023 KPS Spring Meeting
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E12.02

학교 과학 수업에서 사용하는 온도계의 정확도 분석

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Abstract:

두 물체의 열평형 과정을 관찰하는 실험에서 시간이 충분히 지나더라도 각 물체의 온도를 측정하는 두 온도계가 같은 눈금을 가리키지 않는 경우가 종종 발생한다. 측정 장치의 한계를 인식하고 있지 않은 학생은 이 현상을 설명할 수 없어 혼란에 빠질 것이다. 전통적으로 초등학교와 중등학교 과학 시간에 사용하여 왔던 알콜 온도계는 물질의 열팽창 특성으로 인해 넓은 범위의 온도를 정확히 측정하는데 한계가 있고, 제작 과정에서 발생하는 편차까지 감안하면 온도계의 측정 오차는 무시할 수 없을 정도이다. 이 외에도 반도체 온도계나 적외선 온도계도 온도계별 측정 눈금의 편차가 많이 발생하지만 학습 지도에 활용할 수 있는 구체적인 정보가 부족한 실정이다. 본 연구에서는 알콜온도계, 적외선온도계, 반도체온도계를 대상으로 같은 종류의 온도계 사이의 눈금 편차, 다른 종류의 온도계 사이의 눈금 편차를 조사하고, 아울러 수은 표준온도계 눈금과의 차이를 측정하여 제시하고 이를 바탕으로 학교 과학 수업에의 시사점에 대해서 논의하고자 한다.

Keywords:

실험교육, 측정 오차, 온도계

2023 KPS Spring Meeting
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E12.03

텍스트 기반의 인공지능의 발전과 물리교육의 관계

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Abstract:

2010년대 이후 딥러닝을 이용한 모델이 보급된 이후 텍스트 생성과 분석을 위한 다양한 인공지능 모델이 개발 보급되고 있다. 특히, 2022년 11월 발표된 chatGPT는 다양한 분야에서의 반향을 일으키고 있으며 이에 대한 활용 가능성과 함께 여러 가지 부작용에 대해 다양한 논쟁이 이어지고 있다. 특히 이와 같은 언어 모델이 교육에 어떻게 활용될 수 있는지, 어떤 위험성이 있는지 다양한 논의가 필요하다. 본 연구는 언어 모델의 여러 기본적인 알고리즘을 중심으로 그것이 가지는 장점과 한계, 앞으로의 물리교육의 관점에서 전망을 논의하고자 한다.

Keywords:

물리교육, 자연어 처리, 언어 모델, 인공지능, 대화형 인공지능

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

E12.04

The Future of Physics Education: Utilizing ChatGPT to Enhance Learning and Teaching

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Abstract:

The field of artificial intelligence has made significant strides in recent years, particularly in the area of generative AI, which can be utilized in various fields such as text, code, image, speech, 3D image, and video. As a result, there is a growing interest in exploring how AI can transform education and learning in the future. This study focuses on ChatGPT, a text-based generative AI model that is currently available to the public. First, we examine its characteristics and limitations and explore previous educational cases that have applied ChatGPT in education. Secondly, we review how ChatGPT can solve physics problems, such as conceptual and mathematical physics problems. To explore this further, the opinions of physics education experts are analyzed. As the development of generative AI continues to accelerate, this study also discusses the concerns and alternative evaluation methods that physics educators may face in the future.

Keywords:

GenerativeAI, Physics Education, AI in Physics Classrooms, Future Education

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2023-04-19 - 2023-04-21

E13.01

Atomic and Molecular Research Activities for Plasma

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Abstract:

This presentation includes the research facilities of the KFE Research Group of Korea and the data production techniques and data for plasma application. DCPP[1] web database system provides numerical and bibliographic data of atomic, molecular interaction. Also, the system provides functions for the efficient compilation, assessment, and grade evaluation process of atomic, molecular and plasma-material interaction data. We improved our system that focuses on user convenience. About 1000 papers are collected in the first collection, and through the filtering process, about 100 data are finally secured for AMBDAS updates. We studied the chemical and physical properties of candidate gases for the development of new alternative gases by utilizing our research base for the past two years. We established a direct data production base through experimental measurements and developed a measuring device and measured total scattering cross section for e – N_2O[2], C_3F_6O collisions at low electron energies. We have optimized the structure of NF_3O molecules using the Density Functional Theory DFT (wB97X-D/aug-cc-pVTZ) using the Gaussian 09 program and the optimized geometry is used for the calculation and calculated various cross sections at low energies along with the detection of resonances using ab- initio R-matrix method. Our evaluation group strives to provide the data set as complete as possible. If there is no data, we are suggesting data studies to colleagues. So We evaluated the cross section for electron collisions with H_2O[3] and generalized the definition of cross section in this year. In the future, N_2 and CO_2 molecular evaluation will be conducted through the operation of the evaluation group.

* This work was supported by the R&D Program Plasma BigData ICT Convergence Technology Research Project through the Korea Institute of Fusion Energy (KFE) funded by the Government, Republic of Korea.

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Keywords:

Plasma, Data production

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E13.02

Defect identification of nitrogen-doped graphene on Pt(111) via atomic force microscopy / scanning tunneling microscopy/spectroscopy

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Abstract:

Nitrogen (N) doped graphene is a well-known candidate for catalysis, electronic devices or sensors by keeping the advantages of graphene along with additional physical or chemical features. The various atomic configurations of nitrogen, however, induce different features, making it highly important to identify and control the bonding arrangements. In this work, we present a schematic distinguishment on two specific nitrogen defects; Graphitic-N and pyridinic-N. N doped graphene was grown on a Pt (111) surface using pyridine precursors, followed by low-energy electron diffraction (LEED) and X-ray photoelectron spectroscopy (XPS). Atomically resolved simultaneous scanning tunneling microscopy (STM) and atomic force microscopy (AFM) depicted complementary distinctions on the atomic and electronic structures between the both defects. Corresponding theoretical calculations via density functional theory (DFT) further verified the experimental data. In addition to the discernment on the two defects, effects of Pt substrate and a plausible growth mechanism are suggested, through which the numerical proportions of the defects and dissociated pyridine precursors can be explained.

Keywords:

Nitrogen-dope graphene, Scanning Tunnneling Microscopy, Atomic Force Microscopy, Pyridine

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E13.03

Direct observation and control of sub-cycle fishbone and spider interference pattern in photoelectron holography by near-single-cycle pulses

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Abstract:

In the strong field laser-matter interaction, tunneling ionization and the subsequent dynamics of freed photoelectrons are fundamental quantum mechanical processes. Some of freed electrons through a tunnel ionization are driven back to the parent ion by the laser field and then scattered off by or recombine with the parent ion, which gives rise to a number of fascinating phenomena, such as high-order harmonic generation, high-order above threshold ionization, nonsequential double ionization and frustrated tunnel ionization. On the other hand, when the scattered and non-scattered electrons may interfere with each other at the detector, producing an interference pattern dubbed as photoelectron hologram (PH).

Strong-field PH has attracted much interest in recent years due to its capability of providing rich information about the target structure and underlying dynamical processes. In this PH, the non-scattered electron wave packet plays a role as a reference wave and the scattered electron wave packet as a signal wave. The scattered (forward and backward) electron wave packets (as a signal wave) capture and encode the structural and dynamical information of the parent ion during the scattering process. Therefore, the clear observation of a specific interference patterns, differentiating it from other types of patterns becomes important.

For instance, the modulation in the spider-leg pattern reveals the time separation between two ionization events, whereas the density of the spider fringes is related to the electron recollision time. The number (position) of fishbone fringes, on the other hand, contains the information of the internuclear separation in the case of diatomic molecules. However, in the past, the majority of SFPH experiments were carried out with multicycle lasers. The inter-cycle interferences between the cycles have been unavoidable. As a result, the PH pattern is dominated by above threshold ionization (ATI) rings, and the aforementioned holographic patterns are distorted and obscured.

In the present paper, using a carrier-envelop-phase (CEP)-stabilized, near-single-cycle Vis/NIR laser pulse, we have carried out a series of SFPH experiments for molecular nitrogen with a thick-lens velocity map imaging (VMI) spectrometer with high-resolution. In the experiment, we not only observed, for the first time, two distinct sub-cycle holographic patterns, spider and fishbone pattern, simultaneously but also demonstrate the control of them by the change of CEP. Employing the CQSFA theory and 2D-TDSE, we studied the interference patterns of various sub-cycle dynamics, identifying the fishbone pattern. Both the 2D-TDSE and CQSFA simulations qualitatively reproduce the experimental findings. Furthermore, with the effect of the Gouy phase anomaly due to Coulomb focusing effect on the electron wave-packet, which has been obscured in case of multicycle pulses, clearly observed, using the three-dimensional semiclassical trajectory method.

Keywords:

Strong field photoelectron holography , fishbone and spider leg pattern , ultrafast electron dynamics

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

E16.01

Study of Eco-Friendly Gases for CMS improved RPCs

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Abstract:

Over the past few decades, tetrafluoroethane (TFE, R134a Freon) has been widely used in the operation of phenolic resistive plate chambers (RPCs) in many high-energy experiments. TFE, the refrigerant with the high Global Warming Potential (GWP ~ 1430) that has been typically used in air conditioners home and in many industrial areas, is now being replaced by new refrigerants with lower GWPs. In high-energy physics, the use of TFE used in the operation of RPCs should be also reduced and be finally replaced by new ones with significant lower GWPs. Firstly, in the present research for CMS iRPCs, we report a test result of a prototype iRPC obtained by replacing the large portion of TFE in the TFE-based RPC-operation gas mixture by CO_2. The detector performance of the iRPC with new Freon gas, 1,3,3,3-Tetrafluoropropene (HFO1234ze), with a GWP ~ 6 as a candidate replacing the present TFE is reported as a second part of the report.

Keywords:

Compact Muon Solenoid experiment , Muon Detector Upgrade, Resistive Plate Chambers, Eco-Friendly Gases

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2023-04-19 - 2023-04-21

E16.02

Status of the GEM upgrade project for CMS

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Abstract:

In view of the LHC Phase-2, the CMS experiment is being upgraded with three stations of triple-GEM detectors (GE1/1, GE2/1 and ME0) to maintain the excellent trigger pT resolution of its muon spectrometer in the high-luminosity LHC environment and extending its coverage to the very-forward pseudorapidity region $2.4<|\eta|<2.8$. The challenges faced for adapting the triple-GEM technology to a large-area detector have required the introduction of innovations such as discharge protection, an optimized GEM foil segmentation and the development of a complex front-end electronics. The CMS GEM detectors have been tested for the first time under beam irradiation in their final design with their complete front-end electronics and data acquisition software in 2021 and 2022 at the CERN North Area, with the goal of demonstrating the operation of their full readout chain, measuring their efficiency and space resolution under intense beam irradiation and verifying the operating principle of a novel foil sectorization. We describe the setup of the test beam, made of a GE2/1 detector and a second-generation ME0 detector and completed by a high-space resolution beam telescope made of four 10x10 cm2 triple-GEMs. We discuss the preparation of the full DAQ chain, made by the VFAT3 front-end ASIC, an OptoHybrid front-end FPGA and a custom back-end made of a commercial FPGA (CVP-13), all operated with the final CMS GEM acquisition software, and present the performance of both the large-area detectors and the tracker measured with muons and pions.

Keywords:

GEM, Muon, CMS, ME0, Detector

The CMS GE2/1 foil production, QM, and preparing the ME0 foil in Korea

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Abstract:

According to The Compact Muon Solenoid (CMS) of the Large Hadron Collider (LHC) Forward Muon L1 trigger system upgrade plan with Gas Electron Multiplier detector (GEM). The GE2/1, one of the three different-sized CMS GEM detectors installed in the Endcap Muon detector system, is installed in the first ring of the second station. It has a trapezoidal shape with an inner length of about 1.5 m and an outer length of about 3.2 m, corresponding to 20 degrees in the +-YE disk. Korea-CMS (KCMS) provides the foils of four different types last two years. It will be used to build GE2/1 chambers and will be mounted on the YE- this summer. The KCMS conducted quality management to meet the performance specified in Technical Design Report (TDR). Through a total of five stages of Quality Control (QC), the foil was verified, and the production progress and facilities were managed and operated based on QC data. Furthermore, we researched how to improve quality without damage to foil that failed to pass QC. Based on these successful research results and production experience, KCMS is preparing to produce ME0 foil in 2023.

Keywords:

CMS, GEM, Muon, Detector, GE2/1

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

E16.04

UFSD3 LGAD Sensors post-processed and tested in Korea

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Abstract:

As part of the CMS Phase 2 upgrade, MIP Timing Detector is planned to be installed in order to mitigate the impact of pileup that is expected to reach 200 in HL-LHC. In the endcap region, silicon-based Low Gain Avalanche Detector (LGAD) sensors that allow timing resolution of a few tens of picoseconds are used. The sensor design needs to be optimized considering several factors, including radiation resistance, uniformity of gain, and long-term stability. Korea CMS group is working with a company, Memspack, to post-process wafers provided by FBK. As proof of process capability, Memspack post-processed two UFSD3 wafers. The procedure of post-processing and the testing results of these sensors at Korea University are presented in this talk.

Keywords:

LGAD, MTD, CMS, UFSD3, post-process

E19.01

Langevin Simulation of Kinetic/Chemical Equilibrium of Dark Matter Particle in Expanding Universe

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Abstract:

In order to address how efficiently the scalar singlet, heavy dark matter particle maintains kinetic equilibrium, momentum distribution of heavy dark matter particles in expanding universe is studied using Langevin equation with time-dependent drag coefficient and time-dependent temperature. Similar to kinetic/chemical equilibriation of charm/bottom quark in expanding quark-gluon plasma (QGP) background, we study motion of non-relativistic singlet scalar particles in expanding universe. For a benchmark choice of parameters, we found that a gaussian form of momentum distribution is maintained but is with a lower peak momentum than with the corresponding thermal distribution. This reduces the scalar singlet, heavy dark matter annihilation cross-section, which confirms the finding that a larger coupling (~ 20%) than in equilibrium is needed for reaching the correct abundance by other studies.

Keywords:

Langevin equation, kinetic equilibrium, dark matter, non-relativistic dynamics, expanding universe

Quantum Machine Learning for jet image

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Abstract:

We utilize a quantum machine learning algorithm to distinguish signal processes from QCD backgrounds at the high energy collider. In this work, we embed QCD color deposit patterns to qubits to get quantum computational advantagers with a small number of training samples.

Keywords:

Collider phenomenology, Quantum computing, Quantum Machine Learning

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

E19.03

Gauged quintessence

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Abstract:

We introduce the gauged quintessence model, in which the dark energy field (quintessence) has a U(1) gauge symmetry. This is the first quintessence model under a gauge symmetry. We identify the real part of the complex scalar as the dark energy field (quintessence), while the imaginary part is the longitudinal component of a new gauge boson. It brings interesting characters to dark energy physics. The U(1) gauge boson can affect the quintessence dynamics, and the solicited dark energy properties can constrain the gauge coupling constant. While the uncoupled quintessence model severely suffers from the Hubble tension, the gauged quintessence might alleviate the situation.

Keywords:

Dark energy, U(1) gauge symmetry, Hubble tension, quintessence, dark gauge boson

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2023-04-19 - 2023-04-21

E19.04

Mass-varying gauge boson that couples to the dark energy field

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Abstract:

We study the dark gauge boson in the gauged quintessence model. The gauged quintessence is the dark energy field under a gauge symmetry, and therefore its mass varies as the quintessence scalar value changes. The change of the dark gauge boson mass brings interesting consequences. The evolution of the universe is sensitively affected by the mass-varying dark gauge boson. We study various phenomenology of the dark gauge boson, including its production, evolution, and other implications.

Keywords:

dark energy, mass-varying particle, U(1) gauge symmetry, quintessence

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

F1.01

Ultra-High Intensity Lasers in Korea

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Abstract:

An ultra-high Intensity laser will pave the way for exploring novel physics because it can provide an extreme laser field to create an unprecedented physical environment. The laser intensity currently reaches 10^{23} W/cm^2, and a higher laser intensity over 10^{24} W/cm^2 will shortly be accomplished due to upcoming new laser facilities. Several institutes construct or plan the ultra-high intensity laser facility with several tens PW. For example, a 100 PW laser is being built in China, and a 50 PW laser is planned in the USA. Such ultra-high intensity lasers will provide an essential tool for exploring a variety of novel physics, such as high-field physics and quantum electrodynamics, laboratory astrophysics and planetary physics, laser-driven nuclear physics, and particle acceleration and advanced light sources. This talk presents the current status of ultra-high intensity lasers in Korea, and a plan for a new ultra-high intensity laser facility is introduced.

Keywords:

Ultra-high intensity laser, Novel Physics

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

F1.02

The ultra-high intensity femtosecond lasers in SIOM

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Abstract:

Development of ultra-intense and ultrafast lasers have promised scientists with unprecedented extreme physical conditions and new experimental techniques. A series of ultra-intense and ultra-fast lasers (0.2PW, 1PW and 10PW lasers) have been developed in SIOM (Shanghai Institute of Optics and Fine Mechanics, Chinese Academy of Sciences), which have been in opening operation for the internal and international end users. Some laser driven particle acceleration experiments have been carried out based on these lasers recently. For example, the laser driven electron accelerator has been achieved with near GeV energy and <1% energy spread. Further, a free-electron lasing using a laser wakefield electron accelerator has been demonstrated.

Currently, a prototype with 250 TW/ 14fs has been demonstrated. By seeding a broadband pulse, we realized 210 nm broadband amplification at the central wavelength of 925 nm using three-stage LBO based OPCPA amplifiers. This laser is running at 0.1 Hz by employing a home-built rep-rate high energy pump laser, that will be installed as the frontend for SEL-100PW laser.

Keywords:

Ultra-high intensity laser, femtosecond laser, electron acceleration, optical parametric chirped pulse amplification

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2023-04-19 - 2023-04-21

F1.03

Towards laser electron acceleration with 100 PW laser pulses

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Abstract:

Laser wakefield acceleration (LWFA) is a promising technique for overcoming the limitations of conventional RF accelerators owing to its enormous acceleration gradient. Recent advances in ultra-intense lasers have enabled the development of multi-PW lasers, and LWFA research has begun to investigate a new regime of accelerated electron energy near 10 GeV. This presentation will summarize the current state of LWFA with PW and multi-PW laser pulses. In addition, there are several ongoing construction projects and construction plans for 10-100 PW laser systems around the world. Future prospects for LWFA research and applications of accelerated electron beams produced by ultra-intense lasers with peak powers of 10 100 PW will be discussed.

Keywords:

PW lasers, Laser wakefield acceleration, Laser electron accelerator, relativistic laser plasma interactions

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2023-04-19 - 2023-04-21

F2.01

Multiple gravity laws for human mobility within cities

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Abstract:

Human mobility in cities has been a crucial part in urban dynamics, and the gravity model has described the deterrence of travels with distance in mobility patterns, hence general human interactions inside cities. By analyzing the travel data in the twelve most populated cities of the United States of America, we measure the values of the scaling exponent governing the distance dependence of travels between areas of different traffic volumes within each city. Despite the diverse landscape of the cities, we find a common pattern that the exponent value tends to be higher between areas with larger traffic volumes, and vice versa. This indicates that our method can indeed reveal the hidden diversity of gravity laws that would be overlooked otherwise. Thus, our findings give insights into urban travels for the better prediction and optimization.

Keywords:

human mobility, urban dynamics, gravity law, traffic landscape

F2.02

Threshold effects of population density in commuting patterns using KT origin-destination commuting data

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Abstract:

인구밀도는 도시와 비도시 지역을 구분 짓고 인간 집단행동을 결정하는 핵심 변수이다. 매일의 통근은 인간 이동의 주요한 이유이며, 도시의 중심지와 비중심지를 만들며 도시의 구조를 형성하는 중요한 현상이다. 그렇다면 인구밀도와 통근 패턴에는 어떤 관계가 있을까? 인구밀도가 높은 곳과 그렇지 않은 곳의 통근 패턴은 다를까? 우리는 위의 질문에 답하기 위해 KT 이동전화 사용자에서 추출한 통근이동 데이터를 이용하여 노드를 행정동으로, 행정동 사이의 통근자 수를 링크 가중치로 정의한 방향 있는 가중치 통근 네트워크를 만들어 분석하였다. 먼저 네트워크 분석을 통해 다음의 두 종류의 노드 집단이 통근 네트워크에 존재함을 관찰했다. 첫 번째 노드 집단은 동내 통근 비율이 낮고(즉, 다른 행정동으로의 통근 비율이 높음) 연결선 수(degree)와 연결 강도(strength)가 높은 특징이 있지만 두 번째 집단은 동내 통근 비율이 높고 연결선 수와 연결 강도는 낮은 특징이 있다. 또한 통근 시작 노드와 종착 노드가 어떤 집단에 속한지에 따라 통근 패턴의 차이를 분석하였다. 나아가 식별된 두 노드 그룹은 흥미롭게도 인구밀도 691명/㎢ 보다 각각 높거나 낮은 문턱값 효과를 보임을 확인하였다. 우리 연구의 결과는 인구밀도가 통근 패턴에 스위치와 같은 영향을 줄 수 있고 나아가 도시화 정도에 따라 통근 패턴이 질적으로 달라질 수 있음을 시사한다.

Keywords:

Human mobility, Commuting, Population density, Collective behaviors, Mobility networks

F2.03

An empirical test for percolation-based network efficiency indicators to identify bottleneck links in traffic flow networks

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Abstract:

교통흐름 네트워크에서 병목 역할을 하는 링크나 지점을 식별할 수 있다면, 네트워크의 유지와 관리에 큰 도움이 될 수 있다. 병목식별을 위해서는 먼저 주어진 네트워크가 얼마나 잘 작동 중인 상태인지(즉, 막혀 있는지 혹은 원활한지)를 파악할 수 있어야 한다. 최근 교통흐름 네트워크의 전역 효율 상태를 스미기 이론(Percolation theory)을 이용하여 정량화하려는 시도들이 있으며 이는 낮은 속도의 흐름부터 차례로 제거하면서 네트워크의 전역 연결성(Global connectivity)이 어떻게 변화하는지를 관찰하여 교통흐름 네트워크의 성능을 정량화한다. 현재 스미기 기반 성능지표는 주어진 교통흐름 네트워크를 가로지를 수 있는 최대 상대속도인 스미기 문턱값(Percolation threshold)과 상대속도와 주어진 상대속도에서 도달할 수 있는 네트워크의 주요 지점 크기를 모두 고려한 네트워크 신뢰도(Network reliability)가 제안되어 있지만, 두 지표를 통해 식별한 병목이 실제로 어떤 효과가 있는지 실증적인 검증과 비교가 필요하다. 우리는 이 두 가지 지표를 대한민국 주요 도시의 교통흐름 네트워크 데이터에 적용해보고 그 결과를 비교하였다. 특히 거시 변수인 성능지표를 유의미하게 변화시킬 수 있는 미시 수준의 지점인 병목을 찾을 때 스미기 문턱값과 네트워크 신뢰도의 장점과 단점이 무엇인지 확인하였고, 주요 도시의 서로 다른 요일에 조사된 정성적으로 유사한 교통흐름 데이터에서 병목을 조사해 보았을 때, 동일한 도로에서 병목이 나타나는 경우가 매우 드물다는 점으로부터 현재 사용되는 병목 탐색 방법의 한계를 제시하고 새로운 지표 개발의 단초를 제시한다.

Keywords:

Percolation, Bottlenecks, Traffic flow networks, Network efficiency

State Propagation Algorithm Reveals Macroscopic Patterns of Urban Traffic Congestion

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Abstract:

Congestion in traffic flow networks is an important problem involving social, economic, and environmental problems in cities. Most existing methods for measuring congestion are based on raw quantities of local traffic flow (e.g., flow speed) on individual roads, which are potentially biased and therefore limited in their ability to capture the various macroscopic patterns that exist. To better understand the spatio-temporal patterns of urban congestion, we propose a state propagation algorithm that calibrates the states of local flows by propagating information through the traffic flow network. We demonstrate that the algorithm provides a clearer picture of traffic congestion and its structural and dynamic patterns than the existing methods. Our approach indicates that urban traffic congestion is a result of both diffusion and stacking processes, suggesting that an effective measure for urban congestion should consider both processes.

Keywords:

Traffic congestion, Traffic flow networks, Detection algorithm, Macroscopic patterns

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

F2.05

Meta-learning graph neural networks for generalizable representation learning of physical systems

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Abstract:

Recent studies on learning physical laws via deep learning aim to uncover the shared representation of a given system by introducing physics priors or inductive biases to the neural network. However, most of these approaches tackle the problem in a system-specific manner, where a neural network trained on a particular physical system cannot be easily adapted to another system governed by a different physical law. For instance, a neural network trained to forecast the dynamics of a mass-spring system cannot ensure correct predictions for a two-body system or other systems. To address this issue, we first model our system with a graph neural network and employ a meta-learning algorithm that allows the model to gain experience over a distribution of tasks and improve its performance on new environments. Here, we attempt to identify the neural representation of a Hamiltonian manifold, a common feature of the data distribution of Hamiltonian systems.
We trained our model with a dataset composed of five dynamical systems, each governed by different physical laws, using meta-learning. We then evaluated the performance of the meta-trained model by applying an adaptation task to a new type of dynamical system. Our results show that with only a few gradient steps, the meta-trained model adapts well to the new physical system, which was unseen during the meta-training phase. Subsequently, we leveraged the manifold hypothesis to examine the embedding space of the data manifold within the meta-trained neural network, to ascertain the representation of Hamilton's equation that is generalizable across multiple physical systems. Our findings suggest that the meta-learned model can craft the generalizable Hamiltonian manifold shared across various dynamical systems, each governed by different physical laws.

Keywords:

Hamiltonian, Meta-learning, Representation learning, Graph neural networks

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

F2.06

Vaccination Game in Networks of DQN Agents

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Abstract:

Pandemic situations are largely controlled by vaccines, which are made possible by modern biotechnologies. However, some individuals may choose not to vaccinate after weighing the costs and benefits of vaccination, including potential side effects and their perceived risk of infection. As a result, individuals' decision plays a crucial role in the spread and termination of infectious diseases. This can be analyzed from the perspective of game theory, specifically the vaccination game. Previous studies have used an evolutionary game theoretic approach to model how population behavior converges if individuals update their strategies by imitating neighbors' decisions. However, this approach has limitations in capturing complex human behavior. To address this, we adopt reinforcement learning to investigate how individuals' self-interest impacts the spread of infectious diseases and how it interacts with the social structure of the population. We report on micro decisions made by agents trained by a deep Q-network in various situations, as well as the macro behavior of the population as a consequence. Overall, our study provides insights into the interplay between individual decision-making, social structure, and the spread of infectious diseases.

Keywords:

vaccination, game theory, reinforcement learning, epidemic, pandemic

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2023-04-19 - 2023-04-21

F2.07

Strategy inference using the maximum likelihood estimation in the iterated prisoner's dilemma game

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Abstract:

The iterated prisoner's dilemma game has shown how cooperation evolves based on direct reciprocity. In the course of iterated interactions, a player can observe the co-player's past actions, infer his or her strategy, and react to it. Among the above three processes, the fidelity of inference is relatively unexplored compared to the others. In this work, we explicitly construct an inference process between observation and reaction. Specifically, the focal player infers the co-player's strategy by applying the maximum likelihood estimation (MLE) to the observed sequence of actions. Our first finding is that the focal player's inference is accurate when both players take only their last actions into consideration if the observed sequence is sufficiently long. To see the case in which inference must be inaccurate, we also set the focal player's memory length to be shorter than the co-player's. In this case, we choose a combination of Tit-for-tat and Anti-tit-for-tat (TA) as the co-player's long-memory strategy. TA satisfies the following three conditions: 1) mutual cooperation is achieved when all players use the strategy, 2) the strategy exploits unconditional cooperation, and 3) a player using this strategy is not exploited repeatedly by any co-player. The short-memory player inaccurately infers TA as either Tit-for-tat, Win-Stay-Lose-Shift, or Grim trigger, depending on his or her own strategy. This work presents how a long-memory strategy is projected onto a short-memory one by inference with information loss. In addition, we suggest that each of those three well-known strategies could be a facet of a single successful strategy with a higher cognitive capacity.

Keywords:

Prisoner's dilemma, Maximum likelihood estimation, Statistical inference

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2023-04-19 - 2023-04-21

F2.08

Second-order effects of mutation in a continuous model of indirect reciprocity

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Abstract:

We have developed a continuous model of indirect reciprocity and thereby investigated effects of mutation in assessment rules. Within this continuous framework, the difference between the resident and mutant norms is treated as a small parameter for perturbative expansion. Unfortunately, the linear-order expansion leads to singularity when applied to the leading eight, the cooperative norms that resist invasion of another norm having a different behavioral rule. For this reason, this study aims at a second-order analysis for the effects of mutation when the resident norm is one of the leading eight. We approximately solve a set of coupled nonlinear equations by using Newton's method, and the solution is compared with Monte Carlo calculations. The solution indicates how the characteristics of a social norm can shape the response to its close variants appearing through mutation. Specifically, it shows that the resident norm should allow one to refuse to cooperate toward the ill-reputed, while regarding cooperation between two ill-reputed players as good, so as to reduce the impact of mutation. This study enhances our analytic understanding on the organizing principles of successful social norms.

Keywords:

Indirect reciprocity, Private reputation, Leading eight, Perturbation theory

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

F2.09

To Cooperate or Not to Cooperate: The Behavior of Discriminators in the Lack of Information on the opponent

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Abstract:

The emergence of cooperation in social dilemmas has been a puzzle since the time of Darwin. Previous research has identified direct and indirect reciprocity as effective means of achieving cooperation, with direct reciprocity being suitable for repeated games and indirect reciprocity suitable when information about other players is widely available. Most studies on direct and indirect reciprocity have focused on three strategies: "always cooperate" for "the good," "always defect" for "the bad," and "conditional cooperate" for "the discriminators" who selectively cooperate based on partner reputation or past behavior. However, in conventional studies, discriminators are assumed to cooperate when information about their partners is unknown. This talk seeks to investigate the optimal actions that discriminators should take to maximize their payoff when partner information is unknown. We consider the iteration of the Prisoner's Dilemma game among a group of individuals who possess reputations with different discriminators. Our findings suggest that the optimal strategy for discriminators is to use a Tit-for-tat strategy when direct game history information is available, an image strategy when only reputation information is available, and to cooperate when no information is available about the opponent. These discriminators make society more cooperative than conventional discriminators.

Keywords:

evolutionary game theory,, prisoners dilemma, reciprocity

F3.01

Quantitative evaluation of strain, charge density, and temperature in two-dimensional structures via Raman spectroscopy

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Abstract:

이차원 물질은 성장 및 소자 제작 과정에 있어서 다양한 유형의 결함이 형성될 수밖에 없는 환경에 놓이게 된다. 결정구조 결함과 더불어 주름이나 버블 등에 의한 변형은 물질의 전자구조를 변하게 할 뿐만 아니라 광전자소자 효율을 저하시키는 원인이 되곤 한다. 또한, 기판이나 이웃한 물질과의 상호작용에 따라서 층 사이에 원치 않는 전하 이동 현상이 일어날 수 있는데 이는 도핑 제어가 필수적인 소자 응용에 제약으로 작용하게 된다. 레이저 빛은 전하 이동 현상을 향상시킬 수 있으며 종종 샘플의 온도를 높인다. 본 발표에서는 이차원 물질에서의 변형, 전자밀도 변화, 가열 효과 등을 라만 산란 분광법을 이용해서 어떤 방식으로 정량적으로 측정할 수 있는지 소개하고자 한다. [이 연구는 정부(과학기술정보통신부)의 재원으로 한국연구재단의 지원을 받아 수행되었음 (과제번호: 2019R1A2C1003366, 2022R1A4A1033358)]

Keywords:

Raman spectroscopy, Two-dimensional material, Strain, Charge transfer, Defect

On-chip Raman spectrometers based on CMOS image sensors

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Abstract:

Recent advancements in nanotechnology raise the feasibility of a miniaturized, portable Raman spectrometer with promising applications such as material identification, food safety monitoring, and health care. However, miniaturizing Raman spectrometers has remained a challenge owing to the inevitable weakness of Raman signals and the conflict between small size and spectral resolution. Here, we present a portable mini-Raman spectrometer operating in NIR region. Miniaturized Raman spectrometers consisted of a complementary metal–oxide semiconductor (CMOS) image sensor (CIS) integrated with an array of filter sets, a confocal probe, and a laser diode. Using the fabricated on-chip Raman spectrometer, we have measured successfully spectrums of cyclohexane liquid, tylenol pills, and vitamin-C pills with high spectral resolution. Additionally, we also demonstrated the concept of a spectral barcode in drug classification with the Raman spectrometer because our Raman spectrometer based on CMOS image sensors can measure Raman spectrums with 2D images. We classified the type of each drug by capturing its spectrum and using a convolutional neural network (CNN) that we trained to identify 11 major spectral components.

Keywords:

on-chp Raman spectrometers, CMOS image sensors, drug classification, spectral barcode

2023 KPS Spring Meeting
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F3.03

Ultrasensitive Plasmon-free Surface-enhanced Raman Spectroscopy

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Abstract:

The chemical mechanism-based surface-enhanced Raman spectroscopy (SERS) provides reliable Raman enhancement effect owing to its excellent signal uniformity and operational stability. However, the electron transition probability rate between the CM-based SERS substrate and probe molecule is fundamentally limited, resulting in poor SERS performance with inferior limit of detection. Here, ultrasensitive plasmon-free SERS platform was successfully developed by using 1T′ Re-based transition metal dichalcogenides (TMDs). The unique 1T′ phase of Re-based TMDs can have strong coupling interaction with probe molecules owing to their highly active surface. Furthermore, the energy band level and density of states for TMDs can be optimized by the incorporation of oxygen or vanadium atoms within the 1T′ lattice structure, enabling the efficient charge transfer. As a result, the SERS effect of Re-based TMDs is significantly enhanced, achieving the limit of detection to the femtomolar (10^{-15} M) and attomolar (10^{-18} M) levels. In addition, the 1T′ TMDs-based SERS platform exhibits remarkable flexibility, reproducibility, operational stability, and universal detection capability.

Keywords:

Transition metal dichalcogenides, Surface-enhanced Raman spectroscopy

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2023-04-19 - 2023-04-21

F3.04

Raman scattering studies of hybrid organic-inorganic perovskite materials

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Abstract:

We present Raman scattering spectroscopic studies of methylammonium (MA) lead halide perovskite materials, especially single crystalline $MAPbCl_3$, focusing on structural phase transition behaviors. From temperature-dependent Raman measurements, we observed anomalous changes in phonon characteristics across the phase transition temperatures from which we could effectively monitor phase transitions, from cubic to tetragonal and successively to orthorhombic structure. We could also study contributions from each vibration species to the phase transitions whose influence on the phase transitions differs significantly. In addition, from analyzing polarization dependence of particular phonon modes, we could measure orientation information of the MA ions in the material that might induce a macroscopic special texture. We claim, from our results, that Raman scattering spectroscopy is a very effective research tool that can sensitively monitor structural phase transitions and their mechanism, from studying local structural environment. Raman scattering results can also provide unique information of the MA ion configuration in the material whose role in the hybrid perovskite materials is not completely understood.

[1] T. T. T. Nguyen et al., J. Phys. Chem. 11, 3773 (2020).
[2] Y. Kim et al., Chem. Mater. 34, 2972 (2022).

Keywords:

MAPbCl3, phase transition, Raman spectroscopy, hybrid perovskite

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F4.01

Molecular mechanism of nuclear membrane deformation by progerin protein clustering

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Abstract:

The lamina, a structural network of lamin proteins, maintains the shape of the nuclear membrane. Lamina is known to affect gene expression regulation by interacting with chromatin. Therefore, if there is an abnormality in the lamin protein, various diseases are caused. One of the typical diseases caused by lamin defects is premature aging, called Hutchinson-Gilford progeria syndrome (HGPS). HGPS is believed to be caused by progerin generated through alternative splicing of pre-lamin A. In HGPS, progerin is incorporated into the lamina, consequently causing severe nuclear membrane deformation. However, it is unclear how progerin induces nuclear deformation. Here, we generated a cell line that conditionally expresses progerin and observed the process of nuclear membrane deformation in real-time using super-resolution fluorescence imaging. Unlike normal lamin proteins, we found progerin forms clusters in lamina, and confirmed that farnesylation of the progerin c-terminus domain is crucial to the clustering.

Keywords:

Nuclear membrane deformation, Lamina, Super-resolution microscopy

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2023-04-19 - 2023-04-21

F4.02

Adaptive optical isoSTED nanoscopy for thick tissue imaging

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Abstract:

Optical fluorescence microscopy provides molecular specificity and high contrast, which are powerful aspects in biomedical research. However, the resolution limited by optical diffraction, which had hindered its wider application. To overcome this limitation, Stimulated Emission Depletion (STED) nanoscopy improves the resolution by quenching the fluorescent signals in the periphery of the excitation focus so that the size of the effective fluorescent focal spot is directly reduced. However, the conventional STED nanoscopy usually confines the excitation focus only in the lateral direction, resulting in an effective fluorescence focal spot with a needle-like shape. Here, 4Pi geometry was applied to STED microscopy, referred to as isoSTED nanoscopy to generate a hollow sphere-shaped focal spot. Also, adaptive optics is used to compensate for optical aberrations and achieve resolution enhancement, resulting in sub-50-nm isotropic resolution in whole cell and thick tissue samples.

Keywords:

STED microscopy, adaptive optics

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

F4.03

Label-free through-skull brain imaging in vivo at visible wavelength

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Abstract:

Compensating sample-induced aberrations is crucial for diffraction-limited optical imaging in biological tissues. However, identifying and correcting tissue-induced aberrations is limited by strong multiple scattering noise. To overcome this limitation, a label-free deep-tissue imaging technique called DREAM (dimensionality reduction enhanced adaptive-optical microscopy) has been introduced. DREAM selectively attenuates multiple scattering noise by reducing the dimensionality of a time-gated reflection matrix regardless of sample-induced aberrations. This technique enhances the single to multiple scattering ratio, leading to substantial improvement in aberration correction. DREAM was used to image the mouse brain in vivo through the intact skull at a visible wavelength excitation, resulting in a 17-fold enhancement of SMR and the visualization of neural fibers in the brain cortex with a diffraction-limited spatial resolution of 412 nm and a 33-fold enhancement of Strehl ratio.

Keywords:

adaptive optics, bioimaging, deep tissue imaging

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

F4.04

Dielectric Metasurfaces for imaging applications

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Abstract:

Dielectric metasurfaces have shown great advances in the last two decades and become promising candidates for bio-imaging applications. In this talk, we demonstrate the potential of dielectric metastructures in the realization of compact imaging devices and new types of spatial light modulators. We first showcase their potential toward optical field imaging applications. In this regard, we demonstrate a system of dielectric metasurfaces and designed random metasurfaces for single-shot phase gradient microscopes and computational complex field imaging system, respectively. Then, we experimentally demonstrate potentials of tunable resonant dielectric metasurfaces for the next-generation spatial light modulator technology. For example, we show individually addressable, efficient, phase or polarization tunable active metasurface devices. Finally, we conclude this talk with a brief outlook on what aspects of the metasurfaces can be important for their real-world imaging applications in the future and what challenges remain.

Keywords:

Metasurfaces, Phase imaging, Computational imaging, Hyperspectral imaging, Spatial light modulators

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

F4.05

Acousto-optic detection schemes for deep tissue imaging with improved resolution and modulation efficiency

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Abstract:

Optical imaging is an irreplaceable tool in biomedical science as it provides sub-micron resolution and sensitivity to molecular conformation However, scattering of light severely impedes imaging of thick biological samples beyond the ballistic regime, as do recent imaging techniques to improve imaging depth that still primarily rely on ballistic light detection. In contrast, using the fact that the ultrasound can penetrate soft tissues without much scattering and the light passing through the ultrasound focus can be frequency-modulated in a localized manner, acousto-optic techniques may realize a ‘guide star’ inside a highly scattering medium. However, there are two intrinsic limitations in the acousto-optic ‘guide star’ technique; the spatial resolution of the ‘guide star’ determined as the size of an ultrasound focus (~30 μm), and its low modulation efficiency (~1 %). Here, we introduce those fundamental limitations in conjunction with Raman-Nath theory, and present several acousto-optic detection techniques to overcome the limitations.

Keywords:

Acousto-optics, Deep tissue imaging

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

F5.01

Giant phonon drag in homoepitaxial ß-Ga_2O_3 thin films

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Abstract:

Phonon-drag - the process whereby phonons drag along charge carriers - can be harnessed to enhance the functionality of thermoelectric generators. However, doing so requires control of the electron and phonon interaction. Here, we demonstrate giant phonon-drag in homoepitaxially grown β-Ga_2O_3 films. We show that a decoupling of the cross sections of electron-phonon and phonon phonon interaction can be achieved by nanometer-thin films with phonon-transparent interfaces to the bulk. For decreasing film thickness the thermodiffusive and phonon-drag contributions to the Seebeck coefficient reveal that a crossover from three-dimensional to two-dimensional electron-phonon interaction takes place if Umklapp scattering dominates. The ratio of the relaxation times of phonon-phonon to electron-phonon scattering is shown to be up to 10 times larger than that of bulk. This finding generally holds true if the phonon-drag interaction length is larger than the phonon mean free path and the film thickness is smaller than both.

Keywords:

Phonon drag, homoepitaxial thin films, Ga2O3, Seebeck coefficient, Umklapp scattering, phonon-phonon interaction, electron-phonon interaction, nanotechnology, thermoelectric energy harvesting

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

F5.02

Transverse thermoelectric energy conversion utilizing spin Seebeck and anomalous Nernst effects

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Abstract:

A concept of transverse thermoelectric energy conversion has recently been emerging as an alternative to overcome the limitations of the conventional longitudinal counterpart. In a transverse thermoelectric device, a charge current is generated in the direction perpendicular to the applied temperature gradient, which allows that the device performance scales with extrinsic dimensions. Transverse devices do not require the use of separate n and p-type materials, since the plane in which the output voltage arises is always isothermal. Thus, transverse thermoelectric devices can have significantly less complex structure and manufacturing than those of longitudinal devices. Among various spin calotritronic effects, the spin-Seebeck effect (SSE) and anomalous Nernst effect (ANE) have drawn particular interest due to their potential as a suitable transverse thermoelectric conversion mechanism. In the SSE, a temperature gradient on a spin-polarized material creates a spin current that is driven into an adjacent material (Pt). There, the injected spin current is converted into a transverse electric field by the inverse spin-Hall effect via spin-orbit interactions. On the other hand, the ANE utilizes various skew scattering mechanisms of spin polarized electrons, which lead to a transverse electric field perpendicular to both of the applied temperature gradient and magnetization directions. For those two effects to be successfully implemented in real applications, many material- and device-level challenges need to be addressed. In this talk, our recent research efforts to develop highly-efficient SSE and ANE devices are introduced.

Keywords:

Thermoelectrics, Transverse geometry, Spin Seebeck effect, Anomalous Nernst effect, Spin caloritronics

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

F5.03

Thermoelectric Characterization of Thin Films and its Application in Micro Thermoelectric Devices

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Abstract:

Micro-thermoelectric devices have high potential for future applications in the biomedical field, for powering Internet-of-Things devices, and for thermal management. Successful optimization of the thermoelectric figure of merit zT is a critical factor for the introduction of these devices into applications. Such microdevices are usually fabricated by electrodeposition or physical vapor deposition and photolithography. However, in photolithography, heat treatment during deposition is often not possible. Therefore, heat treatment after deposition is required to optimize zT. In this study, we developed a thickness-dependent heat treatment process for n-type Bi_2Te_3 and p-type Sb_2Te_3 films. A thin film analyzer was used to characterize the in-plane Seebeck coefficient, Hall coefficient, electrical conductivity and thermal conductivity. We discuss the influence of temperature effects on transport properties, including in-situ annealing experiments and the relation to structure, grain size, and chemical composition. Furthermore, we substantiate these results with finite element method simulations and discuss possible device designs and applications.

Keywords:

Thermoelectric devices, transport characterization, micro-thermoelectric, annealing effect, full zT characterization

F6.01

Ultrafast x-ray diffraction and imaging

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Abstract:

The quest for new states of matter in the time domain and the need for ultrafast control of material properties has fueled the development of ultrafast experimental techniques using large-scale x-ray light sources. I will present two examples to illustrate how the innovation of pump or probe at free electron lasers (FEL) and synchrotrons (SR) can help reveal ultrafast processes that were difficult to characterize otherwise. First, by targeted excitation using intense terahertz fields at the FEL, we discovered the collective dynamics of ferroelectric polar nanostructures, showing as a group of hundreds of atoms vibrating in a circular pattern [1]. Second, by focusing x-ray to nanometer length scales at SR, laser-pumped x-ray nanoimaging revealed nanoscale nonequilibrium phase transformation that is distinct from the quasi-equilibrium process [2]. The outlook for multimodal imaging will be also discussed.

[1] Q. Li, et al. "Subterahertz collective dynamics of polar vortices", *Nature*, 592, 376-380 (2021)
[2] A. Ahn, et al. "X-ray nanodiffraction imaging reveals distinct nanoscopic dynamics of an ultrafast phase transition", *PNAS* 119, e2118597119 (2022)

Keywords:

Ultrafast materials science, free electron lasers, synchrotron

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2023-04-19 - 2023-04-21

F6.02

X-ray Nanoprobe at XFEL

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Abstract:

Metal nanoparticles (NPs) exhibit plasmonic behavior by localized surface plasmon resonance (LSPR), which can be utilized for various applications such as biomarkers, sensing, data storage, photovoltaics, and cancer therapy. The LSPR of nanomaterials is strongly dependent on the size and shape of the particles. Plasmonic excitation by laser irradiation causes a heating of the nanostructure, leading to surface diffusion of atoms and deformation of the nanostructure. Ultrafast dynamics studies on the plasmonic behavior of NPs will allow us to deepen our understanding of laser-matter interactions and enable the fabrication of advanced NPs for various applications. The ultrashort pulse duration of XFEL sources has enabled femto- and pico-second dynamics studies of various materials. Here, we present our research on the plasmonic behavior of bipyramid Au NPs on femto- and picosecond time scales. We will also discuss about the possibilities of single-particle biomolecular imaging at the European XFEL with improved image resolution.

Keywords:

XFEL, Metal Nanoparticles, Ultrafast dynamics

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

F6.03

Ultrafast polarization control in ferroelectric oxides

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Abstract:

Above bandgap excitation in ferroelectric oxides can lead to a series of changes in the energy landscape of polarization and domain configuration, ultimately resulting in lattice distortion. A key consequent result is the photoinduced lattice distortion on the picosecond timescale set by the acoustic wave propagation. Probing the time-dependent dynamics is crucial to understanding mechanisms of the transitions and discovering new physical phenomena that can exist at an ultrafast time scale. The picosecond dynamics of structural distortion following photoexcitation were probed at the Pohang Accelerator Laboratory X-ray Free-electron Laser (PAL-XFEL). Acoustic pulses resulting from the above bandgap absorption leads to changes in the x-ray diffraction pattern over the picosecond time scales. The detailed analysis reveals that ultrafast changes in polarization and nanodomain configuration involve complex mechanisms. The mechanisms discussed in this presentation include enhanced polarization by depolarization field screening, polarization rotation, externally imposed mechanical strain, and sub-picosecond-timescale polarization change.

Keywords:

PAL-XFEL, Ferroelectrics, optical excitation, polarization control, ultrafast scattering

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

F6.04

Probing Ultrafast Laser Melting with Transient X-ray Absorption Spectroscopy

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Abstract:

Femtosecond transient X-ray absorption spectroscopy (XAS) is a powerful tool for investigating out-of-equilibrium dynamics in materials and energy research. In this contribution, we will describe a dedicated XAS setup at the SCS instrument at the European XFEL, which allows for normalized shot-by-shot analysis of transmission signals and achieves photon-shot-noise-limited sensitivity. Using this setup, we investigated ultrafast melting of femtosecond laser heated copper, which evolves into warm dense matter. Our measurements reveal rich dynamical features of nonthermal electrons and vacancies and their interactions with the lattice. By incorporating improved modeling of electron dynamics, and electron-phonon couplings, we successfully reproduced key features observed in the measurements. These findings advance our understanding of the ultrafast population balance between conduction and localized electrons in materials, and related transport properties under extreme conditions.

This work received support from the National Research Foundation of Korea (NRF2019R1A2C2002864, NRF-2020K1A3A7A09080397).

Keywords:

PAL-XFEL, Warm dense matter, Ultrafast dynamics

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

F7.01

Two-stage screening in Hund metals and heavy fermions

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Abstract:

The dynamical mean-field theory (DMFT) framework has been successful in understanding the physics of strongly correlated metals in terms of the Kondo screening, in that local fluctuations of different degrees of freedom (spin, orbital, etc.) are screened by surrounding electrons. In this presentation, I will show that Hund metals and heavy-fermion systems, two seemingly distinct classes of materials, exhibit a common phenomenon of the two-stage Kondo screening, yet different degrees of freedom are involved. The screening picture explains the smallness of the Fermi-liquid coherence scales of these systems as well as the non-Fermi liquid regime appearing at intermediate energies between the two screening energy scales. Moreover, I will show that the two-stage screening picture resolves open questions in heavy-fermion systems.

Keywords:

Dynamical mean-field theory, Numerical renormalization group, Strongly correlated systems, Hund metals, Heavy fermions

F7.02

Misleading convergence of the bold-line diagrammatic technique: when the correct solution can be found

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Abstract:

Convergence of the bold-line diagrammatic technique (SDT)—in which the full Green's function is determined through summation of Feynman diagrams in terms of itself—to the wrong answer has been associated with the existence of non-perturbative branches of the Luttinger-Ward functional. Although it has been possible to detect misleading convergence without the knowledge of the exact result, the SDT has remained inapplicable in the regimes where this happens. We show that misleading convergence does not always preclude recovering the exact solution. In addition to the established mechanism, convergence of the SDT to the wrong answer can stem from divergence of the inherent diagrammatic series, which allows us to recover the exact solution by a modified SDT protocol based on controlled analytic continuation. We illustrate this approach by its application to the analytically solvable (0+0)d Hubbard model, the Hubbard atom, and the 2d Hubbard model in a challenging strong-coupling regime, for which the SDT is solved with controlled accuracy by the diagrammatic Monte Carlo method.

Keywords:

self-consistent skeleton series, misleading convergence

F7.03

Competing magnetism in layered ruthenates

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Abstract:

Ruthenates have long been a system of interest due to their various unusual electronic and magnetic characteristics. There has been much discussion on the nature of the pairing symmetry in the unconventional superconductor Sr_2RuO_4, which is intimately tied to magnetic fluctuations. In this talk, we first discuss the various magnetism involved in Sr_2RuO_4 and their possible tuning routes. Then, using the heterostructural unit of $SrRuO_3$ and $SrTiO_3$, we attempt to imitate the essential electrical and magnetic properties of Sr_2RuO_4 and describe the specifics.

Keywords:

Sr2RuO4, magnetism, DFT, heterostructure

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

F7.04

Bulk-boundary correspondence in flat band systems characterized by the quantum distance

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Abstract:

Triggered by the discovery of flat bands in twisted bilayer graphene systems, novel many-body and geometric physics of flat band systems have attracted significant attention. Notably, it was recently found that quantum geometric quantities, such as quantum distance and cross-gap Berry connection, play a crucial role in determining the Landau level structures of flat bands. In the present work, we show that the maximum value of the quantum distance between Bloch wavefunctions near a singular point of a flat band is reflected in the band structure of the interface modes formed at an interface between two regions with different potentials or open boundaries. This new kind of bulk-interface correspondence offers us a way of measuring the quantum distance of the bulk by detecting the interface band dispersion.

Keywords:

flat band, quantum distance, bulk-boundary correspondence, interface, two-dimensional system

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

F8.01

Gravitational mechanism for the Plankian dissipation and the emergence of the strange metal

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Abstract:

We show that if we assume the presence of the gravity dual of strongly correlated system near the quantum criticality, the surprising appearance of the plank dissipation can be explained. We also explain that the particle decay rate is also canonically proportional to the linear in temperature.

Keywords:

plank dissipation , , gravity dual, strange metal

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

F8.02

Quantum simulation of far-from-equilibrium gauge theories

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Abstract:

Gauge theories are fundamental frameworks of modern physics that implement the laws of nature through local constraints between matter and electric gauge fields. In recent years, there has been a concerted effort towards the reliable quantum simulation of gauge theories, motivated by the prospect of probing their real time dynamics from first principles on table-top quantum devices. A major challenge in this effort is stabilizing *gauge invariance*, the core property of gauge theories. In this talk, we will discuss our work on *linear gauge protection*, present the underlying theory behind it, and present numerical and experimental results where it was employed to stabilize gauge theories up to all relevant timescales. We then discuss intriguing phenomena that can be probed in gauge-theory quantum simulators such as quantum many-body scars, disorder-free localization, the confinement-deconfinement transition, and Hilbert-space fragmentation. We finally provide outlook for future theoretical and experimental proposals.

Keywords:

Gauge theories, quantum simulation, quantum many-body scars, disorder-free localization, confinement, fragmentation, quench dynamics

Semiclassical approach to random optimization problems and quantum annealing

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Abstract:

The Quantum Approximate Optimization Algorithm (QAOA) has been suggested recently as a promising application on early quantum computers. In this talk, I present a quantum-inspired classical algorithm, the Mean-field Approximate Optimization Algorithm (mean-field AOA) [1], which is constructed by replacing the quantum evolution of the QAOA with classical spin dynamics through the mean-field approximation. I will demonstrate benchmarks of its performance against the QAOA on the Sherrington-Kirkpatrick model and the partition problem and will show that the mean-field AOA outperforms the QAOA in both cases for most instances. Thereby this new algorithm can serve as a tool to delineate optimization problems that can be solved classically from those that cannot and may help to identify instances where a true quantum advantage can be expected from the QAOA. To quantify quantum fluctuations around the mean-field trajectories, one solves an effective scattering problem in time, which is characterized by a spectrum of time-dependent Lyapunov exponents. These provide an indicator for the hardness of a given optimization problem relative to the mean-field AOA.

[1] "Mean-Field Approximate Optimization Algorithm", Aditi Misra-Spieldenner, Tim Bode, Peter K. Schuhmacher, Tobias Stollenwerk, Dmitry Bagrets, Frank K. Wilhelm, arXiv:2303.00329

Keywords:

Random optimization problems, quantum annealing, spin-glasses

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2023-04-19 - 2023-04-21

F9.01

Controlling doping of electrocatalysts though engineering impurities

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Abstract:

Metal nano-aerogels combine high surface area and structural stability with superior catalytic activity towards varied chemical reactions. Their performance sensitively depends on their sub-nanoscale structure and the impurity distribution within the particles. Comparing results obtained by density functional theory (DFT) calculations combined with thermodynamic considerations and characterization techniques like APT and TEM allowed us to rationalize the impact of synthesis conditions on impurity integration and distribution in Pd-nanoparticles during wet-synthesis. This allowed us to gain control over the unexpected ingress of B and study its influence on the HOR activity on Pd nanocatalyst in alkaline conditions, finding it sensitive to a subtle balance between H and OH binding energies. This work demonstrates how DFT predictions can guide experiment to tune the ingress of impurities from the synthesis solution and enable their targeted selection based on their influence on H- and OH-binding energies, and surface integration. [Adv. Mater. 2022, 2203030]

Keywords:

Nano-catalysts, HOR, wet-chemical synthesis, impurities engineering, density functional theory calculations, thermodynamic modelling

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

F9.02

New atomic-scale observations and their macroscopic implications in high-Tc superconductors

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Abstract:

We present new atomic-scale discoveries by STM on Fe-based and Cu-based superconductors. $Ca_{1-x}La_xFeAs_2$ (CLFA112) belongs to a new family of Fe-based superconductors (FeSCs) and has a unique crystal structure featuring an arsenic zigzag chain layer, which has been proposed to be a possible two-dimensional topological insulator. It is speculated that CLFA112 is a potential topological superconductor. We revealed four different types of surfaces exhibiting distinct electronic properties. A clear SC gap of ~12 mV was observed and the FeAs termination layer displayed a dispersing nematic modulation both in real and q space. We also present peculiar zero-bias conductance peaks for the very As chain layer that is believed to exhibit a topological edge state. Cuprate superconductors display unusual features in both **k** space and real space as the superconductivity is suppressed - a broken Fermi surface, charge density wave (CDW), and pseudogap. Contrarily, recent transport measurements on cuprates under high magnetic fields report quantum oscillations (QO), which imply rather a usual Fermi liquid behavior. To settle the disagreement, we investigated $Bi_2Sr_2CaCu_2O_{8+\delta}$ under a magnetic field in an atomic scale. An alternative explanation of the QO results will be discussed by providing a unifying picture where the aforementioned seemingly conflicting evidence from ARPES, SI-STM, and magneto-transport measurements can be understood solely in terms of the DOS modulations in Cuprates.

Keywords:

STM, superconductor, quantum oscillation, ZBCP, topology

Probing spin-dependent charge transport at single-nanometer length scales

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Abstract:

STM not only allows for the imaging of surfaces down to the atomic scale, the quasiparticle interference (QPI) method can also probe electronic properties with unprecedented resolution. However, QPI is limited by the fact that the same STM tip is used to inject and to detect the charge carriers. To circumvent this limitation, multi-probe STMs have been utilized to measure transport at distances ≥ 30 nm, limited by the finite tip diameter.
The molecular nanoprobe (MONA) technique represents an alternative approach, where charge carriers are locally injected by a STM tip, but detected by a single molecule via a reversible electron-induced switching process, such as a tautomerization [1]. Charge transport in surface states [2], anisotropic transport [3], and the damping and coherent superposition of quantum-mechanical waves has been shown [4]. Here, we report on the development of spin-polarized MONA using magnetic STM tips. Using the spin–momentum-locked surface state of a Rashba alloy, we proof that the current direction inverses as the tip magnetization is reversed. We apply SP-MONA to investigate how a single Gd cluster influences the spin-dependent charge transport.

[1] J. Kügel et al., J. Phys. Chem. C 121, 28204 (2017).
[2] A. Christ et al., Phys. Rev. Res. 4, 043016 (2022).
[3] M. Leisegang et al., Phys. Rev. Lett. 126, 146601 (2021).
[4] M. Leisegang et al., Nano Letters 18, 2165 (2018).

Keywords:

Scanning tunneling microscopy (STM), charge carrier transport, Rashba effect, spin–momentum locking, spin polarization

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

F9.04

STM investigation of topological excitations in 1D and 2D broken symmerty states

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Abstract:

In this talk, I provide an overview of the on-going scanning tunneling microscopy activity within IBS Center for Artificial Low Dimensional Electronic Systems. In addition to the characterization of the new material systems synthesized and fabricated within the Center, our STM research has mainly focus on invetigating topological excitations of 1D and 2D electronic systems with broken symmetries such as charge density wave (CDW) and antiferromagnetism (AFM). We have successfully imaged isolated individual solitons in Z3 and Z4 1D CDW systems, revealing their topological and electronic structures. Recent works further tracked the motions of individual solitons and demonstrated the creation of a single soliton. These research works open a new research field, which I call solitonics. We also have identified various domain wall excitations, 2D versions of solitons, in 2D CDW systems, which show rich electronic structures and topological landscapes. Using spin-polarized STM, we have recently succeeded in imaging spin orderings along and nearby such a domain wall. The spin-polarized STM works has been extended to image domain wall networks in AFM systems, which discovered a novel topologically protected quantity during domain wall kinetics and dynamics. Throughout these works, STM is well suited to investigate topological excitations in low dimensional electronic systems and provides unprecedented opportunities towards control and manipulation of individual excitations.

Keywords:

STM, CDW, 2D, solitons, domain walls

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

F10.01

III-V semiconductor-based nano-structures grown by KIST MBE for the application to quantum technology

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Abstract:

Low density quantum dots (QDs) have attracted attention as a single-photon source for the application to quantum cryptography. This application requires the number of quantum dots less than 10 quantum dots on 1 um x 1um.
The most representative compound semiconductor QDs are In(Ga)As QDs grown on (Al)GaAs substrate by Stranski-Krastanow (SK) method. This system has a merit in the point that material and growth method are well-known and widely used. However, these QDs formed by SK method have two crucial problems in an application of single photon source requiring ultra-low density. First of all, SK method is not effective for growing uniform, reproducible low density quantum dots because this growth method comes from lattice mismatch system subtly depending on substrate temperature and growth rate. Also, it has a drawback that it is not easy to grow low density quantum dots on a large area substrate. The second problem is photoluminescence peak wavelength of In(Ga)As quantum dots. In general, the emission line of In(Ga)As QDs at a low temperature is about 0.9~1.0 um. Meanwhile, wavelength shorter than 0.8 um is preferred for efficient and cost-effective silicon array based systems to measure a single photon source or longer than 1.3um is necessary for optical communication.
In this research, low density GaAs QDs/Quantum rings (QR) were grown on Al33GaAs/GaAs substrate by using droplet epitaxy, which consists of perfectly separated introduction of group III metals and group V, instead of simultaneous introduction (SK method). Thus, we could get a low density GaAs quantum dots/rings without defect due to strain. In this experiment, the effect of Ga coverage, Ga flux ratio and substrate temperature on the structural properties of GaAs QD/QR s such as size, density and distribution. Here we achieved low density QDs of 0.75um wavelength with droplet epitaxy and >1.55um QDs with modified SK growth method on GaAs wafers. The formation of InAs QDs in the drilled hole will be introduced for strain balanced QDs.
Finally, In(Ga)As(Sb) nano-wires and high-speed AlGaAs HEMTs for other Qbit applications will be covered.

Keywords:

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2023-04-19 - 2023-04-21

F10.02

Probing the evolution of electronic structure in 2D semiconductors using angle-resolved photoemission spectroscopy

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Abstract:

The electronic structures of two-dimensional semiconductors are crucial for understanding their properties and potential applications. In this talk, we demonstrate an efficient doping method for semiconducting graphene using titanium (Ti) absorbates attached to graphene's energetically favorable site without creating any trap/scattering states. By hybridizing the structure-consistent 2pz orbital of graphene and 3dz2 orbital of Ti, we induce Dirac cone renormalization and observe an effective charge transfer of 0.45 electrons per Ti atom. The doping can be readily tuned by changing the atomic-scale deposition of Ti, and transition Ti metals can also initiate the hydrogen spillover effect for hydrogen storage. Additionally, we present a layer-controlled growth method of hexagonal boron nitride (h-BN) on graphene/4H-SiC substrate using plasma-assisted molecular beam epitaxy (PA-MBE). The ARPES spectrum shows h-BN π band splitting at the K point, revealing our h-BN stacking sequence is AB rather than AA'. According to crystallographic point group theory, AB stacking breaks the crystalline symmetry, resulting in non-zero polarization in the bilayer h-BN system. Our findings demonstrate the potential of ARPES to investigate the electronic structures of low-dimensional systems, even with challenging synchrotron radiation excitation.

Keywords:

Angle-resolved Photoemission Spectroscopy (ARPES), Graphene, Hydrogen spillover effect, hexagonal Boron Nitride (h-BN)

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F10.03

III-V Semiconductor Nanowires Grown on Si by using MOCVD for optoelectronic applications

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Abstract:

We report catalyst-free growth of III-V nanowire array on silicon (Si) substrate grown by metalorganic chemical vapor deposition. The InAs nanowire array has been uniformly grown on entire 2 inch Si wafer with the maximum number density of $2 \times 10^9/cm^2$ without any metal catalyst or pattern assistance. In addition, the ternary $InAs_yP_{1-y}$ nanowire array shows a uniform alloy composition across the nanowire, as confirmed by photoluminescence, X-ray diffraction, and z-contrast scanning transmission electron microscopy analysis. Cross-sectional TEM image confirms a heterogeneous interface between III-V nanowires and Si. Several optical and electrical devices have been demonstrated using these catalyst-free III-V nanowires on Si platform. The wafer-scale, heterogeneous III-V nanowires are promising for low-cost fabrication of nanowire-based devices on Si platform.

Keywords:

F10.04

Electronic and chemical structures of 2D semiconductors studied by synchrotron radiation spectroscopy and microscopy

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Abstract:

Due to the ultra-thin nature and small flake size of monolayer two-dimensional (2D) material systems, it is difficult to study their intrinsic electronic and chemical properties by conventional spectroscopic means. To overcome such barrier, taking the advantages of surface sensitive and high spatial resolution, the synchrotron radiation (SR) based soft X-ray spectroscopy and microscopy are the most suitable techniques to study the 2D material systems.

The National Synchrotron Radiation Research Center (NSRRC) has developed several soft X-ray based spectro-microscopy endstataions in the newly constructed storage ring, Taiwan Photon Source (TPS). Combining with the high brilliance character and pulse nature of TPS, these spectro-microscopy techniques will surely contribute to understanding the nature of the advance semiconductor material systems.

During this presentation, I will showcase the versatility of SR soft X-ray techniques by presenting several examples of their use in studying 2D material systems. These examples include transition metal dichalcogenides semiconducting heterojunctions, homojunctions, and epitaxial graphene. I will also discuss the potential of the new microscopes at TPS, NSRRC.

Keywords:

two-dimensional materials, transition metal dichalcogenides, soft X-ray spectro-microscopy

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F11.01

Two-stage strategy to develop compact, high-magnetic-field fusion reactor: UFR and FDR

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Abstract:

The ITER-grade fusion device is getting familiar to us, as long as huge amount of resources and time for its successor (DEMO) are not often discussed. Nonetheless, if there is a sound alternative path for future fusion reactor, the relevant innovative elements, along with rigourous scientific merits, deserve to be articulated. In fact, the latest development of the high-temperature superconducting (HTS) magnets (>20 T) at MIT has opened the door to seriously consider such an attractive option as compact, high-magnetic-field fusion reactor in our radar [1]. About a year ago, two dozens of Korean colleagues worked together to lay out the first sketch of R&D in that spirit. Specifically, to speed up the whole R&D cycle of fusion reactor developments, a two-stage approach has been prudently proposed: DD first and then DT fusion. While the DD fusion under high magnetic field (>10T) is expected to be mastered primarily for heat exhaust handling first, the DT fusion can be later integrated with all the other proven technologies, including self-sustained tritium breeding and blankets for power extraction. According to the blueprints, each device can be designed within 3 years, constructed for 5 years, and then operated for 10 years. Thus, Ultra-fast-track Fusion Reactor (UFR) is proposed for DD fusion study first as a domestic program, while Fusion DEMO Reactor (FDR) is to be constructed for DT fusion study later. Since UFR is targeting 1) fusion reactor design, 2) high magnet field magnet technology, 3) power handling divertor, 4) reactor materials, 5) heating and current drive technology in high magnetic field, along with fusion diagnostics development, the on-going KSTAR research outcomes, as well as the KFE emphases on blanket and tritium handling technology, can be fully utilized altogether for the FDR design and construction in an integrated manner. Tentatively, UFR (B_T=10.8T, R=1.8m, a=0.5 m, I_p= 6 MA, P_{AUX}=25 MW) is envisioned to possess KSTAR-like (SPARC-like) shape under ITER-grade heat flux on divertor, featured with super X-divertor. Although the HTS magnets are primarily considered for high magnetic field, Plan B allows for the adoption of low temperature superconducting (LTS) magnets at the time of UFR construction decision. Similarly, while the fully non-inductive current drive is proposed without central solenoids (CS), slim-CS would be alternatively planned, as well. Indeed, the unprecedently high magnetic field requires us to newly develop a suite of RF sources (ICRF, LHCD, ECCD, Helicon), whose availabilities could forfeit or reduce the need of neutral beam injector (NBI). Surely, various concepts and ideas are being collected and shared to articualte the two-stage strategy for fusion reactor, while preliminary conceptual elements will be introduced and discussed at the meeting.

Reference
[1] https://www.ans.org/news/article-3240/mit-ramps-10ton-magnet-up-to-20-tesla-in-proof-ofconcept-for-commercial-fusion/

Keywords:

fusion reactor, high temperature superconducting magnet

고교 학점제 시대의 물리교육의 방향 : 일반계 고교를 중심으로

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Abstract:

2022 개정 교육과정으로의 전환에 따라 물리교육에서도 많은 변화가 예상된다. 가장 큰 변화는 고교 학점제의 시행으로, 현재 일반계 고등학교에서 단계적으로 추진되고 있는 고교 학점제에 대한 준비 상황을 통해 물리 교과 교육의 현황을 살펴볼 필요가 있다. 이를 토대로 2022 개정 교육과정 및 고교 학점제의 정착에 따라 미래 물리교육을 위해 무엇을 준비해야 하는지 논의해보고자 한다.

우선, 현재 고교 학점제를 준비하고 있는 일반계 고등학교에서 물리 교과의 선택 현황과 운영되고 있는 모습, 고교 교육과정의 선택과목이자 수능 과목으로서의 역할, 대학 진로 진학과의 연계 등을 중심으로 현 상황에 대해 분석해보았다. 이를 토대로 다가오는 고교 학점제의 본격적인 실행상황에서 어떤 준비와 노력이 필요한지 파악해보고자 한다. 특히, 물리 교과는 이공계 기초학문으로서의 중요성을 가지지만 과학 선택 과목 중 학생들의 선택 비율이 가장 낮게 나타나고 있으며, 이러한 경향은 수년간 지속되고 있다. 따라서 이에 대한 원인을 분석하여, 학생들의 선택을 확대하고 이공계 기초학문으로서의 토대를 확보할 수 있는 방안을 모색할 필요가 있다.

다음으로는, 2022 개정 교육과정의 변화와 맞물려 생기는 물리교육에서의 변화를 파악하여 어떤 방향의 준비가 필요한지를 살펴보고 물리교육의 확대 방안을 논의해보고자 한다. 2022 개정 교육과정에서 일반계 고교 물리 교과 교육과정의 가장 큰 변화는 선택과목 (일반선택, 진로선택) 교과의 개편이다. 또한 고교 학점제 도입에 따른 총 이수학점 감소와 학기당 이수제 등으로 인해 물리 교과의 선택뿐만 아니라 이수 시간이 감소할 가능성도 배제할 수 없다. 이에 대해 물리 교과 편성의 구체적 사례를 살펴보고, 다각도의 논의를 통해 학생들의 진로 선택과 물리교육의 기반 확대를 위한 실천 방안을 마련할 필요가 있다.

Keywords:

고교 학점제, 일반계 고등학교, 물리 교과 선택, 일반선택, 진로선택

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

F12.02

고교학점제 도입에 따른 일반계 고등학교의 물리교육 상황과 변화 및 고민

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Abstract:

고교학점제 도입에 따른 물리교육의 방향을 모색하기 위해 일반계 남자 고등학교의 물리교육 상황과 앞으로의 변화를 살펴보고 일선 학교의 교육과정 실행가로서의 고민을 정리해보았다.

사례 학교는 자율형 공립 고등학교로 지정된 남자 고등학교이며 2019년부터 고교학점제 선도학교로 운영되어 학생 선택에 의한 교육과정을 도입하고 있다. 최근 3년간의 통계로는, 한 학년당 200여 명의 학생 중 물리학Ⅰ 선택자 수는 60~70명 정도이며(약 33%) 물리학Ⅱ 선택자는 40~60명 정도(약 20%)이다. 물리학을 선택하게 된 배경에 대한 학생 응답으로는 진로 영역과의 일치, 물리학에의 순수한 관심 등 입장이 다양하다. 2015 개정 교육과정에서 물리학Ⅰ은 등급 평가와 성취평가가 같이 이뤄지는 일반 선택 과목으로 평가 결과에 따라 내신 등급이 나누어지므로 학생들의 평가 피로도가 높은 편이다. 물리학Ⅱ는 진로 선택 과목으로, 교육과정상의 성취 기준 및 평가 기준에 맞추어 성취 평가가 이루어지므로 학생들의 평가 피로도는 상대적으로 낮은 편이다.

2022 개정 교육과정의 시행과 고교학점제의 전면 도입에 따라 일반 선택 과목인 <물리학>, 진로 선택 과목인 <역학과 에너지>, <전자기와 양자>는 모두 성취 평가 방식으로 평가가 이루어지고, '이수∘미이수' 제도가 도입된다.

고교학점제 도입에 따른 일선 학교의 교육과정 실행가로서의 고민은 다음과 같다. 첫째, '이수∘미이수'를 나누기 위한 최소 성취 수준을 개별 교사가 결정해야 하는데, 이를 어떻게 설정할 것인가. 또한 학교별, 운영 교사별 차이를 어떤 관점으로 봐야 할 것인가. 둘째, 학생의 물리 교과 선택의 이유는 물리 자체에 관한 관심, 희망 진로와의 연계성, 입시 전형 중 학생부 종합 전형에서 유리한 점을 활용하기 위함 등으로 생각해 볼 수 있는데 학생들의 과목 선택 이전 단계에 물리 교과를 어떻게 안내할 것인가, 더 나아가 수업 운영에서는 학생의 기대를 어떻게 효과적으로 반영할 것인가. 셋째, 성취평가제가 도입됨에 따라 대입에 있어 교사의 서술식 평가(학교생활기록부 기록)의 중요도가 올라갈 것으로 생각되는데, '교육과정-수업-평가-기록'에 있어서 각 부분을 어떻게 구성할 것인가와, 반성적 측면에서 평가자로서 나의 평가 기록은 적절한가, 좋은 평가자란 무엇인가. 넷째, 학생의 교과 선택을 존중하는 차원에서 교과 선택 폭을 넓히기 위해 교과별 단위 수(학점)를 줄이는 경우가 있는데 단위 수 차이에 따른 교과 학습 깊이의 차이와 학생의 교과 선택 폭의 확대 사이의 균형은 무엇인가. 다섯째, 2022 교육과정에서는 디지털 소양 함양과 교수학습 환경의 변화를 고려하여 다양한 디지털 기기 및 환경을 적극적으로 활용하도록 안내하고 있는 상황에서 수업 내용과 목표에 맞춰 어떤 디지털 기기 및 환경을 선택하는 것이 효과적일 것인가, 디지털 기초 소양 교육을 물리 수업 상황에 어느 정도까지 도입할 것인가.

이러한 고민은 2022 개정 교육과정 및 고교학점제 도입에 따른 학교 현장에서의 물리교육이 마주할 문제들에 대한 고찰이며, 변화의 상황에서 더 나은 물리교육의 방향을 모색하는 동력이 될 것이다.

Keywords:

고교학점제, 물리교육, 일반계 고등학교

2023 KPS Spring Meeting
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F12.03

영재학교에서 고교학점제 시스템의 물리교육과정 운영 실태 및 개선점

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Abstract:

영재학교인 광주과학고등학교는 학교의 교육목표에 적합한 인재를 양성하기 위해 영재교육 진흥 법에 의거 학교 자체적으로 교육과정을 설계하고 교육부의 심의를 받아 교육과정을 운영한다.

본교의 물리학 교육과정은 입학 후 3학기 동안 모든 학생이 물리 Ⅰ, Ⅱ, Ⅲ (각 3학점)와 물리실험 Ⅰ, Ⅱ(각 1학점)를 이수한다. 필수 교과 이수 후 AP(Advanced Placement) 교과인 일반물리학 Ⅰ, Ⅱ (각 4학점), 일반물리학실험 Ⅰ, Ⅱ(각 1학점)과 일반선택 교과인 물리탐구(3학점)를 선택하여 이수한다. 또한 보다 심화된 물리학 및 진로 선택을 위해 학생 스스로 교과를 설계하는 학생 자율 설계과목 (ex 고전역학의 이해, 기초 전자기학 등)을 이수할 수 있다.

공학 계열 및 자연계열 희망 학생이 증가함에 따라 자연스럽게 AP 교과인 일반물리학과 일반물리학 실험 선택 비율이 증가하고 있다. 4~5년 전에는 일반물리학 수강생은 50~60%도 선택했으나 최근 3년간 70~80% 정도가 일반물리학을 과목을 수강하고 있다. 또한 학생 자율 설계과목 신청자도 증가하여 매년 개설하였던 고전역학의 이해뿐 아니라 과목 첨단 물리의 이해, 기초 전자기학 과목도 추가 개설하였다.

영재학생들의 물리학 선택 비율 증가는 학생의 진로희망에도 영향을 받았지만, 대학에서 학생 선발 시 자기소개서 및 교과 세부능력 특기사항과도 연관된 것으로 평가된다. 과거 영재학생들의 종합대학 입시의 경우 학점 위주의 경쟁이었다면 최근에는 학점보다는 과목 선택 여부 및 활동 내용에 따라 합격 여부가 결정되는 사례들이 누적되었다. 이에 따라 학생들은 진로희망에 대한 희망 여부 및 활동 내용을 드러내기 위해서도 물리학을 선택하는 학생들이 증가하였다.

2024학년도 대학입시부터는 자기소개서가 폐지된다. 이에 따라 일부 학생들은 학점의 향상을 위해 상대적으로 힘든 물리학을 포기할 수 있다고 생각된다. 하지만 자기소개서가 없어짐에 따라 상대적으로 교과 세부능력 특기사항의 중요성이 향상되었으며, 이에 물리학을 선택한 학생들에 대한 일반적인 평가 결과보다는 학생들의 진로 희망 및 활동에 대한 구체적인 평가를 서술해 주는 평가 시스템이 더욱 중요해지게 되었다. 많은 학교에서 교수평기 일체화에 대한 연구 및 노력을 하고 있지만 과도한 행정업무와 현실 여건에 따라 내실 있는 교수평기 일체화가 이루어지지 않음이 사실이다. 또한 물리교육을 중심으로 한 교수평기 일체화에 대한 방안에 대한 연구도 거의 이루어 지지 않았다. 특히 기록 방법에 대한 교사들의 고민이 가장 크기 때문에 향후 물리교육에 있어 평가 기록 방법에 대한 질적 향상이 필요한 시점이다.

Keywords:

영재학교, 물리교육, 물리학, 과학고등학교, 광주과학고

F13.01

원자간섭계 기반 고정밀 중력센서

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Abstract:

본 학회에서는 냉각 원자의 물질파의 중첩현상을 기반으로 하는 원자간섭계를 이용한 고정밀 중력 측정에 관한 내용을 소개한다.
그 중력 측정을 이용한 기본 물리상수 측정 , 물리이론 검증 및 지구물리 연구 등 다양한 응용에 관한 예를 또한 소개하고
현재 표준과학연구원에서 개발중인 원자중력계의 개발 현황에 대해 소개한다.

Keywords:

원자간섭계, 원자중력계

2023 KPS Spring Meeting
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F13.02

Multi-axis inertial sensing with atom interferometry based on an expanding atomic source

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Abstract:

Atom interferometry is a precision inertial measurement technique applicable in the range of geophysics to navigation with exquisite sensitivity and stability. However, it is challenging to implement atom interferometer inertial sensors in a small volume for field uses while maintaining high performances. Point-source atom interferometry (PSI) offers a prospect of realizing compact inertial sensors with relatively low experimental complexity. PSI uses the velocity distribution in an expanding cold-atomic cloud to realize many parallel atom interferometers and simultaneously measure one axis of acceleration and two axes of rotation from atomic population fringes. Here, we present on a magneto-optical trap-based PSI atom interferometer using 87Rb and methods to correct scale factors for arbitrary initial shapes and sizes.

Keywords:

Atom interferometer, quantum sensing

2023 KPS Spring Meeting
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F13.03

Atomic magnetometer and atomic electrometer based on atomic ensemble

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Abstract:

The various quantum states of an atom (orbital, angular momentum, spin, nuclear spin) have sensitive and quantitative changes in response to external magnetic or electric fields. The field of quantum sensors is actively being researched to precisely measure the changes in these quantum states using the interaction of atoms with light. In this invited talk, I will introduce the definition and concepts of quantum sensors, a field of quantum information science that has received a lot of attention in recent years, and introduce various quantum sensor research based on atomic ensembles, such as the atomic magnetometer and the atomic electrometer using Rydberg atoms, which are actively being researched, and their principles and experimental implementation methods.

Keywords:

quantum sensor, atomic magnetometer, atomic electrometer, Rydberg atom

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

F13.04

Battery Diagnostics with Atomic Magnetometer

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Abstract:

Reusable batteries are the crucial technology for enabling the use of renewable energy sources in portable electronics, transportation devices, and other power systems. The development of technology for analyzing the characteristics of commercialized secondary batteries, such as lithium-ion rechargeable batteries (LIBs), is also attracting significant attention across the battery industry. Currently, the characteristics analysis methods have been developed, including synchrotron-based scanning transmission X-ray microscopy, X-ray microdiffraction, and ultrasound diagnostics. Additionally, recent research has explored the use of superconducting quantum interference devices (SQUIDs) to study the magnetic properties of LIBs. In this study, an atomic magnetometer was utilized to establish a measurement system to determine the presence of defects in LIBs and to investigate magnetic field characteristics of LIBs.

Keywords:

atomic magnetometer, battery diagnostics

F13.05

Detecting nonclassicality beyond negativity with multiple points in phase space

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Abstract:

While negativity in phase space is a well-known signature of nonclassicality, many nonclassical states require their characterization beyond negativity. We establish a framework of nonclassicality in phase space that addresses nonclassical states comprehensively with direct experimental evidence [1]. This includes the negativity of phase-space distribution as a special case and effectively analyzes quantum states with positive distributions. We prove that it detects all nonclassical Gaussian states and all non-Gaussian states of arbitrary finite dimension remarkably by examining three phase-space points only. Our formalism also provides an experimentally accessible lower bound for a nonclassicality measure based on trace distance. Significantly, this foundational approach can be further adapted to constitute practical tests in two directions looking into the particle and wave nature of bosonic systems via an array of nonideal on-off detectors and coarse-grained homodyne measurement [2], respectively. All these tests are practically powerful in characterizing nonclassical states reliably against noise, making a versatile tool for a broad range of quantum systems in quantum technologies.

[1] J. Park, J. Lee, and H. Nha, Phys. Rev. Research **3**, 043116 (2021).
[2] C. Roh, Y.-D. Yoon, J. Park, and Y.-S. Ra, arXiv:2212.14343 (2022).

Keywords:

nonclassicality, phase space

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

F13.06

Nonlinear motion of a trapped-ion mechanical oscillator

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Abstract:

본 발표에서는 포획된 이온의 비선형적인 운동의 관측과, 이온의 운동 에너지의 다른 축으로의 전환(motional transduction)에 대해 보고한다. 포획된 174Yb+ 이온을 외부의 AC 전기장을 이용해 구동하며 이온의 형광 신호를 측정하였다. 구동하는 전기장의 신호가 강해질수록 이온의 움직임은 Duffing 진동자와 같은 비선형성을 보이며, 정량적인 분석을 통해 포획 포텐셜의 비선형 계수를 추출하였다. 또한 완벽하지 않은 포획 구조 때문에 움직임의 주축(principal axis)사이에 결합이 발생하여 운동에너지가 구동하지 않은 다른 축으로 전달되는 현상도 관측하였다. 이러한 현상들은 안정적인 끌개(attractor)사이의 자발적인 천이, 위상 공간에서 끌개 영역들의 분리, 이온 트랩 양자 엔진의 효율 향상 등에 응용될 수 있다.

Keywords:

Ion trap, nonlinaer motion

Subcellular-scale hydrodynamic interactions probed by theory and experiment

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Abstract:

We study the hydrodynamic coupling of neighboring micro-beads placed in a multiple optical trap setup. By varying the degree of coupling, we can control the movement of neighboring beads and measure their time-dependent trajectories. We start with simple configurations of a pair of interacting beads moving in one or two dimensions, and progress to a triplet of beads moving in two dimensions. We also conducted fluid dynamics computations that demonstrated good agreement with the experimental data, illustrating the significance of viscous coupling and setting timescales for probe bead relaxation. The findings provide direct experimental corroborations of hydrodynamic coupling at large, micron spatial scales and long, millisecond timescales, of relevance to e.g., microfluidic device design and hydrodynamic-assisted colloidal assembly, improving the capability of optical tweezers, and understanding the coupling between micron-scale objects within a living cell.

Keywords:

hydrodynamics, optical trap, subcellular physics

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

F14.02

Compressed sensing provides a novel perspective on Drosophila olfactory processing

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Abstract:

In linear algebra problems in the form of $\mathbf{b} = A\mathbf{x}$ for given $\mathbf{b}$ and A, where the dimension of $\mathbf{x}$ is much greater than that of $\mathbf{b}$, the problem is under-determined, such that there exist infinitely many solutions for $\mathbf{x}$. However, when we impose a condition of sparsity on $\mathbf{x}$ and incoherency on A, a method called compressed sensing (CS) can determine a unique solution of $\mathbf{x}$. Here, we analyze recent connectome data revealing the olfactory neural circuits of *Drosophila melanogaster* and show that a sensing matrix corresponding to A, defined via the information of synaptic connectivities at the interfaces of projections neurons (PNs), Kenyon cells (KCs), and mushroom body output neurons (MBONs), fulfills the condition required for the operation of CS. We find that the CS is effectively at work under the premise of recovering a sparsely encoded code of odor mixture on PNs. Specifically, the sparse response profile of PNs ($\mathbf{x}$, dim($\mathbf{x}$) ~ 130) can be reconstructed and correctly classified from a much lower dimensional response profile of MBONs ($\mathbf{b}$, dim($\mathbf{b}$) ~ 50) via the sensing matrix (A). We test our framework on hundreds of idealistic and naturalistic odor expression patterns and demonstrate that the CS can accurately classify the given odor. We show that when more than five different odors are simultaneously introduced, the performance of signal recovery degrades significantly.

Keywords:

Olfaction, Drosophila, Compressed sensing

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

F14.03

External electric field effect on the translocation of R-derivatives peptides across a symmetric lipid bilayer using umbrella sampling

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Abstract:

Translating cargoes like nanoparticles (NP) and macromolecules like DNA and RNA across the model membrane through different cell-penetrating peptides (CPPs) has been the point of research for the last few years. Electroporation is a technique to transfer foreign molecules like proteins, drugs, antibodies, and highly charged molecules such as DNA into the cell membrane. However, how the external electric field helps increase the membrane permeability hasn't been elucidated yet. Therefore, in this MD study, the presence and the absence of a constant electric field effect were studied during the interaction of oligoarginine peptides (R4, R8) with the symmetric lipid bilayer having the following lipid composition: DOPC/DOPG(4:1). The results showed, initially, there was not a significant free energy barrier difference for tetra-arginine with and without electric field, but after 100ns of simulation it starts showing a noticeable difference with a higher value for without electric field than with electric field. However, initially, with and without an external electric field, the octa-arginine case showed almost the same barrier. After 100ns, there was a minor difference in the free energy barrier with a higher of a few kJ/mol of magnitude in the presence of an electric field than in an electric field absence. The outcome seems consistent with the fact that the applied electric field must have a threshold value to generate the membrane defect and transmembrane pore to lower the free energy cost. This study explains the external electric field effect on the translocation of R-derivative peptides through the symmetric membrane.

Keywords:

cell-penetrating peptide, electric field, umbrella sampling

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

F14.04

Nonequilibrium diffusion of active particles bound to a semi-flexible polymer environment

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Abstract:

Recent studies have shown that active agents exhibiting nonequilibrium kinetic motion and semi-flexible biofilaments play crucial roles in cellular environments, such as actin-myosin polymer networks, telomere motion in the chromosome, and cross-linking in endoplasmic reticulum networks. Despite the numerous experimental and computational studies of nonequilibrium biopolymer networks, a mesoscopic theory has not yet been fully developed. However, our recent research has shown that the flexible polymer environment provides viscoelastic feedback on the active agent's motion, highlighting the need for further investigation into this area. In this study, we investigate the nonequilibrium diffusion in the active viscoelastic media consisting of active particles and several semi-flexible polymers using Langevin simulations and analytical theory. Our simulation results demonstrate that the active particle bound to the semi-flexible polymer network exhibits several anomalous diffusions with the exponent α according to the time domain. Prior to the self-propulsion time, the active particle shows the superdiffusion with $\alpha=3/2$, while the subdiffusion of $1/2\leq\alpha\leq3/4$ is observed thereafter. The subdiffusion becomes stronger with larger self-propulsion (Pe) due to the viscoelasticity of the system, ultimately converging to $\alpha=1/2$, which may be mistakenly considered as Rouse (flexible) polymer dynamics. Our analytical theory shows that the dynamics can be described by a fractional Langevin equation under an Ornstein-Uhlenbeck noise, enabling us to formulate the mean-squared displacement and velocity autocorrelation function including not only the scaling relation but also the prefactors. We also identify the threshold Pe* above where the active diffusion occurs and their corresponding timescales. The finding may provide a theoretical insight into various nonequilibrium biopolymer networks and intercellular environments.

Keywords:

Active force, Semi-flexible polymer, Biopolymer, Nonequilibrium diffusion, Viscoelastic environment

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

F15.01

Tip-induced light-matter interactions in low dimensional quantum materials

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Abstract:

Structure, functions, dynamics, and interactions are the basic properties to systematically understand physical systems existing in nature. In particular, there have been many scientific adventures to understand light-matter interactions, yet in the classical regime at the microscale due to the diffraction-limited optical resolution. Recently, plasmonic nano-cavity enables to induce light-matter interactions and tip-enhanced nano-spectroscopy enables to probe them at the nanoscale. However, these two approaches have developed independently with their own weaknesses so far. In this talk, I provide a novel concept of tip-enhanced cavity-spectroscopy (TECS) overcoming the limitations of previous approaches to induce, probe, and dynamically control ultrastrong light-matter interactions in the quantum tunneling regime. Furthermore, I provide several new directions of nano-spectroscopy and -imaging, which have not been thought in the near-field optics community before. First, we exploit extremely high tip-pressure (~GPa scale) to directly modify the lattice structure and electronic properties of materials. Second, we dynamically control the near-field polarization by adopting adaptive optics technique to near-field optics. Third, we develop conductive TECS to modify electrical properties of materials by directly flowing an electric current through the cavity junction.

Keywords:

tip-enhanced spectroscopy, TEPL, TECS, TERS

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

F15.02

Optical properties of organic epsilon-near-zero materials and monolithic hyperbolic materials

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Abstract:

Organic epsilon-near-zero (ENZ) materials and monolithic hyperbolic materials are two types of organic metamaterials that display unique optical properties. ENZ materials, typically made from organic polymers, can be easily manufactured using simple solution processing techniques. When light passes through ENZ materials, it slows down significantly, resulting in effects like enhanced light-matter interactions and high-refractive contrast waveguides. In addition, spin-coated polycrystalline organic semiconductor films with layered molecular packing structures exhibit hyperbolic dispersion over a broad spectral range, supporting the existence of surface exciton polaritons. Both organic ENZ materials and monolithic hyperbolic materials can produce novel optical properties, including enhanced spontaneous emission, super-resolution imaging, and topological photonics. This work introduces a new avenue for the single-step solution fabrication of large-area, low-cost, and flexible organic photonic metadevices.

Keywords:

Organic epsilon-near-zero materials, Monolithic hyperbolic materials, Natural hyperbolic material

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

F15.03

Local field-enhanced light-matter interaction on low dimensional materials

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Abstract:

We experimentally demonstrate metal gap-enhanced linear and nonlinear optical responses and ultrafast optical and electrical dynamics of low dimensional materials such as two dimensional (2D) materials and bio- and chemical-nanoparticles. A metal gap composed of two sharp metal edges aims to provide strong focusing of electromagnetic (EM) waves within a deep subwavelength volume, which enables strong interaction of EM waves with nanomaterials by overcoming diffraction limit. In particular, the strong localization of EM waves is essential for studying the optical and electrical properties of nanomaterials performed with long-wavelength EM waves such as mid-infrared light and terahertz waves. This talk focuses on the strong electric field confinement and enhancement of millimeter waves in nano- and angstrom-scale by using a variety of metal gap structures optimally designed for high-sensitivity probing of linear and nonlinear optical responses of nanomaterials and control of high field-induced nonlinear responses. We anticipate many possibilities of both fundamental studies and applications required for strong light-matter interaction when metallic nanostructures are tailored for a wide spectral range of electromagnetic waves.

Keywords:

Metallic nanostructure, Terahertz nonlinear optics, 2D material

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

F15.04

Time-resolved study of exciton and Floquet dynamics in two-dimensional materials

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Abstract:

Exciton dynamics has become a fascinating topic in fundamental and applied physics with recent improvements in pump-probe technics and high-efficiency solar cells. Especially in two-dimensional (2D) materials, the excitonic effect strongly occurs because of the absence of screening along the out-of-plane direction, possibly leading us to exotic phenomena induced by the electron-hole interaction during light-matter interaction. In this research, we theoretically investigate the time-resolved exciton dynamics during the light-matter interaction in 2D materials by numerically solving the time-dependent Schrödinger equation for a tight-binding Hamiltonian, which includes the Rytova-Keldysh electron-hole interaction. Our calculation well reproduces the recently observed valence-like dispersion of exciton states in angle-resolved photoemission spectroscopy (ARPES). Moreover, the results indicate Rabi oscillations among exciton states and enhancement of second harmonics generation, which implies the complex exciton-Floquet dynamics.

Keywords:

Exciton, Floquet, trARPES, Second Harmonic Generation

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

F16.01

Flavor physics with Belle & Belle II

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Abstract:

Belle II is a high-energy physics experiment searching for new physics in a large number of B meson, D meson, and tau lepton decays produced in electron-positron collisions at the SuperKEKB accelerator at KEK laboratory in Japan. Belle II has reported a handful of world-leading or competitive results to date. Examples of the results include the lepton universality tests; search for the new CP-violating phase and the long-lived particles; and measurements of the $Br(B \to K\nu\bar{\nu})$, the D-meson's lifetime, and the tau-lepton's mass. We will report on the latest new-physics search results at Belle II. Belle II operation is currently suspended to upgrade the vertex detector and PID detector. At the symposium, we will also review the status of the upgrade activities and discuss the positive impact of the upgrade to physics output. Relevant results from still lasting the predecessor Belle activities will also be mentioned.

Keywords:

Flavor physics, B factory experiment, Belle, Belle II

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

F16.02

Flavor physics from lattice QCD

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Abstract:

Numerical simulations of lattice QCD provide the first-principles and non-perturbative calculation of hadronic matrix elements, which are crucial inputs to the search for new physics beyond the Standard Model. Recent advance in the computer performance and simulations algorithms have led to precise calculations for the leptonic and exclusive semileptonic decays as well as challenges to more involved processes. In this talk, we review the current status and future prospects of lattice QCD studies of flavor physics.

Keywords:

Flavor physics, lattice QCD, computer simulation

Hadron spectroscopy and exotics from Belle (II) and J-PARC experiments

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Abstract:

The hadron spectrum has increasingly become rich in recent years, owing to experimental observations of new conventional and exotic hadrons. It provides crucial information on Quantum Chromodynamics (QCD) in the nonperturbative regime. This talk discuss the latest achievements in exotic and conventional hadron spectroscopy. A particular focus is recent highlights of discoveries and prospects with Belle/Belle-II and J-PARC experiments.

Keywords:

Exotic hadrons, multiquark states, excited states of hyperon and charmed baryon

Muons, taus and other results from Belle (II) and J-PARC experiments

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Abstract:

Charged Lepton Flavor Violation (CLFV) refers to a violation of the "accidental" conservation of particle flavor, which is considered an unambiguous signature of new physics beyond the Standard Model of particle physics. The Belle experiment has extensively studied CLFV decays of the tau lepton. Currently, the COMET experiment is under construction to study muon CLFV, with Phase-I data taking scheduled for 2024. This talk will focus on recent progress and results from these two experiments related to CLFV. Additionally, the status of a new experiment on the muon anomalous magnetic moment (g-2) measurement at J-PARC will be briefly discussed.

Keywords:

Tau, muon, charged lepton flavor violation, J-PARC, g-2/EDM, COMET, muon conversion, Belle, Belle-II

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

F17.01

Exotic nuclear properties: selected examples

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Abstract:

A nucleus is a delicate collection of quantum marbles (neutrons and protons). Due to its quantum and non-perturbative nature, it exhibits various interesting and unexpected features. In this presentation, a few recent theoretical efforts to understand those exotic features will be
discussed.

Keywords:

exotic nuclei

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

F17.02

Nuclear Reactions and the Behavior of Weakly Bound Nuclei

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Abstract:

In this presentation, we review nuclear reactions involving weakly bound nuclei and present our theoretical analysis. We first focus on elastic scattering results, specifically the cross sections for ^{11}Li+^{208}Pb, ^{6}He+^{208}Pb, ^{11}Be+^{64}Zn, ^{11}Be+^{120}Sn, ^{11}Be+^{197}Au, and ^{17}F+^{208}Pb. These reactions involve well-known neutron-rich nuclei, such as ^{11}Li, ^{6}He, and ^{11}Be, as well as a proton-rich nucleus, ^{17}F. Our results highlight the importance of break up reactions in these processes, particularly when the projectiles are weakly bound. Additionally, we also review fusion reactions involving weakly bound and halo nuclei, specifically ^{11}Li+^{208}Pb, ^{14,15}C+^{232}Th, and ^{9}Li+^{70}Zn. These reactions are particularly interesting due to the involvement of well-known halo nuclei. We introduce the coupled channel method for neutron transfer in the fusion reaction, and to study the neutron-rich projectile nucleus, we construct a folding potential with projectile and target densities using charge density distribution. Our analysis suggests that nuclear reactions involving weakly bound nuclei at energies around the Coulomb barrier exhibit unique and intriguing behavior compared to those involving stable nuclei.

Keywords:

nucler reaction, weakly-bound nuclei, halo nuclei, fusion reaction

F17.03

Deep learning for R-matrix phenomenology

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Abstract:

Phenomenologies are essential in various physics research. They typically contain various parameters to reproduce observational data, where each parameter determination affects the others. Some models include parameters that do not correspond to observables of a system, and frequently ambiguity in the values of unobservables can change the model predictions of observables. Additionally, if the number of unobservable parameters is large, the fitting process will be challenging. The R-matrix phenomenology is dominantly used in nuclear physics to extract nuclear information from measurements. However, it contains unobservable parameters that disturb the fitting analysis of physical properties as the choices of the parameters are somewhat arbitrary. These parameters have complicated the determinations of the critical properties in nuclear physics. Here, we demonstrate that we can disregard such problematic parameters using deep learning. A deep learning model is trained to predict main nuclear properties from observational data without any information on the unobservables. The model finds patterns of the nuclear properties that appear in the observational data. The model successfully predicts the properties with high performance even in the presence of measurement noises. The methodology is applicable to any other physics phenomenology if one tries to connect the observational data and desired parameters without the others.

Keywords:

R-matrix, phenomenology, deep learning

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F17.04

Gamow-Teller transitions by Charge Exchange Reactions in Raon Accelerator

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Abstract:

Gamow-Teller transition is the main reaction in nucleosysthesis.
This talk aims to provide guidelines on Gamow-Teller(GT) transition which is a charge exchange reaction to be performed in future Raon accelerator.

Keywords:

Gamow-Teller transition, QRPA

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F17.05

Toward more neutron-rich isotopes: ISOL + IF

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Abstract:

Neutron-rich isotopes are produced from well-known facilities: ISOL (Isotope Separation On-Line) and IF (In-flight Fragmentation). These two facilities make isotopes from different methods. ISOL produces isotopes using nuclear fission of heavy elements and IF uses fragment nuclei of heavy-ion collisions. To produce more neutron-rich nuclei, the combination of ISOL and IF is one of the challenging methods. RAON already has ISOL and is going to have not only IF but also ISOL+IF. So, it is very important to understand which beam-target combination gives a better isotope production. We systematically studied isotope production using some empirical models, the di-nuclear system model, and SQMD.

Keywords:

ISOL+IF, RAON, SQMD, Isotope production, DNS

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

F18.01

A superconducting tensor detector for mid-frequency gravitational waves: SOGRO

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Abstract:

Recently, a ground-based superconducting tensorial gravitational-wave detector - the so-called SOGRO has been proposed, which can measure gravitational waves in 0.1 − 10 Hz. In this talk, its basic concept and historical developments of several design configurations are summarized. We also propose the design concept of a prototype SOGRO in order to see the feasibility of the technologies involved. This prototype SOGRO is characterized with six 100 kg Nb test masses levitated on each end of three orthogonal 2-meter arms operating at a cryogenic temperature of 0.1 K. Its sensitivity can reach 8 × 10^(−19) Hz−1/2 at 1 Hz.

Keywords:

Gravitational wave, Detector development, Observational astrophysics

F18.02

Data analysis for a superconducting tensor antenna for mid-frequency gravitational-wave

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Abstract:

We present a study on data analysis for recently proposed superconducting tensor antenna for mid-frequency gravitational-wave (GW). The antenna has six GW channels that detect the corresponding components of GW tensor, so it can be thought of as a network of six GW detectors at the same location. Combining the responses of all the channels show the omnidirectional nature of the antenna. Since the antenna observes the full GW tensor, unlike that LIGO observes a representative scalar of GW strain, even a single antenna can be used for the preliminary positioning of a GW source and constrain the upper limit of the stochastic GW background.

Keywords:

gravitational-wave, data analysis, GW tensor detector

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2023-04-19 - 2023-04-21

F18.03

Astrophysical targets of superconducting tensor detector SOGRO

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Abstract:

We have proposed a ground-based superconducting tensorial gravitational-wave (GW) detector, SOGRO, that can measure GWs in the frequency range of 0.1-10 Hz. In this presentation, we will focus on the astrophysical sources that SOGRO is capable of exploring, including compact star binaries and stochastic backgrounds. Using a model for intermediate mass binary black holes ranging from 200-100,000 solar masses, we have predicted a detection rate of 0.003-5.5 events per year, with a horizon distance of up to 10 Gpc for black hole binaries with a few tens of thousands of solar masses. Additionally, dual advanced SOGROs could potentially discover the existence of stochastic GW backgrounds beyond the indirect limit through cosmological observations. We expect that SOGRO will expand our knowledge of intermediate black holes and the early universe.

Keywords:

gravitational-wave, gravitational-wave detector, compact star binary, stochastic gravitational-wave background

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2023-04-19 - 2023-04-21

F18.04

YeMiGO: muGICK and SPEED project using the next-generation GW detector technology

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Abstract:

We introduce the recent construction and current status of a deep underground microgravity laboratory, YeMiGO (Yemi Micro-Gravity Observatory), in South Korea. On October 2022, YeMiGO was built at the YemiLab in Jeongseon-gun, Gangwon-do Province, eastern mountain region of the Korean Peninsula. YemiLab is the underground experiment laboratory constructed and operated by the Institute of Basic Science (IBS) in South Korea, designed for a dark matter search project. Through a collaboration between the National Institute for Mathematical Sciences (NIMS) of IBS and the University of Calgary in Canada, GWR Instruments Inc.'s superconducting gravimeter, iGrav^{TM} (serial #001) was installed in the joint lab, YeMiGO. YeMiGO's surface coordinates are (37.190656N, 128.658326E, and 885m above the mean sea level (MSL)), and the gravimeter was installed at about 1,003m and 118m below the surface and MSL, respectively. In this paper, the construction of the lab, installation, and operation of iGravTM, and its current status are presented. Finally, we introduce the SPEED project using the next generation GW detector technology.

Keywords:

Gravity Measurement, Geophysical Application, Superconducting Gravimeter

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2023-04-19 - 2023-04-21

F18.05

Can we discern microlensed gravitational-wave signals from the signal of precessing compact binary mergers?

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Abstract:

Microlensed gravitational waves (GWs) are likely observable by recognizing the signature of interference caused by ~ O(10–100) ms time delays between multiple lensed signals. However, the shape of the antic- ipated microlensed GW signals might be confused with the modulation appearing in the waveform of GWs from precessing compact binary mergers. Their morphological similarity may be an obstacle to template-based searches to correctly identifying the origin of observed GWs and it seamlessly raises a fundamental question, can we discern microlensed GW signals from the signal of precessing compact binary mergers? We discuss the feasibility of distinguishing those GWs via examining simulated GW signals with and without the presence of noise. We find that it is certainly possible if we compare signal-to-noise ratios (SNRs) computed with templates of different hypotheses for a given target signal. We show that proper parameter estimation for lensed GWs enables us to identify the targets of interest by focusing on a half number of assumptions for the target signal than the SNR-based test.

Keywords:

gravitational wave, gravitational microlensing

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F18.06

Effects of eccentricity and aligned spins in the parameter estimation of CBC inspirals

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Abstract:

We performed Markov chain Monte Carlo parameter estimation (MCMC PE) using the TaylorF2 inspiral waveform with eccentricity corrections. In order to examine the effects of eccentricity in the existence of aligned spins, we considered two binary black holes (GW151226, GW170608) and one black hole - neutron star binary (GW200105) . Our work consists of two steps. The first step is to generate artificial gravitational-wave (GW) signals varying the spin magnitudes and relative directions (up and down) along with eccentricities while the mass values are fixed to be those adopted from the GW transient catalog papers for the selected sources. The second step is to find the set of parameters by MCMC PE considering the advanced LIGO-Virgo network sensitivity. Main results from MCMC PE are probability density distributions of astrophysical parameters relevant to CBCs such as masses, spins, and eccentricity. Our results show a clear advantage of having a long duration signal of the inspiral phase in parameter estimation. Also, larger spin magnitudes are helpful to constrain mass and eccentricity regardless of their relative directions. Effects of the spin directions are not as strong as the magnitudes.

Keywords:

Gravitational Waves

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F18.09

Gravitational Waves by a Wormhole Binary System

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Abstract:

We considered the wormhole binary system orbiting each other. If two wormholes are far enough from each other, we can treat them as point masses and the nature of gravitational waves by the system is very similar to those by binary compact stars. However, as they approach each other and the system is at the late inspiral state, the finite-size effects such as the tidal effects become very important. We found several differences from tidal effects in compact binary systems by using effective one-body method.

Keywords:

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F19.01

Simulation study of several types of Dual-readout calorimeter at low energy particles.

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Abstract:

Dual-readout calorimeters(scintillation and cerenkov channels) have good energy resolution in hadron particles using the dual-readout method. We study how to measure the energy and position of a proton and carbon beam using hadron therapy using Geant4 simulation. We study the fiber based dual-readout calorimeter, consisting of scintillation fibers and cerenkov fibers, absorber material; Cu, and crystal dual-readout calorimeter, CsI and BGO crystal.

Keywords:

Dual-readout, Calorimeter, Geant4, Simulation

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2023-04-19 - 2023-04-21

F19.02

The multi channel system of MCP-PMT with Dual-Readout Calorimeter for future e+e- colliders and its DAQ operation

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Abstract:

Dual-Readout Calorimeter(DRC) has been proposed in IDEA detector conceptual design report(CDR). It consists of two types of optical fiber - cerenkov and scintillation, and is connected to PMTs for readout system. As a prototype of DRC, we are trying to use MCP-PMT (Microchannel plate photomultiplier tube) as a readout system. Generally, one PMT has one channel, but it has the structure of 8 by 8 channels for high speed response and high quantum efficiency. We aim to operate it with our data acquisition system (DAQ system) of DRC.

Keywords:

Dual-readout calorimeter, future e+e- colliders, DAQ system, calorimeter

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2023-04-19 - 2023-04-21

F19.03

Study on Dual-readout calorimeter SiPM channels using 2022 test beam data at CERN

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Abstract:

The dual-readout calorimeter (DRC) offers excellent energy resolution using both Cerenkov and Scintillation channel readouts. In 2022, the Korea DRC team made 2 prototype DRC modules and had a test beam experiment at CERN. One of the modules used SiPMs (silicon photomultiplier), covering a total of 400 channels (200 Cerenkov and 200 Scintillation each) to offer high granularity readout. In this study, we present a study on the performance of DRC using the responses recorded from these SiPM channels in the 2022 test beam experiment.

Keywords:

Calorimeter, Dual readout calorimeter, CERN, Test beam, Future collider

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F19.04

Dual readout calorimeter testing in clinical

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Abstract:

The purpose of this study is to measure more accurate energy in clinical using a dual readout calorimeter. Monte Carlo simulation was conducted to predict experimental results. And the experiment was conducted by shooting electrons and protons at the MeV level used for treatment to the dual readout calorimeter. Unlike existing measuring instruments, the dual readout calorimeter measures the energy of a single particle and measures the energy without using a bragg peak. So accurate and real time energy check is possible. We present the progress of various tests of dual readout calorimeter for clinical in this talk.

Keywords:

Dual readout calorimeter, Monte Carlo, Treatment, Clinical

F19.05

Particle identification for dual-readout calorimeter using deep learning

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Abstract:

The dual-readout calorimeters measure energy using two different readouts from scintillation and Cerenkov fibers, resulting in high hadronic energy resolution. There is inherent capability of particle identification between hadronic and EM showers through signal comparison between scintillation and Cerenkov channel. However, it is difficult to differentiate particles such as the neutral pion. To enhance the particle identification, we have developed a deep learning model that incorporates spatial information. This study also compares the performances by the readout units for a cost efficient plan. In this presentation, we demonstrate particle identification performance and evaluation by readout units for the dual-readout calorimeter.

Keywords:

Dual-readout calorimter, Particle identification, Deep learning

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2023-04-19 - 2023-04-21

F19.06

Study on EM energy resolution of the dual-readout calorimeter for future e+e- collider using the test-beam data

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Abstract:

The dual-readout calorimeter (DRC) is an innovative technology used in calorimeters, which has been proposed to the conceptual design reports of the FCC-ee and CEPC. The DRC enables high-precision measurement of the energy of hadrons and jets by measuring the fraction of electromagnetic showers produced by hadron showers and then correcting the energy measurement event-by-event basis. The Korea DRC team tested the DRC at CERN by taking test-beam. In this presentation, we present the EM energy resolution achieved by the dual-readout calorimeter using the test-beam data.

Keywords:

Calorimeter, Future collider

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F19.07

Module assembly of the dual-readout calorimeter for future e+e- colliders

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Abstract:

The dual-readout calorimeter(DRC), consisting of scintallating and čerenkov fibers, is one of the calorimeter candidates in future e+e- colliders. Modules for the 2023 test beam have new specifications: Copper forming based on the skiving fin heatsink, the possibility of the high-granularity with MCP-PMT, and aluminum sputtering in front of the Čerenkov fiber. In this talk, we present the details of the new procedure of the DRC module assembly.

Keywords:

dual-readout calorimeter, FCC, calorimeter

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F19.08

Wireless DAQ system R&D of the dual-readout calorimeter for future e+e- colliders.

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Abstract:

Dual-readout calorimeter(DRC) has been proposed in IDEA detector conceptual design report (CDR) for future e+e- collider. DRC are implemented by two different types of optical fibers(Cerenkov and scintillation fibers). it is connect with PMT & SIPM readout system and readout system connected to DAQ using ribbon cables, but it`s have big volume & noise. so, we try the wireless Data transfer system. wireless system consist of transmitter and receiver part, communication with RF transfer device. We present the progress of designed wireless DAQ system R&D in this presentation.

Keywords:

future e+e- colider, dual-readout calorimeter, wireless DAQ

2023 KPS Spring Meeting
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F19.09

Plan of dual-readout calorimeter modules for second test beam(2023)

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Abstract:

Calorimeters have played an important role in high-energy physics experiments since they allow 4-vectors of both neutral and charged particles. Future lepton collider experiments (FCC-ee and CEPC) are proposed for the Higgs factory to understand the properties of the Higgs (origin of mass and its relation to the Higgs mechanism). High-quality energy measurements for these experiments are essential to study the coupling between Higgs and all decay products. The dual readout calorimeter (DRC) is considered as a good option to allow for this requirement. The KFC-DREAM (Korea Future Collider Dual-REAdout Method calorimeter) collaboration had a first test beam with two copper and fiber calorimeters at CERN in August 2022. And we have plans for a second test beam this year. In this talk, we will present our plan and programs for this test beam.

Keywords:

Calorimeters, Dual readout , Dual readout calorimeter, FCC-ee, CEPC

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

G1.01

Deep optical imaging in complex scattering media by tracing multiple scattering trajectories

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Abstract:

Obtaining images of objects deep within complex scattering media is a challenging task due to the presence of multiple light scattering. Most existing microscopic techniques that address this problem attempt to remove the multiple scattering while selectively detecting the ballistic waves that carry the object's image information without experiencing multiple scattering. However, such ballistic waves decay exponentially in the scattering medium, resulting in an imaging depth limit. To overcome this challenge, we have developed a method that traces the multiple scattering trajectories to obtain additional object information carried by the multiple scattered waves. Our method, called the Multiple Scattering Tracing (MST) algorithm, identifies a series of complex phase plates that produce similar light trajectories to the original scattering medium from a reflection matrix of the sample. In the process, we utilize the intrinsic wave correlation of multiple scatterings caused by the target object, which is robust and cost-effective. By implementing inverse scattering using these phase plates, our method rectifies the multiple scattering and enhances the amplitude of ballistic waves by nearly 600 times, leading to a significant improvement in imaging depth. Our study makes a groundbreaking advancement in deep-tissue imaging technology. In addition, it achieves a critical breakthrough in solving high-order inverse scattering problems of complex disordered systems.

Keywords:

Deep-tissue imaging, Reflection matrix microscopy

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

G1.02

Imaging through random media without wavefront shaping

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Abstract:

We face the challenge of imaging through random disturbances all around us in our daily lives such as when trying to see through fog, turbulent atmosphere, and shower curtains. The same problem occurs when we try to image inside deep tissue. Recent advances in wavefront shaping has enabled accurate measurements and correction of such optical disturbances. However, many such developments are still limited to proof of principle experiments, mainly because of the difficulty to dynamically follow changing disturbances in real time. Here, we show that we can apply an all computational approach to gather information from randomly distorted images and recover information about the object.

Keywords:

Multiple scattering, computational imaging

G1.03

Super-Depth Imaging with Volumetric Reflection Matrix

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Abstract:

To obtain an image of an object embedded inside a scattering medium, it is necessary to correct for complex wave distortions caused by the scattering medium. To accomplish this, existing approaches optimize the signal waves recorded in each 2D image. Here, we present a volumetric image reconstruction framework that merges two fundamental degrees of freedom, the wavelength and propagation angles of light waves, based on the object momentum conservation principle. On this basis, we propose methods leveraging the correlation of signal waves from volumetric images to better handle multiple scattering. Through experimental systems that scan both wavelength and illumination angle of the light source, we demonstrate a significant improvement in the use of signal waves (32-fold increase) compared to existing 2D-based approaches. Furthermore, we achieve ultrahigh volumetric resolution (lateral resolution: 0.41 μm, axial resolution: 0.60 μm) even within complex scattering mediums as a result of the optimal coherent use of the broad spectral bandwidth (225 nm).

Keywords:

super-depth imaging, volumetric reflection matrix, ultrahigh-resolution microscopy

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

G2.01

Recent Progress in Tensor Network States for Renormalization Group Studies

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Abstract:

Recently, various approaches are developed in the language of tensor network states in studying many-body systems including strongly-correlated models in low dimensions. In this talk, first, I review finite- and infinite-size renormalization group studies in one-dimensional matrix product states. Second, for two dimensions, new approaches including tensor network renormalization using projected-entangled pair states will be reviewed. Finally, how to implement the method numerically will be discussed.

Keywords:

Tensor network states, Renormalization Group, Entanglement entropy

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

G2.02

Renormalization from a fractal geometric perspective

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Abstract:

Real space renormalization transformations (RT's) appeared in the early 1970-ties just before computer graphics started to allow us to visualize geometric scale invariant fractal type structures. Critical exponents at phase transitions are the experimental signatures of fractal dimensions. (Non-)equilibrium statistical critical phenomena generate scale invariant structures characterized by specific sets of fractal dimensions, so-called universality classes. Classic deterministic fractals, such as the Sierpinski-gasket and Koch-islands are simpler structures with typically only one single fractal dimension, but their construction rules are equivalent to RT's, and therefore useful to illustrate the basic concepts and properties of scale invariance phenomena. In his talk I review this in the context of current applications of real space RT.

Keywords:

Real Space Renormalization, Fractal Dimension, Scale Invariance

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

G2.03

Laplacian renormalization group for heterogeneous networks

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Abstract:

Complex networks usually exhibit a rich architecture organized over multiple intertwined scales. Information pathways are expected to pervade these scales reflecting structural insights that are not manifest from analyses of the network topology. Moreover, small-world effects correlate with the different network hierarchies complicating identifying coexisting mesoscopic structures and functional cores. We present a communicability analysis of effective information pathways throughout complex networks based on information diffusion to shed further light on these issues. This leads us to formulate a new renormalization group scheme for heterogeneous networks. The Renormalization Group is the cornerstone of the modern theory of universality and phase transitions, a powerful tool to scrutinize symmetries and organizational scales in dynamical systems. However, its network counterpart is particularly challenging due to correlations between intertwined scales. The Laplacian RG picture for complex networks defines both the supernodes concept à la Kadanoff, and the equivalent momentum space procedure à la Wilson for graphs.

Keywords:

Laplacian Renormalization Group, Network coarse-graining, Scale-invariant networks

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

G2.04

Revealing symmetries in complex networks: Self-similarity and scale-invariance

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Abstract:

Self-similarity is defined, in a wide sense, as the property of some systems to be, either exactly or statistically, similar to a part of themselves. However, in the absence of an explicit embedding geometry, it is not clear how to decide what part of the system should be compared to (and look alike) the whole. In this sense, self-similarity is not an intrinsic property of the system but is directly related to the specific procedure to identify the appropriate subsystem. Scale invariance, on the other hand, implicitly assumes the existence of a metric space where the system is embedded, so that distance in this space gives a natural standard of measurement to uncover similar patterns at different observation scales. Despite many real complex networks are not explicitly embedded in any physical geometry, they can nevertheless be successfully embedded in hidden/effective metric spaces, which can then be used to define scale transformations in the spirit of the renormalization group. In this talk, I will explain how to uncover the self-similarity and scale-invariance of real complex networks. These properties have important implications (as well as applications) for the global structure of networks and the dynamics taking place on them.

Keywords:

Network Geometry, Scale-Free Networks, Self-Similarity, Renormalization Group

G2.05

Multiscale Organization and Cascading Dynamics in Real Multiplex Networks

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Abstract:

Complex systems exhibit intricate organization across multiple scales. The network geometry paradigm [1] provides one of powerful frameworks to investigate network properties by averaging out short geometric distances. We extend such a framework to reveal the multiscale organization of real multiplex networks and its role in cascading dynamics. Our extension yields the spectrum of interlayer geometric correlations while zooming out from a multiplex network. In particular, we find U-shaped spectra in empirical data, implying that the interlayer correlations break down significantly when the microscopic details are washed out to a certain scale. To understand the origin of these nontrivial behaviors, we propose a multiplex model with *clan structure*, where the geometric organization within clans is preserved across layers. In addition, we uncover the intimate relationship between clan structure and cascading dynamics. Our findings expand the role of hidden geometry in multiplex networks and shed light on the interplay between multiscale organization and function in real interdependent systems.

[1] M. Boguñá et. al. "Network geometry", Nat. Rev. Phys. **3**, 114–135 (2021)
*This research is supported by NRF-2020R1A2C1007703

Keywords:

network geometry, multiplex networks, cascading dynamics, multiscale organization

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

G2.06

Toward more efficient and accurate hyperbolic embedding of complex networks

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Abstract:

Many real-world and model networks are embedded in latent spaces. If two nodes are close in the latent space, there is a disproportionately high probability that a link connects them. In most cases, the latent coordinates of each node are not provided, hence it must be discovered by an appropriate method. Estimation of the latent coordinate of each node, along with the determination of the dimension of the latent space is a core topic in network geometry. Here, we present a gradient descent–based embedding algorithm for the hyperbolic network model. We implement the Barnes–Hut approximation to reduce computational complexity. The network is initially embedded in a high-dimensional space, and a potential of continuously increasing strength is applied along the axes of extra dimensions to map the network into low-dimensional latent space. Additionally, the efficiency of the algorithm can be significantly improved by setting the initial coordinates using spectral dimensionality reduction of the graph Laplacian.

Keywords:

Network geometry, Latent space, Embedding algorithm, Hyperbolic network, Dimensionality reduction

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

G3.01

Defect spins and qubits in hexagonal boron nitride from first principles theory guiding experiments

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Abstract:

We have recently developed first principles techniques for theoretical microscopy and spin control of point defects in semiconductors and insulators. We have applied these techniques to several point defects in hexagonal boron nitride (hBN) that are relevant in real hBN materials. We proposed to apply the negatively charged boron-vacancy to realize qubits, confirmed in experiments. We have recently identified the coupling of the electric field and the strain to the electron spin in the ground state of the center with quantifying the theoretical sensitivity limits and interpreting the optically detected magnetic resonance (ODMR) spectrum of ensembles. We identified an oxygen-related electron paramagnetic resonance center in hBN which produces 2-eV emission with relatively small phonon sideband. Furthermore, we proposed two types of ultraviolet (UV) emitters in hBN: (i) the 5-7 Stone-Wales defects and (ii) the carbon-pair defect structures with the most stable form of a carbon ring.

Keywords:

defect qubits, density functional theory, boron-vacancy, Stone-Wales defects, carbon defects, oxygen defects

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

G3.02

Simulation Study on TEM images of defects in graphene and hBN

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Abstract:

Defects in two-dimensional (2D) materials have drawn interest since they induce changes in structural and electronic properties. The transmission electron microscopy (TEM) technique has been used effectively to study the structure and evolution of defects in 2D materials. However, the analysis of TEM images is sometimes difficult due to the uncertainty of images and the fast change between two sequential images. A simulation study has been attempted to analyze correctly the TEM images. In this talk, I will present the analysis of TEM images for graphene defects from the perspective of the recently discovered “mediator atom” by using the tight-binding molecular simulation method [1]. A huge activity has recently arisen in the visible photoluminescence (PL) properties of hBN. More recently, carbon dopants implanted on hBN defects were newly suggested as an origin of single photon emitters. In the second part of my talk, I will report the presence of dopants in the lattice and how they are incorporated into defects from the cooperative work of TEM and simulations [2].

[1] G.-D. Lee et al. Science Advances 6, eaba4942 (2020)
[2] H. Park et al. Small 17 2100693 (2021)

Keywords:

Simulation study, TEM, graphene, hBN

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

G3.03

Origin of tunable UV light emission from hBN defect states

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Abstract:

Light emissions from hBN have received significant attention, and recent new experiments has shown that certain carbon based defect states exhibit strong light emission and are touted as promising candidates for single photon emitter in the UV regime. Experiments have also provided evidence of the signatures of phonon sidebands and more interestingly, the tunability of their relative transition spectral weights with gate voltage tuning. We proposed a physical picture based on the Franck Condon model, in conjunction with a built-in electric field induced by local strains, to account for the observed asymmetric behavior with gate voltage.

Keywords:

single photon, Franck Condon model, color center

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

G4.02

Long-term antimicrobial activity of Cu-/CuO-coated cicada wing replica created by electrohydrodynamic instability

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Abstract:

Antibacterial coatings are gaining increasing attention to prevent contact infections. To address this issue, researchers have studied various biocidal materials. Among them, copper is considered one of the most effective antimicrobial materials. However, copper is susceptible to natural oxidation, which leads to degradation of antibacterial activity. As an alternative, we chose the surface of cicada wings, which are able to kill the bacterial cells even without chemical modification. Cicada wing replica created by electrohydrodynamic instability of the polymer thin film was coated with copper (assay. Interestingly, the antibacterial activity on the CuO-coated surface of the wing replicas was hardly affected compared to the plain Cu-coated surface. Especially, the CuO-coated surface maintained antibacterial performance even after several months (> 10 weeks). Therefore, we believe that our results provide insight into the long-term and practical antibacterial materials.

Keywords:

antibacterial activity, copper, copper oxide, cicada wing, electrohydrodynamic instability

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

G4.03

Formation of InP/BP Heterostructure via In deposition on BP

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Abstract:

Black phosphorous (BP) is one of the emerging two-dimensional layered materials with promising properties for electronics and optoelectronics. Understanding the atomic-scale picture of metallic film formation on BP is important for tuning metal-BP junction properties. However, BP's high chemical reactivity poses some challenges for proper characterizations of electrical properties and structures at metal-BP junctions. Here, we study the physical deposition of In on BP and investigate its microstructure and electrical properties. The formation of InP interfacial layer, which resulted from chemical intermixing between BP and In, was confirmed by transmission electron microscopy, Raman spectroscopy, and energy dispersive X-ray analysis. The photoresponse of InP/BP heterojunctions can be measured using a mono-wavelength laser, while device properties such as current-voltage characteristics and mobility can be evaluated for electronic and optoelectronic applications. Our study indicates that InP/BP vertical heterostructures can serve as a new semiconductor heterojunction with its easy formation and tunable optoelectronic properties.

Keywords:

black phosphorous, Indium phosphides

G4.04

Surface charge carrier transport in Sb2(S,Se)3 thin-film solar cells with various S/Se ratios

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Abstract:

Antimony selenosulfide, $Sb_2(S,Se)_3$, is promising light-absorbing material in inorganic thin-film photovoltaics due to its high phase stability, efficiency, and eco-friendly properties. The S/Se ratio which can be controlled by various deposition method affects the photovoltaic performance.[1] Herein, the current flow and surface potential in the $Sb_2(S,Se)_3$ absorber layer with different S/Se ratios made by various deposition method were investigated.[2] Four samples, (i) Se 2 mM H. (hydrothermal) deposition (ii) Se 2 mM H.+V. (vapor transport) deposition (iii) Se 6.9 mM H. (iv) Se 6.9 mM H.+V., were prepared to compare the electrical properties according to the S/Se ratio. Elemental composition of Se at the surface in the samples fabricated by both H. and V. deposition was higher than that of the samples fabricated by H. deposition only. To probe the current flow at the surfaces, conductive atomic force microscopy was conducted. The results showed that the larger amount of current flow at the surface in the samples with higher Se ratio, indicating that the conductivity of $Sb_2(S,Se)_3$ was enhanced as the amount of Se at the surface increased. Furthermore, Kelvin probe force microscopy was used to obtain the surface potential distribution. Positive potential difference across the grain boundaries (GBs) acting as an electron barrier was detected in all samples. The results showed that the amount of band banding was smaller in the samples with higher Se ratio at the surface. In all samples hindering the carrier recombination by repelling electrons from the GBs. Therefore, Se_{sb} and $2Se_{sb}$ shallow acceptors are the dominant defects, while deep donor, V_{se}, form easily in Se-poor condition.

[1] Woosuck Yang et al., Advanced Energy Materials, 8 (2018) 1702888
[2] Jekyung Kim et al., Solar RRL, 5 (2021) 2100327

Keywords:

Sb2(S,Se)3, thin-film solar cells, conductive-atomic force microscopy, Kelvin probe force microscopy, surface charge carrier transport

2023 KPS Spring Meeting
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G4.05

Interface properties between SnO_2 and lead halide perovskite: impact on charge transport

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Abstract:

Organic-inorganic lead halide perovskite materials have received a lot of attention from the photovoltaic community because of their high efficiency, easy fabrication process, and low cost. During the past years, tin oxide (SnO_2) has emerged as a promising electron transport layer (ETL) in perovskite solar cells (PSC) due to its superior electrical and optical properties and low-temperature process. However, it has been reported that charge accumulation at the interface between perovskite and SnO_2 reduces electron transport and that SnO_2 does not fully cover the bottom electrode (ITO or FTO) leading to charge recombination [1-3]. To solve these problems, several groups applied interface engineering, such as surface passivation or adding an interlayer between the bottom electrode, SnO_2, and perovskite. However, understanding the charge transport between these interfaces is still lacking. We have recently reported that a space charge layer is formed between ITO and SnO_2, which leads to electron depletion and directly affects device performance [4]. As a next step (in this study), we explore the space charge effect between SnO_2 and perovskite. Methylammonium lead iodide (MAPI) is selected as our perovskite layer as it is an archetypal lead halide perovskite material and a mixed ionic and electronic conductor [5]. In a previous study, it was reported that positive ion adsorption at the interface of MAPI and TiO_2 (and Al_2O_3) was responsible for the equilibrium space charge potential [6]. Herein, we investigated the surface property of SnO_2 and its interface effect with MAPI. First, the adsorption behavior of SnO_2 nanoparticles was observed with FTIR and XPS measurements. Next, conductivity measurements were performed with different thicknesses of MAPI spin-coated on top of SnO_2 to describe the charge redistribution at the interface of MAPI/SnO_2. These physical and chemical analyses give us evidence of how the interface effect contributes to charge extraction and recombination between SnO_2 and MAPI. Our work will provide a deeper understanding of lead halide perovskites and open a new perspective on the space charge effect at heterojunctions of perovskite-based devices.

[1] D. Yang et al., Nat. Commun. 9 (2018) 3239.
[2] J. Ma et al., Adv. Sci. 4 (2017), 1700031
[3] Y. Wang et al., ACS Appl. Mater. Interfaces 12 (2020) 53973-53983
[4] S. S.-O. Youn, et al., ACS Appl. Mater. Interfaces 14 (2022) 48229-48239
[5] A. Senocrate, et al., Angew. Chem.Int. Ed, 56 (2017) 7755-7759.
[6] G. Y. Kim et al., Adv. Funct. Mater,30 (2020) 2002426.

Keywords:

perovskite, charge transport

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G4.06

Band Alignment Enabling Effective Charge Transfer for the Highly Enhanced Raman Scattering and Fluorescence of Metal-Nanoparticle-Decorated Conjugated Polymer Nanowires

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Abstract:

The charge transfer (CT) process has attracted much attention due to its contribution to the improvement of spectroscopic phenomena such as Raman scattering and fluorescence. A current challenge is understanding what factors can influence CT. Here, it is demonstrated that the enhancement factor (EF) of CT (~2000) can reach the level of electromagnetic enhancement (~1680) when resonant CT is carried out by (Fermi level energy) band alignment between a metal nanoparticle (NP) and conjugated polymer (polypyrrole (PPy)) nanowire (NW). This band alignment results in an on- or off-resonant CT. As a proof of concept for CT based surface enhanced Raman scattering (SERS) template, the Ag NPs-decorated PPy NW is utilized to effectively enhance the Raman signal of rhodamine 6G (EF of 5.7×10^5). Hence, by means of our demonstration, it is proposed that controlling the band alignment should be considered an important parameter for obtaining a large EF of spectroscopic phenomena.

Keywords:

Surface-Eenhanced Raman scattering, Surface-enhanced photoluminescence , Polypyrrole, Charge transfer, Band alignment

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

G5.01

Large transverse magneto-thermoelectric effects in topological magnets and its device applications

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Abstract:

The anomalous Nernst effect (ANE), which converts heat to electric energy in magnetic materials, has attracted considerable attention for its application to micro-thermoelectric devices such as heat flux sensors. Unlike the Seebeck effect (SE), ANE generates an electromotive force orthogonal to the heat flux. This transverse geometry enables device fabrication techniques commonly used for thin films and offers advantages, including (1) low production cost, (2) large area capability, and (3) flexibility. For the ANE application, however, the small conversion efficiency compared to SE had been a bottleneck. Recent rapid progress in understanding band topology has led to the development of various topological magnets showing a gigantic ANE, a few orders of magnitude larger than conventional magnets, opening a new path for developing thermoelectric devices using ANE. In this presentation, our recent progress in the fabrication of thin films and heat flux sensing devices using topological magnets will be discussed.

Keywords:

Topological magnets, Topological semimetals, Anomalous Nernst effect, Heat flux sensors, Energy harvesting

G5.02

Unusual electron and phonon transport in some themoelectric materials

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Abstract:

In this contributed talk I will present examples of electron and phonon transport in thermoelectric materials, that deviate from the typical concepts used when studying degenerate semiconductors. Electron localisation effects were evidenced in known thermoelectrics like Bi_2Se_3 and Bi_2Te_3 as a consequence of nanostructuring. This offers an exciting playground for realising interesting physical phenomena, but overall improvement of thermoelectric performance may occur only under certain conditions. This will be shown for the case of nano grain bulks and three dimensional spacial arrangements of nanowires.
The interplay of magnetic and lattice vibrational degrees of freedom will be illustrated in the case of $Eu_8Ga_{16}Ge_{30}$ clathrates where the thermal conductivity at low temperatures can be greatly reduced by the effect of magnetic ordering.
Finally strongly anisotropic electron transport but isotropic phonon transport will be shown in the case of $Ca_5In_2Sb_6$.

Keywords:

Thermoelectricity, localization, electron transport, phonon transport, magnetism

Surface Phonon Polaritonic Metasurfaces for Tailoring Infrared Surface Waves

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Abstract:

In recent years, gradient optical metasurfaces have shown great potential for wavefront control of light in free space and optical waveguides by imposing spatially varying optical responses. However, controlling light localized or propagating on a surface has remained challenging due to the intensive scattering of surface waves to metallic nanostructures, resulting in optical power loss. In this talk, I will present our recent experimental demonstration of controlling mid-infrared surface waves using a resonant nano-cavity for localized and propagating surface phonon polaritons (SPhPs). Our research focuses on polar dielectric metasurfaces that host SPhPs, which have emerged as a promising alternative to metallic metasurfaces for long-wave infrared applications. I will also be discussing our recent advancements in the use of resonant nano-cavities with active materials to achieve dynamic resonance tuning of polar dielectric metasurfaces. These active metasurfaces show great potential for developing tunable and multifunctional mid and far-infrared nanophotonic devices. Additionally, we have employed these new active metasurfaces to create a novel polarimetry apparatus, which allows researchers to conduct precise polarimetry studies of sub-micron-size samples at mid and far-infrared wavelengths.

Keywords:

G5.04

FeTe/FeSe Superlattices: Epitaxial Growth and Transport Properties

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Abstract:

Tetragonal FeSe is a well-known superconductor with a transition temperature T_C of 8 K in bulk form and shows a huge enhancement in T_C up to 65 K by reducing thickness to the monolayer level. Whereas -phase FeTe, a parent compound of FeSe, does not exhibit superconductivity at either ambient or high hydrostatic pressure. According to current findings, non-superconducting FeTe might become superconducting via alloying with FeSe, annealing in oxygen, and/or heterostructuring with topological insulators. However, till now, the maximum T_C values of FeTe films have been so far from room temperature. In this work, the concept of interface superconductivity and superconducting proximity of FeSe on FeTe layers are included to design FeTe/FeSe superlattice system. $(FeTe)_m/(FeSe)_n$ superlattices with varying thicknesses down to
sub-unit cell of each constituent layer were successfully grown on As-terminated GaAs (111) substrates with 300-nm-thick CdTe buffer layers via molecular beam epitaxy. The observation of streaky reflection high energy electron diffraction patterns indicates the layer-by-layer epitaxial growth mode. X-ray diffraction patterns show clear satellite peaks demonstrating the periodic stacking structures of FeSe and FeTe. Interestingly, the superlattice films exhibit the onset superconducting transition temperatures around 15 K. Our results offer a possible way to tune the superconducting properties of Fe(Se,Te) thin films.

Keywords:

Superlattice, FeSe, FeTe, 2D semiconductor

G6.01

Recent Advances in Bragg Coherent Diffraction for Nanoscale Imaging of Strain

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Abstract:

Bragg Coherent Diffraction Imaging (BCDI) offers nanoscale resolution imaging with high sensitivity to distortions of the sample lattice. This talk will introduce the technique and describe recent improvements at the BCDI instrument of the Advanced Photon Source (APS) for imaging sub-micrometer scale crystalline objects. The new capability enables in-situ determination of crystallographic orientation via broadband Laue Diffraction Microscopy. With the full knowledge of the orientation of a specific sub-micrometer scale crystal one can measure coherent diffraction around multiple Bragg peaks of the lattice. With such data sets the full strain tensor of the sample can be imaged with tens of nanometer resolution at current generation synchrotrons. The pending upgrades to machines like the APS will significantly improve the capabilities of coherent techniques. We anticipate sub nanometer scale resolution imaging at the new instruments being developed

Keywords:

Coherent Diffraction Imaging, Strain Imaging

Structural Complexity and Local Heterogeneity by Coherent X-ray Diffraction Imaging

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Abstract:

Nanoparticle structure, including strain-field distribution and crystallographic orientation, and local heterogeneities are crucial in many applications since they are key aspects of their functionalities. In particular, identifying chiral nanoparticles with abnormally tuned morphology in three dimensions is essential for optical, catalytic, and biological applications. A fundamental understanding of structural changes of the nanocatalysts is also important for revealing underlying mechanisms and optimizing efficiencies. In my presentation, I present a new methodology for identifying the 3D information of chiral gold nanoparticles with highly concaved gaps. It provides the 3D crystallographic and strain-field distribution of the nanoparticles to the fields where complicated structure and local heterogeneity are crucial, such as plasmonics.

This research was supported by the National Research Foundation of Korea (NRF-2021R1A3B1077076).

Keywords:

Coherent X-ray Diffraction, X-ray imaging, Chiral nanoparticle

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2023-04-19 - 2023-04-21

G6.03

Multimodal X-ray probe station at 9C beamline of Pohang Light Source-II

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Abstract:

In this talk, we present the conceptual design and performance of a multimodal X-ray probe station recently installed at the 9C coherent X-ray scattering beamline of Pohang Light Source-II. The purpose of this apparatus is to measure coherent X-ray diffraction, X-ray fluorescence, and electrical properties simultaneously. A miniature vacuum probe station equipped with a four-point probe was mounted on a six-axis motion hexapod. This enable to study the structural and chemical evolution of thin films or nanostructures, as well as device performance including electronic transport properties. This probe also provides the capability of varying sample environments using a mass-flow-control system and annealing up to 600 °C. We discuss the *in situ* annealing of ZnO and the performance of ZnO nanostructure-based X-ray photodetectors. Our results demonstrate that a multimodal X-ray probe station can be used for performing *in situ* and *operando* experiments to investigate structural phase transitions involving electrical resistivity switching.

Keywords:

Coherent X-ray Scattering, Multimodal X-ray probe station

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

G6.04

Soft X-ray RIXS and its opportunities in energy material studies

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Abstract:

The technical and instrumentational developments of synchrotron-based soft X-ray resonant inelastic X-ray scattering (RIXS) have advanced significantly in the last two decades. The applications of soft X-ray RIXS have impacted many frontier scientific areas from quantum phenomena to technological material studies.

In this presentation, we will first provide a brief survey of some key parameters of RIXS systems in major synchrotron facilities all over the world; then we will focus on the different aspects of RIXS outputs and their association with the different RIXS instrumentation systems, which heavily rely on the optical layouts of the spectrometers. Some of the scientific studies on energy storage materials will be discussed as examples of utilizing RIXS for studying material physics.

This presentation will not discuss the technical details of a particular scientific study, instead, the purpose is to provide a shallow overview of modern soft X-ray RIXS systems for various scientific topics.

Keywords:

Resonant Inelastic X-ray Scattering (RIXS)

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

G7.01

Topological metal arising from strongly disordered Floquet operators

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Abstract:

A time evolution of quantum mechanical states by a time periodic Hamiltonian may contain extra information of topology in the time domain. As a result, there are examples of topological Floquet matter that are distinct from static counterparts. In this talk, I would like to introduce a time evolution operator that simulates the low energy physics of topological metal. The evolution comes with strong disorder mixing information in the quasi-energy domain. I will provide concrete numerical evidences testing the topological metallicity and simple experimental proposals identifying them.

Keywords:

Floquet, disorder, topological, Anderson localization

Quasiparticle Theory Revisited: Fragility and Anisotropy

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Abstract:

Landau quasiparticle theory is one of the greatest triumphs of solid-state physics since it drastically simplifies interacting many fermion problems into the much simpler single-particle Fermi gas problems. In this work, we explore the quasiparticle theory in more depth by looking into the previously neglected aspects of the theory, which are fragility and anisotropy. First, we discuss the robustness and limitations of the Fermi liquid quasiparticle description in 2D electron gas, showing that the basic Landau quasiparticle picture is reliable in a wide range of energy except for a small discrete region where quasiparticles are coupled with plasmon excitations. Second, we investigate the effect of electron-electron interactions on the shape of the Fermi surface in anisotropic 2D electron gas, finding that the Fermi surface deviates from an ellipse in only two distinct shapes with the elliptical Fermi-surface approximation still being valid in most cases.

Keywords:

Anisotropy, quasiparticle theory

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

G7.03

Proximity Superconductivity in Altermagnetic Systems

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Abstract:

Historically, magnetic materials have been classified into two primary categories, ferromagnetism, and antiferromagnetism. Ferromagnetic materials exhibit a strong magnetization and generate time-reversal symmetry-breaking responses, whereas antiferromagnetic materials possess no net magnetization. Recently, a novel magnetic phase, dubbed altermagnetism, has been identified in materials exhibiting robust time-reversal symmetry-breaking responses and spin-polarization phenomena in conjunction with antiparallel magnetic crystal ordering and an absence of net magnetization. This study explores the intricate relationship between altermagnetism and superconductivity, aiming to categorize potential superconducting phases. Furthermore, we investigate proximity superconductivity within heterostructures.

Keywords:

Superconductivity, Altermagnetic System

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2023-04-19 - 2023-04-21

G7.04

Skyrmion and Meron in twisted bilayer magnet CrI_3, $CrCl_3$

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Abstract:

Recent experiments with twisted bilayer materials have provided a versatile platform for the realization of exotic phases of matter. In this talk, we are going to expand the theory of moire systems to spin systems. Starting from the brief review of twisted bilayer graphene, we develop a concrete theory of twisted bilayer magnetism. Using the Monte-Carlo method, we discover a variety of non-collinear magnetic order that has been overlooked in previous theoretical and experimental studies. Based on the first-principles calculations of the two-dimensional honeycomb magnet $CrCl_3$, we show that the twisted bilayer magnet can be a promising platform that harbors interesting topological excitations such as skyrmions and merons.

Keywords:

Skyrmion, Twistronics, Topological excitations, CrI3, CrCl3

Recent progress in quantum thermodynamic uncertainty relation

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Abstract:

Higher precision demands more resources. Although this fact is widely accepted, it has only recently been theoretically proved. The thermodynamic uncertainty relation serves as a theoretical basis for this notion, and it states that current fluctuations are bounded from below by thermodynamic costs, such as entropy production and dynamical activity. In this presentation, I introduce recent developments of thermodynamic uncertainty relation in quantum systems. I first clarify the close relationship between quantum estimation theory and thermodynamic uncertainty relation in general open quantum systems. Moreover, by using the concept of the bulk-boundary correspondence, I show that the thermodynamic uncertainty relation can be identified as a particular case of the quantum speed limit, which places a limit on the speed at which the quantum state can be changed.

Keywords:

Open quantum system, Quantum estimation, Quantum speed limit, Thermodynamic uncertainty relation

G8.02

Out-of-Equilibrium Topological Phases of Quantum Matter

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Abstract:

Topological phases are one of the defining characteristics of quantum matter. While various new classes of topological phases have been imagined and investigated beyond topological insulators, Dirac/Weyl semimetals, and so on, the vast majority of topological phases are still confined within the framework of equilibrium physics. In this talk, I would like to discuss out-of-equilibrium topological phases of quantum matter, which can be obtained by driving quantum matter with time-dependent, periodic, external forces.

Keywords:

Floquet, Quantum Matter, Topological Phases, Out-of-Equilibrium, Nonequilibrium

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

G9.01

From Skyrmions to Antiferromagnets: Nano-scale Spin Textures studied with STM

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Abstract:

Non-collinear magnetic order arises due to the competition of different magnetic interactions. Often the dominant interaction is the isotropic pair-wise exchange between neighboring atomic magnetic moments. An additional sizable contribution from anisotropic exchange (Dzyaloshinskii-Moriya-Interaction) or from exchange between more distant neighbors (exchange frustration) can stabilize uniaxial spin textures such as spin spirals. Periodic two-dimensionally modulated magnetic states can form in zero field due to higher-order magnetic interactions, which can favor superpositions of spin spirals, leading to so called multi-q states. I will discuss several sample systems with nano- or atomic-scale magnetic order of different symmetry. Comparison of spin-polarized scanning tunneling microscopy experiments with theoretical investigations reveal the respective stablization mechanisms for such complex magnetic states, in particular the role of higher-order interactions.

Keywords:

STM, magnetism, skyrmions, antiferromagnets, multi-Q states, domain walls

Ultrafast electron and phonon dynamics imaged at the atomic scale

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Abstract:

The low-energy dynamics of electrons and phonons shape the characteristics and functionality of materials. We combine scanning tunneling microscopy (STM) with ultrafast laser spectroscopy and use single-cycle THz pulses as femtosecond gates in the STM's tunnel junction. This method enables imaging of surface dynamics with atomic spatial and femtosecond temporal resolution.
On metallic surfaces, intense THz pulses induce sub-picosecond Coulomb force pulses between the tip and the sample surface that launch coherent acoustic phonon wave packets that enable measurements of buried interfaces and phonon dispersion with nanometer spatial resolution.
On charge-density wave materials, weak THz pulses directly distort the charge-density wave leading to ultrafast emission of a complex pattern of amplitude and phase excitations from atomic pinning sites. Resolving these fluctuations in real space at the scale of individual impurities provides a new route to unraveling the electronic dynamics of disordered correlated materials.

Keywords:

scanning tunneling microscopy, ultrafast, THz spectroscopy, phonons, charge-density waves

Towards Quantum Computing with Spins on Surfaces

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Abstract:

Scanning Tunneling Microscopy (STM) enables the study of surfaces with atomic-scale spatial resolution and offers the ability to study individual atoms and molecules on surfaces. STM can also be used to move atoms with atomic-scale precision, which enables us to build engineered nanostructures where each atom is in the exactly correct place.
In order to study qubits with STM, we recently learned how to combine STM with electron spin resonance. Spin resonance gives us the means to quantum-coherently control an individual atomic or molecular spin on a surface. Using short pulses of microwave radiation further enables us to perform qubit rotations and learn about the quantum coherence times of our spins. Finally, we will finish with unpublished results on multi-qubit operations with spins on surfaces.

Keywords:

Quantum Information Science, Quantum Computing, Scanning Tunneling Microscopy, Quantum Spins, Molecular Magnetism

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2023-04-19 - 2023-04-21

G10.01

Quantum Hall superfluid in twisted bilayer/double bilayer graphene

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Abstract:

We introduce a novel two-dimensional electronic system with ultrastrong interlayer interactions, namely twisted bilayer/double bilayer graphene with a large twist angle, as an ideal ground for realizing interlayer-coherent excitonic condensates. By exploiting the subnanometer atomic separation between the layers, we demonstrate that a sequence of odd-integer quantum Hall states with interlayer coherence appears at the second Landau level (N = 1). The energy gaps for these states are several orders of magnitude greater than those in GaAs. Furthermore, a variety of quantum Hall phase transitions are observed experimentally. This is made possible by geometrically suppressing interlayer electron tunneling due to the large twist angle. The interlayer coupling can cause a stable Bose-Einstein condensate to form, as observed for half filling in each sheet when the partially filled level has orbital index 1, whereas it is absent for partially filled levels with orbital index 0. This discrepancy is tentatively attributed to the importance of skyrmion/anti-skyrmion interactions in this context. We also demonstrate that the application of asymmetric top and bottom gate voltages enables the manipulation of the orbital nature of the electronic states of the graphene bilayers, allowing navigation in an orbital mixed space. Our observations suggest a unique edge construction involving both electrons and chiral *p*-wave composite fermions.

Keywords:

twisted bilayer graphene, twisted double bilayer graphene, quantum Hall effect, Bose-Einstein condensation, Even-denominator fractional quantum Hall effect

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

G10.02

Tunable Exciton Dynamics in van der Waals Heterostructures

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Abstract:

Van der Waals (vdW) heterostructures represent a promising material platform with rich electronic and optical properties highly tunable via a wide selection of layer materials, electric doping, strain, and twist angle. Monolayers of transition metal dichalcogenide (TMD) semiconductors commonly show strong light-matter coupling and direct bandgaps from the infrared to the visible spectral range, making them promising candidates for various optoelectronic applications. Vertically stacking different vdW materials allows one to create vdW heterostructures with rich and tunable excitonic properties. Among different methods to tune the properties of exciton dynamics, the twist angle is the most unique parameter. In this talk, I will discuss how the twist angle controls the spatial- and temporal-dynamics of interlayer excitons in $MoSe_2/WSe_2$ twisted semiconductor bilayers [1, 2]. Also, I will introduce semiconductor/ferromagnet vdW heterostructures to manipulate exciton's spin and valley degrees of freedom by magnetic proximity interactions [3].

[1] Choi *et. al*. Science Advances 6, eaba8866 (2020)
[2] Choi *et. al*. Physical Review Letters 126, 047401 (2021)
[3] Choi *et. al*. Nature Materials, 1 (2022)

Keywords:

TMD, monolayer, exciton, twisted bilayer

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2023-04-19 - 2023-04-21

G10.03

Topologically protected moiré domain antiferroelectrics in twisted van der Waals homobilayer

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Abstract:

Conventional antiferroelectrics (AFE) with the electric dipoles alternating in atomic scale undergo a phase transition to ferrolectrics (FE) under a strong electric field. In the twisted bilayer transition metal dichalcogenides, periodic arrays of polar domains are formed, exhibiting out-of-plane polarizations alternating in a moiré superlattice length scale. In this moiré domain antiferroelectic (MDAF) configuration, the in-plane lattice shift in moiré domain reverses the out-of-plane polarizations, distinguishing itself from conventional FE or AFE. Here we exploit *operando* transmission electron microscopy to investigate the polar domain dynamics under an applied electric field. We find that the topologically protected domain wall network prevents the MDAF to FE transition even at large electric fields. Moreover, we find that the electric polarizability scales linearly with moire length, indicating the possibility of polarity engineering via twist angle.

Keywords:

domain dynamics, operando TEM, twisted bilayer transition metal dichalcogenides

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

G10.04

Commensuration torques and lubricity in double moire systems

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Abstract:

Twisted van der Waals materials give rise to long period moire patterns when their twist angles and/or lattice mismatch is small. In this regime it is possible to observe sizeable moire pattern strain profiles that can be related with underlying torques and friction forces. In this talk we discuss the commensuration torques and layer sliding energetics of alternating twist trilayer graphene (t3G) and twisted bilayer graphene on hexagonal boron nitride (t2G/BN) that have two superposed moire interfaces. Lattice relaxations for typical graphene twist angles of~ 1° in t3G or t2G/BN are found to break the out-of-plane layer mirror symmetry, give rise to layer rotation energy local minima dips of the order of ~ 10^{-1} meV/atom at double moire alignment angles, and have sliding energy landscape minima between top-bottom layers of comparable magnitude. Moire superlubricity is restored for twist angles as small as ~ 0.03° away from alignment resulting in suppression of sliding energies by several orders of magnitude of typically ~10^{-4} meV/atom, hence indicating the precedence of rotation over sliding in the double moire commensuration process. We discuss the potential implications of our results in the preparation of experimental devices with angle aligned double moire patterns with specific top-bottom layer sliding atomic stacking geometries and how this can impact the electronic structure of the commensurate double moire systems considered.

Keywords:

Moire patterns, Twistronics, graphene, hexagonal boron nitride, double moire

G11.01

Overview of the Laser Fusion

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Abstract:

Researches on the future clean, infinite energy that realizes 'artificial sun' on earth have been conducted for more than half a century. Apart from the magnetic confinement scheme of Tokamak fusion, which is currently undergoing leading research, laser fusion research using the inertial confinement scheme has also been advanced to a considerable level due to the breakthrough development of laser technology. In this presentation, I would like to introduce the basic physics of laser fusion, and review the current status of worldwide research, and physical issues that must be overcome for the success of laser fusion.

This work was supported by the Defense Research Laboratory Program of the Defense Acquisition Program Administration and the Agency for Defense Development of the Republic of Korea.

[1] S. Atzeni and J. Meyer-ter-vehn, *The Physics of Inertial Fusion*, Clarendon Press, Oxford (2004).
[2] S. Pfalzner, *An Introduction to Inertial Confinement Fusion,* Taylor & Francis, New York (2006).
[3] B. Zohuri, *Inertial Confinement Fusion Driven Thermonuclear Energy*, Springer International Publishing (2017).

Keywords:

laser fusion

2023 KPS Spring Meeting
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G11.02

The history and the current status of laser fusion energy (레이저 핵융합 에너지 개발연구의 현재와 미래)

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Abstract:

Fusion energy is known as a Dream energy for it has no pollution emission, 0-carbon, perfectly safe, infinite resource, and non-radio-active waste. There are 2 ways to achieve it, Magnetic fusion Energy and Inertial Fusion Energy. Among Inertial Fusion Energy, the Laser Fusion Energy is known as the most promising way. Recently, on 5th of December in 2022, its experimental proof was demonstrated successfully to obtain the gain of 1.5, producing 3.15 MJ from 2.05 MJ injection. The gain over 1.0 is known as a breakthrough of the fusion energy realization. Now laser fusion energy will be realized as a dream energy for human, if a powerful laser delivering output energy over 5MJ/10ns with high repetition rate over 10 Hz is developed, which is the most challenging issue currently. I will introduce its history, the current status, and the future.

Keywords:

Laser, Fusion, Energy, Gain

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

G11.03

Science of fusion ignition on NIF

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Abstract:

History was made in science in December 2022, that is, the fusion ignition was achieved at the Lawrence Livermore National Laboratory's NIF (National Ignition Facility) experiments. For the first time in more than 70 years of fusion research, the energy produced by fusion reactions exceeds the input energy in the laboratory in a controlled manner. This feat opens the possibility of harnessing fusion reactions for unlimited energy sources.
It is rather straightforward to heat hydrogen isotopes with external sources of energy such as lasers or high energy particle beams and drive fusion reactions. On the other hand, it is extremely elusive to confine the energy from the fusion reactions in such a way that the energy stays in the fuel (that is, confined) and subsequently heats the colder fuel for another fusion reactions. The NIF ignition experiments showed that the energy from fusion reactions driven by laser heating was confined enough to generate multiple fusion reactions resulting in the net energy gain by fusion reactions.
The ignition science is a scientifically rich and interdisciplinary field ranging over a broad spectrum of physical sciences: atomic, molecular, solid-state, plasma, statistical physics, radiation transport, hydrodynamics, laser physics, which have been broadly described as high energy density physics or sciences.
In this session, the concept of laser fusion is explained and the science areas required to understand and improve the laser driven fusion ignition processes on NIF are briefly introduced.

Keywords:

Laser Fusion, Plasma Physics, High Energy Density Physics, NIF

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

G11.04

Laser fusion study at GIST

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Abstract:

In a laser-cluster-fusion experiment, an intense (>10^{16} W/cm^2) laser beam irradiates ~10 nm radius spheres of solid-density deuterium (called deuterium clusters). If the incident laser field is sufficiently strong, the laser-matter interaction leads to an explosion of the individual spheres, generating energetic deuterium ions. The resulting deuterium ions are so energetic (> 10 keV) that they generate nuclear fusion reactions as they collide with each other within the plasma or with ions in the background gas. These fusion reactions produce a ~1 ns burst of neutrons and protons.
At GIST, we have built an experimental platform to study fusion plasmas using high power lasers. We have produced high temperature deuterium fusion plasmas with ion temperatures exceeding 300,000,000 K. We will show that we can control the temperature of fusion plasmas by varying the incident laser intensity. We have measured fusion neutron yields at different plasma temperatures, and preliminary results will be presented.
Finally, we will briefly discuss some of the recent achievements in laser fusion.

Keywords:

Laser fusion, laser-plasma, laser-cluster fusion

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

G11.05

Fusion yield scaling law in laser-cluster fusion experiments

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Abstract:

We present a scaling law ($Y \sim E^{\beta}$) of fusion neutron yields (Y) for laser pulse energy (E) in laser-cluster fusion experiments. We compare the available neutron yield data from previous deuterium cluster fusion experiments with those calculated using the cylindrical fusion plasma model. The calculated neutron yields are shown as functions of the incident laser pulse energy, average number density, and ion temperature. Although the deuterium–deuterium fusion reactivity is known to increase rapidly with ion temperature, the neutron yield shows a modest increase above ~10 keV for a given laser pulse energy. We find the scaling exponent β approaching 1.0 as the ion temperature increases from 1 keV to 100 keV. We explain the observed temperature dependence of β by examining the temperature dependence of the beam–beam and beam–target fusion neutron yields separately. Our scaling law differs from previously reported scaling laws from individual experiments, but it shows an excellent agreement with the scaling law determined by the maximum neutron yields of individual experiments.

Keywords:

Nuclear fusion, Cluster, High power laser, Ultraintense laser, Fusion plasma

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

G12.01

Why did I study physics education?

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Abstract:

1. 내가 물리교육에 관심을 갖게 된 이유는 과학교육이 자신의 역사적 발전 과정에 대해 이야기해주지 않았기 때문이다. 이러한 역사 의식의 결여는 연구자들에게 내재한 학문적 자의식의 결함 때문이라고 생각한다. '과학교육의 사상과 역사'(2014)가 이 관심의 결과지만, 나는 이를 위해 모든 것을 처음부터 다시 공부해야 했고, 모든 기회를 포기해야 했다. 2. 과학 지식의 진보에서 '이론'(논리)과 '경험'(사실)의 관계가 학습에도 적용될 수 있다는 점을 내게 알려준 것은 KYTP/IYPT와 영재교육이었다. 몇몇 헌신적 교수들(그중 한분은 이미 고인이 되었다)이 이룩한 KYPT는 학생들에게 이론과 경험의 연결(Zuordnung)을 훈련하는 기회가 될 것으로 믿는다. 3. 아인슈타인에 대한 나의 관심은 우연한 기회에서 비롯되었지만, 그동안 아인슈타인 연구가 물리교육 관점에서 '의미 있게' 다루어진 바가 없었다는 점은 내게 놀라운 일이었다. 즉 과학교육에서 아인슈타인의 사고에 관한 본격적인 역사적, 인식론적 연구는 아직 없다. 이에 대한 나의 시도가 '칸톤학교 아라우와 아인슈타인'(2019-)의 연작이지만 여전히 진행 중이다. 4. 내가 브리지먼을 연구하게 된 것은 과학교육자들 사이에 광범위하게 퍼져있는 '조작적 정의'에 대한 오해와 몰이해 때문이다. '현대 물리학의 논리'(2022)의 해제를 쓰면서 논리실증주의자들이 발견했던 '논리세계'와 '사실세계' 사이의 관계를 교육적으로 새롭게 의식하게 되었고, 과학교육이 말하는 개념 연구나 구성주의가 소위 '나쁜 의미의 가짜문제들'에 상당히 근거하고 있다는 점을 알게 되었다. 5. 장회익의 '자연철학'(2019)과 '양자역학을 어떻게 이해할 것인가'(2023)는 내게 큰 충격이었다. 어느 물리교육자들도 이런 책을 써보지 않았고, 이에 관심을 가져본 적도 없었다. 열역학적 열린계에서 물질의 상호작용이 만들어낸 생명 현상과 의식에 관한 몸과 마음의 문제나, 개인적 지식을 공적 지식으로 변환하는 문제, 양자역학에 대한 장회익의 논의가 인식론을 넘어 형이상학적 존재론 영역으로 들어간 것에 대해 물리교육자들은 관심이 없다. 아마도 물리교육자가 초등학생에게 양자역학을 설명하는 것은 중세 아리스토텔레스 철학자들에게 고전역학을 이해시키는 것보다 더 어려운 일이겠지만, 이를 영원히 피할 수는 없을 것이다. 문제는 물리교육자들이 자연에 대한 해석의 문제를 교육적으로 다루려고 하지 않고 있다는 점이다.

Keywords:

History of science education, theory and observation in science, KYPT/IYPT, coödination(Zuordnung) of sense experiences to these concepts(Einstein), pseudo-problems in science education, quantum mechanical ontology of H. I. Zhang

G12.02

물리교육자로의 시작과 과정, 그리고 앞으로의 과제

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Abstract:

존경하는 정병훈 교수님의 정년을 기념하면서 물리교육자로서의 선택과 그 동안의 물리교육 연구를 되돌아 보는 시간을 갖게 되어 영광입니다. 저 역시 정년이 몇 년 남지 않은 상황에서 비슷한 주제로 발표를 하고자 합니다. 본 발표에서는 본인이 물리교육자의 길을 걷게 된 과정에서 어떤 선택의 과정이 있었고, 물리교육 연구에 어떻게 매력을 가지게 되었는지를 소개하고자 합니다. 그리고 그 동안 무엇에 초점을 맞추어 물리교육 연구를 해 왔는지에 대해서도 간단히 소개하고자 합니다. 이렇게 과거를 되돌아 보면서, 연구를 위한 남은 시간이 많지는 않지만, 앞으로 무엇을 해야 할지에 대해서도 생각해 보게 되었습니다. 이에 과학교육학회지와 새물리 학술지를 살펴보면서 최근에 어떤 연구들이 진행되고 있는지를 간단하게 살펴보았습니다. 그 결과, 행위 주체성(agency), learning progression, 이론과 실행, core of teaching, 분산인지, 상황학습, 초연결사회, 뇌 신경과학, 과학의 예술적 체험, 전문적 학습공동체, 담화 분석, 시스템적 사고, 초중등학생을 위한 현대물리교육, 메이커 교육, 온라인 물리실험교육, 지능형 과학실, 미래사회와 과학교육, 증강현실, AI, 아두이노와 마이크로 비트 활용 등 많은 새로운 개념과 이슈들이 물리교육에 도입되고 있다는 것을 알 수 있었습니다. 이 외에도 다양하고 새로운 개념과 이슈로 연구들이 진행되고 있다고 봅니다. 이제 늦게라도 이러한 새로운 개념과 이슈들을 계속해서 공부하고 즐겨야 할지, 새로운 세대에게 넘겨주어야 할지 다시 갈림길에 있다는 생각이 듭니다. 아니면 물리교육에서도 이제 전문분야들로 세분화하고 세분화된 분야간 융합적 공부와 연구가 필요한 상황이 아닌가 하는 생각도 듭니다. 이에 함께 좋은 의견을 나누고자 발표를 준비하였습니다.

Keywords:

물리교육 동향, 물리교육의 선택, 물리교육자의 임무

나는 왜 물리교육을 하게 되었는가?

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Abstract:

물리교육, 과학교육을 처음 연구하게 된 동기와 그동안 연구에 대한 나의 입장과 태도, 내용 및 관심이 어떻게 변화했는지를 돌이켜 보고 나 자신이 '물리교육' 연구를 학습하게 된 과정을 이론적 관점에서 재해석해 보았다. 이러한 개인의 물리교육 연구 히스토리 사례를 통해 앞으로 물리교육 연구 후학을 어떻게 지원해야 하며 물리교육 연구 공동체의 실행과 연구를 활성화하기 위해 어떤 점이 고려되어야 하는지에 대해 논의하고자 한다.

Keywords:

물리교육 연구, 공동체, 동기

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2023-04-19 - 2023-04-21

G13.01

Joint probability analysis of strong field ionization

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Abstract:

We describe an approach to the description of a time-development of the processes of ionization of atoms in electromagnetic fields based on the notion of the joint probability of occurrence of two events, event *B* being finding atom in a given state after the end of the laser pulse, event *A* being finding a particular value of a given physical observable at a moment of time inside the laser pulse duration. This approach allows to tackle the questions which are somewhat difficult to address, in particular, to study the characteristics of the ionized electrons for the times inside the interval of the laser pulse duration. For the moments of time inside the interval of the laser pulse duration, when the wave-packet describing ionized electron is not fully formed yet, and is still partly inside the atom, it is not easy to unambiguously single out the part of the wave-function describing ionized electrons from the total wave-function of the system. By choosing the event *B* appropriately, we may circumvent this difficulty. We may require, for instance, that *B* is the detection of an atom in an ionized state and study development of the ionization process, or we may choose *B* to be the detection of atom in a Rydberg state and study development of the frustrated tunneling ionization (FTI) process. We demonstrate the use of this technique by applying it to study time-development of lateral velocity distributions of ionized electrons for the process of strong field ionization of atoms, and time-development of the FTI.

Keywords:

Strong field ionization, frustrated tunneling ionization

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

G13.02

Quantum-enhanced multiple-phase estimation using multi-mode N00N states

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Abstract:

Quantum metrology can achieve enhanced sensitivity for the estimation of unknown parameters beyond the standard quantum limit. Recently, multiple-phase estimation exploiting quantum resources has attracted intensive interest for its applications in quantum sensor networks and imaging. For multiple-phase estimation, it is known that multi-monde N00N states can outperform other probe states for estimating multiple phases. In this focus session, I will present a series of experiments performed at KIST on quantum-enhanced multiple-phase estimation using multi-mode N00N states.

Keywords:

Quantum metrology, Quantum sensing, Multiple-phase estimation, Multi-mode N00N states

G13.03

Quantum sensing with two-mode squeezed states from hot Rb vapor

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Abstract:

Quantum sensing allows us to estimate unknown parameters with enhanced sensitivity over classical approaches by exploring quantum resources. Employing squeezed states of light is one of the most promising strategies for the development of quantum metrology capable of resolving signals beyond the standard quantum limit. In this talk, I will present a generation process for a two-mode squeezed state based on a four-wave-mixing process in hot rubidium vapor. Next, I will briefly discuss the application of two-mode squeezed states to transmission and phase sensing.

Keywords:

quantum sensing, squeezed states, four-wave mixing

G13.04

Atom and Photon Sense Each Other

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Abstract:

중성 원자 혹은 포획된 이온은 공진기에 결합되면 광자와 결맞은 상호작용을 한다. 본 발표에서는 이러한 상호작용에 기반한 두 가지 실험 결과를 보고한다. 첫번째 연구는, 포획된 이온을 이용해 공진기 광자를 비파괴적으로(nondestructive) 센싱한 실험이다. 광공진기에 $^{40}Ca^{+}$이온을 결합한 후, 이온과 공진기의 분산적인(dispersive) 상호작용을 일으킨다. 우리는 광자 개수에 의존적인 큐비트 전이선의 ac Starck 편이를 측정하였다. 또한, 광자 개수의 불확실성이 일으키는 큐비트 전이선의 비결맞음성(decoherence)을 측정하여, 공진기 광자의 개수 분포 비파괴적인 방식으로 추출하였다. 두번째 실험에서는, 측정 대상과 측정 도구를 정반대로 이용한다. 즉, 광자를 이용해 원자의 정보를 알아내었다. 레이저 냉각된 ^{87}Rb 단일 원자의 움직임을 공진기 광자를 이용해 검출하였다. 원자는 다양한 힘을 받으며 공진기 내부에서 확산(diffusion)적인 움직임을 보이는데, 우리는 측정한 이차상관관계 함수를 이용하여 원자의 움직임 중에 Lévy flight과 같은 초확산(super-diffusion)과 관련된 이동이 있음을 확인하였다. 포획된 이온, 원자, 광공진기 등의 양자 광학 실험 도구는 앞으로도 다양한 양자 센싱에 응용될 것으로 전망된다.

Keywords:

Trapped ions, Single atoms, Cavity QED, Quantum sensing

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

G13.05

Third-order exceptional point in an ion-cavity system

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Abstract:

We examine a method for detecting the third-order exceptional point (EP) in an ion-cavity system. In the lambda-type level configuration, the ion is pumped by a laser field from the cavity side, and the cavity is probed with a weak laser field. We take advantage of the highly asymmetrical branching ratio of the ion's excited state, which allows us to neglect a quantum jump operator and obtain the non-Hermitian Hamiltonian. By analyzing the cavity transmission spectrum, we show that the EP emerges when the Rabi frequency of the pump laser and the atom-cavity coupling constant balance the loss of the system. We also provide feasible experimental parameters.

Keywords:

exceptional point, third-order exceptional point, ion-cavity system

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

G13.06

Real-time monitoring of the atomic motion trapped inside a high-finesse optical resonator

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Abstract:

We observe the change of the cavity transmission by the motion of single rubidium atom trapped inside the high-finesse optical cavity. Individual atoms are released into the cavity mode by gravity from the atomic ensemble initially trapped by magneto-optical trap (MOT). When the free-falling atom arrives at the cavity mode, the cavity transmission of probe beam is changed by the atom-cavity coupling and trapped inside the cavity by far-off resonant trap (FORT). We demonstrate the trapping of single atom in several milli-second by FORT and monitored the change of the cavity transmission in real time. From the recorded cavity transmission, we also reconstruct the trajectory of a single atom motion inside the cavity.

Keywords:

Cavity QED, Dipole trap

G14.01

정책위원회 강연

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Abstract:

정책위원회 강연

운영자: 정문석(한양대)

정부가 추진하는 기초과학 진흥을 위한 새로운 과학기술분야 주요 정책들이 물리학자들에게 미치는 영향에 대하여 정부 관계자를 모시고 자세한 설명과 질의 응답을 통하여 심층 토론하고자 합니다.

[프로그램]
정부의 과학기술분야 주요 정책 설명: 윤성훈 (과기정통부 기초연구진흥과장)
질의 및 응답

Keywords:

과학기술 정책

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2023-04-19 - 2023-04-21

G15.01

Raman spectroscopy of two-dimensional materials

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Abstract:

Optical spectroscopy has been used extensively in the study of two-dimensional (2D) materials to probe structural, electronic, mechanical, magnetic, and thermal properties. When other experimental tools cannot be used due to the very small volume of a two-dimensional specimen, optical spectroscopy can play an important role in investigating the physical properties. Raman spectroscopy, in particular, has been established as an essential tool for 2D materials research. In most cases, Raman spectroscopy probes the interaction between adjacent atoms or layers, and the impact on such interactions due to structural, electronic, mechanical, magnetic, or thermal perturbations can be probed. In this presentation, I will review some examples of Raman spectroscopic studies on 2D materials with the emphasis on the analysis of interlayer interactions.

Keywords:

Spectroscopy, Two Dimensional Material, Raman

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

G15.02

Applications of optical pump-probe techniques: from quasi-particle interactions to ultrafast phase transitions

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Abstract:

Optical pumping with an intense laser pulse can excite elections, and disturb spin or phonon sub-systems out of equilibrium states. This can provide us with valuable opportunities to investigate numerous intriguing phenomena realized in the photo-induced non-equilibrium states. In the talk, we present a few representative works revealing interactions among fundamental degrees of freedom in correlated electron systems and also ultrafast phase transitions of the spin-charge-lattice coupled magnetic metal compound.

Keywords:

optical pumping, nonequilibrium state, photo-induced phase transition

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

G15.03

Molecules with strong dipolar interactions – towards a next quantum platform

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Abstract:

Due to their complex internal structures and strong long-range interactions, diatomic molecules are expected to be a promising platform for quantum simulations/computations. The rotational states of the molecules trapped in an optical tweezer array form qubit states with long coherence time. Entanglement between the molecules can be generated using the strong electric dipole-dipole interactions.
To achieve the molecular quantum platform, the molecules should be prepared at ultracold temperatures. One way to cool the molecules is laser-cooling, the workhorse technique to cool the atoms. Despite the complicated internal structures of molecules, laser-cooling and magneto-optical traps of molecules have been demonstrated for several species, reaching temperatures down to 5 μK.
In this talk, two experiments using ultracold molecules will be introduced. I will first start with the CaF experiment at Harvard, where we confirmed dipolar spin exchange due to the strong interaction between the molecules. Here, rotational states of the molecules are adapted as the qubit states, and each molecule is trapped in an optical tweezer. By carefully adjusting the distance between the molecules, a dipolar spin exchange with a rate upto 4.5 kHz is achieved. A two-qubit gate to generate the entanglement is also demonstrated between the two molecules. In the second part of the talk, I will also briefly introduce a new MgF experiment at Korea University.

Keywords:

Ultracold molecules, quantum computing, laser cooling, optical tweezers

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

G16.01

Dark matter experiments

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Abstract:

Dark matter is one of the most enigmatic problems in physics and astronomy. Weakly Interacting Massive Particle (WIMP) is one of the most attractive candidates for dark matter. Various experimental efforts have been made to discover the first evidence. In this talk, recent progress of direct dark matter detection using liquid noble gas is reviewed. Among them, liquid xenon TPC technology is one of the most successful methods to explore the WIMP dark matter. The recent results from liquid xenon TPC experiments and their future development are reviewed. In this scope, indirect detection of dark matter using cosmic rays, such as gamma rays or neutrinos, will be also discussed to some extent.

Keywords:

Dark matter, Underground experiments, WIMP, Astroparticle physics, Liquid Xenon TPC, water Cherenkov detector

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

G16.02

Axion dark matter and its cosmological implications

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Abstract:

Dark matter accounts for 25% of the energy in the universe, yet its true nature remains a mystery. One of the most promising candidates for dark matter is the axion, specifically the QCD axion, which was proposed to solve the strong CP problem in the Standard Model. The QCD axion has a specific relationship between its mass and decay constant and is restricted to a certain mass range in order to account for the observed abundance of dark matter through conventional production mechanisms. This presentation will commence with an overview of axions, followed by an exploration of the dynamics of axions in the early universe. I will then elucidate on the potential production mechanisms that are feasible within the mass range currently being probed by ongoing and future axion search experiments. Finally, I will underscore the cosmological significance of this mechanism.

Keywords:

Dark matter, axion, early universe

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

G16.03

Low mass dark matter searches

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Abstract:

We want to know what dark matter is, so we've been waiting for its signal for a long time in the optimized detectors for optimistic scenarios such as WIMP. Neutrino experiments and cosmic ray observatories have looked for WIMP-induced signal via indirect detection. By searching for an excess of neutrinos in the direction of the Galactic center, Sun or Earth above the atmospheric neutrino background, competitive sensitivity to light WIMPs with masses down to 1 GeV has been achieved. Despite the tremendous efforts over the past decades, not much has been learned. Recently, various ideas of exploiting the current and future
neutrino experiments for dark matter searches are being pursued. For example, some scenario predicts boosted dark matter which can be directly seen in the experimental volume. In this talk, I will present the latest results and on-going analyses of the indirect and direct dark matter searches and future dark matter search potentials of neutrino experiments.

Keywords:

dark matter, light dark matter, neutrino experiment, dark sector

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

G16.04

Dark matter beyond WIMP

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Abstract:

While the existence of dark matter is supported by various astrophysical and cosmological evidence which is based on its non-gravitational interactions with known matter, the searches for dark matter through its non-gravitational interactions have reported null results thus far. The experimental search effort has been mostly focused on a well-motivated dark matter candidate, the so-called weakly interacting massive particle (WIMP). In light of this situation, a wide range of alternative ideas have been proposed and being actively investigated these days. In this talk, I will present an overview of new ideas to search for dark matter beyond WIMP, focusing on large volume dark matter direction and neutrino experiments.

Keywords:

Dark matter, Beyond WIMP, Dark matter direct detection experiment, Neutrino experiment

G17.01

Beam commissioning and early phase experiments of RAON

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Abstract:

In 2022, the first phase of RISP for the RAON heavy ion accelerator facility was finished with beam extraction experiments of SCL3 including machine commissioning experiments of ISOL and all experimental systems. As our focus is on the low-energy accelerator SCL3 and ISOL in 2023, the beam commissioning experiment using KoBRA (Korea Broad acceptance Recoil spectrometer and Apparatus) with stable ^{40}Ar ion beams from SCL3 is being planned. ISOL facility of RAON is also preparing for the RI beam commissioning by employing a SiC target with the 70 MeV proton beam of Cyclotron and expecting to deliver rare isotope beams to MR-TOF (Multi-Reflection Time-of-Flight) and CLS (Collinear Laser Spectroscopy) system for RI beam commissioning experiments. The preparation and progress of RAON with future plans will be discussed.

Keywords:

RAON, SCL3, ISOL, KoBRA

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

G17.02

Possible physics experiments with KoBRA beamline

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Abstract:

RAON has a beam commissioning plan to provide stable beams and RI beams at the first operational stage in 2023. It will provide many opportunities to study nuclear structures, nuclear reactions and nuclear astrophysics.
CENS are considering possible physics experiments with KoRBA beamline for upcoming beamtime, such kinds of ^{40}Ar+p and ^{40}Ar+d elastic scattering studies, ^{40}Ar(p,2p) fast time measurement of ^{39}Cl, and activation method in inverse kinematics for astrophysical studies. In this talk, we will introduce and discuss the possible research topics and issues about current status and future plans for the RI beam production and possible physics experiments with low energy KoBRA beamline.

Keywords:

CENS, RAON, KoBRA, Nuclear Astrophysics, Nuclear reaction and structures

Low Energy Nuclear Physics with KoBRA at RAON - Preparation of the Commissioning and Status

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Abstract:

With the imminent beam delivery by RAON to experimental facilities, especially to KoBRA, spectrometer for low energy nuclear physics, the preparation of the commissioning of KoBRA is well under way. In addition, there has been a series of attempts. to develop experimental proposals and letters of intent (LoIs) using KoBRA once RI or stable beam is available. Major progress is being carried out by the Center for Exotic Nuclear Science (CENS) of IBS. Especially, CENS is heavily involved with the first Wien filter for KoBRA, various detector system for physics experiments and target system. The detector and target system prepared by CENS including HPGe detector array and active target with Si detectors are well suited for low energy experiments at KoBRA. This presentation will cover the current status of the commissioning plan of KoBRA as well as physics proposals and LoIs developed until now.

Keywords:

RAON, KoBRA, nuclear astrophysics, low energy nuclear physics, nucleosynthesis

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

G17.04

Status of the LAMPS experiment

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Abstract:

Large Acceptance Multi-Purpose Spectrometer (LAMPS) is an experimental system for rare isotope collision experiments at RAON, and the detector is designed to study the equation of state and the nuclear symmetry energy of dense nuclear matter. Several detector components for LAMPS, consisting of the Start Counter, Beam Drift Chamber, Time Projection Chamber, Time of Flight, and Neutron Detector, have been developed, constructed, and installed. Active target TPC is also under development for the low-energy experiment. Several beam tests have been done using proton beams at KOMAC and proton and carbon beams at HIMAC to evaluate the detector performance. In this talk, we will present the current status and plan of the LAMPS experiment.

Keywords:

RAON, LAMPS

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

G17.05

Multireflection time-of-flight mass spectrometer at RAON: Science programs and other applicaitons

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Abstract:

Systematic study of the compiled experimentally measured nuclear masses provides a deep insight into the nuclear shell (shape) evolution in the exotic region away from the stability [1] and the nucleosynthetic pathway in the stellar environment [2,3]. A state-of-art mass measurement technique, the multi-reflection time-of-flight mass spectrometry (MRTOF-MS), has drawn attention among the science community since the concept was suggested in 1990 [4]. It allows for fast and sensitive measurement with a high resolution, which can be an ideal tool for rare event cases, especially the mass measurement for the unstable nuclei away from the stability [5]. Recently an MRTOF-MS has been installed in the ISOL beamline at RAON and its performance was tested with off/online ion sources. In this presentation, science programs and other applications using the MRTOF-MS and rare isotope beams produced by the ISOL method as well as the current status of the MRTOF-MS at RAON will be shared.

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[3] X. F. et al., The Astrophysical Journal, 915:29 (2021)
[4] H. wollnik and M. Przwloka, Int. J. Mass Spectrom. Ion. Proc. 96, 267 (1990)
[5] P. schury et al., Nucl. Instrum. Methods Phys. Res. B 335, 39-53 (2014)

Keywords:

MRTOF-MS, Nuclear mass, RAON, RI

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

G18.01

Cold dark mater and Ultralight dark matter

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Abstract:

We briefly review dark matter models such as cold dark matter, warm dark matter, and ultralight dark matter in terms of mass of dark matter particles, which determines the typical scales of galaxies in the models. It is shown that due to wave nature the ultralight dark matter can explain many mysteries of galaxies and supermassive black holes which are difficult for the collisionless cold dark matter models to explain.

Keywords:

cold dark matter, ultralight dark matter, galaxy

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

G18.02

Testing models for self-interacting dark matter

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Abstract:

We review the current status of particle physics models for self-interacting dark matter. We show that self-interactions for dark matter can be velocity-dependent to be consistent with galaxy clusters, due to t-channel or u-channel resonance effects in the presence of light mediators or multiple components of dark matter, respectively. We also point out the importance of self-interactions for determining the relic density for dark matter in the so called Strongly Interacting Massive Particles (SIMP) paradigm. We discuss the prospect of indirect and direct detection experiments for constraining the parameter space for self-interacting dark matter.

Keywords:

Dark matter, Self-interactions, Small-scale problem, Resonance effects, SIMP

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

G18.03

Gravitational-wave phenomenology of dark universe

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Abstract:

We review recent developments of gravitational-wave probes and phenomenologies of dark matter and dark energy.

Keywords:

gravitational wave, dark matter, phenomenology, particle physics

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

G18.04

Dark Matter and the Large-scale Structure of the Universe

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Abstract:

Dark matter is the matter with no or very little interaction with ordinary matter (baryons) and light, and therefore, it cannot be directly detected by ordinary astronomical observations. However, since dark matter is about 5 times more abundant than baryons in the universe and interacts with baryons via gravity, it greatly affects the distribution of large-scale structure of the universe (LSS). In this review, I will discuss how the observation of LSS has been used to determine the properties of dark matter. Also, I will briefly introduce a recent study of reconstructing the local dark matter distribution using galaxy distribution and artificial intelligence.

Keywords:

dark matter, large-scale structure of the universe

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

G18.05

Dark matter direct detection experiment at underground in Korea

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Abstract:

A thallium-doped sodium iodide (NaI(Tl)) crystal is a conventional detector with a long history and is still widely used for particle detection. In particular, since the DAMA/LIBRA experiment claimed an observation of dark matter with a NaI(Tl) detector, low-background and high-light-yield detectors have been developed. In Korea, the COSINE-100 experiment to verify the DAMA/LIBRA signal is being operated at the Yangyang Underground Laboratory using high-purity NaI detectors, which were developed by CUP/IBS. In addition, the COSINE collaboration is preparing for a COSINE-100 upgrade at the new underground laboratory Yemilab in Jeongseon. This is a bridge to the next phase, the COSINE-200 experiment, with the world's best performing high-purity NaI detectors, which are under development at IBS. In this presentation, I will discuss the various efforts and achievements in the direct detection experiment for dark matter in Korea.

Keywords:

Underground Laboratory, Yemilab, COSINE-100, Dark Matter

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

G19.01

Covariant worldline actions and Dual pair correspondences

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Abstract:

Coadjoint orbit actions of flat and (A)dS isometry algebras are shown to give covariant world line actions for various species of particles, upon employing suitable set of Hamiltonian constraints. These constraints form dual symmetries which give rise to the dual pair correspondence, which play important role in various contexts of high energy physics, such as scattering amplitudes, higher spin gravity and twistor theories.

Keywords:

Worldline

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

G19.02

How to Formulate Worldline Action Wisely?

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Abstract:

Worldline particle models provide valuable perspectives on various aspects of high-energy physics, such as effective theory of gravity or string theory, amplitude, and higher-spin theory, etc. We have studied how to construct manifestly covarian worldline action by using coadjoint orbit method and imposing constraints. In this talk, I will introduce the analysis of particles for various isometries(such as Poincaré, (A)dS) and also how can we formulate worldline particle actions for these particles.

Keywords:

Wordline, Particle Action, Coadjoint orbit, Orbit method, Constraint

Extra dimensions, Compactification, and the Higgs mass controversy

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Abstract:

The electroweak naturalness/hierarchy (NH) problem and the unification of gauge theories with gravity, more generally a possible complete unification of forces, are among the most intense driving forces in the search for new physics. More than twenty years ago, the idea emerged that some theories with compact extra dimensions could naturally provide finite (UV insensitive) values for the masses of scalar particles, in particular of the Higgs boson. Some doubts were cast on the correctness of the calculational procedure used, but the community soon came to an agreement in favor of the result. The latter is still greeted with great enthusiasm, as it seems to indicate that a solution to the NH problem can naturally be found in the framework of higher-dimensional compactified theories, originally studied in relation to the problem of the unification of forces, sometimes related to their possible embedding in string theory. The models leading to such a prediction can be divided in two classes: (i) supersymmetric models where supersymmetry is broken through the Scherk-Schwarz mechanism; (ii) gauge models of gauge-Higgs unification where Wilson loops of internal components of gauge fields wrapping the compact dimensions can obtain a non-zero VEV through the Hosotani mechanism. The UV-insensitiveness is usually understood as the result of a non-local spontaneous symmetry breaking (of supersymmetry or gauge symmetry) in the effective four-dimensional theory at distances larger than the compactification radius. In this talk, I will confront this paradigm with a Wilsonian approach, and I will show that some delicate and crucial questions went unnoticed in the previous analysis. Unfortunately, the hope that compactification could provide a mechanism, complementary or alternative to supersymmetry, to solve the NH problem, cannot be satisfied. The illusory UV-finite result is deeply rooted in the usual interpretation and description of higher-dimensional theories with compact extra dimensions as four-dimensional theories with infinite towers of Kaluza-Klein states. I will show that the latter needs to be carefully considered when dealing with the calculation of quantum fluctuations. The correct physical understanding of the Scherk-Schwarz and Hosotani mechanisms will also naturally emerge.

Keywords:

Naturalness, Renormalization, Compactification

Mean-field study of Kondo condensation

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Abstract:

We perform a mean-field calculation of the relativistic Kondo effect including conducting fermions and localized impurities. We show that there is the Kondo condensation, a nontrivial pairing of light and heavy fermions. We also study finite-temperature effects.

Keywords:

Kondo physics, Mean-field theory, Spontaneous symmetry breaking, Kondo condensation

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

G19.05

Construction of superconducting dorm from non-lineaer electrodynamics in holography

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Abstract:

We study holographics superconductor model including non-linear interaction term between complex scalar field and U(1) gague field. We performed Breitenlohner-Freedman (BF) bound analysis to the model and find zero temperature phase transition of background geometry between normal phase and ordered phase can be possible. It can be interpreted as a phase transition between normal phase and superconducting phase in the boundary theory. By taking numerical calculation, we get phase diagram which has dorm-shape superconducting phase. We also study stability issue of the backround gemetry near zero temperature.

Keywords:

gauge/gravity duality, holographic superconductor, non-linear elecgtrodynamics, strongly correlated system

AI for Theoretical Physics

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Abstract:

We have applied deep learning and transformer algorithms to deduce a holography theory from physical observations. We have constructed two models that are working successfully. The first model, based on a deep neural network, can provide us with a gravity theory that satisfies the experimental results of a single graphene. The other model consists of a transformer model, similar to ChatGPT and BERT, which has learned from 10,000 examples of holographic superconductor theory. It can then generate a holographic superconductor theory from the phase diagram of a superconductor.

Keywords:

Holography, Transformer, AdS/CFT, AI, Deep Learning

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

G19.07

Can a Machine Learning Algorithm find a Holographic Model from Data?

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Abstract:

In this work, we find a holographic model of graphene based on experimental data. We utilize a machine learning algorithm to find a model that matches experiments. This algorithm provides horizon data of a black brane explaining measured DC conductivities. We study the physical implication of the holographic model, which can shed light on graphene physics in condensed matter theory.

Keywords:

Holography, DC Conductivity, Machine Learning

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

G19.08

Fermi arc in p-wave and d-wave holographic superconductors

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Abstract:

We have investigated Fermi arc in p-wave and d-wave holographic superconductor models using flow equation in our holographic set-up. All previous investigation on p-wave and d-wave holographic superconductors in literature has not clearly shown the gapped fermionic spectral function. For p-wave holographic superconductors, we have considered the vector model with minimal coupling with fermion to show the gapped spectral function with Fermi arc. We compare our study in the probe limit case with the backreaction case. We have also compared fermionic spectral gap with the order parameter in holographic superconductors. Similarly, we have observed the Fermi arc and gapped fermionic spectral function for d-wave holographic set-up. These results are very similar with ARPES data.

Keywords:

AdS/CMT, holographic superconductors

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

G19.09

Symmetry Breaking Effect in Holographic Fermions

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Abstract:

We study the symmetry-breaking effect on the spectral function of holographic fermions. Previously, the question was studied numerically in AdS4 theory. In this talk, we report the analytic expression of spectral functions in the probe-limit of the important cases for both AdS4 and AdS5 theories. We find that the lowest energy modes localized at the AdS boundary are associated with simple pole-type green functions. On the other hand, the non-localized ones are associated with branch cuts-type singularity. We also show how various flat bands over the finite region of the momentum space emerge. Berry curvature and Chern-number are calculated and analyzed.

Keywords:

Holography and condensed matter physics (AdS/CMT),

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

H1.01

Ultra-intense Laser Development on the MTW-OPAL Facility

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Abstract:

Optical parametric chirped-pulse amplification (OPCPA) implemented using multikilojoule Nd:glass pump lasers shows promise for producing intensities >10^{23} W/cm^2. We have developed a midscale prototype, MTW-OPAL (Multi-Terawatt optical parametric amplifier line), to test technologies for an OPAL pumped by the OMEGA EP Laser System.

Since “first light” in 2020, the system has been optimized to reach 350 TW. The talk will describe these improvements and will highlight our plans to upgrade the back end of the system for increased flexibility, performance, and functionality. A pulse-conditioning chamber after the compressor will contain a variety of subsystems including a deformable mirror, a double-plasma-mirror system, and a system for modifying the laser polarization. A new target chamber is currently being designed. This material is based upon work supported by the Department of Energy National Nuclear Security Administration under Award Number DE-NA0003856, the University of Rochester, and the New York State Energy Research and Development Authority.

Keywords:

Laser, ultrafast, OPCPA, DKDP

ELI Beamlines: the high-peak, high-average power laser facility of the Extreme Light Infrastructure

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Abstract:

The ELI Beamlines Facility is a pillar of the ELI (Extreme Light Infrastructure) ERIC pan-European Research Infrastructure hosting the world's most intense laser sources. ELI Beamlines developed and operates four cutting edge high-peak, high-average power femtosecond laser systems and offers a unique combination of primary (lasers up to 10 PW peak power) and secondary (high-energy particles and X-rays) sources to the international user community. Currently, several beamlines are operational and being upgraded to reach their full performances, while other beamlines are in their commissioning phase.
Laser-driven particle accelerators have gained interest in the recent years thanks to their versatility and innovative features. This interest has pushed forward the development of beamlines where users can exploit the unique parameters (e.g. ultrashort bunch duration and ultrahigh dose rate) of laser-driven particle accelerators (ion and electron beams) and radiation (XUV to gamnma-ray sources) for a wide range of applications.
The current performance of particle and radiation sources available at the ELI Beamlines user facility will be presented and discussed along with their potential use for multidisciplinary applications. The high repetition rate capability of the available primary and secondary sources will be highlighted in combination with a range of advanced target delivery solutions and diagnostics in operation in extreme laser-plasma conditions (>10^{21} W/cm^2 at >1 Hz and >5x10^{18} W/cm^2 at 1 kHz).

Keywords:

High power lasers, ultrahigh laser intensity, laser driven secondary sources

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

H1.03

Strong Field QED in Astrophysics and Laboratory Astrophysics

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Abstract:

A strong electromagnetic field polarizes the vacuum leading to photon-photon scattering and in the presence of an electric field creates pairs of electron-positron pairs. Magnetars, highly magnetized neutron stars with magnetic field comparable to or greater than the Schwinger field, give a significant amount of the vacuum polarization and vacuum birefringence and the induced electric field creates the electron-positron pairs, which are strong field quantum electrodynamics (QED) processes. Recently proprosed sub-exa watt lasers and observations of the x-rays polarization from highly magnetized neutron stars of supercritical fields will open a window to test fundamental physics in the strong field regime through measurements of vacuum polarization effects and spontaneous pair production etc. We advance a formulation of vacuum birefringence and polarization vectors that incorporates the effects of the weaker electric field added to the extremely strong magnetic field using a closed analytical expression for the Heisenberg-Euler and Schwinger QED action and other nonlinear electrodynamics. The proposed formulation will provide accurate x-ray polarimetry for magnetized neutron stars. prove the fundamental aspect of the strong field quantum electrodynamics (QED) and explore the physics in extreme fields of astrophysical bodies.

Keywords:

Strong field QED, pair production, x-ray polarometry, nonlinear Compton scattering, laboratory astrophysics

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

H2.01

Critical-to-Insulator transition and Fractality Edges in Perturbed Flatbands

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Abstract:

We study the effect of quasiperiodic perturbations on one-dimensional all-bands-flat (ABF) systems. ABF networks can be diagonalized by a finite sequence of local unitary transformations parameterized by angles ₩(₩theta_{i}₩)s.
For weak perturbations, we derive effective Hamiltonians and we find the sets of ₩(₩theta_{i}₩)s which coincides with the extended Harper or off-diagonal Harper models which host critical states supporting subdiffusive or almost diffusive transport, respectively.
As we increase the perturbation strength, we oberve an energy dependent critical-to-insulating transition with what we term fractality edges separating localized from critical states.

Keywords:

flatband, localization, multifractal

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

H2.02

Flatband Induced Metal-Insulator Transitions for Weak Magnetic Flux and Spin-Orbit Disorder

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Abstract:

We consider manifolds of tunable all-bands-flat (ABF) lattices in dimensions d=1,2, parametrized by a manifold angle parameter θ. We study localization properties of eigenstates in the presence of weak magnetic flux disorder and weak spin-orbit disorder. We demonstrate that weakly disordered ABF lattices are described by effective scale-free models where the disorder strength is scaled out. For weak magnetic flux disorder we observe sub-exponential localization at flatband energies in d=1, which differs from the usual Anderson localization. We also find diverging localisation length at flatband energies for weak flux values in d=2, however the character of the eigenstates at these energies is less clear. For weak spin-orbit coupling disorder in d=2 we identify a tunable metal-insulator transition with mobility edges. We also consider the case of mixed spin-orbit and diagonal disorder and obtain the metal-insulator transition driven by the manifold parameter θ.

Keywords:

Anderson localization, disordered systems, flatbands, all-bands-flat

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

H2.03

Percolation critical exponents in cluster kinetics of pulse-coupled oscillators

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Abstract:

Transient dynamics leading to the synchrony of a type of pulse-coupled oscillators, so-called scrambler oscillators, has previously been studied as an aggregation process of synchronous clusters, and a rate equation for the cluster size distribution has been proposed. However, the evolution of the cluster size distribution for general cluster sizes has not been fully understood yet. In this paper, we study the evolution of the cluster size distribution from the perspective of a percolation model by regarding the number of aggregations as the number of attached bonds. Specifically, we derive the scaling form of the cluster size distribution with specific values of the critical exponents using the property that the characteristic cluster size diverges as the percolation threshold is approached from below. Through simulation, it is confirmed that the scaling form well explains the evolution of the cluster size distribution. Based on the distribution behavior, we find that a giant cluster of all oscillators is formed discontinuously at the threshold and also that further aggregation does not occur like in a one-dimensional bond percolation model. Finally, we discuss the origin of the discontinuous formation of the giant cluster from the perspective of global suppression in explosive percolation models. For this, we approximate the aggregation process as a cluster–cluster aggregation with a given collision kernel. We believe that the theoretical approach presented in this paper can be used to understand the transient dynamics of a broad range of synchronizations.

Keywords:

percolation critical exponent, pulse coupled oscillator, cluster synchronization

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

H2.04

Parallel flocking and anti-parallel flocking states in the two-species Vicsek model

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Abstract:

We investigate the two-species Vicsek model (TSVM), in which self-propelled particles exchange interactions that favor velocity alignment with those of the same species and velocity anti-alignment with those of different species. Similar to the Vicsek model, the TSVM displays a gas-liquid phase transition between a disordered gaseous phase and a flocking liquid-like phase with an intermediate coexistence phase. In the coexistence phase, particles are microphase-separated into dense bands propagating in the gaseous background. Interestingly, we find that not only an anti-parallel flocking~(APF) state, in which bands of different species propagate in the opposite direction, but also a parallel flocking~(PF) state, in which all bands propagate in the same direction, are stable in the coexistence phase. The existence of the PF state exemplifies the mechanism for collective motion of self-propelled particles with anti-aligning interactions. This work provides opportunities to explore multi-species flocking models with various alignment interactions.

Keywords:

active matter, flocking phenomena, non-equilibrium phase transition

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

H2.05

Finite-size scaling analysis of the two-dimensional random transverse-field Ising ferromagnet

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Abstract:

The random transverse-field Ising ferromagnet (RTFIF) is a highly disordered quantum system which contains randomness in the coupling strengths as well as in the transverse-field strengths. In one dimension, the critical properties are governed by an infinite-randomness fixed point (IRFP), and renormalization-group studies argue that the two-dimensional (2D) model is also governed by an IRFP. However, even the location of the critical point remains unsettled among quantum Monte Carlo (QMC) studies. In this work, we perform extensive QMC simulations to locate the quantum critical point and attempt a finite-size scaling analysis to observe the critical behavior. We estimate the critical field strength of the 2D RTFIF as $\Gamma_c = 7.52(2)$, together with critical exponents as $z = 2.6(4)$ and $\beta/\nu = 0.95(2)$. These values are consistent with predictions of the cavity method in disagreement with the IRFP scenario. We have also considered the McCoy-Wu model, which has randomness in the ferromagnetic coupling strengths but not in the transverse-field strength. Our QMC calculation shows that the critical behavior of the 2D McCoy-Wu model is closer to that of the 2D Ising spin glass than to that of the 2D RTFIF. These numerical findings enhance our understanding of disordered 2D quantum systems.

Keywords:

Quantum Phase Transition, Disordered Quantum System, Quantum Monte Carlo, Finite-size Scaling

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2023-04-19 - 2023-04-21

H2.06

Local Faceting induced by Surface Ising Spins during Interface Growth

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Abstract:

Ising spins coupled to the (1+1)-dimensional Kardar-Parisi-Zhang (KPZ) growth can develop local faceting and quasi-long-range Ising order. In our model, the Ising degrees of freedom move with the interface, e.g., as in surface reconstructions. The spins do not interact among themselves, except indirectly via interface height configurations. Local Ising disorder suppresses local surface growth. Ising Bloch walls have a down-hill or up-hill bias, in accordance with actual surface reconstruction applications. This surface develops mesoscopic facets. The KPZ growth persists beyond the length and time scales of these facets, but with strongly renormalized lattice and time cutoffs. The Ising spins maintain quasi long-range order within these mesoscopic facets. A Cole-Hopf type transformation links our model to the question of whether the wave function of a particle following a directed path through a random medium, can develop so-called *sign-order*. Only quasi-long-range sign-order exists. Our model elucidates this better than earlier studies of that phenomenon.

Keywords:

local faceting, Ising degrees of freedom, Kardar-Parisi-Zhang growht, surface reconstructions, quasi long-range order

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2023-04-19 - 2023-04-21

H2.07

Various types of critical phenomena of the Potts model with hidden spin variable

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Abstract:

The original Potts model predicts that a continuous phase transition will occur in a two-dimensional physical system with S_3 symmetry.
However, experimental results revealed that discontinuous phase transitions occur in some special materials although the conditions of two-dimensinality with S_3 symmetry are satisfied.

Therefore, various attempts have been made to resolve this theory-experimental discrepancy, the most representative of which is a model that introduces a hidden spin state to the Potts model.

Many studies showed that the type of phase transition is changed when a hidden spin state is introduced and suggested the critical number of hidden spin states in which the type of phase transition is changed.

In this study, using the Landau-Ginsberg framework, we reconfirmed the previous results that the type of phase transition varies according to the number of hidden spin states, and in particular, we found that hybrid phase transitions occur.

In particular, it was revealed that the Landau-Ginsberg methodology is valid even in three dimensions through the property that the upper critical dimension becomes 3 at the critical point where the type of phase transition changes when q=2.

Based on this fact, the critical point at which the type of phase transition changes was accurately calculated using the Landau-Ginsberg methodology, and the value was presented.

Models in which the type of phase transition changes from continuous to discontinuous depending on external variables are not limited to models with the hidden spin states, but are quite common.

Even in the case of these models, the upper critical dimension decreases to 3 at the critical point where the type of phase transition changes from a continuous phase transition to a discontinuous phase transition.

This means that finding the boundary point using the Landau-Ginsberg methodology is valid even for these models, and this result is expected to be an important result that will be useful in various studies.

Keywords:

Hybrid Phase Transition, Critical Phenomena, Upper Critical Dimension, Potts model, Hidden spin variable

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

H3.01

Van der Waals Metal Contacts for WSe_2 Transistors and Their Circuits

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Abstract:

Precise engineering of polarity of transistor is essential to fabricate complementary metal oxide semiconductor logic circuits. However, the polarity control of 2D transistor remains a challenges due to prevailing disorders at typical metal-semiconductor junctions, resulting in strong Fermi-level pinning. In this talk, we will present a novel technique to achieve pinning-free van der Waals contacts, in which a metallic chlorine-doped (Cl-$SnSe_2$) is used as contact. We show that atomically clean contact interface is suited for rendering a near-ideal Schottky barrier height, permitting polarity-controllable transistors. Finally, the ability to modulate the carrier polarity enable efficient complementary logic circuits, including inverter, NAND and NOR gates.

Keywords:

2D materials, Fermi-level pinning, Transistors

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

H3.02

Photo-induced interlayer charge transfer in monolayer tungsten disulfide

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Abstract:

단일 층 WS_2와 hBN/WS_2/hBN 헤테로구조에서의 전하 이동 효과를 연구하기 위해 라만 산란 실험을 수행하였다. SiO_2/Si 기판 위에 놓인 이들 구조에 대한 라만 산란 스펙트럼으로부터 WS_2 단일 층에 대한 광학 포논 모드를 확인할 수 있었다. 두 가지 서로 다른 포논 모드 사이의 상관관계 분석 결과 헤테로구조에 비해 단일 층 WS_2에서의 전자 밀도가 높음을 알 수 있었다. 이와 더불어 단일 층 WS_2의 경우 레이저 세기가 증가할수록 전하 밀도가 점차 증가한 반면 헤테로구조의 경우 레이저 세기와는 상관없이 전하 밀도가 일정하게 유지되었다. 이를 통해서 레이저에 의해 SiO_2/Si 기판에서 단일 층 WS_2로의 광유도 전자 이동이 일어났으며 이는 hBN 층에 의해서 효과적으로 억제될 수 있음을 알 수 있었다. [이 연구는 정부(과학기술정보통신부)의 재원으로 한국연구재단의 지원을 받아 수행되었음 (과제번호: 2019R1A2C1003366, 2022R1A4A1033358)]

Keywords:

Monolayer tungsten disulfide, Hexagonal boron nitride, Raman spectroscopy, Doping

2023 KPS Spring Meeting
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H3.03

$MoS_2/MoTe_2$ and MoS_2/WSe_2 Tunneling Field-effect transistors using ion-gel dielectrics

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Abstract:

Two-dimensional (2D) transition-metal dichalcogenides (TMDs) are promising semiconductor materials for heterostructures. The band-to-band tunneling (BTBT) carrier injection process in tunneling field-effect transistor (TFET) is a promising approach to overcome the fundamental thermionic limit of subthreshold swing (SS) of 60 mV/dec at room temperature. In this study, we investigated the van der Waals 2D/2D vertical heterostructures using molybdenum disulfide (MoS_2) grown via metal organic chemical vapor deposition (MOCVD) as an n-type and molybdenum ditelluride ($MoTe_2$) and tungsten diselenide (WSe_2) each having p-type. Those heterostructures exhibit the staggered gap type (type II), which was suitable for TFET applications. The electrical transport properties of the $MoS_2/MoTe_2$ (or WSe_2) heterostructures using ion-gel top gate dielectric exhibits a SS as low as 9.1 (or 7.5) mV/dec. The BTBT process was confirmed by the negative differential transconductance, negative differential resistance behavior, and temperature-dependent *I-V* characteristics. This work offers significant potential for wafer-scale production of next-generation low-power consumption electronic devices.

Keywords:

Tunneling FET, Low power consumption, Subthreshold swing, Ion-gel dielectric

H3.04

Temperature-Driven Rectification Reversal Observed in Graphene/Semiconductor Junction

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Abstract:

We report the temperature-dependent reversal in the rectification direction of the graphene/n-Si(001) junction. The forward current is observed to be significantly suppressed at low temperature and becomes smaller than the reverse current. This reversal of rectification direction can be explained by the asymmetric carrier injection at the graphene/n-Si(001) interface and the suppression of electron-hole recombination which is one of the main contributors to the forward current. The modulation of graphene work function by the surface states and space charges can induce a considerable amount of holes for the forward bias, but not for the reverse bias. As temperature decreases, the recombination current is suppressed, and the asymmetricity of carrier injection at the graphene/n-Si(100) interface becomes more and more significant in accordance with the carrier scattering being reduced. Thus, the forward current driven by the thermionic emission becomes smaller than the reverse current and the intriguing inverse rectifying behavior is unveiled. Our findings offer the intuition for asymmetric carrier injection at the inter-dimensional Schottky junction and a new class of device structure realizing temperature-dependent rectification switching.

Keywords:

Graphene/Si Schottky junction, Rectification switching, Inter-dimensional carrier injection, Electron-hole recombination, Interface carrier scattering

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

H3.05

The Stability Investigation of Polymer-Dopant Composite coated Post-Transition Metal Chalcogenide

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Abstract:

Post-transition metal chalcogenides (PTMCs), which consist of layered structures formed by combining post-transition metals (Group III) and chalcogenides (Group VI), exhibit excellent electrical properties and an adjustable bandgap, making them promising candidates for next-generation materials. In particular, InSe has attracted attention due to its outstanding features, including high carrier mobility (~300cm^2/Vs at RT) and a direct bandgap transition at few layers. However, oxidation on the surface of InSe poses a significant challenge to its practical application.
To address this issue, we developed a polymer-dopant composite that protects the surface of InSe from oxygen and water. The composite was fabricated by mixing PMMA and Benzyl viologen (BV) for n-type doping and spin-coated onto the InSe surface. We performed Raman spectroscopy and electrical measurements to investigate the effect of dopant concentration on the InSe surface. Our results showed that using PMMA polymer alone is insufficient for preventing oxidation, and that changes in the Raman peak position and electrical properties occur after composite coating.
In this work, Raman spectroscopy and electrical measurements effectively revealed the oxidation tendency and doping effect of InSe. Furthermore, this provides a potential solution for fabricating InSe devices that exhibit improved stability and performance in atmospheric environments.

Keywords:

Indium selenide, Polymer, dopant, composite

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

H3.06

Kondo Effect of Double Quantum Dots Coupled to Quantum Hall Edge States

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Abstract:

The Kondo effect refers to the crossover from a naïve spin-scattering of magnetic impurities in a conductor to the profound spin-singlet virtual bound state of local and itinerant electrons. Since its discovery, the effect has provided a framework to generalize many-body interactions between more exotic impurities and conductors. Experimental research had especially flourished after realizing that quantum dots (QD) provide a platform where all parameters relevant to the Kondo effect could be tuned in situ. The double quantum dot (DQD), with a reservoir tunnel-coupled to each QD, is a particularly interesting setup that exhibits the orbital Kondo effect. The symmetry between the QD-reservoir complexes act as a pseudospin degree of freedom, which can be exploited to study many-body effects with pseudospin-resolution. In this presentation, we report the realization of a Kondo system by coupling a DQD to quantum Hall edge states, i.e. the orbital Kondo effect of a pseudospin-1/2 impurity coupled to chiral 1D reservoirs. We compare the Kondo temperatures obtained from temperature, bias, and pseudo-Zeeman characteristics, and describe the challenges to realizing the system. A discussion on the advantages of the system, such as the long coherence length of quantum Hall edge states, and future directions of research are provided.

Keywords:

Orbital Kondo Effect, Quantum Hall Edge State, Quantum Dot

Ultrafast dynamics of decoherence of Dirac semiconductors in high harmonic generation

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Abstract:

Decoherence time *T2* phenomenologically describes electron-phonon or impurity scattering, which changes the dynamics of electrons, e.g., the charge transfer or high-harmonic generation (HHG) spectra. While the HHG has been extensively investigated in real space and time-domain, research into its rapid decoherence processes has been lacking. In this study, we use the quantum master equation to investigate the electron dynamics in Dirac semiconductors, with a specific focus on *T2* values below 20 fs. Our findings show that fast decoherence causes a phase shift in the charge current, leading to delayed charge transfer and harmonic emission over time compared to slower decoherence. These results present a possible application to manipulate the phase of time-dependent current by adjusting a material's intrinsic properties and an understanding of the underlying physical process of short decoherence time in Dirac semiconductors.

Keywords:

Ultrafast dynamics, Rapid decoherence, High-order harmonic generation, Dirac semiconductor

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

H3.08

Enhanced Physical Properties of Transition Metal Dichalcogenides by Passivating the Surface Defects of Substrate by Perfluorinated Polyether

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Abstract:

The optical and electrical properties of transition metal dichalcogenides (TMDs) are sensitive to TMDs-dielectric interfaces. Silicon dioxide, a widely used dielectric substrate, contains various surface defects such as a charge puddle inducing the inhomogeneity of 2D materials. Thus, high-quality dielectric materials such as h-BN or Al2O3 have been applied for homogeneous and enhanced properties. The S10, one of the Perfluorinated Polyether (PFPE), is commercially used as a coating material for surface modification. It can alter the interface environment of TMDs-dielectric by passivating the dielectric surface. Here we report a facile way of passivation for surface charge puddle at SiO_2 substrate. The effect of surface passivation was confirmed by photoluminescence (PL) mapping of TMDs. The enhanced PL feature (six times in the case of MoS_2) with a uniform intensity was observed TMDs on S10 coated SiO_2 substrate.

Keywords:

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

H3.09

Air Stability and Doping Effect of Polymer/Dopant Composite-coated Post-Transition Metal Chalcogenide FETs

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Abstract:

The recent interest in post-transition metal chalcogenides (PTMCs) has led to the investigation of indium selenide (InSe), a III-VI semiconductor compound with excellent electrical properties. However, literature reports that InSe FETs have shown vulnerability to moisture and oxygen exposure in ambient air, which degrades their performance. Previous studies attempted to passivate InSe FETs using Poly methyl methacrylate (PMMA) or Hexagonal Boron Nitride (h-BN), but the doping effect of polymers presented limitations and additional doping processes were required.

In this study, we investigated the doping effects of InSe FETs treated with polymer/dopant composites. The composites of PMMA/Benzyl Viologen and CYTOP/Bis (trifluoromethane) sulfonimide acted as n-type and p-type dopants, respectively. We coated the polymer/dopant composites on the surface of InSe FETs and analyzed their stability and electrical properties according to the concentration of dopants.

The doping effect was effectively controlled by adjusting the concentration of composites, and the passivation and doping processes were performed simultaneously to simplify the procedure. This study could contribute to the development of high-performance InSe devices that maintain their performance in ambient air.

Keywords:

InSe, Chemical doping, Polymer, Air stability, Field effect transistor

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

H4.01

Room temperature van der Waals ferromagnet

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Abstract:

Two-dimensional (2D) van der Waals (vdW) magnets provides exciting opportunities to explore, tune, and utilize the 2D magnetism in an unprecedented manner. The fundamental parameters of key model Hamiltonians, such as generalized Heisenberg Hamiltonian, can now be controlled through strain, gating, proximity effect, twist angle, and optical excitations, readily available in the 2D materials world. The expanded possibilities to tune the material parameters has also promised optimized materials for spintronics and valleytronics applications.
Here, we present the magnetic properties and electronic band structures of van der Waals magnets, Fe_3GeTe_2 and Fe_3GaTe_2. By substituting Ge with Ga, various magnetic properties are changed, such as Curie temperature, saturation magnetic moment, and anomalous Hall angle with large perpendicular magnetic anisotropy. Our findings provide an understanding of the intricate connection between electronic structures and magnetic properties in two-dimensional magnets and propose a method to engineer magnetic properties through doping.

Keywords:

van der Waals ferromagnet, Room temperature ferromagnet, electronic band structure, ARPES

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

H4.02

Spectroscopic evidence of the ferromagnetic transition in monolayer 1T-$CrTe_2$

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Abstract:

Two-dimensional (2D) layered ferromagnetic materials have attracted much interest recently since the discovery of intrinsic 2D ferromagnetism (FM) in atomically thin layers. However, the evidence of 2D ferromagnetic transitions in viewpoint of band structures are still missing due to the difficulty of the sample preparation. In this talk, I will introduce a recent study on a monolayer (ML) 1*T*-$CrTe_2$, which shows the ferromagnetism in 2D limit. The combining study of molecular beam epitaxial (MBE) growth and *in-situ* angle-resolved photoemission spectroscopy (ARPES) characterization found the exotic temperature-dependent band evolutions with FM in ML 1*T*-$CrTe_2$.

Keywords:

MBE, ARPES, 1T-CrTe2

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

H4.03

Spin wavepackets in the Kagome ferromagnet Fe_3Sn_2: propagation and precursors

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Abstract:

The propagation of spin waves in magnetically ordered systems has emerged as a potential means to shuttle quantum information over large distances. An important subset of these systems are "easy-plane" magnets in which the spins are oriented parallel to the planes but without a preferred direction within the plane. In this talk, I describe an experimental and theoretical study of the easy plane ferromagnet Fe_3Sn_2, in which magnetism arises from a Kagome lattice of Fe ions. Our measurements utilize temporal and spatially resolved optical techniques to launch and detect spin wavepackets, providing quantitative information on their amplitude, frequency, and phase. Conventionally, the arrival time of a spin wavepacket at a distance, *d*, is assumed to be determined by its group velocity, v_g. Surprisingly, we observe the arrival of spin information at times significantly less than d/v_g. We show that this spin wave "precursor" phenomenon originates from the interaction of light with the unusual spectrum of magnetostatic modes in Fe_3Sn_2. Related effects may have far-reaching consequences toward realizing long-range, ultrafast spin wave transport in both ferromagnetic and antiferromagnetic van der Waals systems.

Keywords:

Spin waves, Magnons, Propagation, MOKE, Ultrafast optics

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

H5.01

Experimental setup on Yb171 qubits control using 355nm Raman pulse laser

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Abstract:

A trapped ion-based quantum system has been one of leading platforms toward building an universal quantum computer due to the ions'good quantum properties. Several methodologies to control the ion qubits have been demonstrated, for example, using pulse lasers or microwaves. In particular, using the pulse laser can be beneficial in that one can address individual ion qubits by optical focus and one can minimize spontaneous decay due to far-off resonant coupling with atomic levels. Here, we trapped several Yb171 qubits using a 4-rod trap and are setting up the experiment using a 355nm pulsed laser in order to drive two photon Raman transition of Yb qubit. In this talk, we would like to introduce recent progress of our setup such as beatnote lock and optical overlap at the trap, which we plan to use this 355nm setup for single qubit and two qubit entangling gate.

Keywords:

Trapped Ion, quantum computer, Yb, Raman pulsed laser

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

H5.02

A Scalable Fault-Tolerant Three-Dimensional Cluster State Construction Protocol using Linear Arrays of Emitters

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Abstract:

In order to achieve a large-scale fault-tolerant quantum computer, ensuring the scalability of logical qubits is essential. In pursuit of this goal, Wan et al. proposed fault-tolerant three-dimensional cluster state construction protocols using a photon or phonon emitter, as well as an associated setup. A three-dimensional cluster state with a body-centered cubic lattice can be employed in the universal fault-tolerant measurement-based quantum computation proposed by Raussendorf et al. using surface code as a logical qubit. The setup consists of an emitter and a waveguide, with the emitter interacting with the qubits in the waveguide, while the interaction between two qubits is not permitted. Interactions between the emitter and qubits occur successively as qubits move along the waveguide. Despite their scalability via the use of a limited number of components, an emitter and a waveguide, the proposed protocols' scalability is restricted by qubit delay line errors that constrain the waveguide length and the maximum number of qubits moving along the waveguide. To address this limitation, we propose an improved version of the fault-tolerant three-dimensional cluster state construction protocol that utilizes a linear array of emitters. By distributing the construction of the three-dimensional cluster state across multiple emitters and allowing the interaction between two emitters, delay line errors will be reduced. Our protocol restricts interactions between emitters to their two nearest neighbors, facilitating scalability by arranging them in a line and minimizing reliance on a single emitter. We demonstrate that the threshold value of our protocol is tolerant of an increased number of emitters and an increased error rate of emitter-to-emitter gates. Furthermore, we show that our protocol can employ a much larger number of qubits and achieve certain logical error rates with a higher delay line error rate.

Keywords:

fault-tolerant quantum computation, measurement-based quantum computation, three-dimensional cluster state, photonic quantum computation

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

H5.03

Adaptive Quantum Tomography in Weak Measurement with Superconducting Circuits

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Abstract:

The use of adaptive tomography has been widely studied as a means of speeding up the state tomography process in quantum computing. However, the infidelity on nearly pure states in quantum information processing scales as $O(1/N^{-1/2})$, which necessitates a large number of statistical ensembles compared to the infidelity scaling on mixed states of O(1/N). A recent study reported an improvement in infidelity scaling as O(1/N) through the optimization of a measurement basis in a photonic qubit system that uses projective measurements. However, this improvement cannot be applied to weak-value-based measurement systems because perfect measurement reliability cannot distinguish between two quantum states. To address this issue, we propose a new optimal measurement basis that achieves fast adaptive quantum state tomography with minimal infidelity in weak measurement systems. We anticipate that this AQST protocol will reduce the measurement number by approximately 33.74% without changing the scaling of $O(1/N^{-1/2})$. In a superconducting circuit QED system, we have experimentally achieved a 14.81% reduction in the number of measurements.

Keywords:

transmon qubit, quantum computation, pubit state reset

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

H5.04

Magnetic field-agnostic identification of spin-spin interactions with latent embedding learning

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Abstract:

We present an analysis model with a neural network for examining spin-spin interactions in diamonds. With representation learning of dynamical decoupling signals induced from spin-spin interactions, two cases that could not be hitherto dealt with are addressed here; (1) overlapped signals of nuclear spins with similar periods. (2) split signals induced by nuclear-nuclear interaction. We train the classification model with contrastive-center loss and regression model with reconstructive embedding learning especially identifying undistinguishable signals that cannot be evaluated by traditional regression approaches. Experimentally, we measure Carr-Purcell-Meiboom-Gill(CPMG) signal with a total evolution time of only less than 5 μs and with various numbers of unit π pulses controlling interacting time. Our method successfully recognizes the existence of nuclear-nuclear interaction and the undistinguishable overlapped signals with up to 92% accuracy and estimates hyperfine interaction parameters with up to 94% accuracy. We also distribute fully automated python modules for analyzing CPMG signals with various external magnetic fields to obtain individual spin-spin interaction strengths.

Keywords:

NV Center

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2023-04-19 - 2023-04-21

H5.05

Trapping Yb isotopes and progress of qubit manipulation setup

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Abstract:

Quantum computers are expected to be more efficient in solving certain problems than conventional computers. Trapped ion-based system has been one of the leading architectures toward building a scalable and practical quantum computer since the system possesses long coherent time and high gate fidelities. Among various atomic species, Yb is widely used since it possesses a hyperfine structure which is insensitive to fluctuation of the external magnetic field. In this work, we constructed a 4-rods trap, trapped various Yb isotopes, and imaged the fluorescence of Yb ions with optical sidebands generated by EOMs. This helped us to precisely calibrate the experimental setup. In parallel, we are currently setting up an experimental sequencer for single qubit manipulation via ARTIQ system. Through optimizing our system and trap performance, we plan to perform single qubit gates with microwaves and pulse lasers.

Keywords:

Quantum computing, Ion trap, Yb isotopes, single qubit gate

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2023-04-19 - 2023-04-21

H5.06

Experimentally verified efficient machine learning for quantum many problems

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Abstract:

Advancements in technology related to data storage and processing have made it possible to analyze large amounts of data, which has led to the development of new techniques for analyzing data using machine learning. In the field of physics, machine learning has been explored for its potential applications in many-body physics, which deals with systems where the Hilbert space grows exponentially as the size of the system increases. This presentation aims to apply machine learning to tasks that are of interest to the many-body physics community, such as predicting the properties of a system's ground state based on its Hamiltonian and classifying quantum phases with guaranteed performance. To test our algorithm's effectiveness, we use superconducting transmon qubit devices provided by cloud services. Our results show that even in the NISQ era, it is possible to use machine learning to learn important properties of many-body physics problems.

Keywords:

Machine Learning, Many-body Physics

H5.07

Building a quadrupole linear Paul trap and optimizing the trap performance to confine multiple Ytterbium ions for quantum computing

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Abstract:

A linear Paul trap is a traditional device for capturing charged particles with a stable linear chain via combination of RF and DC voltages. The trap has been used to demonstrate fundamental ingredients for trapped-ion based quantum computing and simulation. In our work, we constructed the linear Paul trap consisting of 4 rods and two endcap rod to provide RF pseudo-potential. This generates a saddle-shaped electric potential well at a certain RF frequency.
Also, we successfully trap Yb171 ions and are setting up experiments for single qubit gate control via ARTIQ sequencer. In this presentation, we introduce a detailed process for building the Paul trap assembly and share recent progress of optimizing the trapping conditions.

Keywords:

Quantum computing, Trapped ion, Paul trap

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

H5.08

Fast reset process of a superconducting qubit with an autonomous feedback system

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Abstract:

A high-quality state reservoir is necessary for quantum algorithms, and qubit reset processes are commonly used to achieve this. However, natural qubit relaxation can be slow, leading to extended processing times when using artificial reset processes. We present a novel reset process in superconducting quantum circuits that utilizes qubit state-dependent cavity transmission and frequency conversion by a Josephson mixer. By designing a cavity mode with high transmission for cavity-dressed state frequencies at undesired qubit states, a transmitted pulse with the dressed frequency causes undesired qubit states to Rabi-oscillate after frequency conversion, until the autonomous feedback process stops when the qubit has no population in undesired states. This reset pulse length depends on the Rabi-oscillation frequency, not the qubit relaxation time, allowing for a sub-microsecond reset even when the qubit relaxation time is much longer.

Keywords:

Quantum information, Superconducting qubit, RF mixing

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2023-04-19 - 2023-04-21

H6.01

Orbitronics: new torques and magnetoresistance effects

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Abstract:

While so far the focus has been on spin currents, effects of orbital currents, i.e. the flow of the electrons with finite orbital angular momentum, can outperform conventional spin current effects. As shown, orbital currents can even play a pivotal role in generating spin currents thus leading to torques with unprecedented amplitude to manipulate magnetization. Experimentally, orbital currents for efficient manipulation of magnetization have only recently started to be explored. In order to generate orbital currents, materials with orbital Hall effects can be used that can be light metals and thus cheap, abundant and environmentally friendly.
In our work we studied spin orbit torques generated in TmIG/Pt/(Cu(O)x) heterostructures. We observed that the torques exerted on the TmIG are enhanced by a factor up to 16 if the CuOx is added on top of the Pt compared to the conventional TmIG/Pt stack [1]. Such an enhancement is extremely surprising if one considers only conventional spin-charge interconversion based on spin orbit coupling effects and given the low spin-orbit coupling of Cu and Cu(O)x one does not expect large torques. However the results can be naturally explained as Cu(O)x can generate large orbital currents that are then converted to spin currents in the Pt layer, which then manipulate the TmIG extremely efficiently. More recently we studied magnetoresistance effects in systems with layers that generate orbital currents. We found that the Orbital Rashba-Edelstein Magnetoresistance can be observed in Py/Cu(O)x, which is an orbital magnetoresistance effect related to the conventional spin Hall magnetoresistance [2]. In particular in this work, the length scale of the orbital to spin current conversion in Py could be identified as a key step to harnessing orbital currents efficiently even without a heavy metal based orbital to spin conversion layer [3,4].

References:
[1] S. Ding et al., Phys. Rev. Lett. 125, 177201 (2020)
[2] S. Ding et al., Phys. Rev. Lett. 128, 067201 (2022)
[3] D. Go, MK et al., Perspectives Review in EPL 135, 37001 (2021)
[4] A. Bose, MK et al., arxiv:2210.02283 (2023)

Keywords:

Orbitronics, orbital Hall effect, orbital Rashba Edelstein effect, orbital angular momentum transport

2023 KPS Spring Meeting
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H6.02

Orbital Angular Momentum of Magnons in Collinear Magnets

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Abstract:

We study the orbital angular momentum (OAM) of magnons for collinear ferromagnet (FM) and antiferromagnetic (AF) systems with nontrivial networks of exchange interactions [1,2]. The OAM $L_{zn}(\mathbf{k})$ of magnons at wavevector **k** and magnon band *n* for AF and FM zig-zag and honeycomb lattices becomes nonzero when the lattice contains two inequivalent sites and is largest at the avoided-crossing points or extremum of the frequency bands. Hence, the arrangement of exchange interactions may play a more important role at producing the orbital angular momentum of magnons than the spin-orbit coupling energy and the resulting non-collinear arrangement of spins. However, the spin-orbit induced Dzyalloshinskii-Moriya interactions between next-nearest neighbor sites dramatically change our results for the FM honeycomb lattice by producing a nonzero average value $<L_{zn}(\mathbf{k})>$ for the OAM within each band n = 1 or 2. In recent work, we explore the relation between the semi-classical and quantum approaches to the Berry phase and OAM and establish the limited gauge invariance of the OAM.

References

[1.] R.S. Fishman, J.S. Gardner, and S. Okamoto, Phys. Rev. Lett. **129**, 167202 (2022)
[2.] R.S. Fishman, L. Lindsay, and S. Okamoto, J. Phys: Cond. Mat. **35**, 015801 (2023).

Keywords:

Spin Waves, Orbital angular Momentum

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

H6.03

Theory of generation and conversion of phonon angular momenta

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Abstract:

Phonons in crystals can have rotational motions, having nonzero angular momenta. One can expect novel phenomena associated with phonon angular momentum by using an analogy to electron spins. We show that in nonmagnetic crystals without inversion symmetry, a heat current induces a phonon angular momentum. In such crystals, such as chiral crystals, the total phonon angular momentum in equilibrium cancels to zero by time-reversal symmetry. Meanwhile, when the heat current is flowing in the crystal, this cancellation no longer occurs, and there will be a net angular momentum of phonons. We call it phonon Edelstein effect. We propose several experimental setups to measure this effect. We also explain our microscopic theory of coupling between the phonon angular momenta with electron spins. In a nonmagnetic system with spin-orbit coupling, we show that the rotational motions of the nuclei dynamically induce spin polarization, which can be a microscopic mechanism for spin-rotation coupling.

Keywords:

Phonon, angular momentum, chiral crystal, spin-rotation coupling

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

H7.01

Techniques for superconducting quantum computing

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Abstract:

Superconducting qubit system is one of the promising candidates for a scalable quantum processor. Flexibility in circuit design based on circuit QED architecture and its unmatched sensitivity to external parameters are useful resources for the scalability. In this talk, we present our current status for building a small-scale superconducting quantum processor. By using a multiplexing technique, parallelly operated qubit states can be simultaneously read out up to 5-qubits. We mainly discuss quantum two-qubit gates tested on the system with the recent progress of high-fidelity quantum operation techniques for superconducting quantum computing.

Keywords:

Superconducting qubit, Circuit QED, Quantum gate

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

H7.02

Mitigation of quasiparticle poisoning in superconducting qubit systems

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Abstract:

The presence of non-equilibrium quasiparticles in superconducting qubit systems are detrimental, causing the decoherene of qubits and the reduction of quality factor of superconducting resonators. Such "quasiparticle poisoning" mediated by the high-energy phonons in the substrate generated by high-energy particle impacts from background cosmic ray or radioactivity is known to create correlated errors in large-scale superconducting qubit array. More problematic, the correlated errors presumably can not be corrected by existing quantum error correction schemes. Therefore, it is critical to mitigate quasiparticle poisoning to minimize the correlated errors, making quantum error correction still valid. In this talk, I will present some mitigation strategies developed and show a recent result of the suppression of correlated errors from background radiations via back-side metallization.

Keywords:

Superconducting qubit, Quantum computing, Correlated error, quasiparticle poisoning

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

H7.03

Emergence of Bogoliubov qusaiparticle statistics to critical temperature in unconfinedcircuit quantum electrodynamics

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Abstract:

For their long coherence times and nonlinear nature, superconducting qubits also have distinct merits as excellent sensors for various physical entities beyond their original roles as quantum processors. Detecting tunneling of Bogoliubov quasiparticles across Josephson junctions, essential in superconductivity research, is a renowned example. However, the operation has been limited in the extremely low-temperature regime heretofore since thermally induced pure decoherence decreases the measurement efficiency and compounds extracting the desired information from the experiments. In this work, we break these formidable challenges and investigate the quasiparticle statistics in the Al–AlOx–Al Josephson junctions of transmons up to the critical temperature. We protect the circuits from pure decoherence by driving the transmons to unconfined states and probe the quasiparticle densities through dispersively coupled NbTiN sensor resonators. The thermal statistical model of Bogoliubov quasiparticles excellently explains the experimental results, almost independently of the complicated dynamics of Josephson junctions. We also demonstrate thermometry from 300mK to 1.3K, exhibiting a decent noise-equivalent temperature of approximately 200μK/√Hz. This work dramatically expands the boundaries of fundamental research one can explore with circuit QED architecture. From a practical perspective, this approach will be an indispensable manner to debug excessive heating issues on integrated quantum devices based on superconducting qubits.

Keywords:

Superconductivity, Circuit quantum electrodynamics, Josephson junction

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

H7.04

Qubit with flying single electrons

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Abstract:

Development of on-demand single electron source and coherent manipulation of single electrons are crucial for electron (fermion) quantum optics and quantum information processing in a solid-state system at a single-electron level. Because electrons easily interact with electromagnetic environments contrary to photons, the fermion optics can provide feasible methods in manipulations of energy of emitted electrons and coupling between electrons and environments. In my talk, I will introduce our recent works related to the quantum optics and flying qubits with single electrons.

Keywords:

Single electron source, Elctron quantum opics, Flying qubit

H7.05

Proposal for Detection of the 0' and π' Phases in Quantum-Dot Josephson Junctions

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Abstract:

The competition between the Kondo correlation and superconductivity in quantum-dot Josephson junctions (QDJJs) has been known to drive a quantum phase transition between 0 and π junctions. Theoretical studies so far have predicted that under strong Coulomb correlations the 0-π transition should go through intermediate states, 0' and π' phases. By combining a nonperturbative numerical method and the resistively shunted junction model, the magnetic-field-driven phase transition of the QDJJs in the Kondo regime is investigated and it is found that the low-field magnetotransport exhibits a unique feature which can be used to distinguish the intermediate phases. In particular, the magnetic-field driven π'-π transition is found to lead to the enhancement of the supercurrent which is strongly related to the Kondo effect.

Keywords:

quantum dot Josephson junctions, Kondo effect

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

H8.01

Plasmon-assisted Spectroscopy of 1-, 2-, 3- Layer MoS_2

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Abstract:

Plasmon-assisted optical response of a resonantly excited molybdenum disulfide (MoS_2) comprising of single-, bi- and tri- layers with gold nanoparticle is studied. The localized electromagnetic field in gold nanoring changes the optical response of material by enhancing the light-matter interaction. The Photoluminescence (PL) and Raman intensity enhancement are observed for MoS_2 on top of Au nanoring due to the strong electromagnetic confinement. From the plasmon-assisted PL spectra, red-shift and broadening were observed, which are described by interaction by plasmon-exciton coupling, local strain, etc. Similarly, Raman spectra show redshifts of the vibration modes due to the electron-phonon interaction, local strain, etc.

Keywords:

molybdenum disulfide, Plasmon-enhanced spectroscopy, Resonant Raman, Localized surface plasmon resonance

H8.02

Hofstadter's butterfly and gate tunable Chern insulator states in bernal bilayer graphene

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Abstract:

Bernal bilayer graphene(BBG) is the simplest member of the rhombohedral stacked multilayer graphene family. By breaking the inversion symmetry of BBG with a vertical electric field, BBG shows a tunable gap opening and van Hove singularity which can lead to a cascade of symmetry broken states. Also, in addition to the spin-valley degree of freedom, BBG has a layer degree of freedom, which makes it possible to investigate the proximity effect of substrate surrounding the BBG. In this talk, I will describe transport measurements of BBG aligned with the top hBN encapsulating it. We report the observation of clear Hofstadter's butterfly pattern consisting of Moire superlattice potential induced Chern insulator sequences and some features of correlated insulators at half and quarter filling of Moire subband. And, by changing the vertical electric field, we could tune the sequence of Chern insulators. We also report a curved feature at high magnetic field around the full filling of Moire subband which cannot be explained by the conventional Diophantine equation of carrier density and magnetic flux in the Hofstadter spectrum.

Keywords:

Bernal bilayer graphene, Hofstadter's butterfly, Chern insulator

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

H8.03

Accelerating Theoretical Surface Structure Determination with Machine-Learning Interatomic Potentials: A Case Study on Rutile RuO_2 Surfaces

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Abstract:

First-principles surface structure determination has traditionally been hampered by the high computational costs of the underlying electronic structure calculations and insufficient sampling capabilities. However, the advent of machine-learning interatomic potentials (MLIPs) allows for efficient training up to native DFT level accuracy, enabling more extensive PES sampling by increasing the number of cheap MLIP evaluations by several orders of magnitude compared to direct DFT approaches. We demonstrate and assess this approach in the context of rutile RuO_2 surfaces, identifying new complexion-type surface structures for the RuO_2(101) facet and resolving a long-standing enigmatic reconstruction of the RuO_2(100) facet. The low computational cost of this method allows for further iterative learning, leading to a more accurate prediction of the equilibrium RuO_2 nanoparticle structure, with corresponding (410) vicinal appearing in the Wulff shape, as reported in high-resolution electron microscopy studies.

[1] J. Timmermann *et al.*, Phys. Rev. Lett. **125**, 206101 (2020)
[2] J. Timmermann *et al.*, J. Chem. Phys. **155**, 244107 (2021)

Keywords:

Computational Heterogeneous Catalyst, Machine-learning Interatomic Potentials, Surface Structure Determination, Equilibrium Nanoparticle Shape

H8.04

Structural and phononic properties of twisted two-dimensional transition-metal dichalcogenides

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Abstract:

Two-dimensional (2D) materials show a wide range of interesting physical phenomena that can be tuned by the number of layers, chemical compositions, and twist angles between layers. We present atomic structures and phononic properties of various twisted 2D transition-metal dichalcogenides in the range of the twist angle from θ = 0˚ (3R-stacking) to θ = 60˚ (2H-stacking). To study large moiré supercells efficiently, we use an atomistic model using the Kolmogorov-Crespi interlayer potential energy. With this atomistic approach, we investigate effects of twisting on the atomic structure and low-frequency interlayer phonon modes, and compare the results of various stacking combinations.
This work is supported by NRF of Korea (Grants No. 2020R1A2C3013673 and No. 2017R1A5A1014862). Computational resources have been provided by KISTI supercomputing center (Project No. KSC-2022-CRE-0266).

Keywords:

transition-metal dichalcogenide, moiré supercell, interlayer phonon mode

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2023-04-19 - 2023-04-21

H8.05

Topological complex charge conservation in Z2xZ2 antiferromagnetic order.

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Abstract:

Topological defects, such as solitons and domain walls, are expected to be a strong candidate for information storage due to their robust conserved property. Sr2VO3FeAs, which has a plaquette Z2xZ2 AFM order, has 3 possible domain wall phases and they can be observed and controlled by spin-polarized tunneling current in atomic scale. In this work, we find a novel conserved quantity, i.e. topological complex charge, whose product is invariant during domain wall motions by spin-polarized scanning tunneling microscopy. These conservation rules can be described and proved by Pauli matrix and winding number methods. Our observation of novel topologically protected information may open an avenue toward topological spintronics based on antiferromagnetic systems.

Keywords:

Topological defect, Soliton, Spin-polarized STM, Spintronics, Antiferromagnetism

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

H8.06

Survivability of respiratory droplets based on the wettability of face masks

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Abstract:

When a person talks, coughs, or sneezes, respiratory droplets are expelled and inevitably land on several surfaces, representing a route for respiratory disease transmission. Here, face masks act as a barrier by obstructing the passage of droplets during exhalation and inhalation. Being constantly exposed to respiratory events and carrying droplet residue, understanding the evaporation and absorption dynamics for tiny droplets on the multilayered porous substrates that constitute face masks and the fate of viral particle deposition is necessary to analyze the contamination risk. Here we explore the ideal design for masks from the interaction of mask surfaces with surrogate respiratory droplets composed of virus-sized nanoparticles suspended in artificial saliva. With X-ray microscopy and microtomography, we show that the respiratory droplet survivability is significantly reduced in masks with a hydrophilic surface where absorption takes place, leading to a reduction of the post-evaporation droplet residue at the mask surface when compared with a hydrophobic surface. Furthermore, X-ray imaging enabled a thorough analysis of facial masks' complex morphology, including layers dimensions and porosity. We show that hydrophilic surfaces can effectively reduce the contamination risk, allowing us to propose a better mask layer design dependent on wettability, contributing to the development of potential mitigation actions.

Keywords:

Face Mask, Wettability, Respiratory Droplet, Contamination Risk , X-ray Microscopy

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

H8.07

Charge reconstruction in 1T/1H TaS2 vertical heterostructure

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Abstract:

Mott insulators with strong electron-electron correlation exhibit various exotic physical phenomena, and charge doping is a useful control parameter. In Cuprates, charge doping can induce phase transitions from Mott insulators to metals and high-temperature superconductors, as well as new quantum phases such as nematic or checkerboard charge ordering. Similarly, single layer 1T-TaS2 is a Mott insulator that exhibits periodic lattice distortion forming a cluster of 13 Ta atoms called the David star. Previous studies have investigated the effects of chemical doping on 1T-TaS2, revealing novel phase transitions. In this study, we employed scanning tunnelling microscopy to investigate the surface electronic structure of a polymorphic vertical heterostructure consisting of 1T(Octahedral)-TaS2 and 1H(Trigonal)-phase. Our findings reveal the formation of a root 3 x root 3 charge reconstruction in the David star cluster, with fluctuations in the clumped area. Our spatially resolved spectroscopic data further demonstrate that this new charge ordering is associated with alternating spectral weight transfer. We will discuss the implications of our findings for understanding the charge ordering phenomena in Mott insulators and for exploring new avenues for manipulating the electronic properties of these materials

Keywords:

Scanning tunneling microscopy, Transition Metal Dichalcogenide, heterostructure, charge reconstruction

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

H8.08

Underlying physics of sweat droplet evaporation

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Abstract:

Perspiration is a physiological function of the human body to detoxify and regulate body temperature through the evaporation of sweat droplets from the skin. Human sweat is a common and ubiquitous biological fluid but carries important physiological information driving researchers to develop sweat assisted technologies in recent years. A sweat droplet is rich in chemicals and has complex nature since contains different proteins and salts. This complexity causes a multi-stage complicated evaporation and deposition behaviour that is not well understood yet but is critical for developing evaporation-based biodetection and evaporative cooling techniques. Here, we investigate sweat droplet evaporation and deposition by usage of an artificial sweat droplet on artificial skin in different environmental conditions. We found noticeable differences in evaporation and deposition mechanism between water and sweat droplet even though it contains negligible concentrations of components. Moreover, we found an intense impact of relative humidity on sweat droplet evaporation and deposition dynamics. We detect multi-stage evaporation and condensation for higher levels of humidity. This work suggests a deep insight into the sweat droplet evaporation and deposition that is essential in general healthcare applications like heat-health assessments during extreme global heat events and sweat-evaporation biosensors for clinical analysis.

Keywords:

Sweat droplet, Evaporation, Deposition , Condensation

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

H8.09

Topological complexity and evaporation dynamics of irregular droplets

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Abstract:

Irregular droplets are more common in nature than spherical droplets. The evaporation dynamics of irregular droplets are not fully understood because of their geometric complexity. We explore the evaporation dynamics of irregular water droplets deposited inside micropillar-patterned substrates using X-ray microtomography, providing geometric complexity through time-sequential and three-dimensional geometric information of evaporating irregular droplets. We observe two types of irregular water droplets, such as Wenzel plugs with single-sided air-water surfaces and Cassie-Baxter plugs with double-sided surfaces. From both plugs, we find that the evaporation rates of irregular water droplets are proportional to a square root of the total length of contact lines. This finding suggests a possibility of universal evaporation dynamics of irregular droplets.

Keywords:

Evaporation, Irregularity, X-ray tomography

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2023-04-19 - 2023-04-21

H9.01

Attosecond Transient Absorption Spectroscopy of Strongly Correlated Mott Insulators: Signature of the Creation and Annihilation of Double Occupancy

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Abstract:

We applied the time-resolved attosecond transient absorption spectroscopy to systematically investigate ultrafast optical responses of condensed matter systems. Under an intense pump pulse, absorption spectra indicate that the non-interacting electrons of band insulators produce a field-induced redshift, known as the dynamical Franz-Keldysh effect, as commonly expected. In contrast to the band insulators, in Mott insulators, unconventional spectra are observed which do not fully reflect the dynamical Franz-Keldysh effect. While it still exhibits the fishbone-like structures mimicking the dynamical Franz-Keldysh effect, the spectra show a negative difference absorption below the band edge, rendering a blueshift. In addition, the decomposed difference absorption reveals the creation and the annihilation of double occupancy mainly contribute to the negative signal, implying that the unconventional spectra are purely driven by the electron-correlations. These demonstra- tions of unconventional responses would guide us to the correlation-embedded attosecond electron dynamics in condensed matter systems.

Keywords:

Hubbard model, pump-probe spectroscopy, attosecond dynamics

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2023-04-19 - 2023-04-21

H9.02

Non-equilibrium dynamics of symmetry-broken state in the 1D Hubbard-Holstein model

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Abstract:

Non-equilibrium study of strongly correlated systems has been a major concern in condensed matter physics, and it can be dealt with more efficiently and significantly as technical developments improve for past decades. By means of density-matrix renormalization-group and time-evolving block-decimation methods, we study an electric-field-driven 1D Hubbard-Holstein model out of equilibrium. We focus on the charge ordering of the system and show its dynamics in real-time, which are associated with dynamic quantum phase transitions. We show how each energy scale in the system influences the time-evolution of the system, especially its relaxation phenomena.

Keywords:

1D Hubbard-Holstein model, nonequilibrium, DMRG, TEBD

H9.03

Intermediate Super-exponential Localization in Aubry-André chain

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Abstract:

We demonstrate existence of an intermediate super-exponential localization regime in finite Aubry-André chains (AA) with fine-tuned parameters. The regime approximates the localization properties of the 1D Wannier-Stark ladder. The super-exponential behavior emerges on intermediate length scales for small values of the incommensurate parameter α which is inversely proportional to the winding length – the quasi-period of the Aubry-André potential. This intermediate localisation is present irrespective of the ratio of the potential strength λ to the hopping strength $|t|$, e.g. both in metallic and insulating regimes of the AA chain. In the extended phase $|\lambda| < 2|t|$ the intermediate length scale localisation emerges away from the center of the spectrum. In the localised case $|\lambda| > 2|t|$ the super-exponential localisation is followed by the conventional asymptotic exponential decay predicted for the Aubry-André model. By adjusting the parameters of the model it is possible to push the onset of the asymptotic exponential localisation to arbitrary faraway distances. A similar intermediate scale super-exponential localisation regime is identified in the quasiperiodic discrete-time unitary map. The presence of such intermediate localisation might be of importance in experiments and applications.

Keywords:

quasiperiodicity, Aubry-Andre, localisation, Wannier-Stark

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

H9.04

Subharmonic Fidelity Revival in a Driven PXP mode

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Abstract:

The PXP model hosts a special set of nonergodic states, referred to as quantum many-body scars. One of the consequences of quantum scarring is the periodic revival of the wave function fidelity. It has been reported that quantum fidelity revival occurs in the PXP model for certain product states, and periodic driving of chemical potential can enhance the magnitude of quantum revival, and can even change the frequencies of revival showing the subharmonic response. Although the effect of the periodic driving in the PXP model has been studied in the limit of certain perturbative regimes, the general mechanism of such enhanced revival and frequency change has been barely studied. In this work, we investigate how periodic driving in the PXP model can systematically control the fidelity revival. Particularly, focusing on the product state so called a N´eel state, we analyze the condition of driving to enhance the magnitude of revival or change the frequencies of revival. To clarify the reason of such control, we consider the similarities between the PXP model and the free spin-1/2 model in graph theoretical analysis, and show that the quantum fidelity feature in the PXP model is well explained by the free spin-1/2 model. In addition, under certain limit of the driving parameters, analytic approach to explain the main features of the fidelity revival is also performed. Our results give an insight of the scarring nature of the periodically driven PXP model and pave the way to understand their (sub-)harmonic responses and controls.

Keywords:

Quantum many-body scar, Floquet driving, Subharmonic response

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2023-04-19 - 2023-04-21

H9.06

Multifractality and localization in a disordered flat-band superconductor on the Kagome lattices

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Abstract:

We investigate the effects of disorders on flat-band superconductivity in the attractive Hubbard model on the Kagome lattices by using the exact diagonalization and mean-field methods. We consider two types of disorders: the flat-band-preserving correlated disorder and the uncorrelated random onsite potentials. In non-interacting cases, the correlated disorders keep the fractal dimension D=1 regardless of the disorder strength at the flat-band states; in contrast, weak random onsite potentials cause localization with D=0. We find that these non-interacting features change drastically by turning on the interactions. Our calculations of the mean-field order parameter and the superfluid weight indicate that the superconducting ground state is more robust under the correlated disorders that preserve a flat band. While the system eventually undergoes the localization transition as the disorder strength increases, the inverse participation ratio exhibits 0The fractal dimension computed as a function of disorder strength implies that the system is fragile to localization at small random onsite disorders while it undergoes a localization transition at finite disorder strength with the correlated disorders.

Keywords:

superconductivity, flat-band systems, many-body localization, disordered systems, exact diagonalization

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

H9.07

Variational Monte Carlo Study of J_1-J_d-J_χ Model on the Kagome Lattice

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Abstract:

A quantum spin model on the kagome lattice has been extensively studied as a prominent candidate for quantum spin liquids (QSL). Especially, J_1-(J_2)-J_d model is spotlighted as a typical example of chiral spin liquid with ν=1/2 fractional quantum Hall system. On the other hand, recent studies also focus on the staggered scalar spin chiral term which leads to a non-Fermi liquid behavior of spinon excitation. In this work, we study the competition between those two models: J_1-J_d model and staggered scalar spin chiral term on the kagome lattice using a variational Monte Carlo (VMC) method. Varying third-nearest-neighbor Heisenberg exchange strength J_d/J_1 and staggered scalar spin chiral strength J_χ/J_1, we draw the phase diagram of three different spin liquid phases: U(1)-Dirac spin liquid (U(1)-DSL), gapped chiral spin liquid (CSL), and gapless staggered CSL. We found out that the J_χ induces a tricritical point between U(1)-DSL and gapped CSL near $(J_d/J_1, J_\chi/J_1)$ ~ (0.2, 0.2). By explicitly constructing the Landau-Ginzburg theory, we figure out the emergence of tricritical point. We also discuss static spin structure factor and longitudinal thermal conductance of each phase as a guidance of experiment.

Keywords:

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

H10.01

Fabrication of quantum dot spin qubit device and its electric control

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Abstract:

Silicon spin qubit has got significant attention recently due to its long coherence time and similarity to the conventional CMOS fabrication process. However, achieving sufficient coupling between dots requires electrons to be located in close proximity, typically within 100nm, which presents a challenge during fabrication. To overcome this hurdle and ensure high yield and quality of the device, an overlaid gate design is utilized and optimized. This approach enables the firm formation of quantum dots and the detection of multiple dot signals. In addition, with micromagnet simulation that are tailored to the wafer and the device we demonstrate Rabi oscillation, which indicates successful spin flip operation. These results demonstrate the quality of the device and its potential to implement high-fidelity spin qubit operations.

Keywords:

Qubit, Silicon, Quantum dot, Spin qubit, Nanofabrication

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

H10.02

High-Q singlet-triplet qubit driven by magnetic field gradient in 28Si-purified silicon

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Abstract:

In this study, we demonstrate the effectiveness of an on-chip micromagnet on an isotopically purified 28Si/SiGe substrate to manipulate spin states in semiconductor quantum dot nanostructures. Our results show fast singlet-triplet qubit oscillation in the regime where the valley splitting in each quantum dot exceeds 300ueV. Despite the presence of charge noise presumed to originate from an adjacent dot, we achieved encoded qubit oscillation with a quality factor of over 300 using rf-reflectrometry based single-shot readout and adaptive initialization. We also observed varying singlet-triplet oscillation near the magnetic field inversion region due to the micromagnet's magnetization reversal, allowing for the adjustment of the frequency of S-T oscillation by tuning the magnetic field gradient.

Keywords:

Singlet-Triplet Qubit, Micromagnet, 28Si purified Silicon

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

H10.03

Hidden Markov Model-Based Single-Shot Readout of a Spin Qubit

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Abstract:

The high-precision readout of spin qubits is a challenging task due to the presence of noise in the system but it is essential in quantum computing. In semiconductor spin qubit devices, the spin states are distinguished via spin-to-charge conversion mechanisms such as energy-selective tunneling(EST) method utilizing a charge sensor. The existence of tunneling from the quantum dot to the reservoir in the readout time represents the spin state which generates the difference in signal measured by a radio frequency single-electron transistor(rf-set). Currently, the thresholding technique is used to discriminate whether the tunneling event occurs but it is susceptible to noise.
In this project, we present a novel approach for readout the state of a single electron spin qubit on a Silicon device using a Hidden Markov Model(HMM). The HMM models the system as two states, hidden states and observations. The states of quantum dot can be encoded to hidden states due to the Markovian property of tunneling process, hence we can take advantage of Bayesian Network to discriminate the existence of tunneling events from rf-set signal. Our results show that the HMM-based readout method outperforms traditional threshold techniques, particularly when the signal-to-noise ratio is around 5. This project demonstrates the potential of HMM-based readout techniques for achieving high-fidelity readout of spin qubits, which is critical for the development of practical quantum computing devices.

Keywords:

Spin qubit, Hidden Markov Model, readout, Quantum information, Semiconductor quantum computing device

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

H10.04

Probing two-qubit capacitive interactions beyond bilinear regime using dual Hamiltonian parameter estimations

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Abstract:

We report the simultaneous operation and two-qubit coupling measurement of a pair of two-electron spin qubits that are actively decoupled from quasistatic nuclear noise in a GaAs quadruple quantum dot array. Coherent Rabi oscillations of both qubits (decay time ≈2 {₩mu}s; frequency few MHz) are achieved by continuously tuning the drive frequency using rapidly converging real-time Hamiltonian estimators. By state conditional exchange oscillation measurements, we also observe strong two-qubit capacitive interaction (> 190 MHz). We show that the scaling of the capacitive interaction with respect to intra-qubit exchange energies is stronger than the bilinear form, consistent with recent theoretical predictions. We observe a high ratio (>16) between coherence and conditional phase-flip time, which supports the possibility of generating high-fidelity and fast quantum entanglement between encoded spin qubits using a simple capacitive interaction.

Keywords:

Semiconductor Quantum Dot, Quantum Computing, Quantum Information

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

H10.05

Single-electron spin qubit in isotopically enriched silicon

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Abstract:

Electron spin qubit in silicon quantum dots is a promising quantum platform owing to their long coherence time. Here, we study single-electron spin qubits in the silicon quantum dots. We report coherent Rabi oscillation in single spin qubits using isotopically enriched silicon quantum dots with an on-chip micromagnet. The qubit is defined in an overlaid $^{28}Si/SiGe$ device. The magnetic field gradient from the micromagnet and an oscillating electric field induce spin resonance. Electric dipole spin resonance (EDSR) is used to discriminate the spin state via energy-selective tunneling. We apply a two-stage pulse sequence to demonstrate coherent spin control. We measure an addressable qubit resonance frequency at B_{ext} = 431mT. Also, we apply Ramsey sequence to measure the qubit coherence time $T2^* > 2\mu s$.

Keywords:

quantum dot, spin qubit

H11.01

Status of high energy colliders : luminosity frontier

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Abstract:

SuperKEKB is an e^+ e^- collider constructed at KEK, Tsukuba, Japan as a 2nd generation asymmetric B-factory. B-factory is considered as a key strategy for accomplishing precision physics and searching new physics beyond the Standard Model in the particle physics field. The energy of the electron beam is 7 GeV while that of the positron beam is 4 GeV, which makes the system an asymmetric double-ring collider. The collision energy of two beams is mostly at the Upsilon(4S) resonance and can be varied to cover other interesting physics scenarios.

Compared to its predecessor, KEKB, the luminosity of SuperKEKB is expected to be increased by 40 times, based on an innovative nano-beam collision scheme. The commissioning phase of SuperKEKB started in 2016, and the first physics collision happened in 2019. The luminosity of SuperKEKB broke the previous world record by LHC on June 2021 and has been improved continuously. The most recent record by SuperKEKB is $4.7 \times 10^{34} cm^{-2}s^{-1}$ accomplished on June 2022. Right after this event, SuperKEKB went into Long Shutdown 1 and will be restarted at the end of 2023. It is planned to operate SuperKEKB until early 2030's to collect a sample of $50\, ab^{-1}$ of collision data.

In this talk, the basic strategy of SuperKEKB will be shown with an emphasis on interactions between SuperKEKB and Belle II, the B-factory experiment. Also future collider projects such as ILC and C3 will be briefly introduced.

Keywords:

SuperKEKB, Belle II, nano-beam, B-factory, future collider

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

H11.02

Accelerators for Energy Frontier Particle Physics Experiments

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Abstract:

The growth of particle physics has been with the development of particle accelerators. The history of Standard Model particle discoveries proves accelerator-based particle physics experiments' importance. My talk introduces a brief history of new particle discoveries and the current physics searches at the strongest particle accelerator in the world. In addition, I talk about how the world accelerator and particle physics researchers design and study next-generation particle physics experiments together. In the end, I express my opinion as an accelerator user.

Keywords:

Accelerstor, Particle Physics

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

H11.03

Current status of LWFA and ultra-short radiation sources with PW lasers

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Abstract:

Laser wakefield acceleration (LWFA) is an attractive method for accelerating electrons because it can provide an acceleration gradient that is three orders of magnitude higher than conventional RF accelerations. Electron bunches can be accelerated to the multi-GeV energy range by LWFA due to the development of laser systems with peak powers exceeding PW. In addition, ultrashort radiation sources based on LWFA can be utilized to study radiography, ultrafast x-ray spectroscopy, and nuclear photonics. In this presentation, the current state and trends in LWFA research and the development of LWFA-based radiation sources will be discussed.

Keywords:

Laser plasma accelerator, Laser wakefield acceleration, Laser-driven x-ray/gamma-ray beams, ultra-intense lasers, PW lasers

Student and Preservice Teacher's Understanding of Voltage by Section in Electrical Circuit; Prediction, Measurement of Practical Experiments and Tinkercad Simulation Experiments

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Abstract:

본 연구의 목적은 전기회로의 전압에 대한 학생들의 이해를 분석하여 과학과 교육과정과 대학에서의 교수·학습에 대한 시사점을 얻는 것이다. 본 연구의 대상은 초·중학생 12명, 고등학생 22명, 예비 물리교사 11명이다. 전기회로를 주제로 한 학교 밖 수업에서 전기회로의 구간별 전압 예측, 실험 키트 및 팅커캐드 시뮬레이션을 활용한 전압 측정 등을 통해 작성한 학생들의 활동지를 분석하였다. 그 결과는 다음과 같다. 첫째, 수업 전 전압의 정의를 올바르게 작성한 학생의 비율은 초·중학생이 14.3%, 고등학생이 10.4%로 낮은 수치를 보인 반면, 예비 물리교사는 75.0%로 다소 높은 수치를 보였다. 둘째, 주어진 구간별로 전압을 예측했을 때의 정답률은 초·중학생이 24.2%, 고등학생과 예비 물리교사가 각 39.1%로 큰 차이가 없었다. 특히 스위치가 포함된 구간에서 공통적으로 가장 낮은 정답률을 보였다. 셋째, 학생들은 실험 키트와 시뮬레이션을 이용한 전압 측정 모두 높은 정답률을 보였으며, 대부분의 학생들이 두 가지 방식을 함께 수업에 활용하는 것이 효과적이라고 응답하였다. 결론적으로 저항과 스위치가 포함된 전기회로의 구간별 전압에 대한 교수-학습에서 학교급 수준을 고려한 지도가 요구된다. 또한 다양한 물리 개념에 대한 수업에서 실제 실험과 시뮬레이션 실험을 함께 활용한 연구가 활발하게 진행된다면 과학 교육에 큰 도움이 될 것이라고 기대된다.

Keywords:

전기회로, 전압, 초·중등학생, 예비물리교사, 예측, 실험, 시뮬레이션

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

H12.02

역학에서의 보존력과 Curl 및 스토크스 정리에 대한 예비 물리교사들의 이해 분석

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Abstract:

본 연구의 목적은 예비 물리교사의 보존력, Curl, 스토크스 정리에 대한 이해를 분석하여 물리 교육적 시사점을 얻고자 하는 것이다. 본 연구는 일반물리학 수준 이상의 물리학 강좌를 수강한 물리교육과 학부생 2~4학년 27명을 대상으로 실시하였다. 보존력과 Curl 및 스토크스 정리에 대한 이해를 확인하기 위해 설문을 실시하고 일부 학생들을 대상으로 심층 면담을 수행하였다. 학생들의 응답을 분석한 결과는 다음과 같다. 첫째, 예비 물리교사들은 Curl의 의미를 설명하는 것을 어려워했으며, 2차원 벡터장의 특정 부분에서 Curl 여부를 판별하는 문제와 스토크스 정리에 대한 선·면적분 계산 문제에서 정답률이 낮았다. 둘째, 보존력 개념에 대한 예비 교사들의 과학적 응답 비율은 높았으나, 주어진 2차원 벡터장이 보존력장인지 판별하거나 Curl 연산을 이용한 보존력 판별, 보존력이 한 일을 구하는 미적분 계산에서 정답률이 낮았다. 이를 종합해 볼 때, 보존력을 이해하는 데는 Curl에 대한 이해가 필요하며 수학에 대한 어려움이 물리학을 이해하는 데 영향이 있음을 알 수 있다. 따라서 예비교사 대상으로 교수학습을 할 때 Curl에 대한 개념을 충분히 숙지한 상태에서 보존력의 개념을 이해하도록 돕는 것이 필요해 보인다. 아울러 Curl과 보존력에 대한 어려움을 해결하는 심층적인 연구가 추후 진행될 필요가 있다.

Keywords:

Curl, 보존력, 스토크스 정리

2022 개정 교육과정의 구현에서 양자역학 내용을 어떻게 구체화할 것인가?

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Abstract:

2022개정 교육과정에서 신규 개설된 진로선택 과목이 '전자기와 양자'인 것에서 나타나듯이, 양자역학 관련 내용이 기존보다 강화되었다. 개정 교육과정에서 양자 관련 내용은 기존의 방식인 양자론에 대한 역사적 접근에서 한층 더 벋어나서 이중슬릿 실험을 중심으로 직접적으로 양자이론이 다루어진다. 또한 최근에 주목받는 양자컴퓨터와 양자암호통신도 교육과정에 포함되었다. 이러한 변화에 따라 새로운 교육과정을 구체화하는 교육 방안에 대한 다양한 심층적 논의가 필요하다고 판단된다. 본 발표에서는 이와 관련된 논의를 촉발하고자 한다.

Keywords:

양자역학 교육

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H12.04

지역기반 과학교육을 위한 예비교사 프로그램 개발 및 물리교육에 대한 제언

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Abstract:

본 연구의 목적은 과학적 소양의 의미를 지역 기반으로 확장하고 지역 기반 과학적 소양을 증진하기 위한 방안을 모색하는 데에 있다. 과학적 소양에 관한 기존 연구들은 대체로 보편적/이론적 차원, 사회적/공적 차원, 개인적/실천적 차원의 세 가지 차원을 포함하고 있지만 서로 연결되어 있지 않다는 한계점이 지적되어 왔다. 본 연구에서는 이 같은 한계점과 관련하여 지역을 중심으로 세 가지 차원을 연결하고, 내용으로서의 과학적 소양, 도구로서의 과학적 소양, 중재자로서의 과학적 소양을 세 가지 위상으로 하는 지역 기반 과학적 소양을 제안하였다. 아울러, 지역 기반 과학적 소양의 증진은 지역의 실제 문제를 해결해 가는 과정이 효과적일 것으로 예상하고, 충청남도 소재 교육대학교의 예비교사들이 지역 아동들과 함께 지역의 실제 문제를 탐구하고 해결을 시도하는 마을탐구공동체 프로그램을 교육대학교 정규 교육과정으로 운영하였다. 끝으로 마을탐구공동체의 운영 과정을 바탕으로 지역 기반 물리교육과 예비교사 교육에 주는 시사점에 대해 논의하였다.

Keywords:

과학적 소양, 지역기반 물리교육, 탐구공동체, 예비교사교육

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

H12.05

Developing and Application of Physics Identity Survey Tool for Preservice Teachers

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Abstract:

As physics teachers are scientists whom students meet for the first time, their influence on the students is tremendous. This means that if a new scientific notion is discovered teachers must be the first ones to acquire it. In other words, the continuous participation of teachers in science is necessary. Teachers' Science Identity affects continuous participation in science in the future. Therefore, It can be predicted that the Science Identity of a Pre-service physics teacher will play an important role in Pre-service teacher education and physics education at school. According to Hazari et al.(2010), the Science Identity model consists of four factors: Interest, Recognition, Competence, and Performance. This study aims to develop a Physics Identity survey tool for pre-service teachers and apply it to analyze the Physics Identity of pre-service teachers. To this end, the science identity model and measurement tools suggested in previous studies were critically reviewed and based on this, a Physics Identity survey tool for physics teachers was developed. The developed tool was applied to pre-service physics teachers attending the College of Education through an online survey. From the collected data, the distribution of Physics Identity by component and the distribution of Physics Identity according to gender and grade of pre-service teachers were analyzed. From the results, the implications of the distribution of Physics Identity of pre-service physics teachers in physics teacher education were discussed.

Keywords:

Physics identity, Pre-service physics teacher, Physics education, Teacher education

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H12.06

협력적 2라운드 물리 문제 해결에서 그룹 유형이 그룹 성과에 미치는 영향

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Abstract:

이 연구는 미적분 기반 물리학 입문 과정에서 2라운드 물리 문제 해결 과정을 통해 수집된 3학기 분량의 학생들의 데이터를 조사했다. 참가자들은 2차에 걸쳐 142개의 물리 문제에 대해 질문을 받았고, 개별적으로(1차), 그룹으로(2차) 문제에 답했다. 그룹 내 개인 라운드의 정답자 수, 그룹 내 다수 답의 종류, 개인 라운드 답변의 다양성에 따라 결정되는 그룹 유형을 기반으로, 이러한 그룹 유형이 그룹 성과에 어떤 영향을 미치는지 분석하였다. 그룹 라운드에서 정답을 찾은 비율은 개별 라운드에서 정답을 맞춘 학생 수에 비례하였다. 하지만 개인 라운드 정답자가 적거나 없을 때에도 그룹 내 다수 답의 종류나 답변의 다양성에 따라 그룹 성과가 나타났다. 이를 그룹 내 개인의 인지 자원 측면에서 논하고자 한다.

Keywords:

문제해결, 일반물리, 협력, 그룹

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H12.07

물리학 교육과정 및 교과서의 양자물리학 내용요소 분석
Analyzing Quantum Physics contents in Physics Textbook and Physics Curriculum

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Abstract:

양자물리학이 현대물리학의 한 분야로 정립된 지 100여년이 지났다. 이 분야에서 발전한 기술인 양자컴퓨터와 LED 등의 활용이 일상생활에서 적용되기 시작하면서 양자물리학 교육에 대한 필요성과 중요성이 높아졌다. 그러나 교육 현장에서는 양자물리학 교육에 대한 다양한 어려움이 보고되고 있어, 이에 대한 교수법 연구가 필요하다. 이러한 문제를 해결하기 위한 시도로 이 연구에서는 2015 개정 교육과정 및 2022 개정 교육과정에서의 양자물리학 내용요소를 분석하고, 이를 독일의 Baden-Wuerttemberg의 물리학 교육과정과 비교하였다. 또한, 고등학교에서 사용되는 물리학1 교과서 7종 및 물리학2 교과서 4종의 내용을 분석하여 기초 양자물리학 교육의 내용과 범위를 탐색하였다. 선행 연구에 사용된 양자물리학의 17가지 내용요소에 따라 교육과정 및 교과서에 제시된 내용의 범위(scope)를 분석한 결과, 교육과정에서의 양자물리학 내용요소는 2015 개정 교육과정에 비해 2022 개정 교육과정에서 증가한 것을 확인하였다. 또한, 외국 교육과정과의 비교 결과, 양자물리학의 철학적 해석 관련 내용이 다소 미흡하고, 기술적 적용을 중심으로 내용이 구성된 것을 확인하였다. 그리고 물리학1 교과서에 제시된 내용요소는 교육과정과 비교하여 큰 차이가 없었으나, 물리학2 교과서에 제시된 내용요소는 다소 차이가 있음을 확인하였다. 교과서의 내용요소별 배열(sequence) 및 서술 방식에 대한 분석 및 대학 일반물리 또는 현대물리 교재와 비교하는 후속연구를 통해 국내 양자물리학 기초 교육의 현 주소를 파악하고, 해외 현황과 비교하여 국내 교육 여건에 맞는 양자물리학 내용 및 교수법 관련 시사점을 도출하고자 한다.

Keywords:

양자물리학, 교육과정, 교과서

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H12.08

코로나 시대에 대비한 KPOPE 연구단의 대학 교양물리 개선 성과 소개 및 포스트 코로나 시대에서 대학 교양물리 교육 방향성 고찰

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Abstract:

코로나 시대를 지나오면서 강의실이라는 장소에 구애받지 않으면서 교육적 효과를 극대화 시킬 수 있는 새로운 교육 및 평가 방법에 대한 수요가 높아졌다. Korea Pragmatist Organization for Physics Education (KPOPE Collaboration) 연구단은 이러한 수요에 부응하도록 대학 교양 물리교육을 개선하여 실험측정, 분석방법 및 평가방법을 대대적으로 개선하였고, 그 성과 및 개선결과를 공유하고 앞으로의 대학 교양물리 교육개선의 방향을 모색하고자 한다.

Keywords:

Korea Pragmatist Organization for Physics Education (KPOPE Collaboration)

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2023-04-19 - 2023-04-21

H13.01

Toward a quantum gas microscope for ytterbium atoms at KRISS

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Abstract:

Ultracold atoms become a promising platform to realize analog quantum simulator for exploring many-body physics embedded in strongly correlated systems. Recently, the quantum gas microscope is a state-of-the-art experimental tool, owing to its capability to manipulate and detect at a single atom level. In this talk, we will present the progress of the ongoing development of a quantum gas microscope apparatus for ytterbium atoms at KRISS. Ytterbium atoms offer ideal features beyond alkali atoms to tackle challenging problems ranging from topological systems to quantum transport phenomena. To achieve single-site resolution, we adopt the deep potential method, which does not require any cooling mechanism during the imaging process. The evaporatively cooled ytterbium atoms are repeatedly prepared in a single layer of an accordion lattice and adiabatically loaded in a 2D optical lattice. The atoms are pinned by suddenly ramping the lattice depth and excited by illuminating the resonant pulse. The fluorescence photons emitted from the atoms are collected through a high NA imaging system, which is designed to have a long working distance. We expect an immediate extension to fermionic ytterbium isotopes and aim to explore rich physics such as SU(N) Fermi-Hubbard model and the Kondo physics in the near future.

Keywords:

quantum gas microscope, quantum simulator, optical lattice, Bose-Einstein condensate, Hubbard model

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H13.02

A quantum vortex collider in an ultracold atomic Fermi gas

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Abstract:

Vortices lie at the heart of numerous fluid phenomena both in classical and quantum systems. Dissipation of the energy of quantum vortices, whose vorticities are preserved thanks to the topological nature, constitutes a central role in describing quantum hydrodynamics. A vortex can dissipate its rotational kinetic energy into compressible energy via sound emissions due to vortex-sound coupling. However, the scarcity of convincing experimental demonstrations has limited our deep understanding. To unveil the nature of quantum vortex dissipation, we realize a deterministic quantum vortex collider in flat atomic Fermi gases, and reveal sound-mediated dissipation and its ultimate form, i.e., vortex annihilation.

Reference:
1. W. J. Kwon et al., "Sound emission and annihilations in a programmable quantum vortex collider," Nature 600, 64 (2021).

Keywords:

superfluid, vortex, ultracold fermi gas, sound, annihiliation

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H13.03

Study of Kibble-Zurek scaling in a homogenous Unitary Fermi gas

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Abstract:

Out-of-equilibrium dynamics is an area of great interest in quantum many-body physics. During a continuous phase transition, topological defects spontaneously arise across the critical point. The Kibble-Zurek mechanism provides a powerful theory predicting a power-law scaling between the density of defects and the quench rate of a parameter when a system passes through the critical point, regardless of the system's constituents or microscopic interactions. Ultracold atomic gases are an ideal testbed for this mechanism due to their cleanness and high controllability. However, accurately measuring the scaling has been difficult due to the inhomogeneous trapping of atomic gases. Here, we constructed a homogeneous trap using a spatial light modulator and demonstrated power-law scaling in the ^{6}Li unitary fermi gas. Our results show that the scaling exponent is close to the theoretical prediction and is independent of the final temperature of the system. We also found no noticeable variation in the number of defects when the quench rate was increased after passing through the critical point. This result demonstrates that the decay of defects was small at slow quench rates. Our work represents a systematic investigation of the formation dynamics of topological defects in the normal to superfluid phase transition of the unitary Fermi gas, providing a starting point for quantitative studies of dynamical phase transitions using a homogeneous sample.

Keywords:

Kibble-Zurek mechanism, topological defect, quench, homogeneous, Unitary Fermi gas

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

H13.04

Formation of Ultracold Weakly Bound Feshbach Molecules of $^{23}Na^{41}K$

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Abstract:

Feshbach resonance is a powerful tool that allows for broad, precise tuning of intra- and interspecies atomic interactions, especially enabling the controlled association of weakly bound molecules. In this talk, we present our recent progress on the creation of ultracold Feshbach molecules of $^{23}Na^{41}K$, in an apparatus designed to selectively create ultracold gases of bosonic/fermionic $^{23}Na^{41/40}K$ dipolar molecules. First of all, we demonstrate that ^{23}Na, known to be an efficient sympathetic coolant for fermionic ^{40}K, is also an effective coolant for bosonic ^{41}K. In particular, sympathetic cooling of ^{41}K via evaporative cooling of ^{23}Na allows the creation of a binary mixture of ^{23}Na-^{41}K Bose-Einstein condensates. Feshbach resonances between selected hyperfine states of the two atomic species are investigated in turn by measuring enhanced loss rates, one of which is used to create Feshbach molecules. We characterize these weakly bound pairs by measuring the binding energy dependence on the magnetic field. Our results serve as a starting point for the creation of bosonic dipolar $^{23}Na^{41}K$ molecules in their absolute ground state.

Keywords:

Ultracold, Molecules, Feshbach resonances

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2023-04-19 - 2023-04-21

H13.05

Intensity-Profiling Raman Beams Using a Trapped ion

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Abstract:

Trapped Ion based quantum computer is one among the leading quantum computing platforms. The quantum states of ion qubits are controlled by tightly focused laser beams and simultaneous control of multiple qubits requires well-controlled individual addressing of the laser beams applied to the ions. The crosstalk between individual addressing beam may harm the gate fidelity of quantum operations and precise characterization of beam profile is important to assess the error budget of the system. Here, we characterize the beam delivery system of the STAQ (Software-Tailored Architectures for Quantum Co-Design) setup at Duke University, using a trapped ion as a probe to profile the spatial intensity distribution of individual addressing Raman laser beams. The detailed analysis and discussion will be delivered as well.

Keywords:

Quantum Computer, Atomic Physics, Cold Atom, Trapped Ion, Quantum Information

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2023-04-19 - 2023-04-21

H13.06

Error correction assisted determination of the non-local membrane order parameter.

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Abstract:

Non-local order parameters are expected to distinguish exotic phases of the quantum system. The membrane order parameter, which can determine the phases of the Bose-Hubbard model in two dimensions, is an example of such non-local order parameter. However, the membrane order parameter in the optical lattice system is difficult to measure because of the parity projected measurement and incoherent holes. In this presentation, we will introduce the method to detour the errors from the incoherent holes by introducing the error correction scheme. This error correction method is applied to analyze the superfluid to Mott Insulator system in an optical lattice. We prepared 1200 atoms in the optical lattice and took snapshots of the atoms with different values of J/U with quantum gas microscope imaging. Our system has incoherent holes with probability p = 0.02 from the thermal fluctuation and the losses during the imaging process [1]. Using the error correction assisted membrane order parameter, we could identify the phase boundary between the superfluid and Mott Insulator phases. Furthermore, the scaling depending on the system size consists of the theoretically expected result. Our error correction scheme can be generalized to any system where errors from incoherent sources are unavoidable.

[1] K. Kwon, K. Kim, J. Hur, S. Huh, and J.-y. Choi, Site-resolved imaging of a bosonic Mott insulator of 7Li atoms, Phys. Rev. A 105, 033323 (2022).

Keywords:

Quantum Gas Microscope, Optical lattice

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H13.07

Rydberg atom collision by optical tweezer accelerator

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Abstract:

We present a collision experiment of individual Rydberg atoms. Optical tweezers are used to throw (i.e., accelerate and release) a ground-state atom, which is then excited to a Rydberg state and collides with a stationary Rydberg atom [1]. The collision is made possible by the repulsive force experienced between two Rydberg atoms due to dipole-dipole interaction. To enable the collision between the flying and stationary Rydberg atoms, experimentally we first captured ^{87}Rb single atoms by employing optical tweezer traps and a magneto-optical trap to cool the atom clouds to 30 $₩mu$K temperature [2]. Furthermore, we placed a stationary, trapped atom in the path of a flying atom and excited both to Rydberg states. The flying atom was acoustically controlled to accelerate and then released to fly with a speed of 1.5 m/s. Upon illumination with a Rydberg excitation beam, the flying Rydberg atom collided with the stationary Rydberg atom. This proof-of-principle demonstration of Rydberg atom collision via an optical tweezer accelerator has significant implications for the study of fundamental physics.

Keywords:

Trapped atom, cold atom, collision, Rydberg state

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H15.01

Perspectives on the neuromorphic device application of ferroelectric fluorite oxide thin film

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Abstract:

Ferroelectricity with controllable partial polarization is considered as one of feasible candidates for an analog device for the neuromorphic device in the form of the ferroelectric tunnel junction and ferroelectric transistor. However, in the case of conventional ferroelectric materials, the complex nature of ferroelectric switching mechanism and/or defect mediated uncertainty hinder the deterministic control of ferroelectric subloop switching. This stochastic nature in the control of ferroelectric polarization states are of interest prior to the device application.
Recently, novel ferroelectric HfO_2 thin film has been investigated intensively as an alternative to conventional ferroelectric materials due to the advantages such as good scalability, compatibility with conventional CMOS process technology.

In this study, we present the unprecedented stability of sub-loop polarization observed in the subloop switching of ferroelectric HfO_2. We suggest that the enhanced stability and accessibility of intermediate states in HfO_2 can be attributed to the large activation field for ferroelectric switching with small critical volume for the ferroelectric nucleation of HfO_2. We measured switching dynamics and temperature dependence hysteresis of HfO_2 thin films. The characteristic switching time and temperature dependence of hysteresis showed that ferroelectric HfO_2 has large activation energy while the critical size of ferroelectric domain volume is small. PFM results showed large domain wall activation energy due to stable small critical volume. Theoretical calculation demonstrated the stable switching energy path of ferroelectric HfO_2 during single dipole flip.

Keywords:

ferroelectric HfO2

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2023-04-19 - 2023-04-21

H15.02

Flat-band ferroelectricity and unconventional domain walls in HfO_2

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Abstract:

Domain walls in ferroelectricity is an essential factor for understanding ferroelectric switching, dielectric properties, piezoelectricity and pyroelectricity. Since the ferroelectricity is discovered in HfO2, its domain walls and their dynamics have been barely understood yet. Using first principles simulations, we studied various domain wall structures and their propagation energies in HfO2. Based on the understanding, we will show the ferroelectricity in HfO2 is induced by its flat phonon bands. Then we will propose how to relieve the deleterious wake-up effect, to reduce the switching voltage, and to increase the memory densities by tailoring the flatness of the bands by using epitaxial strain and various dopants in the commercial ferroelectric.

Keywords:

Ferroelectric, Flat band, Switching voltage, Memory density

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H15.03

Origin of ferroelectricity in HfO_2-based ferroelectrics

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Abstract:

Continuous advancement in nonvolatile and morphotropic beyond-Moore electronic devices requires integration of ferroelectric and semiconductor materials. The emergence of HfO_2-based ferroelectrics that are compatible with atomic-layer deposition has opened interesting and promising avenues of research. However, the origins of ferroelectricity and pathways to controlling it in HfO_2 are still mysterious. In this presentation, I will present how we are able to reveal the origin of ferroelectricity in the HfO_2-based ferroelectrics. In particular, we discuss how we are able to control ferroelectricity by He ion bombardment and also discuss the possible competing mechanisms for highly enhanced ferroelectricity. Our piezoresponse force microscopy results indicate that the amplitude of piezoresponse in the ion-bombarded region increased by approximately twofold compared with that in the pristine region and the scanning transmission electron microscopy results show that the large enhancement of ferroelectricity by He ion bombardment can be caused by a homogeneous distribution of oxygen vacancies and a phase transition to the ferroelectric phase. These findings both reveal the origins of ferroelectricity in this system and open pathways for nanoengineered binary ferroelectrics.

Keywords:

HfO2, ferroelectrics, piezoresponse force microscopy, ion beam

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

H16.01

Status of Future Collider Activities in Korea

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Abstract:

Future Collider projects such as FCC (CERN), CEPC (China) and EIC (US) are actively under discussion in global nuclear and particle physics communities. Korea group has participated intensively, for example, the dual-readout calorimeter R&D for FCC-ee and CEPC. We discuss current status and future plan of the future collider activities in Korea.

Keywords:

FCC, CEPC, EIC, Dual-Readout Calorimeter

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H16.02

Status of DUNE(Deep Underground Neutrino Experiment)

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Abstract:

DUNE실험은 삼세대로 이루어진 중성미자의 질량순서와 CP 비대칭 위상을 측정하여, 퍼즐의 빈 곳을 채우는 것을 첫번째 목표로 삼고 있다. 1300킬로미터의 거리를 날아서 중성미자의 종류가 얼마나 바뀌었는가를 정확하게 측정하기 위해, 고밀도의 중성미자 빔을 근거리검출기와 원거리검출기로 통과시킨다. 빔 생산시설과 검출시설을 구축중인 현 단계에서 시뮬레이션을 이용한 가상실험을 수행하고, 더 많은 물리적 타겟을 발굴하고 있다. 이 발표에서, 현재 검출시설의 준비 상황과 추가되는 물리학 이슈들을 소개하고, 한국 DUNE 그룹의 활동에 대하여 보고하고자 한다.

Keywords:

DUNE, 중성미자

H16.03

Status of the Muon g-2 Experiment at Fermilab

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Abstract:

The Muon g-2 experiment at Fermilab aims to measure the muon’s anomalous magnetic moment to 140 parts-per-billion precision, which is about four times more precise than the predecessor experiment at Brookhaven National Laboratory (BNL). Its first result, announced in 2021, confirmed the previous result at BNL, increasing the tension between the Standard Model prediction and the combined experimental average to 4.2 standard deviations. We have accumulated the proposed amount of raw data, 21 times the BNL data, in the final stage of the scientific operation (Run-6). Now we put our efforts into finalizing the analysis and preparing to publish the result from the second and third runs (Run-2/3). This talk will walk you through the experimental overview and the overall analysis procedure we took to obtain the first result, followed by the immediate improvement in successive runs on the analysis technique and experimental apparatus.

Keywords:

Muon g-2

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H16.04

Status of JSNS^2-I & JSNS^2-II experiment

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Abstract:

The JSNS2 (J-PARC Sterile Neutrino Search at the J-PARC Spallation Neutron Source) experiment aims to search for sterile neutrinos with Δm2 near 1eV2. A 3 GeV J-PARC proton beam incident on a mercury target produces an intense neutrino beam from muon decay at rest. The JSNS2 detects the neutrino oscillation to anti-electron neutrinos via the inverse beta decay reaction. JSNS2-I has a fiducial volume of 17 tons filled with GdLS to detect anti-electron neutrinos efficiently and is expected to provide the ultimate test of the LSND anomaly by replicating nearly identical conditions with a much better S/N ratio. JSNS2-I located at 24 m baseline from the target starts the physics run in 2021 and JSNS2-II having 32 tons of fiducial volume at 48 m baseline is under construction. The second detector will improve sensitivity on low Δm2 region for sterile neutrino search. In this presentation, we will summarize the current status, preliminary analysis results, and the prospect of the JSNS2-II experiment.

Keywords:

sterile neutrino, JSNS2

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H16.05

The current status of the GBAR experiment

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Abstract:

The GBAR experiment aims to measure the antimatter's gravitational acceleration by free-fall experiment of the ultra-cold antihydrogen atom in the terrestrial gravitational field. The production of the ultra-cold anti-hydrogen is a key for the measurement of anti-atom's gravitational acceleration below 1% precision. As an important first step, the production of the antihydrogen atom has been prepared.
In here, I present the development status of the GBAR experiment during 2022 year.

Keywords:

antimatter, gravity, antihydrogen, antihydrogen ion

First Data and Status of SND@LHC

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Abstract:

SND@LHC is a compact and stand-alone experiment to perform measurements with neutrinos produced at the LHC in a hitherto unexplored pseudo-rapidity region of $7.2 < \eta < 8.6$, complementary to all the other experiments at the LHC. The experiment is located 480 m downstream of IP1 in the unused TI18 tunnel. The detector is composed of a hybrid system based on an 800 kg target mass of tungsten plates, interleaved with emulsion and electronic trackers, followed downstream by a calorimeter and a muon system. The configuration allows efficiently distinguishing between all three neutrino flavours, opening a unique opportunity to probe physics of heavy flavour production at the LHC in the region that is not accessible to ATLAS, CMS and LHCb. This region is of particular interest also for future circular colliders and for predictions of very high-energy atmospheric neutrinos. The detector concept is also well suited to searching for Feebly Interacting Particles via signatures of scattering in the detector target. The first phase aims at operating the detector throughout LHC Run 3 to collect a total of 290 fb^{-1}. The experiment was recently installed in the TI18 tunnel at CERN and has seen its first data. A new era of collider neutrino physics is just starting.

Keywords:

SND@LHC, LHC, neutrino, Feebly Interacting Particles

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

H16.07

Search for dark photons in the SND@LHC experiment.

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Abstract:

SND@LHC is a recently approved, compact and stand-alone experiment to perform measurements with neutrinos produced at the LHC in a hitherto unexplored pseudo-rapidity range of $7.2 < \eta < 8.4$ complementary to all the other experiments at the LHC, including FASER. In this presentation, we will discuss the possibility of finding dark photons in the SND@LHC experiment.

Keywords:

Dark Photon, SND@LHC

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2023-04-19 - 2023-04-21

H16.08

Status of SUB-Millicharge ExperimenT (SUBMET)

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Abstract:

SUB-Millicharge ExperimenT (SUBMET) sensitive to low-mass millicharged particles produced at the 30 GeV proton fixed-target collisions at J-PARC has been proposed. The detector is composed of long scintillators that allow the particles with a small electric charge to produce photons by ionization energy loss. With the number of protons on target of $5\text{x}10^{21}$, the experiment is sensitive to particles with electric charge below 10^{-4}e for mass less than 0.2 GeV/c^2 and 10^{-3}e for mass less than 1.6 GeV/c^2. The status of SUBMET will be discussed in this talk.

Keywords:

millicharge, J-PARC

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

H16.09

Background study for SUB-Millicharge ExperimenT (SUBMET)

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Abstract:

For SUB-Millicharge ExperimenT (SUBMET) at J-PARC, the main background sources are expected to be the PMT dark pulses and external radiation. Radiation from the structures of the building can generate pulses that are indistinguishable from the pulses due to millicharged particles (mCPs). In particular, if the radiation from the same source produces a single photon signal in the two modules that are aligned, the time difference between them can be small enough to be identified as a mCP signal. Since the condition of radiation strongly depends on the environment, we measured the rate at the detector site. In this talk, the results of this measurements will be discussed.

Keywords:

millicharge, J-PARC, Background

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

H17.01

The GEANT4-based simulation study of the utilization of proton beams at KOMAC

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Abstract:

The proton accelerator facility at KOMAC is actively used in a variety of research and has many potential applications. However, due to the large irradiation area (100 cm^2) and high beam intensity, it is difficult to utilize the proton beams for testing particle detectors which usually require evaluating the performance of single particles. In order to do that, collimators and shields can be used to reduce the size of proton beams and neutron background produced from the interaction between beams and the collimator. Additional studies with targets will be also useful to utilize scattered protons to further reduce the rate. With this setup to control the beam intensity, it is crucial to estimate the background contribution for precise experiments. We perform a Monte Carlo simulation using GEANT4 to optimize the setup for primary protons and estimate the quality of scattered protons. We use different physics lists in GEANT4 for systematic study. A comparison of experimental results at KOMAC and simulation results is also useful to validate the physics lists in GEANT4. This study will help to utilize the beam facility at KOMAC for various applications. In this presentation, we will show details on the GEANT4-based simulation study with 100 MeV proton beams.

Keywords:

KOMAC, GEANT4

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

H17.02

Status of R&D activities of ALICE-ITS3 upgrade project in Korea

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Abstract:

ALICE (A Large Ion Collider Experiment) is carrying out the replacement from the second generation of Inner Tracking System (ITS2) to the new one (ITS3) during the Long Shutdown 3 (2026-2028). The main improvements in ITS3 are to reduce the material budget to 0.05% X$_{0}$ per layer and to be positioned at only 18 mm radial distance from the interaction point. Such features can be achieved by using curved wafer-scale ultra-thin silicon sensors, so the various ITS3 prototypes with bent silicon sensors have been actively studied.
The Ko-ALICE team has been working on the ITS2 upgrade as one of the chip tests and the detector module assembly sites since 2016 and continues contributing to the ITS3 project. In particular, constructing the test system with bent silicon chips and the characteristics measurements of bent chips are the main tasks in the current project.
Based on experience and knowledge from ITS2, we are looking forward to playing a leading role in the research and development of silicon sensors. This presentation shows the current activities and plans of the Ko-ALICE team in the ITS3 upgrade.

Keywords:

LHC, ALICE, Inner Tracking System, ITS, Silicon pixel sensor, heavy ion collision

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

H17.03

Beam test result of Start Counter for LAMPS

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Abstract:

Start Counter measures the reference time of incident particles in the LAMPS. A detector that accurately measures timing is critical for LAMPS detectors to obtain synchronized data, discriminate beam particle types, and determine particle types produced after collisions. The signal from the scintillator is collected by the Multi-Pixel Photon Counter (MPPC) in the Start Counter. Recently, a prototype of the Start Counter was included in the beam test at HIMAC. During the beam test, the Start Counter collected data from 100 MeV proton beam and 200 MeV/u ^{12}C beam. We will present the performance and result from the beam test.

Keywords:

LAMPS, RAON, Start Counter, MPPC

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

H17.04

Status report of prototype Beam Drift Chamber (BDC) of the LAMPS experiment with the cosmic muons

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Abstract:

The Beam Drift Chamber (BDC) is designed to reconstruct the trajectories of ion beams irradiated to the Large Acceptance Multi-Purpose Spectrometer (LAMPS) and generated by the Rare isotope Accelerator complex for ON-line experiments (RAON). To check the performance of the BDC, prototype BDC is designed in advance and tested with the cosmic muons.
In this presentation, the performance results with several variables such as position resolution will be presented.

Keywords:

LAMPS, RAON, BDC, drift chamber, gaseous detector

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

H17.05

Performance test of prototype Beam Drift Chamber(pBDC) of the LAMPS experiment at HIMAC

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Abstract:

The LAMPS (Large Acceptance Multi-Purpose Spectrometer) is a research for nuclear symmetry energy using rare isotope beams produced by Rare Isotope Accelerator Complex for On-line experiments (RAON). Measuring the path of the beam produced by RAON is very important to know if the incident beam has reached the expected position. As this purpose, Beam Drift Chamber (BDC) is proposed to be placed before the LAMPS detector to reconstruct the beam's trajectory.

To verify the performance of BDC, the prototype BDC (pBDC) is made with similar dimensions to real type BDC and tested with several energies of proton and carbon ion beams in HIMAC facility in Japan. This presentation will present the analysis results conducted by HIMAC experiments.

Keywords:

LAMPS, RAON, BDC, Drift chamber, Detector

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

H17.06

Performance test of LAMPS ToF using proton and 12C beams at HIMAC

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Abstract:

We report beam test results on the LAMPS ToF performance using 100-MeV proton and 200 MeV/nucleon 12C beams at HIMAC. We placed two BTOF counters along the beam axis and collected proton-beam coincidence events with a start counter. We also measured scattered particles from the target exposed to a 12C beam at the LAMPS BTOF location. This talk will present preliminary beam test results on the LAMPS ToF performance and discuss the expected performance at RAON.

Keywords:

Time-of-Flight, SiPM, LAMPS, RAON, Attenuation

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

H17.07

Simulation study of scintillator detector with optical photon in GEANT4

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Abstract:

Start Counter is a scintillator-based detector designed to measure the reference time of the incident beam at the Large Acceptance Multi-Purpose Spectrometer (LAMPS). Several performance studies have evaluated the timing resolution with radioactive sources and proton beams at KOMAC. The timing resolution is related to the light yield and its fluctuation of the scintillator in the Start Counter. In addition, the light collection of the readout is also essential. A simulation framework using GEANT4 has been developed to understand the results of the performance study. In GEANT4, the generation and propagation of optical photons in the scintillator material are described by optical physics. This presentation will present a detailed simulation study of optical photons for the Start Counter.

Keywords:

LAMPS, GEANT4, Start Counter

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

H17.08

Development of Beam Aerogel Cherenkov detector for J-PARC E72

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Abstract:

We develop a Beam Aerogel Cherenkov detector (BAC) for a new Λ* resonance search experiment (E72) at J-PARC. The BAC separates kaons from pions in the momentum range of 700-800 MeV/c. It identifies the kaon beam just upstream of the target. Silica aerogel with a refractive index of 1.10 emits Cherenkov light when beam particles exceed the threshold velocity. We use a parabolic reflector for high light collection efficiency with four MPPC arrays. We tested the prototype using a 1 GeV/c positron beam at ELPH, Tohoku University. We verified that the beam test results were consistent with the optical simulation results using Geant4. Based on these results, we are upgrading the detector and planning a new beam test at J-PARC. We will report on the current R&D status and the expected performance of the experiment.

Keywords:

MPPC, Silica aerogel, Cherenkov counter

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

H18.01

Search for the rare interactions of neutrinos from distant point sources with the IceCube Neutrino Telescope

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Abstract:

The recent discovery and evidence of neutrino signals from distant sources, TXS 0506+056 and NGC 1068, provide opportunities for searching for the rare interactions neutrinos might encounter on their paths. One potential scenario of interest is the interaction between neutrinos and dark matter which is invisible but expected to be abundantly spread over the Universe. Various astrophysical observations have implied the existence of dark matter. When high-energy neutrinos from extragalactic sources interact with dark matter during their propagation, their fluxes may be suppressed at specific energy ranges after the interactions. These attenuation signatures from the interaction might be measurable on Earth with large neutrino telescopes such as the IceCube Neutrino Observatory. This analysis is focused on searching for rare interactions of high-energy neutrinos from the IceCube-identified astrophysical neutrino sources with the dark matter in sub-GeV masses and several benchmark mediator cases using the upgoing track-like events. In this contribution, sensitivity studies about the interaction of neutrinos and dark matter are presented.

Keywords:

Neutrino, Dark matter, Rare interaction, IceCube Neutrino Telescope

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

H18.02

Measurement Plans for the IceCube Upgrade Camera System

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Abstract:

The IceCube Upgrade project will expand the South Pole neutrino observatory by adding seven strings with improved designs of the well proven IceCube digital optical modules (DOMs), improving sensitivity and reducing systematic uncertainties in data collected. In order to achieve this, a novel camera system with more than 2,000 cameras has been developed and produced at the Sungkyunkwan University group. In this presentation, we will explore the important role of the camera system in driving the progress of IceCube science. Specifically, our discussion will center around our measurement plans for the integrated cameras, including separate runs to capture a series of images of "hole ice" and "bulk ice" following the deployment phase. These images will provide information about the detector medium's geometry and optical properties of the Antarctic ice, such as local scattering length and anisotropy, which are crucial for refining event reconstruction.

Keywords:

neutrinos, neutrino telescopes, IceCube, cameras, optical properties, astroparticle physics

H18.03

Enhancing Air Shower Reconstruction at the HAWC Observatory with Deep Learning

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Abstract:

This study applies Deep Learning to the problem of air shower reconstruction at the High-Altitude Water Cherenkov (HAWC) TeV gamma-ray Observatory located in Puebla, Mexico. Air showers are produced when high-energy gamma rays or cosmic rays interact with the atmosphere. HAWC observes Cherenkov light produced from air shower particles passing through the water and uses the timing information of photomultiplier tubes to reconstruct the incident angle. The aim of our study is to improve the angular resolution of HAWC by applying Deep Learning to the task of reconstructing air showers created by gamma rays. We train a Vision Transformer with simulated data and compare its performance to the current HAWC reconstruction method. The results of our study contribute to the accuracy of gamma-ray observations in the HAWC experiment.

Keywords:

HAWC Observatory, The angular resolution, Vision Transformer

Improving Gamma Ray and Cosmic Ray Classification in the HAWC Observatory using a Data-Driven Machine Learning Technique

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Abstract:

The High-Altitude Water Cherenkov (HAWC) observatory is designed to detect high-energy gamma rays using a unique array of 300 water Cherenkov detectors, each equipped with four photomultiplier tubes. HAWC observes the cascade of ionized particles and electromagnetic radiation created by air showers from gamma rays or cosmic rays by detecting the Cherenkov light generated when charged particles pass through the water tanks.
In this study, we investigate the use of data-driven deep learning techniques to improve the classification of gamma rays and cosmic rays in HAWC. We develop a machine learning technique called the "Student-Teacher method" to address the challenge of overwhelming backgrounds in our training data. In the Student-Teacher method, we apply a unique learning rate to each event, based on the outputs of a model trained on simulation. Our results show that the Student-Teacher method outperforms standard HAWC classification, enhancing HAWC's ability to distinguish gamma rays from cosmic rays.

Keywords:

Deep Learning, HAWC, Data-driven Learning, gamma ray, cosmic ray

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

H18.05

Signatures of a Higher Temperature QCD Transition in the Early Universe

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Abstract:

Beyond Standard Model physics could increase the temperature the QCD phase transition and transform it to a first order phase transition. Primordial black hole production is enhanced during first order phase transitions due to a softening of the equation of state and could result in significant abundances without a corresponding peak in the inflationary power spectrum. In contrast to the SM QCD transition, PBH produced at higher temperatures would have smaller masses and could be a dark matter candidate within the asteroid mass window or match the proposed Hyper Suprime-Cam microlensing signal. Furthermore, the curvature perturbations that generate these PBH populations can account for the claimed NANOGrav gravitational wave signal.

Keywords:

First Order Phase Transition, Primordial Black Holes, Dark Matter

Indirect dark matter search beyond the unitarity limit with VERITAS

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Abstract:

In the current cosmological paradigm, Dark Matter (DM) constitutes a large portion (about 27 %) of the mass and energy content of the Universe. One DM candidate, the Weakly Interacting Massive Particle (WIMP), can potentially have a mass in the range from 50 GeV to greater than 10 TeV. Self-annihilation and/or decay of WIMPs may produce various secondary particles, producing very-high-energy gamma rays (VHE; above 100 GeV). The signature of the WIMP signal has been searched with state-of-art observatories, but no signature has been detected. This lack of detection, together with recent theoretical developments, motivates searches for ultra-heavy DM (UHDM) above 100 TeV. In this talk, I will summarize the status of the WIMP search, focusing on the Very Energetic Radiation Imaging Telescope Array System (VERITAS) result, and explore the feasibility of detecting the annihilation signature for UHDM with current and future VHE gamma-ray observatories. Finally, I will present the result of the UHDM search with VERITAS. With 216 hours of observations of four dwarf spheroidal galaxies, we perform an unbinned likelihood analysis and find no evidence of a gamma-ray signal from UHDM annihilation.

Keywords:

dark matter, wimp, VERITAS

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H18.07

Bullet dwarfs galaxies: A potentially new probe for the cross section of dark matter particles

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Abstract:

How diffuse dwarf galaxies that are deficient in dark matter—such as NGC1052-DF2 and NGC1052-DF4—formed is a mystery. Along with their luminous member globular clusters (GCs), the so-called dark matter deficient galaxies (DMDGs) have challenged observers and theorists alike. Here we report a suite of galaxy collision simulations using the adaptive mesh refinement code ENZO with 1.25 pc resolution, which demonstrates that high-velocity galaxy collisions induce the formation of DMDGs and their star clusters (SCs) simultaneously. We resolve the dynamical structure of the produced DMDGs and the detailed formation history of their SCs, which are possible progenitors of the DMDG's member GCs. In particular, we show that a galaxy collision with a high relative velocity of ~ 300 km s^{-1}, invoking severe shock compression, spawns multiple massive SCs ($M_* > 10^6\ M_\odot$) in < 150 Myr after the collision. At the end of the ~ 800 Myr evolution in our fiducial run, the resulting DMDG of $M_* \sim 3.5 \times 10^8\ M_\odot$ hosts 10 luminous (MV < −8.5 mag), gravitationally bound SCs with a line-of- sight velocity dispersion 11.2 km s^{-1}.
Recently, van Dokkum et al. (2022) have reported the presence of 7-11 diffuse objects located along the line connecting NGC1052-DF2 and NGC1052-DF4, suggesting that the subsets of these objects containing those galaxies may have originated from a single collision of dwarf galaxies. If the suggested scenario is confirmed, it has the potential to provide a new constraint on the nature of dark matter on a smaller scale than bullet clusters.

Keywords:

dark matter, dark matter-deficient galaxies, cross section of dark matter particles

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

H18.08

Head-on Collison of Fuzzy/Cold Dark Matter

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Abstract:

We numerically consider the head-on collision of two Fuzzy Dark Matter (FDM) halos, whose particle mass is very light of order ~1 e-22eV/c^2 with a de Brogile wavelength of one kpc scale. This FDM model may resolve some of the small-scale issues of the CDM model. We also consider the head-on collision of two CDM halos and directly compare the results with that of the FDM model. Through this, we suggest those the FDM mode may resolve the problem of the CDM model. There are some observations showing collisions of two clusters. Our result may explain possible halo distributions after the collisions.

Keywords:

FDM, CDM, head-on collision

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

H19.01

Measurements of the ^{235}U and ^{239}Pu IBD Yields and Spectra by NEOS-II

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Abstract:

The NEOS searches for sterile neutrinos by detecting reactor antineutrinos in Korea at a very short baseline. The NEOS detectors (1-ton Gd-LS) were deployed at the tendon gallery of the Hanbit reactor unit 5 (2.8 GW thermal power), 24 m away from the reactor core. In NEOS-I, the prompt energy spectrum from inverse-beta-decay was measured using 180 live-days of reactor-on data, which clearly showed the "5 MeV excess." To understand the "reactor antineutrino anomaly" and the origin of the "5 MeV excess," NEOS-II has recorded 388 (112) live-days of reactor-on(-off) data from September 2018 to October 2020, covering a whole burnup cycle of the reactor.

In this talk, we report the measurements of individual IBD yields and spectra from ^{235}U and ^{239}Pu fission, with improved detection efficiencies and uncertainties.

Keywords:

Reactor antineutrino experiment, Reactor antineutrino anomaly, Fission evolution, Neutrino Physics

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

H19.02

NEOS-II sensitivity for a sterile neutrino

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Abstract:

NEOS is an experiment to search for a sterile neutrino from a reactor core at a short baseline. Electron antineutrinos from the reactor are measured by a 1,000-liter volume of gadolinium-doped liquid scintillator detector. The detector was deployed at a 24-m distance from a 2.8 gigawatt-thermal-power reactor core in the tendon gallery of the Hanbit-5 reactor. NEOS-II has recorded 388 (112) live-days of reactor-on (-off) data, including an entire reactor operation cycle and the reactor maintenance periods before and after the operation cycle. The sensitivity of finding the neutrino mass-squared-split and the mixing angle for the active-to-sterile neutrino oscillation using rate and shape analysis has been studied, considering the statistical and systematic uncertainties of NEOS-II.

Keywords:

Sensitivity, NEOS, Sterile neutrino, Neutrino oscillation, Neutrino

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

H19.03

Status of NEON Experiment

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Abstract:

Coherent elastic neutrino-nucleus scattering (CEνNS), predicted by D. Z. Freedman in 1974, was first observed in 2017 by the COHERENT collaboration, using neutrinos from stopped pion source. However, CEνNS of neutrinos from reactor, which have relatively low energies, is still not successfully observed. The NEON collaboration was launched with the goal of CEνNS observations using reactor neutrinos, following the success of the development of a new high-light-yield NaI(Tl) detector. In 2022, the detector was installed at the tendon gallery of unit 5 in the Hanbit nuclear power plant, Yeonggwang, and after two detector upgrades, stable data acquisition began in April 2022. In this talk, we will present the overall status of the NEON experiment, including detector design and operation, analysis progress, and detector sensitivity.

Keywords:

CEνNS, Reactor Neutrino, NaI(Tl)

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

H19.04

Development of low-energy event selection method for NaI(Tl) crystal detectors using waveform simulation

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Abstract:

NaI(Tl) crystals are commonly used as scintillation detectors for various types of radiation, including rare event searches such as dark matter and neutrino detection. The COSINE and NEON experiments are two such experiments that use NaI(Tl) crystals as detectors. To detect rare events, it is necessary to achieve a low energy threshold. However, due to the large number of noise events induced by photomultipliers, a multivariate event selection technique using a boosted decision tree (BDT) was developed to discriminate scintillation events from PMT-induced noise events. For training of the signal-like scintillation events, the waveform simulation was developed and tuned using measured single photoelectron shape, NaI(Tl) scintillation decay time, and pedestal fluctuation. The simulated waveform was subjected to the same trigger conditions and digitization as the NaI detector physics data, and was stored in the same format. In this presentation, I will discuss the development of the waveform simulation of the NaI(Tl) crystal detectors and the progress of the event selection using the BDT with the simulated waveform of the scintillation events.

Keywords:

COSINE, NEON, NaI(Tl) crystal, waveform simulation, BDT

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

H19.05

Time variation analysis of the solar ^8B neutrino flux at Super-KamiokaNDE

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Abstract:

Super-Kamiokande (SK), a 50 kton water Cherenkov detector in Japan, is observing 8B solar neutrinos in order to measure the effects of neutrino oscillations and provide a deeper understanding of the solar model. From 1996 to 2018 there were four separate periods, SK-I/II/III/IV. Using ~20 years of SK data. This presentation focuses on the variation of the solar neutrino flux in three parts. The first part is the seasonal flux variation which is due to Kepler orbit between the Sun and the Earth. Secondly, the oscillation parameters are measured from the the flux during the day and night. Thirdly, a frequency analysis of the solar neutrino flux in 5days and 10days interval is presented with a Lomb-Scargle periodogram and a sinusoidal likelihood analysis.

Keywords:

superkamiokande, time variation of solar neutrino flux, neutrino, water Cherenkov

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

H19.06

Design study of a next-generation gigantic water Cherenkov detector for proton decay search

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Abstract:

Proton decay is a hypothetical process that, if observed, would have far-reaching implications for our understanding of the fundamental laws of physics. The water Cherenkov detector is one of the most powerful instruments for searching proton decay. In this study, we investigated the sensitivity of the proton decay via $p \rightarrow e^+ + \pi^0$. In this talk, we will report details of the simulation results and detector design.

Keywords:

Water Cherenkov Detector, Proton Decay

Evaluating the Performance of the Large Area Picosecond Photodetector

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Abstract:

The Large Area Picosecond Photodetector (LAPPD) is a photon detector that employs microchannel plates to achieve high gain and time resolution on the order of picoseconds, making it a promising tool for time-sensitive measurements in particle physics. Its planar shape and pixel configuration enable a large area coverage while providing high spatial resolution compared to other types of photon detectors. In this study, we evaluated the performance of an 8x8 pixel sample of the LAPPD by measuring its dark count rate, gain per pixel, and ability to detect water Cherenkov radiation. Our results demonstrate that the LAPPD has a dark count rate of approximately 200 Hz per pixel and a gain of around 10^7. Moreover, the LAPPD effectively detected the water Cherenkov signals produced by cosmic muons, indicating its potential use in neutrino experiments.

Keywords:

LAPPD, neutrino

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

I1.01

Engineered light-matter interactions in solid-state quantum systems

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Abstract:

Future quantum information processing would rely on the capacities that generate, manipulate, and readout quantum states in an integrated platform, and therefore, all quantum operations are efficiently possible in a practical photonic platform. Solid-state quantum emitters have attracted much attention as an integrated source of photonic and spin qubits, which are key components for a range of quantum applications. Beyond improving their performance, recent studies on coupling these two-level atoms with optical cavities or waveguides offer a new possibility for achieving efficient linear and nonlinear quantum interactions. Such implementations of cavity(waveguide) quantum electrodynamics bring fascinating quantum functionalities of spin-photon interfaces, deterministic quantum gates, and collective behaviors that entangle multiple emitters or multiple photons. In this seminar, I present recent races for integrated quantum photonics with multiple quantum emitters, waveguides, beamsplitters, and detectors on the same chip.

Keywords:

quantum dots, cavity QED, quantum photonic integrated system

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

I1.02

Cavity optomechanical systems for quantum transduction

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Abstract:

Optomechanical interaction induced by radiation pressure constitutes a coherent coupling between electromagnetic field and mechanical oscillator. As this coupling strength exceeds dissipation rates, quantum transduction between the two physical domains, namely photon-phonon conversion, becomes possible. The photon-phonon conversion has been implemented successfully for both microwave and optical field, and it created a new route to transduce microwave and optical photons coherently by harnessing phonons. Such microwave-to-optical quantum transducers are envisioned to provide optical interfaces for building quantum networks composed of nodes that require microwave photons for access. This talk describes our works on developing the superconducting microwave circuits suitable to the microwave-to-optical quantum transducer applications. To circumvent the issue of heating from optical lights, we employ niobium devices with superconducting transition temperature significantly higher than the conventional aluminum devices. The device manifests optomechanical effects from microwave photons up to 4 Kelvin in temperature and 0.9 Tesla in magnetic field[1], and it demonstrates a novel nonlinear optomechanical effects resulting in microwave frequency combs in a strong drive regime[2]. Our results illustrate important advances in the microwave optomechanical devices that could lead to the microwave-to-optical transducers with sufficient efficiency for quantum networks.
[1] J. Cha *et.al.*, *Nano Lett.* **21**, 1800 (2021).
[2] J. Shin *et.al.*, *Nano Lett.* **22**, 5459 (2022).

Keywords:

quantum transducer, superconducting quantum circuit, cavity optomechanical system

I1.03

Translation from a distinguishable to indistinguishable two-photon state

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Abstract:

Quantum interference lies at the heart of quantum information processing, and a key element to demonstrate quantum interference is the indistinguishability between quantum states. Experimental imperfections, including optical misalignments [1], fabrication errors, temporal variations of quantum light sources [2-4], and polarization rotation, readily induce distinguishability between quantum states, and reducing the distinguishability is a great challenge to push the limit of classical information processing. We demonstrate the ability to erase the frequency distinguishability via Bragg-scattering four-wave mixing (BS-FWM). We prepare a distinguishable two-photon state by creating non-degenerate photon pairs and translate the state to an indistinguishable state by shifting the frequency of the idler photons. We measure the indistinguishability of the two-photon state via a Hong-Ou-Mandel interferometer. The ability to erase the frequency distinguishability via BS-FWM will pave the way toward large-scale quantum information processing such as scalable linear quantum computation and long-distance quantum communication.

[1] B. Kambs and C. Becher, New Journal of Physics 20, 115003 (2018).
[2] M. Borghi and L. Pavesi, Optics Express 30, 12964 (2022).
[3] J. H. Rice, J. W. Robinson, A. Jarjour, R. A. Taylor, R. A. Oliver, G. A. D. Briggs, M. J. Kappers, and C. J. Humphreys, Applied physics letters 84, 4110 (2004).
[4] M. Santandrea, M. Stefszky, V. Ansari, and C. Silberhorn, New Journal of Physics 21, 033038 (2019).

Keywords:

quantum frequency translation, quantum frequency conversion, Bragg-scattering four-wave mixing

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

I1.04

Recovering quantum entanglement after its certification

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Abstract:

Entanglement, which is at the heart of quantum physics, is a major source in quantum applications, such as quantum teleportation, quantum metrology, and quantum computation. To use entanglement for actual quantum technologies, entanglement certification should precede the application. However, the certification test itself destroys the original entanglement because it generally involves projective measurement in the process of gaining information for the certification.
Here we propose and demonstrate a solution to avoid the complete destruction of entanglement during the certification test by introducing weak measurements. Weak measurement prevents the complete destruction of the entanglement in the quantum state while extracting the sufficient information needed for entanglement certification. We have generalized widely-used entanglement certification tests in entangled photonic qubits by taking into account a non-unity measurement strength. After the certification, we implement the reverse measurement for the disturbed state to restore its original entanglement. Through this reversal process, we can provide the fully recovered entangled state for further quantum technological applications.
We implement three different entanglement certification tests which can be classified into three different categories depending on the trust on the measurement devices; entanglement witness, steering, and Bell nonlocality. For witness (W), we can always detect entanglement with non-vanishing measurement strength ($p_{a(b)}$: Alice's (Bob's) measurement strength) since we have the full knowledge of the weak measurement on both sides. For quantum steering (S_3), only one side of the measurement device is known; therefore, it requires a measurement strength above a certain amount, ($p_{a(b)} > 1/\sqrt{3}$). Lastly, the Bell nonlocality test (S), with no trust on both measurement devices, has the most stringent bound for measurement strength for certification; $p_{a,b} > 1/\sqrt{2}$.
To recover the entanglement disturbed during the certification, we implement the reverse measurement on the quantum state after the certification. Using the tomographic result, we calculate the fidelity and the concurrence of the resulting state with its original form. The entanglement has nearly been restored to its original amount since the result of the fidelity and concurrence is close to unity. Also, we check that the recovery of the entanglement happens probabilistically by the information trade-off theory.
In summary, our study makes the certification test compatible with quantum technologies requiring entanglement by introducing weak measurement. To recover the entanglement disturbed during the certification, we implement the reverse measurement. It is possible to apply the recovered entanglement as a source for further quantum applications.

Keywords:

entanglement, entanglement certification, weak measurement, reversal measurement

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

I1.05

Continuous-variable nonclassicality detection under coarse-grained measurement

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Abstract:

Coarse graining is a common imperfection of realistic quantum measurement, obstructing the direct observation of quantum features. Under highly coarse-grained measurement, we experimentally certify the continuous-variable nonclassicality of both Gaussian and non-Gaussian states. Remarkably, we find that this coarse-grained measurement outperforms the conventional fine-grained measurement for nonclassicality certification: it detects nonclassicality beyond the reach of the variance criterion, and furthermore, it exhibits stronger statistical significance than the high-order moments method. Our work shows the usefulness of coarse-grained measurement by providing a reliable and efficient way of nonclassicality certification for quantum technologies.

Keywords:

nonclassicality, quantum information

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

I2.01

In-Vivo Firing Activities in A Spiking Neural Network of The Basal Ganglia

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Abstract:

The basal ganglia (BG) are group of subcortical nuclei located at the base of the forebrain. The BG exhibit a variety of functions for motor and cognition. We construct a spiking neural network (SNN) for the BG, composed of the striatum (main input nucleus), substantia nigra pars reticulata (SNr: output nucleus), and the intermediate control nuclei [globus pallidus (GP) and subthalamic nucleus (STN)]. Also, spiny projection neurons (SPNs) with D1 and D2 dopamine (DA) receptors constitute a major population of primary inhibitory striatal neurons. We note that DA modulates the BG functions. Here, we consider the effect of DA on the excitability of the D1/D2 SPNs and the synaptic currents. Each single neuron is modeled in terms of the Izhikevich neuron model. We also consider the excitatory and the inhibitory synaptic currents and the random noise input into each BG cell. In our SNN of the BG, we study in-vivo firing activities of the BG cells. In each BG cell, we choose the synaptic parameters (synaptic connection parameters, maximum conductance, synaptic decay and delay time) and the noise intensity to match its physiological firing data. Consequently, BG cells in our SNN exhibit firing activities which are nearly the same as in-vivo (awake resting) physiological data.

Keywords:

Basal ganglia, In-vivo firing activity

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

I2.02

Effective rate law for biological feedback control

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Abstract:

In describing the biochemical rate processes, the Michaelis-Menten (MM) rate law has been the dominant paradigm over a century. Despite the wide usage and applications, MM rate law is valid under the assumption that the concentration of the complex of interacting molecules, at each moment, approaches an equilibrium much faster than the molecular concentrations change. Here, we propose the generalized MM rate law that can be applied where the assumption is not justified. Our approach for dynamic
molecular concentrations, termed the effective time-delay scheme (ETS), is based on rigorously estimated time-delay effects in molecular complex formation. The ETS provides an analytical framework to interpret and analyze transient dynamics such as autogenously regulated cellular adaptation, which goes beyond the quasi-steady state assumption.

Keywords:

chemical reaction dynamics, Michaelis-Menten, quasi-steady-state, autogenous regulation, MM

I2.03

Bacteria run faster and tumble more at higher temperatures

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Abstract:

Run-and-tumble is one of the well know locomotion pattern of motile bacteria, describing the two-alternating swimming phases: run phase for straight swimming and tumble phase for switching swimming direction. Assuming random diffusion, Langevin equation-based models can describe this motion with multiple model parameters. With the help of computer vision-aided tracking, we collect over 271,000 trajectories of *Bacillus subtilis* swimming under quasi-2D confinement and infer the model parameter of the run-and-tumble models according to the temperature ranging between 5 and 60 degrees Celsius. The models describe well the experimental trajectories, regardless of the temperature, except high temperature ranges where *B. subtilis* lose their motility. The run speed increases approximately two times at 40 degrees Celsius compared to the one at room temperature, the tumbling rate increase three times, but the tumbling time decreases four times. The authors acknowledge the support from the Korean National Research Foundation through NRF-2020R1A4A1019140.

Keywords:

run and tumble, bacterial swimming

2023 KPS Spring Meeting
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I2.04

Energy transfer dynamics of photosynthesis

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Abstract:

Photosynthesis is the origin of the earth's energy system, where sunlight is converted to chemical energy. Photosystem II is a protein complex of chlorophylls that harvests sunlight during the photosynthesis of green plants. The energy transfer structure between the chlorophylls can be projected as a network based on their energy transfer rate. On the network, we try to understand the transfer dynamics of the excited energy to the reaction center for absorption as an absorbing Markov process. With numerical simulation, we track the energy flow during photosynthesis. We identify distinct energy transfer pathways and quantify the individual efficiency of chlorophylls. Our approach enhances the current understanding of energy dynamics in photosynthetic networks and also be applicable to other absorbing Markov processes.

Keywords:

Markov process, Biological network, flow dynamics

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

I2.05

On the central bead of gaussian semiflexible polymers

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Abstract:

We present a comprehensive study of the motion of the central bead in a polymer chain. We consider both discrete Rouse polymer and gaussian semiflexible polymer models and derive the generalized Langevin equation (GLE) satisfied by the central bead. Our approach involves integrating out all other degrees of freedom in the system and results in an effective description of the motion of the central bead. The derived GLE captures the essential physics of the polymer system and reduces the system to a particle in a viscoelastic medium. By analyzing the memory kernel behavior, it enables us to investigate the dynamical properties of the polymers on different time and length scales.

Keywords:

Semiflexible polymer, Rouse polymer, Generalized Langevin equation, Memory kernel

I2.06

Transient confinement and recovery dynamics in viscoelastic systems

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Abstract:

Biophysical systems, such as bio-filament networks, chromatins, and lipid membranes, often suffer subdiffusive internal dynamics with an anomalous exponent of $0<\alpha<1$ because of the viscoelastic nature of the system. Apart from this, such viscoelastic dynamics are often hampered by a transient confinement (e.g., chromatin interacting with a liquid-liquid phase separation). After the transient confinement, a recovery dynamics is followed to reach the long-time dynamics. While these confinement-recovery phenomena are commonly observed in many soft matter or biological systems, an appropriate theory has not been established yet. Here, we theoretically investigate this problem using a generalized Langevin equation (GLE). From the asymptotic solution of the GLE, we show that the transient confinement is followed by a recovery dynamics of $\alpha=1$, which eventually catches up with the ordinary sub-diffusion of exponent α. In addition, we show that the viscoelastic nature ironically recovers the generalized diffusivity at a long time limit, which is impossible in simple viscous media. We also provide the simulation results which show an excellent agreement with the theory.

Keywords:

Generalized Langevin equation, Viscoelastic, LLPS, Anomalous diffusion

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

I2.07

Active diffusion of self-propelled particles in flexible or semi-flexible polymer networks

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Abstract:

Understanding the active diffusion of self-propelled particles in polymer networks is a challenging problem. The active self-propelled particles consume energy and drive the system away from the equilibrium, violating the fluctuation-dissipation theorem. In these non-equilibrium systems, the viscoelastic feedback of polymer networks drastically changes the diffusion dynamics of active particles therein. Here, we construct a computational model of three-dimensional flexible and semi-flexible polymer networks with cubic topology and perform Langevin dynamics simulations for the active particles. When the active particle size is smaller than the mesh size, it freely diffuses with decreased mobility depending on the polymer-occupation density and Péclet number. However, as the particle size approaches the mesh size, the active particles explore the polymer network through a trapping-and-hopping mechanism. By analyzing the mean square displacement, trapped time, flight length, and long-time diffusivity, we investigate the effects of mesh-to-particle size, Péclet number of active particles, and bending stiffness of polymer networks. Our understanding of active viscoelastic diffusion offers insight into various biological processes with the interplay between biopolymer networks and active particles, e.g. motor-driven cargo transport or drug delivery via active particles in a biological gel.

Keywords:

active matter, polymer network, active particle, Langevin dynamics, diffusion dynamics

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

I3.01

Ejection of quantum dot solution through nanoscale aperture by using an atomic force microscope-combined nanopipette

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Abstract:

3D printing technology supplies powerful solution for various scientific or industrial fields [1-3]. However, there is a limitation of liquid ejection through nanoscale aperture in the condition of ambient. This is possible when the surface tension acting on the inner wall of the nozzle tip can be overcome in order for the liquid to be ejected to the outside when the nanonozzle contains liquid. It is difficult to eject under any pressure. In this study, I introduce a system that can bring the tip of the tip very close to the surface by about several nm to overcome this issue. This was implemented by attaching a nanonozzle (aperture size of about 500 nm) in which a quantum dot solution was injected to one leg of a quartz tuning fork-atomic force microscope (QTF-AFM), and using a private force measurement of an AFM. Through this, liquid was ejected on the surface, and quantum dot nanowires could be manufactured while retracting very slowly after ejection [4].

[1] H. Yang et al., Nature Photonics, 6, 615–620 (2012).
[2] D. Zhao, et al., Scientific Reports, 6, 18860 (2016).
[3] See, e.g., M. Ortsiefer et al., Jpn. J. Appl. Phys. 39, 1727 (2000).
[4] An, et al., Nanoscale Adv., 5, 1070-1078 (2023).

Keywords:

quantum dot, atomic force microscope, nanopipette, nanoscale 3D printing

2023 KPS Spring Meeting
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I3.02

Dark Excitons from WSe_2 Monolayer on the Au Micro-pillar Structures

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Abstract:

WSe_2 monolayer is a direct bandgap semiconductor whose optical properties are dominated by the presence of bound electron-hole pairs, namely excitons. WSe_2, a member of the larger class of semiconducting transition metal dichalcogenides (TMDs), has an attractive property: its monolayer has an optically dark exciton. Dark excitons have much longer radiative lifetimes than bright excitons. Therefore, these dark excitons are appealing candidates for quantum computing and optoelectronics.

However, the process of generating dark excitons in WSe_2, which is currently being studied, is complicated. Most experiments are performed at cryogenic temperatures and use difficult methods, such as applying magnetic fields. Here, we report a method for generating dark excitons in WSe_2 through micro-pillar structures very easily, without the complexity of other physical or chemical methods. We show a ~40 meV intravalley energy splitting between the dark and bright exciton. We also show that significantly enhanced PL intensity was observed in WSe_2 on Au micro-pillars as compared to that on SiO_2 plate and on Au plate, respectively. WSe_2 has a PL lifetime of 146 ps on Al_2O_3 and 270 ps on Au MPs, respectively. These values indicate that the dark exciton is observable when there is strong crystalline strain and gold surface plasmon interaction. Note that the monolayer WSe_2 intrinsic radiative decay time is only a few ps.

Through our research, the dark excitons, which play an important role in optically controlled information processing, can be generated from the WSe_2 monolayer in a simple way, bringing us one step closer to the commercialization of dark excitons.

Keywords:

Dark Excitons, WSe2, Micro-pillar Structure, semiconductor, transition metal dichalcogenides

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I3.03

ZnO TFTs property with photoelectric synaptic devices

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Abstract:

We report the fabrication of ZnO thin-film transistors (TFTs) as neuromorphic devices with photo-sensing properties that can be used in advanced high-energy efficiency applications. Synaptic devices that mimic the operation of the biological nervous system, such as synapses in the human brain, are gaining intensive attention as a new type of power-efficiency next-generation device. Mainly, a single synaptic transistor can perform control and signal propagation separately from its 3-terminals configuration. This feature allows us to achieve reduced integration complexity and enhanced power efficiency. However, most research focused on electrically driven operations. The strong photocurrent response of the ZnO can allow us to achieve optically driven synaptic transistors, where excitation or depression of the device can be performed by the light pulses. Moreover, a combination of electrical and optical stimulation will lead to a continuous, reversible, highly-linear synaptic response. Here, we report the fabrication of ZnO TFTs and their application to photoelectric synaptic transistors.
In this device, ZnO thin films were deposited using radio-frequency magnetron sputtering and utilized as a channel layer of the TFT. The structural characteristics and the surface properties of the deposited ZnO channel layer, as a function of deposition temperature, were investigated by synchrotron-radiated X-ray diffraction and reflectivity. The basic output and transfer characteristics and the photocurrent properties of the fabricated TFT were investigated as well. More importantly, our devices exhibited good synaptic properties when the electrical pulse was used, and improved synaptic response was observed when UV illumination was added. Further tailoring electrical and optical synaptic response by pulse engineering will allow us to achieve synaptic transistors with highly linear or customizable activation functions that can lead to high-performance, next-generation electronic synaptic devices.

Keywords:

ZnO TFTs, Neuromorphic device, Photoelectric, Synaptic transistor

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I3.04

Photovoltaic effect in a single channel WSe_2 pn diode formed by contact engineering

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Abstract:

Two-dimensional transition metal dichalcogenides (TMDCs) are notable materials owing to their flexibility, transparency, and appropriate bandgaps. Because of their unique advantages, electronic and optoelectronic devices based on TMDC p-n diodes have been widely studied for the next generation. However, improving their performance is a challenge for commercialization. In this research, we propose a simple contact engineering of a few-layer tungsten diselenide WSe_2 *without doping or a complicated fabrication process. By combining surface and edge contacts, the photovoltaic effect is observed with a high fill factor of ~0.64, power conversion efficiency up to ~4.5%, and the highest external quantum efficiency value of ~67.6%. In addition, the photoresponsivity value reached to 283 mA/W exhibited an excellent phototransistor performance. These results demonstrate that our technique has great potential application for the next generation of optoelectronic devices.*

Keywords:

WSe2, edge contact, photovoltaic, WSe2 diode, lateral p-n homojunction

I3.05

헬륨 이온조사에 의한 면방향 대칭성이 깨진 페리자성체의 스핀오빗토크 스위칭 연구

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Abstract:

강자성체/비강자성체 2중층 구조는 차ㅇ세대 MRAM 메모리에서 중요한 단위 구조이다. 비강자성체에서 발생된 스핀 전류는 강자성체에 주입되어 스핀 각 운동량을 전달한다. 이러한 현상을 spin orbit torque (SOT)라고 한다. SOT에 의한 수직 자화를 제어하기위해서는 외부 자기장을 인가하여 자화 반전 방향이 결정되는 deterministic 자화반전이 되어야한다. 이는 외부 자기장 발생으로 인한 확장성 및 에너지 효율의 한계를 가져오기 때문에 외부자기장이 없이 결정적 스위칭이 일어나게하는 연구에 관심이 모아지고 있다.
이 연구에서는 He 이온 조사를 통해 측면 대칭이 파괴되는 GdCo 페리자석의 무자장 자화 반전을 시연한다. He ion dose량을 조절함으로써 GdCo의 페리자성 특성(보자력 및 자화 보상 온도 등)이 효과적으로 조절됨을 관찰한다. Dose량을 조절하면서 He 이온을 조사하면서 면방향 대칭성을 깨뜨린 GdCo의 수직방향 SOT 인가 유효 자기장 형성 및 무자장 반전을 증명한다. .

Keywords:

He ion irradiation , Deterministic switching, spin Orbit torque

I3.06

Large polaron 전도 전이를 통한 $NiWO_4$ 산화물의 홀 전도물성 개선 연구

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Abstract:

일반적인 전이금속 산화물 (Transition Metal Oxide, TMO)은 자유전자에 비해 상대적으로 deep-lying level에 존재하는 hole carrier에 의해 conduction mechanism이 small polaron hopping model에 의해 기술되고 이로 인한 이동도의 한계가 존재한다. 본 연구에서는 Cu 불순물이 치환된 $NiWO_4$ 합성 및 물성 분석을 통하여, 그러한 전도 물성의 한계를 극복할 수 있는 TMO 소재 설계 가능성을 고찰한다. 고상 합성법을 통하여 Cu-substituted $NiWO_4$ ($Ni_{1-x}Cu_xWO_4$, $0.00 \le x \le 0.25$) 샘플을 합성하여, 이의 X-ray diffraction (XRD) 및 Rietveld 정밀화 분석을 통해 단일상 형성 여부와 조성 및 치환 site에 대한 분석을 수행하였다. 또한 Inductively coupled plasma-mass spectroscopy (ICP-MS)를 통한 조성분석 결과와의 비교 검증을 통해 최종적으로 Ni-site에 Cu가 치환된 $Ni_{1-x}Cu_xWO_4$의 합성 여부를 검증하였다. Hall measurement와 Impedance spectroscopy를 통해 샘플의 전기적 특성을 분석하였고 상온에서 비저항이 Cu 함량에 따라 3.69×10^{12}에서 최대 3.28×10^{3} Ω・cm 까지 감소한 것을 확인했다. 이동도의 온도의존성 분석을 통해 최적 치환 조성 소재에서 large polaronic conduction mechanism을 보이는 것을 확인하였고, 이를 통해 최고 6.98 $cm^2V^{-1}s^{-1}$의 hole 이동도 물성 증대 현상을 확인하였다. Raman spectroscopy, Ultraviolet photoemission spectroscopy (UPS), Ellipsometry spectroscopy를 통해 각각 샘플의 진동모드, 일함수, 밴드갭을 분석하였고 Vibrating sample magnetometer (VSM)을 통해 합성한 샘플의 자기적 특성을 확인하였다. 또한, DFT 계산을 통해 자성체 물성의 ground state가 반강자성임을 확인했고 실험값과의 비교를 통해 Cu함량에 따른 전자간 상호 작용력 및 전도 물성 간의 상관관계를 분석하였다.

Keywords:

polaron, high hole mobility, electron correlation

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I3.07

Electrolyte-based electroluminescences (EL) from various kinds of wide-band-gap oxide films doped with rare earths and transition metals

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Abstract:

The electrolyte-based electroluminescences (EL) from various kinds of wide-band-gap oxide films doped with rare earths and transition metals on a condutive silicon wafer are reviewed, where the oxide materials have never been reported as an electroluminescent material, even though they shows the efficient photolminescent performance as a a perfect insulator; Eu^{3+}-doped Y_2O_3 (red), Eu^{2+}-doped $(Sr, Ba)_2SiO_4$ (yellow), Ce^{3+}-doped $Y_3Al_5O_{12}$ (yellow), Pr^{3+}-doped YPO_4 (UV). They were deposited on the silicon substrtate through a facile all-solution process, and then they were post-annealed at higer temperature, and finally the ELs were demonstrated under AC and DC voltages between the platinium electrode dipped into the electrolyte as a top electrode and the bottom aluminium electrode onto the silicon rear side. Compared with a conventional AC-driven thin-film EL device with metal or ITO-based top electrrode, these electrolyte-based ELs showed some different chemical and electrical characteristics. They worked at not only AC but also DC voltages. In addition, the surface of active layer contacting the electrolyte was serverly etched, and thus its EL was dominantly quenched, as the operating time goes,

Keywords:

electrolyte-based electroluminescences (EL), oxide film, thin-film

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I3.08

Enhanced ultraviolet electroluminescene from modification of Ce^{3+}-doped $CaSiO_3$ film

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Abstract:

The enhancemet strategy of AC-driven ultraviolet (UV) film electroluminescene (EL) from the modification of Ce^{3+}-doped $CaSiO_3$ ative layer monolithicaly grown on silicon wafer is presented. First, the combinations of alkaline earth ions (Mg^{2+}, Ca^{2+}, Sr^{2+}, Ba^{2+}) were surveyed in order to form deep traps as an isoelectronic defect so as to generate more tunnelinng electrons as an excitation source. Secondly,the codoping of an energy donor (or, sensitiser) like Pr^{3+} and Gd^{3+} ions were demonstrated in order to cause the increase in the impact-excitable number and the energy transfer rate from the codoped donor. Thirdly, the annealing conditions (temperature, time, flux) were optimized in order to conntrol the intrinsic defects as well as the grain boundary acting as a elecron crowding neck causing a low-voltage breakdown. Finally, the voltage and frequency dependencies of UV EL spectrum were investigated; above a threshold voltage of about 20 Vrms and below a breakdown voltage of 40 Vrms, the UV (430-330 nm) light with a peak of 360 nm and a half width of 100 nm due to 5d-4f transitions from Ce^{3+} ion into $CaSiO_3$ acive layer. Furthermore, its thermal stability and short-term reliability were examined for practical application.

Keywords:

film electroluminescene(EL), Ce3+-doped CaSiO3 , ultraviolet(UV), 5d-4f transition

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I4.01

Controlling lasing emissions from halide perovskite thin film devices

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Abstract:

Halide perovskite semiconductors have demonstrated the potential to be a next generation emerging material in the field of solid-state lighting and display applications. Especially, perovskites exhibited outstanding optical gain properties with wide spectral coverage including the visible and near infrared regions by controlling the composition of halides. As a result, there have been numerous lasing demonstrations under pulsed optical excitation regime by using various optical feedback structures such as distributed feedback grating, photonics crystals, distributed Bragg reflectors, whispering gallery modes, etc. In order to be utilized in many applications, it is important to demonstrate coherent lasing emission under electrical excitation which exhibit better conversion efficiency and compact in volume. Thus, many researchers have been trying to operate the perovskite based light-emitting diodes under extreme driving conditions in terms of injectable current density without breakdown of the devices. However, most of the reports in the literature focus only on the demonstration of onset of lasing emission near the threshold, lacking controllability of lasing performance and effect of thermal degradation.

In this talk, I will present the successful controllability of lasing emissions from halide perovskite distributed feedback (DFB) lasers. Perovskite-based laser devices require thick-enough gain layer thickness to support lasing mode, which is typically in the order of 100 nm. In order to support higher TE and TM modes, then the thickness has to be more than 300 nm which require lots of excitation power (or higher lasing threshold). However, by having thick encapsulation layer on top of the perovskite film, it is possible to support higher order TE/TM lasing modes without increasing lasing thresholds. Also, the effective refractive index difference between the modes are closely spaced, so that single grating periodicity can support multiple lasing emissions with different polarization. Thus, control of lasing emissions by using a dielectric layer have been realized. These experimental demonstrations have been confirmed by multilayer slab waveguide simulations. In addition, the lasing properties have been characterized under various excitation intensities exceeding more than 20 times of threshold intensity. As a result, we were able to observe the thermal degradation caused by intense optical pulse and define the damage threshold of the perovskite films.

Keywords:

perovskite, lasers, distributed feedback (DFB), amplified spontaneous emission, polarization

Unveiling the Diffusive Properties and Photocarrier Dynamics of Bi_2O_2Se

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Abstract:

An emerging 2D semiconductor, Bismuth oxyselenide (Bi_2O_2Se) has attracted significant attention in recent years due to the unique electronic, optical, and topological properties. To study the dynamics of charge carrier in Bi_2O_2Se, we use a femtosecond transient absorption spectroscopy (TAS), which is a powerful technique by measuring the changes in the absorption spectrum of Bi_2O_2Se when excited with a short laser pulse. Thus, we observe the ultrafast carrier thermalization and relaxation processes, and obtain a photocarrier lifetime of about 100 ps. Furthermore, by spatially resolved TAS measurement, the photocarrier diffusion coefficient, length and mobility which are key parameters that determine the efficiency of optoelectronics can be investigated. Understanding the carrier transport in Bi_2O_2Se can lead to the development of more efficient energy conversion devices, high-speed electronics, and potential applications.

Keywords:

Bismuth oxyselenide, Transient absorption spectroscopy, Carrier dynamics, Carrier diffusion

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I4.04

Indirect bandgap semiconductor laser operating at room-temperature under continuous-wave excitation of WS2 multilayer cavity

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Abstract:

2D transition metal dichalcogenides (TMD) layers have been in spotlight as promising materials for nanophotonic and valleytronic devices because of direct bandgap characteristics and strong exciton-photon interaction. However, it has not been widely considered that TMD multilayer have high refractive indices at a wide spectral region. Meanwhile, micro-sized lasers are required for on-chip photonic applications such as optical communication, optical computing, and optical sensing. So far, it was theoretically confirmed that lasing action based on an indirect bandgap is possible. In experiment, however, such lasing action has not been observed experimentally yet. Here, we observed lasing action at indirect bandgap transition in multilayered TMD. We made a 50nm-thick WS_2 disk structure which is for whispering gallery mode (WGM) lasing action in indirect transition range (700~ 900 nm wavelength). Then we pumped the WS_2 disk using a 594 nm continuous-wave (CW) laser and measured the light-in light-out curves (L-L curves) of WGM peaks. It showed a clear transition from spontaneous emission (SE), amplified spontaneous emission (ASE) region, to lasing regime at room temperature. We confirmed that indirect bandgap lasing leads to nonlinear increases of photon and phonon densities. We also checked the linewidth of WGM peak reduced by more than half as increasing pumping power and second order correlation of ASE and lasing regime, showing clear evidence of lasing action.

Keywords:

transition metal dichalcogenides, indirect band gap, laser

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I4.05

Spontaneous emission rate in photonic temporal crystals

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Abstract:

For several decades, the manipulation of spontaneous emission has relied heavily on the use of space-periodic photonic structures. However, with recent interest in time-varying photonics, the theory of spontaneous emission needs to be extended to account for temporal variations. The photonic temporal crystal, which controls optical properties in a time-periodic pattern, is the temporal equivalent of spatially periodic photonic crystals. Since the Floquet eigenstates for the photonic temporal crystals are non-orthogonal to each other due to the coupling between positive- (negative-) frequency bands and replicated negative- (positive-) frequency bands, a non-Hermitian framework must be used to understand the relevant phenomena. In this study, we demonstrate that the finite non-zero spontaneous emission rate (SER) at the momentum gap (MG) edges results from the diverging Petermann factor (PF). This highlights the significance of non-orthogonality of photonic Floquet eigenstates and the role of the PF in photonic temporal crystals. Additionally, we show that spontaneous emission within the MG is inhibited even when temporally-growing in-gap Floquet states are present. This discovery indicates that the wavenumber ranges where spontaneous emission and stimulated emission occur are separate.

Keywords:

Spontaneous emission, time-varying medium, photonic temporal crystals, non-Hermitian

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I4.06

Terahertz optical properties of graphene oxide quantum dot and reduced graphene quantum dot

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Abstract:

Our study shows the optical properties of graphene oxide quantum dot (GOQD) and reduced graphene oxide quantum dot (rGOQD) in the terahertz region from 0.2 to 2 THz. Terahertz time-domain spectroscopy (THz-TDS) as a powerful tool for exploring the optical characteristics of materials with nondestructive and noncontact method was performed to obtain the extinction coefficient and refractive index which were used to calculate the complex dielectric constant and complex optical conductivity. As a result, GOQD has a higher optical conductivity than that of rGOQD. Drude-Lorentz (DL) oscillator model was used for fitting and analyzing the behavior of free and bound carriers. The DL model fitting parameters demonstrate the higher mobility of GOQD compared to the rGOQD sample. In the Raman spectroscopy result, it was expecthat the more defect states attributed to the lower mobility of rGOQD by disturbing the movement of carriers.

Acknowledgments: This work was supported by the National Research Foundation of Korea (NRF-2023R1A2C1008272).

Keywords:

Graphene oxide quantum dot, Reduced graphene oxide quantum dot, erahertz time-domain spectroscopy, Drude-Lorentz model, Optical property

I4.07

Circularly polarized perovskite electroluminescence from thin-film metacavities

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Abstract:

Compact circularly polarized (CP) light sources are desirable for variable applications. Extensive research has been conducted for achieving CP photoluminescence from perovskite materials to fully exploit their exceptional optoelectronic properties. However, to date, there has been no demonstration of CP electroluminescence (EL) with a substantial degree of circular polarization (DCP). Here, we experimentally demonstrate CP EL with a peak DCP of ~0.38 from an achiral perovskite material. A periodic lattice of inversion-symmetry-broken patterns is integrated with a perovskite EL device to form a photonic cavity. The interactions between Fabry-Perot and guided resonances result in prominent CP EL with a large DCP. In our device, a pair of left and right circularly polarized EL is split into opposite directions with equal power. The proposed ultracompact light sources are especially advantageous for many applications requiring chiral light beams of both helicities.

Keywords:

Chiral electroluminescence, Metasurface

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2023-04-19 - 2023-04-21

I4.08

Highly efficient biexciton generation and hyper Raman scattering in two-dimensional halide perovskite (C6H5C2H4NH3)2PbI4 under resonant two-photon excitation

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Abstract:

Two-dimensional (2D) halide perovskites exhibit various excitonic phases due to strong quantum and dielectric confinements for investigating fundamental exciton physics. Being four-body quasiparticles in a semiconductor, biexcitons are typically generated via inelastic Coulomb binding of two excitons under strong pulsed excitation. Here we demonstrate that biexcitons can be directly generated by resonant two-photon absorption in a prototype 2D halide perovskite, $(PEA)_2PbI_4$ (PEA = $C_6H_5C_2H_4NH_3$), with the corresponding two-photon absorption coefficient being extremely large (*β=2.0×10^5*cm/MW) due to the so-called giant oscillator strength. The internal energy of the biexciton is precisely determined to be 4658.4 meV by two-photon photoluminescence excitation (PLE) spectroscopy with polarization control, which is consistent with the two-photon selection rules. Quite intriguingly, upon further increasing the excitation level, a sharp peak emerges near the ground state of the biexciton, which turns out to shift by Δ2ω when the excitation photon energy is varied by Δω. We show that this strong signal arises from two-photon hyper Raman scattering into the exciton level, where the biexciton state serves as an intermediate state. Our findings highlight highly nonlinear optical properties of this important material and its potential for photonic applications.

References
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[2] Y. Nozue et al, J. Phys. Soc. Jpn., 44(4) (1978).

Keywords:

2D halide perovskites, biexcitons, hyper Raman scattering, giant two-photon absorption

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I4.09

Enhanced Pockels coefficient in organic epsilon-near-zero films

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Abstract:

The weak second-order nonlinear optical response of an optical media limits the efficiency of nonlinear optical devices, such as coherent nanoscale light sources and light modulators. Through chemical engineering of an organic molecule to hold an aggregated Lorentzian optical response, the Pockels coefficient can be enhanced in the visible spectrum range. We demonstrate a substantial enhanced quadratic nonlinear susceptibility and improved electro-optic effects across a broad spectral range. Enhancement of the EO effect in organic ENZ/ENP films with a large Pockels coefficient is observed.

Keywords:

Epsilon near zero, epsilon near pole, organic thin films, Pockels effect

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I5.01

Development of the 10+ Qubit Superconducting Quantum Processor in SKKU

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Abstract:

초전도 큐비트 기반 양자컴퓨터는 특히 규모확장성이 우수한 플랫폼으로서, 반도체 소자공정을 적용할 수 있고, 고주파 회로 및 냉동기 기술이 매우 성숙되어 있기 때문에 양자컴퓨터 하드웨어를 개발하는 기업들에서 가장 널리 채택하고 있는 플랫폼이다. 현재 세계적으로는 수백 개 수준의 조셉슨 접합을 포함하는 양자 프로세서 소자 및 이를 완전히 자동화하여 운영하는 시스템이 완성도 높게 선보이고 있는 수준이다. 이번 발표에서는 현재 성균관대의 본 연구팀이 실험실에서 진행하고 있는 10개+ 큐비트 규모의 초전도 양자소자 연구개발과정 전반에 대해서 소개하고자 한다. 초전도 회로는 설계에서 매우 자유도가 크기 때문에 10-큐비트급을 넘어가는 경우에는 CAD 도구의 도움을 받는 것이 필요하며, 주파수 및 커플링 등을 세밀하게 조절하면서도 공정 마진을 두는 것이 필요하다. 실제 소자는 웨이퍼 스케일로 제작되며, 조셉슨 접합의 균일도 및 수율이 중요한 변수가 된다. 큐비트의 생존 시간 및 결맞음 시간은 중요한 특성평가 요소이며, 이와 함께 회로에서의 양자 게이트의 충실도를 체계적으로 평가하였다. 본 연구에서는 일단 회로양자전기동역학(circuit QED) 방식의 고정주파수 트랜스몬 회로와 교차공진(Cross-Resonance)방식의 얽힘 게이트를 사용하는 회로를 기본으로 사용하였으나, 다양한 방식의 초전도 큐비트 회로에 대한 프로세스 전반을 충분히 확립하였다. 큐비트의 상태를 효율적으로 읽어내기 위한 원샷-측정을 높은 충실도로 구현하였으며, 다중 큐비트의 동시 측정을 위해서는 주파수 다중화 방식의 헤테로다인 측정을 활용하였다. 큐비트 게이트의 교정을 효율적으로 하는 방법론을 확립하고 양자상태를 분석하는 토모그래피를 수행하여 전체적인 시스템의 특성을 평가하였다. 다중 큐비트 양자소자를 활용한 간단한 알고리듬 수행을 보여주고, 시스템 차원의 운영 요소기술을 소개한다. 연구개발은 전체 과정을 통합적으로 고려하여 진행되고 있으며, 고성능 큐비트와 규모확장성에 필요한 요소기술들을 안정적이고 고품질로 확보하는 것을 목표로 하여 현재 매우 신뢰도 있는 전체 프로세스 흐름을 확립하였다. 본 발표에서는 현재의 양자소자 성능 및 이를 활용한 연구결과들을 간단히 소개한다.

Keywords:

Quantum Computer, Superconducting Qubit, Quantum Processor, Entanglement, Quantum Algorithm

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

I5.02

Calibration of Two-qubit Quantum Gates on a Superconducting Multi-qubit System

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Abstract:

초전도 큐비트는 현재 가장 유망한 양자컴퓨터 플랫폼 중 하나로써, 반도체 소자공정을 활용하여 웨이퍼 스케일의 대규모 양자소자를 제작 가능하다는 장점이 있다. 또한 초전도 양자소자는 전기적 특성을 기반으로 상호작용의 크기를 제어할 수 있으므로, 사용자의 목적에 맞게 회로 설계를 할 수 있다는 자유도가 있다. 하지만 양자소자에서의 양자상태 제어를 위한 양자 게이트는 교정(Calibration)이 필요하며, 큐비트의 수가 증가할수록 교정이 필요한 양자게이트의 수가 증가하여 다수의 변수를 제어하는데 어려움이 있다. 따라서 대규모 양자컴퓨터를 구동하기 위해서는 양자소자를 안정적으로 설계하고 제작할 수 있는 공정확보와 함께, 빠른 시간 내에 대규모 양자소자의 상태를 측정하고 양자게이트를 교정할 수 있어야 한다. 본 연구에서는 10-큐비트 초전도 양자소자를 활용하여 교차 공명(Cross-Resonance) 기반 두-큐비트 양자게이트 대한 분석 및 효율적 양자게이트 교정방법을 확립하고 이를 발표한다. 또한 양자상태 토모그래피를 통해 두-큐비트 양자얽힘 상태의 밀도행렬을 획득함으로써 양자상태 충실도(Quantum State Fidelity)에 대하여 보고한다.

Keywords:

Superconducting Qubit, Quantum Gate Calibration, Quantum State Tomography, Entanglement, Quantum State Fidelity

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

I5.03

Generation and Application of Two-Qubit Entanglement on a Superconducting Qauantum Processor

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Abstract:

양자 얽힘(Quantum Entanglement)은 양자 알고리즘의 구동에 있어 필수적인 요소이다. 이 연구에서는 초전도 트랜스몬(Transmon) 방식의 양자소자를 제작하고 이를 이용한 얽힘 형성 및 분석을 보고한다. 고정 주파수 초전도 큐비트 소자에서 교차 공명 게이트(Cross-Resonance Gate)를 이용하여 얽힘을 형성하고 이를 이용한 얽힘 상태 검증 및 활용을 시연한다. 얽힘 생성에서 높은 신뢰도의 얽힘 게이트 구현이 중요하며, 이를 위하여 교차 공명 게이트에 사용되는 고주파 펄스를 최적화하였다. 이번 연구에서는 양자 게이트를 구성할 뿐 아니라 이러한 얽힘 게이트를 활용한 양자회로 실험을 진행하였다. 벨 부등식의 하나인 C-H-S-H 부등식은 그 값이 고전적으로 2를 넘을 수 없지만, 양자 얽힘을 이용하면 고전 한계를 넘길 수 있다. 본 연구에서는 자체 제작한 초전도 큐비트 소자에서 C-H-S-H 부등식이 위반됨을 측정하고 양자 얽힘이 작용함을 확인하였다. 또한 얽힘 상태를 이용한 소규모 알고리듬을 실제 초전도 양자 하드웨어에서 시행한 결과들을 제시하고, NISQ 시대에 주목받는 알고리즘 중 하나인 VQE를 실제 소자에서 적용해 보도록 한다.

Keywords:

Superconducting Qubit, Transmon, Cross-Resonance, Entanglement, Bell Inequality

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

I5.04

Development of dynamic actuator based on the M13 bacteriophages using 3D colloidal assembly

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Abstract:

The colloidal assembly has been widely used to fabricate functional 2D structures. The colloidal deposition depends on evaporation and both Marangoni and capillary flows. Diverse approaches were tried to control the deposit patterns of 2D assembly using from single to binary colloids. However, the fabrication of the 3D colloidal assembly is not developed on micron-scaled structures. Here, we suggest the fresh fabrication method of micron 3D colloidal assembly consisting of nanoparticles. The capillary tube is used as to ultra-fine fountain pen that supplies nanoparticle-dispersed ink. At the tip end of the pen that contact with the substrate, the water of the ink evaporates and leaves nanoparticles continuously. The remained nanoparticles are assembled in micron 3D structures. The M13 bacteriophages, bio-nanomaterials, are also used for 3D assembly in the same way. The dual fabrication of spherical nanoparticles and bio-materials enables the form of Janus pillars. This can be a dynamic actuator because of the different expanding responses of the two materials to external stimuli like humidity. We expect that the sensor application of the dynamic actuator is valuable since the M13 bacteriophages can take high binding affinity to the target materials using genetic engineering.

Keywords:

Bio-nanomaterial, Colloidal assembly, Evaporation, M13 bacteriophage, Janus structure

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

I5.05

Naked eyes suitable visualization of humidity change using dynamic actuator based on the M13 bacteriophage

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Abstract:

Detecting and monitoring harmful substances through color change without an imaging device is very important with prevent external hazards. In that sense, using the dynamic structural color change caused by coherent light scattering of photonic-crystal-like nanostructures is a good way to be visible to the naked eye. The structural color is based on periodic nano structure of bundles consisting of M13 bacteriophages. Here, we show Fabry-Perot etalon (FPE)-based sensor for color change is directly visualized using M13 bacteriophage that responds specifically to different target substances. Where FPE is assembled by two gold-coated mirrors deposited on the slide glass and a gap of the FPE cavity is adjusted by M13 bacteriophage-based spacer. The white light is filtered by passing through the FPE and is dispersed after passing another transmission grating. The dispersed white light exhibits a discrete rainbow color depending on the gap thickness and the mirror reflectance. Because of the dynamic response of the M13 bacteriophages to the humidity the visualized discrete rainbow is changed dynamically regarding the humidity change. We analyze the dynamic response and improve the sensor to be more suitable for direct naked-eye observation using wedge-shaped FPE. The M13 bacteriophage-based color sensor can regulate its binding affinity to the VOCs by genetic engineering, which is expected to be widely utilized in the visualization of various VOCs.

Keywords:

M13 bacteriophage, Dynamic actuator, Fabry-Perot etalon, Humidity sensor, Genetic engineering

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

I5.06

Development of a droplet-based microfluidic isothermal titration calorimetry

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Abstract:

The development of microfabrication and microfluidics led to the advent of chip calorimeters, miniaturized calorimeters built and integrated as lab-on-a-chip devices. The chip calorimeters, as label-free biosensors, have many advantages due to their small sample volume and high-throughput capability.[1]
Using highly sensitive parylene microfluidic chip calorimeter combined with droplet microfluidic technologies, we developed an isothermal titration calorimeter(ITC) capable of measurements from sub-nanoliter volume droplets. We adopted a thin film vanadium pentoxide(V_2O_5) thermistor with exceptionally low electrical noise, enabling a power resolution of the chip calorimeter in the nW range. In addition, by employing various microfluidic techniques on the polydimethylsiloxane(PDMS), and parylene-C microchannels, we were able to produce sub-nL droplets on-demand with high accuracy and to automate the capture and merging of droplets in the chip calorimeter's chamber.
We demonstrated ITC on sub-nL aqueous droplets containing streptavidin and biotin. This experiment provides a complete thermodynamic characterization of the streptavidin-biotin binding system, revealing the stoichiometry, enthalpy change, binding constant, and entropy change of the reaction. The streptavidin-biotin binding system is an essential tool in many biochemical and medical applications, including immunoassays, drug discovery, and molecular diagnostics.[2] Our sub-nL microfluidic droplet calorimetry platform can provide a powerful method for the investigation of biomolecular interactions with high sensitivity and accuracy, enabling researchers to gain deeper insights into complex biological systems.

References:
[1] W. Lee, J. Lee, J. Koh, Nanobiosensors in Disease Diagnosis, **1.**, 17-29 (2012).
[2] C. M. Dundas, D. Demonte, S. Park, Appl Microbiol Biotechnol, **97.**, 9343-9353 (2013)

Keywords:

MEMS, Chip calorimeter, Isothermal titration calorimetry, Streptavidin-biotin binding

I5.07

Reconfigurable Logic-in-memory in crossbar cortical neuron network Using STDP Learning

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Abstract:

The concept of a logical neural network proposed by McCulloch and Pitts and Hebb's postulate of learning, spike-timing-dependent plasticity (STDP), have had a great influence on the development of brain-inspired computing research. To investigate how these concepts affect the computational principles used by real neurons, we constructed 4 x 4 crossbar neuronal networks on multi-electrode arrays (MEA) using a PDMS microfluidic structure. STDP learning caused a shift in threshold voltage (Vth) to activate neurons, and changed the response time determined by an interval between onset of stimulus and arrival time of evoked spike, indicating that the STDP learning can be achieved using MEA. Furthermore, the connections between neurons are well defined in the crossbar neuronal network; thus, reconfigurable AND/OR logic gates could be successfully realized through STDP learning. These results demonstrate that reconfigurable logic-in-memory can be implemented in the crossbar neuronal networks.

Keywords:

MEA, Logic-in-memory, Neuron network, STDP

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

I6.01

Emission Mechanisms in Spintronic Terahertz Emitters

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Abstract:

Spintronic thin films were shown to be promising high-performance broadband terahertz (THz) emitters. For conventional spintronic THz emitters, THz emission arises from three mechanisms: the magnetic dipolar radiation due to the ultrafast demagnetization, the transient current radiation due to spin-charge conversion, and anomalous Hall effect. Recent progress in orbitronics reveals the possibility of using orbit current as an information carrier. In this study, we show that ultrafast pulses of orbit current can be generated in Ni layers by femtosecond laser pulses. We demonstrate that, by injecting such orbit current pulses into nonmagnetic metals, a transient charge current is induced and emits terahertz electromagnetic pulses. The nonmagnetic metal layer acts as a converter of the orbit current into the charge current. The discovery of the generation and conversion of light-induced orbit current opens a new route for developing future spintronic THz devices.

Keywords:

ultrafast magnetism, spintronic terahertz emitters, orbitronics, ultrafast demagnetization, spin-charge conversion, orbit-charge conversion

I6.02

Orbital angular momentum dynamics observed exclusively by multi-dimensional low-energy probe

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Abstract:

Exploiting orbital angular momentum (OAM) can provide the fundamental principle for next-generation devices. However, to date, the electrodynamics of OAM remain elusive due to the lack of experimental observations. Such bottleneck primarily arises from the coexisting spin angular moment (SAM) and the inevitable orbital quenching in solids.

This talk will cover i) the disentanglement of OAM and SAM and ii) the visualization of the electrodynamics of OAM and SAM. Near-field terahertz (THz) polarimetry and spectroscopy are used to explore the orbital current in the multi-dimensional space (time-, spatial-, and frequency-domain). The accessibility to picosecond timescale and micron spatial resolution allows us to dynamically monitor and visualize the real-space flow, accumulation, and disappearance of OAM with a macroscopic-scale coherence at room temperature.

Keywords:

Orbital angular momentum, Disentanglement, Visualization, Terahertz polarimetry

I6.03

Toward sensing and imaging angular momentum dynamics based on solid-state spin qubits

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Abstract:

Many breakthroughs and new findings in physics have been accompanied with the invention and development of novel and precise experimental tools. Qubits are not only essential components for quantum information science and technologies, but also can be used as novel experimental tools for physics. In this talk, we will introduce examples of the new opportunities using solid-state qubits; nitrogen-vacancy (NV) centers in diamond. We will show our recent efforts toward sensing and imaging angular momentum dynamics in solid-state materials such as ferromagnetic spin waves in YIG magnetic materials and spin waves coupled to surface acoustic waves.

Keywords:

diamond NV center, spin qubit, spin waves, angular momentum dynamics

Observation of the orbital Hall effect in a light metal Ti

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Abstract:

The orbital angular momentum is a core ingredient of orbital magnetism, spin Hall effect, giant Rashba spin splitting, orbital Edelstein effect, and spin-orbit torque. However, its experimental detection is tricky. In particular, direct detection of the orbital Hall effect remains elusive despite its importance for electrical control of magnetic nanodevices. Here we report the direct observation of the orbital Hall effect in a light metal Ti[1]. The Kerr rotation by the accumulated orbital magnetic moment is measured at Ti surfaces, whose result agrees with theoretical calculations semi-quantitatively. As another evidence, we measured the orbital torque in the Ti/ferromagnet heterostructures, from which we determine the orbital Hall angle.

Reference

1. Choi *et al.*, Observation of the orbital Hall effect in a light metal Ti, arXiv:2109.14847.

Keywords:

oribtal Hall effect, orbital angular momentum, Magneto-optical Kerr effect, orbital torque

I7.01

Time-domain braiding of anyons

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Abstract:

Anyons are quasiparticles that do not obey the fermionic nor bosonic identical particle statistics. They show fractional braiding statistics behavior when an anyon winds around another in two dimension. We have predicted anyon braiding in time domain [1,2]. The braiding happens when a dilute anyon beam is partitioned at quantum point contacts in the fractional quantum Hall regime. It dominates over the conventional partition, resulting in nontrivial fluctuations of electrical current at the quantum point contacts. We discuss recent experiment results [3] at quantum Hall filling factor 1/3 which agree with the time-domain braiding with a braiding phase 2π/3, without any fitting parameters, hence, provide an evidence of the fractional statistics of Abelian anyons.

[1] B. Lee, C. Han, H.-S. Sim, Negative Excess Shot Noise by Anyon Braiding. Phys. Rev. Lett. 123, 016803 (2019).
[2] J.-Y. M. Lee and H.-S. Sim, Non-Abelian Anyon Collider, Nat. Commun. **13**, 6660 (2022).
[3] J.-Y. M. Lee, C. Hong, T. Alkalay, N. Schiller, V. Umansky, M. Heiblum, Y. Oreg, and H.-S. Sim, Partitioning of Diluted Anyons Reveals their Braiding Statistics, to appear in a journal.

Keywords:

anyon, fractional statistics, braiding

2023 KPS Spring Meeting
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I7.02

Coherence of a singlet-triplet qubit driven by magnetic field gradient in isotopically purified silicon

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Abstract:

Engineered spin-electric coupling in semiconductor nanostructures enables fast manipulation and individual addressing of spin qubits. In this talk, we demonstrate fast singlet-triplet qubit oscillation (>100MHz) in gate defined double quantum dot in isotopically purified $^{28}Si/SiGe$ with an on-chip micromagnet in the large valley-splitting regime (>250 eV). Combined with rf-reflectometry-based single-shot readout and adaptive initialization, we analyze the variation of coherence time as a function of confinement potential detuning and external magnetic fields which enables tuning of spin-electric coupling strength, single-particle Zeeman energy, as well as magnetic field gradient. We show that the oscillation quality factor of an encoded spin qubit over 550 can be achieved. We will also discuss the comparison between the present method to recently demonstrated other methods like using spin-valley coupling in silicon.

Keywords:

Silicon quantum computing, spin qubits, singlet-triplet qubit, Larmor oscillation, spin-electric coupling

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

I7.03

Gate-voltage-driven quantum phase transition in quantum point contacts

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Abstract:

A quantum point contact (QPC) is a fundamental quantum device with a narrow constriction between two electron reservoirs. The spontaneous formation of a localized spin in the constriction makes the QPC a quantum-dot-like device having Kondo couplings with both reservoirs. The localized spin at the center of the constriction moves away from the center as the side-gate voltage decreases, which signifies a symmetry breaking in the left-right Kondo coupling strength. A quantum phase transition induced by this spontaneous symmetry breaking was studied by analyzing the parameters that recovered the gate-voltage-dependent tunneling conductance line shapes reported in the experiment. The parameter indicating the difference between the left and right Kondo coupling strengths was chosen as the order parameter, and its critical exponent was obtained as $\beta=0.373$. Showing the discontinuity of the derivative of the zero-bias anomaly energy over the gate voltage at the transition point was provided as additional evidence of the continuous phase transition.
A quantum point contact (QPC) is a fundamental quantum device with a narrow constriction between two electron reservoirs. The spontaneous formation of a localized spin in the constriction makes the QPC a quantum-dot-like device having Kondo couplings with both reservoirs. The localized spin at the center of the constriction moves away from the center as the side-gate voltage decreases, which signifies a symmetry breaking in the left-right Kondo coupling strength. A quantum phase transition induced by this spontaneous symmetry breaking was studied by analyzing the parameters that recovered the gate-voltage-dependent tunneling conductance line shapes reported in the experiment. The parameter indicating the difference between the left and right Kondo coupling strengths was chosen as the order parameter, and its critical exponent was obtained as $\beta=0.373$. Showing the discontinuity of the derivative of the zero-bias anomaly energy over the gate voltage at the transition point was provided as additional evidence of the continuous phase transition.

Keywords:

quantum point contacts, zero-bias anomaly, continuous phase transition

Collision of two electrons by Coulomb interactions: theorical study

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Abstract:

Control of Coulomb interaction between ballistic electrons is important for the quantum logic gate of flying qubits. The Coulomb interaction can be analyzed by colliding two counter-propagating electrons at a mesoscopic beam splitter. This collision has been demonstrated for electrons near the Fermi energy [1], where the Coulomb interaction is screened by other electrons and does not play a significant role. The Coulomb interaction becomes important for hot electrons in quantum Hall edges, since the screening becomes reduced as the hotter electrons more separate from the quantum Hall bulk [2].
Here, we study the collision of hot electrons, and demonstrate that the Coulomb interaction strongly modifies the partition statistics of the colliding electrons at a beam splitter. The Coulomb interaction changes the statistics in a way that the beam splitter transmission of the electron later arriving at the splitter is affected by the electron arriving earlier [3]. The strength of the Coulomb interaction and the barrier potential of the splitter can be read out from the statistics signals. Understanding of the collision will pave a way for control of the Coulomb interaction between two ballistic electrons.

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[2] J. D. Fletcher, W. Park et al., Time-resolved Coulomb collision of single electrons, arXiv:2210.03473 (2022)
[3] S. Ryu and H.-S. Sim, Partition of Two Interacting Electrons by a Potential Barrier, Phys. Rev. Lett. 129, 166801 (2022)

Keywords:

Electron quantum optics, Quantum Hall effect, Coulomb interaction, Mesoscopic physics

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I7.05

Phase tailoring of single-electron wave packet

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Abstract:

With recent development of quantum information technologies based on solid-state electronics, quantum devices are getting more complex and delicate. In this circumstance, characterizing and controlling the electron wave packet is considered as an important technic for solid-state quantum devices. Single electrons emitted from a quantum dot defined in a two-dimensional electron gas system have time and energy distributions. These distributions can be described as the Wigner function in an energy-time phase space. Here, we demonstrated a time-correlated energy filtering technique for single-electron wave packets using an potential barrier (PB) biased by a combination of dc and RF voltage signals in the quantum Hall regime (T = 50 mK, B = 12 T). Here, the PB is defined by a surface-metal gate. The barrier can sort out partial wave functions from original wave functions of electrons. A static PB biased by a fixed dc voltage can filter the wave function only along the energy axis in the phase space. The dynamically varying barrier, however, allowed us to filter the wave packet in a time-energy correlated direction. By this way, we successfully reduced the size of the electron wave packet in the phase space by tuning direction of filtering. In the presentation, we will report detailed experiments about the dynamic filtering for the electron wave packets.

Keywords:

Single electron pump, Wigner function, energy filtering

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I7.06

Topological Andreev bands in three-terminal graphene Josephson junctions

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Abstract:

Multiply connected electronic networks threaded by flux tubes was proposed as a potential platform for studying adiabatic quantum transport properties, which are closely linked to topological invariants [1]. This concept could be realized in multi-terminal Josephson junctions (MTJJs) [2]. However, manifestations of topology in MTJJ are still an open case of experimental study.

In this work, we investigate the artificial topological band structure of three-terminal graphene Josephson junctions by using tunneling spectroscopy. Differential tunnelling conductance shows the characteristic features of Andreev bound states (ABS) formed in the graphene. We independently controlled the superconducting phase configurations of the three superconducting leads connected to the junction by applying the flux gates, and obtained the tomography of the ABS energy spectrum as a function of two independent phase differences. Such quasi-momentum v.s. energy map of ABS unveils the transition between gapped and gapless states, which corresponds to the topological band structure of 2D-Dirac semimetals. Our results show the potential of graphene-based MTJJ for engineering band topology.

References

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2. Roman-Pascal Riwar, Manuel Houzet, Julia S.Meyer & Yuli V. Nazarov. *Nature Comm.* 7, 11167 **(2016)**

Keywords:

Weyl singularity, Andreev bound state, Tunneling spectroscopy, multi-terminal Josephson junction

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I7.07

Nonlocal transport in gapped bilayer graphene

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Abstract:

Topologically protected states have been investigated in various materials for their potential use in quantum information technology [1-6]. Of particular interest is in gapped graphene, including mono-, bi-, and twisted graphene with broken inversion symmetry [2-6]. Previous experimental works have demonstrated the presence of large nonlocal resistance in the graphene system, which is thought to arise from topological edge state. However, the origin of this nonlocal resistance is still debated [5,6]. In this study, we fabricated dual-gate bilayer graphene devices with natural edges to investigate the effects of the edge-etching process on transport. We measured local and nonlocal resistances at the charge-neutral points before and after the edge etching process. Before the etching process, the nonlocal resistance was on the same order of magnitude, which is comparable to the trivial ohmic contribution. After the etching process, however, the nonlocal resistance increased by two orders of magnitude, and the band gap estimated from temperature dependence data were decreased. To explain such observations, we suggest that the disordered etched edges induce trivial conducting channels at the edges and induces the large nonlocal resistance, which does not originate from the topological nature.

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Keywords:

Mesoscopic device

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I7.08

Method for observing ideal coulomb blockade peaks of a gate-defined quantum dot

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Abstract:

본 연구에서는 2차원 전자계 기반 양자점 측정시, 외부 환경과의 커플링 제어를 통해, 전자의 에너지 스펙트럼 분석을 개선할 수 있음을 확인하였다.
2차원 전자계 기반의 양자점의 형성은 나노 공정을 통해 제작한 수십nm크기의 전극을 활용한다. 충분히 작은 공동은 양자역학적 에너지 준위를 형성하며, 양자점을 통한 전도도 피크를 측정하여, 양자점 내부에서의 에너지 스펙트럼을 분석할 수 있다.
본 실험에서는 기존의 plunger gate만을 제어하는 방식과 달리 공동을 형성하는 게이트를 동시에 제어하는 것으로 훨씬 많은 coulomb blockade 피크 신호 관측할 수 있었다.
또한 mode-mixing을 제어할 수 있는 방법을 마련하여, 양자점 내부의 에너지 스펙트럼을 자기장, mode-mixing 정도를 변화시켜 측정할 수 있었다. 본 연구결과를 통해, 양자점의 에너지 스펙트럼을 더욱 자세히 분석할 수 있는 기반을 마련하였다.

Keywords:

Quantum dot

I8.01

Hydrogen Separation with a Graphenylene Monolayer: Diffusion Monte Carlo study

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Abstract:

Hydrogen separation plays a critical role in using hydrogen as a new generation of energy resource. In this study, we investigated the potential of graphenylene (GPNL), a two-dimensional network of sp^2-bonded carbon atoms with large near-circular pores, as a hydrogen-selective membrane for gas mixtures using fixed-node diffusion Monte Carlo (DMC) calculations. Our DMC results show that a GPNL monolayer is energetically stable, with a cohesive energy of 6.755(3) eV/atom, comparable to that of γ-graphyne. Moreover, we have found that GPNL has exceptionally high hydrogen selectivity, as high as 10^{10}-10^{11} against CO and N_2 gases at 300 K. It is also found that when compared to our DMC results, DFT calculations tend to overestimate H_2 selectivity, which is mostly due to their inaccurate description of short-range repulsive interactions. Our findings suggest that GPNL is a promising membrane for high-performance hydrogen separation due to its high energetic stability and separation performance.

Keywords:

Quantum Monte Carlo, Hydrogen-selective membrane, Gas separation

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2023-04-19 - 2023-04-21

I8.02

Solvent effects on the piezoelectric response of peptide nanotube using first principles modeling

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Abstract:

Among various biomolecular piezoelectric materials, diphenylalanine (FF) peptide nanotubes are expected to be very promising for bio-implantable devices owing to their unique characteristics, such as robust piezoelectricity, remarkable physical properties, and chemical stability. In this study, we have performed comprehensive density functional theory (DFT) calculations to shed some light on solvent and material-dependent polarization switching. Due to the experimental observation of FF peptide zwitterionic vs. neutral FF structures, we first investigated the relative stability of the zwitterionic (*m*FFZ) and neutral (*m*FFN) conformers of FF in a bulk aqueous solution. Our calculations revealed that while *m*FFZ is more stable in pure water, *m*FFN is preferably present in pure ethanol. To investigate if these preferences hold when the molecules adsorb to the surfaces, we have examined the binding mode of *m*FFZ and *m*FFN on Au(111), Al(111), and Al_2O_3 facets. In addition, we have predicted the strong shear (d_{15}) piezoelectric coefficient of *m*FFZ and *m*FFN nanotubes directed along the long tube axis, considering water and ethanol solvents within the framework of density functional perturbation theory. Due to their robust unidirectional piezoelectric polarization and low dielectric characteristics, our finding reveals the potential for utilizing piezoelectric peptide materials for device applications in nanoscale energy harvesting sensors and actuators.

Keywords:

Solvents, Piezoelectric polarization, First-principle Calculations, Dielectric Constants, Diphenylalanine Peptide

I8.03

Modeling of aqueous electrolyte solutions via machine learning for the development of rechargeable batteries for renewable energy storage

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Abstract:

Rechargeable batteries have become indispensable for our daily life and are considered a promising technology for sustainable energy systems in the future. One of the most important parts of a battery is a liquid electrolyte which is critical in stabilizing the electrode−electrolyte interfaces and constructing safe and long-lifespan batteries. Both experimental and theoretical techniques were employed to study the structure of liquid electrolytes, however, they are limited. In particular, IR and Raman can only partially describe the structure, and ab initio calculations, e.g., DFT are limited due to computational cost and the sizes of models. To model a liquid electrolyte, we employ many-body expansion (MBE) which is an excellent common strategy to model large systems by partitioning energies into an hierarchy of decreasingly significant contributions (one-, two-, three-body, etc.), thus, allowing one to reduce the scaling problem of large systems. Moreover, for each term in the MBE decomposition, we employ machine learning techniques as an excellent alternative to reduce computational cost without loss of overall accuracy. As a model system for a liquid electrolyte, we use an aqueous solution of hydrochloric acid. Although still in the early stage, we will discuss the preliminary results of modeling the solution with H_2O (one-body), $(H_2O)_2$ (two-body), $(H_2O)_3$ (three-body) as well as $H^+(H_2O)$, and $Cl^−(H_2O)$. In the future, to reach a realistic description of the aqueous electrolyte, we will increase the degree of complexity by including additional species, such as $Cl^−(H_2O)_2$, $H^+(H_2O)_2$, as well as $H^+(H_2O)Cl^−$, $H^+(H_2O)_2Cl^−$, etc.

Keywords:

aqueous electrolyte, machine learning, rechargeable batteries

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I8.04

Machine learning to identify magnetic order from electronic properties

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Abstract:

Magnetic state identification is a crucial task with numerous applications in materials science and engineering, but direct experimental methods for determining magnetic states are often limited. In this work, we present a machine learning approach to identify the magnetic structures of materials from their electrical properties. Our dataset is generated through Hartree-Fock calculations targeting $BaOsO_3$, and processed into local density of states (LDOS) and momentum-resolved density of states (kDOS) below the Fermi level. Using decision tree ensemble classifiers, our machines achieve high accuracy in predicting magnetic states, with kDOS outperforming LDOS. To further improve the accuracy of prediction, we process energy of the two DOS peaks nearest to the Fermi level as a feature for our models. Additionally, we simulate angle-resolved photoemission spectroscopy (ARPES) data, generated by the same Hartree-Fock calculations, to test the performance of our models. We also explore the use of a deep learning classifier for the generated ARPES data, which has the potential to further enhance the accuracy and versatility of our approach.

Keywords:

magnetic structure, Hartree-Fock approximation, machine learning, deep learning

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2023-04-19 - 2023-04-21

I8.05

Controlling Spin-Dependent Surface Band Gaps in MnBi2Te4 through Antisite Defects: A First-Principles Study

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Abstract:

MnBi2Te4 (MBT) has recently garnered attention as a remarkable material due to its unique magnetic and topological properties, making it a promising candidate for advanced electronic applications like spintronics. Despite its broken time-reversal symmetry, MBT, an antiferromagnetic topological insulator, exhibits unique topological surface states. This is because the system is symmetric under a nonsymmorphic operation S corresponding to a combination of half-translation and time reversal. This symmetry can be preserved even when a surface is exposed, leading to a gapless surface state, whereas, on a surface with broken S symmetry, there will be a gap in the surface state. as experimentally observed. We also discovered that the surface band gap can decrease by changing the spin orientation of MBT. We verified this correlation between spin orientation and surface gap by combining our DFT results with a model Hamiltonian. Fortunately, we found a way to modify the magnetic anisotropy energy of MBT, by introducing antisite defects, which will change the preferred spin orientations, thereby enabling control over the surface states.

Keywords:

MBT, MnBi2Te4, topological surface states, magnetic anisotropy energy

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

I8.06

Ab initio study on the magnetic properties of layered and randomly mixed Co-Pt alloys

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Abstract:

Co-Pt alloy, Co_nPt_m, has attracted a lot of attention due to its potential applications in spintronics and magnetic storage devices. To investigate the magnetic properties of this alloy, we performed *ab initio* calculations using the Vienna Ab-initio Simulation Package (VASP). Our study focused on magnetic properties such as magnetic moment, magnetization, and magnetic anisotropy energy (MAE), and we analyzed how these properties are influenced by mechanical strain and the composition of Co and Pt. Our calculations showed that increasing the concentration of Pt in the alloy results in an increase in the magnetic moment because of the magneto-volume effect. However, the MAE of Co_nPt_m alloy is dependent highly sensitively on the interfacial effect (Co/Pt), the thickness of each layer, and the direction along which the layers are stacked, either (111) or (100) direction. We also scrutinized the effect of mechanical strain on the magnetic properties of the Co_nPt_m alloy. When tensile stress is applied to an alloy stacked along the (100) direction, the MAE of the alloy changes to the direction preferred in-plane. On the other hand, the (111) oriented Co_nPt_m alloy exhibits a parabolic dependence of the MAE on the strain, with an overall preference for the out-of-plane direction. These results suggest that the magnetic properties of Co_nPt_m alloy can be controlled by varying its composition and crystal structure as well as by applying mechanical strain. This study provides valuable insights into the potential applications of Co_nPt_m alloy and contributes to the understanding of magnetic properties, which can inform further research in this field.

Keywords:

ConPtm, magnetic material, magmagnetic anisotropy energy, MAE, magnetic properties

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

I8.07

Density functional calculation of thermal expansion of γ-GeSe

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Abstract:

We obtain lattice constants of γ-GeSe as a function of temperature based on the density function theory. γ-GeSe is a hexagonal layered material whose unit cell consists of two quadruple layers of Se-Ge-Ge-Se. To obtain lattice constants as a function of temperature, we calculate the total energy of the system as a function of lattice constants without considering any atomic vibration by using the density functional theory and we calculate phonon frequencies in the full Brillouin zone as functions of lattice constants by using the density functional perturbation theory. With these results, we obtain the Helmholtz free energy as a function of lattice constants and temperature. Finally, by finding lattice constants which minimize the free energy at each temperature, we obtain the lattice constants as a function of temperature. We discuss the magnitude and the anisotropy of the thermal expansion of γ-GeSe. This work is supported by NRF of Korea (Grants No. 2020R1A2C3013673 and No. 2017R1A5A1014862). Computational resources have been provided by KISTI Supercomputing Center (Project No. KSC-2022-CRE-0266).

Keywords:

GeSe, thermal expansion, phonon spectrum

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2023-04-19 - 2023-04-21

I8.08

First-principles study on the defects in the monolayer tungsten diselenide

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Abstract:

Monolayer tungsten diselenide has attracted researchers due to its direct band gap, which makes it optically active. One particularly fascinating aspect is the ability to manipulate its luminescence spectrum through atomic defects, which create electron transition states in the middle of the band gap. This type of luminescence has been shown to originate from a single photon emitter, which could be utilized in quantum information technology for flying qubits. However, fully understanding each type of defect is challenging, as experiments can only measure collective signals from crystals. To gain a better understanding, we utilized density functional theory (DFT) calculations with hybrid functional to investigate the electronic structures modified by various defect structures in the monolayer tungsten diselenide. We examined the formation energy to identify their energetic stability and scrutinized defect states to estimate the transition energy corresponding to the photon energy. We also analyzed the effects of hBN encapsulation on this system. Finally, we will discuss the impact of spin-orbit coupling on the defect states, which plays a crucial role not only in their electronic and optical properties but also in their topological property.

Keywords:

WSe2, defect

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

I10.01

Advanced TEM techniques for characterizing emerging materials

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Abstract:

Extending the properties and performance of emerging materials is closely linked to deliberate investigations of certain specific microstructural phenomena. The fundamental understanding of microstructure-property relationship has been improved by virtue of the resolution available using advanced TEM techniques. State-of-the-art TEM has already achieved ultra-high resolution imaging of nanostructures at sub-angstrom level through the use of spherical aberration correctors. High-energy resolution monochromated electron energy loss spectroscopy (EELS) also allows us to study materials properties that correspond to low (<5 eV) energy losses (i.e. band-gaps, plasmons, and excitons) with nanoscale spatial resolution. In this presentation, I will briefly introduce the capabilities of monochromated scanning TEM (STEM) EELS and low-dose STEM techniques to effectively examine optical properties of plasmonic nanoparticles and to resolve the atoms at Å scale resolution for beam-sensitive nanomaterials, respectively. In addition, applications of these techniques to some emerging materials will be illustrated.

Keywords:

Microstructure, Monochromated STEM-EELS, Low-dose STEM

Detecting individual atoms at materials surfaces and interfaces in 3D via atomic electron tomography

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Abstract:

In this talk, we will present a new approach for detecting individual atoms in materials in three dimensions, with a focus on materials surfaces and interfaces. Our method is called atomic electron tomography (AET) and it utilizes aberration-corrected electron microscopy to collect tilt-series data. Advanced algorithms are then applied to reconstruct the data into a 3D atomic-resolution map of the material. We will present recent findings on the stabilization mechanism of new metastable structures [1] and explore the direct correlation between strain at the interface and surface for core-shell structures [2]. A better understanding of the full 3D atomic structures, particularly at surfaces and interfaces, and their physical properties has the potential to lead to the rational design of novel materials, especially semiconductors, at the atomic scale.

[1] Hong et al., *Nature* **603**, 631 (2022).
[2] Jo et al., *Nat. Commun.* **13**, 5957 (2022).

Keywords:

atomic electron tomography, surface-interface strain correlation, stabilization of metastable structures

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2023-04-19 - 2023-04-21

I10.03

Exploring the infrared phonon mode in few-layer graphene by using nanoscale optical-electrical force detection

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Abstract:

There is the in-plane optical phonon mode of layered graphene, which is around 200 meV and depends on the charge doping level. This mode provides valuable information about the quality and properties of graphene, and is useful for developing graphene devices. In this study, we investigate the optical and electrical responses of the infrared phonon mode in few-layer graphene with a spatial resolution of 10 nm, using hybrid nano-IR microscopy and force detection methods. Our methodology enables the examination of the infrared phonon response of few-layer graphene by analyzing both the nano-IR response and electrostatic/surface potential through the implementation of multifrequency atomic force microscopy techniques. The results show that the infrared phonon resonance in bilayer graphene is greatly enhanced due to a charge imbalance between the top and bottom layers, which can be engineered using a nanoscale friction charging method.

Keywords:

low dimensional materials, nano-IR, photo-induced force microscopy (PiFM), Kelvin probe force microscopy (KPFM)

I10.04

Strong Light–matter Interaction Beyond Diffraction Limit with Scattering-type SNOM and Tip-enhanced Spectroscopy

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Abstract:

The strong-light matter interaction, i.e. polariton, commonly inherits light and matter properties. In quantum mechanics, the Hamiltonian of polariton consists of the light, matter, and their interaction, that is, the superposed states of light and matter. The interaction shows new eigenstates giving a significant modification of the optical properties such as split states, anti-crossing behavior in dispersion relation, enhancements of absorption or scattering, and Bose-Einstein condensation in room temperature, and the Purcell effect. However, the diffraction limit of waves defined by half of the input wavelength restricts resolving the spatial distribution of optical properties in the subwavelength scale where the nano-optical properties enormously rise. In other words, the critical information of near-field signals and intrinsic optical properties of matters are lost in far-field measurement. In the late 90s, Lahrech et al. proposed their pioneer work of subwavelength imaging (λ/100 resolution) with a scattering-type near-field scanning optical microscope (s-SNOM). Moreover, beyond the diffraction limits, s-SNOM shows extraordinary performance in exciting and detecting polaritons in ultra-broadband and fine spatial resolution. This presentation will introduce the basic quantum mechanical concepts of strong light-matter interaction, especially surface plasmon polariton and exciton-polariton. s-SNOM system is precisely constructed to investigate strong light-matter interaction in visible to near-infrared regime and optimized to achieve the background-free near-field. In addition, tip-enhanced spectroscopy system is combined with s-SNOM system. The constructed s-SNOM/tip-enhanced spectroscopy system examines surface plasmon polariton and exciton-polariton beyond the diffraction limits. First, selectively decomposed method of surface plasmon polariton (i.e. tip-launched SPP) is proposed that tip-launched SPP is independent to geometrical components such as the edges' angle, the shape of a tip, and dirt. Second, super-spherical nanoparticles on rhenium disulfide layers demonstrate an anisotropy exciton-polariton and plasmonic enhancement without any mathematical correction. Finally, We successfully tip-enhanced photoluminescence spectroscopy mapping on AuNP/TMD system.

Keywords:

Near–Field Scanning Optical Microscopy (NSOM), Surface Plasmon Polariton, Exciton-Polariton, Polariton Coupling, Energy-Momentum Dispersion Relation, Tip-enhanced photoluminescence/Raman spectroscopy, Transition metal dichalcogenides

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

I11.01

Overview of 10 Beamlines in Phase-I for 4GSR and Construction Strategy

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Abstract:

We are now waiting for the 4th generation synchrotron radiation(4GSR) at Ochang, Chuncheong Buk-Do. The new era with 4GSR, which is represented by the high brightness, good coherence, and the small emittances, will be start the end of 2027. With the present working Pohang Light Source-II(PLS-II), 4GSR will lead the scientific leap in basic science and industrial contemporary issues.
Through in-depth discussion between the varieties of expert group, the first 10 beamlines have been proposed for the 4 GSR. In this presentation, I will give an overview of those beamlines, and briefly introduce the construction status of each beamline, discuss the strategy for their construction.

Keywords:

4GSR, Synchrotron Radiation, Beamline

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2023-04-19 - 2023-04-21

I11.02

The introduction and technical approaches of a new nano-ARPES beamline of 4th Generation Synchrotron

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Abstract:

Angle-Resolved Photoemission Spectroscopy (ARPES) is a powerful and only technique that can directly measure the electron band structure. It can be acquired by analyzing the kinetic energy and emission angle of photoelectrons emitted while photons are incident on the material. It is an essential experimental technique for studying the unique electronic structure of low-dimensional materials such as Graphene, transition metal chalcogen compounds, topological insulator, and super-conductors. For the study of the strong interaction between particles in emerging quantum materials, ARPES is most useful. From an industrial point of view, the development of semiconductor micro-processing is increasing the need for nanometer-sized electronic structure research. Now, a fourth-generation synchrotron is under construction in Ochang, Chungcheongbuk-do. One of the 10 beamlines of the construction plan is for the nano-ARPES. We would like to introduce the expected performance and the technical approach to achieve one. In addition, we look forward to the change in the research field caused by the new beamline.

Keywords:

ARPES, nano-ARPES, SARPES, Photoemission, Electron band structure

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

I11.03

A brief review on coherent x-ray diffraction beamline at Korea-4GSR

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Abstract:

Korea-4th generation storage ring (4GSR) features extremely small emittance in the horizontal direction. Therefore, it is expected that the Korea-4GSR will provide x-rays having improved transverse coherence and brightness compared to the 3rd generation storage ring such as PLS-II. Coherent x-ray diffraction beamline is dedicated to coherent x-ray diffraction imaging (CDI) and nanobeam diffraction techniques. It will be one of the beamlines that benefit the most from 4GSR given that the capability of the CDI is greatly affected by the coherent flux of x-rays. In this presentation, specifications, conceptual design, and potential sciences of the beamline will be briefly introduced.

Keywords:

Coherent x-rays, Coherent x-ray diffraction imaging, Nanobeam diffraction, Korea-4GSR

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I11.04

Introduction of Soft X-ray Nanoprobe beamline in 4GSR

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Abstract:

I would like to introduce the Soft x-ray Nanoprobe beamline that will be built at the 4GSR next-generation accelerator. This beamline will be constructed as a beamline capable of realizing broadband photon energy that can cover the soft and tender energy region from 100 eV to 5,000 eV. In this presentation, I will introduce the research areas and experimental End-station utilizing the beamline and discuss the technical limitations of energy realization.

Keywords:

Soft x-ray Nanoprobe beamline, 4GSR next-generation accelerator

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I12.01

챗-GPT와 함께 사는 세상에서 과학커뮤니케이션은?

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Abstract:

챗-GPT와 함께 사는 세상에서 사범대학의 인재상은 무엇인가? 사범대학에서 초중고 학생은 어떤존재인가? 사범대학에서 과학커뮤니케이션은 어떤 의미인가? 그동안 사범대학에서 커뮤니케이션이 얼마나 중요했는가? 지금 우리 사회는 사범대학을 필요로 하는가? 사범대학에서는 교육 수요자가 원하는 선생님이 어떤 역할의 교사인지 알고 있는가? 사범대학과 예비교사의 상호 커뮤니케이션 만족도는? 현직 교사와 학생간의 커뮤니케이션 상호만족도는?
이것은 사범대학 물리교육과정의 다변화, 특히 과학커뮤니케이터를 염두에 두고 고민할 때 등장할 수 있는 수많은 질문들 중 일부입니다. 발표자가 많은 질문들에 답을 제시할 수는 없어도 지난 20여년간 동아사이언스의 온라인 미디어(www.dongascience.com)와 매거진 미디어(과학동아, 어린이과학동아, 수학동아, 어린이수학동아)에서 진행한 과학커뮤니케이션 활동에서 얻은 함의를 공유하고자 합니다.

Keywords:

챗-GPT, 과학커뮤니케이션

I12.02

과학관 인력양성을 위한 물리교육과정 모색

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Abstract:

학생수가 감소하고 정규 학교 이외에 과학소양을 신장시키고 과학문화를 보급하는 다양한 기관과 방식이 생겨남에 따라, 사범대학에서도 교사뿐만 아니라 다양한 역할의 과학소통인력을 양성할 필요성이 높아지고 있다. 본 발표에서는 최근 전국적으로 확충되고 있는 과학관을 중심으로 대학교육과정의 변화방향을 모색하였다. 이를 위해 국내 주요 과학관 인력의 전공분포 현황을 조사하고, 사범대 출신 근무자의 주요 업무와 요구되는 역량, 채용시 필기전형으로 치르는 국가직무능력표준 등을 분석하였다. 인력 비중은 각 과학관의 전시주제와 규모에 따라 다르게 나타났고, 특별전시기획, 전시물기획개발, 과학관교육, 전시장운영/해설 등 다양한 업무를 수행하고 있었다. 교사양성과 비교할 때, 과학관 교육과 해설 관련 업무는 비교적 유사하여 기존교과에 접목가능한 반면, 교과서 내용을 가르치는 것이 아니라 매번 새로운 주제의 전시를 기획하고, 과학원리를 반영한 체험전시물을 기획개발 하는 것은 이를 위한 새로운 대학교육과정이 필요하다고 판단하였다. 교과에 대한 제언과 함께 과학관 관련 정책을 살펴 직군으로서의 인력수요 확대 가능성을 검토하였다. 대학에서 과학관에서 필요한 역량을 갖춘 인재가 공급된다면 과학관이 과학문화를 확산하고 학교밖 교육기관으로서의 역할을 수행하는데 큰 도움이 될 것으로 기대된다.

Keywords:

과학관, 물리교육과정, 커뮤니케이터

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2023-04-19 - 2023-04-21

과학문화 콘텐츠 창작 과정에서 과학 커뮤니케이터의 역할

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Abstract:

본 연구자는 과학교육 연구자이자, 과학 커뮤니케이터로서 다양한 연령, 직업을 가진 대중과 과학문화 콘텐츠(Science Culture Content)로 소통해왔다. 비형식 과학교육기관에서 청소년 과학실험 체험활동을 기획, 운영하였으며, 학교, 도서관, 길거리 등에서 과학강연, 과학 버스킹을 해왔다. 또한, 과학 공연 전문 극단의 기획자로서 연극을 창작하여 대학로에서 상연하였다. 특히, 과학연극 창작 과정에서 배우, 연출의 경험과 연극을 분석하는 연구를 진행하고 있다. 연구 사례인, 과학연극 '양자전쟁'은 연극 전문가가 주도적으로 창작한 과학문화 콘텐츠이다. 양자역학 태동기의 과학자의 논쟁을 다루고 있으며, 과학의 잠정성을 주제로 다루고 있다. 과학 커뮤니케이터와 협업을 통해 창작하였으며 대중에게 유료 공연으로 제공되었다.

과학문화 콘텐츠를 제작하고 대중에게 직접 전달한 경험과 연구 사례로부터, 본 연구자가 도출한 과학문화 콘텐츠 창작 과정에서 과학 커뮤니케이터의 역할은 다음과 같다. 첫째, 과학 뿐만 아니라, 인문학적 시각을 더한 콘텐츠를 제공해야 한다. 과학문화에 관심이 있는 대중에 더하여, 관심을 보이지 않는 대중에게 과학문화의 경험을 제공하기 위해서 그들이 몰입할 동기를 제공해야 한다. 이를 위해 그들의 삶과 과학을 연결짓기 위해 인문학과 융합이 요구된다. 둘째, 직접 콘텐츠를 기획하고 제작할 수 있어야 한다. 대중이 관심 갖는 내용 요소를 발굴하고, 이에 적합한 플랫폼을 선정하여 구성(plot)을 기획한다. 시각, 청각 등 다양한 감각을 유입하여 집중을 유지할 수 있는 콘텐츠를 직접 제작할 수 있는 실무 능력이 필요하다. 셋째, 다른 분야와 협업에서 중재자의 역할이 요구된다. 기존의 과학자 중심의 과학 콘텐츠가 아닌, 문화예술 콘텐츠와 융합한 과학문화 콘텐츠를 제작하기 위해서는 다른 분야에 대한 이해가 요구된다. 또한, 과학 내용 요소를 문화예술 분야 전문가가 이해하기 적합한 형태로 설명하고, 경우에 따라 콘텐츠에 포함할 요소의 위계와 범위를 결정하는 역할이 부여된다. 이 과정에서 다른 분야의 창작 과정을 서로 존중할 수 있으며, 의견을 조율할 수 있는 유연함이 필요하다.

이상의 논의에서 과학 커뮤니케이터에게 요구되는 역량은 사범대학 교육과정을 거친 후 갖게 될 역량과 일부 유사하다. 학교로 공간을 한정하지 않는다면, 학습자의 수준과 관심에 맞는 내용 요소를 조직화할 수 있으며, 콘텐츠를 개발하고 적용하는 과정을 거친다는 면에서 사범대학을 졸업한 과학교육 전공자는 과학 커뮤니케이터로서 과학문화 콘텐츠 창작 과정에서 중요한 역할을 할 수 있을 것으로 기대한다. 아울러 다양한 문화예술 분야 전문가와 협업하며 직접 콘텐츠를 창작하는 경험이 더해진다면, 과학과 인문학을 융합하는 과학 커뮤니케이터로 양성할 수 있을 것이다.

Keywords:

과학문화, 과학커뮤니케이션, 과학교육, 과학연극, 비형식과학교육

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

I13.01

선형잡음문제 공략을 위한 양자알고리즘 개발 연구

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Abstract:

본 발표에서는 양자알고리즘의 계산속도향상과 더불어, 양자컴퓨팅에도 안전할 것으로 믿어지는 양자내성암호의 기본 개념 및 양자내성의 의미에 대해 논의하고자 한다. 특히, 양자내성암호 기반문제의 후보군 중 하나인 격자기반 문제와 선형잡음문제들(Learning-with-errors; LWE, Learning-parity-with-noise;LPN)에 대해 살펴보고, 이를 공략하는 양자알고리즘들에 대한 연구결과들을 소개하고자 한다.

Keywords:

양자알고리즘, 양자내성암호, 선형잡음문제

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2023-04-19 - 2023-04-21

I13.02

Programmable Heisenberg interactions between fixed-frequency superconducting qubits

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Abstract:

The fundamental trade-off between robustness and tunability is a central challenge in the pursuit of quantum simulation and fault-tolerant quantum computation. In particular, many emerging quantum architectures are designed to achieve high coherence at the expense of having fixed spectra and consequently limited types of controllable interactions. Here, by adiabatically transforming fixed-frequency superconducting circuits into modifiable Floquet qubits, we demonstrate an XXZ Heisenberg interaction with fully adjustable anisotropy. This interaction model is on one hand the basis for many-body quantum simulation of spin systems, and on the other hand the primitive for an expressive quantum gate set. To illustrate the robustness and versatility of our Floquet protocol, we tailor the Heisenberg Hamiltonian and implement two-qubit iSWAP, CZ, and SWAP gates with estimated fidelities of 99.32(3)%, 99.72(2)%, and 98.93(5)%, respectively. In addition, we implement a Heisenberg interaction between higher energy levels and employ it to construct a three-qubit CCZ gate with a fidelity of 96.18(5)%. Importantly, the protocol is applicable to various fixed-frequency high-coherence platforms, thereby unlocking a suite of essential interactions for high-performance quantum information processing. From a broader perspective, our work provides compelling avenues for future exploration of quantum electrodynamics and optimal control using the Floquet framework.

Keywords:

Heisenberg interactions, Quantum simulation, Superconducting qubits

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I13.03

Hyperfine Qubits of Neutral Atoms in Programmable Optical Tweezers

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Abstract:

Neutral atoms assembled by programmable optical tweezers are outstanding platforms for quantum simulations, optimizations, and information processing. In this presentation, I will review the recent advances of neutral-atom quantum systems that operate based on their ground-state hyperfine qubits. By selectively switching on and off the strong Rydberg excitations otherwise being well-isolated, the hyperfine qubit-based processors enlarge the range of quantum algorithms running on the neutral-atom systems.

Keywords:

Quantum Information Processing, Neutral-Atom Arrays

Experimental Quantum Transport of Rydberg Excitations

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Abstract:

The Rydberg atom system has emerged as a promising platform for scalable and dynamic quantum simulations. However, previous studies on Rydberg excitation transfer dynamics have been complicated by the need for meticulous initial state preparation involving multiple Rydberg states [1] or susceptibility to thermal noise [2]. In contrast, a simpler method employing a single, thermally resistant Rydberg state has been introduced [3]. In this work, we demonstrate experimentally for the first-time hopping dynamics using this method, by initializing a neutral atom chain to a Rydberg state and applying a laser with detuning far from both resonant and facilitation conditions. We investigate 2- and 3-atom dynamics to verify the theoretically predicted spin exchange rate and observe an 80% success rate of excitation transfer. Furthermore, by adiabatically preparing the single excited initial state, we observe the quantum walk dynamics of a 7-atom chain. Moreover, two-excitation correlated dynamics have been studied, which is a departure from previous studies. We adiabatically prepare dimer and separated excitations and observe correlation spreading through the diagonal of the correlation map, providing evidence of correlated transport. Our scheme is expected to have real-world physics applications, such as exploring rich physics related to nonuniform gauge fields by generating synthetic gauge fields using the multicolor expansion of this experiment [4].

[1] D. Barredo, et al. "Coherent excitation transfer in a spin chain of three Rydberg atoms," Physical Review Letters **114**, 113002 (2015).
[2] M. Marcuzzi, et al. "Facilitation dynamics and localization phenomena in Rydberg lattice gases with position disorder," Physical Review Letters **118**, 063606 (2017).
[3] F. Yang, et al. "Quantum transport of Rydberg excitons with synthetic spin-exchange interactions," Physical Review Letters **123**, 063001 (2019).
[4] X. Wu, et al. "Manipulating synthetic gauge fluxes via multicolor dressing of Rydberg-atom arrays," Physical Review Research **4**, L032046 (2022).

Keywords:

Rydberg atom, Quantum simulation, Excitation transport, Tight binding model

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

I13.05

Dynamical generation of a skyrmion spin texture in a ferromagnetic spinor Bose-Einstein condensate

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Abstract:

In this talk, we present an experimental demonstration of generating skyrmions in a two-dimensional ferromagnetic spinor Bose-Einstein condensate. The process begins by preparing a single magnetic domain wall in the easy-axis ferromagnetic phase. We then imprint the spin current onto the domain wall using a magnetic field gradient. When the spin current exceeds a critical value, a flutter-finger pattern of domain wall waves is observed, which can lead to the formation of skyrmion spin textures [1, 2]. To verify the skyrmion spin texture, we employ the simultaneous readout of magnetization along x and z directions and matter-wave interference technique. An isolated spin up (down) domain is formed in the background of spin down (up) domain, and we observe a fork-shaped interference patterns at the center of the isolated spin domain.
[1] H. Takeuchi, Phys. Rev. A **105**, 013328 (2022)
[2] S. K. Kim and Y. Tserkovnyak, Phys. Rev. Lett. **119**, 047202 (2017)

Keywords:

skyrmion spin texture, magnetic domain wall, ferromagnetic spinor Bose-Einstein condensate, Dynamical generation

2023 KPS Spring Meeting
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I13.06

Two-dimensional coherent motion in a small chain of trapped ions

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Abstract:

In a trapped ion system, the motional degree of freedom is a useful resource that can be utilized to entangle spins (1,2) and simulate bosonic systems(3,4). In these experiments, the quantum motion is excited in only one direction at a time. Here, we demonstrate that the quantum motion along two principal axes can be easily realized. In this experiment, we trap a single ion in a trapping potential highly degenerate in the radial directions. After sideband cooling down to the motional ground state, we apply a bichromatic force to the ion with components in both radial principal axes, which results in a coherent spin-dependent motion in two dimensions. We will discuss some interesting properties of this kind of motion such as a Lissajous-curve-like trajectory. We will also explore how it can be utilized in the implementation of Mølmer–Sørensen gate in a small chain of trapped ions.

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1. Haljan PC, Brickman KA, Deslauriers L, Lee PJ, Monroe C. Spin-Dependent Forces on Trapped Ions for Phase-Stable Quantum Gates and Entangled States of Spin and Motion. Phys Rev Lett. 2005 Apr 22;94(15):153602.
2. Kim K, Chang MS, Islam R, Korenblit S, Duan LM, Monroe C. Entanglement and Tunable Spin-Spin Couplings between Trapped Ions Using Multiple Transverse Modes. Phys Rev Lett. 2009 Sep 16;103(12):120502.
3. Britton JW, Sawyer BC, Keith AC, Wang CCJ, Freericks JK, Uys H, et al. Engineered two-dimensional Ising interactions in a trapped-ion quantum simulator with hundreds of spins. Nature. 2012 Apr;484(7395):489–92.
4. Kim K, Korenblit S, Islam R, Edwards EE, Chang MS, Noh C, et al. Quantum simulation of the transverse Ising model with trapped ions. New J Phys. 2011 Oct;13(10):105003.

Keywords:

trapped ion, atomic physics, quantum information, quantum computing

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I13.07

Quantum Robustness for the Noisy Linear Problem

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Abstract:

In this work, we introduce a fundamental idea and possibility of quantum algorithms for solving the noisy linear problem, which is a basis of modern (digital) cryptography. Those quantum algorithms rely on the famous Bernstein-Vazirani (BV) algorithm, and we mainly suggest that the BV algorithm and its variants are robust to any small noise in the framework of quantum information theory. Finally, we discuss research directions on the ultimate security toward future quantum networks.

Keywords:

Quantum algorithm, Noisy linear problem, Bernstein-Vazirani algorithm, Quantum network

Symmetry engineering of functional complex oxide thin films

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Abstract:

Symmetry plays a crucial role in determining the properties of materials. In particular, deliberate symmetry engineering has discovered and/or maximized a wide range of functional properties in complex oxides, such as ferroelectricity, ferromagnetism, and multiferroicity. Furthermore, when integrated with various electronic properties, such as magnetic and orbital orders, a certain crystalline symmetry promises novel effects and functionalities. In this talk, I will discuss a universal but straightforward approach to exploit symmetry engineering in functional complex oxides.

Keywords:

symmetry, complex oxide, oxide, thin film, transition metal oxide

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

I15.02

New Insight into Mechanisms of Sequential Infiltration Synthesis for Oxide Nanomaterials and Thin Films

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Abstract:

Sequential infiltration synthesis (SIS) has been demonstrated as an emerging route for fabrication of inorganic-organic hybrid materials and inorganic porous materials with an exquisite control over nano- to micro-scale morphology. Previous researchers have proven huge potentials of SIS-derived oxides in a wide range of fields including lithography, filtration, photovoltaics, anti-reflection oil sorption, and triboelectricity. In this talk, I will cover dynamics of precursor infiltration and complex formation within the polymer matrix proved by in-situ Fourier transform infrared spectroscopy, transmission electron microscopy, and atom probe tomography. This work establishes how the new insight into the SIS growth mechanisms can be harnessed to rationally design the process parameters in order to achieve desired pore morphology and chemical composition of the SIS-derived oxide thin films and nanomaterials.

Keywords:

Sequential infiltration synthesis, in-situ FTIR spectroscopy, oxide thin films, porous oxides

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

I15.03

Perovskite oxide-based resistive switching for neuromorphic computing

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Abstract:

음성인식, 사물인지 등 방대한 데이터 처리를 기반으로 '빅데이터' 시대가 도래하였다. 하지만, 현재 주로 하드웨어로 사용 중인 시스템은 폰-노이만 시스템으로 직렬처리 방식 및 정보 처리 저장 파트가 나눠져 있다. 이 시스템적인 단점으로 인해 방대한 양의 데이터를 처리할 때에는 병목현상이 발생하게 된다. 이를 해결하기 위해 메모리 파트에서 정보처리 저장을 진행할 수 있는 프로세스 인 메모리 시스템이 주목받고 있다. 특히, 사람 뇌와 비슷한 병렬처리 시스템으로 뉴로모픽 시스템은 초저에너지 및 휴대 가능하여, 모바일 시스템으로 응용 가능할 것으로 기대된다. 뉴로모픽 시스템은 인간 뇌와 같이, 핵심 장치로 인공 뉴런과 인공 시냅스가 사용된다. 이 두 가지 인공 장치를 페로브스카이트 산화물 구조 기반의 저항 변화 특성을 이용하여 구현하고, 앞으로 나아가야 할 방향을 제시해 보고자 한다.

Keywords:

페로브스카이트 산화물, 저항변화스위칭, 뉴로모픽

I16.01

Updated ECLTRG energy calibration in Belle II Experiment

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Abstract:

We report the status of the updated ECLTRG energy calibration in Belle II.
Our goal is to improve the trigger efficiency and online luminosity monitor(LOM) by improving the ECLTRG energy calibration.
The Belle II experiment accumulated 424 fb^{-1} of integrated luminosity via the SuperKEKB electron-positron collider.
The Electromagnetic Calorimeter Trigger System (ECLTRG) is one of the components of the Belle II detector system consisting of 576 trigger cells (TCs) and provides real-time information about the energy and timing of events.
The energy is calibrated by adjusting the attenuation coefficient (6bits) or gain for fine tuning, or also by using the jumper system which halves the gain.
We have observed that some channels with too high gain cannot be correctly calibrated and can only be calibrated by changing jumper-setting.

Keywords:

Belle II, Energy calibration, Trigger system, Electronmagnetic calorimeter, Attenuator coefficient

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

I16.02

Measurement of branching ratio of B → Xs nu nubar in Belle II experiment

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Abstract:

b→s nu nubar decay is related to the right-handed component which is not expected in Standard Model. Also, new other physics can enhance the branching ratio of the decay. Because the branching ratio of this decay mode does not depend on the form factor, it has theoretically clean. In this presentation, the analysis procedure and expected results are shared. Several kinematic variables are used to suppress background events. Machine learning technique (FBDT) is used in this analysis to improve the result.

Keywords:

EWP, B physics, Belle II

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

I16.03

Measurements of B->₩rho₩gamma at Belle and Belle II

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Abstract:

Flavor changing neutral current (FCNC) is only allowed via at least one loop diagram in the SM, and thus sensitive to the new physics appearing in the loop. B->rhogamma occurred with b->d FCNC, which can seek the new physics effects independently with b->s, such as B->K*gamma. Nevertheless, B->rhogamma suffered from its small branching fraction, which is one order of magnitude less than that of B->K*gamma. Hence the precise measurement using higher statistics is highly important. In this study, branching fraction, CP asymmetry and isospin asymmetry will be measured using Belle (711/fb) and Belle II (364/fb) combined data set.

Keywords:

FCNC, EWP, Radiative, Rare B decay, B factory

I16.04

Search for B^0 -> l τ decays at Belle experiment

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Abstract:

We study lepton-flavor-violating decay $B^0 \rightarrow l\ \tau$ with leptonic τ decay channels (τ to e ν_e ν_τ and τ to μ ν_μ ν_τ). MC samples simulated by Belle detector of KEKB e+e- collider were used. An ₩Upsilon (4S) meson is created by an e+e- collision and decays into two B mesons. One of them is considered as a signal decaying with l and τ, and the other is reconstructed by semileptonic decay. Other B mesons are reconstructed by full-event interpretation (FEI). Basic quality control to suppress events that are dissimilar to signals is performed after skimming. The Toolkit for Multivariate Data Analysis (TMVA) with ROOT toolkit is used for machine learning to perform additional quality control. A boosted decision tree (BDT) i used to optimize the condition that resulted in higher signal purity with more background suppression. For signal extraction, the variable p_l*, which is the basic lepton momentum of the CM frame, is used. From the shape of the signals and the background distribution of p_l*, their PDFs (probability density functions) are estimated. The PDF is used to estimate the MC upper limit in the ToyMC study. The analysis strategy is confirmed by a control sample study using the B -> D π mode. A systematic study is done.

Keywords:

Belle, KEKB, B meson, LFV, BDT

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

I16.05

A Study on Double Dark Photon Modes at e+e- Colliders based on Machine Learning

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Abstract:

We have studied double dark photon modes at electron-positron colliders based on machine learning. Signal modes are e+e- -> A'A' and A'A'gamma with A' (dark photon) decaying into dimuon [1]. Background modes are e+e- -> mu+mu-mu+mu- and mu+mu-mu+mu- gamma. The signal and background data have been generated using MadGraph5 based on the Simplified Model [2] and Standard Model respectively. Next, we have performed detector simulation using Delphes [3]. From the reconstructed physical variables, we have extracted data for machine learning. As a result, we have found the accuracy of separation between signal and background events according to dark photon mass. The result will be used for signal extraction study.

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http://dx.doi.org/10.1088/0954-3899/39/10/105005
[3] See https://cp3.irmp.ucl.ac.be/projects/delphes/browser/git/cards

Keywords:

Dark matter , Dark photon , Electron-positron collider , Machine learning

I16.06

Dark-photon search using B→KA'A', A'→l^+l^- decay at Belle

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Abstract:

We understand only ~5% of our universe, other than that we expect dark matter and energy. Dark-photon is one of the candidate of the dark matter that extend our SM with U(1) mixing. In this presentation, we would like to present recent updated procedure of our dark photon search using B→KA'A', A'→l^+l^- decay, including MC study result and control sample study.
In this analysis, for the data, we used 771 fb^-1 BB samples which was collected from KEKB accelerator and BELLE detectors, for the MC samples we used 10 stream of BB 6 streams of qq 50 streams of rareB 20 streams of ulnu. Each stream corresponds to integrated luminosity of BELLE detector.

Keywords:

Belle, dark photon

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

I16.07

Search for ALP through B to K a' (a' to gamma gamma) Decay at Belle Experiment

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Abstract:

In this study, we present a search for ALPs in the B to K a' decay, where a' is a light boson that can decay to two photons (a' to gamma gamma). The analysis is performed using data from the Belle experiment, a high-energy e+e- asymmetric head-on colliding physics experiment located in KEK, Japan which collect 710 fb^-1 of Y(4S) data.
The procedure for the search involves selecting events with a B meson and a kaon, and searching for a photon pair consistent with the decay of a' to gamma gamma. The expected signal and background yields are estimated using Monte Carlo simulations, which are validated using control samples in data. The main sources of background are shown to arise from processes involving real photons, such as B to K* gamma decays, and fake photons from hadronic decays. The results of the study are presented in terms of upper limits on the branching fraction for B to K a' (a' to gamma gamma) decays, as a function of the a' mass.

Keywords:

ALP, B Meson, Belle Experiment

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

I16.08

Precision measurement of Coherent Elastic Neutrino Nucleus Scattering

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Abstract:

Coherent elastic neutrino-nucleus scattering (CEvNS) was predicted in 1974 as a consequence of the neutral current. It is the dominant neutrino scattering channel below 100MeV. Though CEvNS has the largest cross-section of low-energy neutrino scatterings, it has eluded detection for 43 years. It is because the CEvNS search requires O(10keV) threshold detector and an intense neutrino source. COHERENT collaboration measured the CEvNS on argon target for the first time using the neutrinos from the Spallation Neutron Source at Oak Ridge National Laboratory. The measured result is consistent with the Standard Model prediction, but still shows ~30% statistical uncertainty in cross-section. In this talk, I will introduce the CENNS-1ton detector, a ton-scale LAr CEvNS precision detector.

Keywords:

Neutrino, CEvNS, COHERENT

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

I16.09

First implementation of BSM parton showers in Herwig7

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Abstract:

Physicsists have been scrutinizing vaious types of BSM particles under an assumption that they are generated in hard processes, but thus far no direct evidence is observed. This gives a great chance to explore new phase space with unprecedented processes, especially the study of BSM radiations. This presentation describes necessary steps to implement BSM parton showers in Herwig7. We validate our results by comparing them to fixed-order calculations and evaluate their implications for preceeding BSM studies. This is the first successive attept to implement BSM particle splittings in the general-purpose event generator.

Keywords:

Herwig7, parton shower, generator, Beyond the Standard Model(BSM)

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

I17.01

Target and beam dump at FRIB

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Abstract:

The FRIB accelerator, constructed and commissioned in 2021, is utilized to produce rare isotopes and access elements that lie beyond stability. The production of rare isotopes such as $^{44,45}P$, $^{42,43}Si$, $^{40,41}Si$ and ^{38}Mg for the half-life measurements was done using a 1 kW 48Ca^{20+} primary beam at 172.3 MeV/u on ^{9}Be target. The primary beam power is now being ramped up to the goal of 400 kW. The high-power target and beam dump play a crucial role in the power ramp up phase at FRIB. In 2022, FRIB was successfully operated at 3 kW using beams of ^{124}Xe and ^{36}Ar on a rotating single-slice graphite target and a static beam dump and the primary beam power is now being increased towards 10 kW. We present the current status, and R&D for the target and beam dump at FRIB.
This work was supported by the U.S. Department of Energy Office of Science under Cooperative Agreement DE-SC0000661, the State of Michigan, and Michigan State University.

Keywords:

FRIB, single-slice graphite target, static beam dump

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

I17.02

Current status of KoBRA for low-energy nuclear physics experiments

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Abstract:

A multi-purpose experimental instrument, called as KoBRA (Korea Broad acceptance Recoil spectrometer and Apparatus), has been constructed for low-energy nuclear physics experiments at RAON (Rare Isotope Accelerator complex for ON-line experiments). KoBRA is currently under preparation for the purpose of producing rare isotope beams at an energy of about 20 MeV per nucleon in the early stage of beam commissioning. In this presentation, we report on the detailed design of KoBRA including ion optics and the detection system, together with the test results.

Keywords:

Rare Isotope Science Project, RAON, KoBRA, Recoil Spectrometer

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

I17.03

KoBRA Wien Filter: Specifications and Status

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Abstract:

The Wien filter, also known as a velocity filter, is the key element in ion optics. It consists of a dipole magnet generating a magnetic field, and an electrostatic system generating an electric field. Both fields are perpendicular to each other as well as the beam axis. Ions with the certain velocity can be separated by properly adjusting the field intensities.
KoBRA, Korea Broad acceptance Recoil spectrometer and Apparatus, is one of the low-energy beamlines of RAON, the first RI beam facility in Korea. One of the main purposes of KoBRA is to separate and to identify low-energy rare isotopes using products from the nuclear reaction such as multi-nucleon transfer. KoBRA has been established and tested with radioactive fission source in 2021, and will be commissioned with an ion beam of ~ 20 MeV/nucleon delivered from RAON.
Recently, CENS launched the project to install the Wien Filter in the KoBRA beamline. KoBRA Wien Filter is expected to improve the performance of KoBRA in RI beam production. Its specifications were determined based on the optimal ion optics of KoBRA to produce a low-energy beam. The project is in the manufacturing phase and we expect that it will be installed within 2023.
In this talk, the status of KoBRA Wien Filter development and the details of its specifications will be presented as well as the ion optics calculation results. Moreover, future plans for the RI beam production and separation in KoBRA will be discussed.

Keywords:

RAON , KoBRA, Wien filter

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

I17.04

Development of a LaBr3 detector array for high-energy gamma-ray measurement

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Abstract:

We developed a LaBr3 detector array (HANULball) for measuring capture gamma rays in the energy up to 10 MeV. The HANULball comprises 10 LaBr3(Ce) detectors on the surfaces of a truncated cuboctahedron structure. The LaBr3 crystal is 50 mm in diameter and 75 mm in length. A prototype array uses a photomultiplier tube to detect scintillation light, and a 4x4 MPPC array will replace it for the final detector. We tested the performance of the prototype array using radioactive sources (137Cs, 60Co, and AmBe) and cosmic rays. We also measured capture gamma rays from Al(p,g)Si reaction at Ep=1.317 MeV at KIST. This talk will present the preliminary results of the LaBr3 detector performance over a wide range of gamma-ray energy.

Keywords:

LaBr3, gamma-ray, PMT

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

I17.05

Design of Low-pressure Gas TPC for Stellar Nucleosynthesis Reactions

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Abstract:

We designed an active-target Time Projection Chamber (aTPC) for stellar nucleosynthesis reactions. The aTPC will measure a low-energy 16O recoil track in a 12C(α,γ)16O reaction. It will operate with a low-pressure gas mixture in a 2.5 T magnetic field. A new gas system can control the pressure between 0.05 and 1 atm. The aTPC dimension fits the coil gap and room-temperature bore size of the 3-T superconducting magnet. The aTPC comprises a cathode plane, four field-cage planes, a gating GEM (Gas Electron Multipliers) plane, a triple GEM structure, and a pad plane. The pad plane covers 10 x 10 cm2 with 1000 of 3x3 mm2 square pads. We performed a simulation study on the aTPC performance. First, we generated 12C(α,γ)16O reactions at E=6 MeV and simulated recoil trajectories in a gas volume using Geant4. In addition, we obtained the drift electron and ion properties in a Garfield++ simulation on three different GEM candidates; polyimide, glass, and FR4 substrates between the clad layers. This talk will present the aTPC design and its expected performance with Geant4 simulation.

Keywords:

Active-target TPC, low pressure, GEM, steller nucleosynthesis

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

I17.06

Development of a mono-energetic neutron field in KRISS

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Abstract:

A mono-energetic neutron field using an electrostatic accelerator has been developed at the Korea Research Institute of Standards and Science. The electrostatic accelerator with a maximum high voltage of 400 kV and a maximum beam current of 0.5 mA was installed to accelerate deuterons. A target chamber for the deuterated target and tritiated targets was developed and installed. After validating the performance of the accelerator system, neutrons with 2.5 MeV and 14.8 MeV from DD and DT reactions were produced. Measurement techniques for neutron fluence and energy were under development. The current status and plans with mono-energetic neutron fields will be discussed.

Keywords:

Mono-energetic neutron field, DD reaction, DT reaction

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

I18.01

Conformally stationary locally rotationally symmetric solutions and horizons

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Abstract:

We study the existence of timelike gradient conformal Killing vector (CKV) fields in spacetimes exhibiting local rotational symmetry, and provide explicit candidate examples. Properties of horizons generated by timelike CKVs are studied and the conditions for the existence of blackholes (and consequently incomplete geodesics) are determined.

Keywords:

Local rotational symmetry, Conformal Killing vector, Conformal Killing horizon, Black hole, Incomplete geodesic

I18.02

Scalar Field in Myers-Perry Black Hole with Arbitrary Rotations

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Abstract:

We investigate the scattering of a massless scalar field based on the weak cosmic censorship conjecture in Myers-Perry black holes with arbitrary rotations in general dimensions. From the fluxes of the scalar field flowing into the black hole, the changes in mass and angular momenta of the black hole are obtained. The extremal and near-extremal black holes are herein stable under this process. Hence, the conjecture is valid.

Keywords:

Black Holes, Scattering, Weak Cosmic Censorship Conjecture

I18.03

Constructing Black Hole Dominated Universe Model by Numerical Relativity

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Abstract:

Modern cosmology has dark energy and dark matter problems. There are three major approaches to solving the problem. The first ways are to introduce exotic matters, and the second ways are to modify the theory of gravity. As a third way, we explore the effects of local inhomogeneities on universe. For this purpose, we construct a cosmological model including black holes with a rotation imitating galaxy cores. To solve the Einstein equation, we introduce numerical relativity. Then, we show the solutions and discuss their implications.

Keywords:

numerical relativity, cosmology, black hole

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

I18.04

Growth of Massive Black Hole via Tidal Disruption Events

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Abstract:

The formation and growth history of the massive black holes (MBHs) at the galactic centers is of great importance in astrophysics.
In most numerical experiments until now concerning about the co-evolution of a MBH and its host galaxy, gas accretion has been considered as the main source of the MBH growth. Meanwhile, studies have predicted that stars that are tidally disrupted by the MBH may contribute significantly to the growth of the MBH, especially in dense nuclear star clusters (NSCs).

Yet, this tidal disruption accretion (TDA) of stars onto the MBH has largely been overlooked. In this work, we implement a black hole growth channel via TDA in the high-resolution adaptive mesh refinement code Enzo to investigate its influence on a MBH seed's early evolution.
We find that a MBH seed grows rapidly from 10^3 $M_\odot$ to $\geq 10^6$ $M_\odot$ in 200 Myrs in some of the tested simulations.
Compared to a MBH seed that grows only via gas accretion (GA), TDA can enhance the MBH's growth rate by up to more than an order of magnitude. However, as predicted, TDA mainly helps the early growth of the MBH (from 10^{3-4} $M_\odot$ to 10^5 $M_\odot$) while the later evolution is generally dominated by GA.

We also observe that the star formation near the MBH is suppressed when TDA is most active, sometimes with a visible cavity in gas (of size ~ a few pc) created in the vicinity of the MBH. It is because the MBH may grow expeditiously with both GA and TDA, and the massive MBH could consume its neighboring gas faster than being replenished by gas inflows. Our study demonstrates the need to consider different channels of black hole accretion that may provide clues for the existence of supermassive black holes at high redshifts.

Keywords:

Massive Black Hole, Galaxy, Star Clusters, Tidal Disruption

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

I18.05

Satellite Galaxy Populations In A Cosmological Simulation and its Physical Implications

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Abstract:

We analyze and compare the satellite halo populations at z~2 in the high-resolution cosmological zoom-in simulations of a 10^12 Msun target halo (z=0 mass) carried out on seven widely-used astrophysical simulation codes (ART-I, ENZO, RAMSES, CHANGA, GADGET-3, GEAR, and GIZMO) for the AGORA High-resolution Galaxy Simulations Comparison Project (Roca-Fabrega et al. 2021). We use different redshift epochs near z=2 for each code (hereafter called “z~2”) at which the seven CosmoRuns are in the same stage in the target halo’s merger history. We also study the dark matter-only (DMO) simulations with the same cosmological initial condition to isolate the effect of baryonic physics. Mainly, we investigate so-called "missing satellite problem" and try to find an “astrophysical" solution.

Keywords:

galaxies:formation, galaxies:evolution, galaxies:kinematics and dynamics, galaxies:structure, methods:numerical

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

I18.06

Understanding Galaxy Rotation Curves with Verlinde's Emergent Gravity

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Abstract:

Galaxy rotation curves cannot be explained without dark matter if Newtonian gravity is correct. If Newtonian gravity is not correct, we need an alternative theory of gravity, such as MOND (Modified Newtonian Dynamics). However, while MOND explains galaxy rotation curves very well, it is unsatisfactory from a physical and conceptual point of view. Its key equation was proposed to fit the data, not to explain the data. From this perspective, Verlinde's emergent gravity has a superior advantage. Its theory comes from a simple physical concept, yet it can explain galaxy rotation curves as well as MOND.

Keywords:

MOND, galaxy rotation curve, Verlinde's emergent gravity, alternative gravity theory, dark matter

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

I18.07

Bubble nucleation during inflation and its cosmological consequences.

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Abstract:

We discuss the bubble nucleation process, from false to true vacuum transition, during inflation and the cosmological consequences of such process within the modified gravity framework, namely, Dilaton-Einstein-Gauss-Bonnet gravity. In particular, we present our result by discussing the formation of primordial black holes and the spectral distortions in the CMB spectrum.

Keywords:

Inflation, Bubble nucleation, PBH formation

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

I18.08

An exact solution of the higher-order gravity in standard radiation-dominated era

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Abstract:

We report that the standard evolution of radiation-dominated era (RDE) universe is a sufficient condition for solving a sixth order gravitational field equation derived from the Lagrangian containing B $R^{ab}R_{ab}$+C R $R^{;c}{}_{c}$ as well as a polynomial f(R) for a spatially flat radiation FLRW universe. By virtue of the similarity between RabRab and R2 models up to the background order and of the vanishing property of $R^{;c}{}_{c}$ for H=1/(2t), the analytical solution can be obtained from a special case to general one. This proves that the standard cosmic evolution is valid even within modified gravitational theory involving higher-order terms. An application of this background solution to the tensor-type perturbation reduces the complicated equation to the standard second order equation of gravitational wave. We discuss the possible ways to discriminate the modified gravity model on the observations such as the gravitational wave from the disturbed universe and primordial abundances.

Keywords:

Cosmology, Modified gravity, Radiation-dominated era, Hubble expansion rate

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

I18.09

The Wheeler-DeWitt Equation Beyond the Cosmological Horizon

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Abstract:

We discuss the Wheeler-DeWitt equation for a black hole with cosmological constants. Especially, if we consider a positive cosmological constant, one can consider the wave function beyond the cosmological horizon. Interestingly, we can assign the vanishing boundary condition for beyond the cosmological horizon. We discuss its physical meaning.

Keywords:

quantum cosmology, decoherence

I19.01

Positivity Bounds on Higgs-Portal Dark Matter

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Abstract:

We consider the positivity bounds for WIMP scalar dark matter with effective Higgs-portal couplings up to dimension-8 operators. Taking the superposed states for Standard Model Higgs and scalar dark matter, we show the part of the parameter space for the effective couplings, otherwise unconstrained by phenomenological bounds, is ruled out by the positivity bounds on the dimension-8 derivative operators. We find that Dark matter relic density, direct and indirect detection, and LHC constraints are complementary to the positivity bounds in constraining the effective Higgs-portal couplings. In the effective theory obtained from massive graviton or radion, there appears a correlation between dimension-8 operators and other effective Higgs-portal couplings for which the strong constraint from direct detection can be evaded. Nailing down the parameter space mainly by relic density, direct detection, and positivity bounds, we find that there are observable cosmic ray signals coming from the Dark matter annihilations into a pair of Higgs bosons, WW or ZZ.

Keywords:

Dark Matter, Positivity

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

I19.02

Inflation and tachyonic preheating with twin waterfalls

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Abstract:

In view of the improving measurements of the tensor-to-scalar ratio, hybrid inflation remains a suitable mechanism to achieve low-scale inflation. However, as originally proposed, hybrid inflation with a single waterfall field gives rise to a hierarchy problem, also known as the ₩eta problem. In this work, we consider an extension to the original model in which twin waterfall fields, related by a Z_2 symmetry, ensure the flatness of the inflationary potential. We study the initial conditions required for successful inflation and the post-inflationary epochs of perturbative reheating and tachyonic preheating. We also comment on how our model can arise from a microscopical dark QCD model.

Keywords:

Hybrid inflation, reheating, preheating

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

I19.03

Reanalysis of dark matter detection data from LZ(LUX-ZEPLIN) and PandaX-4T

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Abstract:

Currently, LZ and PandaX-4T are the most sensitive dark matter (DM) direct detection (DD) experiments. We analyze the LZ and PandaX-4T data assuming a standard halo model and spin-independent DM-nucleon interaction. In our calculation, we use the WimPyDD code that accurately calculates the event rate in a DD experiment. We implement LZ and PandaX-4T experiments in WimPyDD, taking advantage of its adaptability to accommodate new experiments. Since no DM signal has been observed in LZ and PandaX-4T experiments, we analyze their exclusion limits on the spin-independent DM-nucleon cross-section.

Keywords:

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

I19.04

WIMPy baryogenesis with Primordial Black Hole

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Abstract:

We propose a model of baryogenesis achieved by the annihilation of non-thermally produced WIMPs from Primordial Black Hole (PBH). Dark Matter (DM) can be produced by PBH evaporation, and consequently re-annihilate to the lighter particles even after thermal freeze-out. The re-annihilation of DM provides the observed baryon asymmetry and the correct relic abundance of DM depending on the PBH evaporation temperature.

Keywords:

PBH, WIMP dark matter, baryogenesis

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

I19.05

The Cold and Light Dark Matter

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Abstract:

The successful formation of structures in the universe requires dark matter to be cold or warm, and thermally produced particles with a mass of several keV or more satisfy this condition. However, non-thermal production can result in much lighter particles that still exhibit the characteristics of cold dark matter. In this study, we investigate the mass range for non-thermally produced particles that can serve as cold dark matter.

Keywords:

Dark Matter, Cold Dark Matter, Light Dark Matter

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

I19.06

Cored Dark Matter halos in the Cosmic Neutrino Background

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Abstract:

We study the impact of the interaction between DM and the cosmic neutrino background on the evolution of galactic dark matter halos. The energy transfer from the neutrinos to the dark matter can heat the center of the galaxy and make it cored. This effect is efficient for the small galaxies such as the satellite galaxies of the Milky Way and we can put conservative constraint on the non-relativistic elastic scattering cross section as $\sigma_{\chi\nu} \lesssim 10-31\ cm^2$ for 0.1 keV dark matter and 0.1 eV neutrino.

Keywords:

Cosmic Neutrino Background, DM Halo Evolution

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

I19.07

Probing sterile neutrino dark matter in the PTOLEMY-like experiment

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Abstract:

We study the prospect to detect the cosmic background of sterile neutrinos in the Tritium β-decay, such as PTOLEMY-like experiments. The sterile neutrino with mass between 1 eV - 10 keV may contribute to the local density as warm or cold DM component. In this study, we investigate the possibility for searching them in the models with different production in the early Universe, without assuming sterile neutrino as full dark matter component. In these models, especially with low-reheating temperature or phase transition, the capture rate per year can be greatly enhanced to be O(10) without violating other astrophysical and cosmological observations.

Keywords:

sterile neutrino, cosmology, warm dark matter, PTOLEMY experiment, cosmic neutrino background

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

I19.08

Secret neutrino interaction at future tau neutrino experiments

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Abstract:

We study the prospects of searching for hidden interaction of neutrinos mediated by a new light sub-GeV gauge boson, $Z^\prime$ and the coupling $g_{\alpha \beta }$ at the future tau neutrino experiments including Liquid argon detector DUNE and the Forward Liquid Argon Experiment (FLArE100) detector at the Forward Physics Facility (FPF) as well as in the emulsion detector experiments, SND@LHC, FASERν2 and SND@SHiP.

Keywords:

Secret neutrino Interaction, Atmospheric neutrino, BSM

Solar neutrinos and future experiments

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Abstract:

In this talk, we review the production of solar neutrinos and their propagation within the Sun and the Earth. The LMA-MSW solution explains the flavor change of solar neutrinos. However, there are some tensions between the data and predictions. In order to resolve these tensions, new physics such as Non-Standard neutrino Interaction (NSI) or the presence of a new sterile neutrino are proposed. Moreover, we are moving to a phase of sub-percent precision with future solar neutrino experiments such as LSC at Yemilab. In this talk, I will discuss how we will be sensitive to the Earth tomography using day-night asymmetry of solar neutrinos and new physics such as NSI and super-light sterile neutrino scenarios.

Keywords:

Solar neutrinos, NSI, Sterile neutrino

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

I19.10

Continuous Spectrum on Cosmological Collider

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Abstract:

We study the effects of a massive field with a continuous spectrum (continuum isocurvaton) on the inflationary bispectrum in the squeezed limit. As a concrete example, we extend the quasi-single field inflation model to include a continuum isocurvaton with a well-motivated spectral density from extra dimensions and focus on a contribution to the bispectrum with a single continuum isocurvaton exchange. In contrast to the usual case without the continuous spectrum, the amplitude of the bispectrum has a damping feature in the deep squeezed limit, which can be strong evidence for the continuous spectrum.

Keywords:

Inflation, non-Gaussianity

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

I19.11

Complementarity of direct detection experiments of dark matter-nucleon scattering in non-relativistic effective theory

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Abstract:

Considering spin one half dark matter-nucleon interaction, it depends on 14 coupling operators. Some of the published upper limits are sometimes neglecting the interference among those operators, therefore they can not be generally applied to various dark matter detections experiments at the same time. I present a method to determine conservative upper limits including all possible interferences including long range interactions via a massless propagator. Combining direct detection experiments such as LZ, PandaX-4T, PICO-60, I show that variation of the exclusion plots can be mild of spin-dependent type interactions thanks to the complementarity of an effect of proton-odd and neutron-odd targets.

Keywords:

Dark Matter, WIMP, Direct detecion experiments

Halo-independent bounds on the non-relativistic effective theory of WIMP-nucleon scattering from direct detection and neutrino observations

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Abstract:

In my presentation I will talk about the halo-independent bounds on the WIMP-nucleon couplings of the non-relativistic effective Hamiltonian that drives the scattering process off nuclei of a WIMP of spin 1/2. We will see that for most of the couplings the degree of relaxation of the halo-independent bounds compared to those obtained by assuming the Standard Halo Model is with few exceptions relatively moderate in the low and high WIMP mass regimes, where it can be as small as a factor of 2, while in the intermediate mass range (10 -- 200 GeV) it can be as large as 1000. An exception to this general pattern, with more moderate values of the bound relaxation, is observed in the case of the spin-dependent type WIMP-proton couplings with no or a comparatively small momentum suppression, for which WIMP capture in the Sun is strongly enhanced because it is driven by scattering events off Hydrogen, the most abundant target in the Sun. Within this class of operators the relaxation is particularly small for interactions that are driven by only the velocity-dependent term, for which the solar capture signal is enhanced because of the high speed of scattering WIMPs inside the strong gravitational field of the Sun.

Keywords:

WIMP dark matter, direct detection, neutrino telescope, non-relativistic effective theory, halo-independent bound

PL1.01

A world view of Nuclear Physics from Working Group 9 of the International Union of Pure and Applied Physics

TRIBBLE Robert E.*[1,2]
[1]Physic & Astronomy, Texas A&M University, USA
[2]Science and Technology, Brookhaven National Lab, USA
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Abstract:

In this presentation, I will briefly discuss the science challenges that the world-wide Nuclear Physics community is addressing and I will give an overview of the major facilities that are now operating, or are under construction, that provide the experimental capabilities to address these challenges. The basis for the presentation is the Nuclear Physics Symposium that Working Group 9 held in June, 2022.

Keywords:

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

PL1.01

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Keywords:

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Keywords:

PL1.01

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Abstract:

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Keywords:

Synthesis of van der Waals semiconductor materials on wafer scale

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Abstract:

Recently, two-dimensional (2D) van der Waals semiconductiot materials have been highlighted due to their exotic physical and chemical properties. For commercial applications, wafer-scale 2D materials are highly required. In this tutorial, I present the recent progress for the synthesis of 2D materials via chemical vapor deposition. The various strategies for diverse 2D materials growth are discussed. In addition, the facile synthesis for single crystal 2D materials is also addressed.

Keywords:

two-dimensional materials, single crystal, graphene, transition metal dichalcogenides

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

TA3.02

Low-dimensional Nanomaterials into Functional Devices

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Abstract:

Low-dimensional nanomaterials have attracted widespread attention in various fields of research endeavors owing to their unique and desirable physical properties. We have synthesized various kinds of high-quality low-dimensional materials using bottom-up (chemical vapor deposition, ligand exchange approach, solution phase deposition, and hydrothermal reaction) or top-down method (mechanical and liquid phase exfoliations). Furthermore, we modulated the physicochemical and optical properties of low-dimensional materials through heterostructure formation, phase transition, vacancy formation, functionalization, and chemical composition control, and demonstrated diverse applications of property-modulated low-dimensional nanomaterials including electrochemical water splitting with outstanding stability and performance and ultrasensitive chemical sensor. We also investigated promising possibility of low-dimensional nanomaterials in various components of photovoltaics including transparent conducting electrode, charge transporting layer, and interfacial buffer layer. The low-dimensional nanomaterials enhanced the performance and flexibility of functional devices through the enhanced charge transfer efficiency, mechanical robustness, and light absorption capability.

Keywords:

low-dimensional materials, transition metal dichalcogenides, perovskite oxide, catalysis

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

TA4.01

Toword useful quantum information processors

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Abstract:

Quantum computing has been attracted a lot of attention due to the potential applications in many area. Yet, it seems undesirable to implement a fully working quantum computer near in the future. On the other hand, rapid development of noisy intermediate-scale quantum (NISQ) computers opens a new avenue to find practical applications using those imperfect devices with hands.

In this tutorial, I introduce basics of quantum information processing and answer how quantum computers can outperform classical computers. Then, I present classical-quantum hybrid computing approach to implement useful applications using near term quantum devices. As an example, variational quantum eigensolver (VQE) will be intoduced. I will also present the recent KIST efforts to contribute useful quantum information processors using photonic system and/or spin system in solids.

Keywords:

Quantum computer, Quantum simulator, Noisy intermediate-scale quantum (NISQ)

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

TA7.01

Machine learning for strongly correlated systems: spectral analysis

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Abstract:

Machine learning has become a powerful tool for identifying hidden correlations in data, making it applicable to various fields, including condensed matter physics. This tutorial provides an introduction to the main processes of machine learning with a focus on its application to spectrum analysis in condensed matter physics. In particular, the tutorial aims to aid beginners in utilizing machine learning for their research by providing an overview of the key processes involved in machine learning. Based on the trials and errors we experienced in our project, I emphasize the importance of data quality in determining the performance of a machine learning model and explore considerations for constructing data sets and analyzing model performance based on training data and features.

Keywords:

Machine learning, Supervised learning, Spectral analysis

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

TA7.02

Computational material design in strongly correlated systems: current status and benefits from machine learning techniques

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Abstract:

The design of correlated materials challenges researchers to combine the maturing, high throughput framework of DFT-based materials design with the rapidly-developing first-principles theory for correlated electron systems. We introduce a material design workflow, and illustrate it via some examples, highlighting the interplay between theory and experiment with a view towards finding new correlated materials. We review the statistical formulation of the errors of currently available methods to estimate formation energies. We formulate an approach for estimating a lower-bound for the probability of a new compound to form. Correlation effects have to be considered in all the material design steps. These include bridging between structure and property, obtaining the correct structure and predicting material stability. We introduce a post-processing strategy to take them into account. Finally, we discuss future directions for computational material designs with machine learning techniques.

Keywords:

Computational material design, Strongly correlated system, Density functional theory, dynamical mean-field theory, Machine learning technique

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

TA14.01

Microfluidics for physicist

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Abstract:

Microfluidics is a multidisciplinary research field handling fluidic phenomena at a micrometer scale, which spans from studying the physics of fluid to applications to many areas including biophysics, biology, chemistry, and material science. Special features of microfluidics including laminar flow and large surface-to-volume ratio allow many advantages compared to bulk counterparts. For example, microfluidic biosensors can have higher sensitivity and fast response time, and laminar flow arising from low-Reynolds-number characteristics allows precise control of samples. Moreover, microfluidic devices can be constructed as parallelized microchannels to enable multiplexed experiments in an automated manner

In this tutorial session, I will introduce the basics of microfluidics and show examples of how microfluidics can help biophysics research. I will also cover practical methods to design and make microfluidic chips for various purposes, such as chemical gradient generation, fast sample mixing, droplet generation, and single-cell capture.

Keywords:

Microfluidics, Biophysics

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

TA16.01

Applications of steering and radiation effects in oriented crystals and their implementation into Geant4

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Abstract:

We present the first results on implementation of electromagnetic processes of charged particles interaction with oriented crystals into Geant4 simulation toolkit. We discuss the impact of this model on the development of the following applications: an X-ray and gamma radiation source for radiotherapy and nuclear physics, a positron source for lepton and muon future colliders, an ultracompact electromagnetic calorimeter for high-energy experiments, crystal-based extraction and collimation of leptons and hadrons in an accelerator, a fixed target experiment on magnetic and electric dipole moment measurement and a compact wake field accelerator.

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Keywords:

Geant4, MC simulations, Oriented crystals

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

TA16.02

A study on Geant4 using beam simulation at fixed target experiments

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Abstract:

A study on Geant4 using beam simulation at fixed target experiments is introduced. In this study Geant4-11.0.2 simulation tool kit is used. In the fixed target experiment, secondary particles have been relatively little concentrated. Therefore, it needs to be studied. The simulation results between liquid hydrogen fixed target and various heavy ion beam were compared with experimental data. To determine the optimized model which best describes the expected physical phenomena, we study various Geant4 physics models. Using the optimized model, we present physical properties of the primary proton beam and secondary heavy ion beam at the fixed target experiment. These results will help future fixed target experiment to get secondary particles.

Keywords:

Geant4, MC simulation, Fixed target experiment, Beam simulation

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

TA16.04

Optimization of the electron endcap tracker for ECCE

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Abstract:

The proposed Electron Ion Collider (EIC) physics program initiated a few studies of the detector design.
The EIC Comprehensive Chromodynamics Experiment (ECCE) detector is
the representative one conducted by a large number of participants.
The ECCE detector offers nearly acceptance and energy coverage along with excellent tracking and particle identification

to achieve the specification dictated by the EIC yellow report[1].
However a shortage was reported for the track momentum resolution in the backward(electron going) direction[2].
We considered possible modifications in the tracker of the electron endcap
and performed studies on the possible improvements.
The outcome of the study will be reported.
[1] arXiv:2209.02580v1 [physics.ins-det]
[2] arXiv:2103.05419v3 [physics.ins-det]

Keywords:

Electron Ion Collider (EIC), EIC Comprehensive Chromodynamics Experiment (ECCE), Detector design

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

TA16.05

Implementation of the ACTS tracking software into the COMET Phase-II experiment

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Abstract:

A Common Tracking Software (ACTS) is a novel track reconstruction toolkit developed from the tracking algorithms in the ATLAS experiment. It intends to serve as a framework-independent and experiment-indepedent toolkit. A preliminary implementation of ACTS into the COMET Phase-II experiment was done. To achieve a target sensitivity of the order of 10^{-17}, more than 10^{20} protons will be produced in the second phase of COMET, and the subsequent data will be collected and analysed with limited computing power. Thus, it is essential to perform the reconstruction of the trajectories of the particles in a timely manner. In this presentation, and overview of ACTS and its implementation into COMET is given.

Keywords:

CLFV, Muon experiment, Track reconstruction

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

TA19.01

Emergent N=4 supersymmetry from N=1

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[2]Walter Burke Institute for Theoretical Physics, Caltech
[3]Deutsches Elektronen-Synchrotron, DESY
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Abstract:

We discover a four-dimensional N = 1 supersymmetric field theory that is dual to the N = 4 super Yang–Mills theory with gauge group SU(2n + 1) for each n. The dual theory is constructed through the diagonal gauging of the SU(2n+1) flavor symmetry of three copies of a strongly-coupled superconformal field theory (SCFT) of Argyres–Douglas type. We find that this theory flows in the infrared to a strongly-coupled N = 1 SCFT that lies on the same conformal manifold as N = 4 super Yang–Mills with gauge group SU(2n + 1). Our construction provides a hint on why certain N = 1, 2 SCFTs have identical central charges (a = c).

Keywords:

supersymmetry, superconformal field theory, N=4, duality, Non-Lagrangian

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

TA19.02

Brane Brick Models for the Sasaki-Einstein 7-Manifolds Y^{p,k}(CP^1 x CP^1) and Y^{p,k}(CP^2)

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Abstract:

The 2d (0,2) supersymmetric gauge theories corresponding to the classes of Y^{p,k}(CP^1 x CP^1) and Y^{p,k}(CP^2) manifolds are identified. The complex cones over these Sasaki-Einstein 7-manifolds are non-compact toric Calabi-Yau 4-folds. These infinite families of geometries are the largest ones for Sasaki-Einstein 7-manifolds whose metrics, toric diagrams, and volume functions are known explicitly. This work therefore presents the largest classification of 2d (0,2) supersymmetric gauge theories corresponding to Calabi-Yau 4-folds with known metrics.

Keywords:

supersymmetric gauge theories, Calabi-Yau 4-folds, Sasaki-Einstein 7-manifolds

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

TA19.03

Holographic entanglement entropy probe on spontaneous symmetry breaking with vector order

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Abstract:

We study holographic entanglement entropy in 5-dimensional charged black brane geometry obtained from Einstein-SU(2)Yang-Mills theory defined in asymptotically AdS space. This gravity system undergoes second order phase transition near its critical point affected by a spatial component of the Yang-Mills fields, which is normalizable mode of the solution. This is known as phase transition between isotropic and anisotropic phases. We get analytic solutions of holographic entanglement entropies by utilizing the solution of bulk spacetime geometry given in arXiv:1109.4592, where we consider subsystems defined on AdS boundary of which shapes are wide and thin slabs and a cylinder. It turns out that the entanglement entropies near the critical point shows scaling behavior such that for both of the slabs and cylinder, $\Delta_\varepsilon S \sim (1-T/T_c)^\beta$ and the critical exponent $\beta=1$, where $\Delta_\varepsilon S \equiv S_{iso} - S_{aniso}$, and Siso denotes the entanglement entropy in isotropic phase whereas Saniso denotes that in anisotropic phase. We suggest a quantity $O_{12} \equiv S_1 - S_2$ as a new order parameter near the critical point, where S_1 is entanglement entropy when the slab is perpendicular to the direction of the vector order whereas S_2 is that when the slab is parallel to the vector order. $O_{12}=0$ in isotropic phase but in anisotropic phase, the order parameter becomes non-zero showing the same scaling behavior. Finally, we show that even near the critical point, the first law of entanglement entropy is hold. Especially, we find that the entanglement temperature for the cylinder is $T_{cy}=c_{ent}/a$, where $c_{ent}=0.163004\pm 0.000001$ and a is the radius of the cylinder.

Keywords:

Holographic entanglement entropy, aniostropic holographic superfluids, spontaneous symmetry breaking

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

TA19.05

Encoding the lattice in the Holography

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Abstract:

We consider how to implement a lattice structure. We use hamiltonian at the tight binding level and embed the result in the Dirac equation. For each band, we assign the Dirac fermion. For example, the three bands system has three fermions, each of which satisfies the Dirac equation in the AdS bulk. We work out the simplest cases: Graphene, Lieb, and Kagome lattice. We compare the result of three examples with ARPES data.

Keywords:

AdS/CMT, Tight-binding, Graphene, Lieb, Kagome, Spectral Density, Holography

2023 KPS Spring Meeting
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TA19.06

Quantum Gravity for Nearly-AdS_2 Revisited

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Abstract:

We study the quantum gravity for nearly-AdS_2. We first present the SL(2) BF theory to describe the nearly-AdS_2, and we demonstrate that this theory is reduced to the Schwarzian theory on the boundary. In addition, we also discuss the Jackiw-Teitelboim model for the nearly-AdS_2, and we provide a precise proof to derive the Schwarzian theory.

Keywords:

JT gravity, Quantum Gravity, Schwarzian theory, SL(2) BF theory

2023 KPS Spring Meeting
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TA19.07

Naturalness and the Wilsonian RG

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Abstract:

The electroweak naturalness/hierarchy problem is one of the most intense driving forces in the search for new physics. Beyond traditional approaches such as supersymmetry and composite Higgs models, that have to cope with the unfriendly outcomes coming from the LHC, several mechanisms have been proposed in the past years as possible solutions. These are often based on the use of technical schemes, most notably dimensional regularization (DR), which is sometimes invoked to be endowed with not-fully-understood special physical properties, and the use of perturbative Renormalization Group (RG) equations to evaluate quantum fluctuations and the dynamical dressing of the Higgs mass. In this talk, I will confront these with the Wilsonian approach to the Renormalization Group, which is at the very basis of the concept of Effective Field Theories and provides the only physical and direct way to deal with quantum fluctuations. The physical meaning of both DR and the perturbative RG equations naturally emerges from that comparison, and as a consequence the proposed mechanisms will necessarily have to be dismissed as they all implement the fine-tuning in an hidden way that will be carefully unraveled. I will show that, on the contrary, a solution to the problem is found when a Wilsonian perspective is adopted on the global flow of the Higgs mass, that shows a previously unnoticed UV-IR connection. What appears as a puzzling fine-tuning of the Higgs mass in usual perturbative approaches finds its physical explanation. The usual multiplicative renormalization emerges as an IR property of the global flow, where the latter describes the dynamical mechanism that naturally connects the measured value of the Higgs mass in the IR with its much higher value at high energies.

Keywords:

Naturalness, Renormalization, Renormalization Group, Regularization

2023 KPS Spring Meeting
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TA19.08

Holographic duals of Higgsed Dp(ABCD)

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Abstract:

We construct the holographic duals of Class S 4d N=2 Argyres-Douglas theories with twist lines. Class S 4d N=2 Argyres-Douglas theories are constructed by compactifying 6d $N=(0,2)$ theory on a twice punctured sphere; with one puncture twisted and a regular singularity and the other an irregular singularity. The theories are specified by a choice of ADE subgroup, a partition of an integer N and an integer corresponding to the irregular singularity. We find that they are dual to a class of AdS$_5 ₩times D ₩times M^4$ solutions, where D is a disc, M_4 a quotient of S^4 and there is an orientifold plane living in the bulk. The metric on the disc is novel, in that it is not of constant curvature, and admits a curvature singularity which arises due to the presence of smeared M5-branes and is the holographic realisation of the irregular puncture. As a check of our proposal we show that the central charges and flavour central charges agree on both sides of the duality.

Keywords:

Holography, AdS/CFT, Argyres-Douglas theory, twisted puncture, orientifold plane

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

TA19.09

Inhomogeneous Supersymmetric Abelian Chern-Simons Higgs Model

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Abstract:

Abelian Chern-Simons Higgs model is studied in 1+2 dimensions, including spatial inhomogeneity through (x,y)-dependent mass parameter $m=m(x,y)$. Though the Poincare symmetry is explicitly broken, the $\mathcal{N}=1$ supersymmetry still survives. For a specific ϕ^6 scalar potential whose vacuum structure is decided by the mass parameter $m(x,y)$, BPS bound is saturated despite of dependence of spatial coordinates. The obtained first-order Bogomolny equations are examined and various BPS multi-soliton solutions are identified, I.e. topological and nontopological vortices, nontopological solitons, and domain walls. Provided that rotational symmetry is assigned, classification of complete soliton configurations is made with the help of numerical works, computation of the Atiyah-Singer index, and existence proof. Possible application to condensed matter samples is briefly discussed.

Keywords:

Inhomogeneous Abelian Chern-Simons Higgs model, BPS vortex, Non-topological soliton

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

W1.01

APCTP 선정, 올해의 과학도서 저자 강연

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Abstract:

APCTP 선정, 올해의 과학도서 저자 강연

운영자: 손승우 (한양대)

아시아태평양이론물리센터에서는 매년 10권을 선정하고 저자 강연을 진행하고 있습니다. 이번 세션에서는 2022 올해의 과학도서 중 정우현 교수(덕성여자대학교 약학과)의 저서 <생명을 묻다>를 주제로 소통의 장을 마련하고자 합니다. 저자 강연 후 APCTP 과학문화위원과의 대담시간 및 강연 도서 관련된 질의응답 시간도 준비되어 있습니다.

· 강연도서 : <생명을 묻다> / 정우현 저
· 사회자 : 손승우 (APCTP 과학문화위원장, 한양대학교 응용물리학과 교수)
· 강연자 : 정우현 (덕성여자대학교 약학과 교수)
· 패　널 : 이은희(APCTP 과학문화위원, 과학커뮤니케이터),
이성빈(APCTP 과학문화위원, KAIST 물리학과 교수),
황정아(APCTP 과학문화위원, KASI 책임연구원)

Keywords:

과학도서

포스터발표논문

Poster session abstract

2023 KPS Spring Meeting
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P1-ap.101

Time-resolved Photoluminescence the MoS_2/ plasmonic nanostructure

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Abstract:

Photoluminescence spectroscopy is a non-contact, nondestructive method of probing materials with light. Through photoluminescence, materials of band gap and material quality molecular structure et. is measured. In order to observe various phenomena such as the carrier velocity of matter and the Auger process, not only the pl but also a Time-resolved photoluminescence is needed. We measured the Time-resolved photoluminescence of MoS_2/ plasmonic nanostructure using with time-correlated single-photon counting instrument. Through the measurement, the transition of excitons with time was analyzed.

Keywords:

Time-resolved Photoluminescence

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P1-ap.102

Analysis of polymer effects using large-area graphene transistors with clean surface

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Abstract:

대면적으로 성장된 이차원 물질은 연구와 산업 분야에서 응용할 수 있는 가능성이 무궁무진하다. 이를 위해 다방면의 연구가 지속적으로 이어지고 있지만, 표면과 계면의 영향을 크게 받는 이차원 물질을 소자로 구현하기 위해서는 이에 대한 연구가 필수적이다. 소자 공정에 포함되는 전사와 패터닝 과정에서의 이차원 물질의 표면이 다른 물질과 접촉하는 일이 발생하기 때문에 이를 소자의 관점에서 이해할 필요가 있다. 본 연구에서는 공정 과정에서 발생할 수 있는 이차원 물질의 표면 상태를 이해하기 위해 화학 기상 증착법 (chemical vapor deposition, CVD)으로 성장된 대면적 그래핀 트랜지스터의 전기적 신호를 분석하였다. 금속 호일 위에 대면적으로 성장한 그래핀을 소자로 구현하기 위해서는 타켓 기판으로의 전사 과정이 필수적이다. 이를 위해 금속 호일을 화학적으로 etching하여 전사하는 방법이 널리 사용되고 있지만, 그 과정에서 assist layer 역할의 PMMA와 같은 폴리머와 이를 지우는 용액이 그래핀 표면에 남아 발생하는 영향을 배제할 수 없다. 또한, 전극 형성을 위한 lithography 공정 과정에서도 동일한 문제가 발생할 수 있는데, 각 공정에서 사용하는 폴리머를 조절함으로써 그 영향을 이해할 수 있다. 그래핀의 표면에 남은 폴리머 잔사의 영향을 분석하기 위해 우리는 널리 사용되는 전사 방법과 패턴 형성 방법을 포함하여 네 가지의 그래핀 전계 효과 트랜지스터를 제작하였다. 이 조합으로 그래핀의 전기적 신호에 영향을 주는 폴리머 수를 제어함으로써 각 폴리머가 소자 특성에 미치는 영향을 분석하였다. 그래핀의 전도 특성 분석을 통해 사용되는 폴리머의 수가 적을 수록 소자의 특성이 균일하게 나타났으며, PMMA와 photoresist를 모두 사용하지 않은 트랜지스터를 제작하고, 이를 이용해 폴리머 잔사의 영향을 채널의 표면과 계면으로 나누어 분석하였다.

Keywords:

CVD graphene, polymer residue, field-effect transistor

2023 KPS Spring Meeting
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P1-ap.103

Optical properties of van der Waals ferromagnet $CrBr_3$

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Abstract:

$CrBr_3$ is a van der Waals ferromagnet with an Ising-type magnetic Hamiltonian and a Curie temperature of 37 K. We have conducted absorption measurements on a bulk $CrBr_3$ single crystal in the energy range of 1.2-3.0 eV under an external magnetic field up to 7 T. Two d-d transitions and an absorption edge were identified at 1.65, 2.2, and 2.7 eV, respectively. In addition, we found that these absorption features show magnetic-field dependence and strong circular dichroism.

Keywords:

van der Waals materials, 2D magnetism, CrBr3, optical spectroscopy

2023 KPS Spring Meeting
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P1-ap.104

TEM dark field analysis on the atomic scale reconstruction in twisted trilayer graphene

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Abstract:

Interfaces formed by joining two van der Waals (vdW) crystals has offered a new route to access exotic electronic behaviors. The interplay between twist-tunable length scale of moire superlattice and underlying atomic scale reconstruction has been key to understand such unconventional electronic behaviors. In the twisted bilayer graphene, for instance, periodic rearrangement of atoms with the moire length scale was reported to be responsible for many exotic phenomena including anomalous electronic transport in small twist angle (q<1°) and the strongly correlated behavior in magic angle (q~1.1°). On the other hand, atomic configuration in twisted trilayer graphene and its correlation with the recently reported unconventional superconductivity has yet to be investigated. Although robust superconductivity in the twisted trilayer graphene has been reported by multiple groups, their insight onto the atomic and moire structure remains elusive due to the complicated nature of the interlayer interaction in trilayer system. The reconstruction between the top and bottom layers through the middle layer in addition to that between the two adjacent layers should be considered to understand the atomistic details of twisted trilayer graphene.

In this study, we utilized the transmission electron microscopy (TEM) dark field (DF) imaging technique to investigate the reconstructed moiré lattice in twisted trilayer graphene. Assuming only a single event of electron scattering with the thin specimen, the intensity of TEM DF image can be interpreted as kinematical diffraction intensity variation in real space. Moreover, by obtaining the tilt-series DF images, one can monitor the change in such diffraction intensity as a function of the deviation from the exact Laue condition. We found that the atomic rearrangement occurs in all three layers, resulting in an array of commensurate domains of Bernal and rhombohedral stacking orders competing with each other.

Keywords:

atomic reconstruction, twisted trilayer graphene, TEM

2023 KPS Spring Meeting
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P1-ap.105

Second harmonic generation of strained WS_2 multilayer

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Abstract:

We have investigated nonlinear optical properties, especially the second harmonic generation (SHG) of strained WS_2 multilayer. Because of the negligible SHG signal in centrosymmetric crystals, most SHG studies have been focused on monolayer transition metal dichalcogenides which are noncentrosymmetric. However, a recent study has shown that although a crystal is centrosymmetric, it can exhibit intriguing SHG properties by introducing external perturbations and breaking symmetries. [1] Here, we carried out strain-, and excitation-dependent SHG spectroscopy of WS_2 multilayer within the A- and B- excitonic transition regime. We will discuss how strain affects crystal symmetry and the excitonic effects of SHG.

[1] Shree, S., Lagarde, D., Lombez, L. *et al. Nat. Commun.* **12**, 6894 (2021)

Keywords:

WS2, Second Harmonic Generation, Strain

2023 KPS Spring Meeting
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P1-ap.106

Designed chemical vapor deposition and characterization of graphene

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Abstract:

During the development of graphene research, many kinds of graphene applications were studied. To extend graphene research to the industrial application, mass production of graphene is necessary. Therefore, high quality and high yield graphene growth is becoming more important. Many researches toward continuous growth and mass production have been reported, but graphene production has obstacles in both quality and production speed.
To overcome these difficulties, we invented an advanced chemical vapor deposition system that can produce several graphene sheets in a row. We also, tried rapid chemical vapor deposition using liquid carbon precursor and succeeded in high speed growth of graphene for 1min at 900℃. Our new system and recipe solved difficulties reasonably. We synthesized 12 large area graphene sheets in total 3 hours in either of pristine and doped graphene. Graphene was analyzed by Raman spectroscopy, XPS and electrical property and was found to have high quality.

Keywords:

Graphene, CVD, Synthesis

Growth mechanism of gamma-GeSe: template growth on graphene with Au catalyst

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Abstract:

The chalcogenides, including group IV chalcogenides, are known to display various polymorphic configurations, ranging from amorphous to different crystalline phases. Therefore, the controlled synthesis of a targeted polymorphic configuration will be of great utility for fundamental studies as well as applications. We recently reported the synthesis of the first hexagonal polymorph, so-called γ-phase GeSe. However, the previous reported synthesis method has limitation in product yield and polymorph selectivity for γ-phase GeSe. In this study, we successfully increased the coverage and growth selectivity of γ-GeSe synthesis by using graphene and h-BN as templates. Our method involves the use of gold as a catalyst, as we found that γ-GeSe was not synthesized without gold. The observed growth modes and products on different target substrates allow us to investigate the growth mechanism of γ-GeSe.

Keywords:

GeSe, Germanium Selenide, CVD, Polymorph, VLS

2023 KPS Spring Meeting
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P1-ap.108

Investigation of vibrational and thermal properties of γ-GeSe

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Abstract:

γ-GeSe is a recently identified polymorphic configuration in group-IV monochalcogenides. Despite its great potential for electrical and thermal applications, the experimental confirmation of vibration modes and thermal conductivity is yet to be reported. Here, we investigate the mechanical properties and thermal conductivity of γ-GeSe using the freestanding sample geometry. The mechanical vibrational modes of doubly-clamped γ-GeSe flakes are measured using optical interferometry. The indentation using atomic force microscopy is also used to measure the mechanical deformation and Young's modulus. By comparison with finite-element simulations, we find that γ-GeSe exhibits Young's modulus of approximately 100 GPa at room temperature. In addition, the laser-irradiation-induced local heating and temperature-dependent Raman peak shifts are used to measure the thermal conductivity of γ-GeSe. We find a low thermal conductivity of approximately 8.5 $Wm^{-1}K^{-1}$ at 350 K.

Keywords:

γ-GeSe, mechancial properties, thermal conductivity, Young's modulus, group-IV monochalcogenides

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

P1-ap.109

Operando TEM study of Barkhausen effects in 2-D van der Waals ferroelectrics

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Abstract:

Two-dimensional (2-D) van der Waals (vdW) materials can host unconventional ferroelectricity. One can control the twist angle in engineering vdW homo- and heterointerfaces to create electrically switchable polar structure. For instance, stacking two layers of transition metal dichalcogenides (TMD) in a parallel manner that breaks the intrinsic centrosymmetry develops dipole moments in vertical directions. Such electric dipole moments can be switched via external electric field, indicating possible usage of ultrathin vdW materials for ferroelectric applications. However, the switching process of the 2-D vdW ferroelectrics is reported to exhibit distinct behavior compared with that of conventional ferroelectrics. Instead of vertical displacement of positive ions as in perovskite structure, collective sliding motion in lateral direction in each layer switches the electric polarization, suggesting unique characteristics of domain dynamics in 2-D vdW ferroelectrics.
Here we investigated the domain dynamics in 2-D vdW ferroelectrics by exploiting operando transmission electron microscopy (TEM) technique. We observe domain structural change under the electric device operating condition in real-time fashion. We found that the domain walls that moves in response to vertical electric fields are pinned by underlying disorder, creating Barkhausen noise in the polarization hysteresis loop. In this presentation, we will discuss the details of pinning behavior under various gating conditions.

Keywords:

Operando TEM, van der Waals ferroelectrics, Barkhausen effect

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

P1-ap.110

TEM Dark Field Analysis on the Temperature Dependent Ferroelectric Properties in van der Waals Bilayers

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Abstract:

The study of 2-dimensional (2-D) van der Waals (vdW) heterostructures has presented the discovery of new physical, more specifically, electronic properties unseen in the building block materials. And starting from the theory of sliding ferroelectricity and the making of artificial ferroelectrics by tear-and-stack method, ferroelectric properties in 2-D vdW materials, such as parallelly stacked hexagonal boron nitride and transition metal dichalcogenides (TMDs), have been recently reported. The mechanism of ferroelectric switching of 2D ferroelectrics, the in-plane lattice sliding without vertical ion displacements, is different from that observed in traditional ferroelectric materials. Furthermore, a recent study suggested the ferroelectric-to-paraelectric transition of vdW bilayers at Curie temperature was caused due to a time average of ferroelectric phases with opposing intrinsic polarizations, unlike traditional ferroelectric materials where the structural symmetry increases due to a thermally induced phase transition. Although ferroelectric phase transitions have been subject to much research lately, the structural dynamics of the phase transition have yet to be identified experimentally.
In this study so far, we have successfully observed the domain wall motion caused by an induced electric field with the use of a TEM holder and specimen grid which enables electrical biasing. As the next step, we're utilizing a temperature-controllable TEM holder and specimen grids including a micro Joule heater design for specimen heating. Along with electrical biasing techniques and transmission electron microscopy (TEM) dark field (DF) imaging techniques, we can analyze the domain dynamics of the ferroelectric switching at various temperatures. We will discuss the temperature-dependent ferroelectricity in 2-D vdW ferroelectrics and possibly phase transition into the paraelectric phase from the structural analytical point of view.

Keywords:

TEM, 2d vdw ferroelectrics, ferroelectric switching, temperature dependence

2023 KPS Spring Meeting
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P1-ap.111

Theoretical study of thermal and piezoelectric properties of janus 2D monochalcongenides

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Abstract:

Since the discovery of graphene, two-dimensional (2D) materials such as transition metal dichalcogenides (TMDs), metal monochalcogenides (MMCs), etc., have been attracting attention due to their various interesting physical and electrical properties. In recent years, considerable research interest in janus 2D materials has sparked various theoretical and experimental investigations. Interestingly, janus 2D materials tend to have different electrical properties compared to general non-janus 2D materials. In this study, we investigate the structural and thermal stability of janus 2D monochalcongenides by using density functional theory calculations. Especially, the characteristics of thermal properties of janus 2D monochalcongenides are compared with typical non-janus 2D ones. In addition, we study piezoelectric properties depending on atomic configurations in janus 2D monochalcongenides. From the understanding of thermal and piezoelectric properties of janus 2D materials, we suggest their possible applications.

Keywords:

Janus 2D monochalcongenides, DFT calculations, piezoelectric property

2023 KPS Spring Meeting
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P1-ap.112

Substrate effect in chemical vapor deposition of WS_2

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Abstract:

Since the discovery of graphene, interest in two-dimensional atomic layer materials has exploded, and research on the synthesis and application of large-area two-dimensional materials using chemical vapor deposition (CVD) has been very active. Based on the research trends in the synthesis of TMD materials using CVD methods, relatively few studies have analyzed the synthesis results according to the crystallinity of the substrate in the case of synthesis using deposited transition metal oxide thin films.

In this study, large-area uniform WS_2 thin films were synthesized by CVD method using transition metal oxide (TMO; WO_3) thin films deposited on amorphous substrates (SiO_2) and single crystal substrates (c-, r-, a-cut Al_2O_3) and mixed gas containing sulfur element as precursors. The influence of the crystallinity of the substrate on the synthesis of WS_2 thin films was investigated by controlling the synthesis temperature and time, and the synthesis conditions were optimized. Optimized condition for WS_2 was sulfurized from 5 nm thick WO_3 thin films on c-cut Al_2O_3 substrates and a bilayer of WS_2 was obtained in this condition. Raman-spectroscopy was used to map the E_{2g} and A_{1g} modes of the WS_2 thin films to compare the effects of the substrate. In addition, SEM and TEM were used to analyze the effect of substrate on the microstructure of WS_2.

Keywords:

2D-Material, TMDs, CVD, Single-Crystal

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P1-ap.113

Effect of Sapphire Orientation on the Growth Behavior of Graphene

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Abstract:

Considerable effort has been dedicated to synthesizing graphene using various techniques. Directly growing graphene on dielectric substrates via chemical vapor deposition (CVD) has emerged as a promising method due to its convenience compared to the conventional wet transfer method. Previous studies have reported the successful formation of graphene layers on c-, r-, and a-plane sapphire substrates through direct growth. This work specifically investigates the behavior and growth modes of graphene formation on m-plane sapphire via CVD.

Keywords:

graphene, direct growth, sapphire orientation

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P1-ap.114

Optimization of spin-coated 2D material films as a mask for thru-hole epitaxy

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Abstract:

When a 3D crystalline material grows on a crystalline substrate, covered with a 2D material that has appropriately sized holes with a high density, the 3D material can align with the substrate. Spin-coated 2D material films have the advantage of greater reproducibility and can cover larger areas when compared to transferred 2D materials. This study aimed to use spin-coated 2D material films as a mask for thru-hole epitaxy. We used either graphene oxide flakes or hBN flakes in a spin-coating process. The thru-hole formation process was optimized to ensure it was suitable for thru-hole epitaxy.

Keywords:

graphene oxide, h-BN, spin-coating, thru-hole epitaxy

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P1-ap.115

Effect of Exposed Facet Orientation of Etched Sapphire Substrates on the Growth of Graphene

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Abstract:

Recently many attempts have been successfully made to grow graphene directly on dielectric substrates. It has been known that the growth mode and rate of graphene vary significantly depending on the type of substrate and its crystallographic orientation. In this work, we used an etched sapphire substrate to simultaneously expose variously oriented facets to control the growth rate of graphene on the sapphire substrate. It turns out that the graphene may be controllably grown on the etched sapphire substrate by adjusting the exposure of differently oriented facets.

Keywords:

graphene, etched sapphire

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P1-ap.116

Study on ReS_2 homo-bilayers using optical spectroscopy

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Abstract:

Rhenium disulfide (ReS_2), one of the transition metal dichalcogenides (TMDs), is a semiconducting material with a direct bandgap from monolayer to bulk. It has an anisotropic structure (1T', distorted tetragonal) unlike most TMDs because Re is a group 7 element, which has one more electron that makes a Re-chain [1]. Furthermore, the two faces of a monolayer ReS_2 are not equivalent. [2] Due to the in-plane anisotropic structure and inequality of the opposite vertical orientations of ReS_2, its homo-structures can have different crystal structures even if it is stacked with the same twisted angle. We systematically studied homo-bilayers of ReS_2 which can have various kinds of crystal structures, starting from the case with near 0° twisted angles.

We made mono-layer ReS_2 samples by using the mechanical exfoliation method and fabricated ReS_2 homo-bilayers by using the dry-transfer method. There are 6 possible crystal structures in ReS_2 homo-bilayer with near 0° twisted angles due to the low symmetry of the ReS_2 crystal. The directions of the Re-chain (b-axis) and the c-axis in each layer were determined by polarized Raman spectroscopy. [3] We observed the interlayer interaction between the two layers by low-frequency Raman spectroscopy. The low-frequency peak near 30 cm^{-1} exhibits small shifts depending on the stacking. Also, the position of Raman mode 1 of ReS_2 depends on the structures of homo-bilayer. Furthermore, new peaks were found in the high-frequency range of the Raman spectrum. In addition, we measured the polarization dependent second harmonic generation (SHG) on the ReS_2 homo-bilayers. The intensity of the SHG signals depends on the structures of homo-bilayers.

Keywords:

Raman, SHG, TMDs, ReS2, interlayer vibration mode

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P1-ap.117

Direct Growth of Graphene on Silicon Substrates Using Low-Pressure Chemical Vapor Deposition (LPCVD)

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Abstract:

The low-pressure chemical vapor deposition (CVD) technique was utilized to directly grow graphene on silicon wafers while controlling the thickness, growth mode, and coverage of the graphene by adjusting the argon flow rate, hydrogen flow rate, and growth time. The outcome of this work could potentially enable the controlled growth of uniform graphene on silicon wafers with the desired thickness, which could find application in a variety of graphene devices developed directly on Si substrates.

Keywords:

graphene, Si, direct growth

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P1-ap.118

hBN 점결함 양자 광원의 광학적 특성 제어

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Abstract:

육방정질화붕소 (Hexagonal Boron Nitride, hBN)은 매우 큰 band gap을 가지는 층상구조 물질이다. 이 물질의 결함구조에서 단일광자를 방출하는 양자광원의 생성이 보고되고 있다. 이러한 단일 광자 광원의 정확한 결함 구조와 발생 원인을 밝히고 양자정보 물질로의 응용을 위해 이들의 특성을 제어하는 연구가 활발히 진행되고 있다. 본 연구에서는 Supercontinuum Laser을 이용하여 저온에서 육방정질화붕소 내부 광원의 여기 에너지에 따른 특성 변화를 체계적으로 관찰하였다. 여기 광원의 에너지에 따라 발광 에너지, 발광세기 등의 발광 특성이 변화하는 것을 확인하였다. 이를 통해 여기 광원의 에너지를 이용하여 광학적으로 단일 광자 광원의 파장 및 세기를 제어할 수 있는 가능성에 대해 연구하였다.

Keywords:

Two-dimensional materials, Single photons and quantum effects, Quantum information, Quantum optics

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P1-ap.119

Graphene transistors for liquid TEM observation

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Abstract:

In situ liquid transmission electron microscopy (TEM) is an emerging technique that allows researchers to apply the powerful characterization methodologies of TEM for the investigation of various liquid-phase phenomena. In particular, there has been significant progress in the observation of electrochemistry and nanomaterial growth at atomic resolution using in situ liquid TEM techniques. However, it is still challenging to understand electron beam-induced phenomena, such as the ionization of solvent molecules and the production of radicals, during liquid TEM. The quantitative understanding of interaction between high-energy electron and solvent molecules is required for the proper interpretation of liquid TEM observation. Here, we present our effort to overcome this issue by incorporating liquid sensors on liquid TEM chips. Graphene transistors serve as sensitive ion sensors. The operation of graphene transistors under different solvent demonstrates its potential for monitoring electron beam effect during liquid TEM observation.

Keywords:

TEM, liquid, ion, sensor, graphene

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P1-ap.120

Gas Sensing Functionality of Two-Dimensional Semiconductors Coated with Metal-Organic Polyhedra Film

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Abstract:

An upsurge of recent interest in transition metal dichalcogenides (TMDs) as gas-sensing device elements due to their promising properties including the huge surface area to volume ratio, the excellent environmental sensitivity, etc. However, to the best of our knowledge, the previously reported gas sensors based on TMDs work with only reactive gas molecules and their sensing capability should be also enhanced further. In this study, the novel heterostructures have been constructed by coating two-dimensional (2D) MoS_2 with metal-organic polyhedra (MOP). The gas sensitivities of field-effect transistor (FET) structures based on the 2D MoS_2 channels coated with and without MOP layers have been compared under various environmental conditions with N_2, Ar, O_2, and dry air gas. These heterostructures exhibited the enhancement of sensitivity to the reactive gases, O_2 and dry air, in comparison to the pristine 2D MoS_2. More interestingly, the less-reactive N_2 and inactive Ar gases were also observed to be detectable by the heterostructures. These results would be closely relevant to developing next-generation gas sensors based on 2D materials.

Keywords:

two-dimensional materials, Molybdenum disulfide (MoS2), gas sensor, field-effect transistor (FET), metal-organic polyhedra (MOP)

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P1-ap.121

그래핀에 속박된 BaTiO3 입자의 표면에서 격자 상수의 변화

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Abstract:

그래핀(graphene)과 산화바륨티타늄(BaTiO3, BTO) 파우더 filler입자를 cyanoethylated pullulan(CEP) 고분자 matrix에 혼합하여 유전체 복합물질(dielectric composite materials)을 합성하였다. 산화그래핀(graphene oxide, GO)을 환원제인 hydrazine을 사용하여 환원된 산화그래핀(reduced graphene oxide, rGO)으로 BTO 입자를 감싼(encapsulate) 복합 filler 입자(rGO@BTO)를 사용하여, 보통의 BTO입자만 있는 고분자 기반의 유전체 박막과 유전 특성을 비교하였다. 이때 rGO@BTO filler의 환원시간을 6, 12, 18, 24시간으로 변화하여, 환원 시간에 의한 영향을 확인하고자 하였다. 총 5종류의 시료 중에 rGO@BTO가 있는 시료가 유전 특성이 대조 시료보다 유전특성이 뛰어났고, 또한 두번째로 긴 환원시간을 가지는18시간 시료가 제일 뛰어났다. 이는 환원제가 산소작용기를 제거하는 주 작용과 질소관련 작용기를 부착시키는 보조 작용의 두 가지 역활을 동시에 하기때문에 발생한 것이다. rGO@BTO가 들어간 복합유전박막을 XRD로 조사하여, rGO 환원시간에 따라 rGO에 속박된 BTO 입자의 격자상수의 변화도 유전특성과 같이 18시간 시료가 제일 변화가 큰 것으로 나온 것을 확인했다. 즉, BTO의 외곽을 꽉 조이는(clamped) 그래핀의 외부에 붙어있는 작용기의 양이 내부에 있는 BTO 결정의 격자상수(lattice constant) 값이 변화한 것으로 추정할 수 있다. 즉, 작용기가 많으면 더 강하게 BTO를 속박하여 BTO 외부의 격자 간격을 좁혀주고, 적어지면 격자 간격이 느스해짐을 확인했다. 이를 간단한 모형을 이용한 계산으로 입증하였다.

Keywords:

reduced graphene oxide, BaTiO3, XRD, lattice constant, dielectric

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P1-ap.122

Study on the electrical properties of single crystalline layered Ta_2Se

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Abstract:

Two-dimensional (2D) layered transition metal dichalcogenides (TMDs) have attracted much attention as promising materials for displays and/or optical devices due to its unique optical and electronic properties. However, most of TMD has of $TmCh_2$ composition, where *Tm* and *Ch* is transition metal and chalcogen element, respectively, and their compositional boundary is still limited. *Tm*-rich chalcogenides are one of exceptional TMDs exhibiting unique layered structure containing van der Waals gap. In this presentation, we report the synthesis of 2D Ta_2Se single crystal and its physical characterizations. We synthesized the single crystalline Ta_2Se by solid state reaction followed by arc-melting process. From X-ray diffraction (XRD) study, Ta_2Se has 2D tetragonal structure with space group *P4/nmm,* which the central Ta body-centered packing between the Se layered. The obtained flake-form sample shows (00*l*) peaks only, indicating the grown Ta_2Se sample is single crystal well oriented along *ab*-plane direction. Temperature dependence of electrical property measurement confirms that single crystallin Ta2Se has metallic ground state originating from a high hole carrier concentration upon ~10^{21} cm^{-3}. The phonon vibration mode and work function are investigated by Raman and ultraviolet photoemission spectroscopy, respectively, and the underlying physical mechanism associated with electrical ground state is studied.

Keywords:

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P1-ap.124

Exciton-Plasmon Coupling in WS_2 Flakes on Au Nanogratings

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Abstract:

Transition metal dichalcogenides (TMDs) have attracted a lot of attention as novel materials for both device applications and basic science. TMDs exhibit unique optical characteristics because of their exceptionally large real and imaginary refractive indices. The extremely small physical volume of TMD layers, however, limits the light-matter interaction in them. Thus, there have been numerous research efforts to fabricate TMD/metal nanostructures. Surface plasmons can result in improved light-matter interactions and can be used to tune the spectral responses of TMD materials in such hybrid systems. In this work, WS_2 monolayers were transferred on Au-nanogratings (AuNGs) with period of 320 nm. AuNGs were fabricated by sputtering Au thin films on blue-ray disc templates. Angle- and polarization-dependent reflectance spectra of AuNGs clearly demonstrated the excitation of propagating surface plasmon polaritons (SPPs). Moreover, the SPP excitation wavelengths are close to those of the exciton resonance wavelengths of the WS_2 monolayer. Measured optical characteristics of the WS_2/AuNGs were compared with calculation results in order to clarify the physical origins. Raman measurements were carried out for the structural investigation. In addition, the surface potential was measured by Kelvin probe force microscopy. The exciton-SPP coupling effects can be studied by measuring surface potential while illuminating linearly polarized light with various incident angles.

Keywords:

exciton, plasmon, coupling

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P1-ap.125

Analysis of interlayer stacking and strain in bilayer phosphorene by transmission electron microscopy

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Abstract:

Phosphorene is an emerging two-dimensional crystal with interesting physical properties such as high carrier mobility, anisotropic in-plane properties, and the bandgap tunability as a function of its thickness. In particular, the number of layers and their relative stacking configurations strongly influence phosphorene's electrical and optical properties. It is important to obtain a quantitative analysis tool for stacking configurations in phosphorene samples. Here, we apply transmission electron microscopy(TEM) to quantitatively analyze stacking relation and strain in phosphorene. We implement TEM image simulation based on bilayer phosphorene with a gradual stacking shift. The relative stacking shift between two layers can be quantified based on pattern recognition and Fourier transform analysis. The method is applied to experimental TEM images of bilayer phosphorene edges, confirming stacking shift and strains in the sample.

Keywords:

TEM, quantitative analysis, black phosphorus, stacking order, FFT

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P1-ap.126

Nb 도핑에 의해 제작한 p형 WS_2의 구조적 특성 연구

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Abstract:

화학 기상 증착법을 사용하여 SiO_2/Si 기판 위에 Nb가 도핑된 단층 WS2을 제작하였다. 여기서 S, WoO_3, 및 $NaCl_3$ 파우더는 각각 35, 15, 및 40 mg로 고정하였으며, $NbCl_5$의 파우더의 양은 60부터 75 mg까지 조절하여 도핑농도를 변화시켰다. X선 광전자 분광법을 이용하여 Nb, W, 및 S 원소가 존재함을 확인하였다. 도핑농도에 따른 영향을 확인하기 위해서 532 nm 파장의 레이저 빛을 이용하여 라만 스펙트럼을 분석하였다. 도핑농도가 점점 증가함에 따라 E^1_{2g} 밴드는 353에서 357 cm^{-1}로, A1g 밴드는 420에서 423 cm^{-1}로 각각 4와 3 cm^{-1} 만큼 청색천이 하였다. 또한, 광 발광 측정을 통해 도핑농도의 증가에 따라 에너지 띠를 자세히 측정한 결과, 초기 상태 WS_2 광 발광 피크는 627 nm 이였지만, 75 mg Nb 도핑된 샘플에서는 712 nm로 85 nm 이동하였다. 본 연구에서는 이러한 라만 및 광 발광 분석 결과와 더불어 일함수 데이터를 토대로 도핑농도에 따른 WS_2의 구조적 현상에 대한 메커니즘을 규명하고자 한다.

Keywords:

2차원 반도체, WS2, Nb, p형

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P1-ap.127

Broadband and ultrafast photodetector using synthesized $PtSe_2$ on hBN by molecular beam epitaxy

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Abstract:

Two-dimensional (2D) van der Waals materials are considered as a promising candidate of the high-performance optoelectrical devices owing to the bandgap modulation, high on/off ratio and ultra-stability compared to bandgap-free graphene and environmentally sensitive black phosphorus. However, the manufacturing large-scale and uniform optoelectrical devices using 2D van der Waals materials is still challenge due to the hardness of synthesis of large-area, uniform and high-quality 2D van der Waals materials. Although several previous studies on synthesis methods using CVD and MBE have been conducted, there are still some limitations such as non-uniformity, lots of grain boundary, and low carrier mobility. Herein, through study on the synthesis method of $PtSe_2$ using hBN buffer layer through MBE, we fabricated the $PtSe_2$ photodetector. The high-quality $PtSe_2$ synthesized on hBN was verified using Raman spectroscopy, AFM, and STEM, which showed that the $PtSe_2$ synthesized on hBN has higher quality, larger grain size, and less grain boundary compared to $PtSe_2$ synthesized on SiO_2. Owing to reduction in the carrier scattering and carrier recombination resulting from the high quality and less grain boundary, fabricated photodetector using $PtSe_2$ synthesized on hBN shows much higher optoelectrical properties than those of photodetector fabricated on SiO_2. Moreover, the performance of the photodetector showed to work very well up to the broadband wavelength region. Therefore, using large-scale synthesized hBN as $PtSe_2$ growth buffer layer, large-scale, high performance, and complicated $PtSe_2$-based optoelectrical devices could be achieved.

Keywords:

PtSe2, Broadband, molecular beam epitaxy, photodetector

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P1-ap.128

Micro Probe System for in-situ x-ray scattering

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Abstract:

Simultaneous electrical and structural measurements provide necessary information for dynamics of structural and electronic phase transition or modulation. In this poster, we would like to present a new platform of next-generation micro probe system, which combine functionality of conventional environmental-controlled micro probe system and x-ray scattering technique. The light weight and compact design are suitable for lab-based and synchrotron x-ray scattering experiments. In addition, it can easily create extreme environments: high temperature as high as 1000^{o}C, high vacuum as low as 0.9 x 10^{-4} Torr, and oxidizing/reducing condition with different gases. With an oxygen sponge $SrFe_{0.8}Co_{0.2}O_x$, the apparatus was tested in a lab x-ray diffractometer and a synchrotron-based diffractometer. Redox-driven structural change was clearly reproduced as demonstrated previously[1]. In addition, simultaneous *dc* transport results clearly support associated modulation in its resistivity. Thus, the system can be applied not only for electrochemical experiments but also field-driven phase transitions in the controlled environments.
[1] J. Lee et al., Phys. Rev. Applied **10**, 054035 (2018)

Keywords:

XRD, Micro Probe System, MPS, in-situ, x-ray

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P1-ap.129

Optical studies of MoS_2-WSe_2 heterostructures

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Abstract:

Heterostructures of two-dimensional transition metal dichalcogenides (TMDCs) in which two or more different TMDCs materials are vertically stacked together and interact by Van der Waals force, forming moiré superlattice, attract great attention due to their distinctive properties from the single constituent material [1]. As reported, (1L) MoS_2/(1L) WSe_2 heterostructures show strong interlayer interaction as shown by emerging new interlayer vibration peaks and are expected to show different behaviors when the thickness of each material is tuned [2].

In this study, we fabricated heterostructures of monolayer MoS_2 with various layers of WSe_2 ((1L) MoS_2/(NL) WSe_2) and reverse order ((1L) WSe_2/(NL)MoS_2) to see the interlayer vibrational modes of the two materials depending on the number of layers and the order of stacking materials. The samples are prepared by mechanical exfoliation, transferred by the stamping method, and the thickness is measured by AFM. Raman measurements are used to study the interlayer vibrational modes of the heterostructures, whereas the twist angles are determined by polarized second harmonic generation measurement.

Keywords:

Molybdenum disulfide (MoS2), Tungsten diselenides (WSe2), Interlayer vibration modes, Raman spectroscopy

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Ion Attachment to Functionalized Terminal of Carbon Nanotubes as a Potential Cause of Disrupted Water Flow

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Abstract:

Water transport plays an important role in various fields of science and technology. Especially, the transport phenomena of water through carbon nanotubes (CNTs) have been a topic of special interest due to the electrostatic and structural properties of CNTs. Among several unresolved issues in this topic, an outstanding problem is that ions disrupt the flow of water due to unknown reasons. Here, we propose a hypothesis that the attachment of ions to the functionalized terminal of CNTs may be the cause of the disrupted water flow. To validate our hypothesis, we performed a systematic molecular dynamics (MD) simulations for various terminal types of CNT—hydrogen, hydroxyl, and carboxylate — and various cation species —Li, Na, and K—. First, the greater the proportion of carboxylate groups with negative charges, the slower the water transport speed, regardless of the type of ion. This is because water molecules mainly move along the CNT wall, and cations attached to carboxylate groups directly hinder this movement of water molecules. Second, the degree of hindrance to water flow varied depending on the type of ion. Na ion and Li ion did not entirely impede the flow of water molecules, whereas K ions almost stopped the water transport compared to the other two ions. This is because the distribution of ions around the terminal is different depending on the ion type: with Na and Li ions mostly clustering near the CNT wall, while K ions are relatively loosely clustered, causing them to block the central part of the CNT. In other words, weaker interaction between ions and terminals results in better hindrance water transport. Thus, the interaction between ions and terminals can have a significant impact on the flow of water molecules and should be considered an important factor in using CNT for transport.

Keywords:

carbon nanotube, osmotic transport, molecular dynamics simulation

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Measurement of In-Plane Thermoelectric Properties for Strong Decoupling Phenomenon in Pt/Si Hybrid Structures

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Abstract:

Among the various sources of renewable energy, the thermoelectric(TE) has attracted significant interest because it allows for the conversion between wasted heat and electricity without any mechanical intervention. At a fixed temperature T, a dimensionless figure of merit, $ZT = S^2\sigma T/\kappa$, is determined by three material properties, namely, the Seebeck coefficient (S), electrical conductivity (σ), and thermal conductivity (κ) of thermoelectric (TE) materials. Various studies have been conducted to enhance the ZT value of single-phase materials by suppressing κ or increasing the power factor ($S^2\sigma$). However, the performance of TE materials is limited by the intrinsic coupling of the Seebeck coefficient and the electrical conductivity such that an increase in one leads to a decrease in the other with respect to the carrier concentration. This coupling makes it particularly difficult to enhance the TE power factor in TE materials. In this study, we added a Pt top layer over a silicon wafer, forming a hybridized Pt/Si structure to drive a strong decoupling of the Seebeck coefficient and electrical conductivity. The results show that the electrical resistance in the Pt/Si hybrid structure decreased by ~94 times compared to that of a single-layer lightly doped Si substrate at 300 K, while the Seebeck coefficient in the hybrid structure decreased slightly compared to that of the single layer. The remarkably high TE performance of the Pt/Si hybrid structure is brought about by the hybridization of the intrinsic high-conductivity Pt layer and the high-Seebeck coefficient Si substrate. In addition, we demonstrate that this novel and effective decoupling method enables the assessment of the in-plane intrinsic Seebeck coefficient of a lightly doped Si wafer, which typically has an electrical resistance that is extremely high to measure the Seebeck coefficient even with a high-resolution voltmeter. These results represent a significant advancement in the understanding of electrical transport in TE materials, which will invigorate further research on Si-based devices for realizing large-area watt-scale TE generation at room temperature.

Keywords:

Thermoelelctric, Hybrid structure, Seebeck coefficient, Pt, Thin film

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Changes in film properties of CuSCN and perovskite induced by DES antisolvent treatment

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Abstract:

Copper(I) thiocyanate (CuSCN) has been researched as a hole transport material that can replace 2',7,7'-tetrakis[N,N-di(4-methoxyphenyl)amino]-9,9'-spirobifluorene (spiro-OMeTAD) in perovskite solar cells. For preparing a CuSCN solution, dimethyl sulfide (DES) is used as a solvent. However, DES solvent damages the underlying perovskite layer in n-i-p structures. Therefore, methods to protect the damage on the perovskite layer caused by DES should be developed.
In this study, we used antisolvent treatment to reduce the time for interacting DES and perovskite during CuSCN solidification. The scanning electron microscopy images were measured to examine the surface changes resulting from antisolvent treatment. In addition, X-ray photoelectron spectroscopy was performed to analyze changes in the electronic structure, and X-ray diffraction patterns were measured to confirm the changes in the crystallinity of the perovskite film due to antisolvent treatment. The results showed not only a significant decrease in perovskite damage but also an increase in the crystallinity of CuSCN.

Keywords:

CuSCN, perovskite, DES, antisolvent, X-ray photoelectron spectroscopy

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CuPc hole transport layer and Ag/HAT-CN anode for cost-efficient and stable perovskite solar cells

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Abstract:

Perovskite solar cells (PSCs) achieved an extremely rapid increase in power conversion efficiency (PCE). A high work function anode and hole transporting layer (HTL) facilitate hole transport and electron blocking and thereby improving the PCE of PSCs. Representatively, Au anode and Li-bis(trifluoromethane)sulfonimide (Li-TFSI)-mixed 2,2',7,7'-tetrakis[N,N-di(4-methoxyphenyl)amino]-9,9'-spirobifluorene (spiro-OMeTAD) HTL are used. However, Au and spiro-OMeTAD are high fabrication-cost. In addition, Li-TFSI is a hygroscopic material.
In this study, we used a Ag anode and copper phthalocyanine (CuPc) HTL for cost-efficient and stable PSCs. To increase the work function of Ag, a 1,4,5,8,9,11-hexaazatriphenylene hexacarbonitrile (HAT-CN) interlayer was inserted between them. The device performance of PSCs was characterized depending on the CuPc and HAT-CN thicknesses. The optimum thicknesses of CuPc and HAT-CN layers were determined and their effects of hole transport and accumulation properties were investigated.

Keywords:

CuPc, HAT-CN, Ag, perovskite solar cell

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Enhanced Performance of X-ray Shielding via Mixture of Bismuth Halides

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Abstract:

The development of effective and lightweight X-ray shielding materials without heavy metal lead has attracted great attention due to their versatility in medicine, electronics, aerospace, and so on. In this work, we successfully developed non-lead shielding materials against X-rays by mixing bismuth halide salts (BiI_3 and $BiBr_3$). The mixing ratio was elaborately modulated to achieve the highest shielding rate per weight (*%/g*). Their crystallinity and elements were characterized using XRD, SEM, and XPS measurements. Consequently, the mixed bismuth halide compounds exhibited improved shielding efficiencies per weight (*%/g*) compared to those of single metal halides. We expect that this work paves the way for the development of advanced X-ray shielding materials.

Keywords:

X-ray, shielding rate per weight, bismuth halide salts

P1-ap.206

광전자 및 역광전자 분광기술을 이용한 유기 반도체 계면의 밴드 오프셋 직접 측정

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Abstract:

유기 발광 다이오드(OLED)와 이종 접합 유기 태양 전지(OSC)에서는 상대적으로 큰 엑시톤 결합 에너지로 인해 수송 밴드갭(Etr)이라고도 하는 HOMO와 LUMO 사이의 에너지 오프셋이 광학 밴드갭과 크게 다르다. 그러나 LUMO 레벨을 독립적으로 측정할 수 없기 때문에 OLED의 음극에서 전자 주입 장벽과 OSC의 Voc에서 전압 손실 메커니즘과 같은 중요한 사항을 규명하기 어렵다.
최근 우리 그룹에서 유기 반도체의 LUMO 레벨 측정에 특화된 고감도 역광전자 분광법(IPES) 장비를 개발했다. 기존의 자외선 광전자 분광기(UPS)와 결합하여 모든 유기 반도체 표면 및 계면에서 모든 관련 수송 에너지 레벨(HOMO, LUMO, 페르미 레벨 및 진공 레벨)을 측정할 수 있었다. 또한 IPES용 전자 소스와 UPS용 전자 에너지 분석기를 결합하여 반사 전자 에너지 손실 분광법(REELS)을 활용하여 단일 및 삼중 광학 갭을 모두 결정할 수 있었다. 먼저 이 모든 측정이 동일한 샘플에 대해 두께의 함수로 수행될 수 있음을 입증할 것이다. 또한 C60/Pentacene 계면에서의 에너지 준위를 결정하여 모델 평면 이종 접합 유기 태양 전지의 관찰된 Voc 값으로 이어진 전압 손실에 영향을 미치는 요인을 확인할 수 있을 것이다.

Keywords:

Surface Physics, Interface, Ultraviolet Photoelectrosopy, Invers Photoemission Spectroscopy, transport gap

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대기 상태에서의 리튬이온전지용 양극 재료에 형성된 표면 불순물의 전기적 특성 연구

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Abstract:

리튬이온전지(LIB)의 에너지 밀도를 높이기 위한 연구에서 시도되는 접근 방식 중 하나는 비용량(specific capacity)이 높은 새로운 전극(음극 및 양극) 소재를 개발하는 것이다. 특히, 리튬의 매우 높은 반응성 덕분에 리튬이온 배터리의 성능은 다른 유형의 배터리보다 우수하다. 순수 리튬 금속 외에도 LIB에 사용되는 대부분의 리튬 함유 물질은 주변 조건에서 반응성이 있으므로 비활성 기체로 채워진 진공 챔버 또는 글러브 박스와 같은 환경에서 보관 및 처리해야 한다. 대부분 깨끗한 양극 재료들은 리튬을 함유하고 있을 뿐 아니라 공기 중에서의 반응성이 깨끗한 음극 재료보다 더 높다. 예를 들면, 깨끗한 NCA($LiNi_xCo_yAl_zO_2$) 소재의 표면에는 주로 Li_2CO_3이 불순물로 성장한다. 주변 환경에 의해 유발되는 표면 불순물의 정확한 특성 분석은 양극 재료의 고유한 특성을 이해하고 고성능 양극 재료를 개발하는 데 매우 중요하게 작용한다. 본 연구에서는 고니켈계(High-Ni) NCA($LiNi_{0.8}Co_{0.15}Al_{0.0502}$)를 재료로 하는 전극을 각각 일반적인 공기와 비활성 기체가 내부에 구축된 글로브박스에 보관하고 주변 환경에 의해 표면에 형성된 불순물을 켈빈 프로브 힘 현미경(KPFM)과 주사 확산 저항 현미경(SSRM)을 사용하여 직접 분석하였다. 공기 중에 보관하던 NCA 전극 샘플에서는 명확하게 구별되는 일함수 및 저항 특성의 변화를 확인할 수 있었다. 일부 불순물은 NCA 표면보다 낮은 일함수를 보이는 반면, NCA 표면보다 높은 일함수를 가지는 불순물 또한 은 주로 성장하는 불순물(Li_2CO_3) 외에 다양한 불순물이 형성되어있음을 알 수 있다. 표면 이미지와 저항 이미지는 입자형 불순물은 단순한 먼지가 아니라 주변 환경에서 NCA 입자가 화학 반응을 일으켜 새롭게 형성된 부산물임을 확인할 수 있다. 글로브박스에 보관했던 NCA 전극 샘플에서는 거의 균일한 일함수를 유지하고 있었으며 측정범위를 벗어나는 높은 저항값이 관찰되지 않았다. LIB의 양극 재료표면은 주변 조건에 의한 화학반응으로 고저항의 표면 불순물이 성장할 수 있으며, 결국 LIB 셀의 성능을 저하시킬 수 있음을 보여준다.

Keywords:

Lithium-ion battery, NCA cathode, ambient-induced impurities, Kelvin probe force microscopy (KPFM), scanning spreading resistance microscopy (SSRM)

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2023-04-19 - 2023-04-21

수평 방향 이온밀링을 통한 리튬이온전지 전극의 대면적 단면 가공 및 동일한 전극 시료에 대한 충방전 전후 상태 변화 분석

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Abstract:

리튬이온전지 전극 활물질들의 특성 분석을 위해 전극의 단면 가공이 필요한 경우가 많다. 이러한 단면 가공을 위해서 현재 주로 이용되고 있는 방법은 집속 이온 빔 (focused ion beam)이나 이온 빔 단면 가공 장치(cross-section polisher)를 이용하여 전극의 수직 방향으로 단면을 가공하는 것이다. 이와 같은 방법들은 매우 평평한 단면을 얻을 수 있다는 장점이 있는 반면, 전극 크기에 비해 매우 국소적인 영역에서 단면 가공이 이루어진다는 단점을 가지고 있다.
본 연구에서는 리튬이온전지 전극 면에 대하여 수평 방향으로의 이온 밀링 최적화를 통한 대면적 단면 가공을 시도하였다. LiNixCoyAlzO2 (NCA) 양극에 대해 10도 정도의 각도로 수평 방향 이온 밀링을 시도한 결과, 기존의 수직 방향 단면 가공 방법들에 비해 전극 활물질 내에서의 평탄도는 다소 떨어진 반면, 대면적으로 전극 가공이 가능하여 훨씬 넓은 영역에서의 활물질 단면 분석이 가능하였다. 또한, 이와같은 수평 방향 단면 가공을 통해 동일한 전극 시료에 대하여 충/방전 전과 후 활물질 상태 변화 비교분석이 가능함을 확인하였다.

Keywords:

LIB, SSRM, KPFM, AFM, SPM, NCA, Cathode

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Investigation of Ga Diffusion on 2D materials

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Abstract:

Atom diffusion is a well-established method for doping materials like Si, and Ga is a commonly used diffusion material due to its high solid solubility. In this study, we investigated the diffusion of Ga on 2D materials. We aimed to successfully diffuse Ga onto 2D materials and observe any resulting properties.

Keywords:

Ga, h-BN, diffusion

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P1-ap.210

A study on the properties of heterogeneous composite materials for electromagnetic wave shielding

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Abstract:

This study proposes a theoretical model for electromagnetic wave shielding of heterogeneous composite materials. Extremely low frequency (ELF) magnetic fields generated in facilities handling high voltage alternating current (AC) transmission are one of the main subjects of many studies. This study proposes simple shield construction guidelines that cover both source current and shield area. A theoretical analysis of a flat shield with multiple layers is presented. Based on this analysis, metrics were defined by adding reflection coefficients and geometric shielding effectiveness. The reflection coefficient can describe the effect of the shielding material in the current source area, and the geometric shielding effect compensates for the weakness of the conventional shielding effect, which cannot accurately describe the effect of increasing the thickness of the shielding material. Solutions of the Helmholtz equation in all regions are obtained by extending the approach of previous studies, regardless of whether the shielding material is a good conductor or not. A detailed parametric analysis for the geometric and electrical parameters of the shielding material is performed using the proposed metrics.

Keywords:

Extremely low frequency (ELF), heterogeneous composite materials, electromagnetic wave shielding

P1-ap.211

ZnO/NiO-Heterojunction Transparent Photovoltaic Devices: Plasmonic Effects of ZnO/Ag-Nanowire Top Electrodes

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Abstract:

Transparent photovoltaic (TPV) devices represent the intriguing possibility of converting any transparent surface, such as window glass or device screens, into electric energy generators. Utilizing heterojunctions consisting of wide-bandgap metal oxides is one way of fabricating such cells, as they selectively absorb short-wavelength light with energy exceeding the bandgap(s), leading to high visible transmittance. In this work, we fabricated and investigated ZnO/NiO heterojunction-based TPV devices. We used ZnO (10 nm)-coated Ag nanowires (AgNWs) as the top electrodes of our devices, similar to most transparent optoelectronic devices. High electrical conductivity and transparency for visible light are advantages of the ZnO/AgNWs. The measured and calculated optical transmittance of the devices clearly indicated the localized surface plasmon excitation of the AgNWs near the wavelength of 400 nm. The photoluminescence spectra of the devices also showed that the AgNWs enhanced the light emission from the ZnO layers. This suggested that AgNWs could boost the amount of photo-generated carriers. Local photocurrent measurements obtained by conductive atomic force microscopy provided strong evidence for the plasmonic contribution of the photocurrent. Time-resolved photoluminescence measurements will be performed in order to further study any plasmon-exciton coupling, and the results will be presented along with detailed discussions.

Keywords:

transparent photovoltaic device, ZnO, NiO, plasmonic effect, Ag nanowire

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Low leakage current metal-insulator-metal structure based on beryllium oxide insulating layer created by a two-step spin-coating method

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Abstract:

Beryllium oxide (BeO) is believed to be an attractive alternative material for use in upcoming industries such as semiconductors, spacecraft, aircraft, and rocket technologies due to its high bandgap energy, melting point, thermal conductivity, and dielectric constants. The most common method used to produce BeO is the Pechini method. Pechini synthesis has successfully been adapted to 100 different mixed oxide compounds, including perovskite powders and metal oxide films, since the method was introduced by Maggio Paul Pechini in 1967. However, limitations of conventional Pechini techniques include a lack of morphology controls for the thin film process due to the viscosity of the gel precursor and the inhomogeneous nucleation that occurs during polyesterification and sintering, respectively. In this context, our approach is a novel method to create BeO insulting layer based on a two-step spin-coating innovation of the conventional Pechini synthesis method. The surface morphology and the crystal structure of BeO thin films were observed to be dependent on the citric acid/beryllium sulfate ratio and the sintering temperature, respectively. To characterize the BeO films, X-ray photoelectron spectroscopy was conducted for an elemental analysis. Furthermore, the bandgap of the BeO thin films was determined by reflection electron energy loss spectroscopy. Finally, the leakage current of a planar metal–insulator–metal device consisting of Au/Ti/BeO thin film/Ti/Au electrodes was determined to be below the nA range over the linear voltage sweeping range of -20 V to +20 V. These results can assist researchers in the areas of morphology control strategies, phase transfer theories, and applications that utilize BeO thin film manufactured by a solution process.

Keywords:

metal-insulator-metal, BeO

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Universal dry synthesis of high-quality and –purity graphene quantum dots by ion-beam assisted chemical vapor deposition

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Abstract:

그래핀 양자점은 수~수십 나노미터 크기의 0차원 그래핀으로 발광특성, 생체적합성, 안정성 및 값싼 재료 등의 장점을 두루 갖추고 있어 기존의 양자점의 단점을 보완할 수 있는 대체물질로써 활발한 연구개발이 이루어지고 있는 실정이다. 최근 화학공정, 전기분해, 유기물 재료 기반 등 다양한 그래핀 양자점 제조기술 등이 학계에 보고 되고 있지만, 현재 그래핀 양자점을 제조하는 대표적인 방법은 화학적 공정을 기반으로 하기 때문에 대부분 산을 통해 흑연이나 2차원의 그래핀을 Top-Down 방식으로 쪼개거나, 계면활성제나 기타 화학물질 이용이 반드시 수반된다는 문제점을 가진다.

이와 더불어 그래핀 양자점은 대부분 액상으로 제조되기 때문에 산업적 활용 시 패터닝이 어렵다는 단점도 있다. 일부 연구자들이 패턴된 전극 상에 그래핀 양자점을 드랍하거나 템플릿 상에 그래핀 양자점을 묻히는 방법으로 그래핀 양자점의 패터닝 연구를 진행하고 있지만, 불순물, 패터닝 해상도 한계 등 실제 반도체, 디스플레이 등의 산업적 활용을 위한 패터닝에는 여전히 많은 한계가 있다.

본 학회에서는 제조공정 중 어떠한 화학물질도 사용하지 않고 단지 이온빔과 가열처리만으로 고결정성 고순도 그래핀 양자점을 제조하는 새로운 건식제조공정법에 대해 발표하고자 하며, 해당 건식 제조공정을 응용한 그래핀 양자점 패터닝 연구에 대해서도 소개하고자 한다. 이러한 연구성과는 향후 패터닝이 매우 용이하기 때문에 다양한 분야 그 파급효과는 매우 클 것이라 기대한다.

Acknowledgement
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Keywords:

그래핀 양자점, 이온빔 조사, 건식제조, 발광

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P1-ap.214

Effect of Coating a Crystalline Substrate with 2D Material as a Mask on the Preferred Orientation of Crystalline Films Grown via Thru-Hole Epitaxy

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Abstract:

When growing crystalline films, slight differences in the formation energy of nuclei with different orientations can lead to varying orientations, even when grown on the same substrate under similar growth conditions. In this study, we suggest and demonstrate that it is possible to achieve different preferred orientations under the same growth conditions by using 2D materials as a mask to coat the substrate.

Keywords:

thru-hole epitaxy, 2D material

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P1-ap.215

Machine learning assisted color design of copper/copper oxide

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Abstract:

The color of an object is determined by the wavelength of reflected light from the surface, which can be theoretically modeled using Fresnel's equation. Recent advances in the fabrication of single-crystal copper thin films using the novel atomic sputtering epitaxy (ASE) technique have enabled highly precise control of the formation of surface oxides, resulting in a rich palette of colors for copper/copper oxide multilayered thin films [1,2]. However, the oxidation process conditions and the combination of copper and copper oxides atop have not been theoretically formulated. In this study, we investigate the subtle correlation between the process conditions and the color of copper/copper oxide using machine learning (ML). We employed general ML models, including polynomial regression, random forest regression, and support vector regression, to find the best model. The hyperparameters and/or kernels of each model were optimized using cross-validation and R2 score.

[1] S. J. Kim *et al., Nature*, **603**, 434 (2022)
[2] S. J. Kim *et al*, *Adv. Mater.* **33**, 2007345 (2021)

Keywords:

machine learning, atomic sputtering epitaxy, regression, single-cyrstal copper thin films, copper oxides

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P1-ap.216

Lateral Overgrowth of GaN on 2D Materials Wet-processed over Sapphire Substrates

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Abstract:

In the past, separating a crystalline GaN film from the underlying sapphire substrates caused damage. However, researchers have found that if GaN is grown on a sapphire substrate coated with 2D material using thru-hole epitaxy, it can be easily separated and transferred to other substrates, which is advantageous for creating flexible devices. To ensure the successful growth of GaN in thru-hole epitaxy, it's essential to achieve full coverage of 2D materials over the substrate, along with the proper size and density of thru-holes in 2D materials. This study specifically focused on the lateral growth of GaN over 2D materials coated on a sapphire substrate by using a wet-based process. The findings suggest that it's possible to achieve crystallographically aligned GaN growth on wet-processed-2D-materials-coated sapphire substrates.

Keywords:

2D material, GaN. wet-processed coating

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P1-ap.217

Organometallic polymer based flexible memristor

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Abstract:

Here we report spontaneous dissolution of ferrocene powders into cured polydimethylsiloxane (PDMS) slab and applications of such composite films. Ferrocene molecules impregnated in PDMS slab could be easily transferred to another PDMS slab by making conformal contact between PDMS slabs, at ambient temperature and pressure, and the mass transfer continued until ferrocene concentrations in both PDMS slabs reach in equilibrium. Based on this finding, we have fabricated ultra-thin ferrocene impregnated PDMS films with hydrophobizing stamps and covalently bound PDMS film (<10 nm) deposited by vapor phase using inert PDMS without crosslinking agent. Redox potential of ferrocene molecules in thin film PDMSs is measured by cyclic voltammetry, and this signifies that polysiloxanes are functionalized with ferrocene. By sandwiching ultra-thin ferrocene impregnated PDMS in between two electrodes, we demonstrate memristor operation of ferrocene-PDMS hybrid structure. Memristor devices fabricated with ferrocene-PDMS hybrid show good non-volatile memory behavior at low bias, and this behavior could be attributed to redox activitity of ferrocene.

Keywords:

Memristor, Ferrocene, PDMS

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P1-ap.218

Design of miniature magnetron sputtering gun for education

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Abstract:

In the semiconductor process, there are several ways to make a thin film during the deposition process. When electrons collide with an inert gas such as argon gas in a vacuum, argon ions in a plasma state are generated. After that, when argon ions collide with the target, which is the cathode, the atoms of the target are separated. This process is called sputtering, which belongs to physical vapor deposition (PVD). At this time, the atoms of the separated target are deposited on the substrate, which is the anode, and form a thin film. If the number of collisions between argon gas and electrons increases, more argon ions will be created and collide with the target. If we attach a magnet to the sputtering gun that mounts the target, it creates a magnetic field in front of the target and collects electrons to promote collision. Then, the sputtering rate can be increased, and the thin film formation time can be shortened. This is called magnetron sputtering [1]. In reality, the equipment used for this technology is digitized, so we will not be able to see full process. Thus, in order to educate this process easily, we made a system with a simple structure by connecting a pump, a magnetron sputtering gun, and a vacuum gauge to the chamber. Especially, this miniature magnetron sputtering gun for education applies dark space shield technology to prevent erosion caused by arcing during sputtering process. Arcing is a high-power density short circuit from the plasma to ground potential. Because this magnetron sputtering gun is minimized, it is simple to educate the structure of sputtering and dark space shied. In this system, the plasma can be seen directly through the observation-door. And since the magnet mounted on the sputtering gun can be easily changed, the shape of the plasma can be observed depending on the structure of the magnet. In addition, it can be observed that the color of the generated plasma changes according to the type of flowing gas. And if the vacuum level is low or a large amount of gas flows, the mean free path of the particles falling from the target is shortened, so deposition is not performed and the thin film does not grow. Through this, the correlation between the vacuum level or the amount of gas and the mean free path can be found.

Reference
[1] W. Kiyotaka, et. al., Handbook of Sputter Deposition Technology., pp.17-22 (2012).

Keywords:

Design and made of miniature magnetron sputtering gun and system, For education, Plasma shapes according to magnet type

2023 KPS Spring Meeting
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P1-ap.219

주문형 3차원 플라즈모닉 나노입자 클러스터 제작 기술 및 응용

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Abstract:

주문형 3차원 나노입자 클러스터는 3차원 나노광학 시스템 개발에 중요한 역할을 할 수 있습니다. 3차원 나노입자 클러스터는 수십 나노미터 크기의 플라즈모닉 나노입자가 클러스터를 이룬 구조체로, 나노입자 간 간격을 10 나노미터 이하 간격으로 배치하는 경우 강한 전자기장 증강효과를 볼 수 있습니다. 주문형 제작 방법은 3차원 프린터 기술을 차용하였으며, 3차원 프린터와 같이 원하는 위치에 원하는 형태와 조성으로 구조를 제작할 수 있습니다. 본 연구에서는 용액증발 기반 자체 조립을 사용하여 프로그래밍된 자유형 3D 구조의 제작 가능성을 보여줍니다. 금 나노입자의 지속적인 공급 및 조립은 마이크로피펫과 실리콘 기판 사이에 형성된 메니스커스에서 일어나는 증발로 인해 발생합니다. 구조의 연속적인 조립은 적절한 속도(300nm/s)를 유지하며 이동하여 이루어집니다. 이 제작 방식의 장점은 플라즈몬 특성이 전체 구조에 걸쳐서 매우 일관되고 균일하다는 것입니다. 금 나노파티클은 제작된 기둥 내에 균일하게 분포되어 있습니다. 또한 표면 강화 라만 분광법을 기반으로 한 초소형 진단 플랫폼의 주문형 제작에 유리합니다.

Keywords:

3차원 나노입자 클러스터, 초소형 진단 플랫폼, 용액증발, 3차원 프린터 기술

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P1-ap.220

Relative chirality of triangularly arranged gold nanoparticles

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Abstract:

Chiral plasmonics is an emerging field that has attracted significant attention in recent years due to its potential applications in a wide range of areas, including chemistry, materials science, and biosensing. This field is concerned with the study of the interaction between light and chiral structures, which can give rise to circular dichroism (CD) signals. This signal can be used to detect the presence of chiral molecules, which are of great importance in many areas of chemistry and biology. Chiral plasmonics has the potential to revolutionize the way we detect and analyze chiral molecules, which could lead to significant advances in drug discovery, environmental monitoring, and other areas. In this abstract, we will explore the basics of chiral plasmonics and its potential applications. When measuring chirality using light, the direction of incident light is fixed that CD can be observed on the structure which is achiral in 4pi direction and we call this relative chirality. In this research, to quantify relative chirality of the structure mathematicaly, gold nanoparticles are arranged in simplest triangle structure and CD is measured and analyzed depends on the angular direction of the incident light.

Keywords:

goldnanoparticle, relative chirality, chiral plasmonics

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P1-ap.221

Moiré heterostructure in graphene by xenon adsorption

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Abstract:

The interface between two-dimensional (2D) materials often forms moiré heterostructure that imposes a new periodicity, which can modify the physical properties of the material and cause novel electronic phases such as unconventional superconductivity, Mott insulating phase, ferromagnetism, and ferroelectricity. Here we report the formation of the moiré heterostructure between graphene and crystalline xenon, that is supported by angle-resolved photoemission spectroscopy and low-energy-electron diffraction. Interestingly, upon the formation of the graphene-xenon moiré heterostructure, the crossing point between Dirac cones shows slight separation, suggesting hybridization among Dirac fermions, and the slope of the Dirac cone increases due to the enhanced dielectric screening, implying suppressed electronic correlations. These findings suggest a simple but direct way not only to create a moiré heterostructure using noble gas on a 2D material, but also to tune the physical properties of a 2D material via moiré heterostructure.

Keywords:

graphene, xenon, moiré, ARPES

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P1-ap.222

$MoS_2/LaVO_3$ 광대역 자가발전 광검출기 소자

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Abstract:

가시광선 영역의 높은 흡수율을 보이는 $LaVO_3$와 2차원 반도체 재료의 접합은 고성능 광대역 광 검출기 응용 분야에 이상적인 구조이다. 본 발표에서는, MoS2/LaVO3 광 검출기 성능에 대해 보고합니다. $MoS_2/LaVO_3$ 접합은 0 전압에서 104의 광전류/암전류 비율, 0.14 AW^{-1}의 광 반응성, 및 4.5 x 10^9 cm $Hz^{1/2}$ W^{-1}의 검출능, 83 dB의 선형 동적 범위, 그리고 260/410μs 응답/복구 시간을 보였다. 특히, $MoS_2/LaVO_3$ 광 검출기의 응답 시간은 이전에 보고된 화학 기상 증착 MoS_2 기반 구조 광 검출기의 응답 시간보다 빠름을 입증하였다. 마지막으로 $MoS_2/LaVO_3$ 광 검출기의 광 반응도 손실은 25°C 온도 및 30% 습도에서 2000시간 동안 원래 값의 16%만 감소함을 확인하였다. 위의 실험 결과들을 토대로 $MoS_2/LaVO_3$ 이종 접합 구조의 물리적인 메커니즘에 대해서 논의하고자 한다.

Keywords:

MoS2, LaVO3, 광대역, 자가발전, 광검출기

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P1-ap.223

Feasibility of 2D nanomaterial window alpha particle detector

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Abstract:

In the case of existing P-I-N type or SB type detectors, AR layer (~100nm), p+ layer (~200nm), and metal layer (~30nm) are used as incident windows, but in case of development technology, the incident window is composed of graphene (~0.3nm). It is expected that the detection efficiency will be remarkably improved as the transmittance of alpha particles increases while maintaining the Schottky junction with the semiconductor substrate.

Electron-hole pairs are formed by the ionization reaction of alpha particles in the depletion layer formed by the graphene-semiconductor Schottky junction and the semiconductor substrate area, and the fast mobility of graphene increases the hole extraction efficiency to develop a high-efficiency alpha particle detector expected to be possible.

In this research, suggested structure of alphaparticle detector was fabricated and characterized. The detection efficiency is improved rather than silicon PIN type alpha-particle detector.

Keywords:

graphene, silicon, alpha-particle detector

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P1-bp.001

Capturing Intermediate States of T199V Variant of Human Carbonic Anhydrase II

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Abstract:

Human Carbonic Anhydrase II (CAII) is one of the most extensively researched enzymes due to its impressive speed, capable of catalyzing reactions at a rate of one million times per second. Its role as zinc metalloenzyme is to facilitate the conversion of CO_2 and H_2O into HCO_3^- and a proton. Researchers have theorized that Thr199 plays as a critical element in ensuring the successful attack of CO_2 by arranging the hydroxyl ion as a nucleophile. In addition, Thr199 aids in the rapid release of bicarbonate by forming hydrogen bonds with two protonated oxygen molecules. The T199V mutation reduces the enzyme's activity by 30 times, and this study aims to investigate the impact of this mutation on the hydrophilic region of CAII's active site. To achieve this, we utilize the High-pressure cryocooling method to pressurize the T199V variant with CO_2 at varying pressures, and conducting a photolysis experiment.

Keywords:

Carbonic Anhydrase, active-site mutation, Intermediate states, CO2 gas pressurization, UV-photolysis

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P1-bp.002

Chemical friction along the minor groove of DNA facilitates enzymatic translocation of λ exonuclease via electrostatic ratchet

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Abstract:

Diffusion and directed translocation of enzymes play an essential role for protein-DNA interactions in gene regulation processes but it is still not fully understood how specific proteins move and search their target sites in the myriad of DNA sequence repertoires. We use λ-exonuclease as a model of nucleic acid-molecular motor that processively translocate along the DNA. Here, we combined single molecule FRET and molecular dynamics (MD) simulation to examine how the dynamic interaction translates into overall enzymatic activity. Transient binding between λ-exonuclease and DNA results in a difference in chemical friction between the positive residue (ARG45) of the enzyme and the electropotential (EP) of the substrate along the minor groove of DNA, resulting in a 150-fold change in translocation rate. Repulsive interaction gives rise to futile slippage events whereas attractive coupling between ARG45 and adenines at the minor grooves provides chemical ratcheting for unidirectional translocation, preventing diffusive backtracking by electrostatic friction. We propose an anti-friction-based ratchet for processive translocation. Our study provides new insights into not only interplay between dynamic chemophysical interaction and enzyme activity but also a role of the minor groove in regulating enzymatic activity based on DNA sequences.

Keywords:

Chemical friction, smFRET, MD simulation

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P1-bp.003

Single-Molecule Studies on The Mechanism of Phage Transcription Termination

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Abstract:

Transcription termination is an essential step in RNA genesis by RNA polymerase (RNAP) and a crucial step for gene regulation. For bacteriophage T7, transcription termination occurs in the Tφ terminator, a hairpin structure followed by the U-tract, which is similar to the intrinsic bacterial terminator. Despite its importance in studies of phage transcription and its widely used application to the in vitro transcription assay, the exact picture of the phage transcription termination is still elusive. To approach this problem, we designed single-molecule assays to observe phage transcription termination in high temporal and spatial resolution, motivated by our previous studies *(1-4)*. Single-molecule assays showed that the post-terminational state of phage termination was almost always decomposing termination and that the average termination timings were slower than the average run-off timing. These characteristics of phage termination are similar to those of stand-by decomposing ρ-dependent termination *(3-4)*, albeit not-meditated by extrinsic factors. Utilizing this single-molecule assay, we try to understand the role of U-track in hairpin-dependent termination and the origin of force in phage transcription termination. Furthermore, we attempt to monitor the effect of ρ, the termination factor of host bacteria.

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2. Kang, Wooyoung, et al. "Hopping and flipping of RNA polymerase on DNA during recycling for reinitiation after intrinsic termination in bacterial transcription." ***International Journal of Molecular Sciences*** 22.5 (2021): 2398.
3. Song, Eunho, et al. "Rho-dependent transcription termination proceeds via three routes." ***Nature communications*** 13.1 (2022): 1-12.
4. Song, Eunho, et al. "Transcriptional pause extension benefits the stand-by rather than catch-up Rho-dependent termination." ***Nucleic Acids Research*** (2023): gkad051.

Keywords:

Sinlge-molecule study, Transcription termination, T7 bacteriophage

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P1-bp.004

Single-molecule studies of human translesion synthesis proteins, polymerase δ, and polymerase η, using FRET.

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Abstract:

While the DNA repair process has been regarded as a critical mechanism to protect overall DNA integrity, however, appropriate DNA damage tolerance (DDT) mechanisms are required to ensure accurate and timely replication of the DNA. Cells encounter various types of DNA lesions during their DNA replication. One of the key DDT pathways, translesion synthesis, enables the cell to bypass DNA lesions and facilitate the proper resuming of stalled replication forks. Translesion synthesis utilizes two different types of polymerase, polymerase δ, and polymerase η, to efficiently bypass typical DNA lesions. The main mediator of polymerase switching is proliferating cell nuclear antigen (PCNA). Several models have been suggested to explain how PCNA switches its partner when it collides with a DNA lesion, but how the affinity of two different polymerase changes was unclear. Recent studies suggest a protein called PCNA-associated factor 15 (PAF15) plays a significant role in polymerase exchange as the majority of PCNA on DNA diffuses together with PAF15. But fundamental information about PCNA-Polymerase-PAF15, such as processivity, switching time, and synthesis rate, have not been fully investigated. We constructed the FRET system to investigate how PAF15 affects the PCNA-Polymerase complex during its replication on CPD (or Control DNA). Our results show the fundamental change in the TLS ability of two different polymerases due to PAF15 binding on PCNA.

Keywords:

Translesion synthesis, FRET, Polyemerase δ, Polymerase η, Single-molecule

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P1-bp.005

Mechanism of Exonuclease-Independent DNA Mismatch Repair

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Abstract:

DNA mismatch repair (MMR) is a critical cellular mechanism that corrects errors mainly occurring during DNA replication. Since malfunctions in MMR can result in genetic disorders such as Lynch Syndrome, understanding the MMR process is important. MLH1/PMS2 is known to have endonuclease activity in human MMR and mismatched DNA strands can be removed from single-strand breaks via Exonuclease I-dependent or Exonuclease I-independent pathways. The endonuclease of MLH1/PMS2 is activated by PCNA. However, the dynamics of the endonuclease activity of MLH1/PMS2 during MMR are not yet understood.
Using a novel single-molecule imaging platform, DNA skybridge, we visualized the diffusion of fluorescently labeled MSH2/6, MLH1/PMS2, and PCNA on DNA. Our observations revealed the dynamics of a complex of MLH1/PMS2-cy3 and PCNA-Cy5, which was formed on DNA. To examine the correlation between these dynamics and the occurrence of single-strand breaks by endonuclease activity of MLH1/PMS2, we exploited DNA polymerase delta and replication Protein A (RPA). Polymerase delta removed DNA by its strand displacement activity from the single-strand breaks, producing single-stranded DNA that was bound by fluorescence-labeled RPA. We were able to detect the presence of single-strand breaks by MLH1/PMS2. Our results provide insights into the mechanism of exonuclease-independent DNA mismatch repair.

Keywords:

DNA mismatch repair, Single-molecule biophysics, DNA skybridge

DNA hanger: novel surface-free/multiplexed single-molecule blotting assay

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Abstract:

All blotting techniques require the surface immobilization of target molecules or substrates, which inevitably results in nonspecific binding to the surface. The resulting noise from nonspecific binding can hinder precise analysis, especially in single-molecule blotting due to its high sensitivity. Although stringent surface passivation can minimize nonspecific binding, it cannot entirely solve the problem. In this study, we developed a novel single-molecule blotting platform called "DNA hanger," which utilizes biotinylated lambda DNA as a scaffold on 3D-patterned quartz. We demonstrate a significant reduction in nonspecific binding of SSB to ssDNA and poly(A)-binding protein to poly(A) mRNA on the DNA hanger platform compared to the conventional PEGylated quartz. Our results suggest that DNA hanger has the potential to be a promising single-molecule blotting assay.

Keywords:

Single-molecule blotting, fluorescence imaging

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P1-bp.007

Demonstration of combined 3-input 1-output logic rules through DNA algorithmic assembly

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Abstract:

The use of a DNA-based algorithmic assembly is a promising approach for future computation and data storage due to its high information density, energy efficiency, and parallel computing capability. While the implementation of M-input N-output logic gates using DNA molecules has been extensively studied, it has been limited by the significant increase in the amount of DNA molecules required when constructing multiple algorithmic lattices using various rules. For example, generating 256 different algorithmic patterns using 3-input 1-output logic gates would require the preparation of all necessary rule tiles. To overcome this limitation, a combination of available rules can be used to generate a large number of algorithmic patterns on DNA lattices. In this study, the design strategy for constructing combined rules is discussed, and DNA algorithmic assembly is demonstrated by combining 3-input 1-output logic rules using complementary and non-complementary rule sets. The complementary (non-complementary) rule set, which means a set of two original rules, gives (doesn't give) the number 255 when two original rule numbers are added. The combination of two rules is a simple and efficient method for constructing various types of algorithmic patterns with ease, and the resulting patterns are visualized and verified using an atomic force microscope (AFM).

Keywords:

DNA, self-assembly, algorithm, logic gate, complementary and non-complementary rules

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P1-bp.008

Study on the effect of hairpin-containing G-quadruplex in transcription of T7 RNA polymerase

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Abstract:

G-quadruplex (G4) is a novel structure of oligonucleotide formed in guanine-rich sequences. Four guanines form a planar structure called as a G-quartet through Hoogsteen hydrogen bonds, and a stack of two or more G-quartets is G4. G4 has been associated with various cellular processes such as DNA replication, DNA damage, genome instability, and oncogene promoter regulation. In G4 structures, the intervening oligonucleotides between guanines form loops that connect G-quartets. Several previous studies suggested that the topology and stability of G4 can be influenced by length and nucleotide composition of the loops. Previous thermal stability studies demonstrated that the loops that are longer than 10-nt induce a parallel conformation of G4s and hairpin-containing G4s are more stable than unstructured loop-containing ones. In addition, *in cellulo* reporter assays showed that the stable G4 perturbs transcription and impedes gene expression. However, the detailed mechanism behind how transcription is affected by hairpin-containing G4 remains elusive. Here, we investigated the functional roles of hairpin-containing G4s in transcription at the single-molecule level. Using DNA curtain, which is a high-throughput single-molecule imaging flatform, and biochemical assays, we observed the transcription of T7 RNA polymerase (T7 RNAP) with different types and concentrations of monovalent cations. We also visualized the transcribed RNA, which formed secondary structures, in DNA curtain. In the presence of monovalent cations (Na+ or K+), the transcription by T7 RNAP was inhibited because G4 was formed. For further works, we have a plan to compare the efficiency of transcription according to the length and composition of the loops in G4. Furthermore, we will visualize the transcription of T7 RNAP in real time using various types of hairpin-containing G4. Through these works, we will provide insight into the roles of G4s in transcription.

Keywords:

G-quadruplex, DNA curtain, Transcription, T7 RNA polymerase

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P1-bp.009

Stabilizing and Retrieving DNA Strands through Salt-encapsulation and Digital Microfluidics for Data Storage

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Abstract:

DNA data storage can provide an alternative to traditional storage with its remarkable properties of higher information density, a longer shelf life, and efficient replication with low cost. Beyond focusing on the development of high-throughput DNA synthesis and sequencing technologies, encoding and decoding strategies, both intact preservation and DNA retrieval have become attractive research. In a DNA preservation framework, we evaluated the effectiveness of salt-DNA encapsulation as a possible solution for preserving salmon DNA (sDNA) and synthetic DNA (DNA) under accelerated aging conditions (up to 14 days at 65°C and 50% RH). Furthermore, we assessed the feasibility of retrieving and measuring DNA from water droplets using the digital microfluidic (DMF) device. Our results indicate that the majority of dried DNA spots can be successfully recovered through droplets. Additionally, the system was also tested by successful digital file read-out via Sanger sequencing of protected heat-treated samples and retrieval experiments, making the approach potentially viable for application in large-scale DNA data storage.

Keywords:

DNA Data Storage, Salt-encapsulation, Digital Microfluidics

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P1-bp.011

Electrical stimulation for proliferation and differentiation of osteoblast cells in a 3D porous scaffold

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Abstract:

The purpose of this study was to investigate how the electric field effect affects and enhances the proliferation and differentiation of osteoblasts in the 3D porous scaffold. The pore size, differences in water absorption, change in Fourier transform infrared (FTIR), and differences in the degree of biodegradability of the scaffold were evaluated, and the cellular response effects were also observed. The scaffold was fabricated using a biocompatible polymer and the upper surface of the scaffold was coated with platinum, and the levels of cell proliferation and differentiation were quantified using a CCK-8 assay and alkaline phosphatase (ALP) assay. Through this study, cell proliferation and osteogenic activity were confirmed through the microcurrent electric field scaffold.

Keywords:

Microcurrent stimulation, osteoblast, proliferation, differentiation, porous scaffold

P1-bp.012

Visualizing PABP-mRNA Interaction: Investigating the Spatiotemporal Dynamics of Translation Initiation in Live Cells

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Abstract:

The translation process is a crucial step in the synthesis of polypeptides, precisely controlled by regulatory proteins during translation initiation. Among the regulatory proteins involved, the poly(A) binding protein (PABP) is associated with the poly(A) tail located at the 3' region of mRNA. PABP-mRNA interactions can modulate the efficiency of mRNA translation and degradation. The length of mRNA's poly(A) tail has been extensively investigated in the context of PABP studies using Next-Generation Sequencing. Previously, it was assumed that the poly(A) tail was fully occupied by PABP due to the high concentration of PABP in the cytoplasm. However, a recent study has discovered that there is no correlation between poly(A) length and PABP occupancy.
To further investigate the kinetics of PABP during translation in live cells, we constructed cell lines of endogenously labeled PABP with a photoactivatable red fluorescent protein, PATagRFP, using CRISPR/CAS9 knock-in. This approach allowed us to visualize PABP binding to mRNA in cells and examine the spatiotemporal dynamics of PABP during translation. By studying PABP binding in live cells, we aim to gain insights into the regulatory mechanisms underlying translation initiation and the role of PABP in this process.

Keywords:

PABP, PABPC1, Translation, Live cell imaging

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P1-bp.013

Liquid-liquid phase separation of GIGANTEA modulates thermosensitive flowering in Arabidopsis thaliana

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Abstract:

To effectively orchestrate various biochemical processes in particular physicochemical environments, cell harbor non-membranous compartments known as 'biomolecular condensates.' Biomolecular condensates are formed via liquid-liquid phase separation (LLPS) and act as unique compartments that can contribute to exotic biochemical reactions which are unlikely to occur in normal cytoplasm or nucleoplasm. Although there are increasing studies on biomolecular condensates with respect to their biological roles, little is known about whether plant cells also take advantage of biomolecular condensates to contribute to plant physiology such as flowering. Here, we report that one of the plant flowering pathway components of *Arabidopsis thaliana*, GIGANTEA (GI), undergoes LLPS to form biomolecular condensates of which the phase properties can be altered by ambient temperature. We revealed that increased ambient temperature disrupts GI condensate formation thereby inducing degradation of floral repressor protein SHORT VEGETATIVE PHASE (SVP) with the aid of FLAVIN-BINDING, KELCH REPEAT, F-BOX1 (FKF1). The study using plant flowering pathway component GIGANTEA will provide insight into how plant cells make use of biomolecular condensates to regulate flowering time in response to environmental cues.

Keywords:

Liquid-liquid phase separation, GIGANTEA, Biomolecular condensates

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UBQLN2 Liquid-Liquid Phase Separation is driven by hydrophobic interactions in vitro and in the cell

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Abstract:

The phenomenon known as liquid-liquid phase separation (LLPS) occurs when molecules in the soluble phase separate into liquid dense phase and liquid dilute phase, much like an oil droplet does in water. Recent research revealed that the ubiquitin binding domain and sticker sites of UBQLN2 drive and regulate the UBQLN2 LLPS. However, there is still debate regarding the precise molecular mechanism causing UBQLN2 LLPS or its biological meaning in Protein Quality Control (PQC). Here, we propose that the multivalency of UBQLN2 is provided by hydrophobicity, which enforces UBQLN2 LLPS *in vitro*. Furthermore, we propose that formation and regulation of Stress Granule (SG) and UBQLN2 LLPS have physiological relevance. This information will shed light on the pathogenic mechanism and biological role of UBQLN2 LLPS.

Keywords:

Liquid-Liquid Phase Separation, LLPS, Biomolecular condensate, Protein Quality Control, Stress Granule

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P1-bp.015

In Silico Engineering of Binding Affinities of Green Fluorescent Proteins

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Abstract:

Green fluorescent protein (GFP) has been used as one of the most effective agents for fluorescence microscopy. However, GFP has weak homodimerization binding affinity, which may interfere with the behaviors of fused proteins and thereby produce unwanted artifacts. Enormous efforts have been made to decrease the binding affinity of GFP homodimers, usually based on chemical intuition. Here, we utilized *in silico* methods to systematically mutate the interface of GFP homodimers and estimate the free energy changes. We first employed mmCSM-PPI, a machine-learning model for assessing changes in protein-protein binding affinity caused by single and multiple missense mutations, to rapidly check the binding affinity changes of all possible single-point mutations at the interface. We then collected the top most stabilizing and destabilizing mutations and carried out molecular dynamics simulations to estimate more accurate binding affinity changes, with the help of alchemical transformation methods. We found that the machine-learning approach and molecular dynamics simulations give generally correlated predictions but their predictions can be drastically different for some specific systems.[j1] We plan to experimentally assess the binding affinity predictions in the future.

Keywords:

green fluorescent protein, molecular dynamics simulation, alchemical transformation, binding affinity

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P1-bp.016

Randomized DNA sequence designs via standard and degenerate bases for data storage

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Abstract:

We can store binary data into DNA base sequence through DNA encoding. Designing randomized nucleotide sequence plays an important role in reducing errors during DNA synthesis on DNA storage. But the standard design that encodes two digits of binary data into one digit of base sequence have no ability to avoid the repetition of same nucleotide base on the sequence. We build new design that can randomize the encoded base sequence than the standard design by using nucleotide dimer as the building block for DNA encoding. We can design the base sequence that have no repetition of same nucleotide on the sequence through this randomizing design. This designed sequence, However, have longer length than the sequence encoded by standard design have since there are constraints that prevent the same nucleotide base as the previous one from following. To increase information density of encoded sequence, we can use degenerate bases on designing base sequence. From the increased number of nucleotide bases we can create more nucleotide dimers, which can lead to higher information capacity of the design.

Keywords:

DNA storage, DNA encoding, Randomizing design, Degenerate base

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P1-bp.017

Percolation-Based Unifying Description of Liquid-Liquid Phase Separation and Gelation of Associative Polymers

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Abstract:

Biomolecular phase separation plays an important role in the formation and regulation of various biomolecular condensates in cells. Recently, the stickers-and-spacers framework, which is based on associative polymer theory, has been developed to explain phase behaviors of biomolecules, and the framework was successfully implemented in a graph-based simulation module. The module uses the concept of percolation, which allows us to describe liquid-liquid phase separation and gelation in the language of graph theory; liquid-liquid phase separation can be depicted by emergence of a giant component, whereas gelation is defined by the diffusion behavior. We introduced *dwell time* to quantify the diffusion behavior of the system, and it could be demonstrated that the dwell time correlates well with the size of the giant component. We also found that there are two relaxation processes, fast and slow; the former can be thought of as initial formation of small clusters (protocondensates or seeds), while the latter displays phase separation. Our study demonstrates that such a simple model can provide qualitative understanding of an apparently complex biological phenomenon.

Keywords:

stickers-and-spacers framework, graph-based simulation, liquid-liquid phase separation, gelation, dwell time

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P1-bp.018

Analysis of Disturbance-embedded Algorithmic Patterns through Machine Learning and DNA Self-assembly

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Abstract:

Machine learning is widely used in various fields of research, especially in image pattern recognition. Pattern recognition analyzes data, identifies patterns, and then uses those patterns to make decisions or predictions. DNA is an applicable molecule to demonstrate logic gates by implementing them as DNA tiles via tile-based algorithmic self-assembly. Here we show that machine learning helps to recognize randomly generated disturbance-embedded patterns comparing with original given pattern. We used a Convolutional Neural Network (CNN) and Residual Network (ResNet) to train data and make prediction of outputs. In addition, randomly generated disturbance-embedded patterns are constructed by DNA algorithmic assembly and visualized by atomic force microscope. By analyzing patterns with disturbances using machine learning, it is possible to increase the understanding of the formation of complex patterns.

Keywords:

machine learning, DNA self-assembly, logic gate, algorithm, disturbance

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P1-bp.019

Uncertainty Quantification and Parameter optimization of Population-based Human Atrial Myocyte Model

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Abstract:

Computational models are increasingly being used to analyze experimental and clinical findings in cardiac electrophysiology. The electrical activity and calcium signaling in cardiac myocytes are important tools for understanding physiology. Model predictions are uncertain because there is typically substantial uncertainty in model input parameters, due to measurement error or natural variability. The sensitivity and uncertainty of models to changes in parameters is often not well-understood. The consequences of such uncertainty are difficult to determine without evaluating the model through large numbers of evaluations.
We used sensitivity and uncertainty analysis to investigate the impact of the conductance and kinetics of potassium currents on biophysically detailed human atrial cell models. We found that certain parameters related to the I_{K1} current were correlated with the excitability and conduction velocity of action potentials, while parameters related to the I_{to} and I_{Kur} currents were most sensitive to action potential durations and repolarization. To estimate these parameters, we also employed a deep learning algorithm to estimate the parameter sets to analyze experimentally measured action potentials. This approach may help to integrate traditional quantitative models with large-scale data sets obtained through high-throughput technologies, allowing for more accurate and reliable predictions in the future.

Keywords:

cardiac arrhythmia, Paramter sensitivity, Uncertainty of paramter, Human atrial model

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P1-bp.020

Active diffusion of self-propelled particles in disordered biopolymer network

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Abstract:

Despite extensive experimental and computational studies for self-propelled particles, the diffusion dynamics of these agents in biopolymer networks remain incompletely understood. In this study, we model active Ornstein-Uhlenbeck (OU) particles in a disordered network where semi-flexible biopolymer chains are randomly connected by the transient crosslinks. Using Langevin dynamics simulations, we investigate the diffusion dynamics of the active tracers in semi-flexible disordered network. Our findings demonstrate that the diffusion dynamics of the active tracers show rich, distinct physics depending on the particle size and active mobility. For small particles, they move as if in free space with decreased mobility. However, as particle size increases, active particles explore the biopolymer network via the trapping-and-hopping mechanism. We study the trapped time distribution, hopping length distribution, mean squared displacement, and long-time diffusivity on varying the tracer size and active mobility. Additionally, we discuss the enhanced diffusion dynamics observed when crosslinks are transient, which originates from a local free volume that active tracer can access in responsive polymer networks. Our results provide important implications for understanding biological processes such as intracellular transport and drug delivery in extracellular matrix.

Keywords:

Active Ornstein-Uhlenbeck (OU) particles, Polymer network, Langevin dynamics simulation, Self-propelled particle, Anomalous diffusion

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P1-bp.021

Characterizing the 1D diffusion dynamics of CRISPR-Cas9 complex via unsupervised machine learning

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Abstract:

CRISPR-Cas9 system is an adaptive immune system of prokaryotic organisms that recognizes and cleaves foreign genetic elements using RNA guide sequences. Due to this mechanism, the CRISPR-Cas9 system is widely used as a gene editing tool, but how this system searches for its target sequences is still elusive. Here, we design an experiment to observe the 1D diffusion of the CRISPR-Cas9 complex with 3 different seed sequences on a long DNA and employ an unsupervised machine learning framework to characterize the dynamics. In this framework, we first measure classical statistical quantities from all the trajectories and find that the dynamics of the CRISPR-Cas9 complex changes after a certain time. To characterize the dynamics, we define a vector extracting key features of each trajectory, visualize all the vectors in the 2D t-SNE space and perform clustering. As a result, we observe multiple distinct clusters in the 2D t-SNE space and find that each cluster shows different dynamics.

Keywords:

Unsupervised Machine Learning, CRISPR, CAS9, Diffusion, Clustering

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P1-bp.022

Heterogeneous active diffusion described by Telegrapher's equation

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Abstract:

We study the diffusion of active particles in a heterogeneous environment using the telegrapher's equation. This equation describes the motion of active particles in terms of directional movement, characterized by a self-propelled time. This time scale can vary and can also form a distribution, depending on the spatio-temporally varying environment. Our focus is on the dynamics of a system with a distribution induced by a heterogeneous environment. It shows various anomalous diffusion such as 'Fickian yet non-Gaussian' or 'Lévy walks' according to the distribution of the self-propelled time. We also investigate the fractional moment spectrum and single-particle fluctuations. Since active particles and heterogeneous environments are commonly found in biological systems, our findings suggest the mechanism for anomalous diffusion in various biological systems.

Keywords:

Heterogeneous environment, Superstatistics, Diffusion in a biological system, Anomalous diffusion

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P1-bp.023

Mixed state of PING and ING state maximizes information encoding in excitatory-inhibitory coupled neural network

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Abstract:

Synaptic excitatory-inhibitory (E-I) ratio is known to be important to maintain brain function, but the relation between the neural oscillation is weakly known. Here, we introduce a model to quantify the encoding capacity and spreading spikes in more realistic situation. In this model we use two types of excitatory and inhibitory neurons and long-lasting synaptic current operated by heterogeneous Poisson synaptic input. Based on the numerical integration, we find three different regimes depending on the synaptic E-I conductance ratio. In each regime, we study the relationship between the synchronization and information encoding. We also discuss possible relation between the observed regimes and physiological disorders.

Keywords:

neural oscillation, neural information encoding, synchronization

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P1-bp.024

Development of a Machine Learning-Based Lipid-Packing Method That Generates Conformational Ensembles Around Membrane Proteins

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Abstract:

Because membrane proteins in living cells are embedded in a lipid layer with various compositions and geometries, constructing a realistic conformational ensemble of protein-lipid complexes is essential for the computational studies of membrane proteins. However, constructing the ensemble requires significant computational resources and manual guidance. Recently, given a large dataset of conformations available, the generative model in the machine learning field demonstrated notable successes in the generation of physically relevant conformational ensembles as well as more popular applications for image generation. Here, we develop a fully automated lipid-packing method around membrane proteins based on a generative model that can predict a conformation ensemble of lipid molecules in protein-lipid complexes. Specifically, we learn physically relevant molecular configurations by applying a graph neural network architecture with a state-of-the-art score-based diffusion model to the MemProtMD database. Our model directly estimates the gradient fields of the log density of atomic coordinates. The calculated gradient fields allow directly generating stable conformations via Langevin dynamics. By using our model, we will demonstrate the lipid ensemble generation of the system with mixed lipid compositions and various geometries including micelles, flat bilayers, and vesicles.

Keywords:

Machine Learning, Membrane Protein

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P1-bp.025

M-input N-output (M, N ≤ 3) Logic Gates through Modular DNA Algorithmic Assembly

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Abstract:

DNA algorithmic self-assembly can be assumed to be a branch of molecular computation. Cellular automaton-like algorithmic patterns can be efficiently generated by M-input N-output logic rules. Among various logic gates, a M-input N-output logic gate with M = N (i.e., 1-input 1-output and 3-input 3-output) reveals important algorithmic characteristics such as feasibility to demonstrate COPY and NOT logic rules, possibility to construct reversible logic gates, and maintaining amount of information after computing logic rules. Operators such as XOR and binary counter can be generated by using rules in 2-input 1-output and 2-input 2-output logic operations among 16 and 256, respectively. Although importance of algorithmic assembly demonstrated by DNA molecules is well established, systematically proposed design scheme of all rules for M-input N-output logic gate is rarely discussed. By purposing efficient way to design all rules, generalization of the rule design is possible. Here, we discussed design strategy for generalized rule tiles for 4, 16, 256, and 2^{24} different available rules in 1-input 1-output, 2-input 1-output, 2-input 2-output, and 3-input 3-output logic operations, respectively. From AFM images, we noticed experimentally obtained patterns on annealed algorithmic DNA lattices were agreed with expected ones. By using the well-designed rule tile modules, DNA algorithmic assembly will be easier and more efficient for molecular computation.

Keywords:

DNA self-assembly, algorithm, logic gate, M-input N-output, generalized logic implementation

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P1-bp.026

Correlation Methods in High-Speed Label-Free Interferometric Scattering Microscopy (iSCAT): Reconceptualizing iSCAT towards a Spectroscopy

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Abstract:

Interferometric scattering (iSCAT) microscopy, label-free high-speed (kHz) imaging technique developed recently, has drawn much attention for its high sensitivity and fast detection. The position, trajectory, and mass of a single nanoparticle or biomolecule can be measured using iSCAT microscopy. Raw iSCAT images, however, should be post-processed to remove background signals, which is often challenging and makes the point spread function of a nanometric target particle obscure and distorted. To overcome this problem, we have developed a concept of ensemble-based single molecule technique that exploits time-series statistics of iSCAT signals. The novel concept can expand the scope of iSCAT research subjects beyond point-like scatterers to include in vivo/in vitro continuum materials. Providing a direct comparison of fluorescence correlation spectroscopy (FCS) and dynamic light scattering (DLS) with iSCAT, we propose a conceptual and theroretical foundation of correlation methods in time-resolved iSCAT signal.

Keywords:

iSCAT, FCS, DLS, Nanoparticle Tracking, Ensemble-based Single-Molecule Technique

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P1-bp.027

Study of amorphous ice induced by high-pressure cryocooling

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Abstract:

If you go to a bar with friends on a nice day, you might have seen a slushy-like soju in a green bottle. When you tap the bottom of the bottle several times, liquid soju surprisingly starts to turn slushy from the bottom. As a physicist, we can explain "This is supercooling of water, cooling below its freezing point without crystallization." While most people just say, "Oh, I see." and move on, some people ask a very sharp question. "Why does supercooling occur?"

It's a challenging question not only for us but also for scientists today. Although the answer to this question seems simple because water molecules have a simple structure with one oxygen atom and two hydrogen atoms, various unique properties of water cannot be theoretically explained due to the complex phenomena arising from hydrogen bonds. Hence, we have developed the research to understand water using experimentally accessible methods. Specifically, we generate amorphous ices which are thermodynamically connected to liquid water, using high-pressure cryocooling.

In this presentation, we would like to introduce amorphous ice and the experimental method based on fluorescence for solvation dynamics. Furthermore, since amorphous ice is closely related to biological research such as cryo-EM or protein crystallography, we'll also explain the research plan that aims to apply it to the biophysical field.

Keywords:

high-pressure cryocooling, amorphous ice, solvation dynamics

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Noise-reduction in cryogenic electron tomography by supervised learning

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Abstract:

Cryogenic electron tomography is a technique that observes the 3D structure of biological samples in low dose conditions to minimize the specimen damage which can be caused by electron irradiation [1]. Due to the low electron dose, the cryogenic electron microscopy (cryoEM) images usually suffer from significant Poisson noise, limiting the spatial resolution of the reconstructed 3D tomograms [2]. There are several cryo-EM image denoising methods utilizing deep-learning based approaches, which can improve the spatial resolution of the resulting 3D structures. However, they use an unsupervised learning scheme which assumes that all target molecules in the measurement should have an identical structure, not being able to capture structural deviations of flexible biomolecules [3,4,5,6]. In this research, we developed a cryo-EM image denoising technique via a supervised learning process using POPC liposomes as a model system. We implemented a cryo-EM image simulation algorithm that reflects the physical process of transmission electron microscopy imaging is applied, so we can make simulation images that are similar to experimental image, and created training sets and ground truths as the simulated images with Poisson noise and noise-free images, respectively. By applying our trained deep-learning based neural network to experimentally measured cryoEM tilt series images of POPC liposome pair, we were able to improve the spatial resolution of reconstructed POPC liposome volume from 5.2 nm to 4.5 nm.

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Keywords:

Cryogenic electron microscopy, Cryogenic electron tomography, Image denoising, Deep-learning

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P1-bp.029

smCamera: an all-in-one tool for single molecule fluorescence imaging and analysis

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Abstract:

Single molecule fluorescence imaging has been widely adopted by many researchers, but there still are more laboratories which are willing to learn the imaging techniques and analysis methods. Here, we present smCamera, an all-in-one tool for single molecule fluorescence imaging. This software enables not also data acquisition but also most of standard analyses for single molecule fluorescence resonance transfer (smFRET) data. We hope the distribution of this software and its source code could promote popularization of single molecule techniques.

Keywords:

Single molecule Fluorescence, smFRET Analysis

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P1-bp.030

Introducing a Novel Carbonic Anhydrase II Mutant: Substitution of Thr 199 with Val for Insight into Enzyme Function and Mechanism.

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Abstract:

Carbonic anhydrase II (CAII) is a zinc-containing enzyme that exists as a monomer and facilitates the reversible hydration of carbon dioxide to bicarbonate and a proton. This enzyme is present widely in living organisms and is essential for various metabolic processes including CO_2 transport, secretory processes, and photosynthesis. Additionally, carbonic anhydrase II is considered one of the most efficient enzymes known to date. [1] [2]
To comprehend its function and mechanism, it is crucial to examine the enzyme's active-site cavity, which is amphiphilic in nature. The active site has one side dominated by hydrophobic residues and the other by hydrophilic residues. A polar residue, particularly Thr 199, forms a hydrogen-bond network with the zinc-bound hydroxide, which stabilizes and positions this moiety for nucleophilic attack on CO_2.
We have developed a new mutant of carbonic anhydrase II through genetic engineering. This mutant differs from the wild-type enzyme in its amino acid sequence at a specific position. Specifically, we substituted the amino acid threonine (Thr) with valine (Val) at position 199 in the active site of the enzyme. This change in the amino acid sequence is expected to affect the function and behavior of the enzyme. By introducing this new mutant, we aim to gain further insights into the role played by Thr 199 residue in the enzyme's activity and function. In this report, we will describe the method used to create this new mutant through amino acid substitution.

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Keywords:

Enzyme , Carbonic Anhydrase , active-site mutation, Amino acid substitution

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P1-bp.031

Hyaluronic Acid-Conjugated with Hyperbranched Chlorin e6 Using Disulfide Linkage and Its Nanophotosensitizer

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Abstract:

Photodynamic therapy (PDT) using a photosensitizer is an alternative treatment that can minimize the aftereffects of conventional cancer treatment. Photosensitizers are not cytotoxic unless exposed to light, and induce cell death by being excited only by light of a specific wavelength. The main purpose of this study is to synthesize novel types of nanophotosensitizers that are based on hyperbranched chlorin e6 (Ce6) via disulfide linkages. Moreover, hyperbranched Ce6 was conjugated with hyaluronic acid (HA) for CD44-receptor mediated delivery and redox-sensitive PDT against cancer cells. Furthermore, HA-cystamine was attached with Ce6 tetramer or Ce6 decamer to synthesize HA-Ce6 tetramer (Ce6tetraHA) or HA-Ce6 decamer (Ce6decaHA) conjugates. The synthesized Ce6tetraHA and Ce6decaHA nanophotosensitizers showed small diameters of less than 200 nm. Ce6tetraHA nanophotosensitizers showed higher intracellular Ce6 accumulation, higher ROS generation, and higher PDT efficacy than that of Ce6 alone. These results indicated that Ce6tetraHA nanophotosensitizers delivered to tumors by redox-sensitive and CD44-sensitive manner.

Keywords:

Photodynamic therapy, photosensitizer , CD44-receptor, chlorin e6

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P1-bp.032

Silica, PCL encapsulation and OHP preservation methods for DNA data storage

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Abstract:

In this era of overflowing information, DNA is emerging as a promising data storage medium. Where DNA data storage technology is being developed in various ways, finding the way to store DNA safely at a low cost is essential for successful commercialization of DNA data storage. Here, we explore several DNA storage methods and analyze their practicality. Recovery of stored DNA in different strand sizes and storage mediums is compared to evaluate the suitability of each method. Finally, we discuss the possibility of applicable DNA storage methods which is highly accessible with minimized cost and procedure.

Keywords:

DNA, data storage, encapsualtion

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P1-bp.033

Mechanisms of Carbonic Anhydrase and its Metal Variants through DFT Calculations

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Abstract:

Carbonic anhydrase (CA) is one of the most versatile metalloproteins which have been found from fish to humans in our animal kingdom. This zinc-based metalloenzyme catalyses the reversible hydration of carbon dioxide to form bicarbonate (HCO_3^-) and proton (H^+), thus playing a key role in pH and CO_2 homeostasis. Changes in CA activity are associated with various diseases such as glaucoma, type II diabetes, mellitus, and liver diseases. As CA is one of the most efficient enzymes (turnover frequency=10^6 s^{-1}) and also an important target for cancer therapy, a robust and clear understanding of the mechanism of carbonic anhydrase activity is crucial. Here, we report our density functional theory (DFT) analysis on CA, comparing energetics of different structures obtained from high- pressure X-ray crystallography. We confirmed that the proton transfer reaction from water to hydroxide is a thermodynamically favourable reaction in the first step and then nucleophilic attack on carbon dioxide happens to form bicarbonate ion. As the central metal atom plays a crucial role in the activity of carbonic anhydrase, we also compared the variants of carbonic anhydrase containing Co^{2+}, Ni^{2+}, and Cu^{2+} and found that the coordination chemistry and consequent enzyme activity hugely depend on the identity of the metal.

Keywords:

Carbonic anhydrse(CA), DFT, Metal-variant of CA

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P1-co.101

펄스 레이저의 에너지 밀도 변화에 따른 NiCo2O4 박막의 격자변형과 수직 자기 이방성

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Abstract:

펄스 레이저 증착법(PLD)를 이용하여 에피탁시 NiCo2O4 박막을 MgAl2O4(001) 기판 위에 제작하였다. 본 연구에서는 다른 증착 변수는 고정시키고 펄스 레이저의 에너지 밀도를 변화시키면서 박막들을 제작하였다. X-선 회절 측정을 통해, 레이저 에너지 밀도가 증가할수록 NiCo2O4의 수직방향 격자상수는 작아졌으며, 모든 시료의 반치 전폭이 약 0.05˚로 매우 작음을 알 수 있었다. 원자 힘 현미경(AFM) 이미지에서 레이저 에너지 밀도가 증가할수록 박막 표면에 작은 알갱이들이 많아지는 경향을 보였다. 그리고 박막의 수직 자기 이방성은 박막 평면에 수직 방향으로 자기장을 걸고 자기광 커 효과(MOKE)를 측정하여 확인하였다. 레이저 에너지 밀도가 증가함에 따라 보자력(Coercivity)은 약 1.9 J/cm2 조건에서 증착했을 때 약 1,200 Oe로 최대였고 이후 다시 감소하였으며, NiCo2O4 박막의 상전이 온도는 레이저 에너지 밀도가 증가함에 따라 증가하는 경향을 보였고 2.1 J/cm2 이상에서 약 390 K로 최대였다. 또한 자기 광 커 현미경을 이용해 각 박막의 보자력 근처에서 자기 구역 형상 변화를 관찰하였다. 특히, 1.9 – 2.1 J/cm2 조건에서 만든 시료는 작은 덩어리 또는 돌기 형태의 수많은 자기구역들을 가지며 상대적으로 뚜렷한 자기구역 형상을 나타냈다.

Keywords:

키워드 : 스피넬 산화물, 준강자성, 수직 자기 이방성

후 열처리 온도에 따른 Co 박막의 구조 및 자성 특성 변화

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Abstract:

절연체 기판위에 얇게 성장된 금속 박막은 높은 온도의 후열처리 과정에서 표면 에너지 차이로 인해서 dewetting 현상이 일어나, 금속 박막에 구조적, 물리적 변화가 일어나게 된다. 이러한 dewetting 과정은 금속 박막이 자발적으로 나노 입자 배열을 형성하게 하는 방법 중 하나로 많이 활용되고 있다[1, 2]. 또한, 강자성체 물질은 입자의 크기, 모양, 결정 방향 등에 따라 다양한 자기적 특성이[3, 4] 나타나 강자성체 박막의 dewetting 과정을 통해서 다양한 자성 특성 제어가 가능하다.

본 연구에서는, flash evaporation 방법으로 Al_2O_3(0001) 기판위에 상온 강자성체인 Co 박막을 얇게 증착하고 후 열처리 온도 (800 ~ 1000 ^{o}C)에 따라 형성된 dewetting된 Co 입자들의 구조적, 자기적 특성을 고찰하였다. 제작된 Co 입자들은 너비가 높이보다 3배이상 큰 타원체 형상을 띄었다. 또한, 대부분 Co (111) 방향으로 높은 결정성을 가지는 것을 확인하였다. 하지만, 해당 입자의 자기적 특성은 열처리 온도에 관계없이 모두 수평 자기장 하에서 더 높은 포화 자화값과 투자율을 가지는 것으로 확인하였다. 이러한 자기적 특성은 Co 입자들의 결정 자기 이방성과 형상 자기 이방성의 상관관계 때문인 것으로 추측된다.

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Keywords:

Co islands, Dewetting, In-plane magnetic anisotropy

PET 기판 변형에 따른 수직 자기 이방성 Pt/Co/Pt 다층박막의 자기적 특성 변화

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Abstract:

스퍼터링(Sputtering) 증착 법을 이용하여 수직 자기 이방성을 갖는 Ta(1 nm)/Pt(2 nm)/Co(0.8 nm)/Pt(2 nm)/Ta(2 nm) 다층박막을 PET(polyethylene terephthalate) 기판 위에 제작하였다. 본 연구에서는 유연한 PET 기판 위에 자성체 다층박막을 증착하고 기판의 휘어짐 정도에 따른 자기적 특성 변화를 관찰하였다. 곡률 반경이 다른 원통형 막대들을 이용해서 박막을 휘게 한 후 다시 복원시킨 상태에서 자기 광 커 효과(MOKE) 현미경를 이용해서 보자력(coercivity) 크기와 자기구역 형성 변화를 관찰하였다. 원통 막대의 곡률 반경을 약 5 mm 이하로 줄임에 따라 박막의 보자력(coercivity) 크기는 약 10% 정도 증가했고, 자기구역 형상은 대칭적인 원형에서 기판의 휜 방향으로 수축된 타원 또는 막대 형태로 바뀌었다.

Keywords:

수직 자기 이방성, 자성체 박막, 기판 변형

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P1-co.104

High magnetoresistance at room temperature for Fe_3O_4 Core-shell Nanostructure

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Abstract:

In this study, we investigated the magnetoresistance properties of a chemically synthesized core-shell nanostructure composed of Fe_3O_4 nanoparticles and RGO(reduced graphene oxide) at room temperature and a relatively low magnetic field. Samples were prepared using the solvothermal synthesize method. The morphology and crystal structure of the core-shell nanostructure was confirmed using XRD (X-ray diffraction) and SEM (scanning electron microscopy). Our results demonstrate a significant enhancement of magnetoresistance in the core-shell structure compared to Fe_3O_4 nanoparticles under the same conditions [1]. This enhancement is attributed to the strengthened spin-orbit coupling between graphene and iron oxide particles, as well as some spin exchange interactions[2-4].

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Keywords:

magnetoresistance, coreshell nanostructure, spin orbit coupling

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P1-co.105

Preparation and characterization of Co doped $MnFe_2O_4$ nanoparticles for biomedical application

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Abstract:

The crystallographic and magnetic properties of Fe oxides with potential applications as biomaterials have been studied. $Mn_{1-x}Co_xFe_2O_4$ nanoparticles were prepared by the high-temperature thermal decomposition method and thin films were prepared by the sol-gel method. The samples are characterized by X-ray diffractometer, Vibrating sample magnetometer, and Mössbauer spectroscopy. It was confirmed that all $Mn_{1-x}Co_xFe_2O_4$ samples were single-phase cubic spinel structures with Fd-3m space groups, and the calculated average particle size was 7.5-11 nm. The lattice parameter of $Mn_{1-x}Co_xFe_2O_4$ was decreased from 8.3997 to 8.3831 Å as the cobalt substitution increased. As the zinc substituted, the saturation magnetization value of $Mn_{1-x}Co_xFe_2O_4$ was 65.78-67.07 emu/g and the coercive force was 28.49-57.49 Oe, respectively. Mössbauer spectroscopy was performed to determine the phase of nanoparticles and to study electromagnetic interactions for their superparamagnetic properties. The exothermic experiment for hyperthermia was performed in an external magnetic field of 250 Oe and 109.8 kHz. The result shows that saturation was achieved at 77.40-97.88 °C at 800 s.

Keywords:

Mn-Co ferrite, Mössbauer spectroscopy

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P1-co.106

On Surface Quantum Chemistry

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Abstract:

Electronic spins are two-level quantum-mechanical systems that can be controllably put in a coherent superposition state by means of external electromagnetic fields. In the paradigm of quantum computation, they are treated as quantum logic units or qubits, with the expectation of expanding the current, classical, computational performances.

Molecules bearing electronic spins offer potential sources of qubits. They can be fabricated in large quantities, while offering high tunability of the spin environment and spontaneous aggregation in long-range ordered 2D or 3D lattices. The rational design of molecular spin qubits, have allowed achieving important milestones, such as implementing quantum operations and have raised expectations for the use of molecular spins qubits, as quantum computation units.

The "On-Surface Quantum Chemistry" project aims at developing high-performance molecular spin qubits, by enforcing an approach that encompasses quantum mechanics, molecular chemistry and surface sciences. While coherence properties can be modulated via the boundless possibilities of the chemical design, the scaling-up of molecular qubits in interconnected arrays, may be realized via 2D crystal engineering, by exploiting self-assembly and supramolecular recognition.

Keywords:

Molecular, Spin, Qubit

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P1-co.107

Magnetic characterization of superparamagnetic Ni-Zn ferrite

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Abstract:

Ni-Zn ferrites are excellent materials in high-frequency usage due to their low coercivity and high resistivity values and little eddy current loss. $Ni_{1-x}Zn_xFe_2O_4$ nanoparticles was prepared by the sol-gel method. The samples were characterized by X-ray diffractometer and Mössbauer spectroscopy. The crystal structure of the $Ni_{1-x}Zn_xFe_2O_4$ nanoparticles was a single-phase cubic spinel (space group: Fd-3m) with an increasing lattice constant from 8.3363 to 8.4185 Å as the zinc substitution. The average particle size of synthesized $Ni_{1-x}Zn_xFe_2O_4$ were confirmed to be 5-14 nm. Mössbauer spectroscopy was performed to determine the phase of nanoparticles and to study electromagnetic interactions for their superparamagnetic properties. Through Mössbauer spectroscopy, it is confirmed all Fe ions are on Fe+3 state.

Keywords:

Ni-Zn ferrite, Mössbauer spectroscopy

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2023-04-19 - 2023-04-21

P1-co.108

Lanthanide double-decker complexes as on-surface quantum nanomagnets

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Abstract:

Lanthanide-based Single-molecule magnets are promising materials for future spintronic applications, such as ultra-high-density memory devices, quantum computing, sensing, and information processing units.
Using a variety of methods, we have succeeded in synthesizing and purifying different double-decker phthalocyanine complexes (M-Pc2; M = Y, Er, Tb) and deposited them onto metal substrates in ultra-high vacuum (UHV) for scanning tunneling microscopy/spectroscopy (STM/STS) investigations. Terbium double-deckers have recently been the object of several investigations on quantum spin control within molecular spin transistors and several STM settings. Departing from these former investigations, we focused our attention on ErPc2 as the magnetic properties of the Erbium molecular complex have not been carefully characterized yet. ErPc2 and TbPc2 were expected to display different magnetic properties and they can be accessed with STMs and several other techniques within our reach.
This study describes the magnetic and electronic characterization of Erbium double-decker supported on an Au(111) substrate. Single molecular units were investigated via STM and STS in order to extract structural, electronic, and magnetic properties. We observed the Kondo effect on the ErPc2 scaffolds, indicative of the presence of an unpaired electron on the molecular complex. Such an electron can be potentially exploited as a sensor for the quantum control of the electronic and nuclear spins of the enclosed and well-isolated Er atom.

Keywords:

ErPc2, spin on surfaces, molecular magnetism, double-decker

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P1-co.109

Spin-flip-driven anomalous Hall effect and anisotropic magnetoresistance in a layered Ising antiferromagnet

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Abstract:

The influence of magnetocrystalline anisotropy in antiferromagnets is evident in a spin flip or flop transition. Contrary to spin flops, a spin-flip transition has been scarcely presented due to its specific condition of relatively strong magnetocrystalline anisotropy and the role of spin-flips on anisotropic phenomena has not been investigated in detail. In this study, we present antiferromagnet-based functional properties on an itinerant Ising antiferromagnet $Ca_{0.9}Sr_{0.1}Co_2As_2$. In the presence of a rotating magnetic field, anomalous Hall conductivity and anisotropic magnetoresistance are demonstrated, the effects of which are maximized above the spin-flip transition. Moreover, a joint experimental and theoretical study is conducted to provide an efficient tool to identify various spin states, which can be useful in spin-processing functionalities.

Keywords:

Antiferromagnetic material, Spin flip transiton, Anomalous Hall effect

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P1-co.110

Unusual double-flat-spiral magnetic structure driven magnetic phase transition in helical-antiferromagnetic kagome metal YMn_6Sn_6

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Abstract:

Kagome magnets have been studied for their novel magnetism and topological electronic properties. Here we study the Kagome antiferromagnet YMn_6Sn_6 with torque-magnetometry to investigate anisotropic properties for various magnetic phases. YMn_6Sn_6 is well known for a centrosymmetric (space group P6/mmm), itinerant helical-antiferromagnet. Its complex helical magnetism originates from competing Ruderman-Kittel-Kasuya-Yoshida exchange interaction across Sn_2Y, Sn_3 layers which trigger the unusual double-flat-spiral magnetic structure of YMn_6Sn_6. The helimagnetic order arises below T_N = 333 K, in which the magnetic moment of Mn rotates in the ab plane, propagating along the c-axis with two propagation vectors k_1, k_2. Magnetic phases of YMn 6 Sn 6 were mostly identified by neutron diffraction in recent reports, but still have an ambiguous part in its phase diagram. In this work, we determine the development of magnetic structures using anisotropic spin model and understand anisotropic magnetic torque data in the presence of a linearly increasing and rotating magnetic fields.

Keywords:

Kagome, Helical-magnet, Torque-magnetometry, Magnetic phase transition

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P1-co.111

Magnetic anisotropy in Weyl RKKY magnet NdAlSi

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Abstract:

Magnetic Weyl Semimetal is a promising platform for potential application in spintronics device due to their noble physical properties. NdAlSi, newly proposed magnetic Weyl semimetal candidiate, also helds Weyl Fermion meditated RKKY interaction so called Weyl RKKY Magnet. A spin-flip transition can occur in antiferromagnets under strong magnetocrystalline anisotropy, inducing a significant modification of anisotropic magnetic properties through phase conversion. In contrast to ferromagnets, antiferromagnets have not been thoroughly examined in terms of their anisotropic characteristics. In this work, we synthesized NdAlSi by self-flux method and measured anisotropic magnetization and magnetic torques. We determined the magnitude of its magneto-crystalline anisotropy energy and visualized the detailed spin configurations that evolved with the application and rotation of a magnetic field, using the anisotropic spin model. In addition, we demonstrated that the verified spin states are directly related to development of angle-dependent torque across the flip transition.

Keywords:

Antiferromagnet, Spin-flip Transition, Weyl Semimetal

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2023-04-19 - 2023-04-21

P1-co.112

Breaking Time-Reversal Symmetry of the Surface Conducting State in Ferromagnet Insulator/Topological Insulator Heterostructures

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Abstract:

Three dimensional topological insulators (3D TIs) are known to exhibit a unique conducting state that is topologically protected and exists throughout the entire surface of the 3D TIs. By performing simultaneous measurements of local and non-local conduction, it is possible to indirectly verify the presence of the surface-conducting state in 3D TIs [1]. This surface-conducting state in 3D TIs is protected by time reversal symmetry, which means that it cannot be easily disrupted. However, if time reversal symmetry is broken, it can lead to the opening of a gap in the surface-conducting state. By using heterostructures composed of ferromagnetic insulator ($CrSiTe_3$) and a topological insulator ($Bi_{1.5}Sb_{0.5}Te_{1.7}Se_{1.3}$), we expect the breaking of time reversal symmetry in the surface-conducting state. The opening of the gap in the surface conducting state is expected to be confirmed by a decrease in the non-local signal. This study provides deeper insights into the surface conducting state by confirming its presence and the protection of its properties by time reversal symmetry through analysis of the non-local signal.

References
1. J. Lee, J.-H. Lee, J. Park, J. S. Kim, H.-J. Lee, *Physical Review X* **2014**, *4*, 011039.

Keywords:

Topological insulator, Ferromagnet insulator

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P1-co.113

Proximity-induced Ferromagnetism in hBN/Graphene/CrPS4 Heterostructure

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Abstract:

Ferromagnetic graphene presents a promising platform for the electronic analysis of 2D ferromagnetic systems by utilizing the unique characteristics of graphene, such as its gate-tunable carrier density. In this study, we investigate magnetotransport in heterostructures hexagonal boron nitride (hBN), graphene, and air-stable van der Waals antiferromagnet $CrPS_4$. The anomalous Hall effect is observed over a temperature range of 2 K to 100 K, and the anomalous Hall resistance in our device is consistent with the known saturation field of $CrPS_4$, which is approximately 4 T [1]. By leveraging the gate-tunable carrier density of graphene, we confirm that the anomalous Hall resistance increases to 250 Ω, along with an increase in longitudinal resistance. These results suggest that this platform has the potential to enable the study of a 2D ferromagnetic Dirac fermion system with reduced air degradation.

[1] R. Wu, A. Ross, S. Ding, Y. Peng, F. He, Y. Ren, R. Lebrun, Y. Wu, Z. Wang, J. Yang, A. Brataas, and M. Kl¨aui, Phys. Rev. Appl. 17, 064038 **(2022)**.

Keywords:

Induced ferromagnetism, CrPS4, Graphene, Anomalous Hall effect

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P1-co.114

Magnetic anisotropy probed by magnetic torque in a van der Waals antiferromagnetic $CrPS_4$

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Abstract:

Exploration of van der Waals (vdW) antiferromagnets greatly enriched our understanding of intrinsic magnetism in the 2D limit. However, there is a limitation to identifying detailed spin states for highly anisotropic magnetism due to the experimental difficulty. In this work, we have revealed intricate spin states formed by rotating magnetic fields in van der Waals antiferromagnetic $CrPS_4$, utilizing combined magnetic torque measurements and spin model calculations. $CrPS_4$ exhibits an A-type antiferromagnetic order along the magnetically easy *c*-axis below T_N = 38 K. Our model calculations with uniaxial anisotropy determined magneto-crystalline anisotropy energy and visualized the spin configurations, closely connected to the evolution of magnetic torques through spin-flop transition. Our approach proposed in this work provides useful guidance for the analysis of distinctive magnetic characteristics in $CrPS_4$, which can be extended to other vdW antiferromagnetic materials.

Keywords:

van der waals, A-type antiferromagnet, spin-flop transition

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P1-co.115

Investigating the phase transition of FeRh thin films by Co doping

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Abstract:

FeRh is a fascinating material that exhibits a first-order phase transition from an antiferromagnetic (AFM) state at low temperatures to a ferromagnetic (FM) state at high temperatures. The transition temperature is around 370 K above room temperature. For specific applications in magnetic memory devices and spintronics, it is necessary to adjust the transition temperature to the desired temperature. One effective way is magnetic doping, which is the substitution of a small percentage of magnetic atoms. In this study, we report how the magnetic doping of Co atoms affects the phase transition and the magnetic properties. We fabricated Co-doped FeRh(001) thin films on MgO(001) substrates by using the magnetron co-sputtering method with FeRh alloy target and Co single target. We controlled the gun current of the Co target to modulate the amount of Co doping. The energy-dispersive spectroscopy data revealed that the percentage of the doped Co atoms is between 1 and 2%, which increases with increasing the Co gun current. The X-ray diffraction results showed that the lattice parameters are not changed due to the small amount of Co doping. However, we observed that the phase transition temperature enormously changes by the Co doping. Even with a small doping ratio of 1%, the transition temperature is reduced by 120 K. This magnetic phase transition is accompanied by a change in the electrical resistance, which is more specific. We discuss the modification of the temperature and field dependence of the phase transition as well as the changes in the magnetic and transport properties of FeRh by the Co doping.

Keywords:

FeRh, Magnetic Doping, Magnetic Transition

2023 KPS Spring Meeting
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P1-co.116

Perpendicular and Longitudinal Exchange Bias Effects in Ferrimagnetism/Antiferromagnetism system

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Abstract:

The exchange bias (EB) effect originates from the magnetic interaction at the interface between ferromagnetism (FM) and antiferromagnet (AFM), FM/AFM bilayer, which is practically used to pin the spin direction of giant magnetoresistance head in hard disk drives. Nevertheless, its mechanism is still unveiled. From the material viewpoint, most studies on the EB effect have been performed in FM/AFM bilayers with in-plane magnetic anisotropic (IMA) geometry, and there are few reports on FM/AFM bilayers with perpendicular magnetic anisotropic (PMA) geometry. In this study, we report the EB characteristics for IMA and PMA, where the spin structure is controlled by the amount of Co of $Mn_{3-x}Co_xGa$. We fabricated two distinct bilayer systems composed of two magnetic components; $Mn_{3-x}Co_xGa$ ferrimagnetic (FI) layer and Mn_3Ga AFM layer. We could change the magnetic anisotropy of $Mn_{3-x}Co_xGa$ FI layer simply by adjusting the Co composition; For $x \leq 0.3$, it is hard FI with PMA, and for $x \geq 0.57$ it is soft FI with IMA. Furthermore, since the AFM Mn_3Ga is cubic with no magnetic anisotropy, we could tune the magnetic anisotropy of Mn_3Ga through the field cooling process. We explain the complex EB effect of FI $Mn_{3-x}Co_xGa$/AFM Mn_3Ga bilayer systems by using the spin-glass model.

Keywords:

Heusler compound, magnetic anisotropy, exchange bias

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2023-04-19 - 2023-04-21

P1-co.117

Magnetic Proximity Effect in FeRh/NiFe Bilayer

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Abstract:

FeRh is a fascinating material that exhibits a first-order phase transition from an antiferromagnetic (AFM) state to a ferromagnetic (FM) state around 380 K with potential applications in magnetic memory and spintronic devices. There have been various efforts to modulate the transition temperature using strain, composition, and chemical doping, but various problems have been encountered in which the AFM and FM phases are not preserved. In this study, we present an effective method to adjust the transition temperature of FeRh by using the magnetic proximity effect. We deposited a FM layer of $Ni_{0.8}Fe_{0.2}$ on the top of FeRh films by using the magnetron sputtering system. The thickness of NiFe layer was varied from 10 nm to 40 nm with a fixed thickness (~ 60nm) of FeRh. The X-ray diffraction patterns of bilayer films revealed that there is no crystal deformation of the two phases. We investigated the magnetic and transport properties of the FeRh/NiFe bilayer. We found that the change in magnetization is accompanied by the change in electrical resistivity and the transition temperature decreases from 380 K for FeRh monolayer to ~ 250 K for FeRh/NiFe bilayer. Noting that in FeRh the AFM and FM interactions are competing each other and this competition is maximal around the transition temperature, we can interpret the change of the transition temperature in the FeRh/NiFe bilayer as the magnetic proximity effect. In other words, the FM material of NiFe in close proximity to FeRh increases the strength of the FM interaction, resulting in the decrease of the transition temperature. This result provides a new avenue for engineering the magnetic transition of FeRh for applicable spintronic devices.

Keywords:

Magnetism, FeRh

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P1-co.118

Determining the Femi level of Cd_3As_2 through transport measurements

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Abstract:

Cd_3As_2 is categorized as a three-dimensional Dirac semimetal that exhibits a linear energy dispersion hosted by massless Dirac fermions. The characteristics of Dirac fermions is the most prominent when the Fermi level lies in close vicinity of the Dirac point, i.e., the charge neutral point. However, the reported Fermi level positions of Cd_3As_2 are diverse due to different sample quality and growth techniques. In this study, we prepared Cd_3As_2 thin films by using the molecular beam epitaxy and fabricated micro-sized patterned devices that could exclude the geometric effect. We observed that the low-temperature electrical resistivity significantly changes as the measurement time elapses. For example, the electrical resistivity of about 4 mWcm at 4 K increases to 18 mWcm after 8 months and decreases again to about 2 mWcm after 4 months. Since there is no directional change in the electrical resistivity, we measured the Hall effect and magnetoresistance in order to reveal the origin. For the sample with high resistivity, we found a low carrier density (3×10^{16} ~ 10^{17} cm^{-3}), a negative longitudinal magnetoresistance (NLMR) at high magnetic fields, and a weak anti-localization (WAL) signal at low fields. These NLMR and WAL are regarded as the evidence for the presence of Dirac fermions, i.e., the Fermi level is close to the Dirac point. These results are compared to the sample with previous studies where the carrier density is larger and the longitudinal magnetoresistance is positively parabolic. These observations demonstrate the inherently environment-sensitive nature of Cd_3As_2, and this report provides an insight to determine the position of the Fermi level by using simple transport measurements.

Keywords:

Dirac semimetal, Weak-antilocalization, Negative magnetoresistance, Cd3As2

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P1-co.119

Transport and magnetic properties of Se-doped $Co_3Sn_2S_2$

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Abstract:

$Co_3Sn_2S_2$, where the Co atoms are arranged in two-dimensional kagome lattices stacked along the c-axis, is emerging as a magnetic Weyl semimetal with nontrivial topological magnetic phenomena such as giant anomalous Hall conductivity and Hall angle due to its peculiar magnetic structure. Nevertheless, the magnetic states depending on the temperature are not clearly uncovered. Earlier ab initio calculations predicted that the Co moments are ferromagnetically aligned along the c-axis, whereas recent muon-spin rotation experiments suggested that the Co moments are coupled antiferromagnetically in the plane and ferromagnetically out of the plane. This competition between the two magnetic couplings can provide a nontrivial magnetic phase, together with the topological nature of Weyl fermions, sensitively varying in terms of temperature and magnetic field, resulting in one of the two dominating. In this study, we performed detailed temperature- and field-dependent magnetic and transport properties of $Co_3Sn_2S_{2-x}$-Se_x (x = 0, 0.26, and 0.86) single crystals. The Se substitution was used for adjusting the two intra- and inter-layer magnetic interactions. The X-ray diffraction data revealed that the Se subsititution increases the lattice parameter. The magnetic measurements showed that the out-of-plane antiferromagnetic and in-plane ferromagnetic transition temperature decreases from 178 K to 164 K and 150 K for x = 0, 0.26, and 0.86, respectively, while the magnetic anisotropy energy increases. At lower temperatures, an additional sharp transition, which is so-called 'A' phase where puddles of ferromagnetic and antiferromagnetic orders can coexist and the anomalous Hall angle is maximal, was observed in the zero-field cooled magnetic data. We discuss the highly anisotropic magnetic phases in $Co_3Sn_2S_{2-x}$-Se_x and explain the peculiar magnetoresistance results depending on the direction of applied magnetic field.

Keywords:

Magnetism, Cobalt Shandite, doping, layered structure, Magnetic Weyl

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P1-co.120

Quantitative Comparison between Field-like Spin-orbit Torque and Dzyaloshinskii-Moriya Interaction

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Abstract:

Spin orbit torque (SOT) and Dzyaloshinskii-Moriya interaction (DMI) have opened a new generation of spintronics. Because SOTs are expected to be used to switch magnetic layer without external magnetic field which in turn, lead SOT-magnetic random-access memory (SOT-MRAM). And DMI can drive chiral spin textures which in turn, can lead skyrmion racetrack memory. These two quantities have been investigated extensively by many researchers for the applicability explained above. Recently, some theoretical papers have indicated that there exists correlation between field-like SOT and DMI because they both have interfacial origin. Nevertheless, experimental evidence are still lacking in these days.

For that reason, we prepare Ta(2.0 nm)/Pt(2.0 nm)/Co(t_{FM})/Pt(2.5 nm) film series and measure both field-like SOT and DMI. Here, t_{FM} ranges from 0.4 nm to 0.9 nm. Samples are 0.1 nm-step made and all samples exhibit perpendicular magnetic anisotropy. We conduct second Hall harmonic technique to measure field-like SOT. To measure DMI, we used so-called effective depinning field method. Both field-like SOT effective field and DMI effective field are gradually increased as t_{FM} decreased for entire measured regime. Similarly, the plot of field-like SOT efficiency and DMI strength X t_{FM} product (which means interfacial contribution of DMI) with respect to t_{FM} show the same trend. Therefore, we can conclude that field-like SOT and DMI are deeply related, which is attributed to their same origin from interfaces. The details will be shown on-site session.

Keywords:

spin-orbit torque, Dzyaloshinskii-Moriya interaction

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P1-co.122

Electromagnon modes in multiferroic van der Waals antiferromagnet NiI_2

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Abstract:

NiI_2 is a two-dimensional van der Waals magnetic insulator. Below the Neel temperature of T_N=59.5 K. NiI_2 exhibits spiral magnetic ordering of proper screw type, and spontaneously forms multiferroic domains. Using optical spectroscopy, we detected the two absorption modes of NiI_2 in the terahertz region. We traced the temperature dependence of these absorption mode down to 1.5 K, and checked they have anisotropy with respect to the polarization of incoming terahertz radiation. With additional optical model fittings, we confirm that these modes are electro-dipole-acitve, i.e. electromagnon modes.

Keywords:

Terahertz, Spectroscopy, Electromagnon, Multiferroic

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P1-co.123

Superconducting and optical properties of Fe ion irradiated MgB_2

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Abstract:

We studied Fe-irradiation effects on the crystal structure and superconducting properties of MgB_2 . The pristine thin film samples were prepared by using hybrid physical-chemical vapor deposition (HPCVD), and the Fe ion irradiation was performed with three different doses of $5x10^{13}$, $1x10^{14}$, and $2x10^{14}$ atoms/cm^2. The measured resistivity showed that the T_c fell from 38.33 K to 3.02 K with the increasing irradiation dose. The crystal structure of the films was investigated by x-ray diffraction measurements (XRD) and x-ray absorption spectroscopy (XAS).
The results showed that the higher the dose, the stronger the changes in crystal structure, such as the lattice constant and bond distance. The results also suggested that the destruction of the crystal structure at a higher dose degraded superconductivity in MgB_2 thin films. The reflection measurement using a Fourier transform infrared (FTIR) spectrometer was also performed, and it revealed that the plasma frequency fell with increasing irradiation dose, indicating that the superconducting properties were suppressed. The results of Raman spectroscopy pointed out that the electron-phonon coupling constant also experienced a decrease in trend with the increase of the irradiation dose, which is related to the reduction in T_c of the samples.

Keywords:

MgB2, superconductor, FTIR, XAS, Raman spectroscopy

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P1-co.124

STM study of In overlayers on Si(111) surface with √7×√3 structures

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Abstract:

We investigated the two In-overlayer surfaces with √7×√3 structures formed on a Si(111) substrate using a scanning tunneling microscope (STM). An In-induced structure, previously known as the 'striped' phase and frequently coexisting with the *4×1* structure, is found to be an In overlayer with a single layer (√7×√3-SL). The other √7×√3 surface is found to consist of double layers of In (√7×√3-DL). The √7×√3-DL In overlayer manifests 'hexagonal' and 'rectangular' registries of bright features in STM images depending on tunneling conditions (bias voltages and tunneling currents). These observations reveals that the two √7×√3 phases [hexagonal (√7×√3-hex) and rectangular (√7×√3-rect)], which have long been believed to be different In overlayer phases, originate from the same structure. The atomic structures of both the √7×√3-SL and √7×√3-DL surfaces will be discussed by comparison of the experimental findings with the previously proposed structural models.

Keywords:

Scanning Tunneling Microscopy, In/Si(111), metal overlayer, √7×√3

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P1-co.125

Development status of a Hybrid Joint Utilizing Low and High-Temperature Superconductors for Tokamak

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Abstract:

KSTAR has successfully conducted plasma experiments for nuclear fusion energy research. The KDEMO project, which is the next step towards nuclear fusion demonstration, is also planned, requiring a Tokamak device capable of generating a larger magnetic field. As a result, larger-scale superconducting coil magnets are needed, with superconducting CICC (Cable-In-Conduit Conductor) up to several kilometers long being used. However, current technology can only handle lengths of approximately 600-800 meters for CICC, requiring joints to connect multiple segments together. Lap joints have been widely used. For improved performance, the ENEA joint was developed in EDIPO, and ITER has designed splice joints for the central solenoid, inspired by the ENEA joint. This study presents a ‘hybrid joint’ design using second-generation high-temperature superconducting tape for joint performance improvement and development of a joint for SUCCEX's CICC. The hybrid joint was benchmarked on the splice joint and designed to connect LTS-HTS sub-cables. A mockup was fabricated using NbTi and GdBCO conductors to analyze the characteristics according to the design of the hybrid joint.

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MSIT). (2022R1A2C1006542; PG2219-2)

Keywords:

hybrid joint, HTS tape, joint, CICC, GdBCO

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P1-co.126

High-entropy alloy superconductor studied by terahertz spectroscopy

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Abstract:

High-entropy alloy superconductors are made up of multiple elements such as Ta, Nb, Hf, Zr, and Ti. High-entropy alloy thin films exhibit superconducting properties with a critical temperature of T_c=6-7 K and an upper critical magnetic field of $\mu_0 H_{c2}$=5-10 T. Here we provide the result of our data with terahertz time-domain spectroscopy investigation. Temperature-dependent optical conductivity closely matches the Mattis-Bardin theory with a superconducting gap of 2Δ = 15 cm^{-1}. By applying external magnetic fields up to 7 T, it is shown that the superconducting gap is systematically suppressed as the magnetic field increases. Our result suggests that the high entropy alloy superconductor Ta-Nb-Hf-Zr-Ti is a standard weak-coupling BCS-type.

Keywords:

High-entropy alloy superconductors, Superconductivity

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2023-04-19 - 2023-04-21

P1-co.127

Optical properties of Nb thin films under an in-plane magnetic field in the terahertz region

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Abstract:

We investigated the optical properties of superconducting Nb thin films by using terahertz time-domain spectroscopy. The complex conductivity is obtained from the transmission spectra in the terahertz region without a Kramers-Kronig analysis. We extracted the order parameter and the spectroscopic gap from the complex conductivity. Under an in-plane magnetic field, the superconducting state of Nb is systematically suppressed, eventually entering the gapless superconducting state near the upper critical field value. Our data on the novel gapless superconducting state acquired in this study will deepen our understanding of superconductivity in the presence of an external magnetic field.

Keywords:

terahertz time-domain spectroscopy, Nb thin films, gapless superconducting state

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P1-co.128

Tuning the electronic structure of FeTe via epitaxial strain

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Abstract:

Recent studies in iron-chalcogenides (Fe-Chs) have attracted immense interest due to a variety of emerging properties via substituting the chalcogenide atoms between Te, Se, and S. For example, superconductivity in FeSe, topological superconductivity in $FeSe_{0.45}Te_{0.55}$, and bicollinear AFM phase in FeTe have been reported. This phase behavior is known to result from tuning the bond angle between Fe and chalcogenide atoms in such Fe-Ch compounds. By growing FeTe thin films on various substrates via molecular beam epitaxy (MBE), we tune the epitaxial strain imposed on FeTe, and thus manipulate the Fe-Te bond angle. Our transport and angle-resolved photoemission spectroscopy (ARPES) measurements show that such modulation in the FeTe structure effectively modifies the underlying electronic structure, giving rise to various emerging properties different from those of bulk FeTe. We further propose to systematically investigate FeTe thin films to reveal novel phases inaccessible in bulk iron chalcogenides and study the origin of such emergent behaviors.

Keywords:

Iron-based superconductor, molecular beam epitaxy, angle-resolved photoemission spectroscopy

P1-co.129

Synthesis of Topological superconductor candidate Ti3X (X= Ir, Sb)

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Abstract:

The A15 phase are series of alloy with the chemical formular A_3B. Many compounds with A15 phase have superconductivity(type-II superconductivity). Recent research results have shown the possibility that A15 materials may have topological superconductivity. Ti_3X (X=Ir, Sb) is one of the A15 compound. We synthesized the material using the arc melting method and measured its properties.

Keywords:

A15 compound, superconductivity, topological superconductor candidate

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2023-04-19 - 2023-04-21

P1-co.131

Magnetic excitations in anisotropic triangular lattice $Ba_3ReO_5Cl_2$

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Abstract:

Low-dimensional frustrated magnets have been a topic of great interest due to their exotic quantum states. Among these, an anisotropic triangular lattice (ATL), consisting of intrachain interaction J and interchain interaction J', provides an excellent platform to tune from a magnetically ordered to a spin liquid state by controlling the ratio J'/J. Cs_2CuCl_4 and $Ca_3ReO_5Cl_2$ have been reported as benchmark materials, which have a similar degree of spatial anisotropy with J'/J=0.32–0.34. However, small perturbations, including Dzyaloshinskii–Moriya and interlayer interactions, set in spiral orders at T_N =0.62 K for Cs_2CuCl_4 and T_N =1.13 K for $Ca_3ReO_5Cl_2$. Inelastic neutron scattering and Raman scattering experiments show deconfined spinons and triplon, which are bound pairs of spinons. In this regard, the compound $Ba_3ReO_5Cl_2$ with J'/J=0.47 without DM and interlayer interactions can be a better system to investigate spinons and triplons.

Here, we present the spectroscopic signature of spinons and triplons in the anisotropic triangular lattice $Ba_3ReO_5Cl_2$. Using polarization-resolved Raman spectroscopy, we find that spinons feature strong intensity in parallel polarization and a function of $\cos 2\theta^{\cos^2\theta}$ to the chain direction. On the other hand, triplons possess a strong intensity in crossed polarization. The thermal evolution of spectral weight in (*aa*) and (*ac*) polarization, is dominated by spinons and triplons, similar to the isostructural compound $Ca_3ReO_5Cl_2$.

Keywords:

Anisotropic triangular lattice, triplon, spinon excitations

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P1-co.132

Raman scattering study of anisotropic triangular lattice compound $Cu_2(OH)_3NO_3$

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Abstract:

Quantum spin liquid (QSL) is an exotic state of matter, where quantum fluctuations prevent the freezing of spins down to 0 K and give rise to fractionalized quasi-particle excitations. This state has long been sought after for both academic research and its potential applications in topological qubits for quantum computation. One of the novel routes to stabilize such a QSL state is geometrical frustration, in which constituent spins are unable to simultaneously satisfy Neel-type ordering with their neighbors. Recently reported $Cu_2(OH)_3NO_3$ is an excellent example of such a system. It crystallizes in the monoclinic $P2_1$ space group, and two distinct Cu^{2+} ions constitute an anisotropic triangular lattice. This system allows for the investigation of intrinsic magnetism without site disorder or subsequent perturbative effects. Previous studies have revealed multiple magnetic transitions at low temperatures without clear long-range ordering (LRO). Furthermore, the coexistence of resonating valence bond (RVB) correlations and LRO was theoretically predicted. Motivated by this theoretical proposal, we conducted Raman scattering measurements of $Cu_2(OH)_3NO_3$. Raman spectroscopy is a powerful method to study spin-spin correlations and corresponding low-energy excitations. Combined with X-ray diffraction and magnetic susceptibility data, our results illustrate distinct magnetic excitations that deviate from classical two-magnon behavior and phonon anomalies as well.

Keywords:

anisotropic triangular lattice, Raman scattering

P1-co.133

Materialization of Kitaev quantum spin liquid on Cu_3Co_2SbO6 Delafossite using Lattice Engineering

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Abstract:

Kitaev quantum spin liquid is a quantum phase of matter observed in 2-D honeycomb lattice structure, which allows long-range entanglement by bond-dependent Ising interaction. However, additional exchange interactions caused by structure deformation impede stable quantum spin liquid phase. $Cu_3Co_2SbO_6$, one of promise candidate of quantum spin liquid, is difficult to have a stable spin liquid state because of trigonal distortion on CoO_6 octahedron. Here, we try to overcome this problem by lattice engineering using heterostructure approach. We synthesize epitaxial and high quality $Cu_3Co_2SbO_6$ thin film on ZnO substrate using pulsed laser deposition method. Controlling the structure deformation of CoO_6 octahedron by lattice engineering is discussed via X-ray absorption spectroscopy. Thickness dependence of Cobalt L-edge and Oxygen K-edge spectrum indicate changes of orbital structure of CoO_6 octahedron due to strain effect. In the future, we will discuss the changes of magnetic property of $Cu_3Co_2SbO_6$ thin film as trigonal distortion diminishes. We expect that sophisticated crystal structure adjustment using lattice engineering can be a useful platform to realize the Kitaev spin liquid.

Keywords:

Kitaev quantum spin liquid , lattice engineering, trigonal distortion

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2023-04-19 - 2023-04-21

P1-co.201

Combinatorial Tungsten-Doping Gradation in Vanadium Dioxide Thin films

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Abstract:

Vanadium dioxide (VO_2) has been intensively researched primarily due to its metal-insulator transition (MIT) phenomena which occur near room temperature at the MIT temperature, T_{MIT}, of ~67℃. Since the T_{MIT} of VO_2 is still higher for device applications, diverse approaches have been considered to lower T_{MIT}. Among various methods, cation substitution of V^{4+} with W^{6+} is known to be an effective and stable way for decreasing T_{MIT}. However, it would be quite laborious to investigate the detailed W-doping effects on the MIT characteristics and optimize the doping process maintaining the structural quality.

In this work, an efficient combinatorial approach, involving VO_2 films with W-doping gradation, was demonstrated for exploring the W-doping concentration-dependent MIT characteristics of VO_2 thin films in detail. These results could pave a way for investigating and exploiting doping effects in correlated oxides and enhancing their applicability.

Keywords:

vanadium dioxide (VO2), metal-insulator transition (MIT), substitutional doping

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2023-04-19 - 2023-04-21

P1-co.202

Annealing time dependence of high entropy alloy superconductor $Ta_{1/6}Nb_{2/6}Hf_{1/6}Zr_{1/6}Ti_{1/6}$ obtained via optical spectroscopy

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Abstract:

High entropy alloy (HEA) has gained extensive attention for material science and condensed matter physics researchers in recent years. Here, multiple (at least four) principal elements are randomly mixed in equimolar or nearly equimolar proportions thus display very high degree of disorder, i.e., a high configurational entropy. As entropic contribution lowers the free energy, these multi-component HEAs are highly stabilized, thus display high strengths (>1 GPa) at very high temperatures (1200-1500 ^{O}C) and also fracture resistant at cryogenic temperatures. In 2014, the first HEA superconductor ($Ta_{34}Nb_{33}Hf_{8}Zr_{14}Ti_{11}$) was found involving elements from 4*d* and 5*d* series that opened new opportunities in superconductivity research. We studied five different samples of the HEA $Ta_{1₩6}Nb_{2₩6}Hf_{1₩6}Zr_{1₩6}Ti_{1₩6,}$ *i.e.,* one unannealed and four annealed samples at 550 ^{0}C having annealing time of 1h, 6h, 12h & 48h. By using *in-situ* gold evaporation technique, we obtained the absolute reflectance of the samples and obtained the optical conductivity and the dielectric function. Also we got various physical quantities, such as the charge carrier density and impurity scattering rate of charge carriers, which paved the way to gather information about the electronic structure and the optical behavior of HEA SC material with different annealing time. We believe that our study will be helpful for further understanding and thereby enhancing the properties of the HEA materials for useful practical applications.

Keywords:

High entropy alloy,optical conductivity,dielectric function,charge carrier density,electronic structure.

2023 KPS Spring Meeting
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P1-co.203

Unusual behaviors of the electric and magnetic properties of $Sr_2RuO_4/CaRuO_3$ superlattices

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Abstract:

The layered Sr_2RuO_4, the first Ruddlesden-Popper phase ($A_{n+1}B_nO_{3n+1}$) of $SrRuO_3$, is interesting material since Sr_2RuO_4 bulk is a perovskite superconductor with a superconductor transition temperature of T_c ~1 K. However, when Sr_2RuO_4 is fabricated as a thin film, it is challenging to observe its superconductivity since defect and/or impurity-induced structural disorder prevails in most thin films. Nevertheless, Sr_2RuO_4 thin film is still fascinating due to exhibits of various emergent properties. For example, it has been reported that Sr_2RuO_4 films exhibit insulator behavior as the thickness decreases to several tens of nm. On the contrary, when the thickness increases to several hundreds of nm, Sr_2RuO_4 films exhibit metallic properties. In addition, the Sr_2RuO_4 thin films show metal-insulator transition (MIT) behavior when A and/or B-site are doped with different elements.
In this study, we prepare the $Sr_2RuO_4/CaRuO_3$ superlattices on $SrTiO_3$ (001) substrates through pulsed laser deposition to investigate the correlation between microstructural changes and physical properties by adjusting the stacking of superlattice. The crystal structure and the octahedral configuration of the fully strained superlattices are characterized by high-resolution X-ray diffractometer. With over than 3 unit-cells of $CaRuO_3$, the half-ordered Bragg peak, indicates that the rotation angle for RuO_6 octahedral distortion of the $CaRuO_3$ layer, is increased. Also, the $Sr_2RuO_4/CaRuO_3$ superlattice have MIT behavior with different T_{MIT} for resistivity as a function of temperature. Interestingly, in the superlattice with one-unit-cell- thick $CaRuO_3$ layer, we observe an unusual resistivity behavior, such as a steep drop or jump. Furthermore, the magnetic properties of superlattices are investigated according to the magnetic field.

Keywords:

superlattice, Sr2RuO4, physical property transition

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

P1-co.204

Synthsis and properties of β-Ti_3O_5 and Al-doped Ti_3O_5 with tetra-arc furnace

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Abstract:

Ti_3O_5 is a type of Magneli phase titanium oxide, which is a MIT(metal-insulator transition) material that changes from semiconductor to metal by phase transition to β, λ, and α with temperature. Ti3O5 is known to have a very high melting point of 1700°C, making it difficult to grow single crystals. One of the methods used to grow materials with high melting points is the tetra-arc melting method. This can instantaneously generate a high temperature of about 3,000℃ using an arc discharged from four electrodes. This research designs a tetra-arc melting furnace for the growth of β -Ti3O5 single crystals, synthesizes pure and Al-doped Ti3O5, and is confirmed the change in structure, phase transition temperature, and heat generation during phase transition according to the amount of Al doping.

Keywords:

Metal-insulator transition, Tetra-arc furnace

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2023-04-19 - 2023-04-21

P1-co.205

Controlling Oxygen Vacancy to Observe Resistance Switching Behavior in LaAlO3/SrTiO3 Heterostructure Memristors

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Abstract:

Memristors based on resistive switching have emerged as promising candidates for next-generation electronic devices, particularly in the field of in-memory computing. Among them, metal/oxide/metal material systems have been shown to exhibit resistance switching behavior mainly due to the presence of oxygen vacancies. Therefore, a detailed study of the conduction mechanism of oxide memristors is necessary by controlling various parameters such as the concentration of oxygen vacancies and carriers. Perovskite oxides have also been explored for their resistance switching behavior, either as thin films or bulk materials with domain walls. Previous studies have demonstrated that memristors built on the perovskite oxide heterostructure $LaAlO_3/SrTiO_3$ in the (001) direction exhibit resistance switching behavior using an electrode and display different behavior depending on annealing conditions. In this study, we investigate the resistance switching behavior of the $LaAlO_3/SrTiO_3$ heterostructure under diverse conditions by controlling the concentration of oxygen vacancies.

Keywords:

memristor, resistive switching, RRAM, LaAlO3/SrTiO3, 2DEG

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2023-04-19 - 2023-04-21

P1-co.206

Mechanism of Metal-Insulaotr Transition in Strontium Niobate thin film under excess oxygen content

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Abstract:

Unlike most of other perovskite oxide, SrNbO3 is known to be metallic, promoting the possibility of application as stable conductor under atmosphere. However, when depositing SrNbO3 thin film via PLD under higher oxygen pressure, insulating film are often deposited Moreover, decreasing oxygen pressure too much means kinetic energy of plasma plume during depsoition is too high and hard to control. Such things treatens stable supply of metallic SrNbO3 thin film. Some mechanisms are suggested to ellucidate such phenomena such as insulating Sr2Nb2O7 phase, impurity or oxygen vacancy. But the exact mechanism is still not clear since the point defects like vacancies are hard to be quantified and varying the oxygen pressure means not only change in oxygen content but also modifying kinetic process during deposition. Here, the SrNbO3 thin film deposition was performed under various oxygen pressures while fixing the total pressure by introducing argon pressure. This experimental technique ensures that the kinetic process is uniform during deposition while the oxygen content is varied. By analysing structure, stoichiometry and electronic property of grown films, we ellucidate the proper mechanism of Metal-Insulator Transition of Strontium Niobate thin films.

Keywords:

Metal-Insulator Transition, Fourier Transform Infrared, Scanning Transmission Electron Microscopy, X-ray Photoelectron Spectroscopy, Strontium Niobate

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2023-04-19 - 2023-04-21

P1-co.207

Transition of temperature dependent resistivity behavior of superlattice according to the $SrIrO_3$ film thickness and the presence of the $SrTiO_3$ capping layer

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Abstract:

When a $SrIrO_3$ thin film is deposited on a $SrTiO_3$ substrate by the pulsed laser deposition (PLD) method, the temperature dependent resistivity behavior changes to “insulator-like”, “metal-like”, and “intermediate” depending on the deposition conditions. In previous research, we paid attention to insulator-like, and observed changes in $SrIrO_3$ by stacking a $SrTiO_3$ capping layer on a $SrIrO_3$ thin film with this characteristic. At this time, the temperature dependent resistivity behavior according to the thickness change of $SrIrO_3$ was systematically investigated. In the experiment, the thickness of the thin film was controlled on a unit cell basis using Reflection high-energy electron diffraction (RHEED). We measured the resistivity by varying the thickness of the $SrIrO_3$ thin film while fixing the thickness of the $SrTiO_3$ capping layer. As a result, it was revealed that the temperature dependent resistivity behavior of $SrIrO_3$ was insulator-like for 9~ 20 unit cells, intermediate for 7 and 8 unit cells, and metal-like for 1~6 unit cells. Afterwards, $SrIrO_3$ was deposited without the $SrTiO_3$ capping layer in the same way and compared with the previous one. Currently, experiments are being conducted on the temperature dependent resistivity behavior of $SrIrO_3$ in thin films deposited in metal-like, and comparisons are made with a difference in the presence a capping layer. As a result of this experiment, we want to find out the role of the capping layer.

Keywords:

SrIrO3, resistivity behavior, perovskite oxide structure

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

P1-co.208

Controlling structural inhomogeneity and magnetotransport properties of 5d pyrochlore oxide filmControlling structural inhomogeneity and magnetotransport properties of 5d pyrochlore oxide film

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Abstract:

5*d* pyrochlore oxides ($A_2B_2O_7$) have received broad interest due to various exciting properties such as giant magnetoresistance, anomalous Hall effect, and Ferro/flexoelectricity. Among the family of pyrochlore oxides, $R_2Ir_2O_7$ (R = rare earth ions) is the platform to discover the proposed intriguing properties. However, due to the volatility of the IrO_2, finding exotic properties in $R_2Ir_2O_7$ has been experimentally difficult. In this work, we demonstrate the controlling of the structural inhomogeneity and magnetotransport properties of $Nd_2Ir_2O_7$ film by varying the percentage of IrO_2 pulse. The structural transition from impurity phases such as Nd_2O_3 and Nd_3IrO_7 to $Nd_2Ir_2O_7$ is observed when the rate of IrO_2 pulse is increased. Furthermore, the insulator-to-metal transition occurs near 80 % of the IrO_2 pulse, which is attributed to decreased structural inhomogeneity. Lastly, we observed the anomalous Hall effect is maximum when structural inhomogeneity is minimum, and the structure of the film is homogeneous. Our work paves the way to synthesize complex pyrochlore oxides and control the structural inhomogeneity.

Keywords:

control, defects, and Ir

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P1-co.209

Optimizing WDS measurement conditions for composition analysis of rare-earth boride thin films

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Abstract:

Change in composition due to intentional substitution or unintentional off-stoichiometry, has significant influences on the physical properties of materials, especially superconductors and topological materials. Therefore, direct or indirect compositional analysis has become a pivotal step in experimental research on condensed matter physics and materials science. Wavelength dispersive spectroscopy (WDS) is a quantitative composition measurement tool suitable for materials containing light elements, like rare-earth borides, which have drawn much attention due to their topological band structure and unique cubic structure regardless of a rare-earth element [1,2]. However, composition analysis using WDS measurement for composite thin films is somewhat troublesome due to the difference in atomic numbers of elements and inhomogeneous composition with respect to depth, including the interface between a thin film and substrate.
In this study, we investigate optimal WDS measurement conditions for rare-earth boride thin films. With common correction methods (ZAF and XPP modes), the measured atomic ratios of rare-earth elements and boron were found to be significantly influenced by acceleration voltages. Monte Carlo simulation using Casino revealed the generation of backscattered electrons and x-ray in the vicinity of the film-substrate interface at the higher acceleration voltage due to a longer penetration depth of incident electrons over the thickness of the film layer. Considering the film thickness, the acceleration voltage can be optimized as a bulk-like measurement to minimize the substrate effects. However, the intrinsic issue in rare-earth borides, *i.e.*, huge atomic number difference between the elements and low x-ray yield under low acceleration voltage still need to be resolved in WDS measurement with the conventional correction models. This work serves as a reference for studying novel thin films containing light elements.

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[1] S. Lee, X. Zhang and I. Takeuchi, "Thin Films of Rare-Earth Hexaborides" in Rare-Earth Borides (Jenny Stanford Publishing, 2021).
[2] S. Lee *et al.*, Nature, 570, 334 (2019).

Keywords:

rare-earth borides, wavelength dispersive spectroscopy, composition, thin film

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P1-co.210

High Harmonic Generation in Monolayer and Bilayer of Transition Metal Dichalcogenide

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Abstract:

In transition metal dichalcogenides (TMDCs), charge carriers have spin, pseudospin and valley degrees of freedom associated with magnetic moments. The monolayers and bilayers of the TMDCs, in particular, MoS2, lead to strong couplings between the spin and pseudospin effects. This feature has drawn attention to TMDCs for their potential use in advanced tech devices.
High-order harmonic generation (HHG) is the emission of light resulting from nonlinear processes in a material under strong laser field. This emission contains dynamic information on the nonlinear process as well as the material's properties. Since high-order harmonics were first experimentally observed in ZnO, their potential in nonlinear optical spectroscopy of solids to characterize the electronic structure, such as energy dispersion, Berry curvature and topological properties, has attracted the attention of ultrafast sciences and condensed matter physics.
In this work, we show theoretical results obtained with the 'philosophy' of using HHG to investigate the structural effects of the monolayer and bilayers of MoS2 on nonlinear optical emission. We use a simple model for MoS2 in the 3R AB staking. We find that the HHG spectrum is: (1) capable of observing differences of the nonlinear optical emission related to the band gap between monolayers and bilayers of TMDCs. (2) Capable of describing a unique difference between the angular rotations and ellipticity dependence of the emitted harmonics as a function of the number of layers concerning the ellipticity of the laser. (3) Susceptible to breaking the inversion symmetries and thus sensitive to the Berry Curvature and its pseudospin character.
This theoretical investigation is expected to pave the way for the ultrafast manipulation of valleytronics and lead to new questions concerning the spin-obit-coupling (SOC) effects on TMDC materials, Weyl Semimetals, and topological phases and transitions in topological insulators.

Keywords:

High-order harmonic generation, Tight-binding model, Transition metal dichalcogenide

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P1-co.211

Landau-Khalatnikov Simulations of Antiferroelectrics for Energy Storage Applications

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Abstract:

Various antiferroelectric properties were modeled using Landau-Khalatnikov (LK) simulations for energy storage applications. LK simulation methods for switching sublattice polarizations of antiferroelectrics were developed through the control of coercive fields and frequency. The
methods were compared with those developed in previous phenomenological studies. Superior energy storage properties were obtained through the coupling of antiferroelectrics and relaxor ferroelectrics. Under optimal conditions, the recoverable energy storage density reached 9.66 J/m^3 and the energy storage eﬃciency was 98%. These results showed that antiferroelectrics can be useful for environment-friendly energy storage applications.

Keywords:

Ferroelectric, Antiferroelectric, Coupling, Simulation, Energy storage

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P1-co.212

Polarization switching dynamics simulation through first order reversal curves method

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Abstract:

We investigated the internal bias field and coercive field in the ferroelectric hafnium oxide thin film capacitor though first order reversal curves (FORCs) method. The fields affect the ferroelectric polarization switching and FORCs method provides the distribution of the fields in the film. We simulated the ferroelectric polarization switching dynamics using the distribution. The simulation results agreed well with the experimental results and reflected the well-known polarization domain switching model. Our simulation also offers the damping parameter which affects the polarization change rate. Our work can be applied in order to investigate polarization switching dynamics in the various ferroelectric materials.

Keywords:

Ferroelectric materials, Computer simulation, Hafnium oxide, Polarization switching dynamics, First order reversal curves

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

P1-co.213

Three-terminal vertical HZO ferroelectric synapse for high-performance and energy-efficient pattern recognition

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Abstract:

For the last decade, ferroelectric properties in doped hafnium oxide (HfO_2)-based thin films sparked renewed interest in ferroelectric materials and devices for developing next-generation electronic technologies. We designed and fabricated a novel and distinctive three-terminal vertical device, ferroelectric synaptic barristor (FSB) using a heterogeneous stack of hafnium-zirconium-oxide (HZO) thin film and graphene, which can function as a scalable artificial synapse for energy-efficient neuromorphic computing with rebound depolarization. When a gate voltage was applied to the device configured in this way, the Schottky barrier height was modulated according to the change in the polarization direction of the HZO, thereby gradually exhibiting conductance switching. This process allows to mimic of rebound depolarization (RD), a crucial synaptic property, and demonstrates excellent linearity, high yield (47/48), and good retention through the RD function. In addition, single-neuron-based learning ability was assessed using MNIST handwritten digits and fashion patterns. The accuracy achieved 90.03% and 74.65%, respectively.

Keywords:

Neuromorphic computing, Artificial synapse, Synaptic barristor, Ferroelectric HZO, Rebound depolarization

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2023-04-19 - 2023-04-21

P1-co.214

Ferroelectric and piezoelectric properties of Bi and Fe-compensated $0.67BiFeO_3$-$0.33BaTiO_3$ lead-free piezoceramics

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Abstract:

Pb-based ceramics have good high piezoelectric, ferroelectric, and electrical properties. However, Pb-based ceramics contain 60~70 wt% lead, raising environmental concerns. Recently, a $BiFeO_3$-$BaTiO_3$ (BF-BT) solid solution bulk ceramic system is presented as a potential lead-free piezoelectric ceramic system. However, poor ferroelectric and piezoelectric properties with high leakage currents are often shown. Because of chemical non-stoichiometric as Bi-rich and Fe-rich phases formed with oxygen vacancies.
In this study, $0.67Bi_{(1+x)}Fe_{(1+y)}O_3$-$0.33BaTiO_3$ (x = 0–0.05 and y = 0-0.07) piezoceramics fabricated by a solid-state reaction method followed by a water-quenching process. The structural and electrical properties of BF–BT ceramic will be presented in detail.

Keywords:

BiFeO3, BaTiO3, non-stoichiometric, Ferroelectric, Piezoelectric

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P1-co.215

Piezoelectric hardening in lead-free $BiFeO_3$-$BaTiO_3$ ceramics

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Abstract:

Hard piezoelectric properties were investigated in lead-free $BiFeO_3$-$BaTiO_3$ (BF-BT) ceramics. Rhombohedral (R) phase ceramics of (1-x)BF-xBT (x = 0.20-0.30) were prepared using a conventional solid-state reaction and water-quenching process. The crystal structures are R at x = 0.20-0.275 and the R and tetragonal phases coexist at x = 0.30. The piezoelectric charge sensor coefficient (d_{33}) and electromechanical planar coupling factor (k_p) increase with increasing BT content, whereas the mechanical quality factor (Q_m) decreases. The x = 0.20 ceramics showed the best hard piezoelectric properties: the highest Q_m = 403, and the highest T_C = 607 °C. In contrast, x = 0.30 ceramics showed soft piezoelectric properties: d_{33} = 301 pC/N and k_p = 0.33 with T_C = 510 °C. These results show that the BF-BT system in R-phase rich region has good hard piezoelectric properties for transducer applications.

Keywords:

Lead-free, BiFeO3-BaTiO3, Mechanical quality factor, Piezoelectric, Curie temperature

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P1-co.216

Tunneling systems based on spontaneous cracks structures in oxide heterostructure films

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Abstract:

The development of advanced materials often goes hand in hand with the explosion of scientific and technological breakthroughs. Oxide films have fascinated researchers for many decades because of their stable structures, multifunctional properties and energy-related applications. For research and applications, intact films are generally preferred while cracks in the films have been considered as unwanted failures. However, we study a novel way which can utilize the spontaneous cracks as functional parts of a oxide heterostructure system. In this work, the creation of atomically straight, flat cracks in single crystal complex oxide films are performed clearly by a controllable method. The lateral electrical transports by tunneling though these cracks in micrometer-size channels were mainly investigated with differential conductance (dG = dI/dV) measurement. The electrical transport can experience various electron tunneling and scattering phenomena due to the cracks, so its unusual transport properties were generated. Our study can trigger exotic research dimensions and applications on heterostructure systems.

Keywords:

Oxides, Thin films, Cracks, Tunneling

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P1-co.217

Substrate orientation-dependent reversible redox reactions of vanadium oxides at high temperatures

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Abstract:

Vanadium oxides exhibit various oxidation states, including V_2O_5, VO_2, and V_2O_3, with distinct electrical and optical properties. Among them, V_2O_5 is the most stable of vanadium oxides and with electrical insulating properties. On the other hand, VO_2 is the most functional oxide, which undergoes metal-to-insulator transition (MIT) at 68°C and rapidly decreases transmission in the near-infrared region. Lastly, V_2O_3 exhibits MIT around -120°C. Therefore, these vanadium oxides could be studied for various applications, such as gas sensors, neuromorphic devices, and smart windows [1],[2],[3]. However, many reported studies were focused on single-state vanadium oxides.

In this study, we present the oxidation state variations during redox reactions, depending on annealing temperature and Al_2O_3 substrate orientation. The vanadium oxide films were deposited using RF magnetron sputtering on different substrates and treated under post-plasma. After that, to improve the reduction reaction of the thin film, Pt island was deposited on the thin film using sputtering. The electrical resistance was measured in real-time under forming gas (H_2 4% / Ar 96%) and O_2 (99.99%) environments. When the forming gas was introduced, a rapid decrease in resistance was observed, regardless of the orientation of the substrate. Conversely, when oxygen gas was introduced, the resistance increased for all films, but there were differences in the degree and rate of change in resistance based on the substrate orientation, with C-cut Al_2O_3 showing the most significant change, followed by M-cut and A-cut Al_2O_3. Furthermore, the real-time Raman spectra showed that the phonon mode of V_2O_5 appeared (disappeared) in an oxygen (forming gas) atmosphere. Lastly, the optical bandgap energy (E_g) changed from black (E_g = 3.63 eV) to yellow (E_g = 2.70 eV) after heat treatment and exposure to forming gas and oxygen gas, respectively.

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Keywords:

Vanadium oxide, Film redox, Multivalent oxide

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P1-co.218

Enhanced piezoresponse and conduction properties on a mixed phase boundary of Ca-substituted super-tetragonal $BiFeO_3$

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Abstract:

In ferroelectric materials, oxygen vacancy defects play a crucial role in controlling the resistance state [1], phase transition [2], ferroelectric transition temperature [3] and defect dipoles [4]. But still, figuring out the mechanism between oxygen vacancies and ferroelectric properties is far from complete. Here, we investigate the interplay of ferroelectric mixed-phase domain structures with oxygen vacancy in a Ca-substituted super-tetragonal BiFeO3 grown on the LAO (001) substrate. Our results show micron-scale domains by piezoresponse force microscopy (PFM) and piezoresponse by point hysteresis loop measurements using DART (Dual AC Resonance Tracking) mode. The relationship between phase boundary and conduction is probed by CAFM (conductive atomic force microscopy) mode under sample-biased tip poling. The base material $BiFeO_3$ is a well-known ferroelectric perovskite that can have R, T, and S phases [5]. R phase is grown on a substrate with similar lattice parameters such as $SrTiO_3$ and has polarization in the <111> direction. On the other hand, the T phase is grown on a substrate with smaller lattice parameters such as $LaAlO_3$, is elongated in the <001> direction with a major polarization direction along pseudocubic [001] and a weak polarization tilting along <100> direction [6-7]. Although our studies are similar to those on R phase Ca-substituted $BiFeO_3$ [8], phase boundaries in super-tetragonal Ca-substituted $BiFeO_3$ are an interesting point of this study. The experimental results would help further deepen our understanding of the interaction between oxygen vacancies and ferroelectrics in strained environments.

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Keywords:

Ferroelectric, Oxygen vacancies, Defect, Strain, Phase boundary

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P1-co.220

Thickness dependence of oxygen evolution reaction in $LaNiO_3$ thin film

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Abstract:

Recently, ABO_3-type perovskite oxides with the *B*-site transition metal elements have attracted much attention as one of the candidates for the potential catalyst. The characteristics of electrochemical activity can be affected by surface roughness, crystal structure, electronic structure, *d* orbital filling, charge transfer energy, octahedral distortion, and the degree of *p*-*d* hybridization. Especially, the electronic properties and structural stability may critically influence the oxygen evolution reaction (OER). Among perovskite oxides, $LaNiO_3$ bulk is known for having good electrochemical catalytic performance in alkaline solutions and high stability.

In this study, the $LaNiO_3$ epitaxial thin films were deposited on $SrTiO_3$ substrates with varying thickness from 10 to 77 unit cells by pulsed laser deposition for studying the electrocatalytic behaviors. The electrochemical performance was investigated with varying the film thickness. The thickest $LaNiO_3$ film exhibits better performance in OER than others while all samples have the onset potential values, higher than 1.5 V. The octahedral configurations and surface topographies of these films were also identified through the characterizations of half-integer Bragg diffraction peak and atomic force microscope. Moreover, the changes in the electronic structure and chemical bonding states were identified using spectroscopic ellipsometry and X-ray photoelectron spectroscopy, respectively.

Keywords:

Electrocatalyst, oxygen evolution reaction, Transition metal oxide

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2023-04-19 - 2023-04-21

P1-co.221

Influence of CoO Nanoparticles on the Magnetism of $SrCoO_{2.5}$ Thin Film

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Abstract:

$SrCoO_{2.5}$ is a brownmillerite structure with alternating CoO_6 octahedra and CoO_4 tetrahedra layers. The brownmillerite structure is well-known for its topotactic phase transition to perovskite structure owing to high ionic conductivity and multivalent features of transition metal. For example, the transition from a cobalt oxidation state of +3 to +4 leads to the formation of $SrCoO_3$ with a perovskite structure from $SrCoO_{2.5}$ accompanied by changes in electrical conductivity and magnetism [1]. During the growth of $SrCoO_{2.5}$ thin film, CoO nanoparticles can be produced in the film due to the rich amount of Co compared to the Sr, resulting in Co with an oxidation state of +2 [2]. However, studies on the mechanism of CoO precipitation in the $SrCoO_{2.5}$ thin films are insufficient, and attempts to control the physical properties of the $SrCoO_{2.5}$ thin film using nanoparticles are absent.

We deposited $SrCoO_{2.5}$ thin film on (001)-oriented $SrTiO_3$ and Nb-doped $SrTiO_3$ (001) substrates using pulsed laser epitaxy, and various CoO contents are achieved by controlling the growth parameters. High-resolution x-ray diffraction and x-ray photoemission spectroscopy are employed to characterize the crystallinity and quantity of $SrCoO_{2.5,}$ and CoO nanoparticle regions in the thin film. Further, it is observed that the CoO nanoparticles grow in the same direction as the substrate in the (001) orientation. Using atomic force microscopy and SQUID, we demonstrate the changes in the surface structure and magnetism of the thin films induced by the emergence of CoO nanoparticles and investigate the mechanism behind this phenomenon. This study is remarkable for presenting a methodology to control properties by controlling defect-like minor crystal regions.

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Keywords:

transition metal oxide thin film, pulsed laser epitaxy, defects, brownmillerite, magnetism

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2023-04-19 - 2023-04-21

P1-co.222

^{63}Cu and ^{27}Al NMR study in the delafossite compound, $CuAlO_2$

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Abstract:

We present a comprehensive study of ^{63}Cu and ^{27}Al nuclear magnetic resonance (NMR) on a $CuAlO_2$ single crystal. The NMR measurements have been carried out at an external field of 5.7 T, applied parallel and perpendicular to the crystallographic c axis, in a temperature range 10-325 K. While the Knight shift and the electric field gradient data are weakly dependent on temperature, the spin-lattice relaxation rate $1/T_1$ reveals an intriguing temperature dependence. It exhibits a quite sharp peak centered near 190 K and a gap behavior at low temperatures roughly below 40 K yielding an extremely small activation gap of ~1 meV. These results suggest that there are two different energy scales which govern the dynamic properties of holes in this intrinsic p-type semiconductor.

Keywords:

delafossite, Nuclear magnetic resonance, CuAlO2

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P1-co.223

Mechanism for Persistent Photoconductivity in LaAlO3/SrTiO3 Heterostructures Probed by Spectral Noise analysis

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Abstract:

$LaAlO_3/SrTiO_3$ (LAO/STO) heterostructures have a strong persistent photoconductivity (PPC). The strong and stable PPC has attracted huge research interest due to the possible applications in optoelectronic devices. Despite promising functionalities, the underlying mechanism of the PPC in the LAO/STO heterostructure is still illusive, hindering its practical applications. In this study, we demonstrate that the photo-induced valence change in oxygen vacancies near the LAO/STO heterointerface results in the strong PPC. Through the spectral analyses and model-fitting studies, we show that the ionized oxygen vacancies near the LAO/STO interface are neutralized during the electron relaxation process, and thereby limit the complete electron relaxation. Our spectral analyses reveal that the oxygen vacancy neutralization near the interface can be directly probed by the persistent power spectral density values in a low frequency region between 1 kHz and 10 kHz. These results provide insights into the role of oxygen vacancies in affecting internal charge distributions and triggering the PPC in LAO/STO heterostructures. Additionally, our approach of spectral analysis provides a promising possibility to probe the spatial distribution of ionized point defects in oxide heterostructures in general.

Keywords:

Persistent photoconductivity, LaAlO3/SrTiO3 heterostructures, Two-dimensional electron gases, Oxygen vacancies, Low-frequency noise

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P1-co.224

Optical and structural properties of LaVO3 and LaFeO3 films

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Abstract:

$LaVO_3$ ($LaFeO_3$) thin films were grown on LSAT ($SrTiO_3$) substrates using radio frequency magnetron sputtering deposition method at 500 ℃. After growth, the LaFeO3 thin films were annealed in air at 800℃ for 2 hours. Both $LaVO_3$ and $LaFeO_3$ films show orthorhombic structures according to X-ray diffraction measurements. We obtained the dielectric functions ($\varepsilon = \varepsilon_1 + i\varepsilon_2$) of the thin films using spectroscope ellipsometry (SE) measurements and obtained the optical gap energies from the absorption coefficients ($\alpha = 4\pi k/\lambda$). The optical gap energy of $LaVO_3$ ($LaFeO_3$) thin films were determined to be an indirect gap energy of 0.95 eV (2.21 eV), and a direct gap energy of 1.95 eV (2.73 eV). Forbidden direct gap energy was estimated to be 1.94 eV for $LaFeO_3$ thin films. The critical point (CP) energies were determined using the second-order energy derivative spectra of the dielectric functions. The optical gap energies and the CP energies were compared to band structure calculations in the literature.

Keywords:

LaVO3, LaFeO3, dielectric function, critical point, sputtering deposition

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P1-co.225

Surface-termination-dependent electronics structure of $EuTiO_3$

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Abstract:

We report the termination-dependent electronic structure of two-dimensional electron gas (2DEG) at $EuTiO_3$ (ETO) surface. The termination of titanate was completely and easily controlled by inserting $SrRuO_3$ (SRO) buffer layer using pulsed laser deposition (PLD). By means of the in-situ angle-resolved photoemission spectroscopy (ARPES) technique, we could observe that A-site(B-site) terminated ETO prefers high d_{xy}($d_{xz/yz}$) orbital occupation. Our result suggests a possible way to manipulate the function of nano-device based on interface physics like 2DEG. Moreover, this method paves the way to study the undisclosed origin of interface physics using orbital engineering.

Keywords:

2DEG, Surface physics, thin film, heterostructure, in-situ ARPES

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P1-co.226

Structural geometry and molecular dynamics of hybrid organic–inorganic $[NH_3(CH_2)_6NH_3]CdCl_4$ crystals close to phase transition temperatures

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Abstract:

Organic–inorganic hybrid perovskites are highly promising for application in various electrochemical devices, such as batteries and fuel cells. The physical properties of crystals of the organic–inorganic hybrid perovskite $[NH_3(CH_2)_6NH_3]CdCl_4$ are important for their future application. Therefore, these crystals were grown and their phase transition temperatures T_{C1} = 337 K and T_{C2} = 472 K were determined using powder X-ray diffraction and differential scanning calorimetry. We observed that the crystallographic surroundings of ^1H and ^{13}C in the cation near T_{C1} did not show significant changes, whereas those of ^{113}Cd in the anion changed significantly. The change in the coordination geometry of C1 around Cd near T_{C1} changed the N–H···Cl bond by connecting with the ^1H of NH_3. The nuclear magnetic resonance spin-lattice relaxation time $T_{1\rho}$ suggested that the ^1H energy transfer processes in phases III and II were easier, whereas the ^{13}C energy transfer processes were easier in phase III than in phase II. The results of the current study for $[NH_3(CH_2)_nNH_3]CdCl_4$ (n = 6) were compared with those for n = 2, 3, 4, and 5 obtained from previous studies. The features of the length of CH_2 and even–odd number of carbons in the diammonium chain are expected to facilitate potential applications in the future.

Keywords:

organic-inorganic hybrid, [NH3(CH2)6NH3]CdCl4, phase transition, nuclear magnetic resonance, thermodynamic properties

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P1-co.227

Structural characterization and dynamics of a layered 2D perovskite $[NH_3(CH_2)_5NH_3]MnCl_4$ crystal near phase transition temperature

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Abstract:

$[NH_3(CH_2)_5NH_3]MnCl_4$ crystals are grown via slow evaporation, and the crystal undergoes a phase transition at 298 K (T_C) according to differential scanning calorimetry, and the structures determined via X-ray diffraction at 173 and 333 K are orthorhombic systems in the space group Imma. These results differed slightly from those previously reported, and the reasons for this are analyzed. The thermal stability is relatively high, with a thermal decomposition temperature of approximately 570 K. The ^1H spin-lattice relaxation times $t_{1\rho}$ exhibited very large variations, as indicated by the large thermal displacement around the ^1H atoms, suggesting energy transfer at $\sim T_C$, even if no structural changes occurred. The influences of the chemical shifts of ^1H of NH_3 and short $t_{1\rho}$ of C1 adjacent to NH_3 in cation are insignificant, indicating a minor change in the N−H···Cl hydrogen bond related to the coordination geometry of the $MnCl_6$ octahedron. These properties will be make it a potential application for eco-friendly solar cells.

Keywords:

crystal structure, organic-inorganic hybrid, [NH3(CH2)5NH3]MnCl4, phase transition, nuclear magnetic resonance

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P1-co.228

Investigating on crystal structure, thermodynamic, and molecular dynamic of lead-free organic-inorganic hybrid $[NH_3(CH_2)_2NH_3]ZnBr_4$ crystals

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Abstract:

In this study, lead-free organic-inorganic hybrid $[NH_3(CH_2)_2NH_3]ZnBr_4$ crystals were grown by slow evaporation and analyzed. The crystals showed orthorhombic structure with the $P2_12_12_1$ space group, and the following lattice constants: *a*=8.3818 (2) Å, *b*=10.8880 (4) Å, *c*=11.8175 (4) Å, and Z=4. The crystals were stable up to 584 K, with two phase transitions at 468 K (T_{C1}) and 503 K (T_{C2}), as indicated by differential scanning calorimetry and differential thermal analysis. The structural environments of the atoms were analyzed by ^1H and ^{13}C NMR. On increasing the temperature, the spin-lattice relaxation time, $T_{1\rho}$, decreased rapidly due to large energy transfer at high temperatures, as indicated by large thermal displacements of the ^1H and ^{13}C atoms of the cation. Additionally, the activation energy, E_a, at high and low temperatures was found to be 49.23 and 1.44 kJ/mol, respectively, for the molecular motion of ^1H, and 37.93 and 2.13 kJ/mol, respectively, for that of ^{13}C. Analyzing the physiochemical properties of $[NH_3(CH_2)_2NH_3]ZnBr_4$ could facilitate its application in stable and environment-friendly solar cells.

Keywords:

organic-inorganic hybrid, [NH3(CH2)2NH3]ZnBr4, crystal sturucture, thermal property, nuclear magnetic resonance

P1-nu.001

Calculation of nuclear structure in neutron capture reaction

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Abstract:

Research on neutron capture reactions has been applied in a variety of fields, nuclear physics, astrophysics, radiation protection design, radiation physics including medical radiation therapy and diagnosis, and the development and design of new reactors. Gamma rays following a neutron capture reaction contain a lot of physical information about residual nuclear levels, such as excited energy, spin, parity, and electromagnetic transition rates. The various information obtained in the experiment contains most of the transitions in the degree of decay and determines the structure of each level by comparing them with theoretical values. There are several theoretical models to describe the nuclear structure, but in this work, we calculate the nuclear structure by selecting IBM(Interacting boson model) and IBFM(Interacting boson fermion model), which well explain the collective properties of low energy levels of intermediate and heavy nuclei. The validity of the nuclear model proposed in this study is reviewed by comparing it with the provided experimental values provided.

Keywords:

IBM, IBFM, neutron capture reaction

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P1-nu.002

인공신경망을 활용한 토카막 플라즈마 내 불순물 수송계수 추론 알고리즘 개발

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Abstract:

토카막의 정상상태 운전 중 노심 플라즈마 내로 과도하게 불순물이 유입될 경우 연료이온이 희석되며 과도한 방사파워 또한 발생하여 이로 인한 플라즈마 성능 하락을 초래할 수 있다. 반대로 디버터에 인위적으로 제어가스를 주입하여 열속 및 입자속을 제어하는 연구가 활발하게 진행되고 있다. 이처럼 토카막 내 불순물의 분포 제어는 운전성능 향상을 이루어 낼 요소 중 하나로 평가받고 있다. 이를 위해 플라즈마 내 불순물 수송을 이해하고 예측하는 것은 필수적이다. 본 연구에서는 물리기반 인공신경망을 기반으로 시간에 따른 불순물 분포를 통해 불순물 수송계수를 추론하는 알고리즘을 개발하였다. 위 알고리즘은 불순물 수송을 기술하는 연속방정식과 초기 및 경계 조건을 제약조건으로 지정해주었기 때문에 불순물 분포 변화가 주어질 경우 경사 하강 알고리즘을 통해 기존 학습데이터 없이 제약조건을 최대한 만족하는 불순물 수송계수를 추론하는 방식이다. 따라서 이전 연구에서 진행되었던 인공신경망을 통한 불순물 수송계수 계산 연구와 비교하여 물리적으로 적합한 불순물 수송계수를 추론할 수 있었다. 본 연구의 알고리즘의 정확도를 검증하고자 0.6 MA의 플라즈마 전류, 2.8 T의 토로이달 방향 자기장, 4 MW의 NBI 파워를 인가한 세가지 종류의 아르곤 주입 실험(# 10640, #10647, #10649) [J. Hong et al., Nucl. Fusion 57 036028 (2017)]에서 기존 불순물 수송 분석 코드인 UTC-SANCO를 통해 추론한 불순물 수송계수와 비교분석하였다. 본 알고리즘에서 추론한 불순물 수송계수는 UTC-SANCO의 결과와 비교하여 모든 실험에서 불순물 수송계수 프로파일이 오차범위 내에 존재하는 것을 확인하였고, 추론 과정에서 각각 약 20분의 짧은 계산 시간이 소요되었다. 추후 연구에서는 제어가스 주입 실험을 통해 획득한 불순물 진단데이터로부터 중간 과정 없이 직접 수송계수 프로파일을 계산할 수 있도록 인공신경망 모델의 고도화를 진행함과 동시에 모델 매개변수의 최적화를 통해 추론에 소요되는 시간을 단축시킬 예정이다.

Keywords:

핵융합, 불순물 수송, 수송계수, 물리기반 인공신경망

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P1-nu.003

The Evaluation on the Alpha-Emitting Radionuclides in Nuclear Medicine Therapy

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Abstract:

The radionuclide therapy is a kind of inner radiotherapy method that uses the radiations emitted from the specified radionuclides to destroy the target cells. In radionuclide therapy, the alpha-mitting radionuclides have its advantage for destroying the target cells comparing to the radionuclides emitting beta of gamma particles. Here, to evaluate the therapy effects of several typical alpha-emitting radionuclides that might be used in radionuclide therapy, the Monte Carlo method is employed. In the investigation, the common cell model is designed, then the dose distributions induced by the alpha particles emitted from specified radionuclides are calculated based on the two kinds of positions of radionuclide in the target cell. According to the calculation results, it can be found that the Ac-225 has a better effect to destroy the target cells.

Keywords:

Radionuclides, Simulation Method, Radiotherapy

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P1-nu.004

Emulsion Scanning System for Double-strangeness Nuclei Search

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Abstract:

Nuclear emulsion is a very suitable detector to identify double-strangeness (S=-2) nuclei due to its submicron spatial resolution. The S=-2 nuclei are double-Λ hypernucleus, twin-Λ hypernucleus and Ξ^- hypernucleus which contain two-strangeness particles (ΛΛ or Ξ^-) in nuclei. And they can give us information on Λ-Λ interaction and Ξ^--N interaction in the nuclei. By using the emulsion detector, we can see very short tracks (~several μm) of the S=-2 nuclei and the complicated event topologies around the points of Ξ^- captures at rest. The Ξ^- hyperons are produced from the quasi-free p(K^-, K^+)Ξ^- reactions at KEK and J-PARC proton synchrotrons. And the S=-2 nuclei can be formed at the capture point by $\Xi^- p \rightarrow \Lambda\Lambda$ reactions in the emulsion. By following Ξ^- tracks and observing the Ξ^- capture points carefully in the emulsion, we can find the S=-2 nuclei. The characteristic of the S=-2 nuclei is that they have 3 vertices around the Ξ^- stopping points. Two methods of emulsion scanning have been developed for S=-2 nuclei search: "Track following method" and "Overall scanning method". In this presentation, we will introduce these scanning methods and recent event analysis including machine learning.

Keywords:

Nuclear emulsion, Double-Λ hypernucleus, Twin-Λ hypernucleus, Ξ- hypernucleus, Double-strangeness nuclei

Model study of charged particle production in Pb–Pb collisions at $₩sqrt{s_₩mathrm{NN}}$ = 5.36 TeV

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Abstract:

In this study, we present the model study of the charged-particle multiplicity density, dNch/dη in Pb-Pb collisions at a centre-of-mass energy per nucleon-nucleon pair of $₩sqrt{s_₩mathrm{NN}}$ = 5.36 TeV. The centre-of-mass energy for Pb-Pb collisions is the highest ever that is planned to be collected by LHC at the end of 2022 for the first time. The multiplicity of charged particles produced in the collisions is a key observable to characterise the properties of the matter created in these collisions, as the overall particle production is related to the initial energy density. Before the new frontier data collection, we prepared the model and theoretical calculations in different mechanisms for particle production in nuclear collisions. Model study of charged particle production in Pb–Pb collisions at the LHC with the ALICE detector.

Keywords:

Pb-Pb collisions, multiplicity, charged particle production, centre-of-mass energy, multiplicity density

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P1-nu.006

Dijet studies at the LHC

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Abstract:

High-energy partons generated in relativistic particle collisions create well-collimated showers of particles, which are called jets. The jet study is used widely in heavy-ion collisions, where the quark-gluon plasma (QGP) medium forms. Previous studies from RHIC and LHC indicate that dijet invariant mass can be sensitive to modifications caused by the QGP medium. In this study, we present a model study of the dijet mass distributions in proton-proton and proton-lead collisions at a center-of-mass energy of 5.02 TeV as preparation before measuring the dijet invariant mass in the data. I used the anti-kt algorithm for jet reconstruction with the resolution parameter R=0.4. In the result, the modifications of proton-lead collisions and proton-proton Monte Carlo simulation results are negligible but significant in the region of low dijet mass. The raw data should be corrected due to the inefficiencies of undetected missed and over-detected fake charged particles, the procedure called unfolding. In this study, I present the unfolded spectra of the proton-lead data, but lead-lead needs to be developed for the correction of lost jets due to background subtraction.

Keywords:

QGP, lead-lead collision, proton-lead collision, unfolding, Nuclear modification factor RpPb

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P1-nu.007

Model study of jet fragmentation transverse momentum distributions in pp collisions using D0-meson tagged jets.

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Abstract:

The fragmentation of partons is studied using the jet fragmentation transverse momentum, j_{T}. The j_{T} is defined as the perpendicular component of the momentum of the constituent particle with respect to reconstructed jet momentum, ₩vec{p}_{jet}. The j_{T} provides a measurement of the transverse momentum spread of the jet fragments. The generated parton emits gluons with a specific angle along the axis of the generated jet. The size of the angle is proportional to the emitter's mass and inversely proportional to its energy. The distribution of jet fragmentation therefore depends on the mass of the emitter quark. In this study, we compare charm quark jets and light quark jets to explore the jet fragmentation distribution to study the mass effect. We also study the leading particles in each jet cone to reduce contamination by gluons outside the cone. the D0 meson is reprentative heavy particle containing charm flavour and decays kaon and pion. the charm quark is created early stage in collision and cannot be created in quark-gluon plasme because they have a large mass. Cham jets, unlike light quarks, have larger regions of suppression of gluons. we expect that the charm jet has more different distribution by comparing with light quark jet.

Keywords:

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P1-nu.008

Development of Radiation shieldings using bismuth halogen and siloxane composites.

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Abstract:

Lead (Pb) is the most widely used shielding material against X-rays, but it is very heavy and toxic to be used. In this work, we successfully developed non-lead shielding materials against X-rays using bismuth iodide(BiI_3) and polydimethylsiloxane (PDMS) composites. It was done by incorporating of BiI_3 into the porous PDMS matrix through a simple solvent-casting method. The shielding agent was characterized by using various techniques such as x-ray photoelectron spectroscopy, scanning electron microscopy, and x-ray diffraction measurement.

Keywords:

X-ray, radiation, shielding, metal compounds, PDMS

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P1-nu.009

Performance improvement of the SiPM coupling with $Tl_2LaCl_5:Ce^{3+}$ crystal at low temperatures

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Abstract:

A $Tl_2LaCl_5:Ce^{3+}$ (TLC) crystal is a novel scintillator which possesses high X- and γ-ray detection efficiency due to the high effective atomic number and density. A silicon photomultiplier (SiPM) has a high gain of 10^5 to 10^6 with low operating voltage. The SiPM coupling with the TLC crystal has an advantage of detecting a low energy X- and γ-ray. Having a good energy resolution of 8.8 % FWHM at 121.7 keV was confirmed in a preliminary study. In this study, we investigate the temperature dependence of the SiPM for improving the detecting performance of low energy. We measure the light yield of TLC crystal and other scintillators at different temperatures. We confirm the reduction of thermal noise. We report our results and discuss the application of the current study such as medical imaging and radiation detection.

Keywords:

Silicon photomultiplier , Tl2LaCl5:Ce3+

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P1-nu.010

Plastic scintillator performance test with ^{90}Sr radio active source

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Abstract:

To test a plastic scintillation detector to be used as a muon trigger, we want to observe the energy spectrum of electrons from a ^{90}Sr radiation source. Since the energy of electrons from a ^{90}Sr radiation source is already well known, it is often used to determine the detection performance of charged particles. This poster reports the results of observing the energy spectrum by connecting PMT to a $20\times30\times160mm^3$ plastic scintillator.

Keywords:

Plastic scintillator, 90Sr , PMT, Muon trigger

LiI:Tl scintillation crystal: Capability of thermal neutron discrimination from background gamma rays

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Abstract:

The LiI crystals have been used worldwide for thermal neutron detection and monitoring due to the high thermal neutron capture efficiency of Li isotopes. It is advantageous if the crystal can separate thermal neutron events from strong background gamma rays. So far, many doped LiI scintillation crystals have been investigated. The most popular crystal is LiI:Eu, which has been commercialized with a good light yield but poor particle discrimination capability. Other crystals, such as LiI:Ag or some codoped LiI crystals, show good pulse shape discrimination (PSD) for thermal neutron-background gamma rays. The search for good discrimination capability of the LiI-based crystal is still of interest. This work investigated the thermal neutron-gamma background discrimination capability of the LiI:Tl scintillation crystals. The LiI:Tl crystal may be a candidate due to its competitive light yield and potential pulse shape discrimination of neutron-gamma. Four LiI:Tl crystals with different thallium concentrations were grown by the Bridgman technique and encapsulated. Thermal neutron measurements were performed with the ^{252}Cf source using paraffin. The discrimination capability was studied using the charge comparison method and evaluated by Figure-of-Merit (FoM). The FoM from the charge comparison method (CCM) can be improved using the fast Fourier Transformation (FFT). The FFT can be used to derive the discrimination characteristic in the frequency domain. The rotation transformation can be applied to the CCM discrimination characteristic based on the relationship between the frequency and time domain. It can improve the FoM values by 6-30%. The results show that the LiI:Tl crystals can separate thermal neutrons from strong background gamma rays at low-doped thallium concentrations.

Keywords:

LiI:Tl, scintillation, thermal neutron, pulse shape discrimination

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P1-nu.012

Study on characteristics of radiography system based on CMOS camera

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Abstract:

The area of radiography has been evolving with new applications in a wide range of scientific, security, medical, environmental, and industrial fields. Previously, conventional methods used physical films to store images and required a darkroom with a chemical solution to treat the films. This is a time-consuming process, and the quality of the images is usually limited by the film's characteristics. Hence, digital radiography has been promoted. By using digital detectors, this method allows users to capture and display the obtained images almost immediately. Also, digital images are easier to store and retrieve, avoiding the need for physical storage space then making them more convenient to analyze and share with other professionals.
This report presents the investigation results of the characteristics of a digital imaging system developed from a CMOS camera in combination with an optical lens and a scintillation screen. The system was constructed with a Raspberry Pi 4 and a CMOS sensor, an optical lens (RPi HQ camera and 10MP lens), while the scintillation screen was fabricated by using a polymer solution. The performance of the developed system on transferring object contrast to image contrast in a wide range of resolution levels - Modulation Transfer Function (MTF) was studied by approaching the slanted edge method (ISO 12233). In addition, relations between MTF and exposure time/gain setting were also studied. The obtained results show that the developed system would be used to resolve objects up to 150 cy/mm resolution. This suggests that the system has promising applications in scientific and medical fields, where high-resolution imaging is often required.

Keywords:

RPi HQ Camera , luminescence , digital radiography, MTF

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P1-nu.013

Properties of flexible scintillator composed of PDMS and $LuGdAl_3Ga_2O_{12}$:Pr_2O_3 phosphors

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Abstract:

The organic scintillator have been widely used as detectors in nuclear/particle physics, and homeland security applications because of the low cost and easy fabrication. However, application of organic scintillator is limited because of its low effective atomic number. Therefore, in order to increase the detection efficiency of high-energy X-ray/ γ-ray, many studies have been conducted to add rare-earth element to the organic scintillator. The phosphor containing rare-earth element can be increase the absorption efficiency of X-ray/ γ-ray because of high atomic number (Z).
We fabricated flexible scintillator using polydimethylsiloxane (PDMS) and $LuGdAl_3Ga_2O_{12}$:Pr_2O_3 phosphors for X-ray detectors. In this presentation, the properties of the flexible scintillator, such as radio-luminescence and sensitivity, are studied.

Keywords:

Radaition detector, X-ray detector, Scintillator

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P1-nu.014

Low-temperature study of CsI(Tl) crystal for dark matter search

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Abstract:

The Korea Invisible Mass Search (KIMS) experiment used low background CsI(Tl) crystals coupled with PMTs to detect the signals from the elastic scattering of weakly interacting massive particles (WIMP) off the nucleus for dark matter search at room temperature. The number of photo-electrons (PE) was about 5.5/keV for the CsI(Tl) crystals, and the threshold was set to 2 keV. To increase the number of photo-electrons and to get a lower threshold for higher sensitivity of WIMP, CsI(Tl) can be coupled with a silicon photomultiplier (SiPM) which has higher quantum efficiency and lower background. However, SiPM suffers from large single photo-electron (SPE) noise at room temperature. It is necessary to operate CsI(Tl) coupled with SiPM at low temperatures to reduce SPE noise. To understand the scintillation properties of CsI(Tl) at low temperatures, we measured the scintillation properties of the CsI(Tl) crystal temperature range from 300 to 10 K using alpha and gamma radioactive sources. The CsI(Tl) crystal was placed inside the vacuum cryostat with a radioactive source, and the PMT was located out of the cryostat to be unaffected by the inside temperature. In this presentation, we talk about the temperature dependence of light output, alpha/beta ratio, decay time, and pulse shape discrimination of the CsI(Tl) crystal.

Keywords:

CsI(Tl), scintillator

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P1-nu.015

Investigating effects of alkali ions on luminescence and scintillation performance of Ce^{3+} doped phosphate glasses for radiation detection

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Abstract:

The luminescence and scintillation properties of Ce^{3+} doped alkali phosphate glasses $56P_2O_5$:$8Gd_2O_3$:$5Al_2O_3$:$1CeBr_3$:30XCl (PGAC:X, X=Li/Na/K/Rb/Cs) were studied for their potential applications in gamma and alpha detection. In the Fourier Transform Infrared Spectroscopy (FTIR), X-ray Luminescence (XRL), Photoluminescence (PL), and transmittance spectra, the red shift was found and explained by the concept of optical basicity. Broad Ce^{3+} emission and energy transfer from Gd^{3+} to Ce^{3+} were observed in XRL and PL measurements. Scintillation performance was studied by irradiating the samples under ^{137}Cs gamma and ^{241}Am alpha sources. The fast, intermediate, and slow decay components under gamma and alpha excitation were found around 30, 200, and 3000 ns, respectively. The decay time increased slightly from PGAC:Li to PGAC:Cs, indicating the less effective transition from Gd^{3+} to Ce^{3+}. The alpha decay time was longer than the gamma decay time, revealing the Pulse Shape Discrimination (PSD) capability for particle identification. The XRL intensity reduced significantly from PGAC:Li to PGAC:Cs samples but did not reflect the scintillation tendency. By successfully detecting gamma and alpha scintillation signals, the scintillation performance of all samples was found to be similar. In general, all samples can be used for gamma and alpha detection. Using Rb^+ or Cs^+ ions is favorable in terms of high density and light yield, while Li^+ ions enhance the transmittance and homogeneity.

Keywords:

Alkali ions, Scintillation glass, Cerium phosphate glass, Light yield, FTIR

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P1-nu.016

Temperature dependency study a pure $LaCl_3$ crystal scintillators for the fast neutron spectroscopy

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Abstract:

The lunar surface has significant temperature variations and interacts with cosmic rays to form a fast neutron field. To calculate the radiation dose from neutrons on the lunar surface, measuring the energy distribution of fast neutrons is necessary. We developed pure $LaCl_3$ crystal scintillators with good pulse shape discrimination (PSD) capability so that gamma, proton, and alpha signals can be separated. We can measure the neutron energy through fast neutron interaction with ^{35}Cl via $^{35}Cl(n, p)^{35}S$ and $^{35}Cl(n, \alpha)^{32}P$ reactions, and the gamma background can be easily removed. To determine the suitability of this scintillator on the lunar surface, we studied the temperature-dependent changes in scintillation properties. One 1 cm^3 of $LaCl_3$ coupled with the PMT was put into the refrigerator where the temperature can be changed from 30℃ to +30℃. To check the gain dependency of PMT, we measured single photoelectrons with different temperatures and corrected the light yield of $LaCl_3$ crystal. We measured the scintillator's light yield, energy resolution, and decay time as the temperature changed. Also, the property of PSD with different temperatures has been measured using a fast neutron source of ^{252}Cf.

Keywords:

Pure LaCl3, Pulse Shape Discrimination, Fast neutron spectroscopy

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P1-nu.017

Designing & Assembling Vertical Gradient Freeze Furnace To Grow CsI Crystals$_2$

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Abstract:

Growing bulk single crystals under laboratory conditions has been challenging. Using popular furnaces such as Czochralski or vertical Bridgman to grow crystals up to 3 inches has noticed a significant issue. That is the inhomogeneity of the temperature profile during the growing process due to the moving of the crystal. Therefore, to handle this problem, the vertical gradient freeze (VGF) method is considered a promising candidate because of its simplicity and the stationary state of the crystal. Controlling temperature changes is one of the most crucial challenges of operating a VGF furnace. This task requires equal effort to manage the moving crystal function of the vertical Bridgman method. It is believed that the speed of the crystal growth and its quality mainly depends on this.
This research aims to introduce the design, the assembly guide, and the user manual of the VGF furnace to educate users on how to grow crystals with a melting point below 1000 °C. A collection of the luminescence characteristics from CsI:Tl, CsI:Na or CsI:Cs2CO3 crystals grown by the VGF furnace was also mentioned as proof of its working capability. Based on these emerging results, it can be said that the target of growing big size crystals is likely to be successful.

Keywords:

Vertical gradient freeze, Crystal melting growth, CsI crystal

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P1-nu.018

Optimization of BGO scintillation crystal and SiPM for KAPAE phase II detector

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Abstract:

In particle physics, the search for positronium rare decays in 3-gamma annihilation such as milli-charged particle, mirror world, new light X-boson, and extra dimensions can be performed by the KNU Advanced Positronium Annihilation Experiment (KAPAE). The ground state of positronium (Ps) has two possible configurations based on the relative spin orientations, the triplet state ($^3S_1$), ortho positronium (o-Ps), and the single state ($^1S_0$), para positronium (p-Ps). Due to C-parity conservation, p-Ps and o-Ps decay to even and odd numbers of gammas. In this study, using a 3 x 3 SiPM array and BGO scintillation crystals, we optimize the light yield, energy threshold, and energy resolution of the KAPAE phase II detector. The diffuse surface of BGO improves the light yield by 23% compared with polished BGO. The threshold of SiPM is lowered by reducing thermal noise through a low-temperature environment.

Keywords:

KAPAE, positronium, annihilation

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P1-nu.019

대기중성자 발생 표적 열부하시험 전산모사

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Abstract:

최근 스마트 기기의 보급확대와 자율 주행차의 도입 등 반도체의 활용처가 국민생활 전반 및 안전과 밀접한 분야로 확대됨에 따라 반도체의 방사선에 의한 오작동이 주요한 연구 관심사가 되었으며, 반도체 제조 산업 분야의 방사선 영향시험을 위한 수요가 증가하고 있다. 이에 대응하기 위해 100 MeV 양성자가속기 기반의 대기중성자 발생 표적 시제품을 제작하였다. 표적 물질은 탄탈륨(Ta)을 사용 하였다. 시제품의 표적창에 대한 열적 건전성 평가를 위해, 유한요소 분석법 기반의 상용 전산모사 프로그램으로 형상을 모델링하고 실제 양성자가속기에서 발생시키는 빔특성을 반영하여 열수력 해석을 수행하였다. 열부하는 직경 3 cm영역에 0.1 kW에서 1 kW까지 증가 시키고, 유동 경계조건은 냉각수 온도 20 ^{o}C, 유량 40 L/min, 유체 압력 2 bar를 사용하였다. 그결과 0.27 kW 이상의 열부하가 인가될때 2 bar에서의 물 비등점을 초과하는 영역이 나타났다. 이러한 고온의 불균일한 온도분포를 가지는 영역에서는 표적창에 열응력을 유발시키고 변형을 일으킬 수 있다. 따라서 열부하를 최소 0.03 kW에서 최대 0.3 kW까지 0.03 kW 간격으로 더 촘촘하게 증가시키는 조건으로 변경하고, 이에 대한 열해석을 다시 수행하였다. 본 연구결과는 전자빔 열부하 실험 측정값의 참조값으로 활용 할 계획이다.

Keywords:

대기중성자, 표적, 열부하시험, 반도체오류, 전산모사

2023 KPS Spring Meeting
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P1-nu.020

Neutronic Calculations for Spallation Neutron Target Assembly of KOMAC

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Abstract:

When an energetic particle beam strikes materials, various secondary particles are generated as a result of nuclear reactions between the incident beam and target materials. The system that produces neutrons via the spallation reaction induced by high-energy proton beams on target is generally called a spallation neutron source. The spallation neutron source consists of many devices; among those devices the neutron-production target system is one of the key components in the source to produce neutrons stably and safely. In this study, neutronic calculation through Monte Carlo simulations was performed for a 1-GeV proton beam on tantalum-clad tungsten targets, and its results are discussed in detail.

Keywords:

spallation neutron source, targetry, neutronic calculations

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P1-pa.001

Reliability testing of 15 kV, 10 kA high-power semiconductor switch for kicker modulators.

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Abstract:

This paper describes a long-term reliability test of a high-power semiconductor switch (solid-state switch) for application in kicker modulators. To verify the reliability of the developed high-power semiconductor switch, a continuous operation test was conducted under conditions (Peak Voltage: 15 kV, Peak Current: 10 kA, Pulse Width: 10 us, Continuous Repetition Rate: 10 Hz) during the 17th User Beam Time (10 days, 240 hours) at the Pohang Accelerator Laboratory in 2022. The test setup was designed to enable remote and local control of the kicker modulator and to monitor the internal conditions and temperature of the laboratory in real-time. As a result, 8,157,098 shots were recorded without any faults during the continuous operation for 10 days.

Keywords:

solid-state switch, semiconductor switch, pulsed power, kicker modulator, high-power

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P1-pa.002

vOscillation: a software package for neutrino oscillation simulation

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Abstract:

Neutrino has challenging topics not yet understood well such as neutrino oscillation, mass hierarchy, and sterile neutrino. There are several experiments ongoing or planned to unveil the physics of neutrinos. We have developed vOscillation, a software package for computing and simulating the neutrino behaviors in experimental situations. We implemented the computations of the flux and energy distributions of neutrinos from various sources, as well as the neutrino oscillations based on the (3+1) neutrino model including considerations of sterile neutrino. We also implemented a Monte Carlo simulation tool to simulate the flux and energy distribution of detected neutrinos for a given neutrino source and detector configuration. In this study, we demonstrate the capabilities of our software and present its applications to the study of future experiments.

Keywords:

neutrino oscillation, sterile neutrino

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P1-pa.003

Gauge coupling unification and proton decay in high-scale SUSY

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Abstract:

Recently, we found that the mass of the Higgs boson is around 126 GeV. Furthermore, there is no experimental evidence for new physics beyond the standard model so far. These can serve as motivations for the high-scale supersymmetry (SUSY) breaking model, where the sfermion mass scales are much higher than the weak scale. The high-scale SUSY breaking model has some advantages over the light-scale SUSY breaking model. First, it can deal with SUSY flavor and CP problems. Second, this model can raise the Higgs mass up to 126 GeV. Lastly, it can make gauge coupling unification more accurate. As a consequence, we would like to investigate the process of proton decay and present directions to establish an experimental basis for SUSY in the context of a high-scale SUSY breaking scenario.

Keywords:

Unification, SUSY, proton decay

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P1-pa.004

Feasibility study on the discrimination of fluor concentration in the liquid scintillator using PMT waveform and short-pass filter

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Abstract:

Neutrinos are difficult to detect because they weakly interact with matter, making their properties least known. The response of the neutrino detector depends on the optical properties of the liquid scintillator (LS). Monitoring any characteristic changes in the LS helps to understand the temporal variation of detector response. In this study, a detector filled with LS was used to study the characteristics of the neutrinos detector. We investigated a method to distinguish the concentrations of PPO and bis-MSB, which are fluors added to LS, through photomultiplier tube (PMT) acting as an optical sensor. Conventionally, it is very challenging to discriminate the flour concentration dissolved in LS. We employed the information of pulse shape and PMT coupled with the short-pass filter. To date, no literature report on a measurement using such an experimental setup has been published. As the concentration of PPO was increased, changes in the pulse shape were observed. In addition, as the concentration of bis-MSB was increased, a decrease of the light yield was observed in the PMT equipped with the short-pass filter. This result suggests the feasibility of real-time monitoring of LS properties, which are correlated with the fluor concentration, using a PMT without extracting the LS samples from the detector during the data acquisition process.

Keywords:

Liquid scintillator; Linear Alkyl Benzene; Fluor, PMT, Waveform, Short-pass filter

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P1-pa.005

^{22}Na activity analysis for the COSINE-100 experiment

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Abstract:

COSINE-100 is a direct search dark matter experiment using ultra-low background NaI(Tl) crystal scintillators. It is crucial to fully understand and model backgrounds, including internal backgrounds, to improve the sensitivity of dark matter search. ^{22}Na, one of the background components, is produced by collisions between NaI(Tl) crystals and cosmogenic neutrons. We detected ^{22}Na through the comparison of the energy spectra of COSINE-100 crystals. In this presentation, we report our result with the activity of ^{22}Na for each crystal. This result will be used for background modeling.

Keywords:

COSINE-100, Dark matter, 22Na, NaI(Tl), Scintillator

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P1-pa.006

R&D on high-temperature superconducting cavities for axion dark matter searches at IBS/CAPP

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Abstract:

IBS/CAPP is searching for a hypothetical particle known as the axion, which has the potential to solve both the strong CP problem and the mystery of dark matter using cavity haloscopes. To optimize the search, high-quality factor cavities are required to enhance the axion conversion power and improve scan speed. In pursuit of this, the center is utilizing commercially available biaxially-textured ReBCO tapes to fabricate the cavity. To characterize the electrical properties of these superconducting tapes from various providers such as Fujikura, Superpower, and Theva, a test cavity with a rutile core was employed to measure their properties at low temperatures under high magnetic fields. For the flagship experiment, CAPP-12T, which requires a large-sized and light cavity, a series of barrel-type cavities have been fabricated by rolling copper sheets. In the near future, we plan to cover the inside of this large copper cavity with superconducting tapes, and a prototype has already been made.

Keywords:

Axion, Dark matter, Cavity, ReBCO

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P1-pa.007

Analysis of the light signal in the AMoRE-I data

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Abstract:

The AMoRE (Advanced Mo-based Rare process Experiment) is an international project to search for neutrinoless double beta decay, expected to appear if the neutrino is a Majorana particle. The AMoRE project uses molybdenum-based scintillating crystals, and we discriminate surface alpha background events through the phonon-photon simultaneous measurement. However, We could not reach enough alpha background discrimination power due to the significant noise generated in the light signal by the refrigerator pulse-tube vibration. Thus, we have been trying th improve the light signal analysis in the software. We will introduce the new method applied to the light signal amplitude calculation and compare its results with the previous ones.

Keywords:

AMoRE-I, neutrinoless double beta decay

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P1-pa.008

Water transparency monitoring using the Korean light injector system in the Super Kamiokande experiment.

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Abstract:

Super-Kamiokande (SK) is an experiment to search for nucleon decays, including proton decay, and to observe neutrinos from various sources, including solar, supernova, atmosphere, and accelerator, using a 50 kt water Cherenkov detector.
Water transparency is important because Cherenkov light from inside the detector is detected by PMTs through the water.
SK Korean Group is monitoring the transparency of water by five light injectors on the barrel of the SK tank, one on the top, and one on the bottom.
Using this system, when Gd was dissolved in the SK tank, the change in water transparency according to the height was successfully monitored.
And recently, the charge linearity of the monitoring PMT, which monitors the amount of light injected from the light injector, was calibrated, and the amount of light measured by monitoring PMT was adjusted to the linear region of the monitoring PMT using a neutral density filter.
This poster reports on the results of monitoring the water transparency of the SK detector and the calibration of the monitoring PMT.

Keywords:

SuperK, Neutrino, Cherenkov light

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P1-pa.009

Light signal analysis with R&D detectors for AMoRE experiments

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Abstract:

Scintillating molybdenum-based crystals are good target materials, used in searches for the neutrinoless double beta decay of ^{100}Mo, such as the AMoRE experiment. The AMoRE experiment has been developing the cryogenic calorimeters using the massive Mo-based scintillating crystals and MMC (metallic magnetic calorimeter) sensors. The detectors are also coupled with light absorbers comprised of Si or Ge wafers, which collect the scintillation light signals from particle interactions in the molybdate crystals.
The light signals are crucial in determining the particle type and rejecting the background in our energy region of interest. The light signals are calibrated using X-rays with known energies that strike the wafer directly, and the scintillation light energy of the crystal detectors is estimated using the convolution fitting technique. The analysis of the light signals from the different detector setups will be discussed, and the light measurement of the R&D detectors for AMoRE experiments will be presented.

Keywords:

MMC, scintillating crystals, X-rays

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P1-pa.010

이미지 센서로 획득한 액체섬광검출용액 이미지 및 계산화학 코드를 이용한 액체섬광검출용의 스펙트럼 CNN 판별 가능성

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Abstract:

상업용 CMOS(Complementary Metal Oxide Semiconductor)이미지 센서의 스펙트럼 반응은 제조사에서 제공하지 않는다. 심층 합성곱 신경망(Convolution Neural Network, CNN)의 분별 능력을 이용해서 CMOS 이미지 센서로 획득된 LS(Liquid Scintillator)의 이미지 스펙트럼 판별을 시도하였다.
LS의 빛 방출은 시간 의존적 밀도 범함수 체계에서 효과적으로 기술된다. 일반적으로 중성미자 검출에서 사용되는 LS는 PPO(2,5-Diphenyloxazole)와 Bis-MSB(1,4-Bis(2-methylstyryl)-benzene)가 있다. 연구에서는 PPO와 Bis-MSB의 여기 준위를 계산했다. 합성한 액체섬광검출용액에 위 형광체 여기 파장들을 참조하여 UV-VIS 형광을 측정하였다. 이미지와 형광 데이터를 학습시켜 신경망의 판별 점수로 스펙트럼 반응을 역으로 유추 가능성을 확인하였다.

Keywords:

액체섬광검출용액(LS), 심층 합성곱 신경망(CNN), 이미지 분석(Image analysis)

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P1-pa.011

Non-thermal leptogenesis in Starobinsky-like inflation

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Abstract:

Seesaw Mechanism is one of the solutions to explain the origin of neutrino masses, based on the existence of Right handed neutrinos(RHN). Neutrinos can carry Dirac or Majorana masses, depending on whether the RHNs are heavy or not. The RHNs can be created efficiently from the thermal bath, but the initial abundance of RHNs can be also created from the decay or scattering of heavy scalar fields such as the inflaton in the early universe. Thus, the production of lepton asymmetry at the early stage of the universe can be thermal or non-thermal in nature. Consequently, the out of equilibrium decays of the RHNs lead to lepton asymmetry when the Yukawa couplings for RHNs have nonzero CP phases. In this work, we focus on the non-thermal leptogenesis in the context of the Starobinsky-like inflation model.

Keywords:

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P1-pa.012

The study of AMoRE-II SQUID electronics for multi-channel flux-locked loop (MCFLL)

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Abstract:

AMoRE is the advanced molybdenum-based rare process experiment for searching the neutrinoless double beta decay of ^{100}Mo.
Currently, AMoRE-I is in progress, and we are preparing the AMoRE-II.
The final goal of AMoRE-II is to increase the ^{100}Mo mass to 100 kg, and the number of detector channels is about 1000.
For this purpose, SQUID electronics for multi-channel are needed. For linearity of the SQUID signal, flux-locked loop (FLL) mode is required with the low-noise condition. Therefore, we are checking the noise condition of the multi-channel flux lock loop (MCFLL), which Magnicon has recently developed.
The test results will be presented.

Keywords:

neutrinoless double beta decay, SQUID, AMoRE, LowTemperature Detector

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P1-pa.013

HPGe and Alpha counting measurements of detector material samples for AMoRE II at the Yangyang Underground Laboratory

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Abstract:

The Center for Underground Physics conducts two major rare-event search experiments,AMoRE searches for neutrinoless double-beta decay, and COSINE explores WIMP dark matter, both at the Yangyang Underground Laboratory(Y2L). Reducing radioactivities (U, Th, K, Pb) in repective detector materials is essential for rare event experiments. We checked the materials used in the newly buil AMoRE II experiment in the Yemilab in order to reduce backgrounds and increase sensitivity. This poster will present alpha counting and HPGe measurements of detector materials which are candidates for o selected for use in the AMoRE II experiments.

Keywords:

HPGe detector, Alpha counter, Radioactive assay, Y2L, AMoRE II

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P1-pa.014

Discrimination of Signal and PMT Noise in NEON Experiment using Machine Learning

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Abstract:

Neutrino Elastic scattering Observation with NaI (NEON) is in progress at the Hanbit nuclear power plant. The main goal of NEON is to observe the reactor electron anti-neutrino coherent scattering using 15 kg NaI(Tl) crystal detectors. Since detection of the signal requires a low energy threshold at around 0.3 keV, we need to eliminate almost all background noise components which are mainly produced in the photomultiplier tubes (PMTs). In this poster, we show characterization of the noise components and present a data-driven improved machine learning to distinguish between the neutrino signals and the PMT noises.

Keywords:

NEON, reactor neutrino, NaI(Tl), machine learning, coherent scattering

2023 KPS Spring Meeting
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P1-pa.015

The status of AMoRE-II background simulation

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Abstract:

The AMoRE-II is the next phase of the AMoRE experiments, which search for the neutrinoless double beta decay of ^{100}Mo isotopes. For a rare process search experiment to achieve a particular desired limit, the background event rate in the region of interest (ROI) must be suppressed below a corresponding level. The first stage of the next phase of AMoRE-II is in preparation at the Yemi underground laboratory (Yemilab) located at the Handuk mine in Yemi mountain. To achieve maximum sensitivity, we aim to achieve 10^{-4} background events/keV/kg/year in the neutrinoless double beta decay ROI. The most common background sources are radioactive contaminants in the construction materials, such as long-lived uranium and thorium isotopes. Other background sources include the environmental fluxes of neutrons, muons, and gamma rays at the experiment site. To estimate the background conditions in the AMoRE-II, we performed the simulations with the GEANT4 Toolkit. Details of the background simulation from near and far components will be presented. Also, estimated background levels in the region of interest will be shown.

Keywords:

Backgrounds for the underground experiment, Geant4 simulation, AMoRE, double beta decay

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P1-pa.016

Radon activity requirement for the CAGe

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Abstract:

Radon is getting to be an important background source to the large scale deep underground experiments searching for the $0\nu\beta\beta$ decay and WIMP interaction. A radon reduction system has been built to provide a radon-free environment for those experiments, but limited supplying capacity. Here, we suggest a method to evaluate a proper radon level for detectors and report a specific requirement for the CAGe as an array of fourteen HPGe detectors to measuring an ultra-low radioactivity of the materials and specific gamma-rays by rare decay.

Keywords:

Radon, Background source, Multi channel HPGe detactor

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P1-pa.017

The performance of the prototype NaI(Tl) crystal and encapsulation

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Abstract:

COSINE-200, the upgrade version of COSINE-100, will be a direct search dark matter experiment also using NaI(Tl) crystals as target material. We have successfully developed an ultra-low radioactive background NaI(Tl) crystal for this upcoming experiment. In addition, a new encapsulation design is required for better resolution of the detectors. In this presentation, we will address the performance of the prototype crystal and the newly developed encapsulation.

Keywords:

NaI(Tl), COSINE experiment

2023 KPS Spring Meeting
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P1-pa.019

Measurement of nuclear recoil quenching factor of the NaI(Tl) crystal using a neutron generator

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Abstract:

NaI(Tl) crystals have been widely used in rare event search experiments, such as COSINE-100 and NEON, which involve WIMP-nucleus scattering or neutrino-nucleus scattering. To calibrate the energy of nuclear recoil interactions, measurement of the nuclear recoil quenching factor is desired. In this poster, we report on the nuclear recoil quenching factor measurements induced by a monoenergetic neutron beam created by a deuteron-deuteron fusion reaction.

Keywords:

NaI(Tl), quenching factor

2023 KPS Spring Meeting
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P1-pa.020

On axion production mechanisms

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Abstract:

A hypothetical particle, the axion, was suggested to solve the strong CP problem. It turns out to be a nice candidate for dark matter. The axion makes the strong CP phase dynamical and drives it towards zero at the minimum of the potential. The initial value of the axion is deviated from the bottom or the hilltop of the potential, accounting for the axion relic density. This is called the axion misalignment. On the other hand, if the axion has a nonzero initial velocity, the right amount of axions can be produced more efficiently in the early universe. This is dubbed the kinetic misalignment. We discuss the current status of the axion production mechanisms and the axion experiments.

Keywords:

Axion, Axion kinetic misalignment, dark matter

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P1-pa.021

Large-Volume Ultra-Light Cavity for Axion Dark Matter Search

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Abstract:

The Center for Axion and Precision Physics Research (CAPP) of the Institute for Basic Science (IBS) has launched the CAPP-12TB experiment equipped with a 12T superconducting magnet with a 32cm bore. The goal of the experiment is to enhance the axion search speed by utilizing large-volume, tunable cavities operating at temperatures below 100 mK in the strong magnetic field. In this presentation, we introduce a series of ultra-light cavities (ULCs), which are made of oxygen-free high-conductivity copper, having weights of about 6 kg and 5 kg for the first (ULC1) and second (ULC2) versions. The thin structure of the cavity allows for large volumes of 37 L and 34 L, respectively, and temperature retension below 50 mK even under the 12T magnetic field. The turnable frequency range is 1.020-1.185 GHz for ULC1 and 1.163-1.529 GHz for ULC2, while the quality factor remains above 10^5.

Keywords:

Ultra-Light Cavity, Axion, Dark Matter

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P1-pa.022

Signal discrimination of a liquid scintillator from a plastic scintillator in a phoswich detector

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Abstract:

The liquid scintillator(LS) and plastic scintillator(PS) are widely used as joint target media in particle detection experiments.
However, since the signals of LS and PS are similar in shape, it is difficult to discriminate the signals from both scintillators when they are combined as one detector called a phoswich.
With a machine learning technique such as Boosted Decision Tree(BDT), the separation power can be improved.
We use independent calibration data separately from LS and PS for training and apply the trained BDT algorithm to the phoswich data.
In this poster, we present the discrimination power of the new method and possible application to rare event search experiments.

Keywords:

Liquid scintillator, Plastic scintillator, Phoswich, BDT, Machine learning

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P1-pa.023

A Progress Report of A WIMP Dark Matter Detector

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Abstract:

Our team has studied a dark matter for the several decades. As a step of long journey, we propose a detector searching for a non-baryonic dark matter, a weakly interaction massive particles (WIMP). The direct detection method with the pulsce shape discrimnation method (PSD) are applied in our detector system. In this presentation, we will show a design of the detector and a actual outer chamber. And a progress of simulation study will be presented.
We estimate a WIMP detecting rate of our detector around 10/year.

Keywords:

Dark matter, WIMP, PSD

Measurement of Reflectivities of Black sheets for Water Cherenkov Experiments

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Abstract:

The Super-Kamiokande (SK) is a water Cherenkov experiment built under Mountain Ikeno in Japan. The inner detector of the SK is covered with Black PET sheets to reduce reflection on the wall, for a better event reconstruction. For future water Cherenkov experiments such as Hyper-Kamiokande being built in
Japan, materials with higher performance are under investigation. For smaller detectors like WCTE (Water Cherenkov Test Experiment) to be built at the CERN in 2023, reducing reflection is even more critical, as reflected lights could form a ghost ring on the opposite wall which is only ~4m distant. The object of this study is to compare total reflectance of various materials using a Photo-multiplier tube (PMT) and an integrating sphere in the water, and choose one with the smallest reflectance and good durability in the water. In this poster, the result of several black samples were shown and the future plan is discussed.

Keywords:

WCTE, Neutrino Physics, Super Kamiokande, optical calibration

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P1-pa.025

Background modeling for Neutrino Elastic-scattering Observation with NaI(Tl) experiment (NEON)

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Abstract:

Neutrino Elastic scattering Observation with NaI (NEON) is an experiment to detect a coherent elastic neutrino-nucleus scattering (CEvNS) using reactor electron antineutrinos. NEON is based on an array of six NaI(Tl) crystals corresponding to a total mass of 15 kg, located at the tendon gallery of the Hanbit nuclear reactor that is 24 m far from the reactor core. The installation of the NEON detector was completed in December 2020 and the detector is currently taking data with full power of the reactor since May 2021. We have fitted this measured data with a Monte Carlo simulation containing a variant of background components. The background modeling for the NEON experiment will be presented in this talk.

Keywords:

Neutrino, Reacotor, CEvNs, NEON

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P1-pl.001

Afterpeak in Atmospheric Pressure Pulsed Plasma

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Abstract:

The peaked emission of afterglow, called afterpeak was observed in atmospheric pressure pulsed argon discharges. The afterpeak is most clearly seen in the 750.3 nm line emission corresponding to the transition from Ar(4p) to Ar(4s), which was never reported in low pressure discharges [1]. We have developed a global model to investigate the mechanism of the afterpeak focusing on the time scales of energy transport and particle transport. The global model study shows that the electron temperature rapidly drops right after the pulse is turned off, and the ion loss by ambipolar diffusion decreases rapidly due to the lowered electron temperature, whereas the electron density decreases relatively slowly. The density of Ar(4p) increases because the low electron temperature condition enhances the rate of electron-ion recombination, causing afterpeak from the spontaneous transition of Ar(4p). More importantly, our study shows that it is necessary to consider radiation trapping and step ionization, including higher levels of argon up to Ar(6s). A model that does not include the step ionization underestimates the ionization degree and leads to lower production of Ar(4p). Without the radiation trapping, the radiational loss rate is so fast, which also leads to lower production of Ar(4p). These results suggest that radiation trapping and step ionization play an important role in the energy transport in atmospheric pressure plasma [2].

References

[1] W J Nam et al, J. Phys. D: Appl. Phys. **51** 444001 (2018)
[2] S Jeong et atl, Plasma Source Sci. Technol. **32** 015003 (2023)

Keywords:

Atmospheric pressure plasma, Pulsed power plasma, Plasma afterpeak, Global modeling, Radiation trapping

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P1-pl.002

Opacity Calculations for Aluminum, Hydrogen, and Gold Plasmas with the Improved FLYCHK code

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Abstract:

Opacity, which describes the extent to which the radiation is absorbed and scattered in the material, is an essential property in understanding the fundamental properties of high-energy-density(HED) and astrophysical plasmas. FLYCHK, a collisional-radiative code, has often been used to calculate the opacities of HED plasmas under a wide range of conditions due to the simplicity and availability of the code. However, it has been confirmed that the FLYCHK opacity has limitations in a strongly coupled regime due to the problem of free-free opacity formalism. In this research, we improve the free-free opacity calculation model of FLYCHK and generate opacities of various materials(Al, Au, H). The FLYCHK opacities are in good agreement with those obtained by the Los Alamos opacity code ATOMIC.
This work was supported by the NRF of Korea (No. NRF-2019R1A2C2002864) and the Defense Research Laboratory Program of the Defense Acquisition Program Administration and the Agency for Defense Development of the Republic of Korea.

Keywords:

Opacity, FLYCHK, Plasma, High-Energy-Density

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P1-pl.003

액체 특성에 따른 플라즈마-액체 시스템 간의 상호작용 변화 연구

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Abstract:

기체 제트를 액체 표면에 분사하는 시스템은 여러 과학 및 산업 분야에서 다양한 목적으로 활용되고 있다. 일반적으로 제트가 분사되는 액체 표면은 분사되는 기체 제트의 운동량이 클 경우 유체역학적으로 매우 불안정한데, 이러한 현상은 학문적으로 큰 관심을 받아왔다. 본 연구팀은 선행연구를 통해 플라즈마가 기체와 액체 사이 경계면의 유체역학적 안정성이 증가시키는 것을 최초로 발견하고 그 원인을 규명하였다 [S. Park et al., Nature 2021]. 본 연구에서는 더 나아가 액체와 경계를 이루는 대기압 제트 플라즈마가 만드는 표면 공동의 깊이 변화와 액체의 전기 전도도의 상관관계를 실험적으로 관찰하였다. Canon EOS 500D 카메라를 사용하여 shadowgraph 이미지를 촬영해 안정화된 이후 공동의 깊이를 측정하였으며, 초고속 카메라(Phantom VEO 1310) 촬영을 통해 방전 직후 공동 깊이의 변화를 확인하였다. 측정 결과, 전기 전도도가 0에 가까운 증류수의 경우에 공동 깊이가 약 2.1 mm로 최대였으며, 인가전압의 duty cycle과 전기전도도가 증가함에 따라 평형상태에서의 표면 공동의 깊이가 얕아지는 것을 관찰하였다. 전기 전도도가 180 μS/cm 이상인 조건에서는 액체표면 공동의 너비는 증가했으나 깊이는 플라즈마가 방전되지 않는 조건과 거의 같았다. 공동 깊이의 시간에 따른 변화도 전기전도도의 증가에 따라 진동이 감소하는 것을 확인하였다. 본 연구를 통해 전기 전도도와 물 표면 공동 간의 상관관계를 확인하였으며, 본 연구결과와 후속 연구를 통해 액체 특성에 따른 플라즈마와의 상호작용 변화에 대한 이해를 높일 수 있을 것으로 기대된다.

Keywords:

제트 플라즈마, 전기 전도도, 플라즈마-액체 상호작용

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P1-pl.004

Radiation Hydrodynamics Simulation of converging laser ablated plasma jet by ring-focused laser

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Abstract:

The laser-produced plasma from a solid target is an effective
source for overdense plasma. The overdense plasma can be used for compression of a frequency-chirped laser pulse, where the long frequency-chirped laser pulse can be compressed to a short pulse by reflection from the overdense dispersive plasma. For the chirped pulse compression in such way, plasma with length of more thantens of microns and exponential density profile is required. In this study, the magneto/radiation hydrodynamics simulation code FLASH is used to investigate the behavior of the plasma that is generated by interaction of an intense laser pulse and a solid target. The generated plasma evolves rapidly in space and time, and the results will be used to determine the experiment parameters for the planned laser pulse compression experiment in our laboratory. This presentation will show the hydrodynamic simulation results for converging plasma jet and diffusion near the surface of the solid target.

Keywords:

Plasma, Laser-ablated plasma

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P1-pl.005

Measurement of electron-phonon coupling parameter for non-equilibrium warm dense copper

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Abstract:

In this study, we present the femtosecond XANES measurements of highly photo-excited copper (E_d = 2.35 MJ/kg), which is excited with a frequency-doubled Ti:Sapphire laser pulse and evolves to warm dense copper (WD-Cu). The experiment was done at SCS beamline, European XFEL facility. A transmission zone plate was used in this measurement, which allowed a single-shot based measurement with a high signal-to-noise ratio. A temporal evolution of XANES around Cu L3-edge ($E-E_F$ = -4.5 ~ 10.5 eV) was measured with 100 fs resolution. The evolution of pre-edge absorption visualizes the equilibration processes in between electronic systems and lattice. To describe the dynamics in the non-equilibrium WD-Cu, we introduced a three temperature model (3TM). With the modified 3TM, the electron-phonon coupling parameter for the non-equilibrium WD-Cu will be presented.

Keywords:

warm dense matter, time-resolved x-ray absorption spectroscopy, electron-phonon coupling

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P1-pl.006

Extending Axial Length of Plasma Ablated from Aluminum Target Using

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Abstract:

High-density plasma generated by laser ablation of targets can be used to replace compressor gratings in chirped-pulse amplification (CPA) of ultraintense laser pulses. To compress the pulse using plasma, the axial length of the plasma should reach up to the millimeter scale with an exponentially decaying density profile. However, current technology has yet to produce plasma at such a length scale. In this study, we performed 2D simulations using the FLASH code to investigate the use of dual-pulse for generating a longer plasma from an aluminum target. By firing two laser pulses at different locations on the target, two plasmas are created that initially expand separately. As they expand, the plasmas will start to overlap with each other, resulting in a significant increase in plasma density. Eventually, the two plasmas merge and create a longer plasma than in single-pulse-driven cases. In contrast, a single pulse would generate a more azimuthally symmetric plasma due to the isotropic ablation of the material. Our simulation results show that the dual-pulse case is 1.2 times longer than that of the single-pulse case. In summary, our study demonstrates that allowing the plasmas generated by two laser pulses to overlap and merge can extend the axial length of the plasma and increase its density, which has important implications for laser-plasma applications.

Keywords:

Flash code, Laser ablation, Dual-Pulse

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P1-pl.007

Analysis of Sharp Density Transition using Fringe Normalization Method

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Abstract:

Sharp density transition schemes in laser wakefield accelerator (LWFA) have been developed for high-quality electron generation. While these schemes have been proven effective, more accurate measurement of rapid density changes has been required. In this presentation, we propose the use of the fringe normalization method to improve the accuracy in density analysis. A comparison between the Fast Fourier Transform (FFT) and the fringe normalization methods was conducted by measuring sharp density profile in argon gas-jet using a Mach-Zehnder interferometer. The results showed that the fringe normalization method is a more accurate and precise method for analyzing the sharp density transition.

Keywords:

Fringe Normalization, Gas jet, interferometer

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P1-pl.008

Experimental Station for Femtosecond EUV Spectroscopy for Warm Dense Matter

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Abstract:

Ultrafast Extreme Ultraviolet (EUV) sources through the high harmonic generation (HHG) process have been used in various fields to investigate electronic and structural dynamics. In this contribution, we will present a tabletop experimental apparatus for femtosecond EUV absorption spectroscopy for Warm Dense Matter (WDM) research. The system consists of the EUV pulse (25-120 eV) probe generation part via an HHG process of femtosecond Ti:Sapphire laser pulses (800 nm) with various gases (Ar, Ne, He), optical laser pulse pump part, a beamline with high-throughput optics and a sample-refreshment system for nano-foil targets, and a grazing incidence flat-field EUV spectrograph. By using two-color laser pulses (fundamental 800 nm pulse and its second harmonic 400 nm pulse), both odd and even harmonics of fundamental pulse can be generated, and the spectral resolution of 1.5 eV is obtained. The commissioning data for laser-heated aluminum nano-foil will be also presented. A clear observation of the change in the aluminum L-shell absorption was achieved in a few 100-fs range. The signature of a nonequilibrium electron distribution over a 10-eV range and its evolution to a 1-eV Fermi distribution was also observed. This demonstrates the capability of this apparatus to investigate the femtosecond electron dynamics as well as the optical conductivity of highly excited warm dense matter in the EUV regime.

Keywords:

EUV spectroscopy, Warm Dense Matter, HHG with two-color laser pulse, Optical pump - EUV probe, Nonequilibrium electron distribution

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2023-04-19 - 2023-04-21

P1-pl.009

Plasma density measurement by differential interferometry using a grating pair

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Abstract:

Laser-produced plasma was generated by focusing an intense laser pulse in gas and the plasma density was measured by differential interferometry. For this experiment, 1 TW-level intense laser pulses were focused on a gas jet with a nozzle orifice size of 100 μm for generation of the laser-plasma. The plasma density was measured using differential interferometry and compared with the result from conventional interferometry. Direct measurement of the phase shift gradients in the differential interferometry can suppress noises arising from the phase measurement, recovery, unwrapping, and Abel inversion. To obtain the more accurate and reliable electron density information for the laser-induced plasma, a new interferometer based on the Moire deflectometry technique was developed in our laboratory. In this presentation, we will present the results.

Keywords:

differential interferometer, electron density, laser plasma, laser wakefield acceleration

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P1-pl.010

Investigating Coherent Transition Radiation from Relativistic Electrons in Solid-Density Plasmas with High Power Laser Excitation

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Abstract:

Research on the production and transport of relativistic electrons in solid-density plasmas generated by intense laser pulses has been a subject of great interest. Intense laser pulses can drive energetic electron bunches separated by a single or half a laser cycle, which are injected into the front side and emerge at the rear side of a target. One way to measure such electron bunches is by observing the optical transition radiation (OTR) emitted when electrons cross from the target material into the vacuum and transit an interface in the dielectric function.
In this study, we set up optical diagnostics for the target rear side and imaged the emission pattern near 400 nm, the second harmonic of the laser frequency. We also measured the spectra and conducted an advanced experiment to observe some Coherent Transition Radiation (CTR) phenomena, such as resonant absorption or vacuum heating, even in the 800 nm wavelength band. As a result, we observed a blue shift in the CTR spectra as the laser intensity increased. These shifts indicate a modulation in the temporal structure of electron bunches, which may be related to the rapid surface motions of the target during electron bunch generation.
Currently, we are developing CTR models for spectral modulations. Combined with Particle-in-Cell (PIC) simulations on which the theory group is working, this experimental investigation could provide more detailed information on the surface dynamics of thin foil targets irradiated by intense laser pulses.

Keywords:

Coherent Transition Radiation(CTR), Solid-density Plasma, High power laser, Relativistic electrons

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P1-pl.011

2D Radiative Hydro Dynamics Simulation of Expansion of Laser-ablated Aluminum Plasma

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Abstract:

We investigate how laser-ablated plasma is formed from aluminum target using a fluid dynamics code. Understanding high-density plasma generation is important for many applications. In particular, it opens the door to plasma-based laser compression. When a conventional thick aluminum slab is used, it is difficult to generate a high-density plasma, as the majority of the laser energy is used for heating the inside of the aluminum on the irradiated surface. We use an aluminum film with thickness 2mm and double laser pulses with total energy 10mJ, which vertically irradiate the foil from opposite directions. Simulation results show that the maximum electron density at the axis of the expanding plasma reaches up to 1E+22/cc at 10 picosecond of laser irradiation and declines to 1.5E+21/cc at 150 picoseconds after laser launch. At this time, the length of the plasma is 2 micrometers . This result may vary depending on the intensity of the laser and the material. This result can satisfy the conditions required for plasma-based laser pulse compression. We also study the properties of the shock front of the expanding plasma to find out if the density of the front end can be controlled.

Keywords:

plasma ablation, expanding plasma

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P1-pl.012

Increased Efficiency by Pulse Shaping in PDO-THz Emission

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Abstract:

Laser-plasma-based terahertz (THz) sources usually emit broad-band THz waves, e.g., CTR or two-color scheme. In contrast, from our novel THz source, where we generate plasma dipole oscillation (PDO) as an emitting antenna, we can generate electromagnetic radiation with narrow bandwidth at the plasma frequency in the THz spectral range ($\omega_p \sim \sqrt{n_0}$, where ***n0*** is the local plasma density) [1]. The PDO can be created by colliding two, detuned laser pulses in a plasma. Bunches of electrons are trapped in the moving train of beat potential of the two laser pulses and are displaced to accumulate the electrostatic force. These trapped electron bunches then commence harmonics oscillation. Recently, various methods for increasing the conversion efficiency of THz radiation sources have been studied. According to our previous study [1], we found that PDO's conversion efficiency theoretically reaches ~10% when the pulse shape, duration, and detuned frequency are optimized such that the maximum electrostatic force can be built-up from minimal driving ponderomotive force. In this presentation, we present our recent study on increasing the efficiency of PDO generation by adjusting the pulse shape; we can decrease the driving pulse energy that is necessary to obtain a given amount of PDO energy, leading to an increased efficiency of THz emission from PDO. According to recently results, we found that driving pulse energy can be reduced by changing the pulse shape, resulting in and obtained twice as high efficiency (***0.41×10^-3→0.84×10^-3***).

Keywords:

laser-plasma interaction, THz-emission

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P1-pl.014

Simulation study of Raman backward amplification using ionized hydrogen gas

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Abstract:

Raman backward amplification (RBA) in plasma is a method for generating ultrashort, high-energy laser pulses without damage from amplified pulses. However, when a pump pulse passes through a pre-loaded plasma, it is pre-depleted by Raman backscatter or collisional energy loss by thermal noise. In this study, we investigate RBA using hydrogen gas instead of a pre-loaded plasma to reduce these effects. From our simulations using 1D particle-in-cell (PIC) code, we found that a pump pulse loses about 30% of its energy before arriving at the seed pulse. In contrast, when a hydrogen gas is used, the pump pulse can pass through 7 mm of hydrogen gas without any interaction as the pump intensity is lower than the ionizing threshold, unlike in the pre-loaded plasma case. This enables the seed pulse, which has a normalized amplitude a = 0.1, to be amplified to a = 0.46, which is approximately twice the amplitude achieved conventional Raman backward amplification in a pre-loaded plasma. Furthermore, the simulation results show that the frequency of the amplified seed is altered considerably by photon acceleration (or deceleration), leading to positive chirping and compression of the seed pulse itself. Overall, these results suggest that using hydrogen gas instead of a pre-loaded plasma can significantly reduce energy loss Raman backward amplification and enable the generation of high energy laser pulses.

Keywords:

Raman backward amplification

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P1-pl.015

Intense narrowband THz emission from a nanoplasma sheet target

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Abstract:

The development of intense compact terahertz (THz) sources is of great importance in THz research. So far, no narrowband THz sources with the field strength of GV/m-level have been reported from laser-solid interaction (mostly half- or single-cycle THz pulses with only broadband frequency spectrum). Here we present a novel scheme to obtain robust, narrowband, tunable THz emission by using a nano-dimensional overdense plasma sheet target that is irradiated by two counter-propagating detuned laser pulses at an oblique angle. From two- and three-dimensional particle-in-cell (PIC) simulations, we found that beat-frequency radiation that lies in the THz range is generated due to the strong plasma current produced by the beat ponderomotive force in the colliding region. Here we report the generation of THz pulse with field strength as unprecedentedly high as 11.9 of GV/m and spectral width (Δf/f~5.3%) at the central frequency f~30THz, which leads to a regime of an extremely bright THz source of TW/cm2. The conversion efficiency of laser-to-THz power is significantly improved from conventional single-pulse-driven systems. Such an extremely bright narrowband THz source is suitable for various ambitious applications.

Keywords:

Terahertz, PIC Simulation, Nanoplasma

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P1-pl.016

Verification of a New 4-D Fokker-Planck Code Development for Tokamak Plasmas

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Abstract:

The efficient plasma heating and current drive are very important for fusion power generation. To optimize plasma heating, it is necessary to model and simulate the plasma distribution evolution in the presence of various heating sources self-consistently. We are developing a new 4-D Fokker-Planck code (2-D velocity space and 2-D real space) designed for calculating the heating and current drive accurately. However, in this presentation, we just focus on verification of the code in a 2-D velocity space domain at a local position. The new code utilizes a fully non-linear Fokker-Planck Landau implicit collision operator [1] that takes into account multi-species collisions [2], and it calculates the evolution of plasma distribution by several heating source terms, including alpha particle productions, neutral beam injection, and quasi-linear RF heating. To verify the modeling of the explicit source terms, we investigate several points. First, we compared the simulation results of the slowing down distribution of alpha particle sources to analytical estimation [3]. Secondly, we simulated the slowing down of high energetic distributions of ions due to neutral beam injection heating [4]. Thirdly, we compared the efficiency of RF heating from simulation results to the Ehst-Karney model [5]. The results indicate that the explicit modeling of source terms is accurately implemented within the allowable errors. Using these results, we found the energy partitions of each source term to the main ion and electron. We will extend this code to the real space (radial and poloidal) by including the parallel streaming and magnetic drift terms to optimize the heating and current drive.
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Keywords:

Fokker-Planck Code, Heating and Current Drive, Plasma Distribution Function

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P1-pl.017

Estimation of the radial electric field of KSTAR operating modes

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Abstract:

Measurement of the internal magnetic field is crucial for determining the equilibrium, stability, and current density of plasma in toroidal magnetic confinement devices. A Motional Stark Effect diagnostic, based on the principle of the Stark effect, which is the shifting and splitting of spectral lines of atoms due to the Lorentz electric field, was developed to provide a measurement of the internal magnetic field in tokamaks. However, it is difficult to accurately measure the internal magnetic field since the combined electric field of a radial electric field inherently formed inside the plasma and the Lorentz field is measured by MSE. Consequently, a radial electric field component must be obtained to determine the equilibrium and stability of the plasma.

The radial electric field relates to force balance perpendicular to the flux surface, which includes pressure gradient and plasms rotations. Experiments for radial electric field measurement have never been attempted at KSTAR due to the absence of measurement capabilities. In this work, diagnostic data in various operation scenarios (i.e. H-mode, ITB-mode, and FIRE-mode) in KSTAR are used and it is applied to the radial force balance equation to evaluate the radial electric field value. As a result, the structure of the radial electric field in each mode is analyzed, and the sensitivity of MSE diagnostic is examined by applying the radial electric field value.

Keywords:

KSTAR, Radial electric field, Radial force balance equation, Operating scenario

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P1-pl.018

Temperature screening effect of impurities in KSTAR tokamak plasmas: a neoclassical transport analysis

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Abstract:

The accumulation of tungsten in the core region of tokamak plasmas can be a serious issue for plasma operation as it can cause radiative cooling and dilution of the main plasma species. [1] Several studies have been conducted to prevent tungsten accumulation by using temperature screening at the edge of tokamak plasmas under ITER Like Wall (ILW) scenarios. [2] Temperature screening is a phenomenon that occurs when the ion temperature gradient is larger than the density gradient, resulting in a favorable outward particle flux of impurities. [3] According to neoclassical transport theory [4,5], temperature screening is influenced by various factors such as collisional regime, geometry effect and impurity charge strength, which can cause different values of temperature screening in different plasma conditions. Recently, there have been attempts to obtain temperature screening effect that is consistent with numerical results by combining drift-kinetic code NEO [6] with theoretical neoclassical transport equation [7,8]. This work reproduces the prior work described earlier and comprehensively analyzes the impurity characteristics considering the KSTAR environment. For instance, we observe that the coefficient of neoclassical transport varies non-monotonically in high rotational plasmas with impurity Mach number [9] and that the temperature screening effect is influenced by the poloidal asymmetry. We also investigate how the charge strength of impurity can affect the neoclassical transport.

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Keywords:

neoclassical transport, impurity, KSTAR, Tokamak

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P1-pl.019

KAIST Impurity Modelling (KIM) 코드를 위한 Graphical User Interface 개발

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Abstract:

토카막 장치에서 불순물은 필연적인 존재이다. 노심으로부터 인가되는 높은 열속에 의해 장치 내벽 재료인 탄소, 텅스텐 등의 불순물이 존재하며, 토카막 대면 재료를 보호하기 위해 질소, 네온, 크립톤 등의 가스 불순물을 주입하여 플라즈마-대면재 분리현상을 유도하기도 한다. 그러나 이 불순물들이 플라즈마 노심 내에 과도하게 축적되면 높은 방사광 방출에 의해 안정성을 잃고 감금성능이 저하되며, 심할 경우 플라즈마 붕괴현상이 일어나기도 한다. 따라서 플라즈마 내의 불순물을 적절하게 제어하는 것이 안정적인 토카막 운용에 있어 중요한 문제이며, 본 연구팀에서는 토카막 플라즈마 내 불순물의 거동을 해석하기 위하여 연속방정식을 이용한 전산모사 코드를 개발하였다. 개발된 KAIST impurity modelling (KIM) 코드는 유한차분법을 사용해 불순물 밀도의 연속방정식과 운동량 균형 방정식을 이용해 불순물의2차원 분포를 계산해 낸다. 이 과정에서 불순물의 수송계수 프로파일이 필요하며 이를 정확히 예상하는 것이 불순물 수송 예측에 있어 중요한 과제이다. 개발된 코드의 접근성을 향상시켜 사용자가 직관적으로 물리해석을 진행할 수 있도록 본 연구에서는 python 언어를 이용해 KIM 코드의 Graphical user interface (GUI)를 개발하였다. 개발된 GUI는 KSTAR 서버의 MDS+ 모듈을 통해 톰슨산란 진단법, CES 등의 진단계에서 해석에 필요한 진단 데이터를 간단히 저장할 수 있도록 하였고, 피팅 기법을 적용하여 데이터의 신뢰성을 증가시켰다. 또한 이미징 볼로미터로부터 데이터를 불러와 불순물의 방사냉각 계수를 이용해 불순물 분포 변화를 재구성하여 코드로부터 예측된 불순물 분포 변화와 비교할 수 있도록 하여 전산모사의 정확성을 확인할 수 있게 하였다. 또 진단된 불순물 밀도분포 변화로부터 수송계수를 계산하는 알고리즘을 추가하여 개발된 코드를 통해 실제 플라즈마 내에서 불순물이 가진 수송계수를 확인할 수 있게 하였다. 이는 실험조건에 따라 불순물의 거동이 어떻게 변화하는지 해석할 수 있는 기반이 될 것으로 예상한다.

Keywords:

플라즈마, 불순물, 수송코드, GUI

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P1-pl.020

KSTAR실험에 연동되는 Visible Spectrometer system 운영 프로그램 개발

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Abstract:

핵융합 플라즈마 내부에서는 많은 불순물 이온이 핵융합 발전효율을 현저하게 떨어뜨린다. 불순물 이온은 다양한 과정을 통해서 발생되고 있고 발생된 불순물 이온은 플라즈마의 상태를 확인할 수 있으며, 특정 불순물의 존재나 양은 핵융합 장치의 안정성에 영향을 미치는 지표로 모니터링 하고 있다. 따라서 지속적인 고성능 플라즈마를 유지하기 위해, 플라즈마 내 불순물 입자의 분석 및 제어는 핵융합 연구에 있어 중요한 연구분야이다.
KSTAR에서는 이러한 불순물 이온을 분석하고 모니터링하기 위하여 visible spectrometer system(VSS)을 설치하여 운영하고 있으며, KSTAR에서는 플라즈마 발생 실험을 실시간으로 관련된 모든 장비의 통합운전을 EPICS를 중심으로 운영하고있다. 따라서 VSS장비를 KSTAR실험에서 통합운전이 가능하게 하기위해서 운영프로그램을 EPICS기반으로 작동될 수 있도록 개발하였다. 이번 논문에서는 KSTAR에 설치되어 있는 VSS 장비의 운영프로그램 개발에 관한 내용을 설명하고자 한다.

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Keywords:

plasma, visible, fusion, EPICS

Correction algorithm for signal drifts in KSTAR magnetic probes using Bayesian statistics

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Abstract:

As the operation time of a tokamak gets longer, nonlinear effects on the magnetic signal drifts become significant. Unlike linear drifts, they become difficult to be corrected and may cause incorrect equilibrium reconstruction of tokamak plasmas. Hence, the drifts should be corrected to sustain stable tokamak operation. We propose a non-linear drift correction algorithm by using constraints on 1) approximate up-down symmetry of the magnetic signals 2) Maxwell's equations and 3) different drifts among the probes. Uncertainties of the constraints are integrated as a single platform using Bayesian statistics. As the sampling procedure of Bayesian statistics requires heavy computation resources, it is hard to be used for real-time application. Therefore, we develop a recurrent neural network trained to follow the non-linear drift correction algorithm. Calculated LCFS using the corrected signals is compared with the one measured by camera image to validate the suggested method.

Keywords:

Magnetic signal drifts, Bayesian statistics, EFIT, Recurrent neural network

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P1-pl.022

Investigating the Effects of Nitrogen Impurity Puff and Pump Interaction on the Divertor SOL Environment in High Heat Flux Tokamaks with SOLPS-ITER

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Abstract:

In high heat flux environments with reactor tokamaks, maintaining low heat flux and temperature on the target surface is critical for achieving long pulse operations. However, in tokamaks such as ITER or DEMO, the heat flux to the divertor is expected to exceed the material limit of PFC (10MW/m^2), reaching up to 100MW/m^2. To address this challenge, researchers are exploring methods for drastically reducing the heat flux in the divertor region, including divertor detachment, a phenomenon in which plasma is separated from the divertor plate. Using SOLPS-ITER computational simulations, this study investigated the impact of changes in the position and puff rate of the Impurity (nitrogen) puffing slot on the particle balance of the Divertor-SOL environment. The results demonstrate the complex interplay of multiple factors in the Divertor-SOL environment and the potential of computational modeling to provide valuable insights into this challenging area of research.

Keywords:

particle balance, SOLPS, detachment, Impurity Seeding

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P1-pl.023

Research result of KSTAR Thomson Scattering Diagnostic in 2022

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Abstract:

Korea Superconducting Tokamak Advanced Research (KSTAR) Thomson scattering diagnostic had been installed for the first time in 2010 [1]. During 12 years, KSTAR Thomson system has upgraded the most of parts. Because of Thomson scattering is a most sensitive diagnostic system in the KSTAR diagnostic systems every year we carefully upgrade, calibrated and fixed. Passive type diagnostic systems in KSTAR are relatively easy to maintain however active type diagnostics like as Thomson scattering diagnostic are hard to maintain. Furthermore, advanced control of the KSTAR Tokamak requires upgrades as well as maintenance of the KSTAR Thomson system. That's why we've been working on the real-time Thomson system for years. In KSTAR some of diagnostic systems Two Colour Interferometer system (TCI), Electron Cyclotron Emission (ECE) etc., offer the real-time data to the KSTAR plasma control system (PCS) to control the KSTAR plasma. This is because if the real-time Thomson system is completed, information on the electron temperature (Te) and electron density (ne) profile distribution can be provided to the KSTAR PCS at the same time. For this purpose, after about 5 years of research, Te data was successfully transmitted to KSTAR PCS in real time in the 2022 KSTAR experiment. In this study, the 5GS/s digitizer's pulse-type Thomson scattering signal was fitted in real-time using GPUs, and Te was estimated in real-time on GPUs using parameters learned from neural network analysis. Finally Te data was transferred to the KSTAR PCS system using AFM card as real-time. In this presentation we will show the result of KSTAR Thomson system such as Raman calibration result and real-time research result in 2022 KSTAR campaign.

References:

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Keywords:

KSTAR, Thomson scattering, Tokamak, real-time diagnostic

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P1-pl.024

중수소 개스 주입에 의한 KSTAR H-mode 디버터-플라즈마 분리의 SOLPS-ITER 전산모사

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Abstract:

H-mode 플라즈마 조건에서 디버터로 입사하는 입자속 및 열속의 상당한 감소를 의미하는 디버터-플라즈마 분리 운전은 Q=10 달성을 위한 ITER의 운전 시나리오로 고려되고 있다. 이에 경계 플라즈마 수송 코드인 SOLPS-ITER를 이용하여 ITER의 디버터 성능 및 운전을 예측하고 있으나, 현존하는 토카막 장치들의 실험 결과를 재현하는 데에 한계가 있는 실정이다. 따라서 가능한 한 다양한 토카막 장치 및 운전 조건에서 코드-실험 비교 분석을 수행함으로써 코드에 사용되고 있는 물리 모델을 보완하고 검증하는 것이 필요하다. 본 연구에서는 KSTAR H-mode 플라즈마에서 중수소 연료 개스를 주입을 통해 디버터-플라즈마 분리를 달성한 실험에 대해 SOLPS-ITER 전산모사를 수행하여 실험 결과를 재현하고자 한 내용에 대해 발표하고자 한다. 실제 실험 조건에 따라 전산모사 조건을 결정하였으며, 그 결과 상부와 하부 Scrape-Off Layer에서 전자 밀도, 온도 및 입자속, 열속 등 주요 플라즈마 파라미터에 대해 실험 결과와 정량적 일치를 보였다. 또한 실험에서 관찰되었던 내측 디버터와 외측 디버터의 입자속 감소율 차이를 재현하였으며 디버터-플라즈마 분리 진행에 따른 경계 플라즈마 영역 별 방사 파워 변화에 대해 정성적 일치를 얻었다. 이러한 일치를 얻기 위해서는 KSTAR의 플라즈마 대면재 물질인 탄소의 recycling이 필요함을 알아내었다. 일부 물리량들에 대해서는 실험과 전산모사 간에 차이가 존재하였는데, 대표적으로 전산모사에서 실험과 비교하여 낮은 방사 파워의 절대값이 나타났고 실험에서 관찰되었던 중수소 개스 주입 위치에 따른 외측 디버터의 입자속 감소율 차이를 재현하지 못하였다. 이러한 불일치를 해결하기 위해서는 디버터 외부 영역의 탄소 소스 및 플라즈마 드리프트 효과에 대한 분석이 필요할 것으로 예상된다.

Keywords:

디버터-플라즈마 분리, SOLPS-ITER, KSTAR, 중수소 개스 주입, H-mode

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P1-pl.025

Development of all-purpose bolometery system for measurement of radiation power in the tokamak

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Abstract:

Steady-state operation of a tokamak requires a reliable measurement of the radiation properties such as radiation power, spectrum, spatial distribution of emissions, and abnormal peaking of emissions. Bolometry is one of the most basic metrologies that can provide absolute measurement of the radiation power. In this work, we have developed a bolometry system to investigate radiation power from steady-state to plasma disruption, with a focus on the high z impurity radiation from tungsten divertor that has a significant impact on the tokamak plasma. The system consists of a thin foil and a Wheatstone bridge circuitry to measure the change of the foil resistance. Considering that the total radiation power from the plasma will be in the order of a few 100s kW in the steady state and up to 1 GW in the transient case of plasma disruption, the foil is expected to receive radiation of the order of a few W and up to 2 kW. To efficiently absorb the emission light and at the same time withstand high temperatures of over 3600 K, the foil is made of tungsten and coated with carbon nanotubes. The expected dynamic change of the foil resistance ranges from 0.3 to 3 Ω. Using the heat equation for the foil, we calculate the radiation power onto the foil from the measured resistance data.

Keywords:

tokamak, radiation power, all-purpose bolometry

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P1-pl.026

KSTAR H-mode 플라즈마에서 디버터 열속 제어를 위한 아르곤 개스 주입 SOLPS-ITER 전산모델링

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Abstract:

국제열핵융합실험로(ITER) 및 핵융합실증로(DEMO) 에서는 노심으로부터 디버터로 막대한 열속 및 입자속이 유입되며, 이를 제어하는 것은 안정적인 토카막 운전을 위해 필요불가결한 과제이다. 불순물의 주입을 통한 디버터 플라즈마 분리 현상이 열속 제어를 위한 핵심 방법론으로서 연구되고 있다. 본 연구에서는 KSTAR H-mode 플라즈마에서 Ar 제어개스 주입을 통해 성공적인 디버터 플라즈마 분리를 획득한 실험결과를 SOLPS-ITER 전산모사를 통해 정성적으로 재현하고 이를 분석하였다. 해당 실험의 물리적 특성을 모사하기 위해 자기평형 정보를 통해 플라즈마 전류 (0.5 MA) 및 자기장(1.8 T) 조건을 재현하였고, 실험 데이터 및 전산모사를 바탕으로 outer midplane에서의 전자밀도 및 열속감쇄길이를 각각 구한 뒤, 비교를 통해 자기장 수직 방향의 수송계수를 정성적으로 결정하였다. 전산모사 결과, SOL 경계에서 입사하는 열속이 2.7 MW, 주입되는 연료 D_2개스 및 Ar 개스의 주입량이 각각 $\Gamma_{D_2} = 3 \times 10^{21}\ s^{-1}, \Gamma_{Ar} = 2 \times 10^{19}\ s^{-1}$ 일 때, 디버터로 향하는 열속 및 입자속이 각각 0.2 MW/m^2 , 8.66×10^{21} /m^2 수준으로 감소되었으며, 플라즈마 에너지 손실의 상당부분이 아르곤의 선 방출광 및 이온-중성입자 상호작용을 통해 발생한다는 것이 확인되었다. 또한, Ar이 주입되지 않은 순수한 D_2 플라즈마와 비교한 경우, 내측 디버터타겟 근처에 분포하는 방사파워가 Ar 불순물의 주입을 통해 X-point 부근으로 이동하였다. Two-Point Model 분석을 통해 순수한 D_2 플라즈마와 비교하여 Ar 불순물이 주입된 경우, 더 효율적으로 디버터 입자속의 roll-over를 발생시킬 수 있음을 정량적으로 확인하였고, 이를 노심 경계에서의 전자밀도를 변화시킨 계산들을 통해 재검증하였다. 본 연구는 미래 토카막 장치들에서 열속 감쇄를 위해 대표적인 중전하 불순물인 Ar을 사용하는 방법론의 정당성을 추가적으로 확인하고, 디버터-플라즈마 분리 조건 달성에 필요한 조건에 대한 이해를 증진할 것으로 기대된다.

Keywords:

Tokamak, Divertor, Argon Impurity, Divertor Detachment

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P1-pl.027

Design of KSTAR divertor Thomson laser beam dump system

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Abstract:

Thomson scattering(TS) is a standard diagnostic device for measuring an electron temperature and density profiles in the most of Tokamaks. For this reason, TS is one of the most important diagnostic system in KSTAR(Korea Superconducting Tokamak Advanced Reasearch). In KSTAR, a tangential type TS system has been developed few years ago and measure the electron temperature and density profile at the plasma core and edge every KSTAR campaign. Resently to increase the performance of KSTAR plasma a tungsten(W) tile is introduced in a divertor. Because of this we need to measure the electron temperature and density profile near the divertor region using TS. To install the divertor TS system we have to design a laser guiding system, a collection optic system, a laser beam dump system which inside the KSTAR vacuum vessel.

In this poster, we will introduce the laser beam dump design of the divertor TS inside the vacuum vessel. Already installed tangential TS system have a knife edge type beam dump which made of SUS316L[1] inside the KSTAR. Design of the divertor TS beam dump also knife edge type similar to the tangential TS beam dump. And in order to properly measure a divertor TS signal, reducing the stray light is one of the most important issues, and the beam dump plays a key role in this case[2]. Thus, we designed the beam dump considering its installation location and incident angle of the TS laser beam. And the beam dump need to withstand the radiation of plasma and do not damage the inner wall of the Tokamaks.

We will show the design of KSTAR divertor Thomson laser beam dump system and discuss about the test result of divertor Thomson laser beam dump system.

Reference

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[2] E. Yatsuka ea al., “Chevron beam dump for ITER edge Thomson scattering system”, Review of scientific instruments 84, 103503(2013).

Keywords:

KSTAR, divertor, beam dump, Thomson scattering

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P1-pl.028

Study of divertor Thomson collection lens system on KSTAR

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Abstract:

In this study, we report on the Divertor Thomson Collection Lens Systems used in the Korea superconducting advanced research (KSTAR) Thomson scattering (TS) diagnostic system. TS diagnostics is one of the plasma diagnostic methods that analyzes the density and temperature of electrons from light emitted through the interaction between ionized free electrons and a laser beam. KSTAR uses various plasma diagnostic systems, and among them, a tangential TS diagnostic system using a 1064nm laser is currently in operation. Recently, KSTAR is in the process of replacing the tungsten divertor, and we are planning the divertor TS diagnostics to perform plasma diagnosis on the divertor X point area. We investigated an appropriate lens system and conducted optical design to plan a collection lens system that allows TS diagnostics to be performed for the area where the laser and the X point inside the KSTAR tokamak intersect.

Keywords:

KSTAR, collection lens, Divertor, Thomson scattering

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P1-pl.029

Conceptual design of a field reversed configuration experiment using RF antennas for current drive

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Abstract:

Field reversed configurations, in short FRCs, have gained attraction in private companies (TAE, Helion) that may someday produce fusion energy in a compact device. FRCs have been known since the 60s when accidently formed plasmoids that seemed to last several lifetimes in theta pinch devices. These plasmoids ever since have been called FRCs, due to the field reversal magnetic structure of the initial bias field. FRCs hold many promising features. It is especially prominent as a high beta device reaching typically 70–90%. This by itself is a favorable trait that allows the device size to become compact as well as being efficient. FRCs are usually formed in a linear device that eases engineering difficulties. The pressure scaling goes as B^2, so that D-T fusion could be reached with only magnetic fields of 1 Tesla. Surrounded by external fields, FRCs have a natural divertor so that heat removal flows out of each end without any additional magnetic gadgets. It would seem that FRCs are very attractive when it comes to being an efficient compact device. However, the magnetic structure is unlike other confinement devices. Physics is not quite according to MHD. To answer some of these issues, a small scale FRC device is presently being assembled. RF antennas that produce E×B fields create an electron current as a method of current drive.

Keywords:

Field Reversed Configuration

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P1-pl.030

Nonlinear Dynamics of NTM in KSTAR Tokamak Plasma

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Abstract:

Nonlinear dynamics of Neoclassical Tearing Mode (NTM) were analyzed from the observed magnetic perturbation data in KSTAR Plasma. The NTM is sensitive to initial conditions. The NTM has the characteristics of metastable state. They can also be triggers for bifurcation, which suddenly alters the topological structure of the magnetic field by a reconnection. The properties of this nonlinear dynamical system were quantified by correlation dimension, Lyapunov exponent, Hurst exponent, DFA, and complexity. The correlation dimension obtained in each section becomes minimum in the transition section, and the correlation dimension has a value close to 1 in the section of strong 2/1 mode onset. It was observed that the metastable state of NTM plasma is maintained at an approximate value of zero Lyapunov exponent.

Keywords:

KSTAR, NTM, Nonlinear Dynamics, Plasma

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P1-se.001

딥러닝을 활용한 XPS 분석 스펙트럼의 조성비 예측

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Abstract:

XPS는 시료 표면에 X-ray를 조사하여 시료의 조성 원소와 화학 결합 상태를 연구하는데 많이 사용되고 있는 분석 기법이다. 분석 스펙트럼 데이터를 목적에 따라 Survey 데이터와 Narrow 데이터로 구분 할 수 있는데 Narrow 데이터는 시료의 구성 원소와 결합 상태에 따라 크기와 범위 등이 변할 수 있는 반면, Survey 데이터는 시료를 구성하고 있는 원소와 그 비율을 전체적으로 보는게 목적이기 때문에 보통 0eV에서 1200eV까지 범위에서 데이터를 얻게 된다. 딥러닝에 데이터를 활용하기 위해서는 일정한 크기의 데이터가 필요하고 이에 잘 부합하는 Survey 데이터가 좋은 재료가 될 수 있다. 본 연구에서는 임의의 Survey 데이터가 주어졌을 때 C1s, N1s, O1s의 상대 비율을 예측하도록 딥러닝을 통해 학습시켰고 정확도 향상을 위한 여러 모델들을 제시하고 비교 분석 하였다.

Keywords:

XPS, 딥러닝

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P1-se.002

반도체 웨이퍼 결함 검출을 위한 딥러닝 기반 이미지 분류 및 탐지에 관한 연구

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Abstract:

반도체 웨이퍼는 반도체 제조공정에서 중요한 역할을 수행하는 핵심 부품 중 하나이다. 하지만, 제조과정에서 웨이퍼에 결함이 발생할 수 있으며, 이는 제조과정의 불완전함으로 인한 불가피한 문제이다. 따라서 웨이퍼 결함 검출 시스템은 제조산업에서 중요한 역할을 수행하게 된다. 이러한 시스템은 웨이퍼 이미지에서 결함을 빠르고 정확하게 검출할 수 있어야 한다. 이를 위해 이미지 처리 기술을 활용하여 결함을 자동으로 검출하는 알고리즘을 개발할 필요가 있다. 이러한 알고리즘을 적용한 웨이퍼 결함 검출 시스템은 제조과정에서 발생하는 결함을 자동으로 빠르게 감지할 수 있으며, 이는 인력과 비용을 크게 줄일 수 있어서 제품 품질 향상과 생산성 증가에 큰 기여를 할 것으로 기대된다. 본 연구에서는 웨이퍼 상의 결함을 검출하기 위하여 YOLO(You Look Only Once)v5 모델을 사용하였다. YOLOv5는 YOLO버젼 중 하나로, 높은 정확도와 빠른 속도를 동시에 제공하며, GPU를 사용하여 이미지를 빠르게 처리하는 강력한 객체 검출 능력을 가지고 있다. 결함 표본 샘플 수집을 위하여 세가지 각기 다른 사양의 광학 장비(웰컴, 보급형, 전문가용 현미경)를 사용하여 결함 표본을 총 800장씩 촬영하고 표본을 촬영 장비와 결함 종류에 따라 분류하여 dataset를 구성하였으며, YOLOv5를 이용하여 이미지 결함 검출 및 분류 시스템을 구축하였다. 이 시스템을 사용하여 실제 탐지하려는 객체와 탐지한 물체의 차이를 기반으로 결함 검출의 정확도를 비교 분석하였다.

Keywords:

웨이퍼, 딥러닝

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P1-se.003

Large-scale synthesis of $CsPbI_3$ nanocrystals by the microwave-assisted method

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Abstract:

Lead halide perovskites nanocrystals (PNCs) exhibit outstanding optoelectronic and optical properties. Due to excellent photoluminescence quantum yield (PLQY), narrow full width at half maximum (FWHM) and bandgap tunability, many studies have been carried out in various fields, such as solar cells, light-emitting devices, and X-ray scintillators. Among those PNCs, synthesis of $CsPbI_3$ PNCs remains challenging and unsatisfying due to stability. The microwave-assisted method has the advantage of being able to synthesize high-quality perovskite nanocrystals more simply with large scale.
In the study, we have investigated the synthesis of CsPbI3 PNCs by microwave-assisted method. By adjusting the precursor ratio and reaction time, the composition of the CsPbI NCs have been optimized. As a result, we synthesized $CsPbI_3$ with high PLQY (about 90 %) and stability via the microwave-assisted synthesis method which is capable of mass synthesis.

Keywords:

Perovskite nanocrystals, Micro-assisted method, High PLQY

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P1-se.004

A study on the electron transport mechanism by applying thermionic emission theory to n-$Nb_xTi_{1-x}O_2$/p-Si

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Abstract:

TiO_2 has been researched for applications as a useful material in photodiodes, resistive switching memory devices, gas sensors, solar cells and light detector devices. By synthesizing TiO_2 and Nb_2O_5 powders, TiO_2 targets doped with 3 %, 6 % Nb and pure TiO_2 targets were fabricated. n-$Nb_xTi_{1-x}O_2$ thin film was deposited by pulsed laser deposition on a p-Si(100). We verified the rectification characteristics at various temperatures by current-voltage (I-V) measurement. we showed the ideality factor and barrier height by applying thermionic emission theory then compare and analyze the temperature dependence of each device.

Keywords:

Thin film, PN junction, Pulsed laser deposition, I-V characteristics

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P1-se.005

A study on the optical properties of InAs/InAsPSb multi-quantum well

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Abstract:

Recently, $InAs_xP_ySb_{1-x-y}$ has been focused on optical devices in mid-infrared (MIR) for applications such as light emitting diode (LED), photodetector, and so on. Among them, we investigate the $InAs/InAs_{0.35}P_{0.60}Sb_{0.05}$ multi-quantum wells (MQWs) LED structure. For the samples used in this study, three samples were grown with different As compositions of the $InAs_xP_{1-x}$ cladding layer of x=0.63, 0.73, and 0.81, respectively. The results of the photoluminescence (PL) measurement at 20 K show that $InAs_{0.35}P_{0.60}Sb_{0.05}$ MQWs emission energy is a similar position of approximately 0.46 eV for all samples. In addition, through Gaussian fitting, the $InAs_xP_{1-x}$ cladding layer PL transition energy was red-shifted as the As composition increases, which are x of As composition is 0.63, 0.73, and 0.81 show at 0.483 eV, 0.475 eV, and 0.465 eV, respectively, according to the Vegard's law. Moreover, an additional signal was observed for $InAs_{0.81}P_{0.19}$ sample at 0.451 eV which is considered the type-Ⅱ transition.

Keywords:

Mid-infrared LED, photoluminescence

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P1-se.006

Parameterization of dielectric function of SnS as functions of azimuthally

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Abstract:

The tin sulfide (SnS) is an attractive layered compound because of its optical anisotropy and thermoelectric properties. Strong correlations between the position of anisotropy materials and optical properties are indispensable for many technological applications. Finding position-property correlations is vital for the properties of SnS. The dielectric functions of SnS have been reported along the principal axes and the discrete angles on the cleavage plane.
To reconstruct the dielectric function of the arbitrary positions on the cleave plane, we present parameters that allow the dielectric function of SnS to be calculated for spectral range from 0.74 to 5 eV at arbitrary azimuthal angle. The data of SnS were reproduced from a previous report. We use the Tauc-Lorentz model to express of SnS analytically for each azimuthal angle. The ε spectra are successfully parameterized with seven Tauc-Lorentz components and a pole. To obtain ε data for arbitrary energies over the range given above and azimuthal angle, we interpolated the parameterized results using cubic polynomials. Our data allow complex refractive indices to be calculated at any azimuthal angle for device design.

Keywords:

SnS , dielectric function

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P1-se.007

An optical properties study of InAlGaAs/GaAs Quantum Dot by Photoreflectance spectroscopy

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Abstract:

We have investigated the optical properties of the InAlGaAs/GaAs Quantum Dot (QD) structures by photoreflectance (PR) spectroscopy. The QD structure was grown by MBE using a digital alloy method. We compared two different growth temperature samples between 462 and 505, respectively. As the growth temperature increases, there is a noticeable variation in the GaAs PR signal, accompanied by a subtle increment in signals from the QD and barrier regions. These phenomena are speculated to result from changes in In migration due to the elevated growth temperature. At 20 K, we observed that each sample had a GaAs and barrier peak in the PR spectrum. As the increase of growth temperature, the GaAs peak moves to high energy due to size modification.

Keywords:

Quantum Dot, photoreflectance, InAlGaAs

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P1-se.008

An investigation of the optical properties of the InAsP metamorphic layers based on diverse As compositions

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Abstract:

Using InAsP metamorphic layers enables the integration of different lattice constant materials, resulting in high-performance electronic and optoelectronic devices. In this experimental work, InAsP metamorphic layers with various As compositions ranging from 0.63 to 0.92 were investigated from the optical point of view. The photoluminescence (PL) and photoreflectance (PR) measurements were carried out to evaluate the optical properties of the layers. Variations of the PL intensity for different temperatures were explored, and the related characteristic parameters were extracted. On the other hand, The power-dependent PR measurements also demonstrate the importance of considering excitation intensity in accurately characterizing the bandgap energy. These findings provide insights into the optical properties of InAsP with varying compositions of As and can inform the design and optimization of optoelectronic devices based on these materials.

Keywords:

Metamorphic layers, Photoreflectance, Photoluminescence

P1-se.009

Impact of Strain on Energy Levels of InAs/GaAs(1-x)Sbx Quantum Wells

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Abstract:

InAs/GaAs(1-x)Sbx quantum wells are highly versatile and can be customized to achieve specific properties, such as bandgap engineering, wavelength control, and modulation of the electronic structure. This theoretical study investigates the impact of strain on the energy levels of InAs/GaAs(1-x)Sbx quantum wells using an *8×8* k.p model with a finite difference method based on the central difference form. The study considers various compositions of Sb (*x:[0-0.19]*) with 0.5 monolayers of well and 50 nm of barrier widths at room temperature. The k.p parameters for different compositions have been calculated using both x-dependent linear and non-linear equations. The study results demonstrate that increased strain shifts the energy levels towards higher energies, revealing the significant impact of strain on the electronic properties of InAs/GaAs(1-x)Sbx quantum wells. These insights can be applied to optimize the design of optoelectronic devices such as lasers and photodetectors.

Keywords:

Strain, Conduction and valance energy levels, 8-band k.p theory, Finite difference method

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P1-se.010

Study on the interfacial electric field with post-thermal treatment of GaAs/AlGaAs quantum dots

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Abstract:

This research investigates the effects of annealing temperature on the interfacial electric field for low-temperature growth (LTG) GaAs/AlGaAs quantum dots (QD). The LTG GaAs QDs were annealed at a temperature of 650, 700, and 750℃. From the photoluminescence (PL) results, we found that the PL intensity was enhanced as the annealing temperature and the emission wavelength blue-shifted with increasing the annealing temperature. The crystal quality of LTG QDs could be improved with post-thermal annealing. The GaAs QD size could be smaller due to the Ga out-diffusion and Al inter-diffusions during the thermal annealing. In photoreflectance (PR) spectra, the Franz-Keldysh oscillations (FKO) above the GaAs band gap are getting stronger with increasing annealing temperature. Therefore, an increase in the electric field at the interface between GaAs and AlGaAs cap layer affected by QDs was also observed due to decreased defect density and changed QDs quality through the post-thermal annealing treatment.

Keywords:

Droplet epitaxy, Quantum dots, Photoreflectance, interfacial electric field, Post-thermal annealing

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P1-se.011

Investigation of photoluminescence properties for AlGaAsSb/InGaAsSb multi-quantum well LED structures

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Abstract:

Laser diode emitting mid-infrared has wide applications of a variety of military and civilian applications. The quaternary AlGaAsSb/InGaAsSb hetero system is one of the most promising for mid-infrared optical devices. We investigated the photoluminescence (PL) spectroscopy of AlGaAsSb/InGaAsSb multiple quantum well LED structures that were grown by molecular beam epitaxy (MBE). The active region was grown with 5 periods of AlGaAsSb/InGaAsSb layers, but there is different InGaAsSb thickness of 9 nm and 12 nm to control the emission wavelength. From the PL results, the PL peak position of the InGaAsSb thickness of 9 nm had a position of 3112 nm at 15 K, while the InGaAsSb thickness of 12 nm had a position of 3097 nm at the same temperature. The PL peak intensity is decreased with increasing InGaAsSb thickness. We consider that this is caused by compressive strain due to lattice mismatch between InGaAsSb and GaSb substrate.

Keywords:

AlGaAsSb/InGaAsSb, multi-quantum well, photoluminescence

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P1-se.012

Analysis of Interface Quality and Barrier Layer Effects in nbn Photodetector using TRPC and I-V Measurements

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Abstract:

The n-$In_{0.25}Ga_{0.75}As_{0.22}Sb_{0.78}$/$Al_{0.35}Ga_{0.65}Sb_{0.78}$/n-$In_{0.25}Ga_{0.75}As_{0.22}Sb_{0.78}$ nbn photodetector were grown by Molecular Beam Epitaxy(MBE). we measured the photoconductivity of device using time-resolved photocurrent(TRPC). Depending on the light intensity, the time constant decreased and then increased again. This is assumed to be due to the interface quality of the device and the effect of the barrier layer. I-V was measured to understand the electrical characteristics of the device. the I-V results and TRPC results were compared and analyzed.

Keywords:

TRPC, I-V, nbn photodetector

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P1-se.013

MAX phase ceramic synthesis for Zr based MXene

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Abstract:

MXene phases materials are a type of two-dimensional inorganic compound having the general chemical formula of $M_{n+1}X_nT_2$ which have a layered structure of metal carbide or nitride. Among the MXene family, the Zr-based MXene holds great potential for photocatalytic water splitting owing to its beneficial characteristics such as the (I) hydrophilicity, (II) nearly zero Gibbs free energy, (III) large surface-to-volume ratio, and a (IV) bandgap covering the energy levels of hydrogen evolution reaction and Oxyzen evolution reaction. Because these advantages are significantly affected by the constitutional material and the number of MX layers, the MAX phase synthesis is therefore crucial for determining most of the properties of MXene. In this study, we have synthesized Zr-based MAX phase ceramic under different temperature conditions such as 1000 ^{o}C to 1600 ^{o}C range using hot press. The crystal structure and chemical bonding of each samples are systemically analyzed through X-ray diffraction and X-ray photoemission spectroscopies. Based on these results, we intend to produce Zr-based MXene by clearly distinguishing 211 and 312 phase conditions.

Keywords:

MAX phase ceramic, Hot press, Phase transition

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P1-se.014

Enhancement of light-harvesting ability on perovskite films via preheated substrates

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Abstract:

Perovskite solar cells are known as commercially valuable solar technologies because they have high power conversion efficiency with low manufacturing costs. However, it is difficult to obtain reproducible and high-quality results in the solution process-based perovskite film synthesis in an ambient atmosphere because it is difficult to control humidity. This problem can minimize the effect of humidity in the synthesis process through the preheating substrate. The preheated substrate induced rapid crystallization of the perovskite wet film, and as the application timing of the antisolvent was faster, it preferentially grew in the film thickness direction. Optical characteristics were analyzed using photoluminescence (PL), time-resolved PL, and ultraviolet absorption spectroscopy, and structural analysis was performed with X-ray diffraction and scanning electron microscopy. In addition, it was confirmed that the light-harvesting ability of the perovskite solar cell was improved in terms of the substrate preheating temperature.

Keywords:

perovskite, light-harvesting, photovoltaic, MAPbI3

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P1-se.015

Investigation of atomic and electronic properties of Janus γ - Ge_2XY (X,Y=S, Se, Te)

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Abstract:

Various theoretical and experimental studies have been conducted on two-dimensional (2D) materials such as transition metal dichalcogenides (TMDs) and metal monochalcogenides (MMCs) etc., because of their excellent physical and electrical properties. Recently, 2D Janus materials have attracted attention due to their different electrical properties compared to their pristine structural configurations. In this study, we examine the atomic and electronic properties of 2D Janus structures for γ-GeSe, a recently fabricated polymorph of GeSe. For ab initio calculations, we use the Vienna ab initio simulation package (VASP). The generalized gradient approximation (GGA) in the form of the PBE-type parameterization is employed. The ionic pseudopotentials are described via the projector augmented wave, and the cutoff energy for the plane-wave basis is set to 400 eV. Atomic configurations of 2D pristine γ-GeSe and their 2D Janus structures (γ -Ge_2SeS, γ-Ge_2STe and γ-Ge_2SeTe) are considered. We study the electronic properties of γ-Ge_2XY (X,Y=S, Se, Te) and further examine their Rashba- and Zeeman-type spin splittings at the valleys to explain their applications in valleytronic and spintronic devices. We investigate Berry curvatures of γ-Ge_2XY depending on strain and out-of-plane external electric field. In addition, we calculate the bi-layer γ-Ge_2XY structures and their heterostructures. Finally, we focus on the effects of different atomic configurations of γ-Ge_2XY on their piezoelectric properties useful for device applications.

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Keywords:

DFT, Janus structure, Berry curvature, Valleytronics

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P1-se.016

Low Reflectivity 35-nm of Ru-Pt alloys EUV mask Absorber via Co-Sputtering Method

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Abstract:

One of the most promising technologies for extending the fabrication limit of semiconductor devices is extreme ultraviolet lithography (EUVL). Imaging aberrations, also known as mask 3D (M3D) effects, are created by the combination of EUV light at oblique incidence and absorber thickness [1]. The M3D effects can be mitigated and overall image performance can be enhanced by using low refractive index (n) and high extinction coefficient (k) mask absorbers with lower thickness.

Currently, EUVL uses non-reflective Ta-alloy-based mask absorbers, which typically range in thickness from 55 to 70 nm [2]. Through the ideal Mo/Si blank mask macleod reflectivity simulation depending on the Ru-Pt alloy absorber composition ratio, the thickness of the TaBN absorber satisfying less than 2% was 46.6 nm, while the thickness of the Ru-Pt alloy absorber was 34.1 nm.

The ratio of Ru power : Pt power was co-sputtered with 12-inch ultra-high vacuum multi-chamber sputter by changing 100 Watt : 170 Watt, 100 Watt : 290 Watt, and 100 Watt : 400 Watt. The result of XPS depth profile analysis was obtained to Ru:Pt composition ratio 1:2 ($RuPt_2$), 1:3 ($RuPt_3$), and 1:4 ($RuPt_4$). Via x-HRTEM analysis, the actual thickness of the deposited $RuPt_3$ absorber was measured to be 31 nm.

The co-sputtering Ru-Pt alloy absorber on 40 pairs of [Mo/Si] EUVL mask with 65% reflectivity was fabricated depending on composition ratio and thickness of absorber. Finally, the 31 nm thick absorber of the co-sputtering Ru-Pt alloy (RuPt3) was observed to have the lowest reflectivity of 0.9676% via CSM.

Acknowledgement

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References

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[2] Sejpal, Rajiv, and Bruce Smith. "Identifying extreme ultraviolet lithography attenuated phase shifting mask absorber materials using effective media approximation modeling." Journal of Vacuum Science & Technology B 39 (2021)

Keywords:

Extreme ultraviolet lithography (EUVL), EUV mask, absorber, mask 3D effect (M3D), Ru-Pt alloys

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P1-se.017

Fabrication of nanopattern structures using nanosphere lithography

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Abstract:

Nanopattern structures on surface and substrate have attracted considerable interest due to their their various applications in sensors, optoelectronic devices, thin-display devices, microfluidic devices, nanogenerators, plasmonics field emitters, and many others. In general, the ordered and nanostructured surface is an effective way to improve the performance of devices and obtain functional devices incorporating small features. To fabricate the nanopattern structures, many different kinds of pattering techniques have been used including photolithography, electron beam lithography, laser holographic lithography, focused ion beam lithography, nanosphere lithography, nanoimprint lithography, extreme UV lithography, directed self assembly, and so on. These nanopattering approaches have several advatages such as low-cost and simple fabrication process, large patterning area, and high compatability with current fabrication process compared to the conventional photolithography technique.
In this regard, here, the periodic nanopattern structures were fabricated using nanosphere lithography with silica nanosphere as a patterning mask. The fabrication process of periodic nanopattern structures with tunable size and shape is discussed in detail.

Keywords:

Nanopattern, Nanosphere lithography

P1-se.018

Fabrication of plasmonic metasurfaces on optical fibers

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Abstract:

메타표면은 수백 나노미터 두께에서 전자기파를 효율적으로 조절할 수 있어 2011년 이후로 많은 연구가 진행되고 있다. 메타표면은 금속 또는 유전체로 만들어진 나노막대 또는 나노구멍을 일정한 주기와 모양으로 배치하는 나노구조물의 어레이로 통과하는 빛의 세기, 위상, 편광 등을 변화시킨다.
최근에는 메타표면의 기능을 광섬유와 결합하기 위하여 광섬유의 코어에 메타표면을 제작하는 연구가 많이 진행되고 있다. 빛이 진행하는 통로로 이용되는 광섬유의 코어에 빔모양 조절이 가능한 메타표면을 형성하여 광섬유에서 나오는 빛의 편광 또는 세기를 조절하여 여러가지 광섬유의 응용에 사용하려 하고 있다. 특히, 금속으로 제작한 플라즈모닉 메타표면은 강한 빛에 대하여 비선형적인 반응을 보이는 것이 확인되어 이를 이용한 모드 잠금 광섬유 레이저 제작 응용이 발표되었다.
본 연구에서는 케이블 광섬유의 끝단에 메타표면을 제작하기 위하여 케이블 광섬유 구조가 고정되기 위한 척을 제작하고 이빔 리쏘그래피를 진행하여 나노구조물을 리쏘하였다. 이후 Ti/Au 리프트 오프를 통하여 광섬유 위에 직접 플라즈모닉 메타표면을 제작하였다. 광섬유에 집적된 금속 메타표면은 FDTD 시뮬레이션을 통해 확인한 투과빛의 비선형성을 실험적으로 확인하여 1 um대역의 모드 잠금 광섬유 레이저를 제작하는데 사용할 예정이다.

Keywords:

plasmonic metasurfaces, optical fibers, e-beam lithography, mode-locked fiber lasers

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P1-se.019

Enhanced perovskite solar cell performance through A-site defect passivation using amine-based materials

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Abstract:

Perovskite solar cells have attracted great attention as next-generation solar cells due to their advantages such as high power conversion efficiency, low material cost, low-temperature process, and tuneable band gap. However, perovskite films fabricated via the solution process have uncoordinated interfacial defects due to their polycrystalline properties, which cause ion migration and high trap density to occur thereby losing the solar cell efficiency. Therefore, in order to fabricate a high-performing perovskite solar cell, a strategy for efficiently passivating grain boundaries and defects present on the surface is required. In this work, we report significant beneficial effects using a new treatment based on amine-based passivating material (bis(2-aminoethyl) carbonate) to passivate the defect sites of methylammonium lead triiodide($MAPbI_3$) and formamidinium lead triiodide($FAPbI_3$) through coordinate bonding between the nitrogen atoms and undercoordinated lead ions. The perovskite film passivated with bis(2-aminoethyl) carbonate reduced grain boundaries and alleviated defect formation, improving the perovskite solar cells performance efficiency to 22.4% with the regular structures.

Keywords:

Perovskite Solar Cell, Amine-based meterials, Passivation

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P1-se.020

Energy level Modulation of MoS_2 by H_2S at Room Temperature

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Abstract:

Monolayer molybdenum disulfide(MoS_2), one of the transition metal dichalcogenides(TMDC), is a promising candidate for next-generation electronics and optoelectronics application due to its intrinsic direct band gap and remarkable electrical properties. However, because of the ultrathin structure and large surface to volume ratio, monolayer MoS_2 is highly sensitive to extrinsic absorbed molecules such as oxygen(O_2) and a water molecule(H_2O) which is generated from the general environment, device fabrication process, and high-temperature growth. The absorbed molecules induce charge trapping in monolayer MoS_2 field effect transistors(FET) giving rise to Coulomb scattering which degrades the electrical performance of the FET device by impeding charge transport.

Here, we reported that MoS_2-based FET showed increased carrier concentration by H_2S gas treatment which reacts with O_2 and H_2O molecules in MoS_2-surface actively at room temperature. The followed MoS_2-surface treatment process was conducted by using ammonium sulfide solution which produces evaporated H_2S gas at room temperature and normal pressure. We further demonstrated that the hysteresis of MoS_2-based FET is lowered after H_2S treatment and the carrier concentration can be controlled depending on the treatment time. This work proposes a facile surface treatment method for monolayer MoS_2 to obtain intrinsic conductivity of MoS_2 by eliminating absorbed molecules at the surface.

Acknowledgement
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Keywords:

surface treatment, H2S gas, Field effect transistor, Transition metal dichalcogenides

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P1-se.021

Controlling the recombination probability to modulate the conductance plasticity of MoS_2-based synaptic devices on moderate conditions

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Abstract:

Mimicking synaptic behavior where the transmission of the information from pre-neuron to post-neuron and storing this takes place at the same time has been widely studied because of not only its parallel process property but also highly integrated scalability. Molybdenum disulfide (MoS_2) is one of the promising materials for synaptic devices because of its atomically thin nature in which electrical and optical properties can be readily modified by extrinsic factors such as electric field, molecules adsorption, and interface interaction between substrate and MoS_2 [1-8]. However, MoS_2-based devices have persistent photoconductivity (PPC) [9-10], which results in a long-lived photocurrent that persists even after the light source has been turned off, leading to undesirable device behavior. Moreover, the high operating voltage is necessary to emulate synaptic function because MoS_2 is a highly n-doped material. Therefore, the suppression of the PPC is crucial for realizing short-term plasticity in synaptic devices under moderate conditions.
One effective strategy for suppressing PPC in MoS_2 is to introduce recombination centers such as Auger recombination or oxygen-related defects [11-13], which can capture and neutralize trapped charge carriers. Controlling the defect sites in MoS_2 thus can be an effective way to suppress PPC by introducing or eliminating recombination centers. These strategies can be evaluated by measuring the decay of the photocurrent after the light source is turned off.
Here, we generated hydroxylated (-OH functionalized) SiO_2 substrate through oxygen plasma treatment to modulate not only the range of operating voltage but recombination probability. The effects of -OH densities are confirmed through electrical and optical measurements, showing the shift of threshold voltage and Raman peak. We further observed that the STP is successfully implemented on tailored operating voltages through additional recombination centers. This method paves an important pathway toward engineering operating voltage and designing synaptic devices based on 2D materials.

Keywords:

Recombination, Operating voltage, Synaptic devices

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P1-se.022

Active control of multi-order Raman scattering in MoS_2 based on flexible nanotip array

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Abstract:

Transition dichalcogenides materials (TMDs) exhibit dynamic responses to external factors such as mechanical strain, pressure, and charge doping which induce changes in band-gap and vibrational properties. Here, we present a method for actively controlling both variations in the lattice constant and surface enhanced Raman scattering sensitivity in MoS_2 transferred on flexible metal nanotips/PET substrate. With inward and outward bending, we show that peak position and full width at half maximum of first and second order Raman mode are modulated by mechanical strain and charge doping from metal nanotips. Additionally, we control the electromagnetic field confinement depending on the distance between neighboring nanotips along bending direction, enabling high sensitive pressure sensing. Our work presents a strategy in developing tunable devices for energy, sensing, and optoelectronics.

Keywords:

Multi-order Raman scattering, MoS2, tunable devices, flexible nanotip array, flexible nanotip array, mechanical strain

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P1-se.023

Optical gain of Mn^{2+}-doped mixed halide perovskite

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Abstract:

Recently, lead halide perovskite $CsPbX_3$ has been extensively investigated in lasing field owing to their low threshold and extremely high mode gain coefficient at room temperature. Mn^{2+} doped mixed halide perovskite exhibits excellent photophysical properties, such as wider color tuning range and enhanced thermal stability. However, gain analysis based on Mn^{2+} doped mixed halide perovskite has been rarely investigated, and doping materials are promising optical gain medium in laser application. Here, we use variable stripe length method to measure mode gain of Mn^{2+} doped mixed halide perovskite, and temperature dependent photoluminescence and time resolved photoluminescence have also been performed, which will pave the way for further research of doping perovskite in lasing.

Keywords:

Optical mode gain, mixed halide perovskite, Mn2+ emission, time resolved photoluminescence

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P1-se.024

Investigation of optical properties of InGaAs two-color dectetor

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Abstract:

The two-color detector structure detects two wavelength bands at the same time, enabling more accurate measurements in temperature, night vision, and security areas that were previously detected in the IR area. In particular, using the SWIR (Short Wavelength Infrared) region enables detection with various advantages such as scattering, absorption, and ion reaction. We evaluated the optical properties of the material using the photoluminescence (PL) measurement method for two active layers of GaxIn1-xAs with different concentrations. In addition, the optical properties were compared with the reverse structure. As a result of PL at 17K, peaks for the two active layers were observed in the reverse structure, but only the In0.83Ga0.17As peak was observed in the case of the forward structure.

Keywords:

two-color detector, SWIR, InGaAs, photoluminescence

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P1-se.025

전기적으로 능동 제어 가능한 그래핀 메타표면 위상 지연기

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Abstract:

전자기파의 편광은 재료 및 장치의 전자기 응답이 입사하는 전자기파의 편광 상태에 의존하기 때문에 광범위한 분야에서 필수적인 역할을 한다. 편광 상태는 주로 이방성 물질의 복굴절성 또는 카이랄성을 통해 조작되어 왔다. 그러나 THz 영역에서 자연물질은 상대적으로 매우 약한 복굴절성을 갖기 때문에 실용적인 편광자 또는 편광장치를 구성하는데 걸림돌이 되어왔다. 본 연구에서는 등방성을 갖는 인공 구조인 메타표면에 그래핀을 결합하여 능동적으로 비등방성을 조절할 수 있는 능동형 그래핀 메타표면 위상 지연기를 THz 영역에서 구현하였다. 먼저, 등방성 메타표면을 단위 메타 원자 간의 축전용량을 증가시켜 높은 굴절률을 가지는 금속 메타표면을 설계하였다. [1] 여기에 그래핀을 전사하고 패터닝하여 한쪽 방향의 축전용량만을 효율적으로 조절할 수 있게 하였다. 외부 전압을 통한 그래핀의 전도도 조절을 통해 [2], 측정결과 x-편광과 y-편광의 위상차이를 0°에서 90°까지 조절할 수 있음을 확인하였다. 이는 능동형 1/4파장판 구현이 가능함을 의미하며 THz파의 편광상태를 효과적으로 조절할 수 있음을 보인 결과이다. 뿐만 아니라, 유연성 고분자 기판에 제작하여 파장보다 매우 얇은 두께 (11 μm < 21/λ)를 가지므로 다양한 초박형 THz 편광시스템에 적용될 수 있으리라 기대된다.

참고문헌

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Keywords:

Metasurfaces, Graphene, Graphene metasurfaces, Active polarization control, Electrically tunable quarter-wave plate

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P1-se.026

Excitation-power Dependence of Whispering Gallery Polaritons in GaN Microwire at Different Temperatures

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Abstract:

We investigated optical properties of whispering gallery mode polariton condensation formed in a GaN microwire. The degree of exciton-photon coupling can be changed from strong coupling into weak coupling regime with increasing power density. Therefore photonic lasing behavior can be observed at higher threshold than polariton condensation. Excitation power dependence of angle-resolved photoluminescence was studied with varying temperature from 10 to 300 K. To reduce threshold and thermal damage caused by high-power optical excitation, we carried out low temperature experiments.

Keywords:

III-nitride 1D microcavity, Exciton-Polariton

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P1-se.027

광전기화학적 식각법으로 제작한 질화물 반도체 기반 마이크로 튜브의 롤링 방향 제어 및 수율 개선

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Abstract:

질화물 반도체 기반 마이크로 튜브는 가시광 영역을 포함한 넓은 파장대를 가지고 있어 광전자 장치나 센서로 이용하기에 유망한 공진기이다. 또한, 질화물 반도체는 뛰어난 화학적, 기계적 안정성을 가지고 있어 긴 수명의 장치를 만들기에 적합하다. 하지만 식각의 관점에서는 이러한 안정성 때문에 쉽게 식각하기 어려운 제한점이 있다. 본 연구에서는 광전기화학적 식각법을 이용하여 질화물 반도체 기반 마이크로 튜브 구조체를 제작하였으며, 적절한 패턴의 종횡비 설계와 제작을 위한 광학 기기를 최적화하여 마이크로 튜브의 수율을 늘림과 동시에 롤링 방향을 제어할 수 있었다.

Keywords:

마이크로튜브, 광전기화학적 식각법, 3족 질화물 반도체

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P1-se.028

테라헤르츠 광대역 고효율 메타표면 편광자

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Abstract:

전자기파의 정밀한 편광 제어는 차세대 광통신, 디스플레이, 물질의 물성분석 등을 위해 매우 중요하게 요구되어지고 있다. 본 연구에서는 테라헤르츠 (THz) 주파수 대역에서 매우 얇고, 광대역의 고효율 메타표면 편광자를 구현하였다. 제작된 메타표면 편광자는 고분자 Polyimide 기판 위에 금속 마이크로 갭의 와이어 편광자를 얇은 필름 형태로 제작하였다. 전산모사를 통한 최적화를 통해 메타표면 편광자는 1.5 μm의 선폭과 1.5 μm 의 간격을 갖는 100 nm 두께의 금으로 제작되었다. THz 시간 영역 분광법을 통해 0.25THz에서 2.5THz 사이의 광대역에서 50 dB 이상의 소광비를 가지는 광 특성을 확인하였다. 제안된 고효율 메타표면 편광자를 통해, 물질의 정밀한 편광 분석을 통한 비접촉 홀효과 측정, 카이랄성 등의 분석에 활용할 계획이다.

Keywords:

Metamaterial, Terahhertz polarizer, Extinction ratio

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P1-se.029

Ideal interfacial contact using a topologically protected electron injection layer for high-performance WSe_2 photodetector

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Abstract:

The carrier scattering in photodetector employing 2D dichalcogenide as an absorber is a major issue impeding carrier transport. Alternative electrode materials are now essential for achieve high photoresponsivity because the scattering at the interface between semiconductor and electrode is a main cause of the restriction in the carrier transport. Using topological insulator (TI) with the topologically protected Dirac surface state as a TI-electron transport layer is one of the powerful alternatives with its strength on reducing scattering at the interface between semiconductor and electrode. In this study, in order to effectively use the topological surface state (TSS)and smooth interface, well-known TI Bi_2Se_3 with well-ordered interfacial structure was used for an electrode to improve the photoresponsivity in WSe_2. The photodetector using Bi_2Se_3 TI-electron transport layer had a photoresponsivity of up to 65.5 mA/W at 520 nm light, which is 34 times higher than the photodevice using Au electrodes only. Through the analyses using photoresponsivity and time-resolved photoluminescence (TRPL) as a function of thickness, it was clearly confirmed that the presence of TSS affects the photoresponse improvement: i.e., the 2nd TSS present in Bi_2Se_3 over 6 QL coincided with the energy band of the hot carrier contributes to the improvement of carrier separation with high carrier transfer efficiency, thereby affecting photocurrent generation. In addition, it was confirmed through STEM that the vdW gap distance of Bi_2Se_3 at the interface was longer compared with that of Au electrode, which suppressed the hybridization state due to chemical interaction acting as a recombination point in the DFT calculation. The role of TSS which helps efficient separation of carriers and suppresses recombination points at the interface make successfully generate ultra-fast and high-efficiency photocurrents in photonic devices using TI-electron transport layer. The role TSS based on carrier dynamics can suggest important technologies for further applications of next-generation optoelectronic devices.

Keywords:

Topological insulator, Bi2Se3, Photocurrent device, Topological surface state

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P1-se.030

Improvement of Uniformity and Nonlinearity of Self-Rectifying Synaptic Memristor Via Ex-Situ Nitrogen Annealing in the Pt/SiO_x/HfO_xN_y/TiN Stacks

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Abstract:

Resistive random access memory (ReRAM) has been actively studied as one of the next-generation non-volatile memories due to fast switching speed, multi-level states, and high scalability. However, ReRAM has limitations for commercializing very large-scale integrated circuits (VLSI) because of poor reliability, electro-forming step, and the necessity of a selector or access device to reduce sneak currents. Thereby, a novel electronic device having high uniformity, forming-free characteristics, and rectifying function in itself is essentially necessary. In this study, we fabricated a self-rectifying synaptic memristor having Pt top electrode, SiO_x rectifying layer, HfO_xN_y resistive switching layer, and TiN bottom electrode. The self-rectifying function was implemented by inserting a SiO_x layer between Pt top electrode and HfO_x resistive switching layer in the conventional ReRAM cell having Pt/HfO_x/TiN structure. Uniformity and nonlinearity of the self-rectifying synaptic memristor with Pt/SiO_x/HfO_x/TiN stacks were improved via ex-situ nitrogen annealing within the HfO_x resistive switching layer. In addition, a deep neural network with 784 input neurons, 200 hidden neurons, and 10 output neurons was designed and trained by hardware-based backpropagation learning rule using long-term potentiation (LTP) and long-term depression (LTD) characteristics of the proposed self-rectifying synaptic memristor having Pt/SiO_x/HfO_xN_y/TiN stacks. Finally, we evaluated the recognition rate of Modified National Institute of Standards and Technology (MNIST) hand-written digits using the trained deep neural network.

Acknowledgement
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Keywords:

self-rectifying synaptic memristor, ex-situ nitrogen annealing, uniformity, nonlinearity, deep neural network

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P1-se.031

Carbon Bond Cleavage of Spin-On-Carbon Film using Ferric Catalyst for Enhancing Chemical-Mechanical-Planarization Polishing Rate

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Abstract:

To scale down semiconductor devices to a size less than the design rule of 10 nm, lithography using a carbon polymer hard-mask was applied, e.g., spin-on-carbon (SOC) film. Spin coating of the SOC film results in a high surface topography induced by pattern density, chemical–mechanical planarization (CMP) for removing such high surface topography is required. To achieve a relatively high polishing rate of the SOC film surface, the CMP principally involves a carbon–carbon (C-C) bond cleavage on the SOC film surface. A newly designed CMP slurry is capable of inducing C-C bond cleavage by converting the hard surface with strong C-C covalent bonds into a soft surface with metal carbon complexes (i.e., C=Fe=C bonds) during CMP, leading to a dramatic increase in the rate of the SOC film surface transformation with an increase in ferric catalyst concentration. However, this surface transformation on the SOC film surface also induced a noticeable increase in the absorption degree (i.e., hydrophilicity) of the SOC film CMP slurry on the polished SOC film surface during CMP. The polishing rate of the SOC film surface decreased notably when ferric catalyst concentration is higher than a specific point. Therefore, the maximum polishing rate of the SOC film surface (i.e., 272.3 nm/min) could be achieved with a specific ferric catalyst concentration (0.05 wt%), which was around seven times higher than the mechanical-only CMP.

Acknowledgment
This research was supported by BrainKorea21 Four.

Keywords:

Chemical-Mechanical-Planarization, Spin-on-carbon, hard-mask, C-C bond cleavage, ferric catalyst

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P1-se.032

Characterization of Proton Beam-induced Defects of Silicon using Terahertz Time-Domain Spectroscopy

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Abstract:

Understanding the electrical properties of semiconductor devices under proton beam irradiation is necessary to enhance the performance of semiconductor-based proton detectors. In this study, we have demonstrated that THz TDS can be used to evaluate the electrical properties of n-type silicon with defects produced by proton beam irradiation with differing proton energy and irradiation flux density. Depending on the irradiated proton flux and energy, THz transmissions affected by proton-induced defects show a few notable characteristics. The THz transmission gradually increases as increasing proton flux but sharply increases above 1013 protons/cm2, possibly resulting from a change in the type of defects. The increase of THz transmission due to the defect is more sensitive to the position of the Bragg peak when the proton flux is lower than 1014 protons/cm2. We also calculated Bragg peaks by SRIM simulation and carrier density and mobility extracted from Drude model.

Keywords:

THz, proton-beam, semiconductor, silicon

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P1-st.001

SIRS model of Malaria spreading coupled with SI model of Mosquito infection in Tanzania.

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Abstract:

The mathematical and stability analysis of the SIRS model of malaria with the inclusion of infected immigrants are analyzed. The model consists of SIRS compartments for the human population and SI compartments for the mosquito population. Susceptible humans become infected if bitten by infected mosquitoes and then move from the susceptible class to the infected class. Similarly, humans from the infected class go to the recovered class after getting recovery from the disease. In this model, we assume that the recovered human generates temporary immunity and becomes susceptible to disease or infection after losing immunity. A susceptible mosquito becomes infected after biting an infected person and remains infected till death. The reproduction number R_0 of the model is calculated by using the next-generation matrix method. Local asymptotical stabilities of the steady states are discussed using the reproduction number. If the average number of secondary infections caused by an average infected, called the basic reproduction number, is less than one, a disease will die out; otherwise, there will be an epidemic. The global stability of the equilibrium points is proved using the Lyapunov function and LaSalle Invariance Principle. The results of the mathematical analysis of the model are confirmed by the simulation study. It is concluded that increasing the natural death rate of mosquitoes and the recovery rate from infection, and decreasing the infection rate of humans and the infection rate of mosquitoes bring the disease under control.

Keywords:

Basic reproduction number, Susceptible human, Infected human, Recovered human, Susceptible mosquito and Infected mosquito

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P1-st.002

Quantitative Analysis on Co-occurrence Network of Physics Curriculum

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Abstract:

물리학은 기초학문에 해당하는 자연과학으로 수 세기 동안 연구되며 대학에서 이른 시기부터 학문으로써 발전되어 왔다. 현대의 학부제도에서 물리학 계열 학과들은 4대 역학을 기반으로 수리적 사고력을 위한 수학 과목을 이수하는 것으로 전공 교육과정(커리큘럼)을 구성해왔다. 본 연구에서는, 2012학년도부터 2022학년도까지 국내 50여개의 대학의 물리학 계열 학과에서 운영하는 총 1300여개의 과목을 분석한 결과 기술 발전 및 산업 수요에 따라 물리학 계열 학과들의 반도체학, 광공학, 인공지능 물리학, 데이터 물리학, 양자정보 등의 신규 전공과목이 학부 과정 내에 추가되는 것을 확인하였다. 이와 같은 신규 과목 추가 및 최근 동향에 따라 핵심 과목들이 단학기 과목으로 개편되는 변화를 확인할 수 있었다. 이러한 국내 물리학 계열 학과들의 교육과정 변화를 (학교-과목)으로 구성된 시간에 따라 변하는 이분 네트워크(bipartite network)로 표현한 뒤, 투사(projection)를 통해 물리학 계열 학과 간의 과목 유사성 및 기초과목 그리고 전공과목 간의 공동 발생 네트워크(co-occurrence network)를 코어 분해(core decomposition), 연결선 수 분포(degree distribution), 그리고 연결 강도 분포(strength distribution)등의 네트워크 분석을 통하여 정량적 분석을 하는 것이 이 연구의 목표이다.

Keywords:

Curriculum, Physics Curriculum, Co-occurrence Network

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P1-st.003

근접 중심성과 프랙탈 차원으로 비교해 본 대구 도시철도망

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Abstract:

그래프 이론에서 제시한 근접 중심성(closeness centrality)에 의거하여 망의 특성을 분석하여 프랙탈 차원(fractal dimension)과 비교하였다. 근접 중심성이 높은 대구 도시철도의 반월당 역과 근접 중심성이 낮은 대공원역을 특정하여 비교해 보았다. 해당되는 두 역의 위도 경도 좌표를 기점으로 반경 매 500m 마다 반경 3000m 까지 몬테카를로 시뮬레이션을 수행하여 근접중심성과의 상관관계를 분석하였고, 분석된 자료를 토대로 원 안에 역의 밀도를 계산하는 방식으로 반경 매 500m 마다 반경 3000m 까지 프랙탈 차원을 산출하여 차이점을 살펴보았다. 이 근접 중심성 값과 프랙탈 차원 값을 통하여 지리학적 정성적인 특징을 물리학적 접근으로 정량적으로 표현하고자 했다. 대구 도시철도역의 노선도와 공공데이터 대구도시철도 역의 경도, 위도 좌표 서비스 이용하여 구글 지도에 구글 API와 자바스크립트로 프로그래밍하여 결과 값을 추출하여 정리하였다. 또한, 그래프 이론의 근접중심성의 위상학적인 한계를 극복하기 위하여 몬테카를로 시뮬레이션을 수행하여 프랙탈 차원과의 상관관계에 대해서도 연구하였다. 그래프 이론의 근접중심성은 지리적 요소와 거리에 상관없이 네트워크의 단계에 대해서만 값을 도출하는 한계가 있기에 밀도라는 분포적인 요소에 접근하여 프랙탈 차원 값의 변화를 살펴보았다. 따라서 지리적, 사회적, 정치적 값들을 배제하고서 몬테카를로 시뮬레이션이나 프랙탈 차원을 이용한 정량적인 값들은 각 요소의 수치들이 밀고 당기는 물리적 반응으로 인하여 투영됨을 관찰하고 표현가능 하다고 볼 수 있다.

Keywords:

네트워크, 도시철도, 차원, 몬테카를로 시뮬레이션

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P1-st.004

Comparison of Stock Price Predictions by the Geometric Brownian Motion and the Autoregressive Integrated Moving Average Models

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Abstract:

In the financial engineering, it is important to predict the evolution of stock prices at high accuracy. For this purpose, we use two different models in the paper; one is the geometric Brownian motion (GBM) and the other is the autoregressive integrated moving average (ARIMA). In the GBM model, it is assumed that the stock prices follow a stochastic process described by two constants, drift and volatility. The drift term is meant to describe the macro trend in the evolution of a stock price and the volatility term the random behavior of stock price. On the other side, the ARIMA model, which is a very well-established model in the time series analysis, is used to model the autocorrelation and the trend of time series to predict the future values. In this model, three parameters are calculated to optimize the model and perform the best predictions. Each parameter respectively represent the order of the autoregressive (AR) model, the order of the integrated (I) component and the order of the moving average (MA) component. We apply these two models to real stock data and try to predict the future values of them. We then compare the performances of these two models. According to the results of our simulation, it has been shown that the accuracy of the ARIMA model is a bit better than that of the GBM model, while the GBM model outperforms the ARIMA model with respect to the time cost.

Keywords:

GBM, ARIMA, stock price

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P1-st.005

Critical behaviors of cascading dynamics on multiplex two-dimensional lattices

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Abstract:

We study the critical phenomena of viable clusters in multiplex two-dimensional lattices using numerical simulations. We identify viable sites on multiplex lattices using two cascading algorithms: the cascade of activations (CA) and deactivations (CD). We found that the giant viable clusters identified by CA and CD processes exhibit different critical behaviors. Specifically, the critical phenomena of CA processes are consistent with the ordinary bond percolation on a single layer but CD processes exhibit the critical behaviors consistent with mutual percolation on multiplex lattices. In addition, we computed the susceptibility of cascading dynamics by using the concept of ghost field. Our results suggest that the CA and CD processes generate viable clusters in different ways.

Keywords:

Percolation, Multiplex network, Critical phenomena

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P1-st.006

The classical discrete time-crystals and thermal effects in the two-dimensional kinetic Ising model

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Abstract:

시간 결정 (Time-crystals) 개념이 물리학에서 등장한 이후, 다양한 이론 및 실험에서 시간 결정에 대한 연구가 이루어지고 있다. 그중에서 2차원 이징 모델에서 고전 이산 시간 결정 (Classical discrete time-crystal, CDTC)을 구현한 선행 연구 [1]는 영도에서 DTC-PM 상전이 다이어그램과 이 계가 이징 유니버설 클래스라는 것을 언급했다. 우리는 이 선행 연구와 동일하게, kinetic monte-carlo simulation과 무질서로 이끄는 무작위 스핀 뒤집기를 한 주기로하는 동적 과정 도입하였고, 영도에서 2차원 이징 모형의 임계온도까지 수행하여 상전이의 범위를 유한한 온도로 확장하고 무질서로 이끄는 주기와 무작위로 스핀을 뒤집는 확률, 그리고 온도를 축으로 가지는 phase diagram을 그려보았다. 또한, 이 고전 이산 시간-결정 계가 무질서에서 비평형 정상상태로 접근하는 동안, 주기의 증가에 따라, 상관 거리가 가지는 power-law exponent가 임계 동적 지수 (임계 점에서)와 코스닝 동적 지수(DTC내에서)가 2차원 이징 스핀 뒤집기 모델과 동일함을 확인하였고. DTC내의 영역에서 잉여 흠 밀도를 측정하여 2차원 이징 모형의 코스닝 동적 지수와는 다르게, 파라미터들에 의존하는 동적 지수를 발견하였다.

Since the concept of time-crystals emerged in physics, studies on time-crystals have been conducted in various theories works, and experiments. A previous study implementing classical discrete time-crystal (CDTC) in a two-dimensional Ising model [1] showed the DTC-PM phase transition diagram and noted this system at zero temp exhibits the Ising Universal class. In the same way as this previous work, we introduce a dynamic process with kinetic Monte-Carlo simulation and random spin flip leading to disorder as one cycle and extend to the range of phase transition to the critical temperature of the two-dimensional Ising model and draw a phase diagram with the period leading to disorder, the probability of random invert the spin, and the temperature as the axis. Furthermore, it is confirmed that the power-law exponent of the correlation length is equal to the critical dynamic exponent (at the critical point) and the coarsening dynamic exponent (in the DTC) as the cycle increases, while this classical discrete time-crystals system approaches from disorder to non-equilibrium steady state. The excess defect density was measured in the DTC and unlike the coarsening dynamic exponent of the two-dimensional Ising model, a dynamic exponent that depends on parameters was found.

[1] F. M. Gambetta, F. Carollo, A. Lazarides, I. Lesanovsky, and J. P. Garrahan, Classical stochastic discrete time crystals, Phys. Rev. E 100, 060105 (2019).

Keywords:

time-crystal, non-equilibrium, DTC, Ising model, phase transition

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P1-st.007

Layering structure and rheological properties at solid-liquid interfaces

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Abstract:

When liquid polymers are rest on the solid surface with attractive interactions, the ordered structure or the layered structure is formed immediately. Such ordered structure can be seen when only using decreased tip-diameter. Using bulk-scale tip, the fluid particles can be treated as continuum fluid. So it can be interpreted using Navier-Stokes equation. As tip size decreasing into micro- or nano-scale, the relative size between tip and the fluid particle become similar. Then using nano-sized tip, it is able to observe the layered structure within 5nm distance from the surface because as tip size decreased, the resolution of acquiring physical data increases. Also such layered structure is composed with metastable solid. Hence at the nano-scale, the force curves of solid-liquid interfaces cannot be solely explained by liquid-like behavior but the hard-sphere model that describes the configuration of fluid particles.Here we used Atomic Force Microscope(AFM) based rheometer with multiscale tip, we observed the bulk-, micro-, nano-scale spectrum of polymer melts. The bulk- and micro-scale can be explained by the solely liquid-like behavior. As we scale down to nano-scale tip, however, we must include the metastable concept that we confirmed that the layered structure is metastable solid state. Also it show the slow dynamics since time evolves it transforms into liquid-like state. Also, using hard-sphere model, under the attractive force, the layered structure has entropic configuration.

Keywords:

Rheology, Atomic Force Microscopy, Polymers

P1-st.008

Commuter Meta-Population Model(CMPM) using telecommunication data in South Korea

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Abstract:

Commuter Meta-Population Model(CMPM) is mathematical model used to describe the spread of infectious diseases by commuting. While classical metapopulation model consider total population in city only, CMPM consider smaller subpopulations that are connected by commuting routine. Subpopulation that commutes to some city in daytime must return to their original city in nighttime. In this study, we used CMPM in case of South Korea using telecommunication data and compared with classical metapopulation model. Since large proportion of population commute long distance regularly, classical metapopulation model become highly synchronized while CMPM does not. We found that CMPM shows non-homogeneous result for different basic reproduction numbers and commuting ratios. We demonstrate that modern human infectious disease is well described by CMPM.

Keywords:

metapopulation model, commuter model, epidemic model, SIR model

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P1-st.009

THE EFFECT OF RARE REGIONS ON THE EXPLOSIVE SYNCHRONIZATION IN MODULAR SCALE FREE NETWORKS.

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Abstract:

The explosive synchronization in scale free networks is an interesting phenomenon that has attracted many researchers in the recent years. Under the condition that the natural frequency of each node in the scale free networks is equal to their corresponding network degree, the order parameter experiences a sharp transition instead of a normal 2nd order transition. This behavior was explained based on the existence of a hub in the scale free networks. Recent research has focused on the variation of the hysteresis area versus different network characters, such as the degree correlation and the network robustness. In this paper, we present the effect of modularity on the explosive synchronization in scale free networks. We especially focus on the networks that has weak interaction between their module, i.e., networks that show rare region effects.

Keywords:

Modular scale free networks, explosive synchronization

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P1-st.010

Dynamical phase transitions associated with the entropy production rate of single-file active Ornstein-Uhlenbeck particles

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Abstract:

Active work quantifies the amount of energy converted into the actual motion of active particles. In the long-time limit, the time-averaged active work quantifies how much energy is dissipated by active particles into the surrounding environment, *i.e.*, it is a measure of the entropy production rate of active particles. Thus, by calculating the large deviation function (LDF) of the time-averaged active work in the long-time limit, we can gain information about (i) the likelihood of an atypical energy dissipation rate and (ii) what the system looks like when such atypical events occur. A previous study on two-dimensional active Brownian particles showed that the LDF exhibits singularities associated with transitions from the collectively moving state via the phase-separated state to the phase-separated arrest state, in the order of decreasing entropy production rate. In our study, we focus on the case of one-dimensional active Ornstein-Uhlenbeck particles, which corresponds to the active particles moving in a single file along a narrow one-dimensional channel. In contrast to the previous study, we find in this case that the collective motion can be induced by decreasing the entropy production rate, and that further decrease of the entropy production rate induces another transition to a crystal state, where active particles effectively repel each other. Our results are based on a recently proposed a machine learning method that utilizes the stochastic optimal control theory.

Keywords:

Dynamical phase transitions, Large deviation, Active matter

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P1-st.011

The most frustrated Ising model on a square lattice

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Abstract:

The Ising model with nearest-neighbor (J_1) and next-nearest-neighbor (J_2) interactions is investigated on a square lattice.
For $J_1 = -2$ and $J_2 = -1$, this model becomes most frustrated because ground states are infinitely degenerate.
We obtain the density of states by using the Wang-Landau Monte Carlo method and then calculate the specific heat.
We find two separate peaks; a sharp peak related with the critical behvior and a round peak as the Schottky anomaly.
As system size increases, the temperature of the sharp peak decreases logarithmically towards zero with a first-order phase transition, and the height increases logarithmically, supporting the assumption that the spatial correlation length diverges exponentially at zero temperature.
Calculation of the partition function zeros clarifies that this model shows a first-order phase transition and the critical temperature is zero.

Keywords:

Ising model, next-nearest-neighbor interaction, Schottky anomaly, partition function zeros

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P1-st.013

Real-Time Voice Conversion Neural Network

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Abstract:

인공신경망을 활용해 그림이나 사진의 스타일을 바꾸는 연구가 발표되고 있고, 이러한 연구의 원리를 활용해 음성에도 적용하여 사람의 목소리를 다른 사람의 목소리로 변환하는 인공신경망 연구 또한 지속적으로 발표되고 있다. 기존의 음성 변환 연구에서는 효과적으로 목표 음성으로의 변환이 가능하지만, 대량의 목표 음성이 필요하고, 실시간 구동이 어려운 문제가 있다. 본 연구에서는 소량의 목표 음성과 소스 음성의 통계학적 분포를 활용해 실시간으로 구동하는 소스 음성을 목표 음성으로 변환하는 연구 결과를 소개한다.

Keywords:

deep learing, voice conversion

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P1-st.014

Oscillating synchronization order parameter of the Kuramoto model with inertia

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Abstract:

Coupled oscillators with inertia are usually observed in our surroundings such as a power-grid system with alternating current, whose governing equation is commonly described by the second-order Kuramoto model. The composition of power demand and generation represented as the distribution of the natural frequency can affect the synchronization stability of the power-grid system. Therefore, it is important to understand the effect of the distribution of the natural frequency on the behavior of the oscillators. It has been well known that hysteresis in the second-order Kuramoto model manifests itself with accompanying the discontinuous transition for the uniform and Lorentzian distributions of the natural frequency. In addition, the previous research has discovered that the secondary synchronization groups of the whirling oscillators at large inertia emerge irregularly when the coupling strength K increases. In this study, we investigate the region of K where the secondary group appears, with the natural frequency distributed from the normal distribution (having the fatter tails than the previous Lorentzian one), together with considering the initial condition dependency. We find that the standard deviation of the synchronization order parameter r plays an important role in detecting the emergence of the secondary groups. The large deviation implies the existence of the giant cluster of the synchronization and the small but nonnegligible clusters. With the aid of an appropriate visualization, we confirm the existence of the globally synchronized and desynchronized oscillators (which are the ordinary classification) and secondary synchronized groups with different angular velocity. At low K and high K with a small deviation of r, either the desynchronized or global synchronized state is observed without the secondary group. At an intermediate K with a large deviation of r, the secondary groups can be detected. We expect that the multiple formations of synchronization groups will contribute to understanding the problems that arise in many applications dealing with synchronization phenomena in real world.

Keywords:

Synchronization, Kuramoto model

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P1-st.015

Neutron-radiography study of hydrogel swelling

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Abstract:

Water-loving polymer network, hydrogel, can be swollen by the imbibition of liquid water. The deformation of the crosslinked network by swelling affect how solvent molecules diffuse into the network, resulting in a complicated coupling between structure and material transport. One of the key parameters to understand the swelling dynamics is spatiotemporally varying solvent distribution, which relates the polymer displacement and stress within the network. Employing the neutron radiography giving notable contrast between hydrogenated polymer and heavy water, *i.e.*, deuterium oxide, we map the spatial distribution of water-polymer fraction through the entire swelling process of a spherical hydrogel gel immersed in the heavy water. The fraction map shows a rather clear boundary between the swollen and unswollen regions and the water fraction gradient in the swollen shell. We also investigate the effects of the hydrogel size and the salt concentration on the diffusion process. The authors acknowledge the support from the Korean National Research Foundation through NRF-2020R1A4A1019140.

Keywords:

Hydrogel, Neutron radiography, Swollen polymer network, Water diffusion

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P1-st.016

Direct observation of water uptake by hygroscopic liquid droplets with neutron radiography

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Abstract:

When a non-aqueous hygroscopic liquid is exposed to the ambient air, it can become a binary liquid as evaporation and condensation co-occur. Notably, the binary liquid droplet placed on a substrate may exhibit sophisticated material transport phenomena because of spatiotemporally varying composition. For instance, solutal or thermal Marangoni stress caused by the surface tension gradient can result in internal flow. Furthermore, a density gradient can exist, leading to a convective flow. These complex phenomena have been of great interest in fundamental science and various technological applications such as coating and printing. The key to understanding these problems is the *in situ* spatiotemporal characterization of the material composition, which optical microscopy cannot provide. By utilizing neutron radiography that can discriminate hydrogen and its isotope, deuterium, we directly observe how a deuterated glycerol droplet absorbs hydrogenated water vapor in the ambient air.

Keywords:

binary fluids, hygroscopic fluids, evaporation, convection, microfluidics

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P1-st.017

How much we can get information about unknown force from observed trajectories?

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Abstract:

The Langevin equation is one of the key tools for studying systems whose motions are stochastically determined by random fluctuations. This equation consists of deterministic forces and random noises so if one know all about forces and noises then one can fully understand the system. However, in many cases, what one can know is limited to the trajectory of the system and a part of the force field. Therefore it becomes important issue that how much one can get information about unknown force from observed trajectories. To address this issue, we introduce the concept of stochastic capacity, which measures the maximum mutual information between the trajectory of the system and the force exerted on the system. We show that stochastic capacity follows the integral and detailed fluctuation theorem, providing a theoretical framework for understanding the information content of trajectories in stochastic systems. To illustrate our findings, we present an example with a simple 2D toy model. Our research offers deeper insights into the behavior of stochastic systems, particularly in situations where we have limited access to force fields. By shedding light on the relationship between trajectories and forces, we hope to contribute to a better understanding of Langevin dynamics and stochastic thermodynamics.

Keywords:

Langevin dynamics, communication theory, channel capacity, fluctuation theorem

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P1-st.018

Global Influence of Over-the-Top Media on Cultural Diffusion: A Study of Netflix Rankings

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Abstract:

The Over-the-Top (OTT) media industry has experienced remarkable growth in recent years, with Netflix emerging as a significant player and offering services in over 190 countries worldwide. As OTT's influence increases, the data on viewership has the potential to reflect the unique cultural characteristics of each country. This study aims to investigate these country-specific characteristics by analyzing the data of two years of Netflix rankings from July 2020 to September 2022. We developed a scoring system to convert the rankings of all Netflix content and calculate "cultural distances" between countries based on the similarities of their scores. We grouped countries based on these cultural distances and found that countries within the same group exhibit either linguistic similarities or geographical proximity. To examine the temporal dynamics of cultural community groups, we conducted separate analyses of the content served each month and calculated the cultural distance between countries every month. We found that cultural groups exhibited relatively stable structures over time, with only minor shifts between adjacent cultural groups. To analyze the cultural transmission patterns between countries, we examined time-lagged correlations of trending content among countries. We also performed a similar analysis with Korean content and found that the transmission patterns of content in East and Southeast Asia are mainly understood by the popularity of K-dramas. Overall, this study sheds light on how the viewership data of OTT platforms can reveal the cultural characteristics of countries and be used to measure the cultural diffusion of OTT content on a global scale.

Keywords:

Over-the-Top media, cultural diffusion, correlations of Netflix rankings

2023 KPS Spring Meeting
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P1-st.019

Monte Carlo simulation of Active Matter with thermodynamic consistency

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Abstract:

We present new thermodynamically consistent Monte Carlo (MC) algorithms describing active particles. In order to calculate energy consumption of dissipative structures forming in active matter system, thermodynamically consistent modeling is necessary. However, a Monte Carlo method that is thermodynamically consistent in discrete system and shows proper dynamics in continuum limit is currently lacking. To address this issue, we propose new algorithms in discrete 2D system. We modify the conventional transition probability in MC by adding virtual work from self-propulsion of an active particle to the potential difference and complement the probability with a self-propulsion-dependent scaling coefficient. We argue that the scaling is necessary to give meaning of velocity to the self-propulsion. We then demonstrate that our new algorithms lead to an appropriate continuous-space-and- time limit, preserving genuine phenomena of active matter, such as motility-induced phase separation, the ratchet effect, and showing a well-defined mechanical pressure.

Keywords:

Active matter, Thermodynamically consistent model, Monte Carlo algorithm

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P1-st.020

Thermodynamic Uncertainty Relation in the interlinked cascade of RabGTPases

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Abstract:

We model the well-known interlinked cascade of Rab GTPases [1, 2] found in eukaryotic cells by using a network of Markov states to investigate the Thermodynamic Uncertainty Relation (TUR) [3] for the non-equilibrium system [4]. First, we prove numerically the TUR in both single Rab species switching model and the double Rab species interlinked model. Our results show that when two Rab GTPase proteins are interlinked at far from equilibrium, the thermodynamic cost is significantly enhanced compared to the single species switching model. This implies that at far from equilibrium, the proteins try to optimize the thermodynamic cost and hence the precision of the performance of their biomolecular processes by forming interlinks in the cascade. Again, our results show that the interlinked cascade (or oscillator) can achieve a range of tunable rate constants (or frequencies) which suggests a means of maintaining its robustness. Lastly, we highlight a close relation between thermodynamic cost-precision, triangular motifs and disease dynamics.

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[4] Chanu, A. L., & Singh, R. K. (2022). *arXiv preprint* arXiv:2204.01627v2

Keywords:

nonequilibrium, Rab GTPases, interlinked cascade, thermodynamic uncertainty relation

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P1-st.021

Translocation of hydrophobic polyelectrolytes

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Abstract:

We study translocation of polyelectrolyte chains (PEs) driven by an electric field through a pore by means of molecular dynamics simulations of a coarse grained HP model mimicking high salt conditions. Charged monomers are considered as polar (P) neutral monomers as hydrophobic (H). The PE sequence is taken regular with the charges equally spaced along the hydrophobic backbone. Hydrophobic PEs are in globular form and they should unfold in order to translocate through the narrow channel under the electric field. We investigate the influence of solvent quality on the translocation behavior of the PE chains. Although translocation of PEs is largely driven by electric field, success is not guaranteed in poor solvents. The translocation process can be described in three steps: (1) capture, (2) waiting at gate, which involves unfolding of the initial globule on the cis side and nucleation of a globule on the trans side (3) driven. Starting from the captured conformations, we obtained distributions of waiting times and drift times at various solvent conditions. The shortest translocation time is observed for slightly poor solvent. After the shallow minimum the translocation time increases with hydrophobicity. The results are compared with the solution of a simplified Fokker Planck equation for the position of the head monomer.

Keywords:

Translocation, polyelectrolyte, Fokker Planck equation

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P1-st.022

Understanding the filoviral entry efficiency by an epidemic spreading model

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Abstract:

Filovirus species such as Ebola and Marburg is highly dangerous for human due to its high fatality rate, which potentially leads to large-scale outbreaks. The interaction between the filovirus glycoprotein and the Neimann-Pick C1 (NPC1) protein in host cell plays a critical role in viral entry that is virus' invasion into host cell. The interaction can be affected by the single nucleotide polymorphisms (SNPs) in NPC1 from person to person. The previous study has attempted to quantitatively compare viral entry efficiency for various SNPs using a compartmental model. In this study to uncover the microscopic rule for the spreading phenomena, we construct an agent-based model. Based on both the previous study and experiment , we introduce the susceptible-exposed infectious-dead model in a triangular lattice to simulate the viral entry for various SNP mutations. The entry efficiency is evaluated by the size of plaques, namely the dead cell cluster in terms of epidemic spreading model. To determine the hyperparameter of this model, we use the empirical data of plaque radius during five days. With validating our framework, we expect to extend it to the more general structure such as scale-free networks.

Keywords:

filovirus, entry efficiency, epidemic model

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P1-st.023

인공신경망을 이용한 실시간 음악감지

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Abstract:

여러 음원이 섞여 있는 오디오 파일에서 음악을 검출하는 음악감지에 대한 연구가 꾸준히 진행되고 있다. CNN과 LSTM과 같은 강력한 인공신경망의 발표 이후, 이를 적용한 분류기를 통해 log-mel spectrogram 이나, mfcc등으로 추출한 특징에서 음악이 가진 특징을 학습하는 것이 주류가 되었다. 본 연구에서는 인공신경망 모델을 사용한 음악 감지 알고리즘의 실시간 구현과 이를 위한 경량화 결과를 소개한다.

Keywords:

neural network, music detection

2023 KPS Spring Meeting
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P1-st.024

Implementation of Reverse-Time SDE Sovler on FPGA

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Abstract:

확산 모델은 입자들이 공간으로 퍼져나가는 확산 현상을 통계적으로 해석한 브라운 운동으로부터 위치의 기댓값과 분산을 다차원으로 확장하여 데이터의 차원에 대응시키고, 그 데이터에 대해 확률미분방정식을 통해 확산을 모사한 뒤 그 역과정을 추론하도록 만들어진 모델이다. 확산 모델에서, 확산 과정에서는 입력 데이터에 가상의 이산 시간에 따라 분산이 커지는 가우시안 잡음이 섞이고, 역과정은 더 긴 이산시간의 상태에서 더 짧은 이산시간의 상태로 역추정을 할 때 가능도를 최대화하는 과정에서 유도되는 스코어를 통해 역과정을 모사하고, 인공신경망을 데이터 차원에서의 스코어를 구하도록 학습한다. 본 연구에서는 확산과 같이 확률 미분방정식으로 주어진 마코프 과정의 역방향 추론을 FPGA상에서 구현하였다. 특히 확산 모델의 스코어를 이용하여 노이즈가 더해진 입력에 대해 그 역방향 추론을 통해 원래 신호로 복원하는 과정을 해결하도록 하였다.

Keywords:

FPGA, Reverse-Time SDE, Diffusion Model

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P1-st.025

The Ising Model in an External Magnetic Field on a Triangular Lattice with Fifteen Spins on a Side: Exact Density of States and Partition Function Zeros

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Abstract:

The triangular-lattice Ising model in an external magnetic field is one of the most outstanding unsolved problems. By using the method of exact enumeration, the exact integer values for the density of states of the Ising model in an external magnetic field on a triangular lattice with L spins on a side up to L=15 are obtained as a function of microscopic energy and microscopic magnetization for the first time. Due to the exact density of states, the exact distributions of the grand-partition function zeros in the complex magnetic-field plane of the Ising model in an external magnetic field on a triangular lattice are evaluated for a given value of temperature.

Keywords:

Triangular-lattice Ising model, External magnetic field

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P1-st.026

The co-movement dynamics of social midea activity-financial market

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Abstract:

The evolution of the relationship between social media activity and financial market in terms of network coincides with an important factors in financial market risk such as instability of economic system. It is unclear how coupling between social media and stock market network disconnects during financial crisis to directly support to systemic risk induced by connectedness in financial market. In this paper, we analyze the dynamics of social media activity(SMA)- financial market (FM) relationship using the never finance data and stock market prices in a sample of 320 firms. We find that the market factors effects on coupling between SMA and FA specialized to certain industry. In particular, SMA-FA relationship was associated with market risk and COVID-19 pandemic as a financial crisis. To test the evolution of SMA-FA coupling in stock market, we estimated the degree of connectivity in the social media activity support the return fluctuations in an individual firm. Leveraging the return time series and social media activity from 480 firms with whole period sample, we applied Pearson correlation between the return data of firms during the period with COVID-19 pandemic. While the average connectivity estimated from both the equity market and social media activity reflects the risk behavior in financial market during COVID-19 period, SMA-FM coupling measured during a financial crisis period shows a lower value.

Keywords:

social media activity, financial market, covid-19

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P2-ap.101

Ferroelectric Hysteresis loop obatined by the SHG under Gate-Voltage sweep

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Abstract:

Optical second-harmonic generation (SHG) is a unique technique which is capable of probing the inversion symmetry breaking, and it has been widely used to investigate ferroelectric and multiferroic materials. In this work, we show the optical SHG signal obtained with a variation of the external electric field. We will show the ferroelectric hysteresis property and aging effect for the CuInP2S6 flakes with SHG signal under the gate voltage. We will discuss the meaning of SHG method for the ferroelctric hysteresis loop and physical interpretation of experimental results.

Keywords:

Ferroelectricity, Hysteresis, CIPS(CuInP2S6), SHG(Second Harmonic Generation), Aging Effect

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P2-ap.102

Analysis of thermal and electromagnetic shielding properties based on copper/diamond composites

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Abstract:

Copper coated diamond particles have shown great promise for improving the thermal and mechanical properties in semiconductor packaging materials. In addition to these advantages, Cu-coated diamond particles may also have the potential to provide the function of electromagnetic shielding effectiveness due to their electrical conductive properties. These versatile functions of copper/diamond composites can be beneficial to reduce the cost of packaging process and increase the performance of recent advanced semiconductor chips.
However, the diamond surface has low wettability with metal layers, which could result in poor coating quality in the interfacial layers between metal and diamond. This issue could cause to decrease thermal conductance of the interfacial layer in composite particle, so that effective thermal conductivity of coating layers could be decreased. Therefore, in order to achieve optimized thermal and electromagnetic shielding properties of copper/diamond composite particles, many elements of composite materials should be studied and analyzed in advance.
In this study, we investigated thermal and electromagnetic shielding properties of copper/diamond composite particles in factors of sizes and volume fractions of diamond particle, and thickness of buffer layer with various materials using FDTD simulation. Overall, the simulation provides valuable analytic insights into the fundamental properties of copper/diamond particles and their potential applications in thermal management and electromagnetic shielding. It is suggested by these results that enhanced thermal conductivity and great potential for EM shielding are exhibited by copper/diamond particles. Further experimental studies are necessary to validate these simulation results and to explore the potential of copper/diamond particles for various industrial applications.

Keywords:

EMI, TIM, Composite materials

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P2-ap.103

Green Synthesis of SiO_x/C Anode Materials for Lithium-Ion Batteries Using Sustainable Sub-Micron NaCl Crystals and Rice Husk Precursors

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Abstract:

In the past, research on replacing graphite, which is used as the anode material for lithium-ion batteries, has primarily focused on solving the low energy density problem. However, due to emerging environmental concerns, it is necessary to conduct research in a direction that minimizes environmental hazards during the material development process, rather than solely focusing on performance. In this study, we introduce SiO_x/C produced through the NaCl salt-assisted synthesis method, which can address environmental destruction and hazards, as well as complicated preparation processes, while improving electrochemical performance. The starting material for this synthesis method is rice husk. During the synthesis process, excess NaCl is added to the rice husks, which serves three main purposes: catalytic graphitization, activation of carbon, and formation of amorphous silica. Additionally, the NaCl used in this process can be infinitely and repeatedly reused through dissolution in water after the reaction is complete.
As a result, the lithium-ion batteries that use rice husk-derived SiO_x/C produced through our salt-assisted method exhibit a high initial charge/discharge capacity of 422.05/915.93 $mAh\cdot g^{-1}$ at 0.05 $A\cdot g^{-1}$ and high cycle stability over 500 cycles. The electrodes produced by the NaCl micro-crystal method had 333.96 $mAh\cdot g^{-1}$ capacity at 0.05 $A\cdot g^{-1}$ current density. By contrast, the electrodes not subjected to the NaCl micro-crystal treatment had 479.77 $mAh\cdot g^{-1}$ capacity at 0.05 $A\cdot g^{-1}$ current density. The results of this research lay theoretical and empirical foundations for the development of innovative energy storage materials with excellent electrochemical performance. They also demonstrate the feasibility of adding value to discarded biomass by using it in the construction of eco-friendly energy storage devices.

Keywords:

lithium-ion batteries, eco-friendly energy storage

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P2-ap.104

Enhancement of Power Output in Spin-coated Poly(vinylidene fluoride-trifluoroethylene) Piezoelectric Nanogenerators via Centrifugal Force

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Abstract:

In this study, we systematically evaluated the structural, electrical, mechanical, and microstructural properties of spin-coated P(VDF-TrFE) films obtained at various distances from the center and under different rotational speeds. With increasing distance, the remnant polarization, dielectric constant, and crystallinity of the films increased, resulting in enhanced piezoelectric power at the largest distance. Additionally, with increasing rotational speed, the remnant polarization, dielectric constant, and crystallinity of films initially increased and then decreased, while Young's modulus continuously increased. As a result, the highest and lowest instantaneous powers obtained were 2.1 mW and 0.5 mW, respectively, at the largest (1.09 $\mu C/cm^2 \cdot GPa^{-1}$) and smallest (0.60 $\mu C/cm^2 \cdot GPa^{-1}$) values of remnant polarization over Young's modulus. These behaviors are explained in terms of centrifugal force-induced shear stress and grain alignment, as well as thickness-dependent β-phase crystallization and confinement. These findings imply that spin-coating conditions of distance and rotational speed should be optimized for enhanced power output of spin-coated P(VDF-TrFE)-based piezoelectric nanogenerators.

Keywords:

Ferroelectric polymer, Spin coating, Centrifugal force, High power generation, Piezoelectric charge

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P2-ap.105

Effect of Bi-doping in lead halide perovskite single crystals for photovoltaic applications

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Abstract:

Hybrid perovskite single crystals possess outstanding potential in photovoltaic applications due to their high stability, the absence of grain boundaries, lower intrinsic trap density, and higher carrier mobility compared to polycrystalline thin films which are why they are good to study the fundamental physics in perovskite. Although doping in hybrid perovskites is significant for controlling their bandgap and defect formation, extrinsically doped perovskites have not been studied thoroughly. In this study, Bismuth (Bi) was used as the donor dopant for the $MAPbBr_3$ single crystal because Bi has similar chemical properties to Pb. The $MAPbBr_3$ single crystals were grown by the widely known inversed temperature crystallization (ITC) method [1] and were doped with Bi doping contents of 1, 2, 5, 10, and 15 %. The structure, optical, and electrical properties were investigated with XRD, UV-Vis spectroscopy, Raman, photoluminescence, space charge limited current, conductivity, and scanning probe microscopy measurements. Although Bi incorporation into the crystal enhances the optical and electronic properties, single crystal quality deteriorated according to the XRD results. Combining all the results, we found the sweet spot of Bi content in $MAPbBr_3$ single crystals for optoelectronic applications. Based on the optimal doping concentration, we will fabricate n-doped $MAPbBr_3$ solar cells and provide insight into fabricating an ETL-free solar cell device. By expanding our strategy to p-doped single crystals a simpler structured solar cell with no charge transport layers can be considered.

[1] Y. Cho et al., Nanoscale 13 (2021), 8275-8282

Keywords:

perovskite, single crystal, photovoltaic application

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P2-ap.106

Enhanced dielectric properties of Be-doped magnesium oxide nanopowder

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Abstract:

Among metal oxide, magnesium oxide (MgO) has been widely used in many fields as one of the most important ceramic materials, owing to its applicability in areas such as catalysis, adsorption, refractory ceramic synthesis, nanoelectronics, optoelectronic and sensing devices, and superconducting products. However, it has a relatively low dielectric constant compared to other metal oxide semiconductors which restricts the range of its bandgap and applicability. Here we report the Be-doped magnesium oxide nanopowder showing increased dielectric constant of 10.4 as the Be ion was substituted to 5% without breaking the cubic crystalline structure of MgO.
A sample of MgO powder doped with Be ions was prepared using the Pechini method. The X-ray diffraction showed that the crystal structure of the doped MgO was maintained with very small lattice constant differences. The bonding structure in the lattice of the sample was identified through X-ray photoelectron spectroscopy, and the change in the bonding structure according to the amount of substitution was identified. The dielectric properties of the samples were analyzed as a function of frequency at room temperature. The real and imaginary parts of the dielectric constant were studied as a function of frequency and composition. It was confirmed that the dielectric constant increased as the Be ions were substituted. We suggest that improving the low dielectric properties of pure MgO can enable the application of MgO to wide bandgap and high voltage applications simultaneously.

Keywords:

MgO nanopowder, Pechini method, wide bandgap

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2023-04-19 - 2023-04-21

A_2SiO_4 (A = Ba, Sr, and Ca)의 Eu 원자가 상태에 따른 구조 및 광학 특성 분석

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Abstract:

Eu 이온을 도핑한 A_2SiO_4(A_2SiO_4:Eu, A = Ba, Sr, and Ca)의 구조 및 광학 특성을 연구하였다. A_2SiO_4:Eu 물질은 ACO_3, SiO_2, Eu_2O_3를 원료로 사용하여 고상 합성법(Solid-state reaction method)을 통해 제작하였다. Eu 이온은 H_2, O_2 환경에서 가열하는 과정을 통해 원자가 상태 2+, 3+로 조절하였다. X-ray diffraction (XRD)를 통한 구조 분석 결과, A 원자의 종류에 따라 각각 orthorhombic (Pnma), orthorhombic(α', Pnma) + monoclinic(β, $P2_{1/c}$), monoclinic(β, $P2_{1/c}$) 구조를 확인했다. 특히, Sr_2SiO_4:Eu는 Eu 이온의 원자가 상태가 Eu^{3+}일때 α', β 상의 비율이 1:2, Eu^{2+}일때 1:1로 크게 변화하였다. 광발광(Photoluminescence, PL) 측정을 통한 광학 특성 분석 결과, H_2 환경에서 가열한 샘플은 Eu^{2+}의 5d-4f 전이로 인한 500 nm 근처의 강한 green 방출, O_2 환경에서 가열한 샘플은 Eu^{3+}의 f-f 전이로 인한 600 – 700 nm 근처의 sharp한 red 방출을 보인다. 특히, 반복적인 Eu 이온의 원자가 상태 전환 이후에도 PL 세기가 크게 줄어들지 않는다. 이 결과들은 A_2SiO_4:Eu 물질이 Eu 이온의 원자가 상태 조절을 통한 넓은 색 범위의 발광체로 활용될 수 있음을 보여준다.

Keywords:

Eu, A2SiO4, Photoluminescence

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P2-ap.108

Computational study of the atomic structure, electronic and thermal properties of $Cr_2Ge_2Te_6$

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Abstract:

The superior properties of two-dimensional (2D) materials with atomically thin layers have led to extensive research and potential applications in various fields. Among these materials, $Cr_2Ge_2Te_6$ (CGT) has garnered significant attention as an intrinsic ferromagnetic material with a layered structure, indicating potential applications in spintronics. In addition to its layered structure, the ferromagnetic properties of CGT suggest potential applications for spintronics, and its inverse resistance change indicates a huge potential to reduce operational energy and scale down. However, despite these promising properties, there have been limited computational studies on the electrical and thermal properties of CGT, mainly due to the challenge of large-scale simulations. In this study, we study the atomic and electronic structures of CGT by using density functional theory calculations and investigate behaviors and characteristics of CGT during melting and crystallization process. Especially, we use neural network potentials (NNPs) to do molecular dynamics simulations. Further, the atomic-scale evolution of CGT depending on temperature and surface interaction with various molecules is examined to study its thermal stability and related electrical properties.

Keywords:

Cr2Ge2Te6 (CGT), density functional theory (DFT), neural network potentials (NNPs)

2023 KPS Spring Meeting
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P2-ap.109

Extraction of spin-wave exchange constant from high order magnon generation in ferromagnets

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Abstract:

We suggest the simple method to extract a spin-wave exchange constant (D_{exc}) using high order magnons generated in one-thick ferromagnet film instead of using first excited magnon in thickness series of samples. Under the external magnetic field of H_{ext} = 0.45 T with angles from the normal to a sample normal direction, we excited a front of MgO(4 nm)/Co(60 nm)/Al_2O_3(0001) structures with pump pulses (50 fs, 400 nm, 1 kHz). By detecting both sides of the film with probe pulses (35 fs, 800 nm, 1 kHz) based on magneto-optical Kerr effect, we measured magnons up to fourth order.
Figure 1 shows the magnon frequencies (solid circles) with magnetic field angles and the fitting lines with the quadratic magnon dispersion equation [1]. We obtained D_{exc} ~ 510 meVÅ^2 which is comparable to the previous results of epitaxially grown Co [2]. This can be a simple way to obtain D_{exc} of ferromagnetic materials without the need to make many samples of different thicknesses.

Keywords:

Magnons, spin-wave exchange constant, pump-probe magneto-optical Kerr effect

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P2-ap.110

Characterization of single phase ZnV_2O_6 Nanorods by using Raman and Photoluminescence (PL) Spectroscopy

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Abstract:

The brannerite-type vanadium oxides MV_2O_6 (M = Ca, Mg, Mn, Co, Ni, Cu, or Zn) have a wide range of potential applications in various fields, including energy storage, photocatalysis, and gas sensor etc. Zinc vanadate (ZnV_2O_6) is of a great promise for use in n-type semiconductors, super-capacitors, and secondary batteries. However, the synthesis of ZnV_2O_6, may lead to the formation of V_2O_5 as a by-product which has the same oxidation number of vanadium of + 5 and is more thermodynamically stable, depending on the specific synthesis condition and method. In this study, we have carefully investigated the differences between ZnV_2O_6 and V_2O_5 nanorods, which were fabricated using a simple acid-base reaction followed by the thermal treatment. We have found that the distinct crystal structures and chemical compositions of ZnV_2O_6 and V_2O_5 nanorods can be characterized and distinguished from each other easily by using Raman and photoluminescence (PL) spectroscopy. Our goal is to optimize the growth conditions to further understand and fully utilize pure ZnV_2O_6 nanorods as a versatile material in various applications, using spectroscopic methods.

Keywords:

Transition Metal Oxide, ZnV2O6, Raman, PL, TMOs

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P2-ap.111

Direct observation of magnetic reversal process in tailored exchange spring nanomagnets

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Abstract:

Magnetic multilayers as exchange bias, exchange spring magnets, etc. have very practical uses in applications like spintronics. Among them, exchange spring magnets have been used to tune the magnetic properties of thin films. Exchange spring magnets are composed of hard and soft magnets. By interacting hard magnets with high coercivity and soft magnetite with high magnetization, magnetic multilayer thin films with desired magnetic properties can be produced. Here we tailored the exchange interaction with a thickness of a nonmagnetic interlayer between the hard and soft magnetic layers. Changing the interaction affects the shape of the hysteresis loops. For this study, FePt and Co layers were chosen as the hard and soft magnetic layers, respectively. And the interlayer for controlling the exchange interaction was a Pt layer. $L1_0$ chemically ordered FePt retains giant uniaxial magnetocrystalline anisotropy. It can reach a high coercivity of ~6T at RT. The spontaneous polarization of Co materials is 1.76 T. Magnetic coupling and interaction of each layer have been monitored by X-ray magnetic circular dichroism (XMCD) investigations. We obtain the spin and the orbital magnetic moments probing Fe and Co from normal and at 60ºangle of incidence at saturation field using sum rules analysis. Dipole moment (Tz) and anisotropy has been compared for each Pt interlayer thickness. The magnetization reversal process has been separated for each layer by element-specific hysteresis loops at the Co and Fe L_3-edges. Revealing the earlier start of the Co soft magnetization reversal compared to the FePt layer, where the interaction could be tailored with interlayer thickness control.

Keywords:

Exchange spring magnet, XMCD, Magnetic reversal process, magnetic interaction

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P2-ap.113

$LaVO_3$ 박막 위에 전사된 n형 그래핀의 도핑농도에 따른 광학적 및 전기적 특성연구

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Abstract:

본 연구에서는 triethylenetetramine (TETA)이 도핑된 그래핀 투명 전도 전극과 자외선부터 가시 광영역까지 광 흡수율이 높은 $LaVO_3$ 박막을 이용하여 반투명 태양 전지를 제작하였다. TETA의 몰농도는 0.1에서 0.3 mM까지 변화시켰으며, XPS를 사용하여 도핑된 그래핀에 N 원소가 존재함을 확인하였다. 몰농도가 0에서 0.3 mM까지 증가함에 따라 그래핀의 면저항은 590에서 210 Ω/sq로 감소하였다. 몰농도가 증가함에 따라 그래핀의 투과도는 점점 감소하였지만, 550 nm에서의 투과도 감소는 약 2 % 정도로 매우 미미하였다. 도핑농도에 따른 전기적 특성 변화를 확인하기 위해서 일함수를 측정한 결과, 도핑농도가 점점 증가함에 따라 일함수는 -4.57에서 -4.41 eV로 이동하였다. 이는 TETA 도핑에 의해서 그래핀이 n형 특성을 나타낸다는 것을 의미한다. TETA가 도핑된 그래핀 기반 $LaVO_3$ 태양전지는 도핑농도가 0.2 mM에서 가장 높은 1.45 % 효율과 62% 평균 가시광선 투과율을 보였다. 반투명 셀에 Al 반사 거울을 추가하여 효율을 2%까지 향상시켰다. 본 연구에서는 실험적인 결과를 토대로 TETA-그래핀/$LaVO_3$ 도핑농도에 따른 전기적 및 광학적 특성에 관한 메커니즘을 규명하고자 한다.

Keywords:

LaVO3, n형 그래핀, 반투명 태양전지

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P2-ap.116

채널 길이에 따른 a-IGZO phototransistor 광 특성

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Abstract:

Amorphous In-Ga-Zn-Oxide(a-IGZO) 기반의 Thin Film Transistor (TFT)는 금속 산화물 반도체로써 투명하고 mobility가 크며 off current가 낮은 장점이 있다. 따라서 디스플레이 응용 분야에서 지속적으로 연구되고 있으며 최근에는 디스플레이뿐만 아니라 메모리, 센서 등 다양한 응용분야에서 연구되고 있다. IGZO 물질은 ~3.0 eV 이상의 wide bandgap을 가지며 주로 자외선 영역 빛을 흡수하여 자외선 센서에 사용될 수 있다. 하지만 비교적 파장이 긴 빛은 흡수할 수 없어 가시광이나 적외선을 검출하는 센서로 사용하기 어렵다는 단점이 있다. 본 연구에서는 용액 공정을 이용하여 TFT 형태의 phototransistor를 만들었으며 채널 물질로 a-IGZO를 사용하였다. 다양한 파장의 빛과 소자의 채널 길이를 변화시키며 광 전류를 측정하였으며 채널의 길이가 줄어들수록 긴 파장의 빛에 대해 광전류가 증가하는 것을 확인하였다. 본 연구에서는 소자의 구조적 변화를 통해 광 특성이 변화할 수 있음을 제시한다.

Keywords:

채널 길이, a-IGZO TFT, phototransistor, 광 전류

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Three-layered Stacking Memristor Array with Non-filamentary WO_x Memristor for Multiple Reservoir System

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Abstract:

Memristor, which simply consists of a switching layer inserted between two electrodes, is one of the most strong candidates to become a device-platform for hardware implementation of the biological neural network due to its nonlinear and dynamic electrical characteristics depending on the history of applied electrical programming [1-3]. In this study, we fabricated a non-filamentary Pt/WO_x/W memristor based three-layered stacking crossbar array and utilized the array as multiple reservoirs for the human-like time-processing applications [4]. The device can exhibit a self-rectification ratio (>10^2), a good ON-OFF ratio (>10^2), robust operations (>10^5 cycles), a low operating voltage (up to 0.7 V) and dynamic switching behavior without the initial electroforming process, where the switching event is attributed to the migration of oxygen vacancies according to bias polarity. Notably, stoichiometric engineering based on sputter system can lead to gradient of oxygen concentration profile within the WO_x layer, thus resulting in the formation of asymmetric interfacial barriers and native mobile species in the device. Moreover, using different voltage pulse sequences, the stacking array has successfully performed time-varying input processing with separation and short-term memory capabilities, showing its applicability for a multiple reservoir system. Then, as a proof of concept, we simulated the cell location detection and Lorentz attractor prediction based on the features of the fabricated stacking array. Taken all together, the designed three-layered stacking WO_x crossbar array could pave the way for a reservoir computing system to process time-series data.

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[3] S. Choi, J. Yang, G. Wang, *Adv. Mater.*, 32, 2004659 (2020)
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Keywords:

Stacking, Memristor, Crossbar array, Reservoir computing, Multiple Reservoir

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P2-ap.118

Additional polarization induced by Internal inversion symmetry breaking via compositionally graded thin film

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Abstract:

The demand of new type of memory device is increased to compensate high energy consumption as the Data-intensive computation becomes important for application in artificial intelligence. The memory device using ferroelectric material is one of candidate for increasing energy efficiency. However, due to the lack of data retention and reliability, it is still ambiguous to use ferroelectric material for memory devices. Here, we report growth and memory property of enhanced ferroelectric thin film, Sr doped $BaTiO_3$ and Zr doped HfO2 via compositionally graded deposition. The compositionally graded structure is to break inversion symmetry internally by different chemical composition within layers. therefore, induces strong built-in potential which is expected to boost formation of ferroelectric phase. Mainly, structure for both thin films are investigated by High resolution x-ray diffractometer (HRXRD) and Transmission electron microscope (TEM). C-V and I-V measurement for checking Ferroelectric property is conducted for Both thin film. In Sr doped $BaTiO_3$ thin film, we show the on-off ratio for dielectric constant between polarization up and down state is increased within the chemical gradient. In Zr doped HfO2, the structure of up/down-graded HxZ1-xO2 and H0.5Z0.5O2 films are studied. As a results, the orthorhombic phase of hafnia showed different behavior regarding the graded structure is up or down-graded

Keywords:

Ferroelectricity, Oxide thin film, Heterostructure

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Microstructural investigation of HfZrO2 thin films using dark field TEM analysis

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Abstract:

Since the discovery of unusual ferroelectricity in Si-doped HfO_2 in 2011, numerous studies have been conducted to investigate the ferroelectric properties and crystal structures of fluorite-structured materials such as HfO_2 and ZrO_2. In particular, Hafnium Zirconium Oxide ($Hf_{1-x}Zr_xO_2$) is considered a promising material for semiconductor devices due to its compatibility with the current complementary metal-oxide-semiconductor (CMOS) technology and its ability to support a wide range of dopants. The non-centrosymmetric structure of orthorhombic $Pca2_1$ phase HZO is regarded to have ferroelectric properties. Nevertheless, due to the polycrystalline nature with small grain sizes, a comprehensive understanding of the domain switching process remains elusive.
Here, we utilize transmission electron microscopy (TEM) dark field (DF) imaging techniques to investigate the distribution of the ferroelectric phases in HZO thin films and polar domain structures in orthorhombic phase. TEM DF imaging techniques have the advantage of distinguishing different crystalline phases with high spatial resolution and further identifying the polar domain distribution under Friedel’s pair breaking condition. By cross-section and plan-view TEM analysis, we identify several phases in polycrystalline HZO and ferroelectric domain structures.

Keywords:

Dark-field TEM, HZO, Ferroelectricity

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P2-ap.121

VO_2-based Mott neuron for stochastic and energy-efficient neuromorphic computing

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Abstract:

The VO_2-based Mott transition memristors exhibiting stochastic threshold switching characteristics have garnered a great deal of interest because they can be used as probabilistic artificial neurons for energy-efficient computing. Typically, the degree of stochastic metal-to-insulator transition (IMT) of the VO_2 memristor is determined by the material configurations influenced by stimuli such as temperature, strain, and electric field [1]. In this study, We fabricated VO2-based Mott meristor using two methods such as a reactive sputtering of VO_2 or post-annealing for the oxidation process of V metal itself. We investigated statistically the stochastic threshold switching characteristics and the ON-OFF ratio for the fabricated VO2-based Mott memristors in response to various electrical inputs and evaluated its applicability as a stochastic artificial neuron for energy-efficient neuromorphic computing.

Keywords:

neuromorphic, neuron, energy efficient, stochastic, memristor

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P2-ap.122

Eu^{3+}이온을 첨가한 강유전체 $K_{0.5}Na_{0.5}NbO_3$의 구조 및 광학 특성

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Abstract:

희토류(Rare Earth, RE) 금속 이온 Eu^{3+} 을 첨가한 강유전체 $K_{0.5}Na_{0.5}NbO_3$의 구조특성과 광발광(Photoluminescence, PL) 특성을 연구하였다. X-ray diffraction (XRD)와 Rietveld refinement 분석을 통해 $K_{0.5}Na_{0.5}NbO_3$는 상온에서 orthorhombic 구조와 tetragonal 구조가 혼재하며, Eu^{3+}를 첨가하면 tetragonal phase의 volume fraction이 증가함을 관측하였다. Eu^{3+} 이온이 도핑 된 $K_{0.5}Na_{0.5}NbO_3$에서의 발광 세기는 Eu^{3+}의 농도가 5%가 될 때까지 증가하다가 7%에서 감소함을 확인하였다. 또한 410nm 파장의 빛을 조사하면 광 변색 (Photochromic, PC) 특성과 관련하여 PL 세기가 변화함을 관측하였다. 열처리를 통해 그 세기를 약90% 이상 복구함을 확인하여, 빛과 열을 통해 발광특성을 변화시킬 수 있음을 보였다.

Keywords:

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P2-ap.123

Low-temperature Raman Spectroscopy of NZP Family Ceramics

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Abstract:

NZP family ceramics, including $NaZr_2(PO_4)_3$ (NZP), $RbZr_2(PO_4)_3$, $Ca_{0.5}Zr_2(PO_4)_3$, and $KZr_2(PO_4)_3$, have low thermal expansion properties, making them a promising choice as an electrolyte material for solid oxide fuel cells (SOFCs) that operate at high temperatures for power generation. SOFCs have the potential for higher efficiency than traditional power generation systems as they involve only one energy conversion process, and they are more environmentally friendly due to their use of hydrogen or hydrogen compounds as fuel. Despite several experiments having been conducted to understand mainly structural properties of NKP family ceramics such as changes in the lattice constants, fundamental research on these materials remains essential for their development. In this study, we used Raman spectroscopy to observe temperature dependence of the individual phonon modes of NKP family ceramics and directly confirmed various changes at multiple temperatures. Our results are consistent with previously reported experiments and demonstrate that several phonon modes exhibit distinct patterns, which can explain the phonon dispersion obtained from DFT calculations. Our findings can provide insight into the NKP family ceramics and contribute to the development of fuel cells. Raman scattering spectroscopy proves to be an effective research tool, as it provides immediate information on various material characteristics.

Keywords:

Raman, NZP family ceramics, DFT

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P2-ap.124

그래핀/$LaVO_3$ 수직 이종 접합 구조의 전기적 및 광학적 특성 연구

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Abstract:

$LaVO_3$은 가시 광 영역에서의 높은 흡광계수로 인해 광전자 활성층으로 각광받고 있다. 본 연구에서는 스퍼터링 증착법을 사용하여 석영기판 위에 $LaVO_3$ 박막을 70 nm 제작하였다. 그 후, 화학 기상 증착법에 의해 제작된 단층 그래핀을 $LaVO_3$ 박막 위에 전사하였다. 광학 현미경으로 관찰한 결과 매우 균일한 표면이 형성되었음을 확인할 수 있었다. 우리는 그래핀의 투과도를 유지하면서 전도도를 향상시키는 방법으로 금 파티클과 TFSA를 도핑 하였다. 결과적으로 투과도는 550 nm에서 5% 감소하지만 면저항은 580에서 132 Ω/sq로 크게 감소하였다. 금 파티클과 TFSA가 도핑된 그래핀 기반 $LaVO_3$ 광 검출기는 620 nm에서 최대 0.22 A/W의 광 응답과 7×10^{11} $cmHz^{1/2}/W$의 광 검출능을 보였으며, 이는 초기상태 그래핀 기반 $LaVO_3$ 소자보다 우수한 성능을 입증하였다. 이러한 결과는 도핑에 의한 투과도 감소의 손실보다 전도도 향상에 대한 영향이 커 소자의 성능이 향상된 것이라 여겨진다. 본 발표에서는 위의 실험들을 바탕으로 소자의 특성과 물리적인 매커니즘에 대해 논의하고자 한다.

Keywords:

LaVO3, p형 그래핀, 광검출기

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P2-ap.125

NTK method에서 kernel의 구조에 따른 성능 평가 연구

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Abstract:

NTK(neural tangent kernel)은 infinity width를 갖는 딥러닝 네트워크의 학습이 어떻게 일어나는 지를 kernel을 사용하여 설명하는 방법이다. 사실 Width가 infinite하지 않고 충분히 큰 어떤 finite한 width를 갖는 경우에도 신경망의 kernel 역시 NTK로 근사가 가능하다.
네트워크의 학습 결과를 kernel을 사용해서 계산하기 위해서는 kernel의 역행렬에 대한 연산이 필요하다. 그런데 데이터의 수가 많아질 경우 kernel의 크기가 증가함에 따라 연산 시간도 증가하게 된다. 만약 kernel이 sparse하다면, 양자 알고리즘을 이용하여 exponential한 speed up을 할 수 있다. 이를 위해 우리는 kernel을 sparse하게 근사하는 방법에 대해 연구하였다. 즉 본 연구에서는 kernel의 어떤 비 대각 성분들을 0으로 만들어 근사를 하는 것이 실제 kernel과 유사한 정확도를 얻을 수 있는 지에 대한 다양한 연구를 진행하였다.

Keywords:

딥러닝, NTK, kernel, sparse matrix

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P2-ap.126

Temperature dependent Raman spectroscopy on magnetic van der Waals $Mn_{0.5}Fe_{0.5}PS_3$ with a spin-glass state

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Abstract:

Two-dimensional magnetism has played an important role in developing the modern understanding of magnetism [1]. With the arrival of magnetic van der Waals materials, experimental studies on 2D magnetism have made progress [2]. Spin glass is a unique magnetic state arising from competing magnetic interactions [3]. Due to the different nature of the first-nearest-neighbor exchange interaction and the different magnetic anisotropy of $MnPS_3$ and $FePS_3$, $MnFePS_3$ has spin-glass state. In this work, we studied the spin-glass phase of van der Waals $MnFePS_3$. We measured the polarized Raman spectrum down to low temperatures and observed several features due to the spin-glass transition. First, we studied with bulk $MnFePS_3$, and then we did the same measurements with few-layer $MnFePS_3$. In both cases of bulk and few-layer $MnFePS_3$, the Raman spectra showed subtle changes, consistent with the nature of the spin-glass transition. We also found a gradual increase in the quasi-elastic scattering signal in bulk, 6L, and 5L $MnFePS_3$, indicating the gradual growth of spin fluctuations. However, such trend was not obvious in 1L, 2L, 3L, and 4L $MnFePS_3$. So we confirmed that spin-glass state exists in bulk, 6L and 5L $MnFePS_3$ but maybe not in 1L, 2L, 3L, and 4L $MnFePS_3$.

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Keywords:

spin-glass, magnetic van der waals materials, Mn0.5Fe0.5PS3, Raman Spectroscopy

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P2-ap.127

Effect of the top electrodes on ferroelectric domain switching in hafnium-zirconium oxide thin film capacitors.

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Abstract:

Effect of the top electrode size on ferroelectric domain switching in hafnium-zirconium oxide thin film capacitors.
Recently, doped HfO_2-based ferroelectric materials have been attracted a lot of attention due to many advantages, especially on CMOS capability and very small critical thickness. Especially, hafnium-zirconium oxide (Hf1-xZrxO2, HZO) is one of the extensively studied HfO_2-based ferroelectric materials, with its wide dophant ranges. In HZO based ferroelectric devices, the switching speed is crucial to evaluates its potential working speed as electronic applications. There are two main parameters of domain switching speed on the device, electric field dependence and its electrode size. The parameters related to electrode size are so called 'size effect'. While electric field dependence is well defined, dependence of 'size effect' is still unclear. In this work, we investigate the effect of top electrode size effect on HZO thin film. We differed top electrode size and materials, then measured its domain switching speed and polarization of each electrodes. We verified the smaller electrode performs smaller switching time, also, it shows that the material composition of the electrode also affects on domain switching time.

Keywords:

domain switching, HZO, ferroelectricity

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P2-ap.128

Observation of Negative Capacitance Effect in $Hf_{0.5}Zr_{0.5}O_2/Al_2O_3$ Bilayer Structure using Short Pulse and PFM Measurements.

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Abstract:

Research on the scaling and integration of electronic devices is ongoing, but the required voltage to drive these devices is not decreasing sufficiently compared to the degree of scaling. As a result, the power consumption per unit area of the device is exponentially increasing. To address this issue, there is active research to create devices with a subthreshold slope (SS) of less than 60 mV/decade at room temperature. Recently, research on Negative Capacitance Field Effect Transistors (NCFETs), which exhibit steep switching characteristics, has been gaining attention. The reason for this is the emergence of HfO_2-based ferroelectrics, which have advantages such as scaling, large bandgap, and CMOS compatibility compared to conventional ferroelectrics. Additionally, since the NC effect can stably exist in the layered structure of ferroelectric and insulator materials, we plan to fabricate a metal-ferroelectric-insulator-metal (MFIM) structure to observe the NC effect. The ferroelectric used is $Hf_{0.5}Zr_{0.5}O_2$, and the insulator is Al_2O_3. We plan to perform a well-known short pulse measurement as an electrical measurement method to observe the NC effect, and then observe the domain switching dynamics in the HZO/Al2O3 bilayer structure through PFM. We believe that by conducting research by varying the thickness of each layer in the HZO/Al_2O_3 bilayer structure, we can provide hints for the optimal conditions for the NC effect and the origin of the NC effect.

Keywords:

ferroeletircs, negative capacitacne, PFM, HZO, NC

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P2-ap.129

Investigation of ferroelectric properties in HZO/Al_2O_3 nanolaminates for future nonvolatile memory devices.

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Abstract:

Since ferroelectric property of Si doped hafnium oxide (HfO_2) was first discovered in 2011 by Böscke et al [1], HfO_2 is receiving great attention for future nonvolatile memory devices. Recent research has shown that the dielectric and ferroelectric properties of nanolaminates are improved compared to single ferroelectric thin film [2]. We investigated the differences in ferroelectric properties of hafnium zirconium oxide (HZO)/Al_2O_3 nanolaminates and single layered HZO thin film. We fabricated various composition of nanolaminates by sputtering. In this study, ferroelectric properties such as polarization-voltage hysteresis loops and polarization switching kinetics were investigated. Through electrical measurements, we also studied polarization direction dependent tunneling electroresistance effect of nanolaminates.

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Keywords:

Ferroelectric, nanolaminate, tunneling electroresistance, FTJ, hafnium oxide

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P2-ap.130

Tailoring Metal-Insulator Phase Transition of Vanadium Dioxide Thin Films by Tungsten Doping Gradation

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Abstract:

Vanadium dioxide (VO_2) is well known for metal-insulator transition (MIT) phenomena at the MIT temperature (T_{MIT}) of ~67℃. However, the device applications of VO_2 are somehow limited to switching devices due to the abruptness of MIT. Moreover, the T_{MIT} is still higher considering the real-world device operational conditions. Therefore, diverse approaches have been demonstrated to adjust the MIT characteristics including the T_{MIT}. Among them, the substitutional doping of W into VO_2 is an efficient and reliable method to reduce T_{MIT}.
In this work, we synthesized the W-doped VO_2 thin films with doping gradation perpendicular or parallel to film surface by co-sputtering and subsequent heat treatments. The temperature coefficients of resistances (TCRs) of these graded W-doped VO_2 thin films were shown to be higher than those of pure VO_2 and uniform W-doped VO_2 thin films in a wide temperature region. These results would be of relevant to developing next-generation temperature sensors and heat detectors as well as investigating doping effects in correlated oxides.

Keywords:

vanadium dioxide (VO2), metal-insulator transition (MIT), substitutional doping, temperature coefficient of resistance (TCR)

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P2-ap.131

The epitaxially grown ferroelectric $Hf_{0.5}Zr_{0.5}O_2$ thin film using pulsed laser deposition method

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Abstract:

The ferroelectric random acces memory (FRAM), one of the nonvolatile memories, has powerful advantages like a fast access time and a low power consumption which allows the FRAM to be a promising technology in memory field. Most researches associated with the advance of the FRAM technology are focused on $PbZr_{0.52}Ti_{0.48}O_3$ (PZT) due to its large remnant polarization and low coercive voltage. However, scailing down a thickness of PZT under 50 nm cause significant leakage current in a FRAM device which is triggered by low bandgap and sidewall problem. HfO_2-related materials are considered to be emerging ferroelectric materials for FRAM devices due to their excellent compatibility with CMOS process. In this study, pulsed laser deposition (PLD) method is used to deposit 10-nm-thick Zr-doped HfO_2 (HZO) films and $La_{0.67}Sr_{0.33}MnO_3$ (LSMO) bottom electrodes on the single crystalline $SrTiO_3$ (STO) substrates. The peaks from X-ray diffraction (XRD) demonstrate that the ferroelectric HZO film with orthorhombic phase is epitaxially grown on the STO substrate. The HZO thin film with very flat surface reveals large remnant polarization of up to 22mC/cm^2 measured by using positive-up negative-down (PUND) pulsed method. Therefore, ferroelectric properties of HZO thin film provide an opportunity to overcome the scaling down problems in the FRAM technology.

Keywords:

PLD, ferroelectric, HZO, heterostructure

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P2-ap.132

Reversible control of 2D Electron gases at $LaAlO_3/SrTiO_3$ heterointerfaces

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Abstract:

Persistent photoconductivity (PPC) at $LaAlO_3/SrTiO_3$ (LAO/STO) heterointerfaces provides an opportunity for developing optically-tunable non-volatile memory devices. However, it has been challenging to rapidly remove the PPC, and thus the reversible control of the conductivity is still limited. In this study, we show the reversible control of the two-dimensional electron gas (2DEG) at LAO/STO heterointerface utilizing the strong PPC and surface-induced quenching effect. The conductance of the 2DEG is gradually increased by UV light pulses, which results from dynamic change in the ionization state distribution of oxygen vacancies in STO. We recovered the PPC of the 2DEG by a water treatment. Since the surface deprotonation affects the ionization state of oxygen vacancies in the STO, the electron relaxation process is expedited, removing the PPC. The mechanism of the reversible 2DEG control is clarified by our X-ray photoelectron spectroscopy (XPS) and spectral noise analyses. Our simple yet effective strategy for tuning the 2DEG provides a stepping stone towards developing optically-tunable non-volatile memory and optoelectronic applications.

Keywords:

Persistent photoconductivity, LaAlO3/SrTiO3 heterointerfaces, Two-dimensional electron gas, Oxygen vacancies, Reversible Photo-modulation

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P2-ap.133

미분방정식 풀이를 위한 인공신경망과 개량된 활성화 함수

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Abstract:

동물의 신경 세포를 구성하는 기본 단위인 뉴런(neuron)은 역치 이상의 신호를 입력으로 받으면 신경전달물질을 내보내 다른 뉴런에 전달하는 방식으로 자극을 전달한다. 이 과정을 모방하여 특정한 규칙을 통해 입력을 변환하여 출력으로 내보내는 대수적 구조를 일컬어 퍼셉트론(perceptron)이라 한다. 이 퍼셉트론은 신경계의 구조를 모방한 인공신경망(artificial neural network)의 기본 단위이다. 인공신경망은 데이터를 다루는 현대의 많은 분야에서 분류 등의 문제를 해결하는 데 사용되며, 기존의 기계 학습 방법들과 다르게 학습 단계마다 적합한 가중치들을 스스로 학습한다는 점에서 유용한 도구이다. 과거에는 인공신경망이 선형 분류 문제를 해결하기 위하여 사용되었다. 하지만 현재는 입력과 출력을 처리하는 대수적 과정을 이용하여 비선형 분류뿐 아니라 신경망의 구조를 개량하여 이미지, 음성, 텍스트 등 많은 분야의 학습에 적용할 수 있다. 이러한 인공신경망의 성질은 또한 수치 계산에 사용될 수 있는 도구로서 물리학 분야의 수많은 연구자들에 의해 연구되고 있다. 변화하는 자연 현상을 다루는 물리학의 많은 식은 미분방정식으로 표현되는데, 해석적으로 풀기 어려운 미분방정식에 대해선 수치 계산이 필요하다. 해당 연구에서는 이러한 인공신경망의 수학적 성질을 이용한 수치 계산을 통해 미분방정식의 해를 구하는 방법을 논한다. 또한, 보편적으로 이용되는 활성화 함수 대신 개량된 활성화 함수를 제시하여 미분방정식에 적용할 수 있는 새로운 심층신경망 모형을 제시한다.

Keywords:

인공신경망, 활성화 함수, 심층신경망, 미분방정식

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P2-ap.134

Raman study of anti-ferromagnetic $NiPS_3/FePS_3$ heterostructures

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Abstract:

Recently, van der Waals (vdW) materials are attracting interest due to their diversity of materials and characters. Especially, magnetic vdW materials show huge potential in electronic and spintronic applications. The heterostructure (HS) formed by vdW materials exhibits many properties that cannot be observed in a single material such as the interlayer interactions and moiré superlattices. However, most of those properties were obtained in the HS with semiconductor transition metal dichalcogenide materials. HS combining magnetic materials has not yet been studied intensively. In this work, $NiPS_3/FePS_3$ HS, in which $NiPS_3$ and $FePS_3$ are two semiconducting anti-ferromagnetic materials with XXZ and zigzag-Ising type magnetic ordering, respectively, is studied with Raman spectroscopy. Raman spectroscopy is an effective method to study vdW materials because it is non-destructive and able to reveal many properties of the crystal structure and electro-magnetic properties in a material. $NiPS_3$ shows the two-magnon scattering, Fano resonance and the suppression of quasi-elastic scattering, and $FePS_3$ shows the one-magnon scattering in the Raman spectrum[1,2]. Our HS was fabricated by mechanical exfoliation and dry-transfer method. Then, the temperature dependent Raman spectra were measured with the 514.4-nm laser. The interlayer vibrational and magnetism interactions between two materials are studied.

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2. Lee, J.-U. *et al.* Ising-Type Magnetic Ordering in Atomically Thin FePS 3. *Nano Lett.* **16**, 7433–7438 (2016).

Keywords:

NiPS3, FePS3, Heterostructure, Raman spectroscopy

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Multiscale modeling of Electrochemical CO reduction on Cu to acetate

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Abstract:

Electrochemical $CO_{(2)}$ reduction is one of the technologies that can pave the way towards closing the carbon cycle efficiently. Electrochemical CO reduction is more stressed due to the simplicity of the process than CO_2 reduction, and in addition, CO is a poisonous gas. According to the literary reports, Cu is the only known catalyst that can reduce $CO_{(2)}$ to C_2^+ products, albeit at higher overpotentials, and hence is more studied to deduce the mechanism of the process. In particular, Electrochemical CO reduction to form acetate is studied extensively due to the enormous applications of acetic acid. Various theories exist in the literature for this process. This work presents a multiscale model for Electrochemical CORR on Cu-based gas diffusion electrode systems. We couple a microkinetic model[1] accounting for kinetics on copper developed using CATMAP[2] and a mass transport model for a gas diffusion electrode system developed using COMSOL Multiphysics. Through this model, we explain the optimal design insights to obtain acetate from kinetics and mass transport aspects and validate our results by comparing them with experiments.

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Keywords:

Electrochemical CO reduction, acetate, multiscale modeling, kinetics, mass transport

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P2-ap.136

Self-poled piezoelectric BNKT epitaxial film grown by hydrothermal synthesis at low temperature

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Abstract:

$Bi_{0.5}(Na_{1-x}K_x)_{0.5}TiO_3$ (BNKT) is known as a good piezoelectrics with high performance because of easy polarization in a morphotropic phase boundary (MPB) between rhombohedral and tetragonal structure. The formation of the BNKT domain structure is closely connected with the emergence of MPB, where more polarization directions exist, which can affect the enhancement of piezoelectric properties. For that reason, it has been widely studied in ceramics but is rare in films. In this work, we tried to overcome this problem in epitaxial BNKT films by the hydrothermal synthesis in which the materials (or films) are directly crystallized at low processing temperature so that relatively reduced the defects such as vacancies, curling, cracking, and grain coarsening. A combination of the structural (HR-XRD, XPS, TEM) and piezoelectric measurement (PFM) reveals its ferro- and piezoelectric responses are attributed to not defects but the coexistence of crystal structures affecting the polarization direction in each grain resulting in excellent piezoelectricity. In addition, each grain in hydrothermal-grown BNKT film shows a self-poling property without any external bias field. The self-polarization is beneficial for some ferroelectric films which are hard to be poled by external field and advantageous for device applications. However, it is still challenging to determine the origin of self-polarization in solvothermally grown film. Therefore, we will discuss how self-polarization is induced based on our results.

Keywords:

Piezoelectrics, PFM, Oxides, self-polarization

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P2-ap.201

In-situ intramolecular synthesis of tubular carbon nitride S-type homojunction and its photocatalytic performance

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Abstract:

Constructing tubular graphitic carbon nitride homojunctions is an attractive endeavor to accelerate the dissociation of its Frenkel excitons and charge transfer dynamics, but the realization of this strategy remains a major challenge. Herein, carbon nitride homojunction with open tubular interior, porosity and interconnected feature has been developed via one-step pyrolyzing urea and L-cysteine. The experimental results and DFT calculations indicate that such unique tubular S-scheme homojunctions not only apparently boost in-plane exciton dissolution and suppress the inversive charge recombination via built-in electric field, but also decrease Gibbs free energy of intermediate hydrogen absorption. Thus, the tubular carbon nitride homojunctions display an excellent hydrogen production (4548.4μmol/g/h), which is 35-fold improvement than that of pristine carbon nitride, outperforming the most reported donor-acceptor-based carbon nitride homojunctions and tubular carbon nitride.

Keywords:

Tubular carbon nitride, S-scheme homojunction, Exciton dissolution, Charge transfer pathway, Intermediate hydrogen absorption

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2023-04-19 - 2023-04-21

P2-ap.202

Luminescence and structural modulation of electric field induced Eu^{3+} doped $(1-x)(Na_{0.5}Bi_{0.5})TiO_3$-$xBaTiO_3$

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Abstract:

Recently, environmental problems have arisen due to the toxicity of commercially available lead-based ferroelectrics. To overcome this problem, research on lead-free ferroelectrics has been actively conducted. $(1-x)(Na_{0.5}Bi_{0.5})TiO_3$-$xBaTiO_3$ (NBT-BT) is attracting attention because it shows good electrical properties in morphotropic phase boundary. In addition, the previous studies have reported that the crystal structure of NBT-BT is transformed when an external electric field is applied. In this experiment, we studied the possibility of developing a multifunctional optical-electric material by doping Eu^{3+} to NBT-BT (NBT-BT:Eu). We observed the sizable red emission of Eu^{3+} in NBT-BT and Eu^{3+} doping did not weaken the piezoelectricity of NBT-BT. Rietveld refinement structural analysis revealed that the structural phase of NBT-BT:Eu was a mixture of rhombohedral (R) and monoclinic (M) phases. And we confirmed that the volume fraction of the R-phase increased when applying external electric field. Interestingly, concomitant with this structural transition, the Eu^{3+} emission was suppressed, indicating that the increase in the local structural symmetry surrounding the Eu^{3+} leads to the luminescence quenching. This correlation between the structural and luminescent properties suggests that NBT-BT:Eu has a high possibility of being used as a multifunctional optical-electric material.

Keywords:

Piezo-electrics, Photoluminescence, NBT-BT, Eu3+, Rietveld refinement

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P2-ap.203

Real-time monitoring of dopamine adsorption on anodized aluminum oxide nanochannels using a surface enhanced Raman spectroscopy

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Abstract:

Nanochannel embedded membranes provide various potential applications utilizing capillary force driven fluid transport through highly dense channel structures. Chemical functionalization on the channel surfaces are implemented to control the transport of specific molecular species or ions, requiring characterization of their adsorption selectivity, and efficiency. In the present study, we demonstrate a real-time monitoring methodology to assess the surface adsorption of chemical species in the nanochannels of an anodized aluminum oxide membrane. The nanochannel surface is coated with thin Ag grains via AgNO3 reduction and then chemically functionalized to target specific molecular species to provide an optical hot spots for surface enhanced Raman spectroscopy enabling real-time measurement of adsorbed target molecules. For the demonstration of proof-of-concept, we investigate the photo induced polymerization of dopamine adsorption on AAO-Ag nanochannels.

Keywords:

SERS, Capillary force

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P2-ap.204

Improving InP Quantum Dot LED Device Properties by Changing its Structure with a Polyethylene Glycol Mixture.

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Abstract:

In our study, we looked at combining polyethylene glycol (PEG) with quantum dots (QD) light-emitting diodes (LEDs) in the QD emission layer (EML) made from InP. We found that when we added 5 wt% of PEG 400 to the QD EML, the current efficiency of the QD-LED increased by 42%, and the external quantum efficiency increased by 36%. By using X-ray reflectivity, we observed changes in the overall morphology of the QD EML mixed with PEG. As we increased the amount of PEG in the QD EML, we saw an increase in the thickness of its dense surface region, but no change in the total thickness, and this altered the electron density distribution. Our findings indicate that adding a plasticizer like PEG can enhance the electrical characteristics and structural features of the light-emitting device, and the efficiency improvement is similar to that obtained by mixing a hole transport material.

Keywords:

InP Quantum dot, EL-QD, Morphology-efficiency relation, Grazing incidence small X-ray scattering, X-ray reflectivity

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P2-ap.205

Refractive index sensing using Fano resonance in excitonic nanostructuring J-aggregation thin films

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Abstract:

Fano-resonance occurs in the hybridization of plasmonic resonance modes in metallic nanostructures, which leads to variety of applications in biosensing, optical filtering and multicolor imaging. Recently, organic excitonic materials with narrow absorption band such as J-aggregated molecules have been proposed as an alternative to achieve a negative permittivity and thus plasmonic resonance. It is expected that nanostructuring the organic J-aggregation films will result in strong coupling between different excitonic modes at the nanoscale. In this study, we demonstrate that the transmission dependent Fano-resonance change by introducing nanohole arrays on a thin film of TDBC with J-aggregation using focused ion beam (FIB) milling. The nanohole arrays are designed to exhibit narrow Fano-resonance in the visible region of 600~700 nm in transmission spectra. The J-aggregation films introducing the nanohole arrays lead to interference between broad excitonic resonance states of J-aggregated film and the excitonic nanocavity modes, resulting in an asymmetric line shape in transmission spectrum. We use this nanostructure arrays having less toxicity than plamsomic nanostructures for refractive index sensing which is used technique for quantifying changes in the refractive index of dielectric layer. The refractive index of the surrounding medium changes the excitonic cavity mode condition, causing a red shifts in the transmission excitonic cavity resonance dip, whenever the refractive index is increasing. This shift can be used to quantify the change in the refractive index, which is promising applications in chemical and biological sensing, multicolor imaging and medical diagnostics.

Keywords:

Fano resonance, Localized surface exciton polaritons, J-aggregation

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P2-ap.206

Optimization of High-power Single-shot Readout for Superconducting Transmon Qubits in circuit QED

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Abstract:

원샷-측정(Single-shot Measurement)을 통해 양자상태를 읽어내는 것은 대규모 양자프로세서를 구동하는 데 핵심 요소이다. 측정 오류를 줄이기 위해서 양자한계증폭기를 활용하는 것이 일반적이지만, 양자한계증폭기는 제한된 대역폭 및 증폭률 한계 등의 성능을 개선하는 노력이 더 필요하다. 양자한계증폭기가 없는 상태에서도 높은 충실도를 갖는 원샷-측정 방법은 시스템의 복합도를 줄이는 측면에서 매우 유용하기 때문에 관련 연구가 필요하다. 본 연구에서는 전형적인 초전도 큐비트 아키텍쳐인 회로 양자전기동역학(circuit QED) 구조에서 나타나는 비선형성을 활용한 높은 충실도의 원샷-측정 구현에 대해 보고한다. 고정 주파수를 갖는 두-큐비트 시스템에 대한 특성분석을 수행하여 비선형성이 나타나는 측정신호세기를 확인하고, 양자상태에 따른 비선형 반응의 차이를 읽어내어 측정 세기에 따라 원샷-측정을 수행하였으며, 비선형 구간에서도 원샷-측정이 가능함을 확인하였다. 그 결과 양자한계증폭기 없이 98.3 % 의 원샷-측정 충실도를 400 나노 초 수준으로 구현하였다. 그리고 비선형을 활용한 원샷-측정 방식으로 양자상태 토모그래피를 실행하였으며, 이를 통해 두 큐비트의 얽힘상태를 96.9 %의 충실도로 측정할 수 있음을 확인하였다.

Keywords:

Superconducting Qubit, Circuit QED, Single-shot Readout, Entanglement, Quantum State Tomography

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P2-ap.207

Optical gain properties and thermal degradation of perovskite thin films under intense optical pulses

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Abstract:

As an emerging semiconductor material in the field of energy-efficient display applications, metal halide perovskites show great promise. As a direct bandgap semiconductor, perovskites exhibited high photoluminescence quantum yields, leading to the rapid development of light emitting diodes with more than 20% of external quantum efficiencies in the visible and near infrared spectral regions. Moreover, due to their outstanding optical gain properties such as high oscillator strength, and modal gain coefficience have enabled the possibility of coherent light emitters. As a result, numerous amplified spontaneous emission (ASE) and lasing demonstration under pulsed optical excitation have been reported from nano- and macro-scale of perovskite-based materials. However, many of them just demonstrated a proof-of-concept level of lasing performance lacking the actual potential to be utilized in many applications. The most challenging part in perovskite optoelectronic devices is the stability issues under ambient conditions. Also, it requires a significant level of robustness that can endure under severe operating conditions such as high current density injection and intense optical excitation. Thus, it is important to investigate the detail degradation mechanisms caused by various operating conditions.

Here in this study, we are investigating the influence of intense optical pulses on perovskites' optical gain properties. Perovskite thin films have been prepared on various substrates with different thermal conductivities (glass and sapphire). Then, one of the samples have been covered by a graphite sheet and copper heat sink to efficiently dissipate the heat generated on the excited perovskite film. Then, we probe
the output amplified spontaneous emission spectra acquired by various levels of pumping intensities. By scanning the input excitation upto more than 20 times of ASE threshold, we were able to observe the thermal degradation of perovskite film caused by intense optical pulses. Importantly, this thermal degradation is affected by thermal conductivity of surrounding materials. Considering the fact that the optical pulse used in this study was only 40 ps-long, the effects of optical pulses and thermal conductivity become significant when we drive the perovskite-based devices in nano-second pulsed regime or extreme operation of LEDs. This study reveals the importance of thermal management in perovskite thin film devices and provides an initial hint on optical/thermal damage mechanisms.

Keywords:

Perovskite, Lasing, Amplified Spontaneous Emission, Thermal Conductivity

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P2-ap.208

Study on polarization properties of binary phase shift keyed optical transmission in birefringent fiber link

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Abstract:

Coherent optical communication systems incorporating coherent detection and digital signal processing have been extensively studied and commercially deployed in the field. The systems have high spectral efficiency and sensitivity compared to conventional direct detection systems and carry out adaptive electronic equalization of hindrances such as chromatic dispersion in the fiber transmission link but may exhibit vulnerability to polarization issues involving polarization mode dispersion. In this study, polarization characteristics of binary phase shift keying optical signal transported along optical fiber link with polarization mode dispersion is investigated via simulation by employing degree of polarization of the optical signal and the results are analyzed.

Keywords:

Coherent optical communication systems, polarization mode dispersion, coherent detection

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P2-ap.209

changes in dielectric relaxational characteristics with the growth of bacteria

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Abstract:

Delayed prescription of proper antibiotics for the patients with bacterial infections decreases survival chances drastically. Therefore, rapid antibiotic susceptibility test (AST) is necessary to fast diagnosis to avoid the misuse of antibiotics. However, conventional AST methods require long time, delaying proper treatment. Here, we report the method of monitoring bacterial growth through dielectric relaxational characteristics. Using inter-digitated capacitance sensors, frequency dependent capacitance was measured up to 1MHz. Analyzing distribution of relaxation times, overlapped dielectric relaxational characteristics were separated. By the results, we monitored the change of bacteria cells along the according to growth. These results are expected that can be applied to the research about the reaction of bacteria by antibiotics, as well as rapid ASTs.

Keywords:

bacteria, dielectric relaxation, capacitance sensor, frequency dependent capacitance

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P2-ap.210

Enhancement of Visible Light Photodetection via Additional Quantum Dots Layer

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Abstract:

Metal oxide semiconductors has been widely studied as hole/electron transporting layers for optoelectronic devices owing to their solution processibility and relatively high charge carrier mobility. Among the metal oxide semiconductors, Nickel oxide (NiO) and Zinc oxide (ZnO) are commonly used in Ultra-violet (UV) photodetectors due to their wide band gap and high transparency. This study aimed to improve the visible light detection of these devices by inserting an additional Quantum Dots (QDs) layer between the NiO and ZnO layers. The resulting NiO/RQDs/ZnO device showed photoresponsivity of 8.23×10^{-3} A/W and 1.84×10^{-1} A/W for 635 nm and 405 nm wavelength light illumination, respectively. Additionally, the NiO/GQDs/ZnO device demonstrated 2.43×10^{-3} A/W and 7.07×10^{-3} A/W for 520 nm and 405 nm wavelength light illumination, respectively. These results suggest that incorporating QDs with metal oxide semiconductors is an effective method for detecting visible light wavelengths.

Keywords:

Oxide semiconductor, Quantum Dots, photodiodes, application, photoresponse

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P2-ap.211

Highly enhanced α-IGZO based ultraviolet phototransistor via ZnO nanoparticles active layer

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Abstract:

Although ultraviolet rays synthesize vitamin D in the human body and have a positive side, it is known that prolonged exposure causes eye diseases such as cataracts and skin cancer. Especially ultraviolet B (UVB) have a fatal effect on the eye and skin, so importance of detecting UVB is increasing. In order to detect UVB with a short wavelength of 280nm~320nm, research on wide band gap materials is essential. Amorphous Indium Gallium Zinc Oxide (α-IGZO) is highly transparent materials due to its wide band gap and considered as promising ultraviolet sensing materials. We demonstrated α-IGZO/ Zinc Oxide (ZnO) nanoparticle thin film transistor (TFT) can effectively detect 300nm wavelength UVB light with an intensity of 7um/cm^2. The maximum photoresponsivity of α-IGZO/ZnO TFT under 300 nm wavelength illumination was 7.176 × 10^3 which is much higher than that of α-IGZO TFT. We confirm that α-IGZO/ZnO nanoparticle TFT effectively detect in UVB region (300nm) as a photo-current is generated thorough photo-excited carriers.

Keywords:

Oxide semiconductor, UV detection, Phototransistor, Solution process, α-IGZO/ZnO nanoparticle

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2023-04-19 - 2023-04-21

P2-ap.212

Hadamard 행렬 마스크를 이용한 단일 픽셀 카메라 영상복원 연구

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Abstract:

가시광 대역에서 작동하는 현대의 카메라는 실리콘 광측정기 픽셀이 배열형태로 이루어져 있는 이미지 센서를 이용하여 피사체의 상을 영상으로 확보할 수 있다. 그러나, 가시광 대역이 아닌 X-선이나 적외선 파장대역에서는 배열형태의 이미지 센서를 비용적인 측면에서 확보하기 어렵다. 이러한 문제를 해결하기 위한 방법 중 하나로, 단일 픽셀 광측정기를 이용한 이미징 방법이 소개되었다. 본 연구는 Hadamard 행렬 마스크를 이용한 단일 픽셀 카메라의 영상복원 연구를 보인다. 영상복원 과정에서 Hadamard 행렬 마스크의 적용 순서에 따른 영상복원효율을 분석하였으며, 영상복원을 위한 최적 알고리즘 분석을 수행하였다. 더 나아가, 측정횟수 변화에 따른 복원영상의 품질을 분석하여, 효과적인 영상복원에 대한 분석을 수행하였다.

Keywords:

단일 픽셀 카메라, 영상복원

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P2-ap.213

레이저 현미경 기반 미세입자 광산란 분석 연구

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Abstract:

본 연구는 파장 수준 직경을 갖는 단일 미세입자의 광산란 신호를 효과적으로 검출하기 위한 레이저 현미경 시스템 개발과 이를 이용한 단일 Polystyrene Latex Bead(PS Bead)의 광산란 신호 검출을 보인다. 파장 수준 크기 미세입자의 낮은 광산란 신호를 효과적으로 검출하기 위해, 입사광을 가우시안 형태의 집속빔이 되도록 하였으며 Balanced 측정과 Lock-in 증폭 방법을 이용하여 광측정 신호에 포함된 노이즈를 최소화하였다. 제작된 레이저 현미경을 이용하여 직경 565 nm PS bead의 광산란 분포맵을 파장 532 nm의 입사광 레이저에 대해 얻었으며, 효과적인 노이즈 제거를 통해 파장 수준 크기 미세입자의 광산란 신호 검출이 가능함을 보였다.

Keywords:

광산란, 레이저 현미경

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P2-ap.214

Highly Transparent Solution Processed Visible-Light Stimulated IGZO based Optoelectronic Synaptic Transistor via CdO Active Layer

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Abstract:

Optoelectronic synaptic transistors, which is inspired by mimicking the human visual system, have recently been tremendously investigated for next-generation neuromorphic computing system. To keep in progress with the numerous advantages of neuromorphic computing systems, challenges of low-cost and large-area fabricable solution processable optoelectronic devices should be further investigated with ensuring long term stability. Herein, we report a IGZO based visible light stimulated, highly transparent visible-light optoelectronic synaptic transistor with cadmium oxide (CdO) active layer. A fundamental synaptic properties including excitatory post synaptic current (EPSC), paired-pulse facilitation (PPF), and short-term plasticity to long term plasticity conversion was successfully demonstrated under visible light stimulation. Along with the synaptic behaviors, CdO with highly n-type characteristic layer resulted in remarkable increase in electrical characteristics such as field effect mobility, on/off current ratio. Our results suggest a useful method for promoting the visible light optoelectronic synaptic transistor for next generation neuromorphic computing system.

Keywords:

Oxide semiconductor, Optoelectronics, Synaptic transistor, Heterostructure

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P2-ap.215

Diagonal-gate synapses based on organic ferroelectric barristor for efficient one-step convolution operation in convolutional neural network

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Abstract:

The development of both novel synaptic device structures and innovative array configurations is crucial for the implementation of high-speed and energy-efficient convolutional neural network (CNN) especially for artificial intelligence (AI)-assisted edge computing applications. Here, we present a three-terminal vertical ferroelectric synaptic barristor (TVFSB) equipped with essential synaptic functions based on Schottky barrier height modulation to actualize a novel neural network enabling parallel concurrent execution. The TVFSB device can be readily extended to a diagonal neural network array architecture while sustaining crossbar array form with non-destructive cell programming as a result of the vertically stacked device structure capable of layered gate line patterning on its top. This inventive array enables fast and energy-efficient CNN operation (so-called diagonal CNN (DCNN)) that is capable of simultaneous weight update of all cells sharing the kernel matrix, which can perform a one-step convolution and pooling process without the need for sequential convolution steps for extracting features and storing feature maps. Consequently, total vector matrix multiplication (VMM) energy for the MNIST digits and Clothes datasets based on DCNN operation can be reduced by 75.80 % and 71.79 %, respectively, compared to conventional CNN (CCNN) operation, while achieving similar recognition accuracy of ~91 % and reducing the image sliding number as 1/4.

Keywords:

Artificial synapse, Neuromorphic device, Organic ferroelectric, Barristor, Convolutional neural network

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P2-ap.216

The characterization of molecular vibration using infrared localized surface plasmon resonance in Si nanowire

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Abstract:

We present the mid-infrared localized surface plasmon resonance (MIR-LSPR) in periodically doped silicon nanowires (Si NW) and the detection of the self-assembled monolayer on the surface of Si NWs. We prepared Si NW showing the MIR-LSPR at ~1200 cm^{-1} with the periodically modulated doping concentration. We transferred Si NWs with the diameter of 200 nm on BaF_2 substrate and deposited trichloro(1H,1H,2H,2H-perfluorooctyl) silane on the Si NWs by using vapor phase deposition method. We measured the vibrational molecular signal by using Fourier transform infrared (FTIR) microscope and photo-induced force microscope (PIFM). The measurements show that MIR-LSPR enhances the molecular signal of self-assembled organic molecules with a few nanometers of thickness. We expect Si NWs with MIR-LSPR can be a measurement platform for the detection of molecules in infrared regime.

Keywords:

Silicon nanowire, Localized surface plasmon resonance

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P2-ap.217

Effect of molecular tilt configuration in molecular heterojunction with two-dimensional semiconductor

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Abstract:

There have been studies of understanding and controlling the charge transport through molecular junction wince it gives fundamental grounds that helps to gain a novel idea to realize numerous potential molecular functional devices. [1,2] There are some key factors considered in molecular charge transport, such as molecular barrier which is directly related to molecular orbital levels, coupling strength, asymmetric factor, and molecular configuration and conformation. Much research has been reported to obtain deeper insights of such key factors under certain controlled conductions with the effect of the external stimuli applied on the molecular junction such as light irradiation [3], electrochemical gating [4], electrical field [5], and mechanical stress such by tip loading force [6]. Molecular heterojunction with two-dimensional (2D) semiconductor provides various key factors for the charge transport through the heterojunction; however, the effect of molecular tilt configuration on the molecular heterojunction have never been studied. Here, we present the effect of molecular tilt configuration on the molecule/mono-layer (1_L) 2D semiconductor heterojunction by tip loading force with conductive atomic force microscopy (C-AFM) technique. With various tip loading force (1-30 nN), the molecular tilt configuration affects differently for the three different interfaces in Au/molecule/1_L-2D semiconductor/Au heterojunction that the transition voltage spectroscopy (TVS), which is a conventional tool to analyze charge transport through molecular junction, rectification ratio (*RR*), non-linearity (N_L) and possible array size are demonstrated. Molecule/2D semiconductor heterojunction system has been reported as molecular diode (with *RR*) and selector (with N_L) and it is a novel platform owning so much various potential in, that understanding the charge transport by the effect of external stress on the heterojunction will help developing such future molecular scale functional devices.

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Keywords:

molecular electronics, molecular heterojunction, 2d semiconductors

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P2-ap.218

Scattering enhancement of dielectric nanoparticles on a molecular j-aggregate film in dark-field microscopy

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Abstract:

In recent years, molecular aggregates have been utilized for a number of optical applications, such as fluorescent sensors, organic light-emitting diodes, single photon sources, and bio-imaging tools. As a bio-imaging technique, dark-field microscopy is a faster and easier way to obtain label-free images of objects. However, it has been well known that for particles much smaller than the wavelength, the scattered light intensity is quite weak since it is proportional to the inverse fourth power of the wavelength and the sixth power of its size. Here, we introduce a molecular J-aggregate film for the scattering enhancement. We demonstrate a label-free imaging method called surface exciton polaritons assisted scattering nanoscopy. The enhanced scattering of nanoparticles situated on an organic excitonic film leads to significantly enhanced imaging contrast, resulting in label-free imaging.

Keywords:

molecular aggregate, label-free imaging, scattering enhancement

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2023-04-19 - 2023-04-21

P2-ap.219

통신파장대역 에탈론 필터 시뮬레이션

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Abstract:

통신파장대역에서의 주야간 양자 암호 통신을 위해서는 협대역 파장 필터를 통한 노이즈 제거가 필수적이다. 다양한 형태의 파장 필터 중에서 우선 에탈론 파장 필터를 개발하고자 한다. 필터 제작과 성능 실험에 앞서 유한요소해석 기법을 이용하여 에탈론 파장 필터의 성능과 특성을 분석하고자 한다.

Keywords:

에탈론 파장 필터

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P2-ap.220

Towards microwave ghost imaging

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Abstract:

물체의 이미징을 위해 고스트 이미징 기법은 물체와 상호작용하지 않는 빛의 공간 정보와 단일 픽셀 검출기로 측정한 물체와 상호작용한 빛 간의 2차 상관관계를 이용한다. 광학 기반의 고스트 이미징 실험들은 이 기법이 배경 노이즈 제거에 효과적임을 보여준다. 원거리 이미징을 위해 마이크로파 영역으로 접목하고자 하는 노력들이 진행되고 있으며, 본 포스터에서는 마이크로파 고스트 이미징 기술 동향을 살펴본다.

Keywords:

마이크로파 고스트 이미징

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P2-ap.221

Superconducting Properties of TiN Films Modulated with Growth Parameters during DC Magnetron Sputtering

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Abstract:

Transition metal (TM) nitride superconducting films have been continuously studied to apply them for fabricating the superconducting devices operating in the microwave regime. Especially, titanium nitride (TiN) is regarded as a promising candidate to replace pure metal superconductors and be used in quantum processors based on superconducting qubit, microwave kinetic inductance detectors (MKID), superconducting nanowire single photon detectors (SNSPD), and so on, owing to their low loss and high kinetic inductance. In this work, we investigate how the material properties of superconducting TiN films grown by DC magnetron sputtering are influenced by growth conditions such as DC power density and the ratio of N_2 to Ar. The surface morphology and crystallographic structure of each TiN film are characterized by SEM, AFM, and XRD analysis. The highest measured superconducting transition temperature and residual resistivity ratio are found to be ~4.6 K and 1.1867, respectively.

Keywords:

Titanium Nitride (TiN), DC Magnetron Sputtering, Superconducting Transition Temperature (Tc), Residual Resistivity Ratio (RRR), Kinetic Inductance

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P2-ap.222

Probe into signal impact on acquirement of optical signal to noise ratio of optical transport systems

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Abstract:

Dynamically reconstuctible optical networks capable of efficient and cost-effective operation and maintenance adapting to traffic and bandwidth on demand allow lightwave channels to take different routes and have different optical signal to noise ratios (OSNR), hence needing OSNR measurement for each wavelength. The previous technique to measure OSNR using optoelectric noises may be influenced by photodetected signal components in a frequency band. In this work, the simulative evaluation of the signal impact on acquirement of OSNR using optoelectric noises are carried out and the analysis and discussion for the simulation results are presented.

Keywords:

Optical signal to noise ratio, optoelectric noises, optical fiber communication

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P2-ap.223

Randomized Benchmarking of Quantum Gates on Fixed-frequency Superconducting Transmon Qubits

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Abstract:

양자컴퓨터는 양자현상을 활용하여 특정 문제를 고전 컴퓨터보다 수월하게 계산할 수 있다는 점에서 각광받고 있다. 한편 양자상태를 제어하는 양자 게이트에서는 오류가 항상 동반하게 마련이므로, 오류의 정도를 분석하는 것이 필수적이다. 토모그래피(Tomography) 기반 양자게이트 교정방법으로 오류를 분석할 수 있지만, 상태의 준비 및 측정에서 발생하는 오류(SPAM)를 분리하기 어렵고, 상대적으로 복잡하고 긴 교정과정이 필요하므로 대규모 양자프로세서에서 실용성이 낮다. 대규모 양자컴퓨터 활용을 위해서는 양자게이트의 충실도를 빠르게 판단할 수 있는 방법론이 필수적이며, 가장 널리 쓰이는 방법은 무작위 벤치마킹(RB, Randomized Benchmarking)이다. 본 연구에서는 우리가 제작한 멀티 큐비트 초전도 트랜스몬(Transmon) 소자의 특성을 평가하기 위하여 양자게이트의 충실도를 빠르게 판별할 수 있는 방법인 RB를 적용한 실험결과를 보고한다. 먼저 제작된 초전도 멀티-큐비트 소자에서는 주파수 분포 및 큐비트의 결맞음 등을 측정하여 기본적인 양자소자의 특성을 분석한다. 그리고 단일 양자게이트를 무작위로 조합하여 게이트의 평균적인 충실도를 관찰한다. 무작위 벤치마킹에서 특정 게이트의 기여도를 추출할 수 있는 interleaved RB를 활용하여 여러 종류의 양자게이트의 충실도를 비교한다. 본 발표에서는 RB를 효율적으로 적용하여 큐비트 소자의 특성을 분석하는 방법에 대하여 전반적으로 논의한다.

Keywords:

Superconducting Qubit, Transmon, Randomized Benchmarking, Quantum Gate Fidelity

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Red luminescent shift of carbon dots derived from o-phenylenediamine

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Abstract:

For past decade, carbon dots (CDs) have been studied as a new type of fluorescent materials in next generation, because the CDs possess a bio-compatible property, easy synthesis, hydrophilic characteristics, high luminescent efficiency, good photo-stability, chemical variety and abundant quantity. Since the CDs are based on organic materials, organic based materials can be used as their precursor. For these reason, various organic precursors were utilized to study the characteristics of carbon dots.
Among the various organic materials, phenylenediamine is one of popular materials because the utilization of phenylenediamine allotropy can realize the RGB luminescence with high luminescence efficiency, excitation independent bandgap. However, the bandgap energy of the CDs cannot be tuned by using single allotropy utilization. In order to improve the application performance, the bandgap energy must be allowed.
In this study, the CDs were synthesized by using a hydrothermal method. In order to control the bandgap, the quantity of nitric acid was varied in the synthesis process. To investigate their characteristics, the structural, morphological, luminescent properties of the CDs was analyzed.

Keywords:

Carbon dot, Red-shift

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Luminescence of a novel $Y_2Sn_2O_7:Eu^{3+}$ red-emitting phosphor for visualization of latent fingerprint and security ink applications

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Abstract:

Generally, fingerprints were traces left on an object's surface when fingers touch it. Fingerprint identification technology is one of the powerful tools and has been widely utilized in forensic science because the fingerprint is unique and permanent for each person and each finger, and not varies with age. In many cases, latent fingerprints are not directly visible. Fluorescence based powder dusting method gives high sensitivity and spatial resolution. Counterfeiting of documents, currencies, goods (spanning from computer software, consumer products, pharmaceuticals, electronics, automobiles, etc.) was an organized crime that creates numerous risks in the public and private sectors, which intern severely affects the global economy. Solving the problem of counterfeiting of currency notes and forgery of credential documents are the need of hour as it causes a significant crisis to the global economy. To elevate anti-counterfeit techniques and preventing a high risk of security breach and duplication, rare earth activated fluorescence materials which can be used in printing documents are developed. From these factors, luminescence materials provide possible applications in forensic science.

Herein, we introduced a sol-gel method to synthesize the red-emitting $Y_2Sn_2O_7:Eu^{3+}$ phosphors for their utilization in latent fingerprint and anti-counterfeiting applications.

Keywords:

Y2Sn2O7:Eu3+, red-phosphor

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P2-ap.226

일체형 해상용 등명기에 적용하는 태양전지 효율 최적화 설계

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Abstract:

선박이 항만 입·출항로 및 연안을 따라 항해를 하면서 선박이 안전하고 능률적인 항해하기 위해서는 자선의 위치를 확인하여야 하나 야간 또는 해무가 짙은 곳에서는 자선의 위치를 확인하기에 어렵다. 따라서 선박 교통량이 많은 항로, 항구, 암초, 수심이 얕은 곳에 빛, 형상, 소리 및 전파 등을 이용하여 선박에 위치 정보를 제공하는 시설을 항로표지라 한다. 이러한 항로표지 중에 등부표나 등주에 설치되어 빛을 내는 항로표지를 해상용 등명기라한다. LED를 적용한 해상용 등명기는 2003년 개발되어, 기존의 등명기는 태양전지, 충방전기, 납축전지, 등명기, 4가지의 타입으로 나뉘어 설치되고 있다. 해상용 등명기에서 LED의 적용과 기술의 발전으로 태양전지, 충방전기, 배터리, 등명기가 하나로 합친 일체형 등명기를 선호되고 있다. 일반적으로 일체형 등명기의 태양전지를 사면에 부착하여 전력을 생산하는 구조이다. 본 연구에서는 태양전지판의 형태 및 여러 배치를 만들어 하루 동안 충전 전력을 확인해 보았다.
일체형 등명기에 적용하는 태양전지 패널의 제작하여 태양전지 배치를 가장 일반적인 사각형 형태로부터 육각형 형태까지 변경하여 제작하여 측정해보았다. 측정 결과 사각 배치는 태양전지 패널은 시간당 충전률이 높아 배터리 완충 가능하였지만 시간 때에 따른 충전량의 변화가 심하였다. 육각 배치의 태양전지는 시간 때에 따른 충전량이 일정하게 들어오는 것을 확인하였다.

Keywords:

해상용 등명기, 태양전지

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Controlling Molecular Orientation in Organic Thin Film Devices: A Study of HAT-CN Using Angle-Dependent X-Ray Absorption Spectroscopy

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Abstract:

The orientation of constituent molecules in organic thin film devices can significantly affect their performance due to the highly anisotropic nature of π-conjugated molecules. In this study, we report on an angle-dependent X-ray absorption study of how the molecular orientation of hexaazatriphenylene-hexacarbonitrile (HAT-CN) is controlled using various film thicknesses. We found that the orientation of the initial molecular layer changes from lying down to standing up depending on the layer density. Furthermore, we measured the tilt angle of zinc phthalocyanine (ZnPc) depending on the molecular orientation of the HAT-CN interlayers. It was observed that the subsequent ZnPc tilt angle improves the π-π interaction at the interface due to well-ordered interlayers, regardless of the orientation direction.

Keywords:

HATCN, ZnPc, XAS, UPS, molecular orientation

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P2-ap.228

컨쥬게이션 폴리머의 형광 소멸을 이용한 폭발물 탐지에서 온도와 습도의 영향

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Abstract:

최근 국토 안보, 대테러 기술 등의 중요성이 부각됨에 따라 폭발물 탐지 기술의 중요성 역시 증가하고 있다. 폭발물 탐지 기술에는 라만 분광법, 이온 이동도 분광법, 전기 화학적 분석, 형광 분석법 등이 있으며, 이 중 형광 분석법의 경우 측정 장비를 간단하게 구성하여 드론, 로봇 등의 플렛폼에 쉽게 응용할 수 있다는 장점이 있다. 형광 분석을 통한 폭발물 탐지를 위하여 형광성 컨쥬게이션 폴리머가 사용될 수 있으며, 컨쥬게이션 폴리머에서 나타나는 폭발물 분자에 의한 형광 소멸(Fluorescence quenching) 현상에 대하여 많은 연구가 이루어졌다. 하지만, 센서의 상용화를 위해서는 폴리머의 수명과 안정성 등에 대한 조사와 개선이 이루어져야 하며, 특히 외부 환경에 의한 폴리머의 형광과 형광 소멸 효율의 의존성에 대해서는 아직 충분한 연구가 이루어 지지 않았다. 이 연구에서는 여러 종류의 컨쥬게이션 폴리머의 형광 세기와 2,4-Dinitrotoluene (DNT) 증기에 의한 형광 소멸 현상에서 온도와 습도에 의한 영향에 대하여 조사하였다. 실험 결과 온도가 낮고 상대습도가 높을수록 폴리머의 형광 세기가 크게 나타났으며, 실험 환경의 온도와 습도 변화가 폴리머의 형광에 영향을 끼치기 까지 수 분의 시간 차가 존재하는 것을 확인하였다.

Keywords:

Conjugated polymer, Explosives detection, Photoluminescence quenching, Open environment

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P2-ap.229

Effects of structural phase transition on the luminescence properties of Eu-doped (1-x)$BaTiO_3$-x$CaZrO_3$

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Abstract:

Recently, multifunctionality that combine two or more desirable qualities in a single entity have recently drawn considerable attention. In this study, we investigated the structural phase transitions and luminescence properties of Eu^{3+}-doped (1-*x*)$BaTiO_3$-*x*$CaZrO_3$ (BCTZ:Eu) with varying *x* (0.00-0.15) which indicates Ca^{2+}/Zr^{4+} ion substitution. Also, we changed Eu^{3+} concentration in A-site designated as *y* (0.00-0.09). Herein, we carried out Rietveld refinement with obtained X-ray diffraction (XRD) pattern, scanning electron microscopy (SEM), energy dispersive X-ray spectroscopy (EDS), photoluminescence (PL), photoluminescence excitation (PLE), and Stark splitting analysis to discover the relation between structural and luminescent properties in BCTZ:Eu. Rietveld refinement results showed the changes of structural phases as increasing *x*. The SEM results were showing drastic increases of average grain size from 0.89 μm to 1.68 μm as increasing *x*. PL spectra of BCTZ:Eu were exhibited typical red-orange emissions that from *f-f* transitions of Eu^{3+} ions. The integrated PL intensity were increased as *x* increased. However, in the case of *y* variation, the integrated PL intensity showed complex behavior. The asymmetry ratio which gives information of local symmetry around the Eu^{3+} ions shows the same trend as the total PL intensity. We believed that phase transition changes the local environment around Eu^{3+} ions, which subsequently affects the luminescence properties of BCTZ:Eu. Furthermore, we compared the number of transition line splits that were highly dependent on structural symmetry, at *x* = 0.00 and *x* = 0.10. The observed number of splits was consistent with the structural phase changes that we found in Rietveld refinement. As a result, we concluded that the luminescent property of BCTZ:Eu can be controlled by composition-induced structural phase transition. These results suggest that BCTZ:Eu has potential for multifunctional material including ferro-, piezo-electricity and tunable luminescence.

Keywords:

BaTiO3, Perovskites, Optical properties, Spectroscopy

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Tailoring the interface with a multifunctional ligand for highly efficient and stable $FAPbI_3$ perovskite solar cells and modules

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Abstract:

Perovskite solar cells (PeSCs) using $FAPbI_3$ perovskite films often exhibit unfavorable phase transition and defect-induced non-radiative interfacial recombination, which result in considerable energy loss and impair the performance of PeSCs in terms of efficiency, stability, and hysteresis. In this work, we report a facile interface engineering strategy to control the surface structure and energy-level alignment of the perovskite film by tailoring the interface between the $FAPbI_3$ film and the hole-transporting layer using 4-hydroxypicolinic acid (4HPA). According to density functional theory studies, 4HPA has prominent electron delocalization distribution properties that enable it to anchor to the perovskite film's surface and facilitate charge transfer at the interface. By enabling multiple bonding interactions with the perovskite layer, including hydrogen bonds, Pb-O, and Pb-N dative bonds, the 4HPA passivation has significantly reduced the trap density and efficiently suppressed non-radiative recombination. The obtained perovskite films had superior optoelectronic properties with improved crystallinity, pure α-phase $FAPbI_3$ and favorable energy band bending. Following this strategy, 4HPA post-treatment PeSCs achieved a champion PCE of 23.28% in 0.12 cm^2 cells and 19.26% in 36 cm^2 modules with excellent environmental and thermal stabilities.

Keywords:

perovskite solar cells, solar modules, interfacial engineering, multiple bonds effect

P2-ap.231

Effect of a microneedle patch containing a conjugate of antibody and magnetic nanoparticles as a drug delivery system and target induction characteristics by attaching a permanent magnet

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Abstract:

A microneedle patch used as a means of a drug delivery system for transdermal administration was a circular needle stamp with a diameter of 11.5 mm in which 42 needles made of titanium alloy with a length of 0.75 mm were distributed at intervals of 1.0 mm. The hair on the back of BALB/c mouse was removed, and the left, right, and upper parts were separated on the spot, and 50 μg antibody-magnetic nanoparticle liquid phase was divided into 2 times for each area, 25 μg antibody-magnetic nanoparticle liquid phase. was dropped on the skin surface for each area and force was applied with a needle stamp. Antibody-magnetic nanoparticle liquid that is administered intravenously from the epidermis to the dermis and subcutaneous tissue as 1/3 of the total amount, considering the amount of antibody-magnetic nanoparticle liquid phase that is exposed to the outside when force is applied with a needle stamp. The amount was set at 100 μg. 100 μg of the liquid phase was administered through the skin surface for each area using a stamp needle patch, and 2 hours later, Concanavalin A (ConA) was administered at 5 mg/kg into the tail vein to induce inflammation. Serum collected by dissecting BALB/c mice after 4 hours was measured by ELISA protocol, and the concentration change analysis of interferon-gamma (IFN-γ) and interleukin-6 (IL-6) showed and confirmed a significant decrease in cytokine levels. In addition, a microneedle patch containing a magnetic nanobio CD3 antibody, a COVID-19 treatment, was administered transdermally, and the drug delivery system induction characteristics were compared and analyzed with a permanent magnet attached to the treatment target site.

Acknowledgements:
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Keywords:

microneedle patch, magnetic nanoparticles, antibody, immunotherapeutic drug delivery system, permanent magnet

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Formation of solid phase powder through polarity control of titanium suboxide for application to photovoltaic devices

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Abstract:

Metal oxide is currently widely used as an interfacial layer in next-generation solar cells due to its advantages of high transparency, thermal and chemical stability, and electrical homogeneity. However, limitations in the ambient stability and solution processability of metal oxide precursors prevent their widespread application. In this study, a new method for the solidification of sol-gel derived metal oxide-based organic composites was developed. Solid-state precursors (PTO) with excellent alcohol solubility were easily obtained by controlling the polarity of a conventional sol-gel derived titanium dioxide solution. The stability of PTO was greatly improved by the reduction of reaction residues. It also showed ideal optical and electrical properties as an electron transport layer. PTO is an optical spacer that enhances light absorption and forms selective charge extraction contacts to suppress recombination and traps at interfaces, improving overall solar cell performance. Owing to optical, electrical and film-forming properties of PTO, the stability and performance of PTO-applied organic and perovskite solar cells have been greatly improved.

Keywords:

Metal Oxide, Interface material, Organic solar cell, Perovskite solar cell

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Effect of conjugated small molecular electrolytes based on indolocarbazole for automatic formation of the electron transport layer in polymer solar cells

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Abstract:

Indolocarbazole (Ic) - based conjugated small-molecular electrolytes (CSMEs) with different numbers of amine groups were designed and synthesized. CSMEs are used to form an electron transport layer (ETL) via spontaneous phase separation in bulk-heterojunction (BHJ) solar cells. The self-assembled bilayer with a BHJ active layer on top and a CSME layer on the bottom is generated by a single coating step of one solution of CSME and BHJ active layer materials, CSME:PTB7-Th:$PC_{71}BM$. The location of CSME layer is confirmed by time-of-flight secondary ion mass spectroscopy (TOF-SIMS). The CSME layer plays a role as ETL, which reduces the work function (WF) of ITO effectively and leads to high power conversion efficiency (PCE) of the CSME-modified PSC. We also use X-ray photoelectron spectroscopy (XPS) to test the relative intensity of hydrogen bonds between the CSME and ITO. With the increased relative intensity of hydrogen bonds between the CSME and ITO, more effective spontaneous phase separation of the CSME/BHJ bilayer can be formed to generate the CSME layer on top of ITO, and the photovoltaic performance of the PSC enhanced. Out of the synthesized series of CSMEs (IcL4N, IcL6N, IcL8N, IcL10N, and IcB8N), IcB8N based device shows the highest relative intensity of hydrogen bonding and the highest PCE with a value of 7.09% without using any other ETL materials, which is the highest PCE value without using any other ETL in a separate processing step, in I-PSCs utilizing PTB7-Th/PC71BM. This study provides new strategies for designing ETL molecules that can reduce the number of processing steps required for device fabrication.

Keywords:

Conjugated small molecular electrolye , Electron transport layer , Single-step solution processing , Spontaneous phase separation , Interfacial layers

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P2-ap.234

Efficient and stable inverted perovskite solar cells via multifunctional additive engineering

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Abstract:

Fabricating high-quality perovskite films with large grain sizes and low defect densities is critical for developing efficient and stable perovskite solar cells (PeSCs). Herein, we report a simple and effective multifunctional additive engineering strategy for producing high-quality perovskite films. By including 2-hexyl-thiophene (2HT) with a thiophene electron-pair donor and a long hydrophobic alkyl chain as an additive in the perovskite precursor solution, we successfully obtained a perovskite film with high crystallinity, decreased trap density, and hindered ion migration. These features are attributed to the strong coordinative interaction between the sulfur atom in 2HT and Pb^{2+} in the perovskite film. The long alkyl chain of the 2HT additive assisted the production of a superior perovskite film with enlarged grain size, smooth surface topography, and hydrophobicity. Consequently, improved efficiency and prolonged operational stability are realized simultaneously for an inverted $MAPbI_3$ PeSC with the 2HT additive. The device with 2HT delivers a higher power conversion efficiency of 20.61% compared with that of the control device (18.65%) and exhibits negligible hysteresis. Moreover, the stability of the device with the 2HT additive is superior to that of the control device under various testing conditions.

Keywords:

defect passivation, crystallization modulation, MAPbI3

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P2-as.001

Time-variation of Amplitude and Phase of Chandler Wobble since 1900

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Abstract:

Instantaneous Earth's rotational pole does not exactly coincide with its principal axis but is deflected by small amount (several meters on the Earth's surface). This deflection is referred as polar motion. Main components of the Earth's polar motion are; 1) Chandler wobble, 2) annual wobble, and 3) slow drift. While the each causes of annual wobble and slow drift are clearly explained as seasonal perturbation and slow change in the Earth's inertia tensor, the cause of Chandler wobble has not yet been clarified but under debates. In this study we report the time-variation of amplitude and phase of Chandler wobble since 1900.

Keywords:

Chandler wobble

Fermionic Compact Objects in Horava-Lifshitz Gravity

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Abstract:

The mass-radius relations of fermionic compact objects are calculated in the Horava-Lifshitz (HL) gravity, a modified theory of gravity. The heavier and larger objects are made of fermions of lower energy, which is already known in general relativity (GR). However, the differences from GR are more easily observed by fermions of higher energy or the compact objects composed of them, since the HL gravity is designed as an ultraviolet complet theory of GR. Considering fermions of a given energy, a compact object composed of the fermions is getting more mass as the deviation from GR in HL gravity is getting larger.

Keywords:

Fermionic Compact Objects, Horava-Lifshitz Gravity

2023 KPS Spring Meeting
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P2-as.003

Development of cosmic neutron spectrometer

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Abstract:

A neutron spectrometer is developed to measure cosmic neutrons on the ground. The spectrometer is designed to measure neutrons in the energy range from thermal neutrons over hundreds of MeV. The spectrometer consists of nine He-3 tube-type thermal neutron detectors with eight different-size moderators. The spectrometer has been operated for months on the ground at Korea Research Institute of Standards and Science. The cosmic neutron spectrum has been measured. Analysis results and preliminary spectrum will be presented.

Keywords:

Cosmic netutrons, Neutron spectrometer

2023 KPS Spring Meeting
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P2-as.004

Atomic structure characterization for future gravitational wave detector's mirror coating material with ePDF analysis.

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Abstract:

The Advanced LIGO (aLIGO) detectors have successfully detected the first gravitational wave signal in 2015. Despite its success, detector's sensitivity is critically limited by coating Brownian noise in the most sensitive frequency band, around 100 Hz. In order to increase the sensitivity and detect signals from various astronomical sources, it is essential to reduce coating Brownian noise by optimizing the performance of future detector's mirror coating. To accomplish this goal, atomic structure characterization research of amorphous oxide coating material is in progress, to find the correlation between local atomic structures and the mechanical loss of mirror coating candidates. One promising track is via electron pair distribution function (ePDF) analysis using a transmission electron microscope (TEM) to investigate the short-range order (SRO) structural information. Previous studies have reported that atomic structure shows a strong correlation with the mechanical loss of mirror coating. In this poster, an introduction to the ePDF analysis is presented, followed by preliminary results for future candidate materials for the next-generation GW detector mirror coating.

Keywords:

Gravitational Wave, Electron pair distribution function, Atomic structure characterization, Advanced LIGO, Transmission electron microscope

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P2-as.005

The Camera System for IceCube Upgrade: Simulation Studies of the Antarctic Ice Properties

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Abstract:

The IceCube Neutrino Observatory, located at the geographic South Pole, has currently the largest volume among neutrino detectors. IceCube detects neutrinos using Cherenkov light emissions from charged particles produced in neutrino interactions. There is a necessity to study the Antarctic ice properties to reduce a major uncertainty of event reconstructions in IceCube. The IceCube neutrino observatory is currently upgrading by adding seven new strings with novel photodetection modules. The Neutrino Astro Particle Physics Laboratory(NAPPL), located in Sungkyunkwan University(SKKU), is currently running a mass production of camera systems which will be installed into the IceCube Upgrade for use in the calibration of Antarctic ice properties. We are generating simulated images for three separate measurement configurations(geometry, bulk ice and hole ice) with differing parameters of scattering and absorption length. These simulated images will provide valuable information on how precisely the camera system can measure the properties of Antarctic ice.

Keywords:

IceCube, IceCube Upgrade, Simulation

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P2-as.006

Production and Integration Status of the IceCube Upgrade Camera

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Abstract:

The IceCube Neutrino Observatory is currently the largest neutrino telescope from deep within the South Pole ice. An upgrade with new designs for Digital Optical Modules (DOMs) is being built, and one of the goals of the IceCube Upgrade is a precise characterization of the optical properties of the IceCube detector medium. The IceCube Upgrade Camera system is a multipurpose calibration tool to investigate those properties. Production of this novel camera system at Sungkyunkwan University, with more than 2000 produced, is nearing completion, and the process of integration into DOMs is underway. The cameras will be mounted in all of the three different DOM types and used for the upgrade. In this poster, a report on the production stages and status is introduced, especially with the process of testing camera characteristics in the production stage and the measurement results of all cameras. And also, integration of cameras into different types of DOMs and the status of the final acceptance tests are introduced.

Keywords:

IceCube, IceCube Upgrade Camera, IceCube Upgrade, Calibration, Camera Acceptance Test

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

P2-at.001

Quantum-Secured Single-Pixel Imaging Against Strong Noise and Counterfeit Attempt

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Abstract:

Non-classical correlations are the key resource for various quantum information protocols. For example, quantum entanglement is exploited for both quantum key distribution protocol and quantum ghost imaging, former for checking the security of the distributed keys and latter for enhancing signal-to-noise ratio beyond classical limit.
In this poster, we present the quantum-secured single-pixel imaging (QS-SPI) scheme that is robust against strong noise and can detect enemy's image counterfeit attempt. Exploiting time correlation of entangled photon pairs, we obtained target image under noise 1000 times stronger than signal. Exploiting polarization correlation, enemy's signal with fake image information can be detected by error rate greater than 25%.

Reference

[1] J. Heo, J. Kim, T. Jeong, Y. S. Ihn. D. Y. Kim, Z. Kim & Y. Jo, arXiv:2209.06365 (2022)

Keywords:

ghost imaging, single-pixel imaging, entanglement, correlation

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

P2-at.002

Optical polarization manipulation of stored light in warm atomic ensemble

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Abstract:

Quantum memory is a quantum interface that can elevate the feasibility and extensibility of quantum technologies based on photonic qubit. Researches on quantum memory for photon storage actively have been being performed using electromagnetically induced transparency (EIT) phenomena. Here, we introduce out research plans to make a quantum memory using EIT phenomena and to control of optical polarization properties of stored light by indirect all-optical phase modulation in thermal rubidium atoms.

Keywords:

Quantum memory, Electromagnetically Induced Transparency (EIT)

Electromagnetically induced absorption and transparency in Rb atoms with circular polarization of laser beams due to effects of neighboring transitions

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Abstract:

The effects of neighboring transitions on electromagnetically induced absorption (EIA) and electromagnetically induced transparency (EIT) in the D2 transition line in Rb atoms with respect to the same circular polarization configurations of coupling and probe lasers have been investigated. Spectra for the open F_g=2 → F_e=2 transition of ^{87}Rb and the F_g=3 → F_e=2 and 3 transitions of ^{85}Rb exhibit EIA due to the neighboring effect of F_g=2 → F_e=3 and F_g=3 → F_e=4 transitions, respectively. However, EIT is observed for the open F_g=2 →F_e=1 transition of ^{87}Rb due to greater hyperfine energy splittings of ^{87}Rb and weaker neighboring effects than those of ^{85}Rb. We confirm that EIT in the case of $F_g > F_e$ for ^{87}Rb for the same circular polarization configuration transforms into EIA due to the magnitude of the neighboring effects with a decrease in the hyperfine energy splittings.

Keywords:

eia, eit, neighboring effect

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

P2-at.005

Probing the Electric Field Sensitivity of Rydberg Atoms using Electromagnetically Induced Transparency

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Abstract:

In this study, the development of a spectroscopic measurement device for Rydberg atom-based electric field measurement is introduced. Since the Rydberg atom has an electrical polarization proportional to the 7th power of the principal quantum number, it is possible to create a quantum state that is very sensitive to electric fields. Electromagnetically Induced Transparency (EIT) technology is a method that can measure precise atomic spectroscopy with a narrow linewidth using quantum interference. The Stark shifted energy levels were measured by applying an internal and external electric field to a rubidium vapor cell containing electrodes.

Keywords:

Rydberg atom, Stark effect, Electromagnetically Induced Transparency

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

P2-at.006

Microfabricated rubidium vapor cell filled with nitrogen buffer gas

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Abstract:

Microfabricated vapor cells are key components of chip-scale atomic instruments such as atomic clocks and magnetometers. For applications in which atomic coherence between the ground states are employed, buffer gas plays an important role by impeding depolarization induced by collision of atoms with the glass wall. The optimal pressure of the buffer gas, which is usually nitrogen for rubidium cells, is larger for smaller cells, often reaching atmospheric pressure or beyond for microfabricated cases.
Here we present a fabrication result of microfabricated rubidium cells with nitrogen pressure of hundreds of torr. We also estimate the actual pressure of nitrogen in the vapor cell by spectroscopic analysis such as linear absorption profile and frequency shift of the clock transition measured by coherent population trapping.

Keywords:

optically pumped magnetometer, microfabricated vapor cell, coherent population trapping

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

P2-at.007

Delta-kick cooling of an atomic sample via Rb 2-photon transition for atom-based quantum sensors

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Abstract:

Atom-light interaction in free-space is well studied and is often used to manipulate the motional and internal state of atoms for quantum preparation and control. In this study we utilize near-resonant light interacting with a dense atomic sample for collective-mode excitations of a ^{87}Rb BEC in a magnetic trap. This motion can be driven by abruptly modifying the atom-atom interaction energy via reduction of the BEC atom number density.
We use the 778 nm Rb two-photon transition from $5S_{1/2}$ to $5P_{3/2}$ to remove atoms from the BEC with minimal change of the spatial atomic density distribution, resulting in a breathing motion of the atomic cloud. We show that the breathing motion controlled from homogeneous density manipulation by the two-photon optical transition can provide an optimal ultra-cold atomic sample for atom-based quantum sensors such as an atom gravimeter.

Keywords:

BEC, collective-mode excitation, ultra-cold atom, atom-based quantum sensor

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

P2-at.008

Spectroscopy of $^{2}D_{3/2}$ -$^{3}D[3/2]_{1/2}$ transition in the $^{174}Yb^{+}$ trapped ion

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Abstract:

포획된 이온의 내부 전이선을 이해하는 것은 최적의 레이저 냉각 및 큐비트 전이선 조작을 위해 필수적이다. 본 포스터 발표에서는 자체 제작된 이온 트랩 장치에서 $^{174}Yb^{+}$의 $^{2}S_{1/2}$ - $^{2}P_{1/2}$ 전이선에 대한 분광 결과와 $^{2}D_{3/2}$ - $^{3}D[3/2]_{1/2}$ 전이선에 대한 분광 결과를 보고한다. 자기장의 세기를 변화함에 따라 Zeeman 천이의 세기가 바뀌었고, 정량 분석을 통해 이온에 가해진 자기장의 크기를 추출하였다. Zeeman 에너지 레벨 사이의 결맞은 상태 잠금(coherent population trapping)현상이 유도하는 불안정성에 대해서도 논의한다.

Keywords:

174Yb+, 2D3/2 -3D[3/2]1/2, 2S1/2 - 2P1/2, Zeeman effect

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2023-04-19 - 2023-04-21

P2-at.009

A cryogenic ion-trap system

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Abstract:

극저온 냉동 시스템을 이용하면 대규모 이온 큐비트를 포획할 수 있다. 본 발표에서는 10켈빈 이하에서 작동하는 극저온 이온 트랩 시스템 개발에 대해 소개한다. 알루미나 기판에 금 코팅을 하여 3차원 포획용 칩을 제작하였다. 냉동기 내부에 이온이 포획되는 공간과, 고개구수 렌즈, 나선형 공진기 등이 위치하는 공간을 분리하여 이온이 포획되는 공간의 진공도를 향상시키고 온도를 최대한 낮추었다. 현재의 실험 진행 상태 및 CMOS foundry 공정을 이용한 소자와 이온 트랩 시스템의 결합 등에 대해 논의한다.
*These authors contributed equally to this work.

Keywords:

ion trap, cryogenic system, Ytterbium ion

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2023-04-19 - 2023-04-21

P2-at.010

Design and Construction of Cryo-based Yb+ Quantum Computer

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Abstract:

In this presentation, we present our progress on building a trapped ytterbium-ion-based quantum computer utilizing mechanically stable cryostat and modular component design. The compact core chamber is designed to be vacuum-pulled by cryo-pumping and differential pumping. 4-rod trap inside the core-chamber provides deep trap depth and large optical access. All systems to control trapped ions including DC/RF electronics to trap and manipulate ions, CW lasers for laser cooling and state preparation, Raman lasers to perform high-fidelity quantum gates are all designed to be modular to improve scalability and reproducibility. Software and hardware stacks are established by a programmable FPGA-based control system called ARTIQ.

Keywords:

Ion trap, Quantum computing, Quantum information, Atomic physics

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

P2-at.011

Trapping Barium ions for Quantum Memory and Quantum Computers

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Abstract:

In this presentation, we report the progress on building an ion trapping experimental apparatus for quantum memory and computing. Barium-ions are appropriate candidates for the quantum memory with a long coherence time and the relatively long transition wavelength which is easy to be converted to the telecom wavelength. The system for trapping barium ions consists of a UHV chamber, a tungsten 4-rod ion trap, a stable atomic barium source, an objective lens designed with high numerical aperture and the frequency-stabilized light sources. The overall system including RF/DC potentials and lasers is remotely accessible via local network and serial communications and key information such as vacuum pressure is automatically logged onto the network-based database. We report the result on our first trapped barium ions and discuss further system development to realize ion-photon quantum interface and quantum operations on Barium ions.

Keywords:

Quantum Optics, Ion Trap, Quantum Network, Quantum Information, Barium

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2023-04-19 - 2023-04-21

P2-at.012

Design of individual detection and control systems for a scalable trapped-ion quantum computer

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Abstract:

Trapped ion quantum computers typically use closely spaced chain of atomic ions that are a few micrometers apart as qubits, and laser beams as control fields [1,2]. Therefore, the detection and manipulation of individual qubits require carefully designed optical systems that operate close to the diffraction limit. In this work, we will discuss the design and preliminary characterization results of an individual qubit measurement system with a fiber array [3]. Also, we will present an optical system consisting of acousto-optic deflectors (AODs) for individually addressing single qubits in a small ion chain [4]. These advancements are crucial for the development of a scalable trapped-ion quantum computer.

1. Benhelm, J., Kirchmair, G., Roos, C. et al. Towards fault-tolerant quantum computing with trapped ions. *Nature Phys* **4**, 463–466 (2008)
2. Debnath, S., Linke, N., Figgatt, C. et al. Demonstration of a small programmable quantum computer with atomic qubits. *Nature* **536**, 63–66 (2016)
3. R. F. Spivey et al., High-Stability Cryogenic System for Quantum Computing With Compact Packaged Ion Traps, *IEEE Transactions on Quantum Engineering*, vol. 3, pp. 1-11, Art no. 5100111 (2022)
4. I. Pogorelov et al, Compact Ion-Trap Quantum Computing Demonstrator, *PRX Quantum* 2, 020343 (2021)

Keywords:

trapped ions, quantum computer, acousto-optic deflector (AOD), fiber array

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

P2-at.013

Indistinguishability of photons in spontaneous and stimulated four-wave mixing processes from two atomic ensembles

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Abstract:

Complementarity in quantum optics is essential for fundamental research on quantum physics and quantum information processing applications. Induced-coherence experiments in the context of single-photon interference focused on which-path information and the role of vacuum fields in realizing complementarity via reduced visibility in single-photon interference. Here we report the demonstration of experiments comparing induced and stimulated coherence by using two coupled interferometers based on spontaneous four-wave mixing (SFWM) in two independent hot-atomic-vapor-based entangled photon sources. We investigate the two-photon interference between two signal photons from two independent Rb atomic vapor cells, responsible for the photon bunching effect and stimulated emission. We believe that the long induced-coherence effect via SFWM from atomic ensemble can be applied to various quantum optics applications such as quantum imaging and quantum communication.

Keywords:

quantum optics, complementarity, induced coherence, stimulated four-wave mixing

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

P2-at.014

Dynamical generation of skyrmions from a domain wall in ferromagnetic spinor Bose-Einstein condensate

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Abstract:

Skyrmions are important topological objects in solid-state physics, especially in the emerging field of spintronics as future data storage applications. In this poster, we report the dynamical generation of skyrmions from a magnetic domain wall (DW) in a ferromagnetic spin-1 superfluid. The Li-7 condensate with a single magnetic DW (m_F=0 state) separating the spin-up domain (m_F=+1 state) and the down domain (m_F=-1 state) is prepared in the easy-axis ferromagnetic (EAF) phase. If a spin current bigger than some critical value is applied along the DW, flutter finger patterns and small isolated spin islands immersed in the opposite spin domain are observed [1]. With simultaneous readout of the magnetization in vertical and horizontal axes and matter-wave interference, we found spin winding and phase singularity for the observed islands, which are identical to skyrmions with Q=1. Investigating the underlying mechanism of skyrmion generation, a critical spin current for skyrmion generation corresponding to the threshold for quantum Kelvin-Helmholtz instability, and the finite lifetime of skyrmions are observed.

[1] H. Takeuchi, Physical Review A **105**, 013328 (2022).

Keywords:

Spinor BEC, Skyrmion, Ferromagnetic superfluid, Dynamical generation

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

P2-at.015

Topological band engineering of a one-dimensional optical lattice system with resonant shaking

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Abstract:

Floquet engineering is a novel way to generate new properties out of a system. We study the topological band of a resonantly shaken one-dimensional optical lattice system, where the lattice potential is periodically modulated to couple the two lowest Bloch bands. In a two-band approximation, we numerically demonstrate that the periodically driven system can exhibit non-trivial topological properties in its band structure, as evidenced by edge states, Zak phases, and the topological charge pumping effect. Finally, we discuss the experimental feasibility of realizing a flat band in the shaken lattice system.

Keywords:

Floquet engineering, topological band, flat band

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

P2-at.016

Degenerate NaK Molecular Gases

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Abstract:

Ultracold quantum gases provide an ideal test ground for simulating complex many-body quantum behavior. Especially, the creation of degenerate gases of dipolar molecules will give access to novel quantum phases of matter such as exotic superfluids and quantum crystals. Additionally, this will also enable the realization of quantum computing platforms based on molecular qubits.
In this poster, we present our latest progress towards creating a degenerate gas of strongly dipolar fermionic/bosonic $^{23}Na^{40,41}K$ molecules. To this end, we created quantum mixtures of Na and K atoms and investigated their interspecies Feshbach resonances in an oblate optical dipole trap. After Feshbach molecules are created, a narrow linewidth Raman laser system will be implemented to transfer the NaK Feshbach molecules to their absolute ground state. Further experimental advancements and outlooks will be presented.

Keywords:

Ultracold quantum gases, Dipolar, Molecules, Fermionic/Bononic, Feshbach resonance

2023 KPS Spring Meeting
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P2-co.101

Antiferromagnetic resonance in the layered antiferromagnet $CrCl_3$

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Abstract:

We report microwave transmission spectroscopy of the layered antiferromagnet chromium chloride ($CrCl_3$) using Nb superconducting microwave transmission line made from Nb thin film. $CrCl_3$ is an antiferromagnet with two magnetic sublattices below the Néel temperature. The net magnetization direction alternates between layers, with parallel alignment within the same layer and antiparallel alignment between adjacent layers. A $CrCl_3$ flake was transferred on top of a coplanar transmission line. The measurement was then carried out in a cryostat at various temperatures. The microwave transmission coefficient was measured using a network analyzer as a function of static magnetic field and temperature. Depending on the magnetic field direction, we observed different resonant features. Only acoustic mode of antiferromagnetic resonance was observed when the DC magnetic field is applied perpendicular to the RF field, but both optical and acoustic modes were observed when the DC magnetic field is applied parallel to the RF field. In this work, we analyzed the origin of the two modes.

This work is supported by the National Research Foundation of Korea (NRF) Grant funded by the Korean Government (NRF-2020R1A2C1008448, 2021R1A2C1011046, and 2022M3E4A1069445) and DGIST R&D Program of the Ministry of Science, ICT, Future Planning (22-CoE-NT-02, 22-IT-01 and 23-KUJoint-01). This work was supported by Institute for Information & communications Technology Promotion (IITP) grant funded by the Korea government (MSIT) (2021-0-01511).

Keywords:

Antiferromagnetic resonance, Microwave transmission

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P2-co.102

Novel Stacking Methods with Minimal Polymer Residues

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Abstract:

After the invention of the dry-transfer method, systematic transport measurement of 2D materials has provided the primary signature of intriguing phases. Since these phases require more intricate structures, the number of layers has been continuously increased. Due to the potential threat of rotational misalignment, we strongly recommend pausing the process midway to check whether it is done correctly. Moreover, fragile parts such as twisted or rhombohedral stacked graphene are highly sensitive to friction or stress during the stacking process, so we are not willing to stack additional flakes beneath these parts. To address these issues, most groups currently separate the stacking process into bottom gate parts and remaining parts. The bottom parts are cleaned through an annealing process, and the remaining parts, which have delicate layers, are smoothly dropped onto the bottom parts. However, polymer residue between the layers of the topmost bottom parts cannot be completely removed and may interfere with the delicate signal. Therefore, we need to develop novel techniques that offer a "flip" without unwanted residues. Here, we will discuss flipping methods that avoid disturbing polymer residues. We will introduce two techniques: (i) PPC to PC transfer and (ii) SiNx-assisted transfer. Using these methods, we can flip heterostructures, especially for clean graphene devices. Furthermore, these techniques do not require an annealing process to remove the polymer, and we can expect them to be useful in complicated twisted systems such as double twisted layer graphene systems.

Keywords:

Dry-transfer method, Graphene Fabrication

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2023-04-19 - 2023-04-21

P2-co.103

Progress in Calibration of Graphene-based Josephson Junction Detector for Dark Matter Search

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Abstract:

Graphene-based Josephson junction have been suggested as a promising platform for the detection of low energy such as microwave single photon and super-light dark matter because of the exceptional low electron heat capacity of graphene and strong temperature dependence of switching current of Josephson junction. Recently, we propose a new strategy for detecting super-light dark matter with masses as low as 0.1 keV, using graphene-based Josephson junction detectors [1]. Here, we present a calibration method based on microwave mixing pulses with different energies, and demonstrate how the thermal relaxation time of the detector can be probed by exciting it with two time-delayed pulses. This calibration allows for the precise determination of the mass region of dark matter that the detector can detect.

[1] https://doi.org/10.48550/arXiv.2002.07821

Keywords:

Graphene-based Josephson junction, Dark-matter

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P2-co.104

Observation of band renormalization in surface-doped black phosphorus

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Abstract:

The electronic band structure of a crystalline solid is based on the periodic arrangement of constituent atoms. In the case of a material system that lacks long-range order but has short-range order, coherent parts of electron waves still form a band structure. Theoretical models for the band structure of short-range ordered systems, such as liquid metals, were developed in the 1960s, which predicted intriguing back-bending energy-*k* dispersion and pseudogap in the density of states at resonance scattering. [1] However, there is little experimental knowledge about band renormalizations caused by short-range order. We present the discovery of such band renormalizations on surface-doped black phosphorus employing angle-resolved photoemission spectroscopy (ARPES). The electrons doped to the surface of black phosphorus undergo multiple scattering from the potential of dopant ions with the short-range ordered distribution. Furthermore, tuning the depth of scattering potential by using different kinds of alkali metal dopants (Na, K, Rb, and Cs) allows us to classify the pseudogap of *p*-wave and *d*-wave resonance. [2]

[1] Anderson, P. W. & McMillan, W. L., In Proc. International School of Physics “Enrico Fermi” Course 37 (ed. Marshall, W.) 50–86 (Academic, 1967).
[2] S. H. Ryu, M. Huh, D. Y. Park et al., Nature 596, 68-73 (2021).

Keywords:

ARPES, black phosphorus, short-range order, pseudogap

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P2-co.105

Ag 박막의 성장 조건 연구

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Abstract:

Ag 박막은 구리와 더불어 대표적인 전도물질이다. Ag 박막은 구리와 달리 산화에 강하기 때문에 황 등으로 오염되어 은을 사용할 수 없는 특수한 환경을 제외하고는 신뢰성을 담보할 수 있다. Al_2O_3 (006) 웨이퍼를 기판으로 사용하고 기판과 Ag 박막 사이에 버퍼층이 없는 경우와 ZnO, Cu 등 두 종류의 버퍼층을 사용하여 성장시킨 결과를 비교하였다. Extended atomic distance mismatch (EADM) 방법을 이용하여 박막의 성장가능성을 사전에 계산하였다. 박막의 결정성, 표면 거칠기 등은 X-선 회절픽의 반치폭, AFM 및 Electron backscatter diffraction (EBSD) 분석을 통해 비교하였다. 버퍼층을 사용한 경우 표면 거칠기가 매우 작고 결정성이 좋은 고품질의 박막의 성장이 비교적 쉽게 이루어졌다. 이는 EADM 결과와도 잘 일치하였다. 반면 버퍼층을 사용하지 않는 경우 고품질 박막의 성장이 잘 이루어 지지 않았으나 EADM 계산을 통해 성막 가능성을 확인하여 증착 조건을 달리하며 증착을 시도한 결과 epitaxy 박막을 제조하는 것에 성공하였다. 기존 연구에서 Al2O3의 경우 epitaxy 박막의 증착이 어렵다고 보고되었으나 박막의 증착 전에 EADM 계산을 통해 가능성을 사전에 예측하여 증착 실험을 진행 함으로써 박막 증착의 효율성을 높일 수 있었다.
이 논문은 삼성전자 미래기술육성센터의 지원 (SRFC- MA2202-02) 과 2022년도 정부(교육부)의 재원으로 한국연구재단의 지원(NRF-2022R1I1A1A01071367)을 받아 수행된 연구임

Keywords:

Ag thin film, buffer layer, EADM, metal thin film

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2023-04-19 - 2023-04-21

P2-co.106

Local Structural Properties of Epitaxaillly-Grown CoO Films

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Abstract:

Rock-salt CoO is known as a direct transition p-type semiconductor and the bandgap is ~2.6 eV. Rock-salt CoO is antiferromagnetic and paramagnetic below and above the Néel temperature of approximately 293 K, respectively. The Néel temperature can be lowered to 225 K by reducing the particles size of CoO and raised up to 525 K by substituting Ni atom for the Co sites. Prior studies reported that CoO experienced an insulator-to-metal transition (MIT) at high pressures, which was accompanied by a magnetic collapse. Magnetic film/CoO bilayers showed the specific magnetic properties of exchange bias. Recent studies show practical applications of CoO-based materials, including catalysts, rechargeable batteries, and memory devices. However, the fabrication of CoO with stable and high quality still needs a laborious task.

We will present the epitaxial growth of CoO (111) and (100) films on α-Al_2O_3 substrates, using radio-frequency sputtering deposition. The structural properties of the CoO films were examined using X-ray diffraction (XRD), X-ray absorption fine structure (XAFS), and canning transmission electron microscopy (TEM). XRD revealed that both CoO(111) and CoO(100) crystals have a rock-salt structure (Fm3m) with the lattice constants of 4.2477 Å and 4.2617 Å, respectively. Full-width at half maximum (FWHM) of XRD from the CoO(111) films indicated a lack of structural residual strain, meanwhile CoO(100) films have substantial amount of the structural strain which exists in the films. Transmission electron microscope (TEM) measurements revealed that both CoO(100) and CoO(111) films have structural disorder and distortion within couple of monolayers developed near the interfaces of the film/substrate. XAFS revealed that there are O and Co vacancies at the initial growth stage and the vacancies are mostly disappeared when the films are thicker than 10 nm. The growth mechanism and the interfacial and the local structures are essentially important to understand the physical and chemical properties of CoO.

Keywords:

CoO, XAFS, epitaxial growth, local structures

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2023-04-19 - 2023-04-21

P2-co.107

Supramolecular Networks of Azobenzene Molecules with Br and OH Ligands on Au(111)

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Abstract:

Supramolecular networks with halogen bonds have become the subject of active study in functional molecular systems due to their unique complementary role to hydrogen bonds. Azobenzene is a promising functional molecule that possesses photo-switching capability, yet its supramolecular networks with halogen bonds remain largely unexplored. Here, we report on the supramolecular structures of 4-bromo-4'-hydroxyazobenzene on Au(111), studied using scanning tunneling microscopy (STM). Our study reveals that sub-monolayer molecular films exhibit a range of patterns, including triangles, hexagons, and stripes. Based on the STM images, we proposed molecular models of these structures, which were found to be stabilized by both hydrogen bonds (O-H and Br-H) and halogen bonds (Br-Br). Our findings suggest that halogen bonds play a comparable role to hydrogen bonds in the formation of supramolecular networks of photo-switchable molecules on metal surfaces. This study provides valuable insights into the behavior of azobenzene-based supramolecular networks, and highlights the potential of halogen bonds as a tool for the design and construction of functional molecular systems.

Keywords:

scanning tunneling microscope, supramolecular network, hydrogen bond, halogen bond

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2023-04-19 - 2023-04-21

P2-co.108

Defect evolution difference on graphene between He^{+} and He^{++} irradiation with the same energy and the same dose.

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Abstract:

When ion beam irradiates on graphene, defects are produced and the defects are related to the ion irradiation energy, dose, and ion species. When He^{++} ion irradiates on graphene with the energy of 60 keV in the electrostatic acceleration tube, the final irradiation energy is 120 keV which is the same energy of He^{+} ion with 120 keV. Although the mass difference between He^{+} ion and He^{++} ion is negligible, the defect evolution on graphene shows considerable difference. We discuss the origin of the defect evolution difference between He^{+} ion and He^{++} ion irradiation.

Keywords:

Defect evolution, Ion Beam, Graphene

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2023-04-19 - 2023-04-21

P2-co.109

Surface characterization of YPc_2 molecular spin qubit candidates on Cu (111)

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Abstract:

Lanthanide-based phthalocyanine double deckers ($LnPc_2$) have been intensively investigated due to their potential as molecular magnets and spin qubit candidates [Nat. Chem. 11, 301 (2019)]. Among this class of molecules, Yttrium phthalocyanine double deckers (YPc_2) are characterized by the absence of localized f-electrons, hence their microscopic properties are mainly associated with the presence of an unpaired electron (S=1/2) delocalized on the molecular scaffolds. For this reason, YPc_2 allows investigation of the spin dynamics associated only with this unpaired electron spin, independently from the one due to f-electrons [Phys. Rev. B 83, 174419 (2011)]. In addition, due to their robust molecular structure, LnPc2 tend to preserve their electronic state on metal surfaces [Prog. Surf. Sci. 89, 127 (2014)]. These properties make YPc_2 a promising system for combined surface science and electron spin resonance (ESR) experiments.

Here, we investigate the composition, surface adsorption, and electronic structure of YPc_2 on Cu(111) using Auger electron spectroscopy (AES), scanning tunneling microscope (STM), and low-energy electron diffraction (LEED). We sublimated sub-mono layers of YPc_2 on Cu(111) in ultra-high vacuum by means of thermal evaporation, and calibrated the amount by acquiring AES and low-temperature STM images (T~100K). By analyzing the peak intensity of carbon, nitrogen, and copper, we found the optimal sublimation parameters to deposit a monolayer of YPc_2 without altering its stoichiometry. The adsorption geometry and orientation are inferred by comparing STM images of YPc_2 on Cu(111) to those of TiOPc on Cu(111). Our study validates the idea of using YPc_2 as potential surface-adsorbed molecular spin qubits.

Keywords:

STM, AES, YPc2, Cu on sapphire, LEED

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P2-co.110

Observation of the Berry curvature dipole signal in the group-IV monochalcogenides

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Abstract:

Two-dimensional (2D) van der Waals crystals have attracted considerable interest not only for the study of fundamental physical properties but also for their potential for application in devices. Black phosphorus has a honeycomb network like graphene, but it is regularly modulated to form a so-called puckered honeycomb structure. This structural anisotropy of black phosphorus results in interesting consequences for the band structure of black phosphorus and its electronic and optical properties. The puckered honeycomb structure is not unique to black phosphorus but common to other 2D van der Waals crystals. The group-IV metal monochalcogenides, the so-called MX materials, also have the puckered honeycomb structure. The main difference between BP and MX is that MX is made of two elements. It was theoretically predicted that inversion-symmetry broken BP exhibits a nontrivial Hall current and a Berry curvature dipole. In this work, we investigate two MX materials, SnS and SnSe, using angle-resolved photoemission spectroscopy (ARPES). We found a signature of broken inversion symmetry, which is interpreted in terms of the finite Berry curvature dipole.

Keywords:

Berry Curvature Dipole, Inversion symmetry breaking, ARPES, Surface state, Group-IV monochalcogenides

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P2-co.111

Turing Machine Algorithm Demonstrated by DNA Molecules

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Abstract:

Turing machines (TMs) are simple computable machines that execute certain algorithms using carefully designed logic gates. We investigate Turing algorithms for the generation of patterns on algorithmic lattices using specific logic gates. Logic gates can be implemented into Turing building blocks. We discuss comprehensive methods for designing Turing building blocks to demonstrate an M-state and N-color Turing machine (M-N TM). The M-state and N-color (M-N = 1-1, 2-1,1-2, and 2-2 TMs generate Turing patterns that can be fabricated via DNA algorithmic self-assembly. The M-N TMs require two-input and three-output logic gates. We designed the head, tape, and transition rule tiles to demonstrate TMs for the 1-1, 2-1, 1-2, and 2-2 Turing algorithms. The total number of possible rules [(2 ´ M ´ N) $^{M \cdot N}$] for the 1-1, 2-1, 1-2, and 2-2 TMs are 2, 16, 16, and 4096, respectively. By analyzing the characteristics of the Turing patterns, we classified them into two classes (DL and DR for states grown diagonally to the left and right, respectively) for the 1-1 TM, three for the 2-1 TM, and nine for the 1-2 TM. Among these, six representative Turing patterns generated using rules R11-0 and R11-1 for 1-1 TM, R21–01 and R21–09 for 2-1 TM, and R12–02 and R12–08 for 1-2 TM were constructed with DNA building blocks. A 2-state 2-color TM requires a 2-input (i.e. head state and tape color) 3-output (i.e. head state, tape color and head position) logic scheme. We designed three types of rule tiles, including 64 head, 3 tape and 7 transition rule tiles, which can demonstrate all 4096 rules in the 2-state 2-color Turing algorithm using just 48 DNA strands. We discuss six representative Turing patterns, including null, triangular, sequential, diagonal, occupied-extended and unoccupied-extended patterns (ruled by R0000, R4095, R3024, R0982, R1971 and R2506, respectively) on DNA lattices. Turing patterns on DNA lattices were observed using atomic force microscopy (AFM). The overall experimental pattern characteristics obtained by AFM images agree well with the simulated patterns. Although most patterns that compute specific functions with any initial values were asymmetric, the experimental patterns exhibited remarkable similarities to the simulated patterns. Our rule tile design scheme with specific binding domains can be extended t**o demonstrate the generalized N-state N/M-color TMs by considering rule regulations in the** Turing algorithm. Thus, efficient molecular computers with understanding operational mechanisms can be constructed.

Keywords:

DNA Self-assembly, algorithm, Turing machine, two-input and three-output, logic gate

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2023-04-19 - 2023-04-21

P2-co.113

Terminal Topography by Linear Chain Polymerization

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Abstract:

The growth mechanism of linear chain polymerization by vapor deposition was investigated based on dynamic scaling analysis of atomic force microscopy images of polymer films grown simultaneously on liquid and solid substrates. This controlled experiment is designed to provide critical information about whether the subsequent growth front of a polymer film is dependent on the height, local and/or surrounding properties of a given previous growth surface. The average global slope of the surface structure evolved along different pathways on different substrates meets at the characteristic value and remains the same, reaching a “terminal topography” within the steady growth regime above d=200 nm where the propagation/initiation ratio stabilizes. Terminal topography, a coarse-grained representation of the surface structure, occurs independently of growth conditions and is an inherent property of linear chain polymer films in which film growth is governed by chemical reaction-limited aggregation.

Keywords:

Parylene, Kinetic roughening, Polymer film growth, Reaction limited aggregation, Vapor deposition polymerization

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

P2-co.201

Hund's metallicity and self-doping enabled double-exchange ferromagnetism in 1T-$CrTe_2$

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Abstract:

1T-$CrTe_2$ is a van der Waals ferromagnetic metal that has recently gained substantial interest as a promising spintronics device owing to its high applicability from high Curie temperature (T_C) down to atomically thin-film form, wafer-size fabrication, and intriguing transport phenomena. Although its ferromagnetism can be intertwined with the orbital-dependent electron correlation, it is poorly understood in 1T-$CrTe_2$, hindering further applicability of this material. Here, we show that Hund's metallicity and self-doping enabled double-exchange ferromagnetism in 1T-$CrTe_2$. Employing density functional theory plus dynamical mean-field theory (DFT+DMFT), we show that Cr-*d* orbitals exhibit highly different electron correlation, albeit they are all metallic. We found that while self-doping together with considerable hybridization is responsible for the itinerant nature of e_g electrons, Hund's metallicity promotes the formation of local moments of t_{2g} electrons. The double-exchange ferromagnetism in 1T-$CrTe_2$ thus can be facilitated through the interplay between itinerant e_g and localized t_{2g} electrons via Hund's coupling. Finally, some experimentally observable quantities are examined to provide the underlying physics thereof.

Keywords:

Hund's metal, DFT+DMFT, vdW 2D magnet

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P2-co.202

Simulating two-dimensional square J_1-J_2 Ising model via quantum annealing

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Abstract:

Efficient methods to numerically solve frustrated low-dimensional spin models in the zero-temperature limit are crucial in the study of magnetism. Conventional methods such as Metropolis algorithm or simulated annealing yield good solutions in most cases, but close to critical points such methods suffer critical slowing down. In this work we employ quantum annealing method, running on D-Wave quantum processing unit, to study frustrated J1-J2 Ising model on a two-dimensional square lattice. We compare quantum and classical simulated annealing methods for magnetization, suceptibility, energy and we found quantum annealing has more efficient for local minimum problems. and we also discuss setting parameter about chain, embedding, annealing time for better quantum annealing calculation

Keywords:

Quantum Annealing, Simulated Annealing, J1J2 Isingmodel, Frustrated Magnetism

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2023-04-19 - 2023-04-21

P2-co.203

First-principles study on Small Polaron and Li diffusion in layered $LiCoO_2$

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Abstract:

Li-ion conductivity is one of the essential properties that determine the performance of cathode materials for Li-ion batteries. Here, using the density functional theory, we investigate the polaron stability and its effect on the Li-ion diffusion in layered $LiCoO_2$ with different magnetic orderings. The localized Co^{4+} polaron appears in the magnetic configurations and sets the Li-diffusion barrier of ~0.34 eV. The polaron also migrates in the opposite direction to the Li-diffusion direction. On the other hand, the polaron does not form in the non-magnetic structure, and the Li diffusion barrier without the polaron is 0.21 eV. Although the existence of the polaron increases the diffusion barrier, the magnetically ordered structures are more energetically stable during the migration than the non-magnetic case. Thus, our work advocates the hole polaron migration scenario for Li-ion diffusion. Moreover, we demonstrate that the strong electron correlation of Co ions plays an essential role in stabilizing the Co^{4+} polaron.

Keywords:

Li2CoO2, polaron, Li-ion battery, first principle calculation, PBE+U functional

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P2-co.204

Angular momentum dynamics in Density Functional Theory

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Abstract:

In quantum mechanics, there are two types of angular momentum: orbital angular momentum and spin angular momentum. When we add both of them, we call them total angular momentum. We developed an orbital angular momentum calculation code and we will show the validity of this code by showing orbital angular momentum quantum number l in a single atom case. We can also get the total angular momentum J with the noncollinear, spin-orbit coupling DFT. In principle, the total angular momentum quanta also can be validated from a single atom. Finally, we will show the orbital angular momentum and spin angular momentum dynamics in a 1-dimensional chiral chain under an external field by real-time TDDFT.

Keywords:

Density Functional Theory, Angular momentum, real-time Time Dependent Density Functional Theory

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P2-co.205

Unraveling Complex Phases in TaS_2 through DFT Calculations

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Abstract:

The phase diagram of tantalum disulfide (TaS2) is investigated using a combination of experimental techniques and theoretical calculations. X-ray diffraction and thermal analysis reveal multiple phase transitions as a function of temperature and pressure. However, in high temperature, It was not clearly identified for the origin of each phases. In this study, we will identify the phase diagram of TaS_2 under variation of temperature and pressure using molecular dynamics. The phase diagram of TaS2 is important for understanding the behavior of this material in a variety of applications, including electronic and optical devices, and we will provide a framework for predicting and controlling its properties under different conditions.

Keywords:

Density Functional Theory, Tantalum Disulfide

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P2-co.206

Investigating Electrocatalytic Systems using Random Phase Approximation

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Abstract:

Random phase approximation (RPA) is one of the most accurate quantum chemical theories readily applicable and computationally challenging but feasible for application to condensed matter physics. RPA is a perturbative approach based on electron density fluctuations that approximate the system's response to an external perturbation as a sum of contributions from individual particle-hole excitations. Due to RPA's high computational costs and unfavorable numerical convergence, the application of RPA to condensed phase physics is, to date, still a challenging task. Here we utilize extrapolation schemes to fully converge RPA calculations and apply them to the study of electrocatalytic systems. We compare in detail the performance of RPA with experimental results and other density functional theory calculations.

Keywords:

Random Phase Approximation, Quantum Chemistry, Condensed Matter Physics, Particle-Hole Excitation, Computational Physics

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P2-co.207

First-principles study of the quasi-two-dimensional electron gas at $LaInO_3/BaSnO_3$ interfaces

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Abstract:

We investigate atomic and electronic properties of $LaInO_3/BaSnO_3$ (LIO/BSO) heterostructures using first-principles density functional theory and tight-binding modeling of the frontier orbitals. The charge transfer from the topmost layer of LIO to the interfacial BSO is observed as increasing the thickness of the LIO layers. The spatial distribution of the interfacial charge density profile as a function of LIO thickness is also investigated. The charge density profile as a function of the charge transfer is further investigated by a tight-binding model considering the self-consistent Hartree potential in which the model parameters, such as the effective mass of Sn-s bands and dielectric constants, are obtained by fitting the charge density profile from the first-principles calculations. Our results by solving the Poisson-Schrödinger equation with a thick BSO limit show that there is a significant change in the spatial extent of the interfacial electron gas with the degree of the charge transfer. We believe that our results provide the electronic structures and charge-density profiles by varying charge transfer in thick BSO limits, which could be useful for understanding the properties of the quasi-two-dimensional electron gas formed at the LIO/BSO interface.

Keywords:

Oxide heterostructure, Transition metal oxide, Density functional theory, Electronic structures, First-principles calculation

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P2-co.208

Electronic Structure Calculations of Materials using Machine Learning

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Abstract:

With the advancement of computing power, it has becomepossible to calculate a wide range of physical properties ofsolids using computers. In particular, density functional theory (DFT) calculations can be performed to obtain atomic and electronic properties of materials using computational programs such as VASP (Vienna Ab initio Simulation Package) and Quantum Espresso. However, using such methods has a limitation in that it takes a long time to handlethe systems containing a large unit cell. To resolve these limitations, many researchers have begun to pay attention to machine learning. The advantages of electronic structure calculations using machine learning not only effectively reduce time but also are useful for finding new materials. In this study, we will use machine learning to calculate the electronic and thermal properties of materials and analyze the differences between the results obtained using DFTcalculations and machine learning.

Keywords:

Electric structure, Machine learning

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P2-co.209

Electronic structures of native defects in bulk InAs

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Abstract:

InAs is a representative III-V complex semiconductor with a direct bandgap and useful properties including high electron mobility and less toxicity. However, due to a considerably small bandgap of 0.4 eV, accurate *ab initio* study of native defect states has been challenging. Here, we present the electronic structure of native defects in bulk InAs based on first-principles calculations. Using the formation energies of native defects, we scrutinized possible defect configurations and their corresponding electronic states. We believe that our computational results can serve as a quantitative guiding principle for estimating the electronic structure of not only native defects, but also impurity-doped InAs in ambient conditions. This study will be a basis to explore optical and transport properties of the bulk crystal as well as extended surfaces or nanocrystals.

Keywords:

InAs, bulk, defect, ab-initio

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P2-co.301

Determining three-dimensional structures of aggregated nanoparticle cluster

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Abstract:

Aggregated nanoparticle clusters comprising numerous nanometer-sized particles as building blocks hold great potential for various practical applications. Since the structure of an agglomerate can influence its properties, determining its three-dimensional (3D) structure is essential for research in various material science fields. One approach to achieving this is through the electron tomography technique that utilizes annular dark-field based scanning transmission electron microscopy (ADF-STEM) to produce a 3D tomogram containing structural information. However, to quantitatively describe the spatial arrangement of the particles, the 3D positions of each entity must be accurately determined. Here, we present a new method for particle tracking using 3D cross-correlation with a fixed template. This enables us to measure the 3D coordinates of individual nanoparticles within the aggregated system. The method involves calculating a 3D cross-correlation map, identifying nanoparticle coordinates by locating a global maximum from the map, and then extracting the identified nanoparticle volume from the 3D tomogram. We tested our approach using simulations for both crystalline and disordered systems, and we experimentally validated it using a supraparticle assembled from Fe_3O_4 nanoparticles. The 3D arrangements we obtained were analyzed using bond orientation order (BOO) analysis, which successfully revealed an amorphous configuration from the experiment.

Keywords:

Electron Tomography, Particle Tracking, Cross-correlation, Bond Orientation Order

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P2-co.302

Optical properties of popular substrate dielectric materials.

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Abstract:

We investigated various dielectric materials that have been used as substrates. We obtained the optical conductivities and dielectric functions of these materials using optical spectroscopy. On these substrates, thin films can be grown using various thin-film growth techniques. The dielectric materials are soda lime glass, Al_2O_3, quartz, $SrTiO_3$, $(LaAlO_3)_{0.3}$-$(SrAlTaO_6)_{0.7}$ (001), $LaAlO_3$ (001), $DyScO_3$ (110), $TbScO_3$ (110), and $KTaO_3$ (001). Most samples are one-sided, polished plates. The reflectance spectra of the samples were measured using FT-IR and monochromatic spectrometers in a wide spectral range from far IR to UV (20 cm^{-1} ~ 50000 cm^{-1}). Using the Kramers-Kronig analysis, the phase of the reflection coefficient is obtained from the measured reflectance spectra. Optical properties (constants) were obtained from the reflection coefficients using the Fresnel equation and the relations between optical constants. The electronic and phononic structures of the materials were obtained.

Keywords:

dielectric materials, FT-IR, optical conductivity, dielectric function, electronic and phononic structure

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2023-04-19 - 2023-04-21

P2-co.303

Development and characteristics of a smart peripheral blood flow rate monitor composed of a clip-type pulsimeter and photoplethysmograph

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Abstract:

It is necessary to develop an AI algorithm platform through data acquisition, data security, data transmission, and data processing to advance normal peripheral blood flow and immunity-enhancing smart medical devices for the aging elderly. As one of the developments of western oriental convergence digital healthcare medical devices customized for the elderly for diagnosing cardiovascular conditions, there is the development of a peripheral blood flow rate monitor consisting of a magnetic sensing Hall element clip-type pulsimter and an optical sensing photoplethysmograph (PPG). Through this, peripheral blood flow rate signal processing to strengthen the immunity of the elderly will lead to portable design design and smart device development to build a western or oriental convergence health care platform. With the advancement of wrist wearable smart watch type peripheral blood flow rate measurement technology, data-based clip-type pulsimeter and PPG are used, and simultaneous PPG1 and PPG2 are produced. Circuit design and wired/wireless system data transmission system are required to implement a simultaneous acquisition waveform display system integrated with a wrist clip type pulsimterr for peripheral blood flow rate measurement and a finger optical pulse digger. It will include production of a prototype that displays the two waveforms measured simultaneously on a PC or smartphone, and processing and analysis of data measured at all times. In particular, to acquire peripheral blood flow measurement data using two PPG sensors, PPG sensor measurement structure, MCU BT communication confirmation, data display android application, and communication between MCU and android application are required. Then, data sampling and comparative analysis based on PPG sensor data accuracy were conducted to study its characteristics.

Acknowledgements:
This research was supported by "Regional Innovation Strategy (RIS)" through the National Research Foundation of Korea (NRF) funded by the Ministry of Education (MOE) (2022RIS-005).

Keywords:

magnetic sensing Hall element, clip-type pulsimeter, photoplethysmograph, peripheral blood flow rate monitor, digital healthcare medical device

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P2-co.304

Spontaneous phase separation in indium gallium oxide thin films deposited using powder sputtering method

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Abstract:

Despite the structural or crystallographic mismatch between In_2O_3 and Ga_2O_3, adding In_2O_3 to the host Ga_2O_3 has been found to chemically alloy it, usually in the form of $(In_xGa_{1-x})_2O_3$. In bulk system based on phase diagram, three major phases are predicted. In addition to intermediate phase with hexagonal structure, Ga-rich monoclinic and In-rich cubic bixbyite phases are normally preferential. Although these alloys are chemically homogeneous, structural phase separation distinctly has been reported in some cases over a wide range of x values. To fully understand the compositional inhomogeneity localized in the Ga_2O_3-In_2O_3 alloy system, it is necessary to investigate the spontaneous phase separation and elemental distribution of $(In_xGa_{1-x})_2O_3$ thin films. In particular, under reducing atmosphere, non-stoichiometric chemical state (deficient O atoms) may cause metallic clustering and the formation of sub-oxide, as in the case of highly oxygen deficient pure Ga_2O_{3-y}, where y represents non-stoichiometry of oxide thin films determined by amount of oxygen vacancy. In this study, we focus on the competition between In and Ga atoms in Ga_2O_3-In_2O_3 alloy system during sputter growth under reducing atmosphere, leading to a spontaneous phase separation of In atoms. We found that In rich domains segregated underneath surface islands are spatially ordered. This induces globally chemical inhomogeneity of non-stoichiometric $(In_xGa_{1-x})_2O_{3-y}$, composed of stoichiometric $(In_xGa_{1-x})_2O_3$, sub-oxide of $(In_xGa_{1-x})_2O$, and metallic In clusters. Furthermore, the growth mode switched from initial thin film to later nanowire growth originating from the exsolution of In atoms to form In clusters that act as a metal catalyst seed to initiate the vapor-liquid-solid (VLS) growth of $(In_xGa_{1-x})_2O_3$ NWs.

Keywords:

Ga2O3, Phase separation, Binodal decomposition, Indium gallium oxide

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P2-co.305

Self-powered solar-blind ultraviolet photodetectors based on SnO_2 nanowires

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Abstract:

We report the performance of self-powered solar-blind photodetectors based on the SnO_2 nanowires (NWs). SnO_2 NWs with a length of several hundred micrometers can be synthesized by thermal chemical vapor deposition using SnO powder as a source material, which has the advantages such as low process temperature and no reducing agent. Based on the characterization results using synchrotron X-ray diffraction (XRD), scanning electron microscopy, and transmission electron microscopy (TEM), it can be concluded that the NW growth via Au-catalyzed vapor-liquid-solid mechanism evolves from the initial in-plane growth to the vertical growth of NWs forming NW cotton. This was optimized at a process temperature of 800 ℃ under an Ar flow of 5 Torr. Moreover, the XRD and TEM results indicated that NWs mainly grow in the form of SnO_2, while the formation of SnO NWs is also possible. Metal-SnO_2 NWs-metal photodetectors were fabricated, and their photo-responsivity to the ultraviolet (UV) light with a wavelength of 254 nm was investigated. The device exhibited a photo to dark current ratio of ~10^6 at a dark current of ~0.1 nA at an applied voltage of 10 V. In particular, the self-powered photocurrent gain at 0 V was ~1 nA under 254 nm UV illumination of 36 mW/cm^2. Our results demonstrate that the SnO_2 NWs are promising candidates for self-powered solar-blind photodetectors and that thermal CVD using SnO power is suitable for growing the SnO_2 NWs at temperatures as low as 800 °C.

Keywords:

SnO2 nanowires, Self-powered photodetectors, Solar-blind ultraviolet, SnO powder, Metal-semiconductor-metal devices

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2023-04-19 - 2023-04-21

P2-co.306

Tilt-focal series alignment for low-dose atomic-scale 3D phase contrast tomography of crystalline nanoparticles using estimated crystal orientation and particle shape

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Abstract:

Atomic-level determination of the 3D structure of materials can help us understand their physical properties. However, tomography techniques utilizing annular dark-field (ADF) based scanning transmission electron microscopy (STEM) methods cause beam-induced damage to delicate samples due to high electron dosage requirements, limiting our capacity to study such samples in a non-destructive manner. We propose a more dose-efficient method: focal series reconstruction tomography utilizing high-resolution transmission electron microscopy (HRTEM). The 3D phase volume, which is directly related to the 3D atomic potential, can be reconstructed from the tilt series of HRTEM image intensities acquired at multiple defocus values. However, the reconstruction requires precisely aligned HRTEM images with different defocus values, as well as an aligned tomographic tilt series. Since the blurred and distorted details of highly defocused HRTEM images make such precise alignment of HRTEM focal series difficult, this approach has not yet been experimentally achieved. We therefore propose a method of precisely aligning HRTEM tilt-focal series by aligning each image with a simulated defocused HRTEM image from an approximated structure. This structure is made by estimating the exterior 3D boundary and the internal crystal orientation from an on-focus HRTEM tilt series. We expect this method to be the first step toward low-dose 3D atomic-scale reconstruction utilizing experimental HRTEM tilt-focal series.

Keywords:

Transmission electron microscopy, Phase retrieval, Focal series reconstruction, Atomic electron tomography

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2023-04-19 - 2023-04-21

P2-co.307

Room Temperature Epitaxy of SnO_2 Thin Films on c-plane Sapphire Substrates Grown by Powder Sputtering Method

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Abstract:

We present x-ray and electrical characteristics study on room temperature epitaxy of tin oxide (SnO_2) thin films various different thickness deposited on sapphire (0001) substrates using radio-frequency powder sputtering. In this study, we analyzed samples in various ways. First, by analyzing XRD profile, unlike general oxide thin films were grown at room temperature is amorphous, we confirmed that tin oxide thin films were epitaxially grown on substrate despite being grown at room temperature. Also, we were able to identify two phases that a general rutile phase (R-phase) known as an insulator and an orthorhombic columbite phase (C-phase) reported to have metallic properties. And we analyzed how the two phases change according to the thickness. XRD profiles were measured on the PAL 5D. Furthermore, we investigated the electrical properties represented by hall mobility, carrier concentration, and conductivity of tin oxide through hall measurement. Through this, we investigated how the changes according to the thickness of C-phase and R-phase affect the above properties. Finally, we investigated how oxygen vacancy and the amount of C-phase affect the band structure according to thickness through HAXPES measurement. In the process, we were able to find clues that the C-phase could be metallic. The measurements were made on a SPring-8 BL46XU. Detailed results will be presented.

Keywords:

SnO2 Thin Films, X-ray Diffraction, Orthorhombic Columbite Phase

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2023-04-19 - 2023-04-21

P2-co.308

Measurement of the 2nd excited state bifurcation of transmon qubit.

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Abstract:

At high photon numbers, the qubit-cavity system undergoes a transition from quantum to classical behavior. In the middle of the transition process, it is showed a bifurcation phenomenon, which has been explained in terms of the system's behavior resembling that of a duffing oscillator. In experimental measurements, it is observed a particularly strong bifurcation signal in the 2nd excited state. To gain a better understanding of this phenomenon, this signal is analyzed using semi-classical dynamics, which allowed me to explore the system's behavior and underlying mechanisms in more detail.

Keywords:

qubit, bifurcation

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P2-co.309

Synthesis of two-dimensional type-Ⅱ Dirac semimetal $NiTe_2$ film

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Abstract:

Among transition metal dichalcogenides (TMDc), $TMTe_2$ (TM = Ni, Pd, and Pd) that has been studied less than other TMDcs, is classified as a Dirac semimetal group with linear band dispersion. In particular, for $NiTe_2$, the Dirac node is located near the Fermi level, so that fascinating transport properties due to the nontrivial topological state are expected. However, there are problems that $NiTe_2$ single crystals are generally made in a three-dimensional bulk form and two-dimensional $NiTe_2$ single crystals are made in a tiny micrometer size . Thus, it is difficult to observe the nontrivial transport properties of two-dimensional $NiTe_2$ Dirac semimetal. In this study, we fabricated $NiTe_2$ thin films by using the chemical vapor transport (CVT) method. Thin Ni films were deposited on sapphire (0001) substrates, and then they were sealed in quartz ampoules under different Te environment. Ni film was placed at one end of the quartz tube, and Te powder was placed at the other end, while keeping the temperature difference between the two ends. We checked the single phase of $NiTe_2$ through X-ray diffraction measurements, and we investigated the surface morphology and the transport properties. We found that there is a strong relationship between synthesis conditions and transport properties. Further studies are needed to optimize the synthesis conditions for fully understanding the nontrivial topological properties of two-dimensional $NiTe_2$ Dirac semimetal.

Keywords:

transition metal dichalcogenines, Dirac semimetal

2023 KPS Spring Meeting
2023-04-19 - 2023-04-21

P2-co.310

In-situ X-ray diffraction studies of order-disorder transition in AuSn alloy nanocrystals

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Abstract:

The order-disorder effect has been known as a factor that affects device performance in nanocrystals. Our research team studied the order-disorder transition in nanocrystals composed of Au_5Sn and $AuSn$ domain used in the Au-Sn solder system process, which are very effectively used in soldering systems due to good thermal fatigue, high-temperature strength, high tensile strength, and high corrosive resistance. The superlattice peak from the ordered structure was observed In-situ while changing the temperature with a point detector and a 2D Pilatus detector in the 5D PAL beamline. In the structure where the initially ordered peak and the disordered peak coexist, when the temperature is raised, the ordered peak disappears near the temperature of 180~190°C, and as the temperature is lowered again, the transition where the ordered peak occurs again at around 180~190°C was confirmed. We intend to confirm the relationship between domain behavior and strain-induced order-disorder transition by further completing BCDI experiments on this system.

Keywords:

X-ray diffraction, AuSn alloy nanocrystal, Order-disorder transitiobn

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2023-04-19 - 2023-04-21

P2-co.311

Control system and DAQ software for on the fly XRF measurement

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Abstract:

To provide abundant experiment opportunities to beamline users, the demand for high throughput is increasing in the field of XAFS and XRF measurement. For this, the time synchronization control system and measurement program were built based on EPICS. On the fly control system and data measurement software for EXAFS and XRF will be discussed.

Keywords:

XRF, On-the-fly

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P2-co.312

Ultrafast Lattice Dynamics in Photoexcited Perovskite-oxides by Time-resolved Bragg Coherent Diffraction Imaging

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Abstract:

A perovskite-oxide, $SrTiO_3$ is very attractive in photocatalytic applications because it is highly stable, displays high quantum efficiency, and shows significant light-driven water splitting. The photogenerated charge carriers can drive redox reactions at the interface with sacrificial reagents. However, these photogenerated charge carriers interact with constituting cations and anions of crystal lattice may result in lattice distortions. The charge carrier behavior, such as charge transport or recombination dynamics in the lattice framework, is a crucial factor in determining the photocatalytic performance of $SrTiO_3$. It is thereby important to understand the lattice-carrier coupling mechanism expected in an ultrafast timescale.
In this poster, we present to study the ultrafast structural evolution of lattice distortions with photoexcitation of $SrTiO_3$ nanocrystals. We did perform time-resolved Bragg coherent X-ray diffraction imaging (tr-BCDI) using an optical pump (to trigger the photocatalytic reaction) with an X-ray pulse probe. From ultrafast tr-BCDI measurements, we can successfully measure directly observe atomic-scale motions of transient internal structural distortions in $SrTiO_3$.

Keywords:

Time-resovled, X-ray diffraction, coherent X-ray diffraction imaging, ultrafast, perovskite

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2023-04-19 - 2023-04-21

P2-co.313

Laser-based high-resolution ARPES on type-2 nodal-line semimetal candidate Mg_3Bi_2

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Abstract:

The intersection of conduction and valence band in nodal-line semimetals (NLS) consists of one-dimensional open lines or closed loops. Similar to the classification of Weyl semimetals into type-1 and type-2 based on whether the sign of the slope of the conduction band and valence band is the same or not, NLSs can also be classified accordingly. Mg_3Bi_2 is recently proposed to be a type-2 NLS, and we synthesized the sample and performed fiber-laser-based high-resolution angle-resolved photoemission spectroscopy (ARPES). Using fiber-laser-based high-resolution ARPES, we were able to clearly track the dispersion of each band, and through circular dichroism, we were also able to identify the spin characters of the expected surface resonance bands assuming strong atomic spin-orbit coupling due to Bi.

Keywords:

ARPES, fiber laser, nodal-line semimetal

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2023-04-19 - 2023-04-21

P2-co.314

Investigation of MoS_2 Trion via Infrared Measurement of Laser-Induced Drude Peak and Fourier-Transform Photocurrent Spectroscopy(FTPS)

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Abstract:

Molybdenum disulfides (MoS_2) are among the most promising materials in the Transition-metal dichalcogenides (TMDCs). One unique property of MoS_2 is the presence of obvious exciton A and B peaks. Because of the spin-obit coupling, MoS_2 enables the formation of various peaks such as exciton A, trion, and biexciton that have less energy than the energy bandgap (2.2 eV). In this poster, we focused on the observing the polarity properties of MoS_2 trion as the Drude in the mid-infrared(MIR) range.
The exciton A peak of MoS_2 was detected at 1.87 eV using Fourier Transform Infrared Spectroscopy (FTIR). We observed MoS2 absorption under 4000 cm^{-1} in the MIR range by radiating MoS_2 with 650 nm(1.905eV) laser. And each laser of different colors - red (650nm), green (520nm), and blue (450nm) - showed different absorption rates, respectively. We supposed that the absorption in the MIR range by the 650nm laser may be most affected by the trion in addition to defects and exciton A since the trion exhibits polarity properties like free carriers.
To accurately determine the position of the trion, we decided to use Fourier-Transform Photocurrent Spectroscopy (FTPS) based on FTIR. FTPS is fast and extremely high-sensitive spectroscopic method. this method also has the advantage of being easy to investigate defect-related absorption. For these reasons, we made FTPS equipment, and we are working to improve the setting of this equipment.

Keywords:

MoS2, Trion, Absorption, FT-IR Spectroscopy, Fourier-transform Photocurrent Spectroscopy

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2023-04-19 - 2023-04-21

P2-co.315

3D Tomography of Mesoporous Particle by Multiple-distance Coherent Diffraction Imaging

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Abstract:

Coherent diffraction imaging (CDI) has enabled high-resolution X-ray imaging of nanoscale objects without a lens by fully exploiting penetration power and short wavelength of X-ray. Although CDI is free from resolution limit by lenses, a sufficient sample-to-detector distance (SDD) constrains spatial resolution to the finite size of the detector size. Here, we demonstrate a multiple-distance CDI (MDCDI) to enhance the resolution by overcoming the limitation imposed by the SDD. A long-SDD diffraction pattern containing the low-frequency information is measured followed by the measurement of a short-SDD diffraction pattern at a larger scattering angle. We developed an algorithm that combines both patterns into a robust and high-resolution real space image free of interpolation error. A simulation and an X-ray experiment were performed to confirm the resolution enhancement. In the X-ray experiment, 3D structure of mesoporous silica nanoparticle at 27.3 nm resolution is obtained by tomographic reconstruction of MDCDI-enhanced 2D images. The high resolution of the reconstructed nanoparticle enabled us to visualize of the onion-like shell structure and to analyze its complex pore network.

Keywords:

Coherent Diffraction Imaging, Single-particle Imaging, X-ray Tomography

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P2-co.316

The effects of thickness variation on properties of CdTe epitaxial films grown by molecular beam epitaxy

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Abstract:

A series of CdTe epitaxial films with various thicknesses were prepared on GaAs(001) substrate by molecular beam epitaxy (PLD). All of the high-energy electron diffraction (RHEED) patterns as a function of layer thickness demonstrated sharp streaky lines, indicating the samples' high-quality single-crystalline structure. X-ray diffraction (XRD) analysis was utilized to investigate the effects of thickness variation on the crystallinity. The electrical and optical properties of the films were also investigated as a function of the film thickness. It was found that the crystalline quality, optical and electrical properties of the eptaxial films depended on the film thickness and were improved with increasing the film thickness. Our experimental results indicate that the thickness effect is critical for heteroepitaxial film growth in semiconductor devices.

Keywords:

CdTe, molecular beam epitxay, Thickness effect

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P2-co.318

Li_2TiO_3 single crystal substrates for thin film growth

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Abstract:

Transparent non-magnetic Li_2TiO_3 (LTO, maximum size 5mm×4mm×1mm) crystals were successfully grown by the flux method [1]. Crystal structure of LTO were investigated by X-ray diffraction. The lattice parameters are found to be a = 5.0623(5)Å, b = 8.7876(9)Å, c = 9.7533(15)Å for LTO. The indirect band gap of LTO was estimated to be 3.44eV by using UV-Vis spectroscopy. Surface polishing and chemical treatment achieved an atomically flat surface with 0.3 nm-height step terraces. Our results suggest that LTO single crystals can be utilized as the transparent non-magnetic substrates for thin film growth of various quantum materials.

Keywords:

Quantum materials, Heterostructure

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P2-co.319

Monitoring the solid surface potential during X-ray resonance using adjacent gas molecules

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Abstract:

The surface potential of semiconductor surfaces has been widely investigated with X-ray photoelectron spectroscopy (XPS). [1] The semiconductor surface potential is closely related to the band bending of semiconductor surfaces. For instance, with UV/Visible illumination, the semiconductor surface potential can be modulated through light-induced band bending reduction, resulting from the accumulation of photocarriers, i.e. surface photovoltage (SPV). [2]

To observe the light-induced modulation of surface potential at the X-ray regime, a tunable X-ray at synchrotron radiation and ambient-pressure XPS (AP-XPS) are utilized to modulate the number of photocarriers of the system, Ar gas/MnO(001). As the photon energies are tuned to the near Mn 2p absorption resonance edge, the presence/variation of surface potential can be monitored [3] via the positions of Ar 2p gas phase peak near the surface as well as O 1s spectra of the MnO(001) surface.

Our results show that the magnitude of the surface potential has a linear correlation with the X-ray absorption strength of the MnO(001). O 1s and Ar 2p photoelectron kinetic energies shift in the same magnitude. The observed linear correlation between X-ray absorption and photoelectron kinetic energy shift cannot be understood as a band bending reduction induced by SPV. Instead, the linear behavior can be related to the change of photoionization cross-section during the resonance. The effects of a) the X-ray-induced photocarriers and b) the resonant Auger emission in surface potential variation will be discussed together.

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Keywords:

Surface Photovoltage, Surface Potential, Ambient Pressure XPS, X-ray Absorption Resonance, Resonant Auger Emission

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P2-co.320

Conversion between Metavalent and Covalent Bond in Metastable Superlattices Composed of 2D and 3D Sublayers

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Abstract:

Phase-change random access memory (PCRAM) is a promising candidate for next-generation nonvolatile memory and in-memory computing applications because of its high speed, high endurance, and excellent scalability compared with other nonvolatile memories. Reversible in bond types between metavalent and covalent bonds has become one of the most promising bases for determining the PCRAM memory performance. However, the comprehensive understanding remains lacking due to difficulties with experimental analysis. Herein, the change in chemical states via vacancy re-ordering behavior was directly observed by combining analysis of charge density distribution, electrical conductivity, and crystal structures. Site-switching of vacancies of Sb_2Te_3 gradually occurs with accumulation of vacancies triggering spontaneous gliding along atomic planes to relieve electrostatic repulsion. Studies on the behavior can be further applied to multiphase superlattices composed alternating layers of two chalcogenide-based phase-change materials (Sb_2Te_3 and GeTe), which represent superior memory performances, but their operating mechanisms were still under debate due to their complexity. The site-switching is favorable (suppressed) when Te−Te bonds are formed as physisorption (chemisorption) over the interface between Sb_2Te_3(2D) and GeTe (3D) sublayers. Depending on the type of interfaces between sublayers, phases of the superlattices are classified into metastable and stable states, where the conversion could be achieved only in the metastable state. These results can provide insights for research into vacancy engineering as a determinant of the properties of versatile materials.

Keywords:

Phase-change memory, metavalent bonding, vacancy engineering, superlattice

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P2-op.001

Simultaneous measurement of topography and optical properties using white light interferometry

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Abstract:

White light interferometry(WLI) is used for measuring topography of the steep height different samples within few seconds. However, phase changes due to the material dependent optical properties can cause confusing results. In this study, optical responses of red, green, and blue are acquired separately by three color bayer pattern camera. We extract the reflectance spectrum by using fast fourier transform of each interferogram and calculate optical properties such as refractive index. As a result, the topography and optical properties are obtained simultaneously. Our work could be utilized for semiconductor metrology.

Keywords:

semiconductor, optical metrology, white light interferometry, three-color camera, fourier transform spectroscopy

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P2-op.002

Absolute Radiometric Calibration of Pyro-electric Detectors

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Abstract:

Pyroelectric detectors offer several advantages for laser power measurement, including high sensitivity, wide dynamic range, and fast response time. Calibration is essential for ensuring accurate and reliable laser power measurements using pyroelectric detectors, and the measurement setup and procedure depend on the specific application. Common sources of error can be minimized by maintaining a stable environment during measurements, and ensuring stable laser power during measurements.
The results shows that pyroelectric detector can be use as a reference detector for optical power measuremts treaceable to the trap detector. In this research paper we presnt the clibration system of this comparision and its related uncertanity budget (as laser stabilty, nonuniformity, nonlinearity ...etc).

Keywords:

Pyroelectric, Trap detector, optical power

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P2-op.003

Non-Destructive Analysis of Thickness of Thin Films using Home-Built Spectroscopic Ellipsometry

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Abstract:

Ellipsometry is a measurement tool that analyzes the change in the polarization state generated in the sample and can be used to determine the optical constants or thickness of film layers. This technique is widely used in various fields due to its high sensitivity and accuracy, as well as its non-contact and non-destructive properties.
Ellipsometry is an indirect measurement method that uses a model to calculate a theoretical value, which is then adjusted until it matches the measured value. Ellipsometry results are obtained by comparing measured and theoretical values, and wavelength-dependent measurements can provide a large number of data points, allowing for more comparisons and ultimately improving the reliability and accuracy of the results. Due to this advantage, Spectroscopic Ellipsometry(SE) has attracted significant attention, and various approaches have been developed. SE, due to the large amount of data it can generate, is particularly useful for analyzing multilayer films. Moreover, since it measures the optical spectrum, it can also be used for studying optoelectronic properties of materials such as band structures.
The Si sample and Si/SiO_2 sample were measured with a home-built rotating analyzer type spectroscopic ellipsometer, and the thickness of the native oxide layer and SiO2 layer was obtained using the Tauc-Lorentz model.

Keywords:

Ellipsometry, Film thickness, Spectroscopic Ellipsometry

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P2-op.004

Realization of non-destructive tomographic image of multilayered structure using geometric phase lens

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Abstract:

기하 위상 렌즈는 메타 렌즈의 한 종류로 빛의 편광상태를 변화시켜 입사광의 초점거리를 파장별로 다르게 나타내는 분산 효과를 가지고 있어 z축 방향의 스캔을 수행하지 않고도 샘플의 깊이 방향에 대한 정보를 획득할 수 있는 색공초점 센서로 활용되고 있다. 기존의 색공초점 센서의 경우 색분산의 효과가 크지 않아 측정 가능한 깊이가 매우 얇은 표면 근처로만 제한되는 단점을 가지고 있었다. 하지만 기하 위상 렌즈는 색분산 효과가 큰 장점을 가지고 있어 광원의 반치폭이 100 nm 이상이 되는 광대역 광원을 이용함으로써 수 mm 이상의 깊이 방향 스캔이 가능하게 되었다[1]. 또한 기하 위상 렌즈는 렌즈의 두께가 매우 얇아 flat lens라고 불리기도 하는데 기존 렌즈보다도 부피가 무척 작고 무게도 매우 가벼운 장점을 가지고 있어 시스템 구성에 있어서도 큰 장점을 가질 수 있다.
기하 위상 렌즈는 마치 회절 격자와 같이 입사하는 파장별로 초점의 위치가 다르게 맺히기 때문에 입사하는 빛의 광축을 따라서 반사면의 위치를 가변하면 특정 파장만을 반사시킬 수 있기 때문에 반사파의 파장 특성을 분석함으로써 반사면의 위치를 구분할 수 있는 장점을 가질 수 있다. 기하 위상 렌즈의 이러한 색분산 특징을 이용함으로써 기계적인 스캔을 수행하지 않고도 높은 안정도를 가지고 샘플 표면의 단차 정보를 획득할 수 있었고 투명한 샘플에 대해 두께도 측정할 수 있었다[2]. 하지만 샘플의 내부 단층영상 구현에 활용한 연구 결과는 아직까지 보고된 바가 없었다.
본 논문에서는 다층 구조를 가지는 투명한 샘플의 두께 정보를 시각적으로 제공할 수 있는 단층 영상을 기존과는 달리 비간섭적인 방법으로 구현이 가능한 기하 위상 렌즈 기반의 방법을 제안하고자 한다. 다층 구조를 가지는 투명한 샘플 내부에서 반사되는 광을 기하 위상 렌즈를 이용하여 파장별로 구분하고 푸리에 변환과 같은 신호처리없이 간단한 신호처리 과정만으로 3차원 단층영상을 구현한 결과를 실험적으로 제시하고자 한다.

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Keywords:

기하 위상 렌즈, 단층 영상, 색공초점

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P2-op.005

Single-shot measurement of a laser field using ionization grating in air

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Abstract:

The temporal characterization of the laser pulse has become an important subject in studying laser-matter interactions. Since a high-power laser operates at a low repetition rate, measuring the laser pulse with a single laser shot is ideal.
Here we demonstrate that the high-power laser field can be visualized by imaging a fluorescence light produced by two replica beams superposed non-collinearly. The result of the single-shot measurement is compared with an original tunneling ionization with a perturbation for time-domain observation of an electric field (TIPTOE) method, verifying the validity of the single-shot measurement.

Keywords:

High power laser, Ultrafast measurement, Ionization grating, Laser induced breakdown

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P2-op.006

High-efficiency optical parametric amplifiers for generating intense narrowband pulses tunable from 4 to 19 THz

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Abstract:

Phonon-driven dynamic control of material properties by narrowband THz lasers has attracted much attention because it allows selective manipulation of functional electronic, magnetic, and structural states on demand by coherently exciting specific low-energy vibrational modes. However, the exploration of hidden phases in quantum materials has been restricted due to the lack of intense narrowband pulses with frequencies below 20 THz.

Here, we report the generation of high-intensity THz pulses tunable between 4 and 19 THz with a bandwidth of around 0.5 THz. The novelty of this configuration is that it utilizes high-energy near-infrared (NIR) pulses with the super-Gaussian spatial distribution, which produce a homogeneous output and enable the usage of higher pulse energy without optical damage on the crystal due to its low intensity, as the pump source to efficiently generate the THz pulses. Furthermore, such an intense NIR pulse with the super-Gaussian profile is obtained by pushing the power amplification process into the highly saturated gain regime in a double-stage optical parametric amplifier (OPA) system without additional complicated optical components to shape the beam profile. We demonstrate that high flux photons of injected signal pulses for power amplification improve the conversion efficiency even near the saturated gain regime, and the spatial profile of the output signal beam becomes super-Gaussian, deviating from a Gaussian profile. In this high-efficiency operation, the output signal pulses have a maximum conversion efficiency of 57% and a high energy stability of 0.7% RMS for over 3 h with a pulse duration of 33 fs full-width at half-maximum (FWHM). By difference-frequency generation of two chirped NIR pulses generated from two identical high-efficient OPAs in a DSTMS organic crystal, the output THz pulses have a pulse energy of 3.2 μJ and a pulse duration of 860 fs, corresponding to an internal THz conversion efficiency of 0.4%, a THz field strength of 6.7 MV/cm, and an intensity of 60.6 GW/cm^2.

Since the energy of pump sources is limited, it is essential to improve the THz conversion efficiency to generate intense THz pulses. In addition, energy stability is also a crucial parameter for application in practical experiments. In this regard, our results present a powerful way to improve the conversion efficiency of both OPA and THz generation with high stability. Such a strong-field narrowband THz pulse could open new possibilities for the advanced manipulation of collective electronic properties in condensed matter by selective excitation of phonon modes.

Keywords:

high-efficiency, super-Gaussian, narrowband, THz pulses

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P2-op.007

Cricular Dichroism analysis in Laser induced FLOQUET chern insulator

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Abstract:

Interactions between light and material cause perturbations of the Hamiltonian, leading to insulator-metal transitions and phase transitions in material structuresIn recent years, researchers have studied laser-induced time-periodic Hamiltonians known as Floquet Hamiltonians. This Floquet system shows different characteristics from the well-known Stark and Zeeman effects. This FLoquet Hamiltonian not only displays band bending, but also duplicates the band structure. Interaction with circular polarization laser and graphene nanoribbon can specially lead to a topological phase transition. This circular polarization laser is breaking the Time Reversal Symmetry (TRS). This Floquet band, which is a duplication of the original band structure, can interact with the original band, leading to band inversion and gap opening. This TRS braking and gap opening cause a topological phase transition, resulting in a transformation from a Dirac semimetal to a Chern insulator.

$$CD_n = \frac{I_n^{RCP} - I_n^{LCP}}{I_n^{RCP} + I_n^{LCP}}$$

A recent paper has suggested that topological features can be extracted from High Harmonic Generation (HHG) while maintaining material properties. This topological chern insulator phase, which has an integer chern number, can be measured using Circular Dichroism(CD) analysis. Equation as follow CD value converged to 1 for co-rotating order (*nth*n^{th} order) HHG signal

Here We theoretically demonstrate the band gap opening, berrycurvature, and integer chern number resulting from the TRS breaking induced by the CPL laser on graphene nanoribbon. To measure the Chern number of Floquet gapped graphene we drived LCP, RCP laser. Result shows clear CD anlysis result. The results of this simulation show that the Chern insulator has a CD value of 1, which is equal to the Chern number, while the trivial Dirac semimetal case has a CD value of 0. This experiment used a 2.1 eV continuous-wave pump laser to generate a Floquet Chern insulator state and a 0.3 eV (4000 nm) mid-IR high-harmonic generation driver to extract topological information from the Floquet Chern insulator.Pump probe intensity ratio set 100:1
This research show CD analysis is good tool for Floquet Chern insulator system

Keywords:

FLOQUET, chern insulator, topological insulator

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P2-op.008

광학 공명 모드의 운동량 및 에너지 분석 방법(Analysis of Momentum and Energy of Optical Resonators)

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Abstract:

어떤 구조가 주어지면 그 구조는 특유의 공명 모드를 가지게 된다. 전자기파 역시 마찬가지로 주어진 구조는 특유의 전자기파 모드를 공명 모드로서 가지게 된다. 구조는 공명 진동수에 해당하는 전자기파 신호를 증폭시키므로 빛-물질 상호작용을 강화하기 때문에 분자 센싱, 레이징, 양자 정보 처리 등 다양한 분야에서 분야에 맞는 광학 공진기 구조가 활용된다. 이에 따라 광학 공진기의 전자기파 공진 모드의 특성, 예컨대 운동량, 에너지, 스핀 각운동량 등을 분석해 내고 구조의 위상적 특징과 연결하는 연구는 활용 목적에 맞는 공진 기반 광소자 설계에 있어 핵심적인 부분이라고 할 수 있다.
본 연구는 광학 공진기의 준표준 모드(quasi-normal modes)의 운동량, 에너지, 각운동량을 통해 공명 모드의 특성을 기술하는 방법을 제안한다. 준표준 모드는 흡수와 산란이 있는 열린 시스템(open system)의 공명 모드로 정의되며, 공명 주파수가 복소수로 주어지며, 전자기장이 공진기에서 멀어질수록 발산하는 특성을 가진다. 이때, 이러한 준표준 모드는 COMSOL Multiphysics와ㅏ 같은 상용 FEM(finite element method) 기반 시뮬레이션 소프트웨어의 고유주파수(eigenfrequency) 계산을 통해 얻을 수 있다.
본 연구진은 이렇게 얻은 복소 공명 주파수가 공간적인 전자기장 분포와 관계가 있음을 밝혔을 뿐만 아니라 복소 공명 주파수가 공명 모드의 운동량과 에너지 비율로 표현됨을 보였다. 더 나아가 광학 공진기가 공명 모드를 공간적, 시간적으로 국한시키는 능력의 지표인 모드 부피와 퀄리티 지수 역시 운동량과 에너지 비율로 표현된 복소 공명 주파수를 통해 도출될 수 있기 때문에 공명 모드의 운동량과 에너지를 통한 공진 기반 광 소자 특성 분석이 가능함을 보였다.
이러한 결과는 분자 센싱을 위한 공진기 구조의 성능 평가에도 사용될 수 있다. 광학 공진기 근처에 분자와 같은 나노 스케일의 구조가 위치하면, 광학 공진기의 공명 주파수와 퀄리티 지수가 변한다. 이러한 복소 공명 주파수 변화를 정확히 예측하기 위해, 앞서 기술한 복소 공명 주파수-전자기장 관계에 섭동 이론을 적용하면 기존 방법에 비해 훨씬 정확한 결과를 얻을 수 있다.

Keywords:

준표준 모드, 모드 부피, 퀄리티 지수, 분자 센싱

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P2-op.009

Effect of common defects on optical properties of metalenses studied by FDTD simulations

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Abstract:

Dielectric metalenses collect light by fine-tuning the phase difference of light transmitted through an individual dielectric resonator. Because refractive index of dielectrics is generally small in visible wavelengths, height of the resonators must be very large relative to the width to provide sufficient phase delay. Such structures are mechanically unstable and prone to structural defects. As realistic metalenses cannot be free from such defects, effects of these on optical properties should be considered for practical use. In this work, we analyze the effects of two common defects, radius inaccuracy and resonator breakage, on a metalens composed of titanium oxide cylindrical resonators. Both types of defects significantly reduce collection efficiency but rarely affect the focal size. Based on this, we determine the tolerance level for production related errors in realistic metalenses and propose potential means to reduce the impact of such defects.

Keywords:

Metalens, FDTD, Defect, Collection efficiency

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P2-op.010

Near- and Far-Field Observations of Polarization-Tunable Bowtie Nanoapertures

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Abstract:

Bowtie nanoapertures can confine light into deep subwavelength volumes with extreme field enhancement, making them a useful tool for various applications such as optical trapping, deep subwavelength imaging, nanolithography, and sensors. However, the correlation between the near-field and far-field properties of bowtie nanoapertures has yet to be fully explored. In this study, we experimentally investigate the polarization-dependent near- and far-field properties of bowtie nanoaperture arrays with different gap sizes using optical transmission spectra and photoemission electron microscopy (PEEM). We observe a nonlinear redshift in the transmission spectra as the gap size of the bowtie nanoaperture decreases for vertically polarized light, while the transmission spectra remain unchanged with different gap sizes for horizontally polarized light. The near-field distributions for using vertically and horizontally polarized light are demonstrated using PEEM to explain the far-field characteristics. Furthermore, the LC circuit model is employed to elucidate the redshift with decreasing the gap size. Lastly, we investigate a near-field mode that does not couple to the far-field (dark mode). Our study provides a comprehensive understanding of the fundamental properties of bowtie nanoaperture, enabling their further use in a wide range of applications.

Keywords:

PEEM, Bowtie, Nanoaperture, Plasmonics, Surface plasmon

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P2-op.011

루틴저 액체 플라즈모닉 격자 나노안테나 분석 (Analysis of Luttinger Liquid-fed Plasmonic Grating Nanoantenna)

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Abstract:

루틴저 액체 플라즈모닉 나노안테나를 이용하면 중적외선영역에서 높은 전자기적-광학적 전력 변환을 얻을 수 있다. 이는 1차원 금속의 기본 여기가 플라즈몬과 스피논으로 제한되는 성질 때문이다.
본 연구진은 격자구조를 사용한 루틴저 액체 플라즈모닉 나노안테나에서의 방사효율을 계산했다. 이에 대한 계산은 FEM(finite element method)을 기반으로 한 COMSOL Multiphysics와 같은 시뮬레이션 소프트웨어를 이용하여 계산했다.
전력 상환 정리(power reciprocity theorem)에 따르면 송신 모드(transmitting mode)에서의 안테나 시스템 전체의 방사 효율은 수신 모드(receiving mode)에서의 안테나 피드의 흡수 단면적과 비례한다. 따라서 수신 모드 계산을 통해 금 도막의 길이와 파장에 대한 격자의 반사도를 분석하고 이를 통해 높은 방사 효율을 얻을 것으로 기대되는 격자의 조건을 얻었다. 격자의 반사도에서 뚜렷한 파노 스펙트럼 모양(Fano lineshape)을 볼 수 있는데 이는 금 도막의 페브리-페로 공명(Fabry-Perot resonance)과 격자가 가지는 블로흐 상태(Bloch states)의 강한 결합으로 인해 파노 스펙트럼 모양이 나타나는 것으로 확인된다.
본 연구진은 격자구조를 사용한 루틴저 액체 플라즈모닉 나노안테나가 기존연구에서 본 연구진이 발표한 23%보다 더 높은 30%의 방사효율을 가지는 것을 확인했다.

Keywords:

루틴저 액체, 플라즈모닉 나노안테나, 방사 효율

2023 KPS Spring Meeting
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P2-op.012

Phonon polaritons in terahertz Mie metasurface studied by multipole decomposition studies

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Abstract:

Dielectric metasurfaces have emerged as a promising platform for achieving strong light-matter coupling, thanks to their ability to support Mie resonances and enhance electromagnetic fields within the dielectric resonators. These properties can be utilized to achieve strong coupling of light and matter, resulting in the formation of polaritons. However, although polaritonic states generally manifest themselves as a splitting of resonance peaks in transmission spectra, referred to as Rabi splitting, this feature may not always be pronounced in the presence of other Mie resonances.

In this work, we utilize multipole decomposition analyses to identify 'hidden' strong coupling phenomena occuring in dielectric Mie metasurfaces. Our study highlights the importance of understanding the role of multipole resonances in strong coupling for achieving efficient light-matter interaction.

Keywords:

Rabi splitting, Mie metasurface, Multipole decomposition

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P2-op.013

3D-printed Terahertz Metasurface Notch Filter

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Abstract:

Metasurfaces are structures consisting of arrays of resonators smaller than the wavelength, which allow for controlling the interaction between light and material in various ways. Among them, metasurfaces made of dielectric resonators can induce Mie resonance inside, enhancing the electromagnetic field and boosting light-matter interactions. In this study, we designed and manufactured a 3D-printed metasurface filter for the terahertz range, and measured its terahertz transmission characteristics. Through FDTD-based simulations, we confirmed the metasurface structure showing sharp resonance modes at about 0.178 THz and 0.197 THz. Next, we 3D-printed the metasurface using LCD-based SLA and characterized it with terahertz time-domain spectroscopy. However, the resonance did not appear in the experiment, which we attribute to a finite loss tangent of the 3D-printed dielectric. We plan to further optimize the material and the structure to enable all-dielectric flat optics for the terahertz frequencies.

Keywords:

Terahertz, Mie Resonance, Metasurface

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P2-op.014

Output power analysis of diode-pumped continuous-wave Yb:KGW laser

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Abstract:

Lasers are used in various industries. Recently, lasers with higher efficiency and stability are increasingly required. The Yb:KGW laser analyzed in this study has high efficiency and stability, and thus has the potential to be used in various applications. In this study, the Yb:KGW laser was designed, fabricated, and the characteristics were analyzed.The Yb:KGW crystal was used as a gain medium,which has a doping concentration of 3% and is a 5 mm long. And a diode at emitting light of 980 nm,which is the maximum absorption wavelength of the gain medium, was used as a pump light source. The pump laser light through a parabolic mirror to focus on the gain medium. Light from the gain medium is reflected by spherical mirror with R=500mm towards a high reflector with a 99.8% reflectance. The reflected light then retraces its path, and is reflected at another mirror with R = 300mm, and is entering to on output coupler. This process resulted in light amplification and laser oscillation. In order to analyze the characteristics, an experiment was conducted by adjusting the power of the pump light source and the reflectance of the output coupler. For an output coupler reflectance of R= 90%, the lasing could be obtained when the pump light source was above 5.01W. For the case of 90% OC, it was confirmed that the power slope efficiency of the Yb:KGW laser was approximately 21%. In addition, when we changed the OC reflectance to 99%, 90%, 80%, and 70%, it was confirmed that the lasing threshold is high at small reflectance, while the slope efficiency is proportional to the output coupler transmittance. Overall, it was found that among the tested ones the OC with R= 90% was the most efficient within the range of pump light source power up to 22W. In addition, it was confirmed that the wavelength of the laser was 1049 nm and the output was linearly polarized.

Keywords:

YB:KGW Laser, Threshold, Slope efficiency

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P2-op.015

Measure refractive index of $CsPbBr_3$ using interferometer

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Abstract:

We use Mach-Zehnder interferometer to get group refractive index of $CsPbBr_3$ and Michelson interferometer for linear refractive index of $CsPbBr_3$. $CsPbBr_3$ is one of the perovskite. Because of perovskite's property which have high optic absorption and long charge carrier diffusion length, perovskite is material which is famous for solar cell and LED. But perovskite is weak at humid, heat and ultraviolet ray. To overcome these weakness, all-inorganic cesium lead bromide ($CsPbBr_3$) is studied.Optical property is important to understand material's physical property and use material perfectly. Our experiment's purpose is measure refractive index of $CsPbBr_3$ to understand $CsPbBr_3$. In this experiment, we use $CsPbBr_3$ which is dissolved at hexane. We measure refractive index of hexane, $CsPbBr_3$ with various concentration.

Keywords:

CsPbBr3, Interferometer, Perovskite, Refractive index

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P2-pa.001

MC study of radiative D meson decays at Belle II experiment

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Abstract:

Belle II experiment have a good performance at reconstruction of charmed hadrons and neutral decays than previous generation of B-factories.

Neutral radiative decays in D^0 meson, denoted by $D^0 \rightarrow V\gamma$ are working on. In our study, we concentrate on $V = \phi, \rho, \bar{K}^{*0}$ and ω . Branching fraction and A_{CP} are what we're measuring. Ultimate goals of achievements are the first observation of $D^0 \rightarrow \omega\gamma$ and much improved precision in other modes, by using the high-statistics data sample from Belle II in future. We developed π^0 veto to suppress the dominant background source from $D^0 \rightarrow V\pi^0$. In present, we are working on π^0 veto calibration and estimating the measurements in MC.

In the poster, current status of MC study will be reported.

Keywords:

Belle II, D meson, Radiative, Charm

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P2-pa.002

Search for D decays to invisible final states in Belle II experiment

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Abstract:

The search for D^0 decays to invisible final states is sensitive to any dark matter particles that don't leave any trace on detector because the expected branching fraction of $D^0 \to \nu\bar{\nu}$ in standard model is beyond the current reach of experiment.
This analysis is being done by using energy-momentum conservation law and precisely known initial state of e^+e^- collision. I select events by reconstructing one charm hadron that is called as tag side along with well-measured light hadrons, which is called as fragmentation part, and identifying the recoil part against of system consist of tag and fragmentation part as being D^* by examining the recoil mass. If there is no trace that correspond to the recoil part, it can be the candidate event of D^0 decays to invisible final states.
In this poster, I report Monte-Carlo simulation study using Belle II set-up.

Keywords:

Belle II, Charm, tagging

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P2-pa.003

The study of track trigger for Bhabha background suppression

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Abstract:

The purpose of the Belle II experiment is for the B factory and the search for new particle physics phenomena. The upgrade from the previous Belle experiment allows for a luminosity 40 times greater, resulting in significant background noise. Search for new physics loosens requirements for data collection known as the trigger system which increases noise. The background consists of two sources, one from the initial electron-positron beams called the beam background and the other from the byproducts of the beam collision called the luminosity background. The main focus of this study is the Bhabha process which outputs electrons and positrons. The luminosity background was initially simulated through Monte Carlo samples, which then required validation through extrapolation of experimental results. The results validified the use of Monte Carlo samples to study the Bhabha background. The Bhabha process occupied approximately 60 percent of the luminosity background. Various single beam veto efficiencies were checked. Out of many applications, around 10 percent of the Bhabha process was removed and further research should be done to create efficient vetoes.

Keywords:

Trigger, Belle 2, Bhabha

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P2-pa.004

Improvement of 2D interferometer Analysis Algorithm for Beam Diagnostics at PLS-II

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Abstract:

The Pohang Light Source II (PLS-II) is a third-generation synchrotron light source that produces intense beams of synchrotron radiation for various scientific experiments. The accurate measurement of the beam properties is crucial for optimizing the performance of the facility. In this poster, we present the improvement of the 2D interferometry software for beam diagnostics at PLS-II, with proper fit functions in consideration of backgrounds. The software is optimized in terms of the speed by choosing appropriate initial values extracted with the FFT algorithm, fast numerical libraries and multi-CPU environments. Our improved software is expected to analyze interferograms at over 120Hz which is expected to be enough to analyze the low-frequency noise component.

Keywords:

PLS-II, PAL, Interferometry, Beam Diagnostics

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P2-pa.005

Vertex Reconstruction with Dynamic Graph Convolution Neural Network(DGCNN) in JSNS^2 Monte Carlo simulation

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Abstract:

The JSNS^2 (J-PARC Sterile Neutrino Search at the J-PARC Spallation Neutron Source) experiment searches for neutrino oscillations at 24m baseline from the J-PARC's 3 GeV 1 MW proton beam incident on a mercury target at the Materials and Life science experimental Facility (MLF). The JSNS^2 detector consists of three cylindrical layers including an inner most neutrino target, an intermediate gamma-catcher, and an outer most vetoes. The neutrino target is made of 17 tons of Gd loaded LS (Gd-LS) stored in an acrylic vessel, 3.2m(D) x 2.5m(H). The detector consists of a total of 120 photomultiplier tubes (PMTs), 96 PMTs for inner and 24 PMTs for outer veto. n JSNS^2, a maximum likelihood method based on the PMT charges is used to reconstruct vertex position and energy of the event. We present the results of the first application of a deep learning model called DGCNN for vertex reconstruction in JSNS^2. DGCNN is a combined model of PointNet and Graph Neural Network (GNN). The input positrons used for model training were generated by Monte Carlo simulation. The features used in the model training were the position and charge information of the PMTs.

Keywords:

deep learning, GNN, JSNS2, neutrino

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P2-pa.006

Study of systematic uncertainty and reconstruction performance for KDAR MC in JSNS^2

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Abstract:

JSNS^2(J-PARC Sterile Neutrino Search at J-PARC Spallation Neutron Source) experiment will search the unique ability to precisely measure monoenergetic 236 MeV neutrinos from charged kaon decay-at-rest (KDAR). KDAR neutrino gives the Optimized data for studying the neutrino-nucleus interaction, energy reconstruction, and cross sections in the hundreds of MeV energy region. we had a simulation to understand our detector response effect from the KDAR interaction. In this presentation, we will report systematic uncertainty study and reconstruction performance study using KDAR MC.

Keywords:

KDAR neutrino , Material and Life Science Facility (MLF) , energy reconstruction

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P2-pa.007

Background study for the GE1/1 detector in the CMS experiment

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Abstract:

As a part of the CMS muon system upgrade, the installation of the GE1/1 detectors has been completed in 2020. Because the GE 1/1 system is located in the forward region of the CMS endcap, we expect high background rates due to the heavy radiation environment. There are some additional components of the electronics-induced noise which can affect the background rate measurement. So, they must be filtered to obtain the true background rate. In this study, we measure the background rate after the noise filtering using the first year of data from LHC Run 3.

Keywords:

CMS, GEM, Muon system upgrade, Background study

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P2-pa.008

Data Quality Monitor modularization of trigger timing jitter of Event T0 based on the Belle II Electromagnetic Calorimeter trigger system

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Abstract:

The Belle II experiment has accumulated 424 fb^{-1} physics data in luminosity run at the SuperKEKB electron-positron collider. Over the following decades, it will record 50 ab^{-1} of data. With this vast data set, Belle II does perform various measurements that test the Standard Model (SM) and probe for the existence of New Physics beyond the SM. In this report, we will present the Data Quality Monitor (DQM) modularization of the Electromagnetic Calorimeter (ECL) trigger jitter of Event T0 based on the ECL trigger fine event.

Keywords:

DQM, ECL, trigger

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P2-pa.009

Study of the J/psi --> Xi$^-$ Xibar$^+$ at the BESIII experiment

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Abstract:

We study the $J/\psi \to \Xi^-\overline{\Xi}^+$ decay mode, using the 100 billion J/ψ data samples collected by the BESIII detector at the electron-positron collider BEPCII located at the IHEP of Beijing, China.
We first aim for the most precise mass measurement of the Ξ^- to the same precision as the statistical error level of the J/ψ by investigating the decay chain of $\Xi^- \to \Lambda\pi^-$ and $\Lambda \to p\pi^-$. The results of a Dalitz analysis, optimization of event selection, etc, on the way to achieving that goal are reported here.

Keywords:

BESIII, J/psi --> Xi- Xibar+, collider BEPCII

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P2-pa.011

PAL-EUV Magnet Power Supply(MPS) System

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Abstract:

This paper presents an overview of the magnet power supply (MPS) for the PAL-EUV. A total of 202 MPS units are installed, with 11 units in the injection section, 56 units in the booster section, and 135 units in the storage ring section. The current capacity of the MPS ranges from 5A to 400A and is divided into two categories: the injection and storage ring sections that require DC operation, and the booster section that requires AC current operation of ramping up/down. These MPS units meet the high stability requirements specified by the beam dynamics specifications. This paper describes the overall MPS requirements, the MPS power circuit and control configuration, and the its test results.

Keywords:

Magnet Power Supply

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P2-pa.012

New Electronics for JSNS2

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Abstract:

In JSNS2 (J-PARC Sterile Neutrino Search at the J-PARC Spallation Neutron Source) experiment, we were currently using the CAEN DAQ (Data Acquisition) system with 8 bits. Flash ADCs(CAEN V1721) are used for the digitizer, and various NIM (Nuclear Instrumentation Module) were used for Trigger with analog signal. JSNS2 Electronics Group developed new DAQ with 14 bits, so resolution of raw waveform would be improved. With this resolution, we expect to better performance of PSD (Pulse Shape Discrimination) than before. And trigger system of new DAQ works between software and FPGA (Field Programmable Gate Array). So we don’t need complicated connections between FADC and NIM modules and easier to implement triggers without hardware. In this poster, status of new DAQ and analysis for Dry-run data would be shown.

Keywords:

DAQ, FPGA, Neutrino

2023 KPS Spring Meeting
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P2-pa.013

A magnetic field measurement system for new kicker magnet of pohang accelerator laboratory (PAL).

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Abstract:

The new kicker magnet system of pohang accelerator laboratory (PAL) reduces beam vibration to less than 100μm in the vertical direction and 30μm in the horizontal direction. The injection kicker power supply of PAL supplies a pulsed current with a magnitude of up to 10kA for 6.8μs to the kicker magnet. This paper presents a magnetic field measurement system for new kicker magnet. The proposed system uses a single turn coil to measure the magnetic field at the high current. In order to spatially measure the magnetic field of the magnet, the coil moves in three dimensions using step motors which have a position error of less than 25μm. The magnetic field was measured in a space of 330mm X 30mm from the center of the kicker magnet to the outside of the kicker magnet.

Keywords:

magnetic field measurement system, kicker magnet

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P2-pa.014

Belle II DAQ

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Abstract:

Brief summary of the service works done in Belle II Data Aquisition part.

Keywords:

Belle, Belle II, Belle2

2023 KPS Spring Meeting
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P2-pa.015

Search for Heavy Neutral Lepton(HNL) with Tau Lepton Decay in Belle

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Abstract:

HNL is sterile neutrino that interacts only with neutrino mixing. It can answer the question about the matter-antimatter asymmetry of our universe. We introduce the way to measure $|U_{\tau 4}|^2$ (extented PMNS matrix component) with tau lepton decay in Belle experiment. The merits of using tau lepton decay in Belle are high statistics of tau decay in B factory and high sensitivity in 1-1.2GeV region compared to other methods.

Keywords:

Belle, tau lepton, heavy neutral lepton

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P2-pa.016

Interference effect due to W boson in heavy charged gauge boson search at the LHC

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Abstract:

The effect of interference arising from the W-W' mixing in an electron plus missing transverse energy final state is explored with simulated events in proton-proton collisions at sqrt(s) = 13 TeV. Effective signal shapes are studied on the transverse mass distribution with various W' mass and coupling strength parameters. Events are selected using a special kinematic feature of the signal. The Higgs Combine Tool is used to set a limit. As a result, a 95% CL expected limit on the coupling strength of W' in the interference scenario is set for an integrated luminosity of 138 fb^{-1}.

Keywords:

Interference, BSM, W'

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P2-pa.017

Search for the rare decay B0→τ+τ- at Belle II experiment

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Abstract:

A search for the rare decay *B0→τ+τ-* is performed at the Belle II experiment using the superKEKB asymmetric electron-positron collider. The standard model predicts that the branching fraction of the decay mode is suppressed, but several extensions of the standard model expect enhancements. The results will be obtained with data samples corresponding to an integrated luminosity of 363 fb^{-1} collected at the Υ*(4S)* resonance. We use a hadronic tagging method that reconstructs fully accompanying B meson and try to find signals from the remaining part of the event. The result of this study will be the measurement or upper limit setting of the branching fraction of the decay. We present the results based on Monte Carlo simulation samples.

Keywords:

Rare Decay, Hadronic Tagging, Leptonic, Belle II Experiment

2023 KPS Spring Meeting
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P2-pa.018

Neutron detection with a 3D-projection scintillator tracker and its application to neutrino oscillation experiments

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Abstract:

Neutrino oscillation experiments require a precise measurement of the neutrino energy. However, the kinematic detection of the final state neutrons in the neutrino interaction is missing in current neutrino oscillation experiments. A novel 3D projection scintillator tracker can detect the neutron kinetic energy and direction on an event-by-event basis. Through neutron detection, the neutrino energy can be reconstructed precisely. The measurement of neutron kinematics also enables an antineutrino flux measurement using the complete final state particle information in desired channels.

Keywords:

2023 KPS Spring Meeting
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P2-pa.019

Progress of DUNE

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Abstract:

DUNE is a large-scale particle physics experiment that measures the physical constants associated with mass through neutrino oscillations and studies the properties of neutrinos. The neutrino beam with the highest luminosity and multi-component detectors at the near site will make it possible that DUNE extends its potential to search or test all possible frontline physics. As a prototype experiment for the far detector with 40-kton liquid Argon time-projection chambers, ProtoDUNE is scheduled to collect data in 2023 at CERN. This presentation introduces the designs and sciences of the near and far detectors and shares the current progress of the DUNE experiment.

Keywords:

DUNE, Neutrino

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P2-pa.020

Physics of DUNE

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Abstract:

The Deep Underground Neutrino Experiment (DUNE) is a long-baseline neutrino oscillation experiment. DUNE shoot a neutrino beam produced at Fermilab toward South Dakota, 1300km far away. DUNE aims to study physics goals that include measuring accurately the oscillation parameters as neutrinos travel through matter, determining the neutrino mass hierarchy, measuring CP violation that could answer why the universe is made of matter, and detecting the neutrinos produced by a supernova. DUNE also searches for the baryon number violation process such as proton decay, and BSM interaction between neutrino and dark matter. In this poster, we describe DUNE's physics goals and expected results.

Keywords:

DUNE, Neutrino

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P2-pa.021

Kinematic features of non-isolated muons inside b-jets in the CMS experiment

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Abstract:

This poster presents non-isolated dimuon signatures inside jets using 13 TeV proton-proton collision data collected by the CMS experiment. The dataset is collected in 2016 which corresponds to the integrated luminosity of 36 fb-1. Non-isolated muons are powerful objects to study new physics in leptonic channel inside a jet and to study heavy flavour jets. Several kinematic features of non-isolated muons will be presented and we will discuss possibility of non-isolated muons as discriminant of the heavy flavour jet.

Keywords:

CMS, non-isolated muon, b-jet

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2023-04-19 - 2023-04-21

P2-pa.022

Study of WWZ in fully leptonic final state production in proton-proton collisions at High-Luminosity LHC

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Abstract:

High-Luminosity LHC (HL-LHC) project is being pursued to acquire unprecedented amounts of data. In the HL-LHC environment, it is expected that rare physical phenomena can be observed. This study explores the possibility to observe of WWZ process which has a fully leptonic final state. WWZ signal and background samples are generated by Madgraph5, Pythia8, and Delphes3. The main background is the ZZ process which has the same final state as the signal. Cut-based and deep neural network algorithms are applied to discriminate the signal and background processes. We compare the two methods and present which method is more effective in the HL-LHC environment.

Keywords:

WWZ, HL-LHC, machine learning

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P2-pa.023

BDT analysis for Anomalous triple gauge couplings in electroweak dilepton tails at the LHC

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Abstract:

We study the electroweak dilepton production with two forward jets at the LHC, aiming to measure the anomalous triple gauge couplings in the Effective Field Theory (EFT) approach. We use the invariant mass of the dilepton mass system as well as the transverse momentum to derive the sensitivity to anomalous triple gauge couplings at the LHC and the high luminosity LHC. Boosted Decision Tree (BDT) is used to suppress the Drell-Yan + multijet events. The details of the BDT method as well as the results of the analysis will be presented in this poster.

Keywords:

aTGC, BDT, HL-LHC, VBF, Drell-Yan

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P2-pa.024

Adaptive Baseline Estimation (ABE) algorithm for SUB-Millicharge ExperimenT (SUBMET)

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Abstract:

In SUB-Millicharge ExperimenT (SUBMET) at J-PARC, the full trace of the analog signal from PMTs is saved in data. For the charge below 10^-3e, a single photon is produced when the millicharged particle goes through a scintillator bar. Therefore, single photoelectron (SPE) signals should be identified. Since SPE signals are small, understanding the baseline of the analog signal is important. We developed an algorithm, called Adaptive Baseline Estimation (ABE), which finds the baseline in an iterative procedure. The algorithm and its performance will be presented in this poster.

Keywords:

millicharge, baseline, iterative, algorithm, J-PARC

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P2-pl.001

Effects of Multi-electrode Cylindrical DBD Plasma on Catalytic and Antifungal Activity

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Abstract:

Dielectric-barrier-discharge (DBD) plasma has a wide range of applications in the industrial, medical, anti-bacterial, antifungal, and catalytic fields. It is an attractive, novel, quick, efficient, inexpensive, and environmentally friendly technique. One of the main advantages of DBD plasma is the production of high-energy electrons with reactive oxygen and nitrogen species (RONS) and a strong electric field, UV light, and thermal energy. The plasma was diagnosed using optical emission spectra (OES), and current-voltage characteristics. The electron density and temperature of the DBD plasma were obtained from the OES. The plasma-induced reactive species were analyzed from the FT-IR spectra. For the first time, the effects of RONS on the catalytic and antifungal activities were investigated by using plasma activate water (PAW) from the multi-electrode cylindrical DBD. Catalytic and antifungal effects are attributed to the cocktail of several RONS existing in the PAW.

Keywords:

DBD; antifungal; catalytic fields; RONS; electron temperature; FT-IR spectra

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P2-pl.002

Comparison of the ion energy distribution function according to the dielectric constant of Focus Ring in pulse-driven capacitively coupled plasma

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Abstract:

The pulse-driven capacitively coupled plasmas(CCPs) used to improve the semiconductor etching process. Pulse-driven CCPs control the density of ions by controlling input pulse and improves plasma uniformity. Accordingly improving the distortion of etching in the process.

According to previous research results using 2D Particle-in-Cell(PIC) simulation, changes in duty ratio and pressure affect the ion energy distribution function (IEDF), and the energy of ions entering the wafer can be adjusted according to the purpose of the process.

In this study, the IEDF according to the dielectric constant of Focus Ring in the CCPs argon discharge was analyzed using a two-dimensional particle-cell simulation [1,2] parallelized with GPU.

Keywords:

Pulse-driven, Particle-in-Cell Simulation, IEDF, Focus Ring

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P2-pl.003

Particle Image Velocimetry and Schlieren Image for a Plasma Actuator Based on Three-Electrode Surface Dielectric Barrier Discharges

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Abstract:

Recently, there has been a wide increase in the study of atmospheric pressure plasma applications to electro-hydrodynamic (EHD). One such application is the use of a plasma actuator with a surface dielectric barrier discharge (sDBD), which can delay the separation point caused by adverse pressure gradients in an airfoil. This delay reduces fuel consumption by decreasing drag force and increasing lift force. In this research, we investigated the breakdown voltage and power consumption of the plasma discharge by applying AC sinusoidal wave voltage to a three-electrode sDBD plasma actuator. We varied the electrode width, thickness, and structure, and measured the Lissajous curve. Additionally, we analyzed particle image velocimetry (PIV) data and Schlieren image to confirm fluid behavior and observe the changes in the discharge region and velocity profile, which were accelerated by the plasma.

Keywords:

Plasma actuator, Surface Dielectric Barrier Discharge, Particle Image Velocimetry, Schlieren image

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P2-pl.004

물리기반 기계학습 기법을 적용한 실험데이터 기반 충돌-방사 모델에 의한 아르곤 플라즈마의 전자 온도 및 밀도 측정

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Abstract:

충돌-방사 모델 기반의 광방출 분광법을 통한 플라즈마 전자 온도 및 밀도 진단은 플라즈마 특성 분석에 유용하다. 충돌-방사 모델에는 확산계수와 방사가둠계수 등 이론적 가정들이 반영되는데, 실험조건에 따라 전자 온도 및 밀도 진단에 오차가 발생할 수 있다. 이를 해결하기 위해, 본 연구에서는 물리기반 기계학습 기법을 적용한 실험데이터 기반 충돌-방사 모델을 제시한다. 개발된 모델에 사용된 인공신경망에서는 각각 분광 데이터와 실험조건을 입력변수, 충돌-방사 모델의 비결정 물리변수인 기체온도, 광학 및 확산 특성 길이와 예측할 변수인 전자온도, 밀도를 출력변수로 지정하였다. 그리고 인공신경망의 출력 결과를 충돌-방사 모델에 입력하여 이론적 광방출 세기를 계산하였다. 인공신경망의 손실함수는 계산된 방광출 세기와 측정값의 차이 및 인공신경망을 통해 계산된 전자 온도 및 밀도와 랑뮤어 탐침 측정값 간의 차이의 조합으로 정의하였으며, 이를 최적화하는 방식으로 인공신경망을 학습시켰다. 이로써 특정 실험조건에 최적화된 물리변수를 예측하여 충돌-방사 모델에 반영할 수 있는 방광출 분광법을 제시하였다. 본 연구에서는 개발된 모델의 검증을 위해 방전전력 100 – 400 W의 아르곤 유도결합 플라즈마에서 측정한 방출광 세기와 랑뮤어 탐침을 이용해 측정한 전자 온도 및 밀도 데이터를 활용하였다. 인공신경망의 학습 데이터는 방전전력 100 – 350 W, 시험 데이터는 400 W 측정 케이스로 분류하였다. 학습 데이터를 통한 인공신경망 학습 후 시험 데이터를 통해 추론한 결과, 방전전력 400 W, 기체압력 400 mTorr의 조건에서 전자온도 1.6 eV, 전자밀도 6×10^{17} m^{-3} 를 도출하였다. 이를 통해, 본 연구를 통해 설계한 모델이 시험 케이스에서 전자온도 및 밀도를 15% 오차 이내로 잘 예측함을 확인하였다.

Keywords:

플라즈마 광진단, 충돌-방사 모델, 물리기반 기계학습, 아르곤 유도결합 플라즈마

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P2-pl.005

활성 산소종 및 질소종의 밀도 측정을 위한 흡광 스펙트럼 해석기법

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Abstract:

저온 대기압 플라즈마는 화학공학과 농식품 등 다양한 응용 분야에서 각종 활성종의 발생원으로서 각광받고 있는데, 플라즈마를 산업적으로 활용하기 위해서는 플라즈마에서 발생하는 활성종의 종류와 밀도를 정확하고 경제적으로 진단하는 것이 중요하다. 기존 진단법 중 흡광 분광법은 자외선-가시광선 파장대에서 측정한 흡광 스펙트럼으로부터 비어-램버트 법칙에 의해 각 활성종의 밀도를 역산한다. 이 진단법은 경제적이지만, 기존 진단법은 몇몇 특정 파장들만 사용하고 측정 스펙트럼과 활성종들의 흡광 스펙트럼을 순차적으로 맞추는 방식을 사용하였기 때문에 활성종들의 밀도가 부정확하게 측정되고 흡광 단면적 스펙트럼의 모양이 비슷한 활성종들을 분간하기 어려운 문제점이 있었다. 본 연구에서는 실험에서 측정한 흡광 스펙트럼을 자동으로 해석하여 여러 활성종의 밀도를 동시에 측정할 수 있는 해석 기법을 개발하였다. 개발된 해석기법은 회귀분석을 통해 각 활성종의 흡광 단면적으로부터 측정된 흡광 스펙트럼과 가장 유사한 흡광 스펙트럼을 재구성함으로써 각 활성종의 밀도를 구한다. 기존 방법과는 달리 측정한 스펙트럼의 파장 전 영역에서 흡광 스펙트럼을 동시에 맞추어 활성종 밀도를 계산하고, 오류 보정 절차를 회귀분석 전후에 걸쳐 시행하여 더욱 정확한 분석 결과를 얻어낼 수 있다. 그 결과 개발된 전산 프로그램은 각 흡광 스펙트럼의 분석 시간을 15 ms 수준으로 단축하고, 흡광 단면적 스펙트럼 모양이 비슷한 활성종들을 구별하며, 주요 활성종인 O_3, NO_2, NO를 각각 최고 밀도 대비 0.086%, 0.79%, 그리고 4.4%의 불확실도로 측정할 수 있었다. 또한 기존에 이 활성종들의 밀도를 측정하는데 쓰이던 상용 O_3와 NO_x 분석기에서 나타나는 과다측정 및 과소측정 문제를 극복할 수 있었다. 언급한 활성종 외에 플라즈마에서 생성되는 다른 활성종들의 측정 결과의 불안정성 문제는 향후 NO_3 흡광 단면적을 측정하여 포함시키고, 화학 시뮬레이션을 개발하고 이 진단법과 결합하여 해결을 시도할 예정이다. 본 연구 결과는 저온 대기압 플라즈마의 활성종 분석을 정확하면서도 경제적으로 가능하게 하여 저온 대기압 플라즈마 연구뿐 만 아니라 상용화에도 도움이 될 것으로 전망한다.

Keywords:

오존, 질소산화물, 흡광 분광법, 해석 기법, 진단법

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P2-pl.006

ExB 탐침 진단을 이용한 원통형 홀추력기의 제논/크립톤 이온빔 다중 이온 비율 비교

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Abstract:

홀추력기는 플라즈마 내 가속된 이온을 이용하여 추력을 얻는 전기추력기의 일종으로, 높은 추력밀도와 전력효율(>50 mN/kW), 높은 연료 효율을 기반으로 인공위성의 궤도 천이 및 궤도 수정과 심우주탐사 등에 활발히 사용되고 있다. 특히 홀추력기의 일종인 원통형 홀추력기는 플라즈마의 표면적 대비 부피 비율을 증가시켜 방전채널로의 열 및 입자 손실을 줄인 추력기이다. 본 연구에서는 원통형 홀추력기 이온빔에서 제논 및 크립톤 방전시 ExB 탐침을 통한 다중이온 비율 진단을 진행하였다. ExB 탐침은 자기장과 전기장에 따른 로렌츠힘 관계식을 이용하여 각 이온종의 분포를 측정할 수 있는 탐침으로, 전기장 세기를 변경해가며 모든 이온종 분포의 합인 ExB 스펙트럼을 얻을 수 있다. 본 연구에서는 각 이온종 분포마다 2개의 가우시안 분포를 이용하는 이중 가우시안 기법을 사용하였으며, 모든 방전조건의 ExB 스펙트럼은 결정계수(R-squared) 0.99 이상으로 피팅되었다. 이때 각 이온종 분포의 넓이 분석을 통하여 이온빔 내부의 다중이온 비율 계산이 가능하며, 제논 방전시 원통형 홀추력기 이온빔의 2가 이상 다중이온(Xe II, Xe III, Xe IV) 비율은 약 50%로 확인되었다. 이와 다르게 상대적으로 높은 이온화에너지를 가진 크립톤 방전시, 이온빔 플룸의 2가 이상 다중이온(Kr II, Kr III)의 비율은 약 30%로 확인되었다. 본 발표에서는 제논 및 크립톤과 함께 제논/크립톤 혼합개스 방전시 원통형 홀추력기에서 측정된 다중이온 비율 상세 분석 및 결과에 대해 논의하고자 한다.

Keywords:

홀추력기, ExB 탐침, 다중이온

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P2-pl.007

우주 플라즈마 추력기용 1 암페어급 LaB_6 할로우 냉음극 개발

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Abstract:

홀추력기나 이온추력기와 같은 플라즈마를 기반으로 하는 우주 플라즈마 추력기에는 플라즈마 방전을 개시 및 유지하고 추력기 플룸 플라즈마의 전기적 중성을 유지하기 위한 전자공급이 필수적이다. 따라서 우주 플라즈마 추력기는 전자공급을 위한 음극을 활용하며 10 A/cm^2 이상의 전자를 공급할 수 있는 할로우 음극이 가장 널리 사용되고 있다. 하지만 할로우 음극 내부 형상에 따라 음극 방전 유지에 필요한 키퍼전력과 방출 전류가 달라지게 된다. 그러므로 최소한의 전력소모를 위해서는 추력기의 방출전류에 맞도록 음극의 최적화가 필요하다. 본 연구에서는 우주 플라즈마 추력기를 위한 1 암페어급 LaB_6 할로우 냉음극을 개발하고 소모전력을 최소화하는 음극 내부 형상을 탐색하였다. 열전자 방출에 있어 가장 중요한 인서트의 재료는 일함수가 낮고 산화나 수분과 같은 오염에 강건한 LaB_6를 사용하였다. 또한 인서트를 지지하는 음극 팁은 열전도율이 낮은 티타늄과 녹는점이 높은 탄탈룸 조합으로 구성하여 열전도에 의한 열손실을 최소화하고 높은 열전자 방출온도를 견딜수 있도록 설계하였다. 그리고 별도의 가열소자가 필요하지 않은 냉음극 방식으로 음극을 설계하여 총 길이 30 mm, 키퍼 외경 20 mm로 컴팩트하게 설계하였다. 전자방출 유지에 필요한 소모전력(키퍼전력)을 최소화하기 위해 방전전류 1 – 2 A 범위에서 인서트 내경과 키퍼 오리피스 구경을 변화하여 키퍼 소모전력을 비교하였다. 인서트 내경과 키퍼 오리피스 구경에 대하여 각 3가지 크기를 적용하여 총 9가지 형상의 키퍼 소모전력을 비교한 결과 인서트 내경 2 mm, 키퍼 오리피스 구경 1.4 mm 형상조건에서 가장 낮은 키퍼 소모전력과 안정적인 방전을 확인하였다. 마지막으로, 개발된 음극의 성능을 검증하기 위해 700 W급 홀추력기와 연동시험을 진행하였다. 고정된 홀추력기 방전조건(양극전압 300 V, 양극 제논유량 24 sccm)에서 키퍼전류를 1 – 2 A 범위 내로 변화시켰으며 실험결과, 모든 음극 방전조건에서 안정적인 홀추력기 방전과 키퍼전력 46 W 이하를 유지하였다. 개발된 음극은 추후 수명시험과 반복 개시시험을 거쳐 장기적인 활용을 할 수 있도록 개선될 것이며 앞으로 우리나라의 우주 플라즈마 추력기 개발에 기여할 것이다.

Keywords:

Heaterless hollow cathode, LaB6, 1 A-class cathode, Electric propulsion

Mode Transition (α - γ) and Hysteresis in Low-pressure Plasmas driven by Microwaves

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Abstract:

A hysteresis in microwave-driven argon plasmas at low pressures has been discovered, which occurs across the transition of discharge modes (α and γ) [1, 2]. The hysteresis is manifested in that the critical pressure of mode transition depends on the direction of pressure change. The discharge mode transition is identified by abrupt change in the plasma shape as well as ion population and electron temperature estimated from line emissions [3]. As a result, it is demonstrated that the plasma can have different characteristics at the same operating parameters (pressure, power, frequency, and gas composition) within the hysteresis regime, suggesting the possibility of bi-stable states under the same global operating condition in processing plasmas. The details of the hysteresis are investigated by measuring the rotational and vibrational temperatures from OH (A-X) line emissions [4]. It is found that the hysteresis during the mode transition is mainly due to fast gas heating [5] in the γ-mode, leading to a lower density compared to the α-mode. Thus, the mode transition occurs at a higher pressure for the γ-to-α transition than the α-to-γ transition. This interpretation is verified by replacing the abscissa from pressure to normalized neutral density, which results in the elimination of the apparent hysteresis. Therefore, we suggest a simple and cost-efficient method of preventing the hysteresis by monitoring the neutral density along with the operating pressure. Further experiments imply that this microwave-driven plasma operated with the γ-mode produces a double layer that is free of current [6]. The double layer results in a dip in the density of electrons along the axis of plasma expansion. This discovery could have significant applications in areas such as plasma thrusters and ion sources that require high-energy ions. This work was supported by Samsung Electronics Co., Ltd (IO201209-07922-01) and the BK21+ program of the National Research Foundation of Korea (NRF).

Keywords:

fast gas heating, hysteresis, double layer formation, microwave plasmas, α-γ mode transition

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P2-pl.009

Investigation of relations between the electron density and temperature profiles in cylindrical inductively coupled plasmas

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Abstract:

The plasma parameters, which highly govern the outcomes of plasma processing, is explored using two different probes inside the source region of a cylindrical ICP with a driving frequency of 13.56MHz. A cutoff probe is used to measure electron density by locating the cutoff frequency which is equal to the plasma frequency. A Langmuir probe with three RF filters of 13.56MHz, 27.12MHz and 40.56MHz is used to measure electron temperature and plasma potential. The advantages, limitations and uncertainties of the diagnostic systems are presented. In this work, the positions of the probes are varied radially to measure the radial profiles of each plasma parameter. By varying the chamber conditions such as the input power and neutral pressure, the characteristics of the electron density profile and its relation to electron temperature and plasma potential is discussed.

Keywords:

ICP, Cutoff Probe, Langmuir Probe, RF plasma

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P2-pl.010

Study of the Normal Spectral Emissivity Measurement on Tungsten by Long-wave Infrared Thermography

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Abstract:

In the tokamak machaine such as ITER and DEMO, the expected heat flux on the divertor and limiter plasma-facing components (PFCs) can be reached up to 10 MW/m^2 during steady-state tokamak plasma operation. Thus accurate temperature measurements on PFCs of the tokamak machine are clearly crucial, both for testing applications and for the tokamak machine protection. Infrared (IR) thermography is well-suited to this task and has become a standard tokamak diagnostic [1-3], but the problem is complicated in tokamak environment and is especially the use of tungsten as the PFCs material with low emissivity. The emissivity of tungsten is dependent on wavelength, temperature, and surface state, i.e. roughness, oxidation, and erosion/deposition, which can evolve during the time along with plasma operation.
This study aims to investigate into emissivity of tungsten samples by using IR thermography and we have developed the IR thermographic system to measure tungsten emissivity. The system includes a high-temperature furnace, a vacuum control module, its temperature control module, a long-wave infrared thermographic camera (band range from 7.5 um to 14 um), and a control module. The target sample is bulk tungsten with a 5 × 8 × 5.5 mm dimension. The background pressure in the vacuum chamber during a measurement with a furnace is in general 3 × 10^{-5} Torr and the samples of W and graphite are simultaneously heated by the furnace up to 800 C°. Finally, we will present the experimental setup designed in the laboratory and the principle of the measurement. In addition, the calibration results will be reported in this study.

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Keywords:

Emissivity,, IR thermography,, Surface temperature

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P2-pl.011

3U 큐브위성용 100 W급 홀추력기 시스템을 위한 토륨 텅스텐 필라멘트 음극 설계 및 소모전력 최적화 연구

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Abstract:

홀추력기는 직교하는 전기장과 자기장에 의해 자화된 전자들이 ExB 방향인 방위각 방향으로 표류하면서 방전을 유지하고, 자화되지 않은 이온들은 전기장에 의해 추력기 축방향으로 가속되어추력을 발생시키는 고효율 우주추진 장치의 일종으로 위성 및 우주탐사 용으로 활발히 이용되고 있다. 홀추력기 방전채널 끝단 부근에 위치하는 음극은 방전채널 내부에 전자를 공급하여 플라즈마 방전을 개시 및 유지하며, 방출되는 이온빔 플룸의 전기적 중성을 유지시키는 역할을 한다. 최근 각광받는 큐브위성의 경우, 제한된 전력사용 조건 하에서 효율적인 추력 생성을 위해 양극과 음극 간의 적절한 전력 배분이 요구된다. 본 연구에서는 100 W급 전력의 3U(10x10x30 cm) 큐브위성용 홀추력기 및 필라멘트 음극 시스템의 설계 및 소모전력 최적화 연구를 수행하였다. 홀추력기의 운전조건은 개발중인 큐브위성의 전력예산과 임무를 고려하여 제논유량 5 sccm 및 양극전압 200 V로 설정하였고, 양극전력 및 전체 소모전력은 70 W급 및 120 W 미만을 목표 소모전력 조건으로 하였다. 해당 조건을 달성하기 위하여, 0.15 mm 직경의 1% 토륨 텅스텐 필라멘트 음극을 사용하였다. 필라멘트 음극은 추력기 축방향 및 반경방향을 변경하며 큐브위성 설계 규격을 만족하는 세가지 위치에서 실험을 진행하였다. 방전실험의 결과, 플라즈마에 노출된 필라멘트 음극 길이 26 mm 및 가열전류 3.2 - 3.4 A 조건으로 세 위치에서 홀추력기의 안정적인 방전 개시 및 목표 소모전력 내에서의 방전 유지가 가능함을 확인하였다. 특히 필라멘트 음극의 무게중심을 기준으로 추력기 출구면에서 반경방향 25 mm, 축방향 4 mm의 위치에서는 양극전력 70 W 및 전체 소모전력 96 W로 가장 낮은 전력을 소모하였으며, 반경방향 20 mm, 축방향 8 mm의 위치에서는 양극전력 84 W, 전체 소모전력 112 W으로 가장 높은 전력을 소모함을 확인하였다. 본 발표에서는 토륨 텅스텐 필라멘트를 활용한 100 W급 홀추력기 시스템의 소모전력 최적화에 관하여 논의한다.

Keywords:

홀추력기, 토륨 텅스텐 필라멘트 음극, 큐브위성

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P2-pl.012

Reconstruction of Plasma Density Profile from Reflectometry using a Half-cycle Pulse

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Abstract:

Diagnostics of plasma density is an essential part in researches that require non-uniform plasmas. For reconstruction of the density profile, reflectometry technique can be used. Generally the reflectometry uses a microwave with swept-frequency or many channels of different frequencies to reconstruct the plasma density profile. Here we study a new method to use a half-cycled pulse for reflectometry, instead of the multi-frequency pulses. Underlying principle is using the large bandwidth of a single-cycle pulse. Such an extremely short pulse has multi-frequency components over a very wide spectral ranges. When such a pulse is reflected in plasma that has a non-uniform density, each frequency component is reflected at different plasma densities and the dispersion of the pulse is induced. In this process, each frequency component undergoes a different phase change, which can be sampled using the Fourier-transform. From this sampled data, we reconstruct the plasma density profile using the WKB approximation and the polynomial approximation.

Keywords:

Plasma recunstruction, Reflectometry

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P2-pl.013

Multi-Objective Genetic Algorithm optimization of the electron linac.

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Abstract:

This presentation discusses on the optimization of an electron linac with beam dynamics simulations using MOGA (Multi-Objective Genetic Algorithm). The linac was designed to accelerate a bunched beam using an RF cathode gun and traveling wave cavities. The objective of the optimization was to minimize the transverse emittance and energy spread of the beam at the linac end, while also satisfying constraints on other beam parameters such as beam size, beam divergence, and average energy. The simulation included variables such as the positions and input phases of the RF cavities and the position and strength of the solenoid magnet. The optimization process used MOGA to obtain the pareto front of the objective, and the results successfully met the design requirements.

Keywords:

electron linac, beam dynamics simulation, optimization, Multi-Objective Genetic Algorithm

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P2-pl.014

Study on Beam acceptance of a Laser-accelerated electron beam in a ring-type dipole for Compact light source

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Abstract:

A ring-type dipole using a permanent magnet for a compact light source has a periodic magnetic field along the trajectory due to the cylindrical asymmetric shape of the H-shaped iron yoke. A simple analytical calculation shows that the beam acceptance from the laser electron accelerator depends on the modulation of magnetic field strength, which offers the possibility of improving the beam stability and lifetime with somewhat larger energy spread and angular divergence of electron beams from laser accelerators. The vertical focusing can be also increased by increasing the hill-to-valley ratio of iron pole, at the expense of average field strength.
The beam dynamics and beam loss rate of an electron beam depending on its energy spread and angular divergence have been investigated using CST simulation code to determine the acceptable parameters of laser accelerated electron beam as well as the design parameters of the ring-type dipole. In the paper, the optimal design of ring-shape dipole will be discussed for typical beam parameters of laser accelerated electron beams and the spectrum of dipole radiation at the extracting port depending on the beam parameters will be presented.

Keywords:

plasma, laser, light source

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P2-pl.015

알라닌 ESR을 이용한 가속기 표면 방사선량 측정

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Abstract:

100 MeV 선형 양성자가속기는 운전 중에 여러 원인으로 2차 방사선을 발생하게 된다. 이 때 발생되는 방사선량은 가속기 내 가속관의 종류와 특성에 따라 달라지게 되는데, 이는 가속기 내 빔수송 시 발생하는 빔손실에 의한 영향이 큰 것으로 알려져 있다. 현재 한국원자력연구원 양성자과학연구단에서 운영 중인 100 MeV 양성자가속기는 구축을 완료하고 빔 서비스를 개시한지 10년이 경과하였고, RFQ와 20 MeV DTL은 개발기간을 포함해 20년 이상이 경과하였다. 가속기의 노후화 관리 및 운영 데이터 확보를 위해서 가속기 표면이나 터널 내 방사선량 데이터의 정기적인 측정과 관리가 필요하다. 본 연구는 알라닌 ESR을 이용한 방사선량 측정에 대한 기초 실험에 대한 데이터를 제시하고, 가속기 내 방사선량의 측정 주기와 설치 위치 등에 검토 결과를 제시함으로써 향후 효율적인 측정 방법과 데이터 관리 방법을 제시하고자 한다.

Keywords:

양성자가속기, 알라닌, ESR, 방사선량 측정

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P2-pl.016

Study on the effect of magnetic field off-centered electron beam on a traveling wave tube (TWT)

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Abstract:

A traveling wave tube (TWT) is one of miniature vacuum electron devices (VEDs) operating at sub-THz frequencies. When the electron beam enters the RF circuit of the TWT, the electron bunches are formed by the axial component of the electric field. Then, the extracted energy from electrons is transferred to input RF signals, which amplifies output RF signals. In the TWT amplifier, the magnetic focusing system such as solenoid magnet is used to allow the electron beam to converge on the RF circuit. If the electron beam deviates from the magnetic center, the electron encounters the radial magnetic field. The radial magnetic field affects the motion of electrons in the RF circuit, leading to significant problem in the TWT amplifier system. The rotational electrons are subjected to a force in the direction of the propagation by the radial magnetic field. Therefore, the velocity of some electrons starts to be in discord with circuit velocity[(최(1] . In addition, the radial magnetic field changes the center of electron beam, in which the beam transmission is significantly reduced. Due to the mismatch of the velocity and the degradation in the beam transmission, there is a substantial decline in the efficiency of the TWT amplifier. In addition to these factors, the beam radius and beam scalloping percentage, which are influenced by the off-centered electron beam, also affects the TWT amplifier system.
We present study on the motion of electrons deviated from the center of the magnetic field which ultimately affects the efficiency of the TWT system. The study was conducted by using the CST particle studio simulations. The RF circuit employing a folded waveguide structure was designed to operate on 81–86 GHz with 15.3 kV, 110 mA electron beams, and 2.7 kG maximum magnetic field. The gain of the TWT amplifier at the center frequency is 25 dB for an ideal electron beam case. However, the efficiency of the TWT amplifier becomes substantially lower considering the misalignment of the electron beam, resulting in the poor electron beam quality. In this paper, we analyze the efficiency of the TWT amplifier with respect to the electron beam parameters affected by the radial magnetic field: beam transmission, velocity spread of the electrons, beam filling factor, and beam scalloping percentage.

Keywords:

Traveling wave tube (TWT), Millimeter wave, VEDs

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P2-pl.017

Current Status of the 4GSR Control System Design

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Abstract:

새로운 fourth generation synchrotron radiation source (4GSR)은 2027년까지 대한민국 오창에 건설될 예정입니다. 4GSR은 대형 과학 실험 및 연구를 위한 중요한 장비중 하나로 4GSR에 대한 기술 설계 검토가 현재 진행중이며 2023년 중반에 완료될 것으로 예상됩니다. 4GSR 가속기 제어 시스템은 대형 과학 실험 및 연구를 위한 핵심 장비로 안정성과 신뢰성이 매우 중요합니다. 4GSR 가속기 제어 시스템은 EPICS 기반의 분산 제어 시스템으로 구성되어 있으며, 운영자 인터페이스, 네트워크 및 하드웨어 인터페이스로 구성되어 있습니다. 운영자 인터페이스는 리눅스 또는 윈도우 기반의 워크스테이션에서 GUI를 사용하여 제어됩니다. 이 워크스테이션은 시설 네트워크의 어느 지점에나 위치할 수 있으며, 제어 디스플레이를 생성하고 변경하며, 알람 핸들러, 아카이버, 대화식 제어 프로그램, 사용자 지정 코드 등에 액세스할 수 있습니다. 이를 위한 네트워크 구현은 광섬유 기반의 이더넷을 사용하며, 허브를 통해 연결됩니다. EPICS IOC는 가속기의 하위 시스템에 대한 직접 제어 및 I/O 인터페이스를 제공합니다. 이를 통해 사용자는 하위 시스템을 직접 제어하고 모니터링할 수 있습니다. 4GSR 컨트롤을 구현하는 그룹은 높은 연계성, 가용성, 안정성, 용이성, 확장성 및 유연성을 갖춘 시스템을 설계하는 것이 목표입니다. 이를 위해 하드웨어 및 소프트웨어 개발을 진행중이며, 시스템의 디자인 진척 사항을 보고하고 미래 계획에 대해 논의할 예정입니다.

Keywords:

4GSR, Accelerator Control System

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P2-pl.018

Development of an image segmentation routine specialized for texture processing

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Abstract:

Segmenting an image in which several objects are mixed by object is a basic task for recognizing an object in the image. In this study, I decided to develop my own image segmentation routine specialized for texture processing.
Mean Shift (Mean Shift clustering algorithm) is known to be suitable for image segmentation because it can consider not only color similarity but also regional proximity [1]. However, since it takes an extremely long calculation time [1], K-Means (K-Means clustering algorithm) was applied was applied to divide a test image into 30 regions. By inputting not only the RGB colors but also the coordinates of a pixel in the image into the K-Means data matrix, it was possible to obtain an effect similar to Mean Shift and reduce the calculation time.
On the other hand, in order to process the textures of the image in batches, the density of the Canny edges was calculated over each 5×5 pixels. By applying the cluster center colors, resulted from K-Means, on the central parts of the textures and selecting the cluster center colors closest to the colors of the original image pixels using K-NN (K-Nearest Neighbors algorithm) on the edge parts of the textures, it was possible to obtain a significantly improved segmented image compared to the existing method.
However, in the final image, objects that are not yet small in size, such as clouds and stars, have disappeared, and Canny edges are cut off in several places. Efforts to address these problems will continue.

[1] I.S., Oh, Computer Vision - from basic concepts to modern mobile application examples, Seoul: HANBIT Academy, Inc.; 2014

Keywords:

texture , image segmentation , Mean Shift clustering algorithm , K-Means clustering algorithm , K-Nearest Neighbors algorithm

2023 KPS Spring Meeting
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P2-pl.019

Development of Dual Frequency Gyrotron operating at 142/208 GHz

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Abstract:

We have developed and are currently fabricating and testing a dual frequency gyrotron that operates at 142/208 GHz. The gyrotron operates in TE7,2 and TE9,3 modes at 142 and 208 GHz, respectively. The electron gun is designed as a diode-type and operates at a cathode voltage of 40 kV and a current of 7 A. The simulated output power is about 100 kW, and the output beam has a duration of 20 us. We designed the gyrotron with in-house code (UGDT), and compared with the commercial code (CST). This gyrotron can provide a high-power terahertz source for various applications, including remote detection of radioactive material through plasma breakdown.
The gyrotron is a device that consists of three main components, which are an electron gun, an interaction cavity, and a mode converter. The electrons emitted from the electron gun move in helical orbits. As the electrons pass through the interaction cavity, they excite a higher-order mode of electromagnetic waves. Normally, the cavity and electron beam size optimized for a single frequency and mode are developed. However, we designed the cavity generating two modes under two different conditions of the electron beams with the same size of the cavity. These higher-order modes spread out rapidly in free space, making it difficult to use the beam effectively. To address this issue, a mode conversion process is necessary to convert the higher-order modes into the lower mode, such as a gaussian mode, which can be effectively used in free space.
We selected two operating modes carefully for those modes to get similar output power. To operate the TE7,2 and TE9,3 modes in a single size of the cavity, electron beam radii of 2.4 mm, and 2.2 mm are required, respectively. For several issues, we re-use an electron gun optimized for the previously operated 95 GHz gyrotron. Therefore, the electron beam was not optimized for the two operating modes, which limits the dual gyrotron efficiency. The size of the interaction cavity was also chosen delicately so that two modes are generated with similar power. The simulated output power is 100 kW for 208 GHz, and 60 kW for 142 GHz according to the in-house UGDT code. The mode converter can convert the higher-order mode to gaussian mode with 95% of power coupling.

Keywords:

Gyrotron, Dual gyrotron, high power source, Terahertz, Electron gun

2023 KPS Spring Meeting
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P2-pl.020

Laser Assisted Free Electron Laser

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Abstract:

Needs of intense terahertz radiation have increased for the studies of rotational spectra of molecules, vibrations of biologically important modes of DNA and proteins, and intermolecular interactions due to its non-ionizing and small Rayleigh scattering features. Free electron laser can be developed in the terahertz spectral range for the frequency tunable and the more intense radiation than that from the table-top terahertz range radiation sources. In this work, we show the possibility of using Donut-like Laguerre-Gauss profile laser for focusing low energy (~5 eV) electron bunch which is the source of the terahertz spectral range free electron laser while the bunch passes through the undulator section.

Keywords:

Terahertz, FEL, Donut-laser

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P2-pl.021

Progress of UNIST Electron Beam Ion Trap (EBIT) Upgrade

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Abstract:

The physics of Highly Charged Ions (HCIs) is one of the important domains of astrophysics. Furthermore, HCIs are currently used in many applied fields such as semiconductor lithography, heavy-ion induced fusion, atomic clock, and particle therapy. Electron Beam Ion Trap (EBIT) is a small-scale laboratory instrument that uses an electron beam to create, trap, and probe HCIs. UNIST group developed a tabletop EBIT with up to 8 keV electron beam and 0.8 T preferment magnet. The goal is the measurement of the spectrum of iron HCI to understand the evolution of the galaxy with iron HCI plasma flow near a Supermassive black hole. Moreover, we plan to measure the total charge and charge distribution of HCIs produced in the UNIST-EBIT. In this presentation, we introduce our UNIST-EBIT and report the progress of current research. Lastly, we will discuss the status of device upgrades.

Keywords:

EBIT, Highly Charged Ion

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P2-pl.023

Terawatt hard X-ray FEL for PAL-XFEL HX2 beam line

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Abstract:

The generation of terawatt-scale free electron lasers (FELs) is of significant interest in the field of X-ray science as it enables single molecular imaging experiments and nonlinear x-ray studies. At Pohang Accelerator Laboratory X-ray Free Electron Laser (PAL-XFEL), a new scheme called Enhanced Self-Amplified Spontaneous Emission (E-SASE) will be implemented in the second hard undulator plan (HX2) using an external laser pulse to produce a single high peak current spike that can be used to generate a terawatt-scale XFEL or attosecond XFEL. The current profile of the spike is manipulated by adjusting the external laser wavelength, the modulator, and the bending angle in the magnetic chicane. At the entrance of the undulator, the electron beam has a peak current of a few tens of KA and a pulse duration of less than 10 fs. To further enhance the XFEL energy, the self-seeded FEL scheme is utilized by tapering the undulator. This presentation introduces the terawatt-scale XFEL using ESASE and the self-seeded FEL scheme.

Keywords:

XFEL, free electron laser, TW scale x-ray , ESASE

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P2-pl.024

Introduction of the Standardized Sequence for Machine Start-up and Optimization of PAL-XFEL

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Abstract:

PAL-XFEL provides the intense and stable XFEL in hard and soft x-ray lines since 2017. It provides the 2.5-15 keV SASE and self-seeded FEL in the hard x-ray line and the 0.3-1.5 keV SASE FEL in the soft x-ray line. Also, it is operated with over 98% availability for the 190-days user time per year. Since reduce the time for the FEL optimization and maintain the machine effectively, we standardize the sequence of the machine start-up and FEL optimization. We initialize magnets by the degaussing, check the calibration between the RF power and energy gain of accelerators, and conduct the linac Beam Based Alignment (BBA) for the machine start-up. Also, we measure the emittance at the injector, conduct the BBA of undulator lines and the beam size matching with quadrupole magnets, adjust the RF phase and dipole magnets in the bunch compressors, and optimize the undulator parameters for the FEL optimization. In this paper, we present the detail sequence for the machine start-up and FEL optimization. Also, we introduce programs for these sequence made by CSS, MATLAB, and Python.

Keywords:

optimization sequence, program, PAL-XFEL, standardize

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2023-04-19 - 2023-04-21

P2-pl.025

Operation Status of 80 MW Klystron and 200 MW Modulator for PAL-XFEL#

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Abstract:

The construction of Pohang Accelerator Laboratory X-ray Free Electron Laser(PAL-XFEL) was completed by the end of 2015. Acceleration modules used in the 4th generation electronic acceleration are 51 modules including Hard X-ray and Soft X-ray. Among the high power pulse power devices used as energy source for accelerating electrons in the 4th generation linear accelerator, the beam is being supplied to the user in 30 Hz, 4uS, SLED tune mode of the 49sets module installed in the hard X-ray. The PAL-XFEL needs a highly stable electron beam. The very stable beam voltage of a klystron-modulator is essential to provide the stable acceleration field for an electron beam. Thus, the modulator system for the XFEL requires less than 50 ppm beam voltage stability. To get this high stability on the modulator system, the inverter type HVPS is a pivot component. And the modulator needs lower noise and more smart system. The commissioning began in April 2016, and the lasing of the hard X-ray FEL was achieved on end of 2016. Beginning to provide users with beams from 2017, we will present the operating status of the Klystron-modulator when providing beams to users in 2022.

This work is supported by Ministry of Science and ICT(Information/Communication Technology).

Keywords:

Klystron Modulator

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P2-pl.026

Preliminary Design of the Booster HPRF system for the KPS

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Abstract:

The 4th generation storage Ring (4GSR) as the second synchrotron light source in Korea was launched from 2021. The Korea-4GSR was named to KPS (Korea Photon Source) by multi-purpose synchrotron radiation construction project management division in KBSI (Korea Basic Science Institute). The KPS is technically designing to be one of the world's best performance with a beam energy of 4 GeV / 400mA of the storage ring. Therefore, the booster RF system is preliminary designing the HPRF (High Power Radio Frequency) system with solid-state power amplifier (SSPA) which is effective RF source instead of klystron due to the high redundancy and enhanced reliability in the accelerator technology. The 80kW SSPAs are needed to supply to the 5 cell Petra type cavities for ramping from 0.2 GeV to 4 GeV of 2mA to inject the beam to the storage ring.
This presentation describes the preliminary design and composition of the HPRF system with mainly 80kW SSPA for the booster RF system.

Keywords:

4GSR, KPS, Booster, RF system, HPRF, SSPA

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P2-pl.027

Beam steering study at the high energy accelerator section of the RAON accelerator

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Abstract:

The first stage of the RAON accelerator project will be finished in 2023, and the beam commissioning has been carried out at the low energy superconducting accelerator section since 2022. After the first stage, the development and construction of the high energy superconducting accelerator section will start. At the period of the first stage, the beam dynamics researches for the high energy accelerator section has been also conducted. Among these researches, machine error was a significant issue for a safe beam operation, therefore the effect of errors to the beam should be mitigated with devices like steering magnets. Here we will present the effect of machine errors to the beam orbit and describe the recent study of the beam steering simulations with steering magnets and BPMs at the high energy accelerator section of the RAON accelerator.

Keywords:

RAON accelerator, machine error, beam steering

Design study of a mass analyzing magnet for the low energy high current ion implanter for the semiconductor device fabrication

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Abstract:

The ion planters for the fabrication of advanced semiconductor devices typically consist of an ion source, a mass analyzing unit, a beam correction unit, an energy filter, and an end-station. We designed a mass analyzing unit, which is capable of transporting a wide ribbon-shaped beam. The ion species such as boron, phosphor, and arsenic are considered with a wide beam energy range from less than 1 keV to above 50 keV. The magnetic field profile was optimized to reduce multipole components, especially the sextupole effect by using a curved pole face, and the beam trajectory was analyzed. Detailed design features and beam tracing results will be given in this presentation.

This work was supported by MOTIE of the Korean government [RS-2022-00154978].

Keywords:

mass analyzing magnet, ion implanter, beam trajectory

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P2-se.101

Factor analysis affecting structural feature and optical quality in perovskite nanocrystals

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Abstract:

Colloidal lead halide perovskite nanocrystals (NCs) have drawn much attention as a promising material for diverse potential applications due to their attention-getting optical and electronic properties. Broad studies have been done to comprehend the reaction chemistry and attain phase and optical stability of these materials. Major obstacles lowering photoluminescence quantum yield of perovskite NCs are strongly correlated to a surface halide vacancy which can form intermediate states and trap the exciton. Meaningful efforts have led to the development of perovskite NCs with tuning precursors and ligands, controlling the reaction temperature, and using reaction controlling agents for enhancing the phase and optical durability. In this work, we aim to evaluate the influence of structural feature on optical properties of Cs-based all inorganic perovskite with different reaction conditions. Our investigation for kinetic aspects of perovskite NCs suggests a framework to develop various strategies for suitable halide perovskite candidates.

Keywords:

Perovskite nanocrystals, Reaction conditions, Structural feature, Optical properties, Kinetic aspects

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P2-se.102

Tuning cation-anion ratio and its effect on optical properties of CdS quantum dots

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Abstract:

Colloidal quantum dots (QDs) have received a lot of attention in recent decades because of their size-dependent properties, which allow them to be used in a variety of applications such as displays, LEDs, solar cells, and so on. Managing the synthesis conditions to produce QDs with the required size and distribution becomes an exciting area of focused research. Moreover, surface passivation is essential for enhancing photoluminescence (PL) quantum yields. Due to the higher surface area to volume ratio, nanocrystals contain many surface defects which can be reduced by using excessive cation ions. In this work, the CdS QDs with different Cd:S ratios (1:1, 2:1, 3:1, and 4:1) are synthesized by the hot injection method. The absorption and PL spectroscopy show that the optical peaks shift to the shorter wavelength range at the start of the growth as Cd concentration increases. In particular, the QD sizes, distribution, and trap states properties are provided to indicate the effect of the cation-anion ratio on the optical properties of CdS QDs.

Keywords:

Quantum dots, CdS, Hot injection method, Cation-anion ratio, Optical properties

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P2-se.103

Effect of ligand chain length on carrier dynamics in colloidal CdSe quantum dots

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Abstract:

Quantum dots (QDs) are semiconductor nanocrystals with a size of several nanometers that are widely used in industry applications because they are smaller than the exciton bohr radius and can easily control electrons and holes. It is well known that the ligand's hydrocarbon chain length, core-shell structure, and other factors can all be used to influence the carrier. The carrier properties can be more easily regulated than other processes, in particular when CdSe QDs are produced by altering the hydrocarbon chain length of the ligand. The hydrocarbon chain length of the fatty acid ligands used in the synthesis of CdSe QDs can make a difference in monomer delivery, resulting different crystal shape of these material. The carrier interaction characteristics can be controlled, depending on the crystal structure. In this work, CdSe QDs with varying ligand chain length were synthesized by using the hot injection technique and the optical properties and carrier dynamics were analyzed.

Keywords:

Quantum dot, CdSe, Ligand chain, Carrier dynamics, Hot injection

2023 KPS Spring Meeting
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P2-se.104

Fabrication and characterization of h-BN encapsulated WSe_2 field-effect transistors

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Abstract:

Two-dimensional transition-metal dichalcogenide (TMDC) materials are attracting considerable attention due to their unique electronic properties and potential applications in electronic devices. In this study, we investigate the transfer curve characteristics of TMDC heterojunction field-effect transistors (FETs).

We fabricated hBN/WSe_2/hBN heterojunction FET structure on p-doped Si with SiO_2 insulator layer and measured the change in drain-source current of the WSe_2 channel according to the gate voltage change. When a positive voltage is applied to the gate, the holes in Si are pushed to the interface between SiO_2 and Si by electrical force, and the electrons are accumulated in WSe_2 by the capacitor model. Conversely, when a negative voltage is applied to the gate, the electrons remain at the interface between SiO_2 and Si, and the holes are accumulated in WSe_2.

By analyzing the gate-dependence of the transfer curve of the FETs, we find the doping type and density of the WSe_2 layer, and additionally, we investigated the change of the transfer curve according to the WSe_2 channel length.

Keywords:

Transition-metal dichalcogenide, Field-effect transistor, Transfer curve, WSe2

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P2-se.105

Plasmon-Induced Charge Transfer in Graphene/Au-Nanopillar-Arrays

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Abstract:

Graphene is a material comprised of atomically thin hexagonal carbon that has attracted great attention, since it has remarkable electrical and optical properties. However, light-matter interaction is limited in graphene because of its extremely small physical volume. Thus, there have been numerous research efforts to fabricate graphene/noble-metal nanostructures. In such hybrid systems, surface plasmons can give rise to enhanced light-matter interactions in the graphene. We investigated the optical and electrical characteristics of the graphene monolayers transferred on Au-Nanopillar (AuNP) arrays. The AuNPs increased the graphene monolayer's Raman intensity by as much as 20-fold when compared to that of flat Au. The angle- and polarization-dependent reflectance spectra of AuNPs showed the dips originated from propagating surface plasmon polaritons (SPPs) and localized surface plasmons (LSPs). Current–voltage characteristics were obtained using conducting atomic force microscopy (C-AFM) to investigate plasmon-induced hot electrons transfer at the graphene/Au interfaces.

Keywords:

graphene, surface plasmons, conducting atomic force microscopy

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P2-se.106

Strong light-matter interaction between WSe2 and a topological photonic crystal

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Abstract:

The topological photonic crystal provides unique properties due to its topological band structure and the resultant topological edge states, which are robust and immune to defects or disorders. Strong light-matter interaction between such topological photonic crystals and transition metal dichalcogenides (TMDs) naturally attracts significant attention in the field of photonics and semiconductor optics. Here, we show strong excitonic luminescence distortion from a hybridized structure made of WSe2 and a topological photonic crystal structure generated from Wu – Hu model. The strong interaction between the two materials results in a variety of interesting physical phenomena that could pave the way for developing new types of photonic devices.

This work was supported by NSF grants 2019K1A3A1A14064815, 2020R1I1A3071811, 2021R1A2C2010592, and Nano·Material Technology Development Program (2009-0082580)

Keywords:

topological photonic crystal, light-matter interaction, transition metal dichalcogenides

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P2-se.107

Tip-induced nanoscale oxidation of graphene in aqueous media

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Abstract:

Graphene oxide (GO) has unique optical and electrical properties with high stability. In addition, reduced GO is also extensively investigated for large scale synthesis, as well as nanoscale lithography. However, no alternative to producing GO from graphene is presented except chemically oxidizing graphite in acidic solutions. Here, we present tip-induced graphene oxidation in aqueous environment to produce GO with tip-enhanced Raman spectroscopy approach. We observed local oxidation of graphene, changing into GO, when the graphene immersed in water and the laser-excited metallic tip approaches to the graphene. The oxidation of graphene is confirmed by the increased Raman D-band intensity of the GO only at the tip-approached region. The spectral feature of GO preserved after we retract the tip and exposed the sample in air. We believe the oxidation process is based on the plasmon-induced chemical reactions of the metallic tip, liquid H_2O, and the graphene.

Keywords:

Graphene, Graphene oxide, Tip-enhanced Raman spectroscopy

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P2-se.108

Fabrication of the novel field-effect transistors using ReS_2 and Te

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Abstract:

In this study, thin-film transistors (TFTs) were fabricated using two-dimensional materials: tellurium (Te), a p-type semiconductor, and rhenium disulfide (ReS_2), an n-type semiconductor. The performance of each transistor was investigated by evaluating its optical and electrical properties. To overcome the yield problem of mechanical exfoliation, Te, which can also be used to fabricate new p-type two-dimensional semiconductor devices following black phosphorus (BP), was synthesized using hydrothermal methods. For the ReS_2 device, hexagonal boron nitride (h-BN) was used as a dielectric to reduce the subthreshold swing (S.S.) at the interface with SiO_2. Using h-BN as a dielectric significantly reduced S.S. values by about five orders of magnitude compared to SiO_2.

Keywords:

tellurium (Te), rhenium disulfide (ReS2), hexagonal boron nitride (h-BN), Hydrothermal Synthesis, Chemical exfoliation

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P2-se.109

Exciton signatures in laterally isolated nanostructure of atomically thin films

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Abstract:

Monolayer transition metal dichalcogenides (TMDs) are an appealing platform for examining and manipulating excitonic properties in the atomically thin limit due to their intrinsic strong Coulomb interactions and alleviated screening effects. In addition to electronic band renormalization to direct gap semiconductor, the optical signature of monolayer TMDs can be further engineered by nanostructuring. Herein, we introduce a high-throughput nanofabrication of laterally confined monolayer TMDs in a hexagonal array. We then investigated their photoluminescence (PL) characteristics by performing a series of power and temperature (4 ~ 300 K) dependent measurements. We observed the unconventional emission in sub-20 nm WS_2 nanodots, which is presumably associated with the laterally confined excitonic transport behavior and reconstructed band structure. Within the nanostructures, exciton movable length is restricted, thereby their excitonic interaction is also changed. This platform is suitable tool for understanding of confined quasi-particle transport behavior and size-dependent photoluminescence (PL) study. The fabricated nanostructures are patternable and transferrable, then can be integrated to nanophotonic structures, providing a new degree of freedom in designing the future photonic devices.

Keywords:

TMD, Excitonic behavior, 2D semiconductor, Exciton transport, Nanostructure

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P2-se.110

High-Performance WSe2 Field-Effect Transistor with WTe2 as a Buffer Layer

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Abstract:

In recent years, researchers have been exploring the semiconductor structure of two-dimensional transition metal dichalcogenide (TMDC) materials as a promising alternative to traditional silicon-based transistors. TMDCs are promising candidates for next-generation electronic and optoelectronic materials due to their unique band characteristics that depend on the number of layers and high carrier mobility, and gate-tunability.[1] However, the performance of such materials is limited by the contact resistance between the TMDC and metal contact, which is called the Schottky contact. In this study, we use tungsten ditelluride (WTe2) as a buffer layer between the tungsten diselenide (WSe2) channel and the metal electrode. WTe2 is one of the TMDC materials and has band overlap, or metal-like properties.[2] We explore its impact on the electrical properties of the field-effect transistor. Also, we use oxidized WTe2 as a buffer layer by adding the annealing process in an oxygen atmosphere. Our results show that the use of WTe2 as a buffer layer leads to a significant enhancement in device performance, including reduced contact resistance, increased carrier mobility, and shift of the threshold voltage. This improvement is attributed to the role of the WTe2 as a buffer layer, which serves to minimize the Schottky Barrier Height (SBH) formed at the Metal-Semiconductor interface and enhance the carrier injection. This work provides valuable insights into the design and optimization of high-performance TMDC-based electronic and optoelectronic devices.

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Keywords:

TMDC, WTe2, buffer layer, carrier mobility, SBH

2023 KPS Spring Meeting
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P2-se.111

Study on spin and valley polarization of Janus 2D materials

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Abstract:

After discovering the low-dimensional materials, many studies have been conducted on transition metal dichalcogenides (TMDCs). Janus TMDCs, which consist of different atoms on each side, are possibly fabricated by the development of the synthesis technology. Conventional TMDCs can be used as excellent ultra-thin flexible devices. Furthermore, the Janus TMDCs are more useful due to their asymmetric structure. Since the Janus structure has two faces, out-of-plane mirror symmetry is broken, which induces the effective electric field in the out-of-plane direction. This symmetry breaking enhances the spintronic properties of TMDCs. In this work, we made a model with an effective Hamiltonian from the DFT results and simulated charge transport with numerical calculation. The structural property is focused, especially the inversion symmetry broken of Janus TMDCs. The spin-splitting enhancement is confirmed by calculating the band structure of the Janus TMDCs compared to conventional TMDCS. Due to external electric and magnetic fields, spin or valley characteristics are manipulated to implement more degrees of freedom. With these ingredients, we give light to the Janus TMDCs-based spintronic devices.

Keywords:

Janus, 2D materials, spintronics, tight-binding model

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P2-se.112

Optical and electrical control of nanoscale metal-semiconductor tunnel junction

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Abstract:

Electron density of 2D transition-metal dichalcogenides (TMDs), a key metric determining optoelectronic performance, significantly influences their optical characteristics, such as radiative emission rate and valley polarization. However, precise modulation of the doping density in 2D TMDs at the nanoscale remains a challenge. Here, we present a nano-mechanical engineering of metal-semiconductor tunnel junction through conductive tip-enhanced photoluminescence (*c*-TEPL) spectroscopy. By exploiting dynamic atomic force regulation, we systematically control the level of metal-semiconductor interaction. This enables the manipulation of the doping density of the MoS_2 monolayer at the nanoscale region, confirmed with the spatial resolution of ~25 nm. Moreover, we facilitate the doping-dependent switching of TEPL intensity and valley polarization, induced by the tip-induced local electric field. This allows us to induce and probe nanoscale optical heterogeneities in TMD monolayers, opening a pathway toward ultrathin optoelectronic device applications.

Keywords:

TEPL, 2D semiconductor, c-AFM, Metal-semiconductor tunnel junction

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P2-se.113

Deterministic control of electron density in atomically thin semiconductor

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Abstract:

Electron density plays an important role in determining optical and electrical characteristics of 2D transition metal dichalcogenide (TMDs), leading to versatile applications of optoelectronic devices. Here, we present a nanoscale electric pulse generator induced by the metallic tip, enabling spatial modification of the electron density in a reversible manner. The nanoscale Schottky contact between the tip and MoS_2 monolayer modifies the electron population, which consequently enhances photoluminescence (PL) quantum yield. Employing tip-induced electric pulse generator regulates the electron depletion region. Thus, we can demonstrate the frequency-dependent modulation of PL intensity by manipulating the electron depletion region. Quantitative analysis of the obtained PL intensity with a theoretical model confirms the dynamic control of electron density in our experiment. We envision that this modality paves the way toward the electrically tunable nano-optoelectronic devices.

Keywords:

depletion region, Schottky, photoluminescence, quantum yield, transition metal dichalcogenide

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P2-se.114

Anomalous ellipticity dependence in high-order harmonic generation of Chern and topological insulators

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Abstract:

High-order harmonic generation (HHG) has been attracting the attention of condensed matter physics, mainly because of the capability of light to encode electron structural, dynamical and topological information. In this study, we check whether HHG can map topological information in two-dimensional materials by studying the interaction between the topological material and elliptically polarized laser. We used the Haldane model for the topological Chern insulator (CI) and the Kane-Mele model for the topological insulator (TI). We observe the enhancement of the harmonic intensity yield near the circular polarization of the driving field in both the CI and the TI. In addition, we observe that the effect of interference between two spin bands is not critical when we choose co-rotating orders in the plateau region.

Keywords:

HHG, Toplogical materials, 2d

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P2-se.115

2차원 층상구조 $MoWS_2$ 의 두께에 따른 광학적 및 구조적 특성 연구

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Abstract:

2004년 그래핀이 발견된 이후로 2차원 물질은 독특한 물리적 및 화학적 특성으로 인해 매우 큰 관심을 받아오고 있다. 그 중에서도 2차원 층상구조 전이금속 디칼코제나이드(Transition metal dichalcogenides, TMDs)는 금속 원소로 이루어진 하나의 단원자층 위, 아래로 칼코젠 원소가 결합되어 있는 구조로서 3차원 구조와 매우 다른 특징으로 인해 광전자 및 센서 분야에서 응용 가능성이 높은 흥미로운 재료이다. 본 연구에서는 덩어리(bulk) $MoWS_2$ 결정으로부터 기계적 박리법을 이용하여 다양한 두께를 가지는 2차원 층상구조 $MoWS_2$를 제작하였으며, 두께에 따른 구조적 및 광학적 특성을 연구하였다. 두께는 원자 힘 현미경을 이용하여 측정 및 분석하였으며, 2~40nm의 다양한 두께를 가지는 시료들을 준비하였다. 라만 산란 스펙트럼에서 2차원 $MoWS_2$와 관련된 $A^1_{g(Mo-S)}$, $E^1_{2g(W-S)}$, $E^1_{2g(Mo-S)}$ 피크가 관찰되었으며, $A^1_{g(Mo-S)}$와 각각의 $E^1_{2g(W-S)}$ $E^1_{2g(Mo-S)}$피크 간격을 Δ_1, Δ_2라 할 때, 각각의 Δ_1과Δ_2 크기는 $MoWS_2$시료의 두께가 증가함에 따라서 증가하였다. 그리고 광루미네센스 스펙트럼에서는 A-엑시톤, B-엑시톤과 관련된 광루미네센스 피크가 관찰되었다. 두께가 2nm에서 40nm로 증가함에 따라서 A-엑시톤(666.89-682.95nm)과 B-엑시톤(598~604 nm)은 적색천이 하였다. 이어서 우리는 온도 및 편광각도에 따른 광루미네센스 및 시분해 광루미네센스를 측정 및 분석하였으며, 이를 바탕으로 2차원 층상 $MoWS_2$의 두께에 따른 발광 메커니즘을 규명하고자 하였다.

Keywords:

2차원 층상구조, MoWS2 , 라만 스펙트럼, 광루미네센스, 엑시톤

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P2-se.116

Perovskite Quantum Dots Growth Controlled by Ligand-Solvent Interaction

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Abstract:

Halide perovskite quantum dots (PQDs) have excellent optoelectronics properties and show emissions in easily tunable wavelength region. To change the emission wavelength, we may change the composition of halide or control the growth conditions of PQDs by mixing different halides, ligand engineering, or changing synthesis temperature. However, these methods might show some limitations such as undesirable ion migration in electronic field or freezing of solvents in low temperature. We propose size control of $MAPbBr_3$ PQDs through facile synthesis by using solvents of various dipole moment, which have oxygen at room temperature. The size of PQDs was controlled by interaction between solvent polarity and ligand. As a result, it was observed that the PL peak blue-shifted to 468 nm from 510 nm.

Keywords:

Perovskite Quantum Dots, Blue perovskite, Wavelength tunable perovskite, solvent polarity

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P2-se.117

Effects of proton irradiation damage on SiN/GaN interfaces in GaN-based MIS-HEMTs

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Abstract:

Gallium Nitride (GaN) have superior properties such as a high critical electric field, a high electron velocity, and a high treshold displacement energy as a wide-bandgap semiconductor. GaN-based electronics have been studied as high frequency and power electronics for the space application owing to these outstanding properities. Considering the space environment, cosmic radiation effects on the reliability of GaN-based electronics have been researched using the proton accelerators. We conducted the proton beam experiment and analyzed the effects of proton irradiation on GaN-based metal-insulator-semiconductor high-electron mobility transistors (MIS-HEMTs) in this work. GaN-based MIS-HEMTs were fabricated using the AlGaN/GaN heterojunction on sapphire and SiN passivation layer were deposited using plasma-enhanced chemical vapor deposition (PECVD) equipment. The impact of proton irradiation damage depending on the SiN/GaN interface quility were verified by using the electrical measurement.

Keywords:

Gallium Nitride, Wide-bandgap Semiconductor, Proton Irradiation

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P2-se.118

Methodological development, fabrication, and physical properties of various nanomaterials-functionalized DNA foam

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Abstract:

Deoxyribonucleic acids have high dielectric constant, large band gap, and abundant negatively charged phosphate groups make it a promising template or scaffold for nanostructure creation. Herein, we discuss the approach for fabrication and functionalizing various nanomaterials into DNA foam and their physical properties utilizing a straightforward magnetic stirring and liquid nitrogen freeze-drying procedure. The physical measurements provided information regarding the nanoparticles' interactions with DNA. Using Fourier transform infrared (FTIR) spectrum, fluorescence spectrometer, Raman spectroscopy, and current-voltage (I-V) characteristics, the physical properties of the functionalized DNA foams were investigated to comprehend the changes formed in the DNA structure and their effect on the properties. The FTIR, fluorescence, and Raman spectra confirm DNA structural modifications and nanomaterial diffusion. By embedding several nanomaterials (watercolor dye, ions, carbon-based materials, drug molecules, manganese oxide), it was shown how to fabricate DNA foam and use it as a template for functional materials for nanotechnology applications.

Keywords:

DNA foam, nanomaterials, freeze drying, physical characteristics

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P2-se.119

Lattice Thermal conductivity calculations based on machine learning force field

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Abstract:

The calculation of thermal conductivity is one of the very challenging topics due to extensive computational time. Recently, machine-learning regression algorithms show great promises for building high-accuracy interatomic potential fields for atomistic modeling.

In this study, we demonstrate a machine learning based interatomic potential using the first-principles molecular dynamic simulations to calculate thermal conductivity of these materials and doped systems based on Green-Kubo formula which presents relationship of thermal conductity with the ensemble average of the auto-correlation of the heat flux.

We find that our theoretical prediction is in good agreement with experimental observation, and show that machine-learning force field methods can accurately predict the thermal conductivity of complex compounds including asymmetric doped systems composed of hundreds of atoms with very high accuracy.

Our works suggest that machine learning force field method can be a promising tool for predicting the lattice thermal conductivity of realistic materials with high accuracy.

Keywords:

lattice thermal conductivity, machine learning force field, first principle calculation, molecular dynamics, asymmetric doped system

2023 KPS Spring Meeting
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P2-se.120

Investigation on the strain profiling of GaN based power electronic device using surface-plasmon enhanced Raman spectroscopy

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Abstract:

Ex-situ strain profiling is analyzed by selectively obtaining surface specific Raman spectra as a function of the distance from the surface in GaN based power electronic devices. With obliquely truncated structures and by optimizing surface plasmon resonance of the Ag nanoparticles attached at the surface, it became possible to observe the development of strain relaxation process through the epilayer thickness. The optimized condition for the surface plasmon enhanced Raman spectra was found by controlling the size and shape of the nanoparticles as well as the distance between particles. Through this analysis, we found that insertion of the carbon-doped layers takes a crucial role to change the overall strain of layers grown on top of that, and we quantitatively estimated the effect of carbon-doped layers on the lattice constants.

Keywords:

ex-situ strain profiling, Raman spectra, surface plasmon resonance, Ag nanoparticles

2023 KPS Spring Meeting
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P2-se.121

Bright red emission with unconventionally low operating voltage in InGaN multiple quantum well structure through tunneling injection and barrier recombination

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Abstract:

Micro-sized LED (μ-LED) development is critical for producing next generation high definition displays, such as smartphones, smartwatches, virtual reality, and augmented reality. A typical large area red LED uses an AlInGaP-based quantum well structure. In this case, as the size of the LED decreases due to the high surface recombination rate and the long carrier lifetime, the light emission efficiency rapidly decreases. In the case of using InGaN-based quantum well structure for red emitter, defect density increase as In composition increases and non┐radiative recombination rate increases, while the surface recombination rate is not as large as in AlInGaP-based quantum wells. Therefore, developing InGaN-based high-efficiency red μ-LEDs to replace AlInGaP-based LEDs attracts much attention.
In this research, active layers with relatively low indium composition ratio and higher barrier quality were grown. Photoluminescence with different excitation wavelength with additional biases and electroluminescence with various injection current with additional laser excitation were systematically analysed, EL spectrum and EL spectrum increase according to excitation irradiation, I-V curve, internal quantum efficiency, and wall-plug efficiency were measured.
As a result, we observed that bright red emission with smaller operating voltage with minimal wavelength shift with current was possible from the quantum well structures with a relatively low indium composition The I-V curve does not follow the conventional exponential featurein the low-current region. In addition, LEDs are driven at low voltage rather than the minimum operating voltage by thermal injection.
Based on the experimental results, we propose a barrier recombination mechanism through trap assisted tunneling injection and wavefunction coupling of adjacent quantum wells, not luminescence by electron hole recombination in the quantum wells.

Keywords:

InGaN red LED, tunneling injection, barrier recombination, low operating voltage

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P2-se.122

Optical properties of doped β-Ga_2O_3

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Abstract:

β-G_2O_3, an oxide semiconductor with an ultra-wide bandgap of 4.8-4.9 eV, is a promising material for high-power and high-frequency electronic devices and solar cells. Ongoing research is focusing on various other potential applications of β-G_2O_3. In this study, we report on the fundamental optical properties of doped β-G_2O_3, such as the bandgap and impurity absorption, using optical spectroscopic measurements in the UV-V-NIR region. Vanadium and copper, which are known to create n-type carriers in β-G_2O_3, were found to cause, respectively, a red-shift and a blue-shift of the bandgap. Our results are consistent with recent theoretical predictions [1].

[1] S. Gao et al., Mater. Res. Express 8, 025904 (2021)

Keywords:

Doped materials, Wide bandgap semiconductors

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2023-04-19 - 2023-04-21

P2-se.123

The ultraviolet electroluminescenc and photodectection in Ga2O3 and ZnGa2O4 films on silicon substate

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Abstract:

The ultraviolet electroluminescenc and photodectection were demonstrated with the wide-band-gap oxide sensitive film on a heavily-doped silicon substate. The Ga2O3 and ZnGa2O4 films were selected due to their semiconduting and chemically-thermally stable properties. The films were formed through a all-solution process and then an high-temperature annealing process. The very thin Ni-Au metal as a top electrode was photolithographically patterned to be interdigitated. The broadband-violet-wavelength EL was shown when only A.C. voltage was applied, which is attributed to the intrinsic defects such as oxygen or zinc vacancies. In addition, the high photosensitivity to ultraviolet was observed when only D.C. bias voltage was applied. Moreever, the transient behaviors of both functions was investigated in ordet to analyze their response and decay times, and their concurrent operation was exammined when the A.C. voltage sinoidal waveform with a D.C. voltage oftset.

Keywords:

2023 KPS Spring Meeting
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P2-se.124

The color tunability of green-to-yellow electroluminescene from alpha- and beta- phase Zn2SiO4:Mn oxide film in metal-oxide-semiconductor

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Abstract:

The color tunability of AC-driven green-to-yellow electroluminescene (EL) froma time and temperature-controlable mixture comosition of alpha- and beta- phase Zn2SiO4:Mn oxide film grown through a radio-frequency sputter was demonstrated in metal-oxide-semiconductor structure. The yellow EL from the beta phase was very sensitive to the annealing temperature and time; it was dominated only at the critical rapid-thermal process (less than 10 seonds around 800 ℃), while beyond the condition, the green EL from the alpha phase got dominated. breakdown. In addition, the the dependence of EL performance on applied a.c. voltage and frequency were investigated in the case of the pure greeen, the intemediate, and the pure yellow due to d orbital intratransitions from Mn^{2+} ion doped in Zn2SiO4 host lattice. Furthermore, the metastability of the beta phase were examined through the re-heatinng proces at the notmal condition where the beta was perfectly phase-changed.

Keywords:

2023 KPS Spring Meeting
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P2-se.125

The effect of magnetic field of ultraviolet (UV) electroluminescene (EL) from Gd3+-doped Ga2O3/BaTiO3 layers on silicon substrate

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Abstract:

The effect of magnetic field of ultraviolet (UV) electroluminescene (EL) from Gd3+-doped Ga2O3 active layer/BaTiO3 dielectric layer on a conductive silicon substrate was demonstrated. The film was grown through a rf magnetron sputter, and then rapid-thermal-anneaded at a high temperature of about 1000 ℃. The EL device emitted the UV B light with a shrap spectrum at 315 nm peak, which is originated from the f-f intratransition of Gd3+ dopant. The EL intensities weris e exponetially increased with voltages above the theshod volage (~ 10 V), which follows the Fower-Nordeim voltage-current relation based on the tunneling effect of electrons from deep traps. Notably. the EL intesity was significantly enahnced without any spectral change when the magnetic field was applied between two electrodes, and thus the corealtion and the origin were investigated. Furthermore, this EL enhancement strategy by the magnetic field will be re-examined in other EL structure and materials such as a conventional powder-dispered EL with ZnS emititng layer.

Keywords:

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P2-se.201

Diffusive character of α–$CH(NH_2)_2PbI_3$ ($FAPbI_3$) by using QENS (Quasi-Elastic Neutron Scattering). Is this real? Or Artifact?

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Abstract:

Perovskite type materials which are regarded as a promising next generation solar cell are being feverishly investigated. Using solvent and compositional engineering methods, the efficiency reached at 25% in 2019 [1,2]. Even though the amazing advance in the conversion efficiency, the instability has been still the key issued to be overcome in near future for the practical use. To keep aligned with the need to understand the underlying mechanism, QENS experiments were performed using $FAPbI_3$ powder sample between 300K and 463K at FOCUS, PSI. The main excitation of $FAPbI_3$ is concentrated on only low Q range, contrary to $CH_3NH_3PbI_3$($MAPbI_3$) which is excited mainly at high Q range [3]. Additionally HWHM (Half Width at Half Maximum) clearly shows Q-dependence in HWHM vs Q diagram. Another measurement using triple axis spectrometer PUMA installed at FRM-II also shows a Q-dependence which is indicative of a long-range diffusion. But corresponding measurements on $CH(NH_2)_2PbBr_3$ ($FAPbBr_3$) and $MAPbI_3$ clearly exhibited no q-dependence at all [3,4]. Interestingly, δ-$FAPbI_3$ shows no Q-dependence. The black α–phase has a high photovoltaic efficiency but this black phase is very unstable in ambient air so that the phase transformation into the yellowish δ–$FAPbI_3$ easily occurs. A spontaneous back-transformation into a black phase is impossible. Before and after the measurements, the sample color was black. During the whole measurements, the sample was kept in a cryostat, so that there was no chance to have a contact with a humidity air. We speculate that a long-range diffusion of the hydrogen atom in α–phase triggers a partial transform from α–phase to δ–phase during the measurement. Besides based on our measurements, it seems that the replacement of MA^+ ion with FA^+ ion could make a molecular rotation difficult due to the difference in a molecular geometry and as a result a phase containing FA molecule in a crystal structure is more stable than a phase with MA molecule.

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Keywords:

QENS, Solar Cell, Perovskite

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P2-se.203

Piezoelectric energy harvesting technique using plasmon-enhanced light pressure using $Pb(Zr_{0.52},Ti_{0.48})O_3$ and Ni metal

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Abstract:

To supply energy to sensors, we tried light pressure as a new energy source instead of using various energy sources that have been used so far. However, light pressure is so weak that intensity amplification is essential. In order to increase the light pressure intensity, we made a crater structure by wet-chemical etched GaAs (100) wafer, then $Pb(Zr_{0.52},Ti_{0.48})O_3$, which are piezoelectric materials, and Ni were sequentially deposited therein. The device made it possible to increase the light pressure intensity through resonance with laser and numerous Ni nano-roughness. This plasmon-enhanced light intensity immediately acts as a pressure and deforms the $Pb(Zr_{0.52},Ti_{0.48})O_3$. As a result, we obtained 40 nA of current value from 401 nm laser. We analyzed the light amplification using the surface-enhanced Raman scattering method. In addition, through finite-difference time-domain and COMSOL multiphysics program, we confirmed that these experimental results were due to the plasmon-enhanced light pressure by Ni nano-roughness.

Keywords:

Light pressure, Surface plasmon resonance, Ni, Piezoelectrtic materials, Energy harvesting

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P2-se.204

Enhancement of radiation pressure by generating local electric field in the visible light band by AuNPs

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Abstract:

In this study, we tried to increase the efficiency of the light pressure electric generator (LPEG) device that generates electricity by applying the amplified radiation pressure to a piezoelectric material. Ag film and Au nanoparticles (AuNPs) were deposited on the PZT layer to amplify the light pressure. AuNPs used a self-assembling method, and at this time, optimized particle size and incubation time were obtained. Under these conditions, a localized surface plasmon with increased intensity compared to the existing devices was obtained by the hot spot formed at the interface between the Ag layer and the AuNPs. Through this, the amplified electric field acted on the piezoelectric material according to $P = |E|^2/c^2\mu_0$, and as a result, the efficiency increased by more than 60% compared to the previous one. These results were confirmed through Raman measurement, finite-difference time-domain (FDTD) simulation, and COMSOL Multiphysics analysis.

Keywords:

Energy harvesting, Piezoelectric, Light pressure, Au nanoparticle, FDTD simulation

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P2-se.205

Light-pressure energy harvesting device using multiwalled carbon nanotubes-PZT composite film

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Abstract:

In previous studies, we fabricated a light pressure electric generator (LPEG). In this device, a noble metal is coated on the surface of a crater structure that can condense light, and the roughness formed on the metal surface increases surface plasmon. This leads to increase in pressure and can deform the piezoelectric material. Therefore, we report a method for further increasing the applied pressure on piezoelectric materials. In general, it has been studied that the stress applied to the piezoelectric material can be enhanced through a composite film composed of piezoelectric material and multiwalled carbon nanotubes (MWCNTs). Therefore, in this experiment, PZT-MWCNTs composite film with various concentrations was deposited by spin coating method. The role of MWCNTs was analyzed by COMSOL Simulation, Raman measurements, and dielectric properties. As a result, when the MWCNTs concentration was 10 wt%, the maximum power density of 1.26 mW/cm^2 was obtained under the solar simulator.

Keywords:

Energy harvesting, Light pressure, Piezoelectric materials, Multiwalled carbon nanotube

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P2-se.206

Improving electrical properties by graphene oxide coupled with Ag nanoparticles in light pressure devices for energy harvesting

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Abstract:

We utilized localized surface plasmon resonance (LSPR) phenomenon occurred on the metal surface to fabricate energy harvesting devices using light pressure. At this time, Graphene Oxide (GO) and Ag Nanoparticles (AgNPs) were combined to increase the intensity of the surface plasmon generated on the metal surface. The crater structure that can collect light is made by the wet-etching method and deposited Ag/PZT/Pt/Ti on the inner side. The GO film with high transmittance is deposited inside the structure to make additional AgNPs. The AgNPs/GO formed in this way promotes additional LSPR without affecting the existing structure, resulting in improved electrical output. The 6nm Ag layer was deposited on the GO and the Ag layer was aggregated to become a nanoparticle through RTA process. The output was optimized by varying the spray coating conditions of GO and the size of AgNPs, and the results were compared and analyzed with FDTD simulation data.

Keywords:

Energy harvesting, light pressure, piezoelectric materials, Graphene Oxide, Ag nanoparticles

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P2-se.207

V_2O_5 나노물질의 합성 및 수성 아연 이온 배터리용 고성능 cathode전극용 전기화학적 특성

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Abstract:

에너지 저장 및 자원에 대한 필요성이 증가함에 따라 휴대용 전자기기 및 전기차의 공급 확대와 함께, 리튬 이온 배터리에 대한 수요가 폭발적으로 증가하고 있다. 하지만, 리튬 공급원 부족과 전해질의 불안정성으로 인해 대규모 에너지 저장 시스템에서 리튬이온 배터리의 추가 적용이 제한되고 있다. 이에 대한 대체로 수성 아연 이온 배터리는 안전, 낮은 비용, 안정성 및 친환경성으로 인해 많은 관심을 받고 있다. 수성 아연 이온 배터리의 cathode 전극으로 사용하기 위해 수년 전부터 바나듐계 물질이 준비되어 왔다. 그러나, 고성능 수성 아연 이온 배터리를 개발하는 데에는 해결되어야할 다양한 이슈가 존재한다. 본 발표에서 V_2O_5@MoS_2 나노구조가 손쉬운 수열합성법을 통해 합성되었고, 이에 대한 물성평가와 함께, 고성능 수성 아연 이온 배터리의 cathode전극재료로 사용되었다. 합성된 V_2O_5@MoS_2 나노구조의 형태는 주사전자현미경으로 분석되었으며, 또한 관련된 물성은 X선 회절 및 X선 광전자 분광 분석을 통해 추가적으로 조사되었다. V_2O_5@MoS_2 나노구조 우수한 비용량을 나타낸다. 또한 높은 전류 밀도에서 우수한 rate 성능과 장기 사이클링 안정성을 나타냈다. V_2O_5@MoS_2 나노구조의 이러한 우수한 성능은 나노구조, 다공성 특성 및 높은 비표면적 때문일 수 있다. 이러한 연구는 수성 아연 이온 배터리의 연구 및 적용을 확장할 수 있는 수성 아연 이온 배터리용 바나듐기반 cathode전극 재료 설계에 대한 중요한 접근 방식을 제공한다.

Keywords:

V2O5@MoS2, 나노구조, 수열합성법, 수성 아연 이온 배터리

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P2-se.208

슈퍼커패시터 응용을 위한 전이금속 황화물 나노구조의 합성 및 특성

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Abstract:

기하급수적으로 악화되는 재생 불가능한 에너지 자원과 달리 현대 세계에서 에너지 소비에 대한 수요가 계속 증가함에 따라 연구자들은 자연 친화적이고 비용이 저렴하며 재생 가능한 에너지원을 찾고 있다. 이러한 지속적인 노력에서 배터리 및 슈퍼커패시터와 같은 전기화학 저장 시스템은 화석 연료에 대한 의존도 및 이와 관련된 부정적인 환경 영향을 줄이는 데 도움이 될 수 있다. 특히 울트라커패시터 또는 전기화학 커패시터라고도 하는 슈퍼커패시터는 전기 에너지를 빠르고 효율적으로 저장 및 방전할 수 있는 에너지 저장 장치이다. 동작 메커니즘 관점에서 슈퍼커패시터는 EDLCs (electrochemical double-layer capacitors), PCs (pseudocapacitors) 및 EDLC와 PC의 병합 특성을 가진 HSCs (hybrid supercapacitors)로 광범위하게 분류된다. 본 발표에서는 유망한 전극 재료로 많은 관심을 끌고 있는 전이금속 황화물기반 HSC에 대해 발표하고자 한다. 황 (S)이 산소 (O) 원자로 대체되면 전이금속 황화물은 향상된 전기화학적 특성을 나타낸다. 위에서 언급한 장점에 따라 고다공성 나노시트 구조의 클러스터를 포함하는 고효율 니켈 몰리브덴 황화물을 합성하기 위해 pH 제어 방식이 제안되었다. 합성된 물질은 적절한 안정성과 함께 우수한 전기화학적 특성을 보여주었다. 또한 음극과 쌍을 이루어 소자를 형성할 때 우수한 상용성을 보였다. 이 HSC 셀은 높은 커패시턴스를 나타낼 뿐만 아니라 상당한 에너지 및 전력 밀도 값도 나타낸다. 결과적으로, 제작된 니켈 몰리브덴 황화물은 에너지 저장응용을 위한 슈퍼커패시터 전극으로 유망할 것으로 사료된다.

Keywords:

슈퍼커패시터, 전이금속 황화물, 전기화학특성

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P2-se.209

Effect of Alkaline Earth Materials Doping on Garnet LLZO Solid Electrolyte

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Abstract:

The $Li_7La_3Zr_2O_{12}$ (LLZO) garnet is a solid electrolyte that has potential for use in all-solid-state Li-ion batteries due to its excellent performance, which includes fast ionic conduction, a broad electrochemical stability range (against Li/Li^+), and enhanced safety. However, there are two polymorph phases of LLZO, tetragonal and cubic, with the cubic phase displaying about two orders of magnitude higher Li-ion conductivity. Unfortunately, the cubic phase is thermodynamically unstable at room temperature, so doping with aliovalent elements is necessary to stabilize it by inducing Li-vacancies and distorted occupations. In this study, we fabricated and examined the effect of some Alkaline earth materials (Ca, Sr, and Ba) on co-doped LLZO with Ta^{5+} and Ga^{3+} ($Li_{7-3x-z+y=6.45}Ga_xLa_{2.95}A_{0.05}Zr_{2-z}Ta_zO_{12}$), which were characterized using X-ray diffraction, Raman spectroscopy, scanning electron microscopy, and electrochemical impedance spectroscopy.

Keywords:

solid state Li-ion electrolyte, garnet LLZO, Alkaline Earth Materials

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P2-se.210

High efficiency alkali-alloyed kesterite CZTSSe solar cells

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Abstract:

We employed the aqueous spray deposition method to fabricate kesterite CZTSSe solar cells that are alloyed with alkali metals. By performing in-situ alloying, we were able to introduce Li, Na, K, Rb, and Cs into the CZTSSe absorber layer. We conducted structural and opto-electrical analyses on all of the samples to examine the impact of alkali alloying. The results indicated that optimal amounts of alkali alloying led to enhanced power conversion efficiency (PCE) due to the passivation of defects in the alloyed absorbers. Based on our experimental findings, this paper will offer an in-depth analysis of the passivation effect

Keywords:

Alkali alloying , Aqueous spray deposition , Kesterite solar cell

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P2-se.211

Defect site density modulation for HER performance increase of MoS_2

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Abstract:

Molybdenum disulfide (MoS_2), is being considered as a promising replacement for Pt in the hydrogen evolution catalysts due to its reasonable cost and element abundance. However, the low active sites density and semiconducting properties in MoS_2 can limit the catalytic performance in hydrogen evolution reaction (HER). Here, we demonstrated the improved catalytic activity in selectively etched bilayer MoS_2 crystal by using precisely controlled laser etching technique. The bottom layer in the bilayer MoS_2 effectively inject the charge carrier to the etched upper layer, which leads to rapid electrochemical charge exchange process. Furthermore, we can effectively engineer the etched-area density in specific laser exposed area, which exposed to electrolyte during reaction. The active site density dependent catalytic behavior can be observed in electrochemical measurements. Despite of its bilayer characteristics, the catalytic performance was comparable with that of metallic MoS_2 crystals.

Acknowledgement
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Keywords:

MoS2, hydrogen evolution, laser-induced thinning

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P2-se.212

Integrated optical and electrical mapping for characterization of thin film solar cells

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Abstract:

In our study, we sought to develop a novel approach for analyzing the performance of solar cells (CZTS, CIGS, and perovskite solar cells) by measuring the current at each point of a solar cell when exposed to light, using a combination of LBIC and Raman mapping systems with Keithley 2400. This allowed us to obtain a contour image of the measured current at each point and simultaneously generate Raman mapping results. We applied this approach to compare the current mapping and Raman mapping results of two solar cells: a high-efficiency CZTS solar cell and a low-efficiency one, and observed that this combined method effectively characterizes cell performance at sub-micrometer scale resolution.

Keywords:

Optical mapping, LBIC, Solar cell

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P2-se.213

Ti_2CT_x QDs/Reduced Graphene Oxide Nanocomposites as Electrocatalysts for Hydrogen Evolution Reaction

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Abstract:

MXene quantum dots have attracted much attention due to their quantum confinement effect. They can provide more active sites while retaining the properties of the parent material. However, their properties are compromised by their tendency to agglomerate, which is due to their high surface energy. Introducing quantum dots into carbon-based matrices with high surface area and high electrical conductivity not only solves the aggregation problem but also lowers their charge transfer resistance. In this study, we report the synthesis and characterization of Ti_2CT_x quantum dots (MQDs) and reduced graphene oxide (rGO) nanocomposites as electrocatalysts for hydrogen evolution reactions (HER). The MQDs/rGO nanocomposites exhibited excellent electrocatalytic activity toward HER due to the synergistic effect of MQDs and rGO, which provide large surface area, abundant active sites, and efficient charge transfer. Our results demonstrate the potential of MQDs/rGO nanocomposites as efficient electrocatalysts for HER in renewable energy applications.

Keywords:

MXene, Quantum Dots, Nanocomposite, Electrocatalyst, Hydrogen Evolution Reaction

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P2-se.214

A one-step in situ approach to prepare pure electroactive β-polymorphs in polyvinylidene fluoride

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Abstract:

Polyvinylidene fluoride is an attractive electroactive material that is ideal for the fabrication of flexible devices. The challenges are the expensive equipment and complicated procedures required to get the pure -phase from PVDF We developed a novel approach to convert from the - to the -phase of the PVDF. The highest possible -phase fraction is 97.2%, because of the electrical interaction between the reduced graphene oxide and ionic liquid and the PVDF. The proposed synthesis method creates a PVDF-based composite compatible with flexible substrates and better than commercial materials. This approach may allow the use of -phase composites in low-cost devices.

Keywords:

PVDF, β-phase, ionic liquid, reduced graphene oxide, piezoelectricity

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P2-se.215

Cobalt phosphide coated with conjugated polymers as catalysts for the hydrogen evolution reaction

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Abstract:

Herein, cobalt phosphide (Co_2P) is synthesized onto a Ni foam (NF) support via phosphorylation under an N_2 atmosphere, followed by coating with tetrahydroxyquinone (THQ), a conjugated microporous polymer, using a hydrothermal method. Owing to the synergistic effect of the NF support, CoP_2, and THQ, high electrical conductivity of THQ, and modified electronic structure of CoP_2, the as-synthesized CoP_2/THQ@NF exhibits remarkable electrocatalytic activity for the hydrogen evolution reaction and excellent durability in acidic electrolytes. This study provides a powerful method for improving the HER catalytic performance by introducing conducting conjugated polymers into non-precious-metal phosphide nanomaterials. Furthermore, This study also provides sufficient ideas for the modification of electrodes by organic compounds as well as organic functional groups, It also provides certain conceptions for the combination of organic and inorganic compounds.

Keywords:

Transition metal phosphides, Conjugated microporous polymer, Electrocatalysis,
Hydrogen evolution reaction

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P2-se.216

Hierarchical FeOOH@CoMo/NF heterostructure catalyst for oxygen evolution reaction at the high current density

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Abstract:

The electrochemical water splitting has the potential to play a crucial role in the achievement of global carbon neutrality goals by facilitating the production of green hydrogen. To make this technology economically feasible for industrial applications, it is imperative to develop cost-effective electrocatalysts that can function efficiently at high current densities. In this study, we have devised a robust core-shell architecture through interface engineering, wherein FeOOH nanowires are grown directly on nickel foam coated with CoMo microcolumn arrays (FeOOH@CoMo/NF). This heterostructure design synergistically enhances the number of active sites, wettability, stability, conductivity, and intrinsic activity. Remarkably, the FeOOH@CoMo/NF heterostructure exhibits exceptional activity in the oxygen evolution reaction, with low overpotentials of 260 mV and 346 mV required to achieve high current densities of 100 and 1000 mA cm^{-2} in 1M KOH electrolyte, respectively. Moreover, the FeOOH@CoMo/NF electrode demonstrates remarkable long-term stability at high current densities (500 mA cm^{-2}), retaining its performance without any degradation for over 500 hours. This simple but efficient interface engineering approach provides valuable insights into developing core-shell heterostructures for high performance water splitting.

Keywords:

Oxygen evolution reaction, High current density, Interface engineering

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P2-se.217

Evaluation of the correlation between sensitivity and LAG performance according to the mobility of the reset transistor

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Abstract:

X-ray digital image sensors are widely used in the medical field, and the technology has been gradually developed, it has come close to inspect nano-scale electronic components in result. However, in order to inspect at a faster speed, it is necessary to secure a high signal within a short scan time. In addition, low image LAG performance is essential even at the high radiation dose condition to penetrate high-density parts. In this study, we observed how the sensitivity and image LAG is changing according to the mobility of the TFT in an X-ray digital image sensor. The image sensor having a separate reset transistor, which is individual with the active transistor for data transmission, and InGaZnO (IGZO) is used as the transistor in this experiment.

Keywords:

Thin film transistor, Digital X-ray Image, Image Lag, PIN Photo diode, Reset transistor

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P2-se.218

Dark current, capacitance voltage, etc. are analyzed by adjusting the halide reaction of the lead halide perovskite solar cell to the applied voltage

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Abstract:

Lead halide perovskite has significantly improved efficiency and stability over the past decade. This has been achieved by various passivation and surface treatment, such as understanding the trap density and interface of the perovskite thin film. However, perovskite still has limitations in photoelectric characterization in its unusual photoelectric behavior, where halogen elements cause perturbation with peripheral carriers along the electric field by continuous electric fields. Dark current analysis is typically analyzed by various fitting formulas of Space charge Limited Current(SCLC). In addition, by measuring the capacitance-voltage(C-V), it is possible to extract a charge carrier, a depletion region, built in potential(V_{bi}), and further, trap density inside the device. However, the above-described measurement method generally has an inaccurate measurement value due to the movement of halogen elements under continuous voltage. The movement of halogen elements is restricted using a pulse voltage source and the measurement can be carried out by changing the inside of the perovskite film, which is a unsteady state, to a steady state. In the case of $MAPbI_3$, the same V_{bi} can still be obtained even during continuous measurement. The trap density derived from the characteristics of low-temperature C-V was measured as $5x10^{16}$ cm^{-3}. This shows the same value as $MAPbI_3$ measured by SCLC under the same pulse voltage. here, we provide an accurate analysis tool of dark current and capacitance-voltage using pulse voltages to control iodine in halogen materials, which are the causes of the unusual photoelectric behavior of perovskites.

Keywords:

perovskite solar cell

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P2-se.301

Implementation of Gate-Tunable Memtransistive Behavior Via WOx Oxygen Migration Layer Insertion In the IGZO Thin Film Transistor

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Abstract:

Memtransistor, a compound word of memory and transistor, has been actively researched as next-generation synaptic devices in neuromorphic computing architectures due to gate-tunable synaptic plasticity. However, the most of reported memtransistors mainly use a two-dimensional monolayer such as MoS_2. Thereby, they are not compatible with CMOS processes, so there are limitations in commercialization. Here, we developed gate-tunable memtransistor based on CMOS-compatible indium-gallium-zinc-oxide (IGZO) thin film transistor by inserting a WO_x oxygen migration layer between 3-D IGZO active channel and gate oxide. The proposed novel memtransistor has bi-stable resistance depending on the source/drain bias polarity, which is due to the mechanism in which the Schottky barrier height between the source/drain and the channel has changed by diffusion and drift of oxygen ions. In addition, we deposited the WO_x oxygen migration layer while controlling the amount of argon and oxygen gas flow during DC magnetron sputtering, so that the nonlinearity and conductance margin of the proposed memtransistor was improved by controlling the oxygen vacancy concentration within the WO_x oxygen migration layer. After that, we designed the deep neural network with 784 neurons, 200 hidden neurons, and 10 output neurons for training Modified National Institute of Standards and Technology (MNIST) hand-written image datasets. Finally, we evaluated the training speed and test accuracy caused by the difference in nonlinearity depending on the oxygen vacancy concentration in the WO_x layer.

Acknowledgement
This research was supported by BrainKorea21 Four.

Keywords:

Memtransistor, indium gallium zinc oxide (IGZO), Schottky barrier, oxygen migration layer, heterosynaptic plasticity

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P2-se.302

Enhancing the durability of ZrO2 abrasives on a nanoscale by utilizing protonated phosphite ions and performing chemical mechanical planarization on Tungsten film surfaces

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Abstract:

To downscale state-of-the-art nanoscale semiconductor devices, a tungsten (W)-film surface planarization process has been developed to accelerate the penton reaction to increase the W-film surface abrasive rate and improve the stability of nanoscale abrasive (i.e., ZrO2) dispersants in CMP slurry by adding a scavenger. Multiple to suppress the penton reaction. To improve the stability of the ZrO2 abrasive dispersant, a scavenger with protonated-phosphite ions was prepared to suppress the time-dependent Fenton reaction. As can be seen from the low H2O2 decomposition rate and the long H2O2 port life, the scavenger concentration had a significant and linear effect on the stability of the ZrO2 abrasive dispersant. However, during CMP, the corrosion size of the W-film surface increased significantly with the scavenger concentration. As a result of the addition of scavengers to the CMP slurry, the W-film surface polishing rate was linearly significantly reduced as the scavenger concentration was increased through the CMP mechanism due to the decrease in radical amount and improvement of corrosion by inhibiting the penton reaction in the CMP slurry. On the other hand, the SiO2-film surface polishing rate showed peaks at specific scavenger concentrations through the chemically and mechanically dominant CMP mechanism. However, the addition of corrosion inhibitors with protonated-amine functional groups to the W-film surface CMP slurry effectively inhibited corrosion of the W-film surface during CMP without reducing the W-film surface polishing rate and SiO2-film surface polishing rate.

Acknoweldgment
This research was supported by the National Research Foundation of Korea(NRF) grant funded by the Korea government(MSIT)(No. 2021R1A4A1052085) and by BrainKorea21 Four.

Keywords:

CMP, chemical mechanical planarization, semiconductor, tungsten, penton reaction, abrasive, ZrO2, particle, surface

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P2-se.303

Overcoming Quantum Capacitance Limits of Negative Capacitance Field-Effect Transistors using Polycrystalline Channels

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Abstract:

The subthreshold swing (SS) of metal oxide field-effect transistors (MOSFETs) is limited to 60 mV/dec by the Boltzmann limit. To overcome the limitation, negative capacitance field-effect transistors (NCFETs) using the negative capacitance behavior of ferroelectrics have been investigated actively. While significantly affecting inversion layer charge density in nanoscale devices, quantum capacitance is an obstacle to achieving hysteresis-free subthermionic SS of NCFETs [1]. Interface trap states are known to improve the NCFET performance by circumventing the quantum capacitance limit [1,2]. We will report an investigation into overcoming the NCFET limit by employing polycrystalline channels with inherent traps. We compare the performance of MOSFETs and NCFETs in terms of Hysteresis and SS according to whether the channel is polycrystalline or crystalline. The EDA Tool was supported by the IC Design Education Center.

[1] W. Cao and K. Banerjee, Nat. Commun. 11, 196 (2020).
[2] T. Rollo and D. Esseni, IEEE Electron Device Lett. 39, 1100 (2018).

Keywords:

NCFET, quantum capacitance, polycrystalline, trap

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P2-se.304

Correlation Analysis between Memory Retention Time and Channel Parameters of IGZO Channel-based 2T-0C DRAM

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Abstract:

The conventional 1-transistor-1-capacitor (1T-1C) DRAM faces various limitations, such as scalability, power consumption, and leakage current. To overcome these limitations, researchers have been developing alternative DRAM architectures. One promising architecture is the 2-transistor-0-capacitor (2T-0C) DRAM, which accesses a single storage node without a capacitor using two transistors. The IGZO-based 2T-0C DRAM architecture offers the feasibility of 3D DRAM integration due to its capacitor-less storage node, while the IGZO channel material reduces leakage current and provides low temperature processibility with conventional complementary MOS methods. In this work, we conducted extensive simulations to evaluate the proposed DRAM architecture under various conditions, including channel length, width, and gate oxide thickness of the read-transistor (RTR) and write-transistor (WTR), respectively.
Our simulation results show an increasing tendency of retention time with respect to the increase of channel width and the decrease of gate oxide thickness. By optimizing the scale, the proposed IGZO-based 2T-0C DRAM architecture is expected to be a promising solution for future high-density, low-power, and high-performance memory applications. The results of this research can serve as a basis for further development of IGZO-based DRAM technologies.

Acknowledgement:
This research was supported by BrainKorea21 Four.

Keywords:

2T-0C DRAM, Retention Time, InGaZnO, Monolithic Three-Dimensional (M3D) Integration

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P2-se.305

Double Gate Transistor for Improved Retention Time in Monolithic 3D-Integrated 2T-0C DRAM with IGZO Channel

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Abstract:

In the quest to improve the performance of memory semiconductors, researchers have been exploring ways to increase the density of DRAM through stacking. However, conventional DRAM faces challenges in scaling down due to difficulties in securing the capacitance of the cell capacitor. To overcome these limits, a DRAM cell with a 2 Transistor 0 Capacitor (2T0C) structure utilizing an InGaZnO (IGZO) channel-based transistor has been demonstrated, capable of implementing Monolithic 3D integration (M3D).

During the 2T-0C DRAM memory process based on oxide semiconductor channel materials like IGZO, the low process temperature and deposition via Atomic Layer Deposition (ALD) offer advantages over Si channel deposition. The low off-current characteristics of IGZO also contribute to improved retention time.

To further enhance retention time, the Read Transistor gate capacitance must be increased. To this end, the read transistor has been implemented as a double gate, increasing the gate capacitance of the RTR. Electrical characteristics such as mobility, retention time, sense margin, SS, and on/off current were simulated to verify the effectiveness of this approach.

Acknowledgement:
This research was supported by BrainKorea21 Four.

Keywords:

2T-0C DRAM, M3D, Double Gate, Retention Time, InGaZnO

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Chalcopyrite CIGSSe thin film for resistive random-access memory (ReRAM) device

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Abstract:

With the explosion of information in modern society, high-performance resistive random-access memory (ReRAM) has emerged as a promising next-generation non-volatile memory technology. In this study, we explored the potential of using $Cu(In,Ga)(S,Se)_2$ (CIGSSe), a material commonly used in solar cells, as a ReRAM. We utilized a spray method to deposit CIGS onto a Mo glass substrate, followed by selenization in a graphite box, and then deposited silver using thermal evaporation to create an Ag/CIGSSe/Ag structure resistive switching device. Our results indicate that the operating voltage was less than 1.5V and the resistance switching effect between high resistance state (HRS) and low resistance state (LRS) was approximately 20, indicating that CIGSSe is a suitable material for use in ReRAM. This paper will provide a detailed explanation of the characteristics of CIGSSe devices as ReRAM.

Keywords:

Chalcopyrite CIGSSe, ReRAM, non-volatile memory

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Optimization of Ge-film Chemical Mechanical Polishing for Sequential Integrating 3D-Structured Transistor Cells

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Abstract:

The development of advanced semiconductor devices with improved performance and reduced power consumption has led to the exploration of three-dimensional (3D) integration technology as a potential solution to the challenges of fabricating smaller transistors. Achieving the integration of the 3D structure of a transistor cell requires a high Ge-film polishing rate during the fabrication of the germanium on insulator (GOI) substrate or Ge channel . This study investigated the chemical composition of the Ge surface and the chemical mechanical polishing (CMP) of Ge-films at different pH levels using a slurry containing H2O2 and colloidal silica abrasive . The main mechanism in the CMP process, in both neutral and alkaline pH regions, was found to be the formation of GeO and GeO2 via oxidation reaction between the Ge-film surface and dissolved oxygen, according to our results. When the pH of the slurry ranged from 7 to 10, the formation of the oxidation layer on the polished Ge-film surface increased linearly, and it slightly decreased when the pH was higher than 10. At a pH of 10, we achieved a high Ge-film polishing rate of 623.8 nm/min, which coincided with the formation of the maximum number of layers of GeO and GeO2 on the Ge-film surface. Our study has significant implications for the development of 3D integration technology. Adjusting the pH level of the slurry during the CMP process is critical for achieving a high Ge-film polishing rate, which is essential for integrating 3D transistor cells in nanomaterials.

Acknowledgement
This research was supported by BrainKorea21 Four.

Keywords:

Chemical-mechanical polishing, Germanium thin film, Epitaxial growth, Oxidation, 3D integration technology

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P2-se.308

Crosstalk Analysis for TSVs with MOS Effects

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Abstract:

Through Silicon Via (TSV) refers to a packaging technology used to connect top and bottom chips with electrodes by forming through holes in a silicon (Si) substrate. Three-dimensional integrated circuits (3-D ICs) using TSVs have evolved with the development of high-density packaging technology that can integrate heterogeneous systems on the same platform by arranging processors, memories, power ICs, and sensors. However, as the complexity of these systems increases, the number of TSVs per unit area used in one package increases and the distance between TSVs and logic cells decreases, resulting in deterioration in electrical performance of the package. Therefore, crosstalk analysis between TSVs is particularly important. Since TSVs typically have a metal oxide semiconductor (MOS) structure, a depletion region inevitably exists. Although the MOS effect has been discussed in previous studies, the full-depletion-approximation (FDA) method was used, which means that mobile charge carriers in the depletion region surrounding the TSV dielectric are ignored. It is also important to consider charge type defects. These charges, generated by via hole etching or dielectric deposition, cause a flat band voltage shift of the capacitance of the MOS device and these charges change the Si substrate's electromagnetic field. Therefore, it is required to develop a physical model that can describe the behavior of charge carriers in Si substrates and the influence of charge-type defects in TSVs. In analyzing the MOS effect, we presented an accurate physical model rather than an approximation method. Based on this model, we performed near and far crosstalk analysis of TSV.

Keywords:

Through Silicon Via (TSV), Three-dimensional integrated circuits (3-D ICs), metal oxide semiconductor (MOS)

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The role of defects in ferroelectricity of HfO2

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Abstract:

Recently, the unexpected large ferroelectricity in Hafnium oxide (HfO_2) has been experimentally reported in energetically unfavorable defective orthorhombic phase. However, the underlying mechanism has not been clearly revealed yet. In particular, it is well known that the phonons play an important role in determining material properties such as specific heat, thermal conductivity, electron-phonon coupling and thermodynamic stability. Hereby combining first-principles density functional theory calculations, molecular dynamic simulations, and machine learning algorithm, we find that cation defects such as Y, Si, Zr and oxygen vacancies incorporate with monoclinic HfO_2 lattice, and largely distort the lattice, and then stabilize the orthorhombic $Pca2_1$ ferroelectric phase. We expect that our results could help to identify the optimal doping parameters and concentrations for enhanced stability and performance of ferroelectric devices. The details of machine learning force field method and relevant underlying mechanism for ferroelectricity in defective HfO_2 will be presented.

Keywords:

HfO2, ferroelectricity, defects, first-principles calculations, machine learning

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P2-se.310

Threshold switching characteristics of chalcogenide medium-based selectors for crossbar array applications

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Abstract:

Crossbar array-based non-volatile memory is a promising technology for achieving high integration density, but it was found to initially suffer from the unintended sneak-path current issues. Thus, to overcome this issue, various selector devices have been studied, including chalcogenide material-based selectors with their potential benefits of high non-linearity, on-current, and fast response time. Here, we address the switching characteristics of new binary chalcogenide-based selectors by varying cell size and thickness of the switching medium. The optimized chalcogenide-based selector yielded stable switching performance with high non-linear properties, including a low off-current level of around 10^{-10} and an on/off ratio of approximately 10^4. These results are promising for the development of crossbar array-based non-volatile memory with improved control of the sneak-path current.

Keywords:

selector, threshold switching

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P2-se.311

The width of the stripe domain pattern changes depending on the Ta insertion layer

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Abstract:

We conducted the manipulation of magnetic stripe domain widths in perpendicularly magnetized systems, which can be affected by various spin interactions, including the Dzyaloshinskii-Moriya Interaction(DMI), Heisenberg exchange interaction, and dipole-dipole interaction. Thus, we introduced an edge-type Ta layer into a W/CoFeB/Ta/MgO stack to validate anisotropy energy-dependent magnetic stripe domain width. The insertion of the Ta layer was found to distribute the orbital bondings at CoFeB/ MgO interfaces, leading to changes in the perpendicular magnetic anisotropy (Hk). In addition, the experimental results showed that the stripe domain width varied with the thickness of the Ta insertion layer, which significantly affected Hk. We also tested the generation of magnetic skyrmions by varying Hk with different external magnetic fields, Hx. Overall, these findings could have important step towards to their use in future technological applications.

Keywords:

Perpendicular magnetic ansitotropy, Stripe domain, Skyrmion and Half Skyrmion, Dzyaloshinskii-Moriya Interaction

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P2-se.312

그래핀/질화붕소/다공성 실리콘/bathocuproine 광검출기 소자

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Abstract:

다공성 (porous) 실리콘은 벌크 실리콘에 비해 높은 광 흡수를 나타내어 광전자 소자의 효율을 향상시키는 데 많은 연구가 진행되어 왔다. 우리는 그래핀 투명전도성 전극/다공성 실리콘 사이에 육각형 질화붕소 (h-BN)를 중간 계면층과 실리콘 후면에 bathocuproine (BCP) 패시베이션 층을 사용하여 광검출기 소자에 적용하였다. 그 결과, 그래핀/h-BN/PSi/n-Si/BCP 소자는 0 V에서 광전류를 나타내어 자가발전 특성을 보였다. 또한, 소자는 300-1100 nm에서 최대 0.58 AW-1 반응도, 1 x 10^{11} $cmHz^{1/2}/W$의 검출능을 보였다. 특히, 검출능은 그래핀/다공성 실리콘 소자에 비해 100배 향상하였다. 본 광 검출기 소자의 광전류는 2000 시간 후에도 초기 값의 98% 이상 유지되는 것을 확인하였다. 이러한 결과는 우수한 장기 안정성을 나타내는 것이다.

Keywords:

그래핀, 질황붕소, 다공성 실리콘, bathocuproine, 광검출기

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P2-se.313

Substantial Schottky Barrier Effects on Conductive Channel Migration in WSe_2 Multilayer Transistor

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Abstract:

Conductive channel migration depending on thickness of 2D multilayers has been well demonstrated theoretically and experimentally. This can be explained by the high interlayer resistance (or interlayer energy barrier) and the thickness-dependent carrier mobility via electrostatic gate and drain bias. When a high Schottky barrier was established at metal-to-2D semiconducting multilayers, however, the distinct charge carrier transport feature would disappear. In this poster, we report the substantial Schottky barrier effects on conductive channel migration in WSe_2 multilayer transistors. At the constructed top-contact electrodes exhibiting a pseudo ohmic behavior, the clear double humps in the second derivative of transconductance ($\mathrm{d}g_m$) curves were obtained, manifesting that the redistributed channel density profile along the *c*-axis of WSe_2 multilayers regardless of drain bias (V_D) conditions (10 mV ≤ V_D ≤ 3.0 V). Meanwhile, at the bottom-contact electrodes demonstrating a strong Schottky barrier, the second hump of $\mathrm{d}g_m$ appears exclusively at high V_D regimes (2.0 V ≤ V_D), implying that the restricted channel migration incurred by a poor contact quality even in the identical WSe_2 multilayers. Additionally, we consistently confirmed the double humps in $\mathrm{d}g_m$ curves with a vertical double contact configuration in which the top- and bottom-electrodes are connected together.

Keywords:

2D multilayers, WSe2, Carrier transport mechanism, Channel migration, Contact resistance

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P2-se.314

Contact-Structure-Dependent Conducting Channel Migration of Multilayer WSe_2 Field-Effect Transistors

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Abstract:

In addition to the effects of Thomas-Fermi screening length and distribution of surface trap density effects, the presence of interlayer resistance and the thickness-dependent carrier mobility of 2D van der Waals multilayers strongly trigger a conducting channel migration along the thickness. Nevertheless, the direction of spatial channel location under electrostatic drain and gate bias conditions has not clearly resolved yet. In this presentation, we report the direction of conduction channel migration in 2D WSe_2 multilayer by constructing different contact electrode structures; i) bottom-contact (BC), ii) top-contact (TC), and iii) vertical double contact (VDC), respectively. On the basis of the drain and gate bias dependent-shape modification of transconductance linking closely to the charrier transport mechanism in 2D multilayers, the redistribution of carrier density along the thickness of WSe_2 multilayers was clearly probed in terms of BC, TC, and VDC. Our results would provide a clear device layout and further insights into the distinct carrier transport mechanism in 2D multilayers.

Keywords:

2D multilayer, channel migration, tungsten diselenide

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P2-se.315

MXene의 수열 합성과 전기도금을 통한 전기화학 센서 제작

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Abstract:

다양한 유무기물, 환경호르몬, 암과 관련한 바이오마커들을 탐지하는 센서 연구가 여러 분야에서 진행되고 있다. 센서 전극으로 활용되는 2D 물질 중에서 MXene의 경우, 높은 전도성과 전기용량, 촉매작용, 표면의 작용기 등의 장점으로 센서 뿐만 아니라 배터리 등의 다양한 분야에서 연구되고 있다. MXene 합성을 위해서는 Ti_3AlC_2 과 같은 MAX phase에서 알루미늄의 선택적 에칭 과정을 통하여 최종 형태인 금속 이온(Ti)과 탄소 (또는 질소) 이온이 결합한 형태가 되어야 한다. 이를 위한 다양한 에칭 방법 중, 수열 합성 방법을 이용해 MXene을 합성하였다. 수열 합성의 경우에는 고온의 조건에서, 고농도의 알칼리 용액내 에서 Ti_3AlC_2 MAX phase의 알루미늄 그룹을 에칭하여 $Ti_3C_2T_x$ MXene을 얻게 된다. 우리는 이렇게 합성한 MXene을 전기도금 방법을 통해 전극 표면에 MXene 박막을 증착하였다. 우리는 chronoamperometry, chronopotentiometry, 펄스 전압 인가 방식 등 다양한 전기도금 방법을 통하여 MXene 박막 전극을 제작하여 전기화학 센서로 사용하였다.

Keywords:

MXene, electrochemical sensing, hydrothermal etching

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P2-se.316

그래핀 양자점과 bathocuproine의 사용으로 암전류를 감소시켜 성능이 향상된 페로브스카이트/다공성 실리콘 이종접합 광검출소자

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Abstract:

페로브스카이트 기반 광검출소자에서 암전류를 감소시켜서 소자의 성능을 향상시키고자 하는 연구는 이 분야에서 가장 주요한 연구주제 중의 하나이다. 본 연구에서는 암전류를 감소시키기 위한 방법으로서, 페로브스카이트 ($MAPbI_3$)에 그래핀 양자점 (Graphene quantum dots, GQDs)을 추가하고 (GQDs:$MAPbI_3$), 다공성 실리콘 (Porous silicon, PSi)과 bathocuproine (BCP)를 사용하여 GQDs:$MAPbI_3$/PSi/BCP 이종접합 광검출 소자를 제작하였다. 이렇게 만들어진 소자는 박막의 결정성, 광반응성, 광검출능, 및 반응속도가 향상되었으며 후면에서의 passivation 및 전하 차단 효과도 나타내었다. 아울러, 0 V에서도 광반응을 보이는 소위 “자가 발전” 특성으로 최대 10^5의 광전류/암전류 비율을 나타내었다. 소자의 광검출능은 그래핀 양자점과 BCP를 사용하지 않은 경우보다 약 50배 이상 증가하였다. 또한, 380~950 nm 영역에서 0.2 AW^{-1}이상의 광반응도를 보일 정도로 검출파장의 영역이 확대되었으며 약 735 ns의 감쇠시간을 보였는데, 이러한 성능 수치들은 단결정 실리콘 기반 광검출소자보다 훨씬 우수한 것들이다. 600 nm 파장의 빛과 백색광에서 2000시간동안 노출시켰을 때, 노출 전의 성능 대비 약 73및 65 % 이상 성능이 각각 유지되어 소자의 장기안정성이 우수함을 보였다. 본 발표에서는 위의 실험 결과들을 토대로 GQDs:$MAPbI_3$/PSi/BCP 광검출 소자의 암전류 감소를 통한 성능향상에 대한 메커니즘에 대해서 논의하고자 한다.

Keywords:

페로브스카이트, 그래핀 양자점, 다공성 실리콘, bathocuproine, 광검출소자

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Work Function Engineering using Copper Sulfides Electrode at Room Temperature

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Abstract:

According to emerging importance of 2D semiconducting materials such as MoS_2, WSe_2 etc., efforts of finding suitable electrode for them have been accelerated. In the case of metal-semiconductor junction, the contact barrier was formed at the junction interface and significantly affects the charge carrier transport, which determine conductivity, sheet resistance, and carrier concentration, etc. Therefore, favorable energy level alignment should be implemented. In this regard, a number of studies have been performed, such as using alloy metals on the electrodes, inserting dielectric, or choosing different materials for each electrode. But many efforts are involved in finding a suitable(/proper) combination of elements and the proper ratio of them for using alloy metals and dielectric layer. However, due to the limited material candidates and/or the sophisticate process to modulate the work function of the electrode materials, there should be a viable way to modulate work function of electrode materials.
Here, we present simple but effective method to modulate electrical property of Cu-based electrode, no need to multiple deposition process. Copper Sulfides (CuS_{2-x}) are fabricated at room temperature (RT) air ambient sulfurization synthesis on PVD-deposited Cu. After sulfurization, the electrical properties can be improved by annealing process. With different sulfurization time, we can easily tailor the work function of CuS_{2-x} which is crucial factors for governing electrical property and making them suitable for 2D field effect transistor (FET) electrode.
We evaluated the change of work functions using kelvin probe force microscopy (KPFM) and it is comparable value of WF difference when different materials are used for electrodes, so it is sufficient to implement the diode characteristics. To manifest the mechanism of WF changes, Energy dispersive Spectrometer (EDS), Raman spectroscopy (Raman), and X-Ray diffraction (XRD) are conducted. As a result, we found the atomic ratio between Cu and S is the factor of change WF of $Cu_{2-x}S$. Finally, we fabricated 2D channel FET using $Cu2_{-x}S$ electrode with monolayer MoS_2 channel, and measure the electrical properties.

Acknowledgement
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Keywords:

2D semiconducting materials, work function, Copper sulfides, field effect transistor

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외부 전기장에 따른 질화물 반도체 피라미드 꼭지점에 형성된 양자점 발광 특성 변화

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Abstract:

단광자광원은 미래 양자기술 개발에 필수적인 구성요소이다. 특히 질화물 반도체 기반 양자점은 큰 엑시톤 결합 에너지를 가지기 때문에 상온에서도 구동가능성이 있으며, 자외선부터 근적외선 영역까지 다양한 방출파장을 가진다. 또한 양자점의 방출파장은 외부 전기장을 이용해 미세 조정할 수 있으며, 이를 통해 다른 광학구조 및 전극과 결합해 전기 구동 장치의 개발이 가능하다. 본 연구에서는 질화물 반도체로 형성된 피라미드 꼭지점에 형성된 양자점에 전기장을 가해 방출파장을 조절하였다. 이를 위해 피라미드에 절연체를 증착 후 꼭지점만 여는 공정을 적용하였다.

Keywords:

반도체 양자점, 외부 전기장, 단광자광원

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Enhanced Photoresponse in Self-Powered Photocurrent Generators Using DNA Thin Films Embedded with Ni^{2+} Doped ZnO Nanorods

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Abstract:

The use of organic biopolymers in combination with inorganic semiconductors has gained significant attention in recent years, as it offers a way to create versatile hybrid structures that are not possible through conventional combinations. Here, we developed DNA thin films embedded with transition metal Ni-doped ZnO nanorods (NRs) to probe for UV photo detection. We found that the metal ion-doped ZnO NRs in DNA showed rectification behaviour, indicating a space-charge region that allowed for effective charge separation. Furthermore, our self-powered photodetector exhibited a higher responsivity of 0.89 μA for DNA thin films embedded with Ni-doped ZnO NRs compared to pristine ZnO NRs. We attributed this increased photo responsivity to the localised plasmon resonance induced by DNA thin films with metal ion-doped ZnO NRs and the space-charge region between organic DNA and inorganic ZnO NRs, which facilitated the separation of electrons and holes. Our findings demonstrate the potential for developing reliable Biosensors.

Keywords:

DNA, ZnO nanorods, Thin films, Optical characteristics, Photodetectors

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P2-te.001

도해법에 의한 전구의 직렬연결과 병렬연결로 구성된 전기회로의 정량적 분석

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Abstract:

초등학교와 중학교에서는 전구의 밝기를 비교하여 전기회로에서의 저항의 직렬연결과 병렬연결에 대한 개념을 학습한다. 하지만 비선형 전류-전압 특성을 가진 텅스텐 전구로 구성된 전기회로 실험에서는 옴의 법칙을 근거로 예상한 결과와 실제 측정된 결과와의 불일치 사례가 계속 보고되고 있다.
이 연구에서는 전구의 직렬연결과 병렬연결로 구성된 전기회로를 정량적으로 분석하는데 목적을 두고, 옴의 법칙에 근거한 방법들과 그 대안으로 제시된 도해법을 비교하고자 하였다.
전기회로는 텅스텐 전구 2개의 직렬연결과 병렬연결로 구분하고, 전구의 실온저항 동일 여부에 따라 구분하여 총 4가지 종류를 대상으로 실험하였다. 전기회로를 정량적으로 분석하는 방법으로는 전구의 실온저항을 그대로 전기회로에서의 고정저항으로 사용하는 경우와 전구의 정격 전압과 정격 전류 정보를 통해 옴의 법칙으로 구한 저항을 전기회로에서의 고정저항으로 사용하는 경우, 전구의 전류-전압 특성 곡선을 통해 도해적으로 구한 저항을 전기회로에서의 저항으로 사용하는 경우로 총 3가지 방법으로 구분하였으며, 각각의 방법으로 구해진 저항을 전구의 실온저항, 전구의 옴저항, 전구의 도해저항으로 명명하였다.
연구 결과는 실온저항, 옴저항, 도해저항을 적용하여 분석한 각각의 전기회로에서의 전압과 전류의 결과들을 실제 실험을 통해 측정된 전압과 전류의 값과 비교하여 퍼센트 오차로 제시하였다.

Keywords:

도해법, 전구의 비선형 전류-전압 특성, 전기회로, 전구의 직렬연결, 전구의 병렬연결

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디스플레이 제품을 활용한 수업 사례

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Abstract:

학교 현장에서 다양한 첨단 제품을 활용한 수업이 많이 진행되고 있으며, 첨단 디스플레이 제품을 활용하여 STEAM 을 적용하여 수업 차시 구성을 하였다. 홀로그램의 원리, 응용, 제작, 입체 영상, AR/VR 의 이해 등으로 차시 구성을 하고, 기본 이론 수업과 제작 수업으로 구성하였으며, 카드보드를 활용하여 영상을 얻는 수업을 하였다. 학생들이 흥미를 지니고 참여 하였으며, 높은 만족도를 얻었다.

Keywords:

디스플레이, 홀로그램, AR/VR

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P2-te.003

A Study on the Perceptions of Physics Education of Freshman in Engineering College(Ⅲ)
- Focusing on National Universities in the Chungcheng Region for the Last 3 Years -

공과대학 신입생들의 물리교육에 관한 인식(Ⅲ)
- 최근 3년 충청지역 국립대학교를 중심으로 -

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Abstract:

충청지역에 소재한 3개 국립대학교 공과대학 신입생들이 갖고 있는 물리교육에 대한 인식을 조사하였다. 인식은 크게 두 부분으로 나누어 조사하였다. 첫번째로 고등학교 과정에서 물리학 선택 정도, 이해도, 실험실습 수행 정도 등을 조사하였다. 두 번째로 대학에서 경험한 물리실험에 대한 이해도, 실험실 준비 현황 등을 조사하였다. 연구방법은 매년 설문지를 제작하여 투여한 후 회수하여 분석하였으며, 연구기간은 3년이었다.

공과대학 신입생 중에서 고등학교에서 자연계열을 이수하고 입학한 학생은 평균 95%로 대다수가 자연계열을 이수하였다. 자연계열을 이수자 중에서 물리학Ⅰ 및 물리학Ⅱ 모두를 공부한 학생은 35%, 두 과목 모두 공부하지 않은 학생은 24%로 나타났다. 물리학Ⅰ 및 물리학Ⅱ를 공부한 학생 중에서 공부한 내용을 아주 잘 이해한다는 응답은 7%로 나타났으며, 전혀 이해하지 못한다는 응답은 5%였다. 고등학교에서 물리실험을 경험했다는 응답은 극히 소수였으며, 경험한 실험주제 역시 극히 제한적이었다. 일반물리학 교과가 <공학교육인증 프로그램>의 MSC교과목 중 하나라는 사실을 인지하고 있는 학생은 30%로 나타났으며, 응답자의 97%는 물리학이 공과대학에서 전공이수에 중요한 기초 교과로 인식하고 있었다. 실험실습의 내용에 대해 어느 정도 이해하고 있다는 응답은 48%로 나타났으며, 대학 실험실의 실험 준비는 70%가 비교적 잘 되었다고 응답하였다. 본 연구를 통하여 공과대학 신입생들의 물리학에 대한 인식의 단면을 파악할 수 있었으며, 연구 결과는 대학 일반물리학 지도에 참고자료로 활용이 기대된다.

Keywords:

물리교육, 물리실험, 공학교육인증 프로그램, 일반물리학및실험

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학생들의 연령대별 열 개념과 과학사적 흐름에의 대응

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Abstract:

이 연구에서는 학생들의 연령대별로 어떠한 열 개념을 가지고 있는지를 열에 대한 오개념을 다룬 선행연구를 분석하여 추출하고, 이 개념이 열 개념 발달의 과학사적 흐름에서 어느 부분에 해당하는지 파악하고자 한다. 이를 통해 학생들의 개념 발달이 과학사적 흐름과 유사한지를 알아보고자 한다. 이를 위해 학생들의 열 개념을 다룬 국내외 선행연구 34편에서 총 151개의 학생 개념을 추출하였다. 추출한 학생 개념들은 열을 열기로 인식하는 열기 개념, 열이라고 하는 알갱이가 존재한다는 열입자 개념, 열과 온도를 동일시하는 온도 개념, 열이 물질 혹은 물체의 고유한 특성이라는 물질의 특성 개념이라는 네 종류로 분류되었다. 선행연구에 나타난 학생들의 열 개념을 연령대별로 분류한 결과, 열 개념의 과학사적 발전 흐름과 유사하게 발전해나가기보다 연령대별로도 여러 개념이 동시에 나타남을 알 수 있었다. 연령대에 따른 열 개념에 큰 차이가 없는 이유와 열에 대한 과학적 개념을 학습하고 난 이후에도 받아들여지지 않은 이유에 대하여 고찰하고자 한다.

Keywords:

열, 과학사