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The Korean Physical Society

2023 KPS Fall Meeting

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장소 : 창원컨벤션센터(CECO)

• 한국물리학회 초록집

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구두발표논문

Oral session abstract

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A1.01

나의 새물리 연구와 기대 방향

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Abstract:

다양한 분야에서 탄소 재료를 효과적으로 활용하려면 각 요구에 맞는 특성과 구조를 갖춘 탄소 재료가 필요하다. 또한, 탄소 재료의 대량 합성도 중요한 요소이다. 발표자는 'Ni 그래파이트 코어쉘 나노입자의 합성량 확대 연구'를 주제로 중소기업과 협력하며 꾸준히 연구해왔다. 기존의 수평 열화학기상증착기(TCVD)에서 제한된 합성량을 가진 Ni-그래파이트 코어쉘 나노입자(Ni-그래파이트 CSNPs)를 대량으로 합성하는 것을 목표로 연구를 이어가고 있다. 이번 발표에서는 그래파이트 코어쉘 나노입자 제작 연구를 주제로 새물리 학술지에 발표한 논문들에 대한 경험을 공유하려 한다. 더불어 새물리 학술지가 연구에 어떠한 도움을 주었는지, 그리고 연구의 방향성과 비전에 대해 논의하고자 한다.

Keywords:

core-shell nanoparticle, thermal chemical vavor deposition, scale-up

A1.02

새물리 발전방안 1

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Abstract:

새물리는 물리학회에서 출판하는 물리 전분야를 다루는 유일한 국문지로 SCOPUS에 등재되는 등 발전을 거듭해 왔다. 그러나 최근 학술지 수의 증가와 학술지 간의 경쟁이 심화되는 가운데, 새물리 투고수와 정량적 평가 지표 측면에서 어려움이 관측되고 있다. 이러한 상황에서 새물리의 지향 및 발전 방향에 대해 생각하고 편집위원회 수준에서 수행할 수 있는 다양한 방안에 대해 모색하는 기회를 가지도록 한다.

Keywords:

새물리, 발전방안, 편집위원회

A1.03

새물리 발전방안2

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Abstract:

한국물리학회 발행 학술지인 새물리(New Physics: Sae Mulli)는 물리학의 전분야를 대상으로 우수한 연구 성과를 발표하고 있습니다. 본 발표는 지난 수년간 게재된 논문 분석을 통해 현황을 파악하여 새물리가 더 나은 방향으로 발전할 수 있는 방안 탐색을 목적으로 합니다. 이를 위해 게재된 학술 연구의 영역, 인용 및 피인용 지수 등을 분석하여 새물리 발전 방안을 위한 몇 가지 고민을 공유하고 효과적인 발전 방안을 함께 모색할 것입니다.

Keywords:

New Physics: Sae Mulli, Analysis of Development Plan

A2.01

슈퍼카미오칸데실험의 현황

CHOI Koun [3], JANG Jee Seung [2], JUNNG Seunghyun [4], KWON Eunhyang [5], MOON Dongho [1], YANG Byeongsu *[4], YANG JEONGYEOL [4], YOO Jonghee [4], YU Intae [5], IOVINE Nadege [3], LEE Seonghak [1], JANG Mincheol [1], LEE Minwoo [5], SEO Jiwoong [5], PARK RyeongGyoon [1]
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Abstract:

슈퍼카미오칸데(SK)는 일본 기후현 히다시 카미오카초의 지하 1000 미터 실험실에서 5만톤의 물을 담은 체렌코프 검출기를 이용해 양성자 붕괴를 포함한 핵자 붕괴를 탐색하고, 태양, 초신성, 대기, 가속기 등 다양한 곳에서 생성되는 중성미자를 관측하는 실험이다. 1996년부터 2018년까지 초순수를 사용하였지만, 중성자 검출 능력을 향상시켜 초신성배경중성미자 탐색 등의 감도를 높이기 위하여 가돌리늄을 투입하기로 하였다. 이를 위하여 약 1년간 검출기를 개수한 후 2019년 실험을 재개하였다. 2020년 1차로 가돌리늄을 0.01%까지 투입 후에, 2022년에 2차로 가돌리늄 농도를 0.03%까지 높였다. 이 보고에서는 2018년의 검출기 개수 이후 최근 수년간 SK의 현황에 대해 보고 한다.

Keywords:

슈퍼카미오칸데, Super-Kamiokande, Super-K, SK, 가돌리늄

A2.02

Search for proton decay via $p \to e^+ \pi^0 \pi^0$ and $p \to \mu^+ \pi^0 \pi^0$ in Super-Kamiokande I-V

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Abstract:

We searched for proton decay via $p \to e^+ \pi^0 \pi^0$ and $p \to \mu^+ \pi^0 \pi^0$ in 0.401 megaton-years of data collected in entire pure water detector phases of Super-Kamiokande (SK) I-V. Some theory attempts to consider proton decay rates without specificity underlying theory "model-independently" and say that three body nucleon decays with pions may not be necessarily very strongly suppressed compared to two-body p->e^+pi^0. It is the first time in SK searching for $p \to e^+ \pi^0 \pi^0$ and $p \to \mu^+ \pi^0 \pi^0$. In this talk, we will report the result of $p \to e^+ \pi^0 \pi^0$ and $p \to \mu^+ \pi^0 \pi^0$.

Keywords:

proton decay, SK, Super Kamiokade, GUT

Search for rare interactions of Dark Matter with high-energy neutrinos from distant point sources with the IceCube Neutrino Telescope

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Abstract:

The recent discoveries of neutrino signals from distant sources, TXS 0506+056 and NGC 1068, provide opportunities to search for rare interactions neutrinos might encounter on their paths. One potential scenario of interest is the interaction between neutrinos and the dark matter in between a distant high-energy neutrino source and the Earth. 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 focuses on searching for rare interactions between sub-GeV dark matter and high-energy neutrinos from the IceCube-identified astrophysical neutrino sources for the first time. It considers several benchmark mediator cases and uses ~ 10.4 years of the upgoing track-like events observed by IceCube. In this contribution, the status of the analysis is presented.

Keywords:

IceCube, Neutrino, Dark Matter, Rare Interaction, Point Source

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A2.04

Characterization of large-diameter photomultiplier tube

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Abstract:

In neutrino experiments of large-scale Cherenkov and liquid scintillation detectors, a photomultiplier tube (PMT) with a large-diameter is commonly used. We performed a characterization of a 50cm-diameter PMT. As a result of various investigation, a single photoelectron peak and PMT gain were measured. We also measured the dark count rate and after-pulse. Additionally, a methodology for Transit Time Spread measurement has been developed. In this presentation, several measured characteristics of the 50cm-diameter PMT will be shown.

Keywords:

PMT

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A3.01

Edge mode in supersymmetric Jackiw-Teitelboim gravity

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Abstract:

We study the edge mode of the two-dimensional supersymmetric Jackiw-Teitelboim (SUSY JT) gravity. First, we present the superspace formalism of the SUSY JT gravity. We demonstrate the wiggling boundary of the superspace can lead to the edge mode of the SUSY JT gravity which can be described by super-Schwarzian theory. In addition, we discuss the alternative derivation of the edge mode by the standard analysis for would-be gauge mode in the gravity.

Keywords:

quantum gravity, edge mode, SUGRA, SUSY JT gravity, Super-Schwarzian theory

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A3.03

End of the World Perspective to BCFT

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Abstract:

We study the thermodynamic properties of the system based on the viewpoint of the AdS/BCFT correspondence. By analyzing the solution of the junction equation, we found that the degrees of freedom on the boundary can be re-interpreted as a partial thermal entropy of the black hole. Furthermore, depending on the temperature, a BTZ black hole with a compact conformal boundary allows the merging of two distinct endpoint branes, enabling the formation of a singular brane configuration. The observation provides some clues to understand the structure of the inside of the horizon. We also argue the extended first law of thermodynamics on higher dimensions.

Keywords:

AdS/CFT, AdS/BCFT, Thermodynamics, Black hole

A3.04

End of the world perspective to BCFT

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Abstract:

We consider holographic BCFT systems with temperature. The end of the world brane geometry is the JT black hole with the same temperature. We found a generalized first law of thermodynamics called "Grafted thermodynamics". Also, we consider two EOW branes on the BTZ black hole. By temperature lowering, It can be shown that two JT black holes are combined into an AdS spacetime with a conformal matter. We also discuss extensions in higher dimensions.

Keywords:

Black hole, BCFT, Holography

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A6.01

Effect of quark degrees of freedom on nuclear matter properties

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Abstract:

We study the effect of nucleon structure variation on nuclear matter using the quark-meson coupling (QMC) model, in which the quark degrees of freedom are explicitly taken into account within mean-field approximation. Compared with the relativistic mean-field model where nucleons are considered as point-like particle objects, we explain the self-consist treatment of quarks using the MIT bag model both in theoretical and numerical calculations. Especially, we focus on the variation of nucleon size and mass differences between nucleons and delta-isobars in nuclear matter using the updated QMC model with one-gluon exchange contribution.

Keywords:

quark degrees of freedom, quark-meson coupling, nuclear matter, one-gluon exchange, MIT bag model

A6.02

Measurement of K*(892) production in the $^{12}C(K^{-}, p)$ reaction at 1.8 GeV/c

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Abstract:

K*(892) production from nuclei provides a crucial test ground for exploring possible in-medium modification of K*(892) properties. Recently, we collected high-statistics datasets for $^{12}C(K^{-},p)$ reactions at 1.8 GeV/c. We performed this measurement simultaneously in the J-PARC E42 run for the H-dibaryon search. The HypTPC helps reconstruct the K*(892)-> $K_{s}^{0}\pi^{-}$ decay, while a forward spectrometer tags a proton in the angular range $0^{\circ} < \theta_{K^{-}p} < 20^{\circ}$. This talk will present preliminary results on the differential cross-section measurement for $^{12}C(K^{-}, p)$K*(892)X and $p(K^{-},p)$K*(892) at 1.8 GeV/c. Furthermore, the measurement of decay particles from the kaonic-bound region will be also discussed, which can be a good probe for kaonic-bound nuclei

Keywords:

J-PARC, K*(892), differential cross section

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A6.03

Production of S=-2 systems near the threshold in the $^{12}C(K^-,K^+)X$ reaction at 1.8 GeV/c

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Abstract:

While studying the double Λ hypernuclei and Ξ^-hypernuclei is essential in further understanding baryon-baryon interaction with S=-2 systems, experimental data still need to be provided. Several earlier experiments, such as KEK-PS E373 and J-PARC E07, reported possible attractive Ξ^-–nucleus interaction from bound Ξ^- hypernuclear states.
Recently, the E42 experiment which has a primary goal to search for an H-dibaryon collected 300K $^{12}C(K^-,K^+)X$ reaction events in the ranges of $\theta_{K+} < 25^\circ$ and $p_{K+} > 0.5\ GeV/c$ via $1.8\ GeV/c$ K^- beam at the J-PARC. A large time-projection chamber (HypTPC) highlights the E42 detector, facilitating a charged particle reconstruction for subsequent decays of the double-strangeness system produced near the threshold region in the $^{12}C(K^-,K^+)X$ reaction. Therefore, the E42 data would first measure all decay channels involving charged particle emission from $^{12}C(K^-,K^+)X$ reaction with high statistics.
This talk will present the preliminary results of the J-PARC E42 experiment.

Keywords:

J-PARC, TPC, Xi-, Lambda, double-strangeness

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A7.01

Odd-even staggering and kink structure of charge radii of Hg isotopes by the deformed relativistic Hartree–Bogoliubov theory in continuum

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Abstract:

We examine the odd-even staggering (OES) of charge radii of Hg isotopes, which has been first measured 1977 and recently has been confirmed by advanced laser techniques. To understand the nuclear structure underlying this phenomena, we utilize the deformed relativistic Hartree–Bogoliubov theory in continuum (DRHBc). Our analyses reveal that the OES observed in $^{180-186}$Hg isotopes can be attributed to the coexistence of different nuclear shapes in the Hg isotopes. Specifically, we find that prolate shapes of ^{181,183,185}Hg result in an increase in the charge radii compared to the oblate even-even ^{180,182,184,186}Hg isotopes, whose deformations are determined by considering the shape coexistence. We explain the OES due to the change of the deformation in terms of the evolution of the nucleon single-particle-states of the Hg isotopes in detail. We also investigate the kink structure of the charge radii of the Hg isotopes in the vicinity of the N = 126 shell.

Keywords:

odd-even staggering (OES), shape coexistence, charge radii, DRHBc theory

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A7.02

Unitary Fermi System in Lattice EFT

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Abstract:

Successful studies for Carbon and Oxygen dripline by using a Nuclear Lattice Effective Field Theory approach lead fundamental questions about general behavior of neutron dripline. We investigate simple unitary fermi gas system with external simple potential given depth and radius to extract universal behavior of the dripline. In this talk, we will present the results of unitary system in Nuclear Lattice Effective Field Theory and discuss them in relation to the neutron dripline.

Keywords:

Nuclear Lattice Effective Field Theory, Two neutron separtion energies, Nuclear structure, Neutron dripline

A7.03

Shell-Model Description of the Mirror Asymmetry in Gamow-Teller Transition Rates

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Abstract:

Studying the mirror asymmetry in Gamow-Teller transition rates provides a sensitive probe of nuclear structure models, particularly the isospin nonconserving component of the nuclear Hamiltonian. This weak process has also been employed in the search for new physics beyond the Standard Model, as any non-nuclear contribution to such asymmetry would be attributed to the existence of the weak tensor current. We present our new results from shell model calculations of the isospin-symmetry breaking correction to Gamow-Teller matrix elements and discuss their impact on the mirror asymmetry. The results are further compared with experimental data as well as existing theoretical calculations for comprehensive insights.

Keywords:

Shell Model, Isospin-Symmetry Breaking, Gamow-Teller transitions, Mirror Asymmetry, Weak Interactions Beyond the Standard Model

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A7.04

Improvement of sd-shell effective interactions from Daejeon16

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Abstract:

We present new microscopic effective *sd*-shell interactions, obtained from the modern Daejeon16 *NN* potential. This interaction was derived from the no-core shell model (NCSM) wave functions of 18F at Nmax=6 model space through the Okubo-Lee-Suzuki (OLS) transformation. We compare the monopole properties of that interaction with the phenomenological universal *sd*-shell interaction, USDB, and with our previous interaction derived at Nmax=4. Also theoretical binding energies and low-energy spectra of the O isotopes are presented.

Keywords:

effective interaction, Daejeon16

A8.01

Experimental investigation of a quantum heat engine coupled to superradiant reservoirs

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Abstract:

Quantum coherence, a fundamental quantum mechanics concept, holds significance in thermodynamics with emerging applications in quantum heat engines. Quantum coherence has been proposed as a resource for heat engines, especially in the context of superradiance—a quantum phenomenon causing strong collective emission in correlated emitters. This emission, proportional to the squared number of emitters, can enhance radiation-based devices like thermal machines. We will present an experimental demonstration of a quantum heat engine driven by superradiance. Coherently prepared reservoir atoms traverse a Fabry-Perot cavity, transferring coherence to the engine—a photon gas and cavity mirrors acting as a piston. Work is extracted from coherence within a heat reservoir, maintaining a nearly constant reservoir temperature during engine operation. This setup benefits from augmented superradiance-induced mechanical power, which scales non-linearly with the number of interacting atoms.

Keywords:

Superradiance, Quantum optics, Quantum thermodynamics, Ergotropy, quantum coherence

A8.02

Photon statistics in thresholdless superradiant lasing

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Abstract:

In recent years, significant efforts have been made to reduce the lasing threshold and achieve coherent light at very low output power. While the inflection point in the input-output power curve has been lessened, the output photon statistics still produce thermal light below the reduced threshold. Here, we demonstrate a coherent light source based on superradiance, operating below the conventional lasing threshold. This is accomplished by employing phase-correlated atoms in a beam traversing a high finesse cavity through a nanohole array. The prescribed phase correlation eliminates the conventional lasing thresholds that would occur around unity mean photon number. The superradiance does have a threshold at unity atom number. Above this threshold coherent photons are generated with the associated mean photon number less than unity, thus complementing the conventional lasing below its threshold. To quantify the output photon statistics, we measured its second-order correlation function around and below the anticipated conventional threshold. Values as low as 1.03(2) were observed, confirming our expectations.

Keywords:

superradiance, nanohole array, thresholdless lasing, phase correlated atoms, photon statistics

Locked nucleic acid (LNA)-based tension sensor for measuring strong integrin tension

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Abstract:

Cells detect and react to mechanical cues from neighboring cells or the extracellular matrix (ECM) through their transmembrane receptors. Various force sensors, such as PEG, DNA-based, PNA-based, and polypeptide, offer sensitivity in the 1-56 pN range. While these sensors have proven effective in detecting mechanical forces, their measurement capability is limited to approximately 60 pN. This limitation impedes our understanding of cellular processes that involve higher forces acting on membrane receptors. To address this knowledge gap, we developed a novel tension sensor, the "LNA-based TGT", by combining locked nucleic acid (LNA) with our pre-existing DNA-based "tension gauge tether" (TGT) framework. LNA is known for its strong binding affinity to complementary DNA and offers advantages such as resistance to DNase enzymes, thermostability, and accurate cellular force detection. Magnetic tweezer measurements reveal that the LNA-based TGT can tolerate tensions exceeding 110 pN. Preliminary tests show that the LNA-based TGT is resilient against both soluble DNase I and membrane-bound DNase. Moreover, the force readings from our sensors are consistent with previous data, highlighting their reliability. In conclusion, the incorporation of LNA to develop a new class of tension sensors holds considerable promise for advancements in cell mechanobiology.

Keywords:

Single molecule force probe, TGT, LNA, Intengrin tension

Non-invasive Assessment of Reduced Stemness in Induced Pluripotent Stem Cells through Holotomography

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Abstract:

Induced pluripotent stem cells (iPSCs) offer a potential resource for personalized regenerative medicine. Consequently, researchers have persistently sought to enhance and leverage the capabilities of iPSCs.
One persistent challenge in the effective utilization of iPSCs has been the determination of their stemness. Stemness, denoting a cell's capacity to differentiate into various subtypes, stands as a pivotal criterion for therapeutic applications. Current methods to evaluate stemness are either inaccurate or inefficient. For instance, examination with routine microscopy introduces inconsistency due to manual and qualitative processes. More precise techniques measure cell differentiation or relevant gene expression. However, these approaches are indirect and exhaustive as the examined iPSCs are altered or destroyed. Hence, a non-invasive yet robust means to assess the stemness of iPSCs has been a sought-after objective among researchers and clinicians.
In this study, we introduce holotomography (HT)—a microscopic technique that obtains the three-dimensional (3D) refractive index (RI) distributions of cells and tissues—to profile iPSC colonies without biochemical labeling. In our measurement, HT unveiled the intricate structures in iPSCs across colonial, cellular, and subcellular scales. Owing to the quantitative nature of RI, properties such as volume, average dry mass density, and lipid ratio were obtained for each colony. Differences in these properties were observed in iPSC colonies that were exposed to differentiation-promoting agents. Based on this observation, a machine learning algorithm was constructed to screen out stem iPSC colonies with reduced stemness. Additionally, each colony could be segmented into individual cells, facilitating analyses of spatial heterogeneity.
Our demonstration underpins the potential utility of HT as an advisory tool in maintaining invaluable resources for cell therapy. We also note that HT can help investigate the reprogramming or differentiation process of iPSCs, owing to its capability for prolonged measurement.

Keywords:

Holotomography, Induced pluripotent stem cell, Cell therapy, Machine learning

2023 KPS Fall Meeting
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A9.03

Direct Measurement of the Strength of Protein-Protein Interactions Within Living Bacterial Cells by Accurate FRET Imaging

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Abstract:

Protein-protein interactions (PPIs) play a pivotal role in governing numerous biological processes. Assessing the strength of these interactions is often achieved through a critical parameter known as the dissociation constant (K_d). While measuring K_d in vitro is relatively feasible due to the controlled protein concentrations and environments, characterizing PPIs directly within intact cells, particularly in Escherichia coli cells, has remained challenging. This challenge arises from the low fluorescence resonance energy transfer (FRET) signal within cells and the difficulty in employing noninvasive techniques to quantify intracellular proteins. In response, we have developed a three-channel accurate FRET imaging system that provides accurate measurements, enabling the determination of K_d for PPIs within individual living cells. This breakthrough is anticipated to usher in a new era in protein-protein interaction research, significantly enhancing our comprehension of the intricate intracellular milieu.

Keywords:

Protein-protein interaction (PPI), Dissociation constant (Kd), FRET imaging

2023 KPS Fall Meeting
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A9.04

ER-associated organelle dynamics across microtubular and ER networks

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Abstract:

Visualizing the transport of endoplasmic reticulum (ER)-associated organelles along dynamic ER networks is essential for understanding fundamental biological processes. While fluorescence-based microscopy offers high-contrast imaging with chemical selectivity, it often neglects contextual information from the microenvironments surrounding fluorescently-labelled targets. In this study, we investigate the ER's role in transporting LC3-labeled autophagosomes (APGs) using fluorescence-combined interferometric scattering (F-iSCAT) microscopy. In contrast to the rigid microtubule (MT) filaments, the ER's tubular network exhibits greater flexibility and higher-frequency thermal fluctuations. Consequently, by filtering out signals from relatively static subcellular structures, iSCAT can directly reveal the spatial architecture of the dynamic ER and its remodeling linked to transportation of the dynamic cargos along microtubule networks. Our observations highlight two distinct dynamics exhibited by APGs during their transportation on ER and MT networks as well as during different maturation stages. Taken together, our findings underscore the potential of F-iSCAT as a potent tool for shedding interferometric light on the in vivo structures and dynamics underlying various intracellular phenomena.

Keywords:

Interferometric scattering microscopy, Endoplasmic reticulum, microtubule, Autophagosome, Intracellular transport

A10.01

Study on physical characteristics of single and nano polycrystalline structure of Ti_6Al_4V under indentation using molecular dynamics simulations

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Abstract:

Ti6Al4V is a popular high-performance metal alloy for various applications, such as aircraft, rockets, vehicles, and medical devices. Recently, metal 3d printing, sometimes called additive manufacturing, has become one manufacturing method for Ti6Al4V products due to design optimization, environment friendliness, and time and cost efficiency. Therefore, understanding the characteristics of Ti6Al4V media during additive manufacturing is a crucial requirement to produce qualified printing outputs. This presentation will show a way to reveal the underline physics of transformations of Ti6Al4V microstructures via irradiation and external forces. However, characteristic times for microscopic systems are constrained by the experimental apparatus's limit. Molecular dynamics simulation is a well-known technique for conducting research in various science and engineering fields for the microscopic world. The reference structure of Ti6Al4V is set based on experimental observation and measurements as the bi-crystalline structure of α and β titanium. For further study, nano-polycrystalline structures with the averaged size of randomly oriented grains of O(1-10nm) are built using the reference structure. The interatomic potential is selected as the modified embedded atom method (MEAM) due to the excellent agreement with experimental measurements. Our primary objective is to elucidate the effects of external irradiation and initial configurations of crystal structures. We calculate the thermal and mechanical properties, such as elastic modulus and hardness of bi and polycrystalline structures, before and after irradiation. In addition, variations of structural orders during transformation are quantified to reproduce the conformational entropy variations. This presentation will give an in-depth intuition of nanocrystalline structure under thermal transformation processes to design the titanium alloy powders and relevant metal 3d printers.

This study is supported by the Defense Innovation Cluster grant funded by Defense Agency for Technology and Quality (DCL2020L).

Keywords:

Ti6Al4V; Molecular dynamics; Nanocrystalline structure; Mechanical Properties; Conformational Entropy

2023 KPS Fall Meeting
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A10.02

Comparison of Fourier-transformed and Wavelet-transformed EXAFS

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Abstract:

Local structural properties of compounds are often critical to understand the physical and chemical properties of the systems. Extended X-ray absorption fine structure (EXAFS) is a unique tool to describe local structural properties around a selected species of atoms in matters. A detail analysis of Fourier-transformed EXAFS (FT-EXAFS) data is used to quantitatively determine the local structural properties. Recent studies suggested that wavelet-transformed EXAFS (WT-EXAFS) can visibly distinguish between atoms, which are different species elements located at the similar distances from a probing atom. We theoretically examined the WT-EXAFS of transition metals, including Ti, Cu, and Zr atoms to distinguish from Pt atoms using superlet methods with an enhanced resolution. The theoretical calculations of WT-EXAFS showed that Ti, Cu, Zr atoms are clearly distinguishable from a Pt atom. Meanwhile Ti and Cu atoms are indistinguishable, when they are located at the same distance from a probing atom. Ti and Cu atoms are distinguishable when the FT-EXAFS of the two atoms is reasonably fitted. The combination of FT-EXAFS and WT-EXAFS can more accurately describe the local structural properties of materials.

Keywords:

EXAFS, Local structure, Wavelet transform, Fourier transform, Pt

2023 KPS Fall Meeting
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A10.03

Defect identification of nitrogen-doped graphene on Pt (111) via atomic force microscopy and scanning tunneling microscopy

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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 different atomic configurations of nitrogen defects lead to different features depending on their respective structures, so identifying and controlling the bonding arrangement is important. In this work, we present two nitrogen defects, graphitic-N, and pyridinic-N, in nitrogen-doped graphene on Pt(111). Nitrogen-doped graphene grown on Pt(111) using pyridine was analyzed for its atomic and electronic structure using a scanner that measures Atomic Force Microscopy (AFM) and Scanning Tunneling Microscopy (STM) on an atomic scale based on a q-Plus sensor. The atomic and electronic structures of nitrogen defects were confirmed through DFT calculations to verify the experimental results. In addition, we found an intermediate step in forming nitrogen-doped graphene from pyridine precursor and suggested the formation mechanism. Through this study, we can expect to provide a deeper understanding of nitrogen-defect-based graphene applications.

Keywords:

N-doped graphene, Atomic force microscope (AFM), Scanning Tunneling Microscopy (STM), Graphitic-N, Pyridinic-N

2023 KPS Fall Meeting
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A10.04

The effect of bilayer graphene substrate on epitaxially grown monolayer $TaSe_2$ film

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Abstract:

The layered transition metal dichalcogenides (TMDCs) provide a useful platform for studying complex electronic phases in two dimensions (2D), such as charge density wave (CDW), superconductivity, and topological orders. Especially, epitaxially grown monolayer (ML) 1*T*-$TaSe_2$ on bilayer graphene (BLG) substrate have been intensively paid attention due to the Mott state by CDW order and the evidence of the quantum spin liquid phases. However, the substrate effect to ML 1T-$TaSe_2$ from BLG has not been understood yet.
Here, I will discuss the substrate effect on MBE-grown ML $TaSe_2$ on BLG substrate using angle-resolved photoemission spectroscopy (ARPES). By direct comparison of graphene π band before and after growing ML $TaSe_2$ films on BLG substrate, I will uncover the effect of BLG in ML $TaSe_2$.

Keywords:

Angle-resolved photoemission spectroscopy (ARPES), TaSe2, Molecular beam epitaxy (MBE), Substrate effects, Graphene

2023 KPS Fall Meeting
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A12.01

Interface defect passivation through LiF post deposition treatment in $Cu_2ZnSn(S,Se)_4$ solar cells

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Abstract:

$Cu_2ZnSn(S,Se)_4$ (CZTSSe) is a potential light-harvesting material for emerging photovoltaics, owing to its non-toxicity, earth abundance, and high stability. Incorporation of light alkali elements in CZTSSe has been regarded as an effective approach to mitigate V_{OC} deficit by defect passivation. LiF post-deposition treatment (PDT) can possibly enable precise Li-doping by modulating the Li supply and finely passivating CZTSSe surface region by tuning the substrate temperature. Undoped, LiF as-deposited, and LiF PDT-processed CZTSSe were fabricated and characterized to demonstrate the effect of PDT. A 0.7 nm of LiF layer was deposited on CZTSSe and annealed at 200 ℃. [1] Secondary ion mass spectroscopy confirmed successful Li diffusion only after LiF PDT process. Energy dispersive spectroscopy and Raman analysis revealed little effect of Li on CZTSSe phase formation.[2] CZTSSe solar cell was mechanically grinded to examine the band alignment at the CdS/CZTSSe interface. The lateral work function at the exposed layer was measured by Kelvin probe force microscopy. Difference in work function between bulk and interface decreased after LiF PDT, reducing conduction band offset. Moreover, surface photovoltage increased by Li diffusion. The favorable band alignment adjustment by modified defect types reduced carrier recombination and enhanced open-circuit voltage (V_{OC}) and power conversion efficiency (PCE).

[1] Dae-Ho Son et al., J. Mater. Chem. A **7** (2019) 25279
[2] Juran Kim et al., Solar Energy Materials & Solar Cells **250** (2023) 112091

Keywords:

Kesterite solar cell, Light alkali doping, open-circuit voltage, atomic force microscopy (AFM)

2023 KPS Fall Meeting
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A12.02

Exploring Laser-Patterned Hybrid Perovskite Modules through Optical Spectroscopy

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Abstract:

In recent years, significant research endeavors have been directed towards advancing the effectiveness and durability of hybrid organic-inorganic perovskite (HOIP) solar cell materials. As a result, photovoltaic devices have achieved an impressive conversion efficiency of around 26%, yet a notable challenge persists in the form of these materials' vulnerability to ambient environmental conditions. Therefore, recent focus in these materials has been on improving conversion efficiency and stability at the same time. Our work centers on understanding the mechanism behind the improved stability and efficiency when utilizing laser scribing on the $Rb_{0.05}(FA_{0.95}MA_{0.05})_{0.95}Pb(I_{0.95}Br_{0.05})_3$ perovskite module. Through the utilization of micro-Raman scattering spectroscopy and photoluminescence (PL) mapping, the study pinpointed localized changes caused by the laser process. The results strongly suggest that the enhanced characteristics of the module can be ascribed to a secondary effect of the laser scribing process namely, a passivation effect.

Keywords:

Perovskite, Passivation

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A12.03

Myth and Truth in the Exploration of Dzyaloshinskii-Moriya Interaction based on Hysteresis Loop Shift Measurement

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Abstract:

Dzyaloshinskii-Moriya Interaction (DMI) is antisymmetric interaction which is responsible to chiral magnetic texture [1, 2]. Recently, there has been a broad exploration of the DMI through the hysteresis loop shift measurement by exploring the effective magnetic field generated by the spin-orbit torque (SOT) [3]. Nonetheless, a comprehensive understanding of the mechanism governing the transition in domain-wall (DW) chirality remains an ongoing pursuit [3, 4], eventually leading to imprecise measurement of the DMI. In this study, we experimentally examined the hysteresis loop shift measurement within Pt/Co-based magnetic films and propose a novel physical model, elucidating two DW chirality transitions for given polarity of magnetization. Our theoretical model aptly elucidates the experimental findings, and the measured DMI aligns with outcomes derived from both conventional approaches to the DMI assessment: centered on the DW depinning [5] and the DW speed [6] measurements. Our examination rectifies the misapprehension associated with utilizing hysteresis loop shift measurement as a means of determining the DMI.

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Keywords:

Magnetic Domain-Wall, Dzyaloshinskii-Moriya Interaction, Spin-Orbit Torque

A12.04

Circuit Model Analysis of Negative Refraction in a Photon-Magnon Hybrid System

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Abstract:

In recent years, metamaterials displaying a negative refractive index (NRI) have garnered significant interest due to their potential applications in diverse areas such as superlenses, invisibility cloaks, and optical devices [1-3]. The construction of NRI metamaterials poses challenges as it necessitates the manipulation of both the permittivity and permeability of a material within a desired frequency range. To address this, metamaterials, often referred to as 'metastructures,' have been the focus of extensive research across various fields [4]. In this study, we introduce a novel photon-magnon hybrid system to adjust both permittivity and permeability through magnetic field control. By integrating inverted split-ring resonators (ISRRs) with Yttrium Iron Garnet (YIG) film [5-6], we explore negative refraction and its nonreciprocity using an analytical circuit model rooted in complex left-handed transmission lines. Numerical calculations based on this model indicate that the origin of nonreciprocal NRI is a combination of coherent and dissipative photon-magnon coupling (PMC) terms. We also detail a systematic approach for computing permittivity and permeability based on series impedance and shunt admittance. The derived effective refractive index confirms the presence of NRI in the PMC system, shedding light on how PMC strength and the coherent and dissipative coupling effects alter the permeability, permittivity, and nonreciprocal refractive index [7]. Our analytical framework offers insights for the design of innovative quantum metastructures in the development of quantum information devices.

This research was supported by the Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Science, ICT, and Future Planning (No. NRF-2021R1A2C2013543).

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Keywords:

Photon-Magnon Coupling, Coherent and dissipative coupling, Negative Refraction, Circuit Model, Left-handed Transmission Line Theory

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A13.01

Electric-Field-Driven Trion Drift in a Suspended Monolayer of $MoSe_2$

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Abstract:

Excitons, electron-hole pairs in semiconductors, have potential as information carriers with spin or valley degree of freedom. However, the neutral charge characteristic of excitons imposes limitations on using them as information carriers within electrical devices. Charged excitons (i.e. trions), while displaying electrical characteristics, are constrained by a significantly shorter lifetime due to their lower binding energy compared to neutral excitons. Here we demonstrate electric-field-driven drift of trions toward the center of a $MoSe_2$ monolayer.[1] By employing a simple bottom-gate device design, we can manipulate the electric fields in the proximity of the suspended monolayer, which increases the trion density. Furthermore, the structure in which a monolayer is suspended leads to an extension of the trion lifetime. We observe that locally excited trions are subjected to electric force and, consequently, drift toward the center of the stretched layer. The imposed electric force on the trion is estimated to be 10^2–10^4 times stronger than the strain-induced force in the stretched monolayer, through this, we successfully demonstrated the use of the electric force to induce trion drift. Our findings present a novel pathway towards achieving a new type of optoelectronic device that utilizes charged excitons as information carriers.

Lee, S. W.; Choi, W. H.; Cho, H.; Lee, S.; Choi, W.; Joo, J.; Lee, D.; Gong, S. Electric-Field-Driven Trion Drift and Funneling in $MoSe_2$ Monolayer. *Nano Lett*. **2023**, 23, 4282−4289.

Keywords:

transition-metal dichalcogenide, MoSe2, trion drift, optoelectronics, suspended layer

2023 KPS Fall Meeting
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A13.02

Photoreflectance Study of InAsPSb/InGaAs Multi-Quantum Well LED Structures With Different Quantum Well/barrier Numbers

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Abstract:

Multiple Quantum Well (MQW) light emitting diodes (LEDs) structures play a pivotal role in modern technology due to their multifaceted significance. This work reports the photoreflectance (PR) study of two InGaAs/InAsSbP multi-quantum well (MQW) LED samples with different numbers of quantum wells (QWs). The first samples have 6 QWs and 15 QWs. The PR measurements were performed at room temperature and different temperatures (20-300K). The quantum transitions in the samples were investigated at different temperatures to explore the effect of the well numbers on the thermal behavior. This effect can reveal the importance of the well numbers in designing LED structures for achieving efficient structures. The results of this study show that the PR properties of InGaAs/InAsSbP MQW LED samples can be affected by the number of QWs. The findings of this study can be used to design and optimize InGaAs/InAsSbP MQW LED structures.

Keywords:

multi-quantum well, light emitting diode, photoluminescence

A13.03

콜로이드 분석을 위한 광학계 구성 및 시뮬레이션

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Abstract:

유체 내 부유하는 입자의 크기 분석기술은 제약, 생명과학, 반도체 분야에서 널리 사용된다. 예를 들어, 반도체 공정 중 Chemical Mechanical Polishing 공정에서, 웨이퍼 표면을 평탄하게 연마시키는 용액인 슬러리 분석에 사용된다. 슬러리 내 거대입자가 존재할 시 웨이퍼 표면에 다양한 결함을 발생시켜 수율을 감소시키는 문제가 발생한다. 이러한 문제를 해결하기 위해 유체입자 계수기(Liquid Particle Counter)의 센서 알고리즘을 활용한 광학계를 구성하고, 유체 내 입자의 크기를 분석하는 연구를 진행하였다. 가우시안 빔의 초점을 통과하는 입자에 대한 산란 신호는 입자의 크기와 입자가 통과하는 초점 내 위치에 따라 다르다. 이를 사분할 광 검출기를 사용하여 초점을 통과하는 입자의 위치정보와 감소된 빛의 양을 수집하고 광학정리를 적용해 입자의 굴절률과 크기를 분석하는 방법을 제시한다. 추가로 시뮬레이션 결과와 실제 실험 결과를 비교한다. 이를 활용하여 다른 물질의 입자 크기 및 굴절률 분석에 활용될 수 있을 것으로 기대된다.

Keywords:

콜로이드. 슬러리. CMP, 광학계

Influence of Luttinger Parameters on the First Transition Energy of InAs/GaSb Superlattice Structures

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Abstract:

This study investigates the theoretical exploration of how Luttinger parameters influence the first transition energy within a 10 ML (~3 nm) thick InAs/GaSb superlattice structure. These semiconductor structures are recognized as cutting-edge materials, applied in various fields like high-speed transistors and infrared imaging devices. The research employs the 8-band k.p method to comprehensively assess the electronic and energy properties of these structures. By manipulating experimental Luttinger parameters, including atomic displacements, and measuring distinct energy levels, their impact on the initial transition energy is thoroughly examined. Findings indicate that a 10% increase/decrease in Luttinger parameters corresponds to an approximate 20 meV decrease/increase in the initial transition energy. This significant effect underscores its relevance. The research offers insights for enhanced, tailored designs of these structures for diverse applications. Moreover, distinctions and variations in transition energies provide valuable insight into the structural and electronic attributes of these nanoscale configurations.

Keywords:

Luttinger parameters, Conduction and valance energy levels, 8-band k.p theory, Finite difference method

A14.01

에너지 하베스팅 응용을 위한 $Ba_2NaNb_5O_{15}$ 물질의 합성 및 특성 분석

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Abstract:

최근 마찰전기 나노발전소자 (triboelectric nanogenerator: TENG)는 주위환경에서 발생하는 버려지는 기계적 에너지를 전기로 변환하는 능력으로 인해 많은 관심을 받고 있다. 나노발전소자의 전기적 성능은 복합 폴리머 필름(composite polymeric film, CPF)을 제작하기 위해 폴리머에 강유전성 물질을 매립함으로써 향상될 수 있다. 본 발표에서는 강유전성 바륨 나트륨 니오븀 산화물 ($Ba_2NaNb_5O_{15}$) 입자를 고상법으로 제조하고 PDMS (polydimethylsiloxane)에 매립하여 CPF를 형성하였다. PDMS에 내장된 강유전성 재료는 전하 생성을 향상시켜 제조된 TENG의 전기적 성능을 향상시킨다. 제작된 마찰전기 나노발전소자의 전기적 성능은 PDMS 폴리머에서 $Ba_2NaNb_5O_{15}$ 입자의 양을 변화시켜 최적화되었다. 또한 준비된 복합 섬유 필름, 종이 및 알루미늄을 사용하여 소자를 제작했다. 복합필름과 알루미늄은 각각 마찰전기 나노발전소자에서 음극 및 양극 마찰 전기 매체로 작용한다. 마찰전기 나노발전소자의 전기 출력은 복합 필름의 재료 부하 농도를 기반으로 최적화되었다. 다양한 복합 필름의 향상된 유전 상수와 유사하게 전기 출력의 향상이 관찰되었다. 제안된 $Ba_2NaNb_5O_{15}$/PDMS 기반 마찰전기 나노발전소자에서 생성된 전기는 일상생활 인간활동에서 기계적 에너지를 수확하고 다양한 휴대용 전자 장치에 전원을 공급하는 데 사용될 수 있음을 나타낸다.

Keywords:

복합폴리머필름, 마찰전기, 나노발전소자, 에너지 하베스팅

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A14.02

전기촉매 응용을 위한 코발트-황화물 나노 아키텍처 합성 및 특성 분석

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Abstract:

물이 분해되어 수소를 생산할 때 수소발생반응 (HER)을 위한 안정적이고 비용 효과적인 비귀금속 전기촉매 개발에 많은 관심이 있어 왔다. Co_3S_4/Co_9S_8 나노구조는 희귀 금속을 대체할 수 있는 유망한 전기촉매이다. 본 발표에서는 ZIF-67로 탄소 나노와이어를 캡슐화한 Co_3S_4/Co_9S_8 나노구조 개발과 기능적인 전기촉매 응용에 대해 발표한다. 질소 도핑된 탄소 나노튜브 Co_3S_4/Co_9S_8 나노구조는 황분말을 ZIF-67에 첨가한 다음 이를 불활성 분위기에서 처리하여 ZIF-67로부터 얻었다. 제작된 ZIF-67의 물성은 X선 분말 회절계, 주사전자현미경 등의 분석기술을 사용하여 분석되었다. 제작된 Co_3S_4/Co_9S_8 나노구조의 HER 촉매 활성 성능은 평가되었다. Co_3S_4/Co_9S_8 나노구조 전기촉매에 대한 반응 및 지속 사이클링 안정성 또한 평가되었다. 본 결과는 제안된 코발트-황화물이 효율적인 전기촉매 HER을 위해 저렴하고 효율적이며 견고한 전기촉매 응용의 높은 가능성을 나타내는 것을 시사한다.

Keywords:

코발트-황화물, 수소발생반응, 전기촉매

A14.03

전기방사를 이용한 니켈 세륨 셀레나이드 나노섬유 전극기반 준고체 슈퍼커패시터 제작

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Abstract:

최근 에너지 저장소자에 대한 관심과 함께, 전기방사기반 바이메탈 칼코겐 나노섬유는 구조제어, 높은 기계적 강도와 유연성, 합성의 용이성, 친환경성 등의 장점으로 인해 새로운 나노구조체로 대두되고 있다. 본 발표에서는 바인더가 없는 전기방사기반 니켈 세륨 셀레나이드 나노섬유구조 재료를 제조하기 위한 새로운 직접 분사 기술을 제안한다. 인가된 전기방사 전압이 제작된 나노섬유구조의 평균 섬유직경에 미치는 영향을 분석하였다. 25 kV의 적용된 전기방사 전압은 거칠게 상호 연결된 나노섬유로 100 nm 이하의 평균 섬유 직경을 얻기에 최적이다. 최적화된 니켈 세륨 셀레나이드 나노섬유전극은 정전류 충전-방전 장기 주기 안정성을 나타낸다. 또한 제작된 준고체 슈퍼커패시터는 우수한 전기화학적 특성을 나타낸다. 제안된 니켈 세륨 셀레나이드 나노섬유기반 준고체 슈퍼커패시터는 플렉서블 에너지 저장소자 응용에 활용될 높은 가능성을 보여준다.

Keywords:

전기방사, 니켈 세륨 셀레나이드, 나노섬유, 준고체 슈퍼커패시터

A14.04

Enhancement of Thermoelectric Property by Magnetic Impurity in Half-Metallic Ferromagnet

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Abstract:

Various thermoelectric materials and methods to improve their property have been studied for decades. However, rigorous studies on thermoelectric materials had to confront the severe fact that high charge carrier density results in low Seebeck coefficient. Recently, to overcome this trade-off and design a material with both high Seebeck coefficient and high electrical conductivity, manipulating the material via spin degree of freedom is taking interest.
Our new experimental observation on Fe/Co doped higher-manganese silicides material showed that tiny amount of substantial doping can strongly enhance both Seebeck coefficient and electrical conductivity. Here, we suggest a general mechanism how tiny amount of magnetic impurity doping on half-metallic ferromagnet leads to such enhancement of thermoelectric property.
In contrast to previous studies on impurity doping which concentrated on scattering parameter change via doping, our mechanism has two significant strength. First, our new mechanism can explain why so small amount of magnetic impurity in the host material can lead to strong increase of Seebeck coefficient. Second, our new mechanism can explain how Seebeck coefficient and electrical conductivity can increase simultanously, in contrast to common knowledge on thermoelectrics based on modern electron transport theory.
In our mechanism, magnetic coupling between the impurity and the host material originates the thermoelectric enhancement. Two-spin-channel (two-current) model, which is a simplified toy model for our mechanism is suggested, and is expected to be applied for any case in which impurity magnetically couples to half-metallic host material. Generalizing this idea, manipulating by other degree of freedom such as orbital might be discussed in the future.

Keywords:

Seebeck Coefficient, Thermoelectric Material, Magnetic Material, Ferromagnetism

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A15.01

Effect of mass position on the resonance mode of graphene nano-electromechanical drum

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Abstract:

In this study, we present the observation of resonance mode shapes depending position of mass on a graphene nano-electro-mechanical drum. The graphene resonators were suspended on silicon oxide/silicon trenches and the mass on the graphene drum was composed of tungsten, which was deposited using FIB(Focused Ion Beam) technique. The dimensions of the deposited tungsten particles on the graphene drums were systematically controlled within the nanometer scale. The particles were placed along the nodal lines or within antinode regions of the graphene drum in varying quantities and combinations. The motion of an electrostatically actuated graphene resonator was investigated by resonance frequency vibration modes. Utilizing a motorized nano-positioning stage, the sample can be scanned in x-y direction and the mechanical vibration mode of the graphene drum was observed using an optical interferometry system. The positioning of mass significantly influenced the shape of resonance multi-mode in graphene drum resonator and these findings offer the methods for developing the graphene mass sensor with high sensitivity.

Keywords:

Graphene, Graphene Resonator, Resonance Mode, Nano-electromechanical System

A15.02

Array of One-dimensional Atomic Crystals for Emerging Electronic Platform

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Abstract:

One-dimensional (1D) array of dislocation cores can function as an electronic channel in an extremely confined geometry with highly tunable conductivity. Here, we report a method to form a pattern of grain boundaries (GB) of MoS_2 monolayer with controlled dislocation core structures at the atomic scale. In the method, which we coined "patterned regrowth with tilt", patterned single-crystalline MoS_2 films are transferred onto an epitaxial sapphire substrate with control of the in-plane orientation, then another MoS_2 grains are epitaxial grown on the exposed sapphire, resulting in tilt GBs between the transferred 1st grain and the re-grown 2nd grain. A periodic array of dislocation cores at the GB host dispersive electronic states along the boundary. In particular, the embedded 1D structure makes the electronic channel as completely dangling bond free, enabling a high electronic mobility. An array of field-effect-transistors has been batch-fabricated with the GB arrays, demonstrating a novel low-dimensional material platform for electronics.

Keywords:

1D Array at MoS2, Grain Boundary

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A15.03

Ferroelectric domain wall dynamics in trilayer transition metal dichalcogenides

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Abstract:

Sliding ferroelectricity realized in non-centrosymmetrically stacked bilayer transition metal dichalcogenides (TMDs) has shown a new pathway to switch the electric polarizations. Recent demonstration of the ferroelectric switching in non-centrosymmetrically stacked trilayer TMD system exhibited more than two states of the polarizations, suggesting the sliding ferroelectricity in trilayer TMD host distinct switching mechanism compared with that in bilayer TMDs. Indeed, sliding of the top and bottom layer with respect to the middle layer can form the two different types of rhombohedral stackings (ABC, CBA) with finite polarizations as well as the other two types of Bernal stacking configurations (ABA, ACA) with zero polarizations. However, the direct observation of those domains with distinct polarization states and their switching dynamics under an applied electric field have yet to be investigated. In this work, we utilized operando transmission electron microscopy (TEM) to investigate the process of polar domain switching in trilayer TMDs in real-time fashion. We have observed switching between the up and down polarizations in rhombohedral trilayer TMD occurs through the intermediate state of the Bernal stacking. Furthermore, domain walls formed at the top and bottom interface interact with each other, exhibiting complicated switching mechanisms distinct from that of the bilayer TMDs.

Keywords:

Ferroelectricity, Two dimentional materials, Transmission electron microscopy

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A15.04

Electrical response of a flexible MoS_2 monolayer-based electronic device under a controllable mechanical deformation

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Abstract:

Molybdenum disulfide (MoS2) in its few-layer form exhibits remarkable potential as a two-dimensional semiconductor due to its outstanding semiconducting, mechanical, and electronic properties. This study describes the fabrication process of MoS_2 monolayer-based electronic devices utilizing MoS_2 monolayer grown via chemical vapour deposition (CVD) on a flexible substrate. The procedure of transferring MoS_2 monolayers from their mother substrate to the desired substrate and the method for making electrodes on a flexible substrate is illustrated. The electrical response of MoS_2 monolayer-based devices is investigated by subjecting them to a controlled mechanical strain, and observation under an optical microscope.

Keywords:

Flexible , Molybdenum disulfide, electrical response

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A16.01

Study of Non-Equilibrium Energetics in Van der Waals Ferroelectric Tunnel Junctions using Multi-Space Density Functional Theory

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Abstract:

The escalating surge in data generation has intensified the demand for memory storage, driving the need to scale down memory devices. Ferroelectric tunnel junctions (FTJs) have received considerable attention among all memory technologies due to their potential in mitigating statistical fluctuations at the nanoscale and fulfilling the persistent demand for downscaling. In the present study, based on the multi-space constrained-search density functional theory (MS-DFT) recently developed in our group [1-3], we study the finite-bias electronic structure and quantum transport characteristics of the two-dimensional Van der Waals vertical capacitor model. This model is composed of $CuInP_2S_6$ monolayer positioned between the graphene electrodes. Based on the electric enthalpy concept, we calculate free energy profiles at different nonequilibrium bias conditions in a first-principles manner. These profiles unravel insights into the interplay between paraelectric and ferroelectric phases, divulge the energy barrier height for polarization switching, and unveil the coercive voltage. Notably, we scrutinize the origins of polarization switching by parsing the contributions arising from electronic and ionic influences by analyzing Hartree electrostatic potentials, Landauer residual dipoles, and depolarization field profiles. It is noteworthy that our results are also compared with prior research stemming from equilibrium DFT calculations and their extensions. To our knowledge, our work represents the pioneering exploration of nonequilibrium energetics in FTJs within the first-principles framework, demonstrating that MS-DFT is a promising tool for the future developments of energy and memory devices.

Keywords:

FTJ, MS-DFT, Ferroelectricity

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A16.03

Realization of Hofstadter butterfly in quantum computer

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Abstract:

Hofstadter butterfly is a fractal energy spectral that has been predicted to be observed from the motion of electrons under a strong magnetic field. However, the realization of the Hofstadter butterfly requires a tremendously strong magnetic field that may not be realized in solid-state systems. In this talk, we propose the realization of the Hofstadter butterfly in the current IBM quantum computer platform (IBM-Q). Unlike the electrons in a solid system, the quantum computer can effectively realize the chiral fermions in the presence of a magnetic field, which shows a discrepancy from the conventional Landau levels. Finally, we also discuss the protocol to extract the quantum geometric quantities such as the Berry phase and Berry curvature.

Keywords:

quantum simulator, Hofstadter butterfly, IBMQ, quantum computer

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A16.04

Moiré flat bands and interfacial charge polarization in lattice relaxed twisted bilayer hexagonal boron nitride under perpendicular electric fields

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Abstract:

Interfacial charge polarization of twisted bilayer hexagonal boron nitride (t2BN) is calculated as a function of twist angle and perpendicular electric fields through tight-binding calculations on lattice relaxed geometries, where the atomic and electronic structure models are informed by density functional theory input data from small unit cell simulations. We show that lattice relaxations tend to increase the bandwidth of the nearly flat bands, where bandwidths smaller than 0.01 eV are expected for θ~1.08∘ for BN/BN alignment near 0∘, and smaller than θ ~ 1.5∘ for BN/NB alignment near 60∘. Local interfacial charge polarization maxima of ~$3*10^{12}cm^{-2}$ expected for h-BN bilayers near 0∘ degrees at the AB and BA stacking sites tend to decrease with increasing twist angle, while the interlayer charge polarization is negligibly small for antiparallel alignment twists. Perpendicular electric fields are found to alter the AB and BA stacking areas and interlayer distances, giving rise to changes in the band gaps, the bandwidth of the nearly flat bands, and the local interlayer charge distributions.

Keywords:

Twisted bilayer h-BN; Lattice relaxation; interlayer charge polarization

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B2.01

국내 지하 실험의 시작과 암흑물질 탐색

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Abstract:

국내 연구진이 주도하는 암흑물질 탐색 실험인 KIMS 실험을 수행하기 위해 양양발전소에 지하실험실이 세워진 지 20년이 되었다. 그동안 양양지하실험실은 우리나라 지하실험연구 발전의 중심적 역할을 해왔다. KIMS의 후속 암흑물질 탐색 실험인 KIMS/NaI 및 COSINE 실험을 성공적으로 진행하였고, 중성미자 방출이 없는 이중 베타 붕괴를 탐색하기 위한 AMoRE 실험 1단계를 성공적으로 진행하였다. 이러한 성공적인 노력을 통해 기초과학연구원(IBS) 지하실험연구센터를 국제적인 지하실험연구의 중심으로 발전시키고 정선에 새로운 지하실험실(예미랩)을 건립하는 데 중추적 역할을 하였다. 본발표에서는 양양지하실험실 설립과 암흑물질 탐색실험을 중심으로 한국의 지하실험 연구의 발전과정을 되돌아 보고자 한다.

Keywords:

지하실험, 양양지하실험실, 암흑물질, KIMS 실험, COSINE 싫

B2.02

이중베타붕괴 실험의 시작과 AMoRE

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Abstract:

국내 지하실험실을 이용한 연구로 KIMS 암흑물질탐색 실험이외에도 국내에서 가능한 이중베타붕괴실험 및 중성미자미방출 이중베타연구 대한 R&D를 장기간 수행하였고, 마침내 지하실험연구을 주축으로 9개국의 100여명의 국제공동연구로 Mo-100핵종을 기반으로 하는 AMoRE실험을 진행하고 있다. R&D단계를 거쳐 AMoRE-pilot및 AMoRE-I실험을 성공적으로 마쳤으며 새로 건설된 예미 지하실험실에서 AMoRE-II의 실험을 조만간 시작할 예정이다. 20여년 동안의 국내 이중베타붕괴실험의 아이디어, R&D과정, 난관, 결과 및 AMoRE실험에 대하여 소개하고 차세대 중성미자미방출 이중베타붕괴 실험의 가능성에 대하여서도 언급할 예정이다.

Keywords:

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B2.03

예미랩 건설과 앞으로의 지하실험

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Abstract:

양양지하실험실에서의 암흑물질 실험을 주도하였던 국내 그룹은 새로운 지하실험실의 필요성을 바탕으로 기초과학연구원의 지하실험연구단을 구축하게 되었다. 여러 방안중, 한덕철광의 수갱을 이용한 고심도의 지하실험실 구축이 현실적인 방안으로 제시되었고, 마침내 2022년에 구축을 완료함으로써, 세계적인 지하 실험시설로 자리매김하게 되었다. 예미랩에서는 아모레-II 실험과 COSINE-200 실험등이 준비중에 있으며, 낮은 질량의 암흑물질 탐색실험과 새로운 액체섬광체등에 대한 연구가 추진될 것이다. 본 발표에서는 예미랩에 대한 개괄과 앞으로의 연구계획에 대해서 기술해 보고자 한다.

Keywords:

암흑물질 이중베타붕괴 예미랩

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 studied using 2017+2018 data of proton-proton collision at a center-of-mass energy of 13 TeV, collected by the CMS detector at the LHC 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*, μ*) dominantly produced via contact interaction in pp collision and decaying to a SM lepton and a photon (l*→lγ) are considered, which gives final state of two same flavor leptons and a photon (llγ). For full run 2 result, the result of the 2017+2018 data analysis with updated search strategy and the published result with 2016 data analysis are statistically combined. As a result, assuming excited lepton mass equal to compositeness scale Λ, expected limit on excited electron and muon masses at 95% confidence level and the best expected limit on the compositeness scale Λ are obtained. In this talk, preliminary results will be presented.

Keywords:

cms, excited lepton

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B3.02

Search for a heavy neutral boson decaying into a pair of boosted dileptons

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Abstract:

We present a status report about the search for a heavy neutral boson decaying into a pair of boosted dileptons using CMS Run2 datasets. A pair of boosted electrons may merge via clustering energy deposits in the electromagnetic calorimeter. Dedicated multivariate identification techniques were developed to select merged electrons. A highly collimated pair of muons may share their inner tracker hits, and a trajectory cleaner can remove either of the tracks during reconstruction. We propose utilizing missing transverse energy to find signatures from the collimated muon pair.

Keywords:

CMS, four-lepton, boosted, merged, dilepton

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B3.03

Inclusive search for new physics with razor variables and boosted objects in hadronic and leptonic final states using CMS Run 2 data

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Abstract:

A search for supersymmetry in hadronic and leptonic final states with highly boosted top quarks or W/Z/Higgs bosons is presented. The search is performed using proton-proton collision data at a center-of-mass energy of 13 TeV, collected by the CMS experiment at the LHC, corresponding to an integrated luminosity of 138 fb^{-1}. Events containing candidates for hadronic or leptonic decays of boosted top quarks and W/Z/Higgs bosons are identified using jet substructure techniques. They are analyzed using the razor variables M_R and R^2, which characterize a possible signal as a peak on a smoothly falling background. The analysis is used to interpret a wide range of SUSY final states, including those arising from R-parity violation.

Keywords:

supersymmetry, CMS, LHC, Razor variables

Search for light charged Higgs boson decaying into W boson and CP-odd Higgs boson in top pair production using CMS full Run2 dataset

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Abstract:

This passage describes a study that has been conducted to search for a charged Higgs boson ($\mathrm{H^+}$) decaying to a W boson and a CP-odd Higgs boson(A). The study uses data collected by the CMS detector at the CERN Large Hadron Collider(LHC) during Run2, with an integrated luminosity of 137.5 $\mathrm{fb^{-1}}$. The signal process being targeted involves three steps: first, the top quark (t) decays into $\mathrm{H^+}$ and a bottom quark (b), then $\mathrm{H^+}$ decays into W and A, and finally A decays into two muons ($\mu^+\mu^-$). The mass range being studied for the charged and CP-odd Higgs bosons is between 70 and 160 GeV, and 15 and ($\mathrm{M_{H^+} - 5}$) GeV, respectively. The search for the signal process is performed using events with at least two opposite-signed muons and either an electron-muon-muon ($e\mu\mu$) or a muon-muon-muon ($\mu\mu\mu$) final state, along with multijet events. The final results are reported as the limit on the experimental signal cross section times the branching fraction $\sigma_{\mathrm{sig}} = \sigma (\mathrm{pp \rightarrow \mathrm{t\bar{t}}}) \times [\mathrm{Br(t \rightarrow H^+b)} \times \mathrm{Br(H^+ \rightarrow W^+A)} \times \mathrm{Br(A \rightarrow} \mu^+\mu^-) + \mathrm{c.c.}]$. To increase the sensivity in the Z-dominated dimuon mass region, graph-baased deep neural network has been utilized.

Keywords:

LHC, CMS, Higgs, 2HDM

B3.06

Search for new physics with Monophoton final states in proton-proton collisions at √s = 13 TeV with CMS detector at LHC

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Abstract:

Exploring the enigma of dark matter (DM) remains a dynamic and far-reaching field of investigation at the LHC. Utilizing a dataset obtained from CMS Run II, the CMS experiment demonstrates unwavering dedication to uncovering the distinctive signatures indicative of DM. Given that DM particles do not directly generate detectable signals within the CMS detector, a strategy to observe them involves their production in conjunction with visible standard model (SM) particles, denoted as X. These reactions, evident at colliders when particles or jets are observed recoiling against an imperceptible state, are termed 'mono-X' searches. The monophoton final state, characterized by a high-energy photon coupled with a significant amount of missing transverse energy, offers the opportunity to detect potential indications of dark matter (DM) generation through the q-qbar->γχχ process. The monophoton final state, defined by a high-energy photon coupled with a significant amount of missing transverse energy, offers the opportunity to detect potential indications of dark matter (DM) generation through the q-qbar->γχχ process. In this presentation, we present various estimations of the backgrounds as well as signal studies along with the expected limits on the cross-section.

Keywords:

Dark matter, Monophoton, CMS, LHC

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B3.07

Search for long-lived particles with delayed photon signature from CMS experiment using 2017 & 2018 data

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Abstract:

Search for new physics involving long-lived particles undergoing decays into photons, utilizing proton-proton collisions at $\sqrt{s}$ = 13 TeV collected with the CMS detector during 2017 and 2018, is performed. The findings are interpreted within the Gauge-Mediated Supersymmetry Breaking (GMSB) model, where prompt gluino decays yield long-lived neutralinos, followed by their subsequent decay into a photon and a gravitino. Notably, a Deep Neural Network (DNN) approach was employed for precise identification of delayed photons, enhancing the study's sensitivity to these unique signatures. Based on the DNN-based method, the delayed photon ID scale factor was calculated. Moreover, new upper limits on the neutralino mass using 2017 and 2018 data are presented.

Keywords:

long-lived particle, GMSB, neutralino, DNN

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B3.08

Search for Right-Handed W Bosons Decaying Into Heavy Neutral Leptons

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Abstract:

A comprehensive analysis of the Left-Right Symmetric Model (LRSM) through the study of a right-handed W boson decaying into a heavy neutral lepton (HNL) using Run-II data collected by the CMS detector is presented using the dataset with an integrated luminosity of 138 /fb. Our investigation not only seeks to scrutinize the predictions of the LRSM but also explores uncharted kinematic phase spaces that have hitherto remained unprobed, as this study targets to test the tau flavor mixing of HNLs in both regions where objects are highly collimated and resolved. With state of the art techniques to well define physical objects especially in the merged region will provide high sensitivity in such regions never explored before.

Keywords:

CMS, LHC, Heavy neutrino, Neutrino

B3.09

A phenomenological study of light Z' boson using non-isolated muons in the CMS experiment

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Abstract:

Various physics models lying beyond the Standard Model predict Z' boson, a new kind of neutral gauge boson. Z' boson decays to opposite-sign dimuons leaving signals in the CMS detector system. However, events including light Z' boson might be discarded after the trigger selection, because of the low transverse momentum of muons. In this case, the existence of an extra jet can help events to be recorded, but then one should also consider muons that are located near the jet. Thus, we suggest to investigate new phase space associated with non-isolated muons. We especially focus on light Z' boson that highly interacts with 3rd generation quark. This talk will give the current status of this phenomenological study.

Keywords:

non-isolated muon, LHC, CMS, BSM

Unique functionalities of organic nanoantennas

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Abstract:

Optical nanoantennas, the building blocks of metasurfaces, can manipulate light at the nanoscale. While nanoantennas based on metallic or high-index dielectric materials have been widely studied, organic nanoantennas have only recently shown their potential to form a new category of nanoantennas, providing their unique functionalities. In this presentation, nanoantennas based on both metallic and semiconducting organic materials as well as interrelated nanofabrication methods will be presented. The functionalities provided by these new types of optical nanoantennas may open for applications such as large-area, flexible, fully-organic metasurfaces for tunable meta-optical components, bio-sensors, smart windows, etc.

Keywords:

Organic nanoantennas, Localized surface plasmon resonances, Mie resonances, Tunable metasurfaces, Dual functionality

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B4.02

Surface Photovoltage Characterizations of TMD-Based Nanostructures using Kelvin Probe Force Microscopy

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Abstract:

Transition metal dichalcogenides (TMDs) have gained significant research attention due to their sizable bandgap energies (1~2 eV) and high carrier mobility. The optical absorption and subsequent photo-generated current of the TMD-based devices are limited by the atomically thin physical thickness. To overcome such limitations, researchers are exploring the use of nanostructures, which can concentrate incident light across a wide spectrum or within a specific narrow wavelength range. The integration of 2D TMDs with well-designed 3D nanostructures can significantly enhance the light-matter interaction in TMDs. Moreover, the physical properties of 2D TMDs can be modified in 2D/3D nanostructures due to strain-induced bandgap modulation and/or charge transfer at the interfaces. Nanoscale electrical characterization tools are necessary for thorough investigations of these intriguing phenomena. Since the sign and magnitude of surface photovoltage (SPV) signals depend on the polarity and density of excess charges, they can show how illumination affects semiconductors. Kelvin probe force microscopy (KPFM) is a technique that enables the visualization of the spatial distribution of photo-generated charges in nanostructures. In order to understand the KPFM-SPV maps, it is necessary to take into account both the charge drift along the in-plane direction and the interfacial charge transfer along the out-of-plane direction. This presentation will introduce some of the recent research works in our group, where KPFM-SPV mapping can reveal interactions between excitons, photons, and plasmons in TMD nanostructures.

Keywords:

TMD, surface photovoltage, Kelvin probe force microscopy, light-matter interaction

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B4.03

Mid-infrared plasmonics in nanostructures

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Abstract:

The mid-infrared (MIR) light carries rich information of light-matter interactions including molecular vibrational absorption, surface phonon-polariton resonances, and blackbody thermal emission. By exploiting MIR light, one can develop various applications from molecular and bio-sensing platforms for health and environmental monitoring to terrestrial and space technologies. Recently, the demand for compact and integrated mid-infrared optical devices is increasing for the development of high-performance sensor platforms in health and environmental monitoring and remote detection in earth and space technologies. The strong MIR light-matter interaction is the key elements to achieve high performance sensor devices, however, it is still restricted because of the weak molecular absorption cross-section in this wavelength regime. In this talk, we present the rational design of subwavelength nanophotonic systems using graphene and silicon nanowire with mid-infrared localized surface plasmon resonance (LSPR). LSPRs are desirable for strong MIR light-mattering interaction in a subwavelength scale, allowing for the confinement of micron-scale wavelengths into nanometer-scale objects. We expect LSPR in artificial nanomaterials allow us to develop new optical sensor devices in the mid-infrared wavelength regime with extremely small size compared to the wavelength.

Keywords:

Mid-infrared, plasmonics

B5.01

Controlled-NOT gate with neutral atoms in a 1D optical lattice

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Abstract:

In this talk, I will present site-specific and coherent manipulation of individual qubits and the implementation of a Controlled-NOT (CNOT) gate operation.
Regarding site-specific and coherent manipulation, we demonstrate gate operations on a single atom at a specific site without perturbing the coherence of an adjacent atom. Three types of qubit operations are performed on the target atom with fidelities between 0.88±0.05 and 0.99±0.01. We achieve the site-specific resolving power in the frequency domain by eliminating the inhomogeneous broadening using "*magic*" polarization for the lattice beam.
Furthermore, we demonstrate the CNOT gate operation by utilizing neutral atoms in the optical lattice. Using the algorithm of the first realization of the CNOT gate, we attempted to create entanglement between the internal state and external state for neutral atoms in an optical lattice.

Keywords:

Atomic Physics, Laser cooling, Quantum information

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B5.02

Hybrid quantum computation using cat code against photon loss

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Abstract:

In bosonic modes, there are two different approaches of encoding quantum information, discrete variable (DV) and continuous variable (CV), each with its own advantages and drawbacks. We introduce a scheme of DV and CV hybrid quantum computation based on single photon and cat code. We define the hybrid logical basis of qubits by taking the advantages of both DV and CV photonic qubits. By implementing the cat code in CV qubit, the hybrid qubit becomes robust against photon loss. Near-deterministic Bell measurements on hybrid qubits enable efficient implementation of logical universal gate operations by employing the gate teleportation scheme. Photon loss is inherently corrected by the teleportation process as the Bell measurement of cat-code qubits detects the loss of single photon or the parity change. Our scheme outperforms previous proposals of photonic quantum computation in fault-tolerance analysis.

Keywords:

Quantum computation, Quantum error corrections, Continuous-variable quantum information

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B5.03

Training Parametrized Quantum Circuits for Optimal Measurements

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Abstract:

In this work, we construct a quantum circuit for maximum confidence measurements with parameterized quantum circuits. We set a framework of training parameterized quantum circuits to achieve maximum confidence measurements and present various qubit examples showing agreement with exact circuits. The results are readily applied to practical and photon-based quantum information applications where measurement is noisy and lossy.

Keywords:

parameterized quantum circuits, maximum confidence measurements, photon-based quantum information

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B5.04

Towards exact ultrashort quantum gates

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Abstract:

In order to properly perform an algorithm requiring at least thousands of qubits and correspondingly many operations, e.g. factorization of a 2048-bit semiprime, it is necessary to prepare gates with sufficiently high fidelity, at least above the fault-tolerance threshold. Furthermore, achieving a fidelity even higher than this threshold is important for reducing the overhead in resources such as additional qubits and gate operations for quantum error corrections. There are basically two factors which limit the fidelity: one is a control error due to an inaccuracy of a coherent control of qubits, the other is a decoherence error. In order to reduce the decoherence error, one can use fast gates. However, due to the highly-diabatic and broadband/ultrabroadband nature of a fast control pulse, it is nontrivial to accurately control qubits in this fast-driving regime. Finding a way to perform an accurate coherent control at a sufficiently short timescale is a challenging but essential goal for entering the era of large-scale quantum computations.
We apply a unitary perturbation theory [1] to find an optimal control pulse that results in a high-fidelity quantum X gate. We start at the limit of an infinitesimally short pulse, where an exact X gate can be implemented by fixing the pulse area to π. Since the pulse cannot be arbitrarily short, limited either by practical implementation issues or by a finite bandwidth set to prevent excitation outside of the subspace of qubits, the error due to a finite pulse duration arises. This error has to be understood and brought under control for its mitigation. We identify the error in the orders of the pulse duration and determine how each error term depends on the pulse shape. We then find pulse shapes which eliminate the error terms up to the first few orders and observe an order-by-order enhancement of fidelity.

[1] A. S. Moskalenko, Z. Zhu, J. Berakdar, Charge and spin dynamics driven by ultrashort extreme broadband pulses: A theory perspective, Physics Reports, vol. 672, pp. 1–82, (2017).

Keywords:

Ultrafast quantum gates

B5.05

Coherent control of an optical trapped-ion qubit

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Abstract:

이온 트랩에서 이온 큐비트를 안정적으로 포획 및 조작하는 것은 양자컴퓨터 및 시뮬레이터로의 응용을 위해 필수적이다. 본 연구에서는 이터븀과 칼슘을 안정적으로 포획할 수 있는 자체 제작 이온트랩 장치를 이용하여 칼슘 이온을 포획하였다. 칼슘 이온에서 양자 점프 현상을 관측하여 큐비트의 0과 1 상태가 구분될 수 있음을 보였고, 큐비트 전이선의 선폭인 약 1 Hz와 유사한 선폭을 가진 레이저를 이용하여 Rabi 진동을 관측하였다. 이와 함께 실험 장치의 최적화 방안에 대해 논의한다.

Keywords:

Ion trap, Rabi oscillation, 40Ca+, Optical Qubit

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B6.01

Evaluation of Astrophysically Important Nuclear Structure in ^{19}Ne

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Abstract:

The ^{15}O(a, g)^{19}Ne and ^{18}F(p, a)^{15}O reaction rates are influential to explosive astrophysical phenomena. For instance, the ^{15}O(a, g)^{19}Ne reaction is a trigger reaction for rp-process burning in x-ray bursts and the ^{18}F(p, a)^{15}O reaction is a destruction channel of ^{18}F, whose abundance is strongly related to 511 keV gamma-ray emission in novae. Since their reaction rates at stellar temperatures are dominated by isolated narrow resonance reactions, calculations of the reaction rates require nuclear structure properties of the compound nucleus ^{19}Ne. Due to its importance, numerous experiments have been performed to measure the resonance parameters over many years, and an evaluation of these parameters is needed. The conventional evaluation approach involves selective weighted averaging of the most reliable measurements - typically the most recent ones – followed by uncertainty estimates relying on the experience and techniques of the evaluator. This can result in an under– or over-estimation of uncertainties, with different evaluators assigning different uncertainties. In this work, a new methodology with Bayesian approach is discussed to compile and evaluate all available experimental data. The priors are initial resonance parameters, and the likelihoods are extrapolated from previous experimental measurement reports with some statistical assumptions. By integrating the prior and likelihood, the posterior (*i. e.*, updated) resonance parameters can be obtained in a statistically robust and reproducible manner. These posteriors will be presented and directly used as probability density functions for Monte-Carlo reaction rate calculations.

Keywords:

X-ray Burst, Novae explosion, Evaluation

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B6.02

Magnetic Effect on the Potential Barrier for Nucleosynthesis in Astrophysics

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Abstract:

We demonstrated that a weak magnetic field can increase the permittivity, leading to a reduction in the potential barrier within the Debye sphere consisting of electrons and a nucleus. By solving the Boltzmann equation with the inclusion of the magnetic field, we obtained the magnetized permittivity. The resulting enhanced permittivity field inversely decreases the potential barrier, thereby increasing the reaction rate between two fusing nuclei. We compared this Boltzmann kinetic approach with the Debye potential method. We found that they are qualitatively consistent. Further, we also derived the magnetized Debye potential composed of the conventional term with a new magnetic effect. Both approaches indicate that magnetized plasmas, which have existed since the Big Bang, have ultimately influenced permittivity, potential barrier, and nucleosynthesis.

Keywords:

Magnetic effect, Potential barrier, Nuclear Reaction, Plasma, Boltzmann equation

B6.03

Equation of state for neutron stars including fermionic dark matter

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Abstract:

The properties of neutron stars with fermionic dark matter (FDM) are calculated using relativistic mean-field (RMF) models. We study how their properties are influenced by nuclear incompressibility and symmetry energy with the realistic nuclear equations of state (EoS). We here use the basic RMF models which include the sigma, omega, and rho mesons. Then the energy density and pressure of neutron-star matter are considered. In addition, the FDM is assumed to affect only nuclear EoS. Thus, we present the difference between neutron-star EoS with and without FDM.

Keywords:

relativistic mean-field, dark matter, neutron star

B6.04

Study of the $^{14}O(\alpha,p)^{17}F$ Cross Section for Type Ⅰ X-ray burst light curve

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Abstract:

The $^{14}O(\alpha,p)^{17}F$ reaction rate holds significant importance as it exerts a strong influence on the light curves of Type Ⅰ X-ray burst models, as well as determines the transition from the hot CNO cycle to the rp-process at sufficiently high temperatures (T_9 > 0.5). Despite its astrophysical role, its large uncertainty due to the lack of experimental measurements causes challenges in the precise demonstration of astrophysical observables.

To address this issue, a direct measurement of the $^{14}O(\alpha,p)^{17}F$ cross section was performed at the CNS RI beam separator (CRIB), RIKEN. The ^{14}O beam is produced by bombarding a ^{14}N beam with the energy of 8.40 MeV/u to H_2 cryogenic gas cell. The TexAT_v2 (Texas Active Target Time Projection Chamber version 2) was used, enhancing detection efficiency for the (α,p) cross section measurement. The three-dimensional particle tracking capability of TexAT_2 improved the energy and positional resolution of detected charged particles from the reaction. Incorporating segmented silicon and CsI(Tl) detectors around the field cage enabled more accurate cross-sectional measurements as a function of center-of-mass energy. In order to manage the vast array of data from diverse detectors, the GET electronics with the GANIL data acquisition system were employed.

This presentation will explain of the experimental configuration and provide preliminary analysis results

of the experimental data.

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Keywords:

14O(α,p)17F, AT-TPC, TexAT_v2, X-ray busts, CRIB

B6.05

The thermal history of the dark ages in the early universe with Kompaneets equation

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Abstract:

표준 빅뱅 모델에 따르면, 최초의 핵들(수소, 중양성자, 헬륨 등 가벼운 핵과 극미량의 리튬, 베릴륨)은 우주의 열핵반응(thermonuclear reactions)에 의해 형성되었다.
그 후, 우주의 팽창은 수소와 헬륨 핵, 방사선, 전자의 원시플라즈마(primordial plasma)가 충분히 냉각되어 neutral species를 형성할 수 있게 되었으며, 이 시기를 재결합 시대(recombination era)라고 부른다.
이 후, 재결합 시대(z≈1000)부터 재이온화 과도기 단계(z≈15)를 거쳐 최초의 별이 형성되었다고 여겨지며, 이 재결합 시대부터 재이온화 과도기 단계를 우주의 암흑기(dark ages)라 부른다.
이때, 최초의 별 형성을 기술하기 위해서는 암흑기의 화학조성(chemical composition) 결정이 선결되어야 한다.

우리는 이러한 암흑기의 화학조성을 결정하기 위한 노력의 하나로써, 우주의 단열팽창, 자유전자와 CMB(cosmic microwave background) 간 에너지 교환 등을 통해 물질 온도(matter temperature)를 계산하고자 하였다.
또한, three-level hydrogen atom model을 기반으로 암흑기의 이온화도를 결정하는 값인 fractional ionization을 결정하였다.
마지막으로 우리는 암흑기의 화학조성을 기술하기 위해, $z=10^4$에서 모든 atomic species 들이 완전히 이온화되었다고 가정하였다.
이때, 재이온화가 발생하지 않은 우주와 발생한 우주(tanh phenomenological model)를 가정하여, 각각 전산모사를 진행하고자 하였으며, 이를 소개하고자 한다.

Keywords:

early universe, cosmology, dark ages

2023 KPS Fall Meeting
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B6.06

Simulation studies for a $^{12}C(\alpha,\gamma)^{16}O$ reaction experiment near stellar energies

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Abstract:

The COREA (Carbon Oxygen Reaction Experiment with Active-target TPC) is an experiment to measure the precise cross-section of the $^{12}C(\alpha,\gamma)^{16}O$ reaction in stellar nucleosynthesis. The reaction rate of $^{12}C(\alpha,\gamma)^{16}O$ determines the $^{12}C/^{16}O$ abundance ratio in the universe and the entire scenario of the stellar nucleosynthesis after the helium burning up to the Fe core in the last years of stellar life. We are developing a novel detector system consisting of an active-target time projection chamber in a conduction-cooled superconducting magnet of the magnetic field up to 3 T and a $LaBr_3$ gamma detector array. In this talk, we will present the development of the unique COREA detector system and the Geant4 simulation results.

Keywords:

stellar nucleosynthesis, He burning, active-target time projection chamber

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B6.07

Dark matter effect on the neutron star equation of state

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Abstract:

This talk explores the effect of dark matter, captured by the strong gravity and high density of neutron stars, on the equation of state (EoS) of neutron stars. We establish a theoretical framework incorporating dark matter interactions and demonstrate potential modifications in the neutron star EoS. These theoretical modifications allow us to explore potential constraints on the properties of dark matter by comparing them to observational data. In particular, we would like to discuss whether they can provide unique insights into the characteristics of the dark sector. We conclude this talk with a discussion on future prospects.

Keywords:

Dark Matter, Neutron Star, Constraints, Equation of State, Dark Sector

2023 KPS Fall Meeting
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B6.08

Resonance Strength Measurement of the $^{27}Al(p, \gamma)^{28}Si$ Reaction near E_p=2.05 MeV

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Abstract:

The $^{27}Al(p, \gamma)^{28}Si$ reaction plays a crucial role in the Mg-Al cycle of stellar nucleosynthesis, as it competes with the $^{27}Al(p,\alpha)^{24}Mg$ reaction of the cycle. However, there remain significant uncertainties and discrepancies in the values of resonance strength reported by many experiments with different detector systems and analysis methods. Therefore, the more accurate measurement of resonance strengths could improve our understanding of stellar nucleosynthesis and help us to develop more accurate models of the evolution of stars. We measured the resonance strengths of the $^{27}Al(p, \gamma)^{28}Si$ reaction near E_p=2.05 MeV using a $LaBr_3$ gamma-ray detector array. We performed this measurement in the KIST Advanced Analysis Center using a 2 MV tandem accelerator. A typical beam current was 2 μA. The gamma-ray detector array comprises 14 cylindrical $LaBr_3$(Ce) crystals of 50 mm(Φ) x 75 mm. Scintillation light was read using 2-in photomultipliers. We measured the angular distribution of gamma rays from the excited states 28Si* in the energy range up to 12 MeV. We used two characteristic gamma-ray transitions, 1.78 MeV (2+ → 0+) and 2.84 MeV (4+ → 2+) to extract the resonance strength. This talk will present the preliminary results of the $^{27}Al(p, \gamma)^{28}Si$ reaction and prospects in the COREA program with the KIST facility.

Keywords:

27Al(p, γ)28Si, LaBr3(Ce) detector, KIST, Nucleosynthesis

2023 KPS Fall Meeting
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B6.09

Radiative decay of the sub-threshold 1_1^- and 2_1^+ states of ^{16}O in cluster effective field theory

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Abstract:

Radiative decay of the sub-threshold 1_1^- and 2_1^+ states of ^{16}O is studied in cluster effective field theory. Asymptotic normalization coefficients of 0_1^+, 1_1^-, 2_1^+ states of ^{16}O for the two-body α-^{12}┐C channel, equivalently wave function normalization factors for the initial and final states of the radiative decay amplitudes, are fixed by using the phase shift data of elastic α┐-^{12}C scattering for l = 0, 1, 2: only one unfixed parameter remains in each of the radiative decay amplitudes. We fit it to each of the experimental decay widths and perform a parameter-free calculation of radiative α capture on ^{12}C, ^{12}C(α,γ)^{16}O, by using the fitted parameters. We find that the order of magnitude of the astrophysical S factors of ^{12}C(α,γ)^{16}O, compared to the experimental data, is reproduced and discuss how the calculation of S factors of ^{12}C(α,γ)^{16}O can be improved.

Keywords:

Radiave decay of 1_1^- and 2_1^+ states of 16O, S factors of radiative alpha captire on 12C, Cluster effective field theory

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B7.01

The Study of 230 MeV Proton Beam monitoring system using a Faraday Cup for Flash Proton Therapy.

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Abstract:

Purpose: The FLASH-RT, which uses an ultra-high dose of 40-200 Gy/s, is an emerging new technology in Radiation Therapy. Clinical trials showed promising results in treating cancer tumors while preserving normal tissue, which is more effective than conventional radiation therapy. The proton therapy beam is preferred in current clinical systems because of the ease of implementation of FLASH-RT and the uniform dose distribution on the plateau region proton beam. However, special beam monitoring and control technology is required to accurately control the ultra-high dose rate, which is about 1000 times higher than general radiation therapy. In this study, a Poor Man's Faraday cup (PTFC), widely used for measuring charged particles, was developed to measure the proton beam used for proton therapy. The possibility of using it for proton flash therapy was investigated.

Method: Considering the dose distribution characteristics of the proton therapy beam, a PTFC was fabricated, and the 230MeV Ultra-high dose-rate proton beam was measured. Geant4 Monte Carlo simulations were also performed to evaluate the feasibility.

Results: PMFC showed reliable results in general dosimetric performance tests. It showed a good linear response to both irradiated dose and dose rate. It was also possible to measure the phenomenon that the fluence of the proton beam gradually decreases according to the penetration thickness of the medium. The Fraday Cup backscattering effect was insignificant compared to the irradiation beam signal data.

Conclusion: This study investigated the feasibility of utilizing the Poor Man's Faraday Cup for Ultra-high dose-rate proton beam measurement. The PMFC has the potential to role as both a beam stopper and secondary monitoring system on FLASH Proton Therapy.

Keywords:

Flash Therapy, Proton Therapy, Ultra-high Dose-rate, Faraday Cup

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B7.02

Energy Deposition of C14 and Protons in Body Phantoms: A Geant4 Simulation Study

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Abstract:

In our research, we have used the simulation. This tool, geant4 simulation, is great for showing how particles interact with materials, to study two particles: C14 and protons. We were interested in seeing how these particles deposit energy on body phantom at three specific energy levels, 1 MeV, 10 MeV, and 100 MeV. Geant4 is well-known for its ability to simulate and show how different particles behave when they move through various materials. We study on the way C14 behaves at 1 MeV might be different from how it behaves at 100 MeV. Similarly, protons also showed different behaviors at these energy levels. We tried to understand the reasons behind these differences. This understanding is crucial because it can be applied in real-world scenarios. For example, in medical treatments where radiation is used, knowing how these particles deposit energy can help in making treatments more effective.

Keywords:

medical physics

As an application of Nuclear Physics, Available Medical Physics Study in JNU

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Abstract:

For a couple of decades, a team of Jeju National University has studied in the fields of high energy physics application. Here, we will introduce the medical physics studies among several nuclear physics applications.
Generally, we can categorize the medical physics into several fields, such as thr digaonosis, the treatment, etc. For the diagonosis, our team in JNU concentrates on the particle detection and identification, especially gamma ray, using particle detection technology. For treatment, our team concentrates on the cancer treatment using rhe high energy paticles, currently a proton beam and C-14, from the particle accelerators.

Keywords:

Medical Physics, Nuclear Physics Application, particle identification

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B7.04

Effect of Ionizing Radiation on the 28nm MOSFETs

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Abstract:

The front-end ASICs in the detector systems of the LHC are built with the consideration on radiation hardness technique. Characterization of the CMOS technology under the radiation must be performed as a part of the consideration. The radiation damage is expected to be smaller for devices with thiner gate oxide, but various factors affects the radiation hardness of the circuit in ultra-scaled technologies. We submitted a few transistor designs to the 28nm CMOS processes through IC Design Education Center(IDEC). We performed the irradiation test of the fabricated transistors up to 250Mrad with the X-ray generator. We will report the changes of the transistors characteristics with the irradiation including the effect by annealing.

Keywords:

28nm CMOS Process, Changes in Transistor Characteristics, Irradiation, TID, Annealing

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B7.05

Searching for an optimized selection of Monte Carlo dose calculation parameters for line-scanning proton beam therapy

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Abstract:

To provide a practical guide on the selection of Monte Carlo (MC) dose calculation parameters for scanned beam proton therapy in RayStation, we generated treatment plans with various combinations of two MC dose calculation parameters in the optimization and compared the elapsed time and dosimetric properties of those plans. We selected 23 clinical cases treated with scanned beam proton therapy. For each clinically approved treatment plan, we generated 26 exploring plans (1 plan with clinical pencil beam dose algorithm and 25 plans with MC dose algorithm with varying dose calculation parameters). We recorded the elapsed time for individual plans in the dose calculation using an automated RayStation script. To evaluate the dosimetric quality of the exploring plans, the conformity and homogeneity indices of each plan were calculated and dose–volume histograms for the target volume and organs-at-risk were assessed. We found the combination of 12,000 ions/ spot in the optimization and 0.5% uncertainty in the final dose calculation would provide a dosimetrically competent plan with a reasonable amount of dose calculation time. We would suggest using 8000 ions/spot in the optimization and 1.0% uncertainty in the final dose calculation as a starting point in the treatment planning of scanned beam proton therapy. The practical recommendations resulting from this study, related to MC dose calculations, have the potential to enhance treatment planning strategies for scanned beam proton therapy and to make the iterative process of treatment planning more efficient.

Keywords:

Proton beam therapy, Monte Carlo dose calculation, Dose calculation parameters

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B7.06

Results of a 9-year Investigation into Workload in Two Treatment Vaults at a High-capacity Cancer Center

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Abstract:

Purpose: The purpose of this study is to analyze factors related to shielding requirements for modern linear accelerators (linacs) used in radiation therapy and to report whether changes are consistent with recommended safety guidelines. This study focuses on the amount of change in the workload and includes the investigation of the amount of change in the Intensity-Modulated Radiation Therapy (IMRT) factor based on the monitor unit (MU).

Materials and Methods: Digital Imaging and Communications in Medicine (DICOM) radiotherapy (RT) plan files of treated patients collected from two Elekta linacs from 2014 to 2022 were obtained. Data pertinent to workload, MU, energy, rotation angle, treatment technique, and treatment area were extracted from the DICOM RT plan file through employment of the MATLAB program. Statistics were aggregated on a monthly basis. The study concentrated on modifications in fractional dose, MU, treatment sessions, usefactor, and IMRT factor.

Results: The average workload for an individual patient exhibited an ascending trend from 2014 to 2020, followed by a subsequent decline, and a subsequent resurgence in 2022. Nonetheless, the average monthly workloads demonstrated yearly insignificant fluctuations while maintaining a consistent overall pattern. In the case of energy use, there is little change from year to year. On average, 85% used 6 MV, 9% used 10 MV, and the remaining 6% used 4 MV. IMRT factors were 2.5 ± 0.3 and 2.7 ± 0.6 in the treatment room, respectively. Treatment techniques have undergone significant changes. IMRT was not used in this treatment room, and in 2014, the 3D-CRT technique was dominant at more than 99%, but as it was gradually replaced by the Volumetric Modulated Arc Therapy (VMAT) treatment technique, the implementation of the VMAT treatment technique accounted for more than 90% from 2019 onwards. The use of 3D CRT was common in linac until 2015 due to the combination of Tomotherapy, but it seems to have decreased sharply since then. The usefactor tends to be more and more equally distributed in all directions from 2014 to 2022.

Conclusions: This study investigated the workload associated with the shielding requirements of modern linacs used in radiation therapy. According to the findings, there was an increase in both the workload and MU with the alteration of the treatment technique. Despite these changes, the workloads in terms of the total number of weekly treatment sessions appeared to be stable. Finally, the study affirmed that the shielding evaluation factors employed for defensive purposes adhered to the suggested guidelines outlined in National Council on Radiation Protection & Measurements (NCRP) Report 151.

Keywords:

Radiotherapy, IMRT factor, Usefactor, Workload, Shielding evaluation

B7.07

Overview of R&D activities of ALICE-ITS3 upgrade project in Korea

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Abstract:

Inner Tracking System (ITS2) is the most central vertexing and tracking detector in ALICE based on Monolithic Active Pixel Sensors (MAPS), and its upgrade to ITS3 is planned during the Long Shutdown (2026-2028). In the ITS3 upgrade, the three inner-most layers are replaced by the ultra-thin (< 50 $/micro$m) wafer-scale (up to ~ 10 x 26 cm^2 in size on 300mm wafers) sensors. Such thickness allows enough flexibility for the sensor to be bent into cylindrical shapes by targeted radii of 18, 24, and 30 mm. Also, stitching technology is applied to produce single sensors that make unit-sensor size than the reticle size and big enough to cover half-cylinders. These newly developed features enable us to reduce the material budget (0.05 % X_0 per layer) and improve the pointing resolution by a factor of 2 to the current detector (ITS2) configuration.

The Ko-ALICE team has been working on the ITS3 upgrade project, focusing on the silicon chip characterization measurements and construction of the bent chip test system. In particular, we are interested in constructing a bent chip test system with Flexible Printed Circuit (FPC) and ITS3 prototype sensors and making the telescope with multiple chip layers. In Oct, we had a one-day beam test at KOMAC to check the performance of our mini ITS3 telescope. The experimental setup was designed to reduce the fluence of the beam based on GEANT simulation to make possible tracking study at KOMAC. In addition, the beam test campaign at the Japanese beam facility, KEK, is also planned for this winter and early next year.

In this presentation, we talk about the ongoing activities and upcoming beam test plan of the Ko-ALICE team in the ITS3 upgrade.

Keywords:

ALICE, ITS, Inner Tracking System, Silicon pixel sensor

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B7.08

Current status of the Active Target TPC development in CENS

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Abstract:

Active Target Time Projection Chamber (AT-TPC) is one of state-of-the-art particle detectors which allows a precise measurement of nuclear reactions using rare isotope beams at the present and future nuclear physics facilities.
Active Target TPC for Multiple nuclear physics eXperiments (AToM-X) is under development at the Center for Exotic Nuclear Studies (CENS).
It consists of a highly segmented Time Projection Chamber (TPC) using a Micromegas, a field cage, and solid state detectors.
It enables the high resolution measurement of the 3-dimensioinal particle tracks, energy, and position with the high detection efficiency.
Details of the development status will be presented.

Keywords:

Active target TPC, Nuclear Astrophysics, Nuclear reaction

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B8.01

Generation and applications of superradiant FEL pulses

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Abstract:

A free-electron laser oscillator (FELO) operated at a specific condition generates superradiant pulses whose peak intensity and duration are proportional to N^2 and 1/N, respectively, where N is the number of electrons. The scaling law is the same as superradiance in two-level systems as defined by Dicke despite the difference in physical systems. In a superradiant FELO operating at the large-N limit, high-intensity few-cycle optical pulses can be generated. Due to the wavelength tunability of the FEL, such optical pulses are particularly useful in the mid- and long-wave infrared. We are conducting a research program aimed at the application of superradiant FELOs for high-harmonic generation (HHG) from gaseous and solid targets. Two FEL facilities, KU-FEL at Kyoto University and LEBRA-FEL at Nihon University are being utilized. The presentation will report on the recent progress of the research program.

Keywords:

superradiance, free-electron laser, few-cycle pulse, high-harmonic generation

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B8.02

Superabsorption: Enhanced cooperative absorption as a time-reversal counterpart of superradiance

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Abstract:

Superabsorption is a time-reversal process of superradiance, where superradiance is a quantum phenomenon that a group of atoms or molecules can emit light faster and more collectively than individual ones. In superabsorption, a group of atoms or molecules can absorb light faster and more completely than individual ones. Although superradiance phenomena is observed in diverse systems including Bose–Einstein condensates, trapped atoms and nitrogen-vacancy centers in diamond, collective absorption was rarely observed due to the fast decay.
The first superabsorption was realized by implementing a time-reversal process of superradiance, wherein phase manipulation of the superradiant state within a cavity was utilized. The whole system was reversed in time—not only the atomic state but also the photonic state. By controlling the phase of the superradiant field opposite to that of an input field in a cavity, the superradiant state undergoes an upwards transition in the Dicke ladder, resulting in a time reversal of the superradiance. The experimental outcome revealed a substantial enhancement in absorption, with the number of absorbed photons scaling with the square of the number of atoms, while its rate was much greater than that of the ordinary ground-state absorption.
Experimental realization in an organic microcavity also marks noticeable progress. The study demonstrated that superabsorption can be used to create a quantum battery, which is a device exhibiting superior charging rates and capacity. The concept of a quantum battery has garnered substantial attention due to its superextensive scaling of energy absorption, with the charging rate being proportional to N. We anticipate that the studies on superabsorption will pave the way for harnessing collective effects in light-matter interactions, leading to applications in nanoscale energy capture, storage, and transport technologies.

Keywords:

Superradiance, Superabsorption

B8.03

DNA grabbers and steerers of quantum emitter for superradiance

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Abstract:

In this talk, I would like to introduce that DNA can arrange quantum emitters in a highly controlled manne, which could act as a pivotel role in superradiance research. As is well-known, DNA forms a double helix structure by the complementary binding of two single-stranded DNA (ssDNA). Using this exotic complementary binding of DNA, it is possible to fold a ultralong ssDNA (with about 8000 bases) at desired locations to create nanostructures with around 100 nm in size and virtually any desired shape. This technique is referred to as DNA origami. Similar to assembling logs to create a raft, DNA origami involves connecting DNA double helices to obtain controlled structures of diverse shapes. Moreover, within the DNA double helix, quantum emitters such as organic dyes can be integrated with a precisely controlled direction and position. The accuracy of positioning can reach the nanometer scale, while the directional control can be achieved with an accuracy of about 5-10 degrees. As a result, the integration of quantum emitters based on DNA origami holds promise as an experimental approach for future implementations of superradiance.

Keywords:

Superradiance, DNA origami, Quantum emitters, Molecular engineering

B9.01

Single-molecule studies of RNA polymerase II transcription

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Abstract:

Gene expression is regulated primarily at the level transcription by which RNA transcripts are synthesized from a DNA template by enzymes called RNA polymerases. In eukaryotes, RNA polymerase II (Pol II) transcribes messenger RNAs (mRNAs) and many noncoding RNAs. To successfully produce mRNA, distinct transcription initiation, elongation, and termination factors need to be recruited to and released from Pol II in a timely manner. However, the association and dissociation kinetics of these factors are poorly characterized partly because past Pol II transcription studies utilized ensemble assays, which can only reveal the averaged behavior of individual molecules. To investigate the dynamics of Pol II transcription at unprecedented resolution, in vitro multi-wavelength single-molecule fluorescence microscopy was implemented. Our single-molecule microscopy experiments reveal several unexpected features of activator-dependent Pol II transcription. Initial recruitment of Pol II and some general transcription factors, TFIIE and TFIIF, does not require the core promoter. Instead, they first interact with enhancer(UAS)-bound activators, with dwell times on the order of a few seconds. More interestingly, multiple Pol II complexes can simultaneously bind a single enhancer, creating a localized Pol II cluster. This Pol II cluster could potentially explain the mechanism underlying transcription bursting. In contrast to other factors, TFIIH association with DNA is dependent on the core promoter. In sum, our kinetic measurements lead to a new branched model for activator-dependent Pol II preinitiation complex assembly that has so far been masked by ensemble assays.

Keywords:

Single-molecule fluorescence microscopy, RNA polymerase II, transcription, enhancer, transcription factor, upstream activating sequence

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B9.02

Initiation of Parental Genome Reprogramming in Fertilized Oocyte by Splicing Kinase SRPK1-Catalyzed Protamine Phosphorylation

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Abstract:

The paternal genome undergoes a massive exchange of histone with protamine for compaction into sperm during spermiogenesis. Upon fertilization, this process is potently reversed, which is essential for parental genome reprogramming and subsequent activation; however, it remains poorly understood how this fundamental process is initiated. Here, we report that the splicing kinase SRPK1 initiates this life-beginning event by catalyzing site specific phosphorylation of protamine, thereby triggering protamine-to-histone exchange in the fertilized oocyte. Interestingly, protamine undergoes a DNA-dependent phase transition to gel-like condensates and SRPK1-mediated phosphorylation likely helps open up such structures to enhance protamine dismissal by nucleoplasmin and enable the recruitment of HIRA for H3.3 deposition. Remarkably, genome-wide ATAC-sequencing analysis reveals that selective chromatin accessibility in both sperm and MII oocytes is largely erased in early pronuclei in a protamine phosphorylation dependent manner, suggesting that SRPK1-catalyzed phosphorylation initiates a highly synchronized reorganization program in both parental genomes.

Keywords:

SR protein-specific kinase, protamine, fertilization, histone chaperones, protamine-to-histone exchange, genome reprogramming

B9.03

Alterations in Chromatin Dynamics in Living Cells due to Transcription-Dependent Physical Disturbances

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Abstract:

Single-particle tracking in living cells has recently demonstrated that transcription directly affects chromatin dynamics. However, the specific mechanisms explaining how transcription alters the physical behaviour of chromatin are not yet clear. Using CRISPR-labelling focused on telomeric DNA repeats, we investigated the diffusion characteristics of chromatin. We found that inhibitors targeting transcription factors globally enhance chromatin movements. In contrast, inhibitors acting via DNA intercalation reduced chromatin motion. This disparity suggests that variations in chromatin rigidity may underlie the increased mobility with transcription inhibition and the restricted movement with DNA intercalation inhibitors. Furthermore, we tested the impact of nuclear space's volume confinement on chromatin dynamics. Our observations indicate that chromatin movements diminish in response to osmotic pressure and elevated expression of chromatin architectural proteins, which induce chromatin compaction. In summary, our research indicates that modifications in chromatin's physical properties can dictate its motion and transcriptional functionality. However, comprehensive studies observing entire chromosome movements are crucial for verification.

Keywords:

Single-particle tracking, Chromatin, Transcription, CRISPR-labelling

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B9.04

Revisiting DNA with Single Molecule Methods

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Abstract:

DNA contains information that defines life phenomena and is a biomolecule found repeatedly in consistent form at all levels of life. Through the discovery of the double helix structure 70 years ago, the discovery of the human genome sequence 20 years ago, and the recent completion of the complete human genome sequence, its physicochemical properties and biological functions have been studied in detail. But recent single-molecule measurements and computational simulations are revealing new facts that were not known about this molecule that was thought to be well understood. For example, it still remains controversial how flexible DNA is and what determines its bending flexibility. In this talk, our recent finding on how the base sequence and chemical modification determine the condensation and looping properties of DNA based on single-molecule fluorescence measurements, atomic force microscopy, and all-atom molecular dynamics simulations. It was found that the C5 methyl group of thymine is critical in the polycation-induced DNA compaction, which relates to the cysteine methylation, an important epigenetic marker. Deformation energy of neighboring stacks of bases was found to heavily depend on the base sequence, which results in a large variation in the looping propensity of short DNA, more than an order of magnitude. These findings suggest a biophysical mechanism for spatiotemporal regulation of chromatin structure, and also can be utilized for gene therapy through sequence manipulation.

Keywords:

DNA, Single Molecule Methods

2023 KPS Fall Meeting
2023-10-24 - 2023-10-27

B10.01

Emergence of chaos in magnetic skyrmions driven by magnetic fields via quasiperiodic route to chaos

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Abstract:

Chaos plays a crucial role in understanding the intricacies of nonlinear systems in nature. Even though these systems adhere to deterministic laws, their behavior can seem unpredictable due to their sensitivity to initial conditions—a phenomenon famously known as the 'butterfly effect'. The implications and applications of chaos span a wide range, from meteorology to engineering and physics. In this study, we delved into chaos within a specific magnetic texture known as the skyrmion. We examined the nonlinear dynamic behaviors of magnetic skyrmions under oscillating magnetic fields. The onset of these nonlinear dynamics is due to the interaction between gyrotropic modes and a non-uniform, breathing-like mode. This interaction changes the skyrmion's moment of inertia and spring constant, subsequently influencing the eigenfrequency of the primary gyrotropic mode. Such changes markedly affect nonlinear characteristic parameters, notably the cusp number and hypotrochoid type, leading to intricate hypotrochoidal motion patterns over time. Using calculated bifurcation maps and local Lyapunov exponent maps, we effectively differentiated various nonlinear behaviors. These spanned from structured patterns to chaotic motions, seen across diverse field strengths and time intervals [1]. This thorough analysis of the field-strength and time-dependent chaotic dynamics of magnetic skyrmions offers deep insights into the myriad nonlinear pathways culminating in chaos. Furthermore, it sets the stage for crafting novel computational strategies that harness the deterministic chaos dynamics sensitive to initial conditions [2].

[1] G. Park and S. -K. Kim, *submitted* (2023)
[2] S. Sinha and W. L. Ditto, *Phys. Rev. Lett.* **81**, 2156 (1998)

Keywords:

chaos, emergence of chaos, skyrmion, magnetic skyrmions

2023 KPS Fall Meeting
2023-10-24 - 2023-10-27

B10.02

Noncollinear magnetic order, in-plane anisotropy, and magnetoelectric coupling in a pyroelectric honeycomb antiferromagnet $Ni_2Mo_3O_8$.

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Abstract:

$Ni_2Mo_3O_8$ is a pyroelectric honeycomb antiferromagnet exhibiting peculiar changes of its electric polarization at magnetic transitions. $Ni_2Mo_3O_8$ stands out from the isostructural magnetic compounds, showing an anomalously low magnetic transition temperature and unique magnetic anisotropy. We determine the magnetic structure of $Ni_2Mo_3O_8$ utilizing high-resolution powder and single-crystal neutron diffraction [1]. A noncollinear stripy antiferromagnetic order is found in the honeycomb planes. The magnetic space group is P_Cna2_1. The in-plane magnetic connection is of the stripy type both for the *ab*-plane and the *c*-axis spin components. This is a simpler connection than the one proposed previously. The ferromagnetic interlayer order of the *c*-axis spin components in our model is also distinct. The magnetic anisotropy of $Ni_2Mo_3O_8$ is characterized by orientation-dependent magnetic susceptibility measurements on a single crystal, consistent with neutron diffraction analysis. The local magnetoelectric tensor analysis using our magnetic models provides new insights into its magnetoelectric coupling and polarization. Thus, our results deliver essential information for understanding both the unusual magnetoelectric properties of $Ni_2Mo_3O_8$ and the prospects for observation of exotic nonreciprocal, Hall, and magnonic effects characteristic to this compound family.

[1] P. Yadav, S. Lee, G. L. Pascut, J. Kim, M. J. Gutmann, X. Xu, B. Gao, S.-W. Cheong, V. Kiryukhin, and S. Choi, Phys. Rev. Res. **5**, 033099 (2023).

Keywords:

Magnetic anisotropy, Neutron Diffraction, Noncollinear magnets, Pyroelectric, Crystal structures

2023 KPS Fall Meeting
2023-10-24 - 2023-10-27

B10.03

Single-crystal synthesis of 3-dimesional quantum spin liquid candidate $Yb_3Sc_2Ga_3O_{12}$

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Abstract:

Geometrically frustrated magnetism originates from the intrinsic incompatibility between antiferromagnetic interactions within the underlying geometry such as 2-dimensional (d) triangular or 3-dimensional pyrochlore lattices. These magnetic systems can maintain a disordered magnetic spin configuration down to very low temperature (T) and even at T = 0 by means of quantum fluctuation, stabilizing a quantum spin liquid (QSL) state. While there have been some representative 2-d frustrated magnets that exhibit signatures of a QSL, it is uncommon to realize 3-d systems to host emergent quantum states due to more complex lattice geometry and less prominent quantum fluctuations.
In this presentation, we will introduce a new 3-dimensional QSL candidate $Yb_3Sc_2Ga_3O_{12}$*, which forms a hyperkagome lattice networks of* Yb^{3+} *ions with* $J_{eff.}$ *= 1/2 [1]. We have successfully synthesized large single-crystals by utilizing a laser-diode floating zone furnace. The lattice constant of the grown single crystal is a = b = c = 12.388 Å, closely matching that of the previously reported polycrystal work. Details of the synthesis, structural, and magnetic properties of will be given as well as future prospects for critical examination of this system as a QSL.*

[1] B. Sana, M. Barik, U. Jena, M. Baenitz, J. Sichelschmidt, K. Sethupathi, P. Khuntia, arXiv:2304.07350v1

Keywords:

quantum spin liquid, hyperkagome structure, 3-dimensional QSL, antiferromagnetism

2023 KPS Fall Meeting
2023-10-24 - 2023-10-27

B10.04

Rare earth free Fe_3MnC_2 alloy permanent magnet: First principle and Atomistic Simulation

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Abstract:

Due to the importance for device applications and also other subtle issues, study on rare-earth free permanent is becoming more and more important subject. Here, we investigate the temperature dependent magnetic characteristics of the Fe_3MnC_2 structure. We find that the Fe_3MnC_2 alloy exhibits a critical temperature of 640 K with perpendicular magnetic anisotropy. With increasing temperatures, both the coercive field and the magnetic anisotropy constant monotonically decrease. From temperature dependent magnetization and coercive field, the (BH)max of the Fe_3MnC_2 system obtained is 396 kJ/m^3 at zero Kelvin. The (BH)max suppressed with increasing temperature. Nonetheless, we find the (BH)max of 253 kJ/m^3 is at 300 K. Compared with the (BH)max of ferrites and $SmCo_5$, the Fe_3MnC_2 alloy structure exhibits better permanent magnetic properties. Therefore, we suggest that the Fe_3MnC_2 could be a suitable candidate for a Fe-based gap permanent magnet between ferrite and Nd-Fe-B (or Sm-Co) at room temperature.

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Acknowledgments
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Keywords:

permanent magnet, temperature dependency

2023 KPS Fall Meeting
2023-10-24 - 2023-10-27

B10.05

Possible unconventional superconductivity in altermagnetism

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Abstract:

Altermagnet is an exotic class of magnetic materials that exhibits nodal point degeneracy on Fermi surface. In this talk, we study the possible intrinsic superconductivity of altermagnetism. Using the self-consistent mean field theory, we show that symmetry-protected point degeneracy plays an important role in determining pairing symmetry. p+ip chiral superconductivity can arise due to the spontaneous symmetry breaking of time-reversal symmetry. Finally, we discuss the realization of topological superconductivity in altermagnet, RuO_2.

Keywords:

Altermagnet, Unconventional superconductivity, Mean field theory

2023 KPS Fall Meeting
2023-10-24 - 2023-10-27

B10.06

Large anomalous Hall effect and intrinsic Berry curvature in magnetic Weyl semimetal NdAlGe

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Abstract:

Weyl semimetals driven by both time-reversal (TRS) and inversion symmetries (IS) are rare and be a good platform to investigate the relationship between chiral current and magnetic order. NdAlGe compound, grown in a single crystalline form by the flux method, has a noncentrosymmetric I41md crystal structure. The magnetic susceptibility $X(T)$ shows anisotropic behavior; ferromagnetic with divergence of field cooling (FC) and zero field cooling (ZFC) in H||c, and antiferromagnetic transition at T_N = 6 K for magnetic field H⊥c. A spin reorientation is found near H = 20 kOe for H||c and to be the first-order phase transition from the hysteresis. The band structure calculation without consideration of magnetic order has revealed that NdAlGe is the type-II Weyl semimetal with four types of Weyl nodes in the ab-plane and there is no Fermi surface nesting vector, implying that the Weyl nodes are not directly related to the magnetic ordering and spin density wave instability. There is a significant anomalous Hall coefficient Rs and large anomalous Hall conductivity $\sigma^A{}_{xy}$, for H||c. The giant anomalous Hall conductivity $\sigma^A{}_{xy}$, constant $S_H=\sigma^A{}_{xy}/M$ (H = 50 kOe) value, and their Karplus and Luttinger (KL) analysis support the intrinsic Berry curvature in NdAlGe compound.

Keywords:

Weyl semimetal, Anomalous Hall effect, NdAlGe, Berry curvature

2023 KPS Fall Meeting
2023-10-24 - 2023-10-27

B10.07

Unexplored magnetic anomaly inside a noncollinear magnetic order in a buckled honeycomb lattice of magnetoelectric $Co_4Ta_2O_9$

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Abstract:

Magnetoelectric materials usually indicate compounds possessing magnetic and electric properties simultaneously. These materials have been examined vigorously to develop future applications, such as more energy-efficient devices. Based on their unique intervening correlations, the main idea is manipulating their magnetization and polarization states by the electric and magnetic fields.

One such candidate is Co4Ta2O9, which belongs to a new family of magnetoelectric materials, A4B2O9 (where A = Mn, Fe, Co and B = Nb, Ta). Recently, we determined a noncollinear magnetic ground state of Co4Ta2O9 at 15 K, where the temperature for the long-range magnetic order is about 20 K, which can explain its unusual magnetoelectric properties. However, the anomaly at the low-temperature range with the bifurcation between the zero-field-cooled and field-cooled susceptibility is not yet understood.

In this talk, we present our systematic dc and ac magnetic susceptibility measurements on multiple Co4Ta2O9 single crystals, which show a wide range of the strength of the anomaly. For the direct comparative study, we also perform single-crystal neutron diffraction measurements on selected single crystals, which are analysed by the group theory. Having the combined results, we will discuss how we can understand its structure–property relationship, and its possible implications for magnetoelectric applications.

Keywords:

Quantum magnetism, Magnetoelectricity , Honeycomb lattice, Neutron diffraction, dc and ac susceptibility

2023 KPS Fall Meeting
2023-10-24 - 2023-10-27

B11.01

Potential Spin Liquids of Anion-Centered David Star in 1T-Transition Metal Dichalcogenides

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Abstract:

1T-transition metal dichalcogenides (TMD) have been an exciting platform for exploring the intertwinement of charge density waves and strong correlation phenomena. While the David star structure has been conventionally considered as the underlying charge order in the literature, recent scanning tunneling probe experiments on several monolayer 1T-TMD materials have motivated a new, alternative structure, namely the anion-centered David star structure. We show that this novel anion-centered David star structure manifestly breaks inversion symmetry, resulting in flat bands with pronounced Rashba spin-orbit couplings. We discuss potential spin liquids realized in such systems with projective symmetry group analysis and variational Monte Carlo, finding spin liquids that can spontaneously break either rotational or time-reversal symmetries.

Keywords:

Spin Liquids, TMDs

2023 KPS Fall Meeting
2023-10-24 - 2023-10-27

B11.02

Emergent Excitations with Non-trivial Configurations of Visons in the Kitaev Quantum Spin Liquid

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Abstract:

The Kitaev quantum spin liquid is one of the promising candidates to realize non-Abelian anyons in quantum magnets, and its deeper understanding has been strongly called for. In this work, we investigate the properties of emergent excitations by employing the parton mean-field theory and exact diagonalization, focusing on the non-trivial configurations of visons.

Keywords:

Majorana fermions, emergent excitations, quantum magnets

2023 KPS Fall Meeting
2023-10-24 - 2023-10-27

B11.03

Dynamics of exceptional points in non-Hermitian toric code

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Abstract:

Toric code is one of the well-known topologically ordered quantum many-body systems. In contrast to conventional ordered phases, the topologically ordered phases have robust degenerate ground states against the local perturbations. In this talk, we study the toric code in the presence of non-Hermitian perturbations. By controlling the non-Hermitian perturbation, we show that the ground states of the toric code can have a non-Hermitian spectral singularity, known as an exceptional point. By adiabatically encircling the exceptional point, we propose the controllable transitions between the topologically ordered ground state. Finally, we demonstrate the dynamical encircling of the exceptional point, which provides a useful controllable protocol for topological quantum computations.

Keywords:

Toric code, Non-Hermitian physics, Topologically ordered phase

Control of trigonal crystal field and critical temperature in cobalt-based Kitaev quantum spin liquid candidates $A_3Co_2SbO_6$ (A=Cu, Na)

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Abstract:

The Kitaev quantum spin liquid (KQSL) is the new limelight state for realizing macroscopic quantum entanglement without classical long-range ordering. While cobalt-based honeycomb lattice oxides $A_3Co_2SbO_6$ (A=Cu, Na) have been proposed as new candidates of KQSL, the presence of trigonal crystal field in real materials leads to a classical long-range ordered ground state at low temperatures. It is, therefore, mandatory to control such a trigonal crystal field to realize the KQSL. Here, we studied the splitting Δ of a_{1g} and e_g^{π} state of trigonal field caused by CoO_6 trigonal distortion in $A_3Co_2SbO_6$ (A=Cu, Na) thin films, by employing X-ray absorption spectroscopy. Notably, our findings indicate that the e_g^{π} level is higher than the a_{1g} level, and reducing the trigonal distortion leads to a reduction in the trigonal field Δ, contrary to the direction suggested by previous theoretical [1] and experimental [2] investigations. Furthermore, we controlled the CoO_6 trigonal distortion in $A_3Co_2SbO_6$ (A=Cu, Na) thin film via He implantation, resulting in suppression of antiferromagnetic ordering temperature. It implies the strong correlation between the trigonal crystal field and the stability of classical long-range ordering. This research proved that the control of the trigonal crystal field is key to achieving the KQSL.

[1] Liu, H., Chaloupka, J., & Khaliullin, G., 2020 *Phys. Rev. Lett.*. **125** 047201
[2] Chaebin Kim *et al* 2022 *J. Phys.: Condens. Matter* **34** 045802

Keywords:

Kitaev quantum spin liquid, X-ray absorption spectroscopy, trigonal distortion, trigonal crystal field

2023 KPS Fall Meeting
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B11.05

The Effects of the Strain on Kitaev Quantum Spin Liquids

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Abstract:

The ground state of isotropic 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. The interaction with deformations of the crystal lattice is a crucial ingredient in many experiments realizing quantum information processing schemes. Here, we derive the symmetry-allowed Hamiltonian with strains on the Honeycomb lattice. Using general symmetry analysis with perturbation for microscopic spin Hamiltonians, we uncover the effects of the strain on Kitaev's quantum Spin Liquids, including strain-induced topological phase transitions.

Keywords:

Quantum Spin Liquid, Kitaev's Honeycomb Model

2023 KPS Fall Meeting
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B11.06

Point-gap topology and skin effect of non-reciprocal many-body systems

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Abstract:

The Hatano-Nelson model is a one-dimensional non-Hermitian Hamiltonian featuring non-reciprocal hopping. This model reveals complex eigenvalues, that trace closed curves in the complex plane, under periodic boundary conditions (PBC). These curves are characterized by the winding number. In contrast, all eigenvalues become purely real numbers under open boundary conditions (OBC). Concomitantly, all eigenstates are exponentially localized at the boundary sites, a phenomenon known as the non-Hermitian skin effect (NHSE).
In this study, we investigated the NHSE of the many-body fermion systems by utilizing the half-filled Hubbard model with non-reciprocal hopping. We found that eigenstates, in which finite doublon-holon pairs play a significant role, exhibit robustly complex eigenvalues even in the strong coupling limit. Notably, the eigenvalues are characterized by their point-gap topology. Furthermore, we demonstrated that the NHSE in these systems can be elucidated through the segregation of doublon-holon pairs.

Keywords:

Non-Hermitian skin effect, Hubbard model, Doublon-holon excitation

2023 KPS Fall Meeting
2023-10-24 - 2023-10-27

B11.07

The Influence of UV/IR Mixing on Topological Entanglement Entropy in Two-Dimensional Lattice Models

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Abstract:

The topological entanglement entropy (TEE), symbolized as γ, is closely connected to the quantum dimension $\mathcal{D}$ of a model, expressed as $\gamma = \log \mathcal{D}$. Within the landscape of two-dimensional lattice models, an emergent phenomenon termed UV/IR mixing has gaining attention, which involves the blending of ultraviolet (UV) and infrared (IR) scales. In such models the ground state degeneracy (GSD) and the number of independent logical operators depends on the system size in a sensitive manner, and it must influence the quantum dimension. This study aims to shed light on how UV/IR mixing affects TEE and its connection to the quantum dimension. We focus on a particular example, the $\mathbb{Z}_N$ rank-2 toric code (R2TC), and find something interesting: TEE remains unchanged by UV/IR mixing when the system has a contractible boundary. However, with a non-contractible boundary, we observe distinct signs of UV/IR mixing within the TEE. Additionally, we construct minimum entropy states for the R2TC and derive the corresponding TEE. A significant difference emerges between the way UV/IR mixing affects the ground states compared to its impact on TEE. This difference is due to "invariant anyons," which are particles that keep their quantum properties intact even after they move around a torus. Importantly, the method we use to calculate TEE can be applied to other models that involve UV/IR mixing, broadening our understanding of quantum entanglement and topological phenomena.

Keywords:

UV/IR mixing, Topological entanglement entropy, Topological order, Quantum dimension

2023 KPS Fall Meeting
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B11.08

Geometric aspects of the multipartite entanglement via modular commutator

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Abstract:

Quantum entanglement in many-body systems is one of the key concepts in quantum science and technology. The recent introduction of the new entanglement quantity modular commutator enables extracting chiral central charge from a single wave function. In this study, we study geometric aspects of multipartite entanglement of quantum states using modular commutators. We discuss their salient features in conformal field theory and provide concrete examples.

Keywords:

modular commutator, chiral central charge, multipartite entanglement, area law of entanglement entropy

2023 KPS Fall Meeting
2023-10-24 - 2023-10-27

B12.01

Voltage control of magnetism in $Fe_{3-x}GeTe_2/In_2Se_3$ van der Waals heterostructures

EOM Jaeun [1,2], LEE Inhak [1], KEE Jung Yun [1,3], CHO Minhyun [4], SEO Jeongdae [5], SUH Hoyoung [6], CHOI Hyung-Jin [7], SIM Yumin [8], CHEN Shuzhang [9,10], CHANG Hye Jung [6], BAEK Seung-Hyub [7], PETROVIC Cedomir [9,10], RYU Hyejin [1], JANG Chaun [1], KIM Young Duck [4], YANG Chan-Ho [5], SEONG Maeng-Je [8], LEE Jin Hong [1], PARK Se Young [*3,11], CHOI Jun Woo [*1]

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Abstract:

We investigate the electronic and magnetic properties of ferromagnetic/ferroelectric in $Fe_{3-x}GeTe_2/In_2Se_3$ heterostructures. It is observed that gate voltages applied to the $Fe_{3-x}GeTe_2/In_2Se_3$ heterostructure device modulate the magnetic properties of $Fe_{3-x}GeTe_2$ with a significant decrease in the coercive field for both positive and negative voltages. Raman spectroscopy on the heterostructure device shows a voltage-dependent increase in the in-plane In_2Se_3 and $Fe_{3-x}GeTe_2$ lattice constants for both voltage polarities. Thus, the voltage-dependent decrease in the $Fe_{3-x}GeTe_2$ coercive field, regardless of the gate voltage polarity, can be attributed to the in-plane tensile strain. This is supported by density functional theory calculations showing tensile-strain-induced reduction of the magnetocrystalline anisotropy, which in turn decreases the coercive field. Our results demonstrate an effective method to realize low-power voltage-controlled vdW spintronic devices utilizing the magnetoelectric effect in van der Waals ferromagnetic/ferroelectric heterostructures.

Keywords:

van der Waals materials, Magnetism, Density functional theory, magneto-optic Kerr effect, Raman spectroscopy

2023 KPS Fall Meeting
2023-10-24 - 2023-10-27

B12.02

Accelerated Variational Eigensolver in combination with Quantum annealer

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Abstract:

거대 해밀토니안의 기저에너지를 빠르게 찾기 위한 계산 방법의 개발은 과학계에 강한 흥미 있는 주제이다. 고전컴퓨터는 해밀토니안의 크기가 증가하면서 계산양이 Polynomial 증가를 따르기때문에 거대 해밀토니안의 기저에너지를 빠르게 찾는게 쉽지 않다. 본 연구는 양자어닐러와 고전컴퓨터에서 사용되는 optimizer를 사용하여 기존 고전컴퓨터에서 계산보다 빠르게 기저에너지를 계산 하는 방법을 제시한다. 본 연구의 알고리즘이 잘 작동하는지 확인하기 위하여 일차원 쩔쩔맴을 가지고 상호작용이 없는 전자모델과 볼츠만 모델에서 기저에너지 계산을 보여 본 연구의 알고리즘의 효용성을 확인한다.

Keywords:

Eigensolver, Quantum Annealing

B12.03

Screening of semiconductor materials using hybrid density functional theory

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Abstract:

First-principle density functional theory (DFT) has been regarded as one of the most efficient methods for investigating the properties of semiconductor materials. Recently, a lot of efforts have been devoted to building computational databases through high-throughput DFT calculations. It is also gaining more momentum to make machine learning models based on free computational databases. However, when the local or semi-local functionals are used to perform DFT calculations, the electronic band gap of semiconductors is severely underestimated. To make reliable machine learning models for solar cells or LED applications, the electronic band gap should be improved. In this presentation, we discuss a cost-effective hybrid DFT by employing downsampled k-point grids [1-4]. The importance of structure relaxation will be also discussed.

[1] J.-S. Park, Curr. Appl. Phys. 20, 379 (2020).
[2] J.-S. Park, J. Jung, and S. Lee, J. Phys. Chem. Lett. 12, 7885 (2021).
[3] B.-H. Jeong, M. Jeong, Y. Song, K. Park, and J.-S. Park, Crystals **11**, 883 (2021).
[4] K. Park, B.-H. Jeong, and J.-S. Park, J. Phys. Commun. **6**, 065001 (2022).

Keywords:

hybrid density functional theory, downsampling, reciprocal space, k-point, high-throughput

B13.01

Highly conducting delafossite thin films for high-performance interconnects

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Abstract:

The pursuit of efficient and reliable interconnects is a cornerstone in advancing modern electronic devices. In this context, ABO2 delafossite thin films have attracted considerable attention as a promising candidate due to their outstanding electrical properties. ABO2 delafossite, composed of hexagonal A and BO2 layers, exhibit a natural heterostructure that contributes to a diverse range of physical attributes. Notably, A-site electrons in delafossite oxides occupy a band proximate to the Fermi level with distinct band dispersion, realizing high mobility and high carrier density at the same time. The layer-by-layer growth method enables the controlled synthesis of these thin films, facilitating the integration of their multifaceted properties into future electronic devices. However, there are challenges in achieving high-quality delafossite thin film growth. In this talk, the possibilities and limitations of delafossite thin films will be discussed.

Keywords:

Thin film, Conducting oxides, Delafossite

B13.02

Two-dimensional pure electron liquid and hetero-surface

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Abstract:

Strong electron correlation plays a key role to determine diverse quantum phenomena. One intuitive way to figure out the role of electron correlation in many solid materials is to form a system purely consisting of electrons independent of lattice and orbital degrees of freedom. Indeed, pure electrons spread in two-dimensional space can have several different phases of gas, liquid, and even solid – so called Wigner crystal depending of their kinetic energy and Coulomb interaction. Though the pure electron system can give a new insight for the condensed matter physics, however, the requirements to realize such pure electrons set huge hurdles for the further studies. I will report our recent work of observing the intriguing surface electronic state purely consisting of electrons. Using ARPES combined with first-principles calculation, we successfully characterized that the surface electrons are in electron liquid state decoupled from the top-most layer, thus, free from other degrees of freedom. In addition, by controlling the electron correlation of those electrons, we observed the phase transition to the liquid crystal phase. We believe that these result can provide an opportunities to study the role of electron-electron interaction in strongly correlated electron systems. In the presentation, I will also introduce a further reult of coexisting of two distinct surface states akin to the heterojunction on the single platform of layered electride compouond. We believe that these states can provide a new type of heterostructure mimicking the stacking of two distinct atomic layer in bulk form in which intriguing quantum phenomena can be emerged.

Keywords:

2DES, Electronic structure, ARPES, Heterostructure

2023 KPS Fall Meeting
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B13.03

Bose-Einstein Condensation of Composite Fermions in Twisted Bilayer Graphene

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Abstract:

We introduce a novel two-dimensional electronic system within twisted bilayer graphene characterized by a pronounced twist angle, positioning it as a prime platform for studying interlayer-coherent excitonic condensates. The system's atomic proximity between layers ensures strong interlayer interactions, while the notable twist angle naturally restricts interlayer electron tunneling. Harnessing these features, we identify a succession of odd-integer quantum Hall states with interlayer coherence at both the lowest and second Landau levels. Remarkably, the energy gaps for these states near 1 K, distinctly outperforming those in GaAs systems. Additionally, we observe R_{xx} minima coupled with R_{xy} plateaus at a filling factor approximately equal to 1/3 in the zero displacement field limit, suggesting half-filled Λ-levels from the top layer and another half-filled Λ-level. It's worth noting that the Λ-level represents the Landau level for composite fermions. Our temperature and magnetic field-dependent studies further corroborate these emerging quantum Hall states.

Keywords:

Bose-Einstein condensation, twisted bilayer graphene, composite Fermion

2023 KPS Fall Meeting
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B13.04

Single electron manipulations

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Abstract:

On-demand single-electron sources represent an electron-based counterpart to the single-photon sources utilized within photonic quantum optics. The coherent manipulation of individual electrons holds the potential to establish a robust framework for advancing quantum information and quantum computation technologies. In my talk, I will introduce the methodology of manipulating individual electrons through the utilization of quantum dots and detectors integrated into GaAs/AlGaAs heterostructures, to enhance and quantify their coherence properties.

Keywords:

Single electron, Quantum dot

B14.01

Quantum acoustics: a surface-acoustic wave assisted single-photon emission

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Abstract:

A surface acoustic wave (SAW) is a combination of strain and electrostatic potential waves that propagate at the velocity of sound along the surface of a piezoelectric crystal. This potential wave can collect electrons from a two-dimensional electron gas (2DEG) and transport them through a depleted channel. The SAW minima form a continuous series of dynamic quantum dots, each transporting a controllable number of electrons along the channel. A single-photon source driven by a surface acoustic wave (SAW) is developed and characterized. This single-photon source is based on a SAW-driven lateral n-i-p junction structure. On this device, the lateral n-i-p junction is formed by gate-induced electrons and holes in two adjacent regions. The SAW potential minima create dynamic quantum dots in a 1D channel between these two regions and are able to transport single electrons to the region of holes along the channel. Single-photon emission can therefore be generated as these electrons consecutively recombine with holes which can potentially be instrumental in implementing scalable quantum processors and quantum repeaters, by facilitating interaction between distant qubits.

Keywords:

Quantum acoustics, Hybrid quantum systems, Surface acoustic waves, Quantum computation, Single electron to sinlge photon conversion

2023 KPS Fall Meeting
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B14.02

Functionalized graphene for chemical sensor applications with improved stability and selectivity

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Abstract:

Functionalization of graphene with nanoparticles is an effective method for improving target material selectivity and sensitivity of graphene-based chemical sensor application. Target gas selectivity and response of graphene-based chemical sensors can be improved by functionalization the graphene with specific nanoparticles. By choosing functionalized materials for graphene that have high binding affinities with the intended target chemical species, it may be possible to provide selective chemical sensors for various target gases with graphene transducers. In addition, graphene-based sensor system can improve stability of the electrochemical sensor. For the improve the stability of the electrochemical sensor, we used the electrochemical transparency property of graphene. The established redox properties of Prussian blue (PB) were maintained irrespective of the presence of the graphene overlayer and that graphene did not hinder the ionic interaction of the alkali cations in the electrolytes with the Fe^{III} ions in the PB, we confirmed that graphene is transparent to electrochemical reactions.

Keywords:

Graphene, Chemical sensor, Electrochemical transparency, Glucose sensor

2023 KPS Fall Meeting
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B14.03

Strategies to enable the reliable electronic devices based on two dimensional layered materials

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Abstract:

Artificial synapses based on two-dimensional (2D) MoS_2 memtransistors have shown promise for use in complex neuromorphic systems. However, the random variations in field-induced defect migration have led to unreliable synaptic plasticity and analog switching in previous memtransistor devices. In this study, a reliable 2D MoS_2/oxide heterostructure memtransistor device was demonstrated, with oxide interlayer thickness found to be a critical material parameter for inducing and tuning analog switching characteristics. The device showed dual-terminal stimulated heterosynaptic plasticity and precise multi-states, with a low power consumption and reliable potentiation/depression endurance characteristics. Additionally, a tunable sulfur vacancy-modulated MoS_2 memtransistor was demonstrated using an O_2 plasma treatment method, allowing for effective tuning of resistive switching characteristics and successful implementation of long-term potentiation/depression behavior. These findings demonstrate the potential of these memtransistor devices for use in flexible and energy-efficient neuromorphic systems.

Keywords:

neuromorphic synapse, 2D memtransistor, heterosynaptic plasticity, switching device

2023 KPS Fall Meeting
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B14.04

Copper Sulfide Electrodes for Electronic and Optoelectronic Applications

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Abstract:

2D nanostructures have garnered intense interests due to their 2D structure that enables super flexibility, optical transparency, and facile integration with disparate materials through van der Waals forces. In this presentation, I will introduce a new class of covellite 2D copper monosulfide (CuS) nanosheet film as a promising candidate for transparent, flexible conductive electrodes, which can be employed in various flexible and wearable electronic and optoelectronic devices. Especially, the presentation will cover from the synthesis of 2D CuS using facile sulfurization method to its employment in various electronics and optoelectronics devices including the source-drain electrode materials for 2D MoS_2 channel. We achieved record high electron mobility up to 100 $cm^2V^{-1}s^{-1}$ at room temperature in a back-gate device configuration. We will also cover effective doping method to tune its electrical and optical properties.

Keywords:

Copper Sulfide, 2D Electronics, Flexible Electrodes

2023 KPS Fall Meeting
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B15.01

Fabrication of 2D Heterostructure by Lithography-free Method and their Characterization

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Abstract:

In this work, the lithography-free fabrication method and characterization of two-dimensional (2D) heterostructure has studied. We found condition for picked up and dropped down the 2D materials only using PDMS gel-pak and stacked the 2D material-based heterostructure by using this dry transfer method. Through this method, various nano devices could be fabricated quickly and accurately. Also, transferred graphene was used as the electrodes for electrical property measurement instead of metal deposition. We applied the voltage to the graphene electrode to conduct the current-voltage characteristic, and confirmed the electrical properties of 2D heterostructures. The details of fabrication method and conditions will be suggested in this presentation.

Keywords:

2D materials, Fabrication

2023 KPS Fall Meeting
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B15.02

Full spectrum photothermal catalytic effect in narrow bandgap $SnFe_2O_4$ quantum dots

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Abstract:

$SnFe_2O_4$ is a magnetic semiconductor with a spinel structure. Its narrow bandgap energy of 1.77 eV enables remarkable visible light absorption and photothermal effects in the NIR region, which promises full solar spectrum photocatalysis. However, detailed research on the photothermal effect of $SnFe_2O_4$ remains limited. In this work, we systematically investigate the photothermal catalytic performance of $SnFe_2O_4$ quantum dots (SFO QDs) through the degradation of an antibiotic CTC. The SFO QDs were prepared by hydrothermal synthesis at 100°C. The absorption band edge of SFO QDs was determined to be 767 nm by UV-Vis-IR DRS. At 45°C for 150 minutes, thermal catalysis achieves 67.8% degradation, while photo-thermal catalysis reaches 87.7%. Furthermore, degradation efficiencies are 57.0% and 81.4% under NIR and Visible light, respectively. These findings demonstrate that SFO QDs can be further explored for highly responsive photo-thermal catalysis applications.

Keywords:

Photocatalyst, Tin Ferrite, Photo-thermal effect

2023 KPS Fall Meeting
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B15.03

In-situ Parameter-Driven Exploration of Stacked 2D Material Characteristics

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Abstract:

In this study, we investigate the influence of interlayer rotation within stacked structures on their electrical and optical properties, including electrical transport and the change in the bandgap. We examine the possibility of tuning physical properties, such as electrical conductivity, by independently manipulating two layers within a vertically stacked structure. We specifically conducted *in situ* measurements to explore this phenomenon. We vertically stacked graphene so that the clean sides of the graphene contact each other. We created multiple structures using the same graphene flake with different twist angles between the two layers. We will report the interlayer angles derived from the Raman spectra for each structure

Keywords:

graphene

2023 KPS Fall Meeting
2023-10-24 - 2023-10-27

B15.04

Laser Induced Phase Transition of 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 these polymorphs has great potential for memory application. In this study, the phase transition of γ-GeSe to α-GeSe via laser irradiation is reported. After the laser mapping, encapsulated γ-GeSe changes into a single crystalline α-GeSe aligned with a crystal direction of γ-GeSe. The whole irradiated region changes into α-GeSe and a boundary between original γ-GeSe and α-GeSe was identified via TEM dark field imaging. Our works demonstrate that GeSe is a unique chalcogenide material that shows crystal-to-crystal phase transition with a great difference in resistivity.

Keywords:

GeSe, phase transition

2023 KPS Fall Meeting
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B15.05

Imaging disorders in moiré superlattice at a mesoscopic scale

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Abstract:

Moiré superlattices of two-dimensional (2D) materials, originating from the interference between periodic lattices, have been widely studied due to their exotic electronic and optical properties. [1, 2] Since 2D materials are significantly influenced by their surroundings, disordered moiré superlattices are easily formed, making the investigation of their fundamental properties challenging. In this presentation, we present a method for visualizing the disorders in moiré superlattices by using Raman spectroscopy and second harmonic generation (SHG). We measured Raman spectra of twisted bilayer WS_2 (tWS_2) with a twist angle from 0˚ to 60˚ and observed angle-dependent signatures of lattice reconstruction and moiré phonons. By using the angle-dependent phonon properties, we visualized the variation of twist angle in tWS_2. Additionally, we utilized SHG to distinguish domains with twist angles of $30^{\circ} - \theta$ and $30^{\circ} + \theta$, which cannot be distinguished using Raman spectroscopy alone. Furthermore, we simultaneously obtained the distribution of strains in tWS_2 by tracking the position of the E_g mode of WS_2 which is sensitive to in-plane strain. We found that the dominant strain arises from the shear-lag effect at large twist angles, while lattice reconstruction plays a major role in reconstructed tWS_2. This work contributes to the research on moiré materials, both in terms of fundamental understanding and practical applications.

[1] Cao, Y. et al. *Nature* 556, 43–50 (2018).
[2] Huang, D., Choi, J., Shih, CK. *et al. Nat. Nanotechnol.* 17, 227–238 (2022)

Keywords:

Moiré superlattice, Raman spectroscopy, Second harmonic generation, Lattice reconstruction

2023 KPS Fall Meeting
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B15.06

Growth mechanism of γ-GeSe: template growth on graphene and h-BN 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:

Germanium Selenide, Group IV monochalcogenide, Chemical vapor deposition, Screw dislocation, Heterostructure

2023 KPS Fall Meeting
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B15.07

Investigation of vibrational and thermal properties of γ-GeSe

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Abstract:

γ-GeSe is a recently identified polymorph 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 geometry. The mechanical vibrational modes of doubly-clamped γ-GeSe flakes are measured using optical interferometry. The nano-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 lattice thermal conductivity of approximately 1 $Wm^{-1}K^{-1}$ at room temperature.

Keywords:

Young's modulus, Thermal conductivity, Group-IV monochalcogenide, γ-GeSe, Freestanding structure

2023 KPS Fall Meeting
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B15.08

Chemical reaction mechanism in metal-free defective carbon-based materials

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Abstract:

Since the N-doped carbon nanotube was first reported to activate Oxygen reduction reaction (ORR) in 2009, carbon-based materials have attracted much attention as an alternative electrochemical catalyst for noble metal catalysts, such as Pt and Ir. Extensive research has been conducted on metal-free carbon-based catalysts, and recently, both platinum-based catalysts and high-performance, durable carbon catalysts have been developed. However, the detailed mechanism of catalytic reactions remains uncertain and subject to debate. In this study, we conducted DFT calculations to elucidate the role of doped N and vacant carbon defects on the activation of ORR in view of structural deformations. We show that both types of defects enhance the non-local structural flexibility of the carbon plane, thereby reducing the energy barrier for the sp2/sp3 transition of carbon atom and facilitating the adsorption of external molecules onto carbon atom. Our results can contribute to a more comprehensive and profound understanding of chemical reactions in metal-free carbon-based materials.

Keywords:

Metal-free defective carbon, Chemical Reaction, Non-local Structural Flexibility

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B16.01

Electronic correlation effect in the Kagome lattice system AV_3Sb_5 (A = K, Rb, Cs)

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Abstract:

In this study, we employ density functional theory calculations to compute the electronic structure of the kagome lattice material AV3Sb5 (A = K, Rb, Cs). In these calculations, we consider on-site U and inter-site V Coulomb interactions on vanadium d-orbitals to account for strong electron-electron interactions and investigate their impact on the electronic structure. Our results reveal that the incorporation of V promotes charge density wave (CDW) phases, while U suppresses the CDW phases and stabilizes the pristine phase. This finding implies that the intricate interplay between U and V significantly affects the electronic structure of KV3Sb5. We have computed electronic structures with several values of U and V and compared them with experimental angle-resolved photoemission spectroscopy data to determine which set of U and V explains the experiment. Our findings provide valuable insights into understanding the electronic structure of this intriguing material and the impact of electronic correlations.

Keywords:

Kagome lattice, Density functional theory, Electronic correlation, Charge density wave

2023 KPS Fall Meeting
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B16.02

Condensation of preformed charge density waves in kagome metals

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Abstract:

Charge density wave (CDW) is a spontaneous spatial modulation of charges in solids whose general microscopic descriptions are yet to be completed. Layered kagome metals of AV_3Sb_5 (A = K, Rb, Cs) provide a unique chance to realize its emergence intertwined with dimensional effects as well as their special lattice. In this talk, based on state-of-the-art molecular dynamics simulations, I will show that the phase transition to CDW state in kagome metals is a condensation process of incoherently preformed CDWs. It will be demonstrated that charge modulation first forms on each kagome layer at a well-defined temperature but its phase still fluctuates with 10^5 times slower frequencies than typical phonon vibrations until reaching their freezing temperature. The size of spacer A layers controls the competition between the fluctuation and condensation of preformed orders, results in a maximized CDW transition temperature with Rb atom. Our results resolve controversial observations on CDW formations and highlight roles of weak interlayer interactions for CDWs in kagome metals.

Keywords:

Kagome metal, phase transition, molecular dynamics

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B16.03

Charge Density Wave and Magnetism in a Magnetic Kagome Metal FeGe

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Abstract:

Recent discoveries in kagome metals have unveiled emergent phases encompassing magnetic orders, charge density waves (CDW), nematicity, and superconductivity. Despite extensive investigation, the connection between CDW and magnetism remains largely unexplored. We discovered a CDW phase in a magnetic kagome metal FeGe, providing a new platform for understanding the interplay between CDW and magnetism.

In this presentation, I will show and discuss angle-resolved photoemission spectroscopy (ARPES) results that observed three characteristic electronic structure signatures of kagome lattices, namely flat bands, Dirac crossings, and VHSs. A monotonic shift of the VHSs toward Fermi level was found as temperature increases. We attribute the shift to temperature evolution of magnetic exchange splitting. At the onset temperature of the CDW, we identify spectral gap formation at the Fermi level on the VHS-forming band. The nesting between them satisfies the CDW wavevectors. Electron-phonon coupling in kink structures was uncovered from ARPES, in alignment with phonon hardening observed in neutron scattering. Those observations point intertwined nature of CDW and magnetism in FeGe, encouraging future theoretical and experimental investigations.

Keywords:

Kagome, Charge Density Wave, ARPES

2023 KPS Fall Meeting
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B16.04

In-plane electronic correlations vs incoherent scattering processes in the charge-density-wave phase of Kagome metals

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Abstract:

Metallic kagome lattices with their rich electronic band structure features, such as flat bands, Dirac points, and van Hove singularities close to the Fermi energy, constitute a promising platform to achieve exotic topologically non-trivial states, e.g., topological superconductivity. Particularly, the family of vanadium-based kagome metals AV_3Sb_5 (A=Cs, K, Rb) is prone to topological electronic phases and related instabilities. The discovery of superconductivity in these compounds has ignited a massive research effort to elucidate the nature and the pairing mechanism of this potential topological superconductor [1,2]. Of special relevance may be a neighboring charge-density-wave (CDW) phase - yet, its true role in establishing superconductivity in AV_3Sb_5 remains unresolved until now.
In this talk detailed temperature and polarization resolved Raman scattering results on various vanadium-based kagome metals are discussed [3]. Our highly angular-resolved data shed a light on the symmetry of CDW-related excitations and on selected phonons, which allude to an emergent C_2 symmetry within the CDW phase. This symmetry-breaking together with phonon anomalies and electronic Raman scattering at T_{CDW} signify the formation of a nematic phase through a concerted interplay of electronic correlations and electron-phonon coupling within the exotic CDW phase.

[1] Ortiz, et al., Phys. Rev. Mater. **3**, 094407 (2019).
[2] Ortiz, et al., Phys. Rev. Lett. **125**, 247002 (2020).
[3] Wulferding, et al., Phys. Rev. Res. **4**, 023215 (2022).

Keywords:

Kagome metals, Charge-density waves, Flatbands

2023 KPS Fall Meeting
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C1.01

Primordial density perturbations as a tool to probe new physics

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Abstract:

The Higgs boson was discovered in the LHC experiment, but given the current lack of physics beyond the Standard Model of particle physics, such as supersymmetry, the importance of the universe as a means of exploring more fundamental laws of physics at high energies is expected to increase. In more fundamental theories beyond the Standard Model, it is believed that many new particles exist in addition to those of the Standard Model, but their mass scales are, of course, unknown. Although particles on the order of a few TeV may be found in the near future using ground-based accelerators, it will be almost impossible to directly produce particles with masses far beyond the TeV scale using ground-based accelerators even in the future. Therefore, the only way to elucidate the nature of such new particles is to look for their traces in the universe. In this talk, we will explain how to extract information about physics beyond the Standard Model through the properties of primordial density perturbations produced during inflation.

Keywords:

Dark matter search using NaI(Tl) at the COSINE-100 experiment

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Abstract:

The DAMA/LIBRA collaboration has claimed the presence of an annual modulation signal that is compatible with expectations for dark matter interactions. COSINE-100 is an experiments that aims to test this dark matter signature using the same target material, NaI(Tl) crystal. The experiment has collected data for 6.5 years, since September 2016. Data taking is paused to prepare for the detector upgrade and move to the new experimental site from YangYang Underground Laboratory to Yemilab in Jeongseon. In the most recent analyses, COSINE-100 has reported the limits of WIMP spectral analysis and annual modulation search, using an updated background model and a threshold that has been lowered to 1 keV. We also report results from a number of searches for exotic dark matter scenarios using COSINE-100 data. In this presentation, the overall status and latest dark matter search results from COSINE-100 will be presented. In addition, the status of the latest WIMP spectral analyses with improved strategy will also be summarized.

Keywords:

WIMP, NaI, COSINE-100, dark matter

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C2.02

COSINE-100 upgrade at Yemilab

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Abstract:

COSINE-100 dark matter search experiment with a total of 106 kg low-background NaI(Tl) crystals had operated stably from September 2016 to March 2023 at the Yangyang underground laboratory. The experiment is currently in the decommissioning stage for moving to the new underground laboratory, Yemilab in Jeongseon with detector upgrade. The new crystal encapsulation focused on improved light correction will be applied for the COSINE-100 upgrade experiment at the Yemilab that will allow us to search unresolved regions of dark matter parameter space. In this presentation, we will discuss the progress and the prospects of the COSINE-100 upgrade experiment.

Keywords:

COSINE-100, dark matter, NaI(Tl)

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C2.03

Measurements of quenching factors for NaI(Tl) scintillating crystal

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Abstract:

Understanding nuclear recoil quenching factors, the ratio of the scintillation light yield produced by nuclear and electron recoils of the same energy, is critical for rare event searches, such as dark matter and neutrino experiments. Because NaI(Tl) crystals are widely used for dark matter direct detection and neutrino-nucleus elastic scattering measurements, the low-energy quenching factor of the NaI(Tl) crystals is substantially important. The quenching factor for NaI(Tl) scintillating crystals has been measured by several experimental groups for energies above 5 keVnr for Sodium and 10 keVnr for Iodine. We have developed a NaI(Tl) detector with a high light yield of approximately 25 photoelectrons per keVee and an event-selection and analysis method based on waveform simulations that are specialized for studies of events with energies as low as a sub keVee region. As part of these efforts, we have measured quenching factors for nuclear recoil energies below 5 keVnr and 10 keVnr for Na and I, respectively. This talk will present the results and prospects for future quenching-factor measurements for NaI(Tl) crystals.

Keywords:

NaI(Tl), Quenching factor

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C2.04

Neutrino Elastic-scattering Observation with NaI(Tl)(NEON)

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Abstract:

The NEON experiment aims to observe coherent elastic neutrino-nucleus scattering (CEvNS) using reactor anti-electron neutrinos with NaI(Tl) crystal detectors at the Hanbit nuclear power plant in Yeonggwang, South Korea. Although CEvNS has been observed by the COHERENT collaboration using a spallation neutron source, the same process with reactor neutrinos has not yet been observed. The NEON detector consists of a 16.5 kg NaI(Tl) target mass installed 24 meters from the reactor core. The probability of CEvNS observation relies on detector performance, such as background level and low-energy threshold. The light yield of the detector is approximately 23 NPE/keV, which is about 50% higher than the previous detector due to R&D. The background level of roughly 6 counts/day/kg/keV and a below 0.6 keV energy threshold have already been achieved. Further analysis is ongoing to optimize the low-energy threshold through waveform simulation, which is used as scintillating signal sample for Boosted Decision Trees (BDT) training. Current physics data were collected during both reactor shutdown (5 months) and reactor operation (ongoing for approximately 9 months). This presentation will provide an overview and current status of the NEON experiment.

Keywords:

CEvNS, Neutrino, NaI(Tl)

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C2.05

XMASS 전 데이터를 사용한 암흑 물질 직접 탐색

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Abstract:

일본 기후현 히다시 카미오카초의 지하 1000 미터의 실험실에서 1 톤의 제논을 이용한 단상 액체 제논 검출기로 암흑물질, 중성미자, 액시온 등을 탐색하던 XMASS 실험은 2010년 후반 처음으로 데이터를 받기 시작하여 2019년 2월 1일 데이터 수집을 종료하였다. 2012년 중반에서 2013년 후반기까지 검출기를 개수한 이후에 5년 이상의 안정적인 데이터를 수집하였다. 이 발표에서는 2013년 11월 20일부터 2019년 2월 1일까지 총 1590.9일의 실제 데이터 수집 시간에 분석 임계값이 전자기준으로 1.0 keVee로 낮은 XMASS 데이터를 사용하여 다양한 WIMP 암흑 물질 탐색의 결과를 보고한다. 검출기 안쪽의 낮은 배경 사건 영역의 97 kg 제논으로 WIMP 신호를 탐색하여 90% 신뢰 수준에서 60 GeV/c^2 WIMP에 대한 WIMP-핵 산란 단면적 1.4×10^{-44} cm^2의 상한을 제시한다. 또한 검출기 안쪽의 832 kg의 액체 제논을 사용하여 WIMP 에 의한 에너지 스펙트럼의 연간 변동을 탐색하였다. 8 GeV/c^2 WIMP에 의한 핵 산란의 경우 이 분석을 통해 2.3×10^{-42} cm^2의 90% CL 단면적 상한을 제시한다. 0.5 GeV/c^2의 WIMP 질량에서 Migdal 효과와 Bremsstrahlung 에 의한 신호를 탐색하여 각각 1.4×10^{-35} cm^2와 1.1×10^{-33} cm^2 의 90% CL 단면적 상한을 제시한다.

Keywords:

XMASS, 암흑물질, WIMP, Migdal effect, Bremsstrahlung

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C2.06

Result of AMoRE-I Experiment Analysis

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Abstract:

AMoRE is an international experimental project to search for the neutrinoless double beta (0νββ) decay of ^{100}Mo utilizing enriched molybdate scintillating crystals and metallic magnetic calorimeters in a mK-scale cryogenic system. The project aims for zero background in the region of interest near 3.034 MeV, the Q-value of ^{100}Mo 0νββ decay, by simultaneously measuring phonon and photon signals for 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 experiment in Sep. 2020, we have accumulated good, stable physics data of live exposure over 8 kg·yr with advanced noise suppression, lowering the background level below the pilot phase. With an improved ROI estimation analysis method and cut efficiency calculation, we will report a new half-life limit of ^{100}Mo 0νββ decay from the AMoRE-I experiment data.

Keywords:

AMoRE, Neutrinoless Double Beta Decay, 0νββ, Underground Experiment

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C2.07

A search for ^{7}Li solar axions with Li_2MoO_4 detectors in the AMoRE-I

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Abstract:

A comprehensive study was conducted within the framework of the Advanced Mo-based Rare process Experiment (AMoRE) framework, focusing on searching for ^{7}Li solar axions using Li_2MoO_4 crystals. Axion, a hypothetical particle, was proposed to address the CP violation problem in strong interactions. Should axions exist, they could be abundantly generated within the core of the Sun, and subsequently be detectable through the reverse reaction of resonance absorption, involving particle detection.
The Li_2MoO_4 crystal employed in the AMoRE experiment serves a dual purpose, functioning both as a target and a detector for this mechanism, with a 13% detection efficiency. Over a duration of 6.5 months, data from 1.6 kv of Li_2MoO_4 crystals were collected via a cryogenic system at the Yangyang Underground Laboratory (Y2L) in South Korea. Using this data, we have obtained an upper limit on the axion mass to be less than 5.63 keV, which stands as the world's best limit. This presentation will provide the analytical procedures employed to derive the results and furthermore, discuss the potential in the future AMoRE-II experiment with a much bigger target mass.

Keywords:

Solar axion, AMoRE, Resonance absorption

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C2.08

Multi-crystal-hit study of 2υββ decay of ^{100}Mo to the excited states of ^{100}Ru at AMoRE

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Abstract:

The study of two neutrino double beta decay of ^{100}Mo to excited states of ^{100}Ru helps us understand nuclear matrix elements and nuclear models and search for the bosonic (symmetric) fraction of the neutrino wave function.
The AMoRE (Advanced Mo-based Rare process Experiment) project aims to study the double beta decay of ^{100}Mo using a cryogenic technique. Because the AMoRE is an array of detectors, the detection efficiency for the decay to the first 0+ excited state of ^{100}Ru is higher than for the transition to the ground state when the multiplicity is 2 and 3. So it is possible to reliably observe the ground state(g.s.) to the first 0+ excited state transition signal. Furthermore, coincidence event selection using a multiplicity of signals reduces the background significantly. The beta energy distribution can also be measured with a multiplicity of 3.
The AMoRE-I, the second phase with 18 enriched ^{100}Mo-based crystal scintillator detectors, is carried out at Yangyang Underground Laboratory. In total, 487 days of physics data were used to measure the half-life of 100Mo relative to the 2υββ decay to the first 0+ excited state of ^{100}Ru.
The AMoRE-II is under construction at a 1000 m deep Yemi Underground Laboratory, aiming for a tonne-year exposure of ^{100}Mo. A simulation study for observing the electron energy for the decay of ^{100}Mo to the first 0+ excited level of ^{100}Ru and verifying events from the decay to the suppressed 2+ excited state transition has been initiated, searching for bosonic neutrino under the AMoRE-II scale.

Keywords:

AMoRE, double beta decay to excited state, 100Mo

C2.09

Status of AMoRE-II preparation at Yemilab

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Abstract:

The AMoRE project aims at search for the neutrinoless double beta decay of ^{100}Mo isotopes using molybdate scintillation crystals enriched in the isotope ^{100}Mo and a cryogenic detection technique. To reach the experiment's goal, we are trying to advance the current state-of-the-art methods in background rejection, radio-pure crystal growing, and cryogenic radiation detector techniques.
The AMoRE-I, the first phase using about 6 kg of calcium and lithium molybdate crystals, is completed its operation at the Yangyang Underground Laboratory. The next phase, AMoRE-II, will be started at the Yemilab, a new, deeper underground laboratory at Jeongseon, using about 360(157kg) $Li_2{}^{100}MoO_4$ crystals.
This talk will present the preparation status of the AMoRE-II in the Yemilab and plans.

Keywords:

AMoRE, neutrinoless double beta decay, Yemilab, underground physics

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C3.01

Measurement of noise term in JER using random cone method at CMS detector with Run2 data and the asymmetry study of CP violating top quark in dilepton channel

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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, we obtained noise terms by JEC with 30 GeV cut and the various cone size from 0.3 to 0.5. Thus, we can compare the noise term with different JEC and cone size. In this talk, the noise terms in the random cone, based on the full 13 TeV Run2 data samples collected by the CMS experiment, and the current status of comparison with JEC and with various cone size are presented.JER also is an important systematic source in CPV of top quark study. So, we are doing a noise term study and we expect that we can reduce the systematic uncertainties in 2017 and 2018 or round 2 analysis. We have studied CPV of top quark in dilepton channel in parallel. As the first step, we firstly search the asymmetry of top quark in dilepton channel using other variables.

Keywords:

CMS, Noise term, random cone method, JER

Performance of the local reconstruction algorithms for the CMS hadron calorimeter with Run 2 data

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Abstract:

The algorithms used to reconstruct energy deposited in the CMS hadron calorimeter during Run 2 (2015-2018) of the LHC will be presented. During Run 2, the characteristic bunch-crossing spacing for proton-proton collisions was 25 ns, which resulted in overlapping signals from adjacent crossings. The energy corresponding to a particular bunch crossing of interest is estimated using the known pulse shapes of energy depositions in the calorimeter, which are measured as functions of both energy and time. A variety of algorithms were developed to mitigate the effects of adjacent bunch crossings on local energy reconstruction in the hadron calorimeter in Run 2, and their performance is compared.

Keywords:

CMS, HCAL, energy reconstruction, Run2

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C3.03

Reinterpreting Studies with ADL/CutLang

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Abstract:

LHC's high-energy physics (HEP) research has been extensive and varied. However, with the multitude of analysis languages, delving deeply into one another's research has been challenging. To address this, we have developed the Analysis Description Language (ADL). ADL is a domain-specific language that slightly shifts focus from intricate computing languages, providing a more approachable syntax without delving into the complexities of languages like C++ or Python. The runtime interpreter, CutLang, assists in executing ADL on events, streamlining intricate analyses by emphasizing the physics algorithm. Recently enhanced with machine learning integrations and a Jupyter interface for plotting, ADL/CutLang's efficacy has been underscored in LHC analysis validations. This has cemented its position as a pivotal tool for the experimental and phenomenological communities, as evidenced by its application in CMS open data studies and re-interpretation results of SUSY research. In this presentation, we will be discussing the results of re-interpretation studies conducted using ADL.

Keywords:

CERN, CMS, SUSY, ADL/CutLang, re-interpretation

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C3.04

Transformer-based Deep Regression Model for Estimating Missing Transverse Momentum

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Abstract:

We introduce a Transformer-based regression model for estimating missing transverse momentum (MET) at hadron colliders. MET represents an imbalance in the vector sum of transverse momenta for all reconstructed particles and serves as a proxy for invisible particles such as neutrinos and dark matter candidates. The deep learning model takes all reconstructed particles as input and directly performs regression on MET components. This model must capture the complex relationship among the many particles to infer the genuine MET originating from invisible particles. This is necessary because pileup particles and non-perfect detector responses can contaminate the momentum imbalance in a reconstructed event. Thus, the model deploys the Transformer's attention mechanism, enabling the extraction of long-range dependencies among particles. In this presentation, we will showcase the results of applying the Transformer-based model to the Monte Carlo simulation of top quark pair production in the dilepton channel in pp collisions.

Keywords:

hadron collider, deep learning, reconstruction, neutrino, dark matter

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C3.05

Test of the Endcap Timing Readout Chip 2 for CMS MIP Timing Detector Project

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Abstract:

The Endcap Timing Readout Chip (ETROC) is a readout Application-Specific Integrated Circuit (ASIC) for the CMS Endcap Timing Layer (ETL) in the endcap region of the MIP Timing Detector (MTD). The ETROC2 is the first full-size, full-functionality prototype of the future production version of ETROC. ETROC2 features a 16×16 pixel array designed to pair with a 16×16 Low Gain Avalanche Diodes (LGAD) sensor, each pixel having a size of 1.3×1.3 mm^2. The goal of the study is to test the timing resolution to achieve a level of 50 ps with LGAD. In this talk, we present the results of system tests conducted at Fermi National Accelerator Laboratory, which cover precise Time of Arrival (TOA) and Time over Threshold (TOT) evaluation, as well as semi-automatic baseline calibration. In the future, a coarse hit map can be available for every bunch crossing, and the users can define the hits using TOA and TOT information. This work is potentially useful for online occupancy monitoring, luminosity monitoring, as well as potential trigger application.

Keywords:

Endcap Timing Layer, MIP Timing Detector, ETROC2, CMS Phase-2 Upgrade

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C3.06

Assembling Mockup Modules with Robotic Gantry for CMS Endcap MIP Timing Detector

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Abstract:

High-Luminosity LHC (HL-LHC) will enable a more detailed exploration of new phenomena thanks to an anticipated increase in the number of collisions where pileup is expected to reach approximately 200 simultaneous interactions. The MIP Timing Detector (MTD) project for the CMS Phase-2 Upgrade is designed to address pileup mitigation. The MTD is set to provide a timestamp accurate to 30 to 40 picoseconds for every event, ensuring sustained detector performance at HL-LHC. The project incorporates the use of the Low Gain Avalanche Detector (LGAD) sensor and the Endcap Timing Readout Chip (ETROC) within the Endcap Timing Layer (ETL). The ETL detector will require approximately 8 thousand modules, each consisting of 4 LGAD sensors and ETROCs. These modules will be assembled using an automated robotic gantry, which guarantees precise placement at a level of 10 micrometers. In this talk, an overview of the throughput test conducted on mockup modules and the current status at the Fermi National Accelerator Laboratory are reported.

Keywords:

MTD, ETL module assembly, Robotic Gantry, Throughput Test

C3.07

Preproduction and quality assurance of improved RPCs for Phase-2 upgrade of the CMS Muon System

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Abstract:

We report the current status of detector production and the quality-assurance tests of the improved RPCs (iRPCs) which will be added for the future CMS experiment in high-luminosity (HL) LHC runs (Phase-2). In order to ensure endurance of iRPC gas gaps to radiation background, several prototype iRPC detectors have been tested using intensive Cs-137 gamma rays (661.7 keV) provided by a 13 TBq Gamma Irradiation Facility (GIF) at CERN and by a 4.7 GBq source at Korea University. In the current plan, first 50% iRPCs (72 detector modules) will be produced, quality-control tested to be installed at RE3.1 and RE4.1 regions of one side of the CMS muon endcaps during a period of year-end technical stop (YETS) 23/24. The rest iRPCs are planned to be installed in the following YETS period.

Keywords:

Resistive Plate Chambers, Compact Muon Solenoid, Large Hadron Collider, Gamma Iraddiation facility

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C3.08

Efficiency study using Tag and Probe method for the GEM Detector in the CMS Experiment

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Abstract:

In the CMS experiment at the LHC, the Gas Electron Multiplier (GEM) detector has been recently installed to provide for increased trigger efficiency and reconstruction of muons. The precise determination of detector efficiency is paramount for reliability of a detector. The Tag and Probe method employs a "tag" particle as a reference passing a tight identification, paired with a "probe" passing a loose identification, forming a resonance as a pair. The efficiency of a detector is determined by the ratio of probes with detected hits to the total number of probes. We present GEM efficiency using this method, to continually monitor the performance of GEM for further operation.

Keywords:

CMS, GEM, efficiency, TnP, Tag and Probe

C3.09

R&D status of the compact TPC for a high-precision 3D beam diagnostic system

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Abstract:

To measure the three-dimensional (3D) beam profile of electron and ion beams, a compact Time Projection Chamber (TPC) can be a good candidate detector. A compact TPC has been designed with a field cage and gas electron multiplier (GEM) based on the simulation results (Garfield++ and COMSOL). The field cage (FC) has a 1 mm strip pitch and a 1-liter gas volume. The triple-GEM configuration consists of the standard GEM and spacers. The two kinds of readout board (64 and 160 pads) have been made and it connected to the front-end-electronics (FEE) board through the 34-pin ribbon connectors. The DAQ system for compact TPC consists of the FEE boards, DAQ boards, and TCB board. The TCB board is the main control system, which has an external trigger input and optical links, and USB-3 ports to control the DAQ boards. The DAQ board has 36 input channels (4 LEMO-00 and 34 ribbon connectors) and each channel has the preamp, discriminator, TDC (10 bits data, 1 ns accuracy), and ADC (12 bits data, max -2V). The dynamic range of the preamp is about 1 ~ 4.5 pC depending on the resistor. In this talk, we will present the R&D status of the compact TPC for a high-precision 3D beam diagnostic system.

Keywords:

TPC, GEM, field cage, DAQ, beam diagnostic

C4.01

The study of single-photon emitters formed in two-dimensional materials and their coupling to optical structures.

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Abstract:

Single-photon emitters are a fundamental component of quantum communication. Color centers in semiconductor quantum dots, diamond or SiC are widely studied as single photon emitters. Many attempts have been made to integrate them with dielectric optical resonators or plasmonic metal nanostructures to improve the Purcell enhancement and increase the spontaneous emission efficiency. More recently, there has been a growing interest in single-photon emitters formed in two-dimensional materials. The h-BN single-photon emitter, which can emit a single photon at room temperature, has attracted much attention and has been studied. In addition, quantum dot single-photon emitters have been found in TDCs. In this talk, we will present our work on analyzing the interaction of h-BN single-photon emitters with Ag nanowires and experimentally combining them to increase the single-photon emission efficiency. We will also present the results of controlling the position and polarization of single-photon emitters by applying local strain to WSe2 and combining them with photonic crystal resonators.

Keywords:

single photon

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C4.02

Ultra-thin 2D semiconductor waveguide

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Abstract:

The emergence of 2D materials stimulated intensive research on both electronic and photonic applications. Especially, transition metal dichalcogenides (TMDs) provided an excellent platform for photonic applications due to their strong light-exciton interaction. Various photonic devices such as a light-emitting device, laser, and exciton-polariton device have been successfully demonstrated experimentally using TMD monolayers. However, multilayered TMDs have attracted far less attention than TMD monolayers because they become indirect bandgap materials.
Here I propose an ultra-thin exciton-polariton waveguide based on a WS_2 multilayer for sub-wavelength light guiding [1-2]. The waveguide is constructed using a WS_2 multilayer and is designed to guide sub-wavelength light. Remarkably, even with a mere thickness of a few tens of nanometers, the WS_2 waveguide can support guided exciton-polariton modes. We confirmed through theoretical analysis that the WS_2 waveguide exhibits notably lower propagation loss compared to a plasmonic mode, despite having a similar thickness to plasmonic waveguides. Through practical experimentation involving the injection of white light, the functionality of a 20-nm-thick WS_2 waveguide for light guidance is validated. An interesting aspect of the study involves the integration of the WS_2 waveguide with a WSe_2 monolayer, demonstrating the coupling of monolayer emission with the polariton waveguide. This investigation highlights the potential of WS_2 multilayers as an innovative material platform with promising applications in nanophotonics, particularly for the development of ultra-thin optical integrated circuits.

References

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[2] S. W. Lee, J. S. Lee, W. H. Choi, and S.-H. Gong*, Ultra-thin WS_2 polariton waveguide for efficient light guiding, Advanced Optical Materials, DOI: 10.1002/adom.202300069 (2023)

Keywords:

Exciton polariton , Van der Waals materials, 2D semiconductor, Guided polariton, Exciton

C4.03

High-conductivity nanometer-thick transition metals and their applications

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Abstract:

Ultrathin (around ten nanometers or less in thickness) transition metals are capable of enhancing the performance of diverse photonic applications such as transparent electrodes, energy-saving windows, and color filters. Furthermore, these materials demonstrate the capacity for modulating plasmonic resonances within the mid-infrared spectrum (3–30 micron), with the integration of structures designed to achieve phase matching such as subwavelength gratings. This attribute leads to the development of molecular sensors. However, a challenge arises from the intrinsic tendency of transition metals to agglomerate into nanoscale islands across the substrate during the early stage of deposition. This disconnected geometry inevitably impairs their electrical characteristics. In this talk, I will discuss how to reduce the percolation threshold thickness of deposited transition metals, based on graphene as a growth seed layer. Furthermore, I will outline potential applications that can be harnessed from these high-conductivity nanometer-thick transition metals, including thermal management and microwave shielding.

Keywords:

2D plasmonics, nanometer-thick metals, percolation threshold, thermal emissivity

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C5.01

이온 트랩 진동자의 카오스 운동

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Abstract:

본 발표에서는 포획된 이온의 비선형성 제어, 안정적인 끌개(attractor)간의 noise-induced transition과 분기 현상 관측 결과에 대해 보고한다. AC 전기장에 의해 구동된 174Yb+ 이온은 변형된 Duffing 진동자와 같은 움직임을 보이고, 이때 비선형 계수는 포획 포텐셜 조작을 통해 제어 가능하다. 이를 활용하여 비선형성을 억제할 경우 정밀하게 secular frequency를 측정할 수 있다. Bistable 상태로 구동된 이온은 특정 노이즈 성분에 의해 두 개의 안정적인 끌개 간의 천이 현상이 유도되며 이를 확인하였다. 또한 임계치 이상의 전기장으로 이온을 구동하여 카오스 운동과 분기(bifurcation) 현상을 관측하였다. 이러한 현상들은 포획된 이온을 활용한 고감도 노이즈 센싱, 카오스 이론과 같은 동역학 현상 연구에 활용 가능하다.

Keywords:

ion trap, nonlinear dynamincs, quantum computing

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C5.02

Pushing single atoms into an optical resonator

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Abstract:

본 연구에서는 push beam 을 사용해 원자를 공진기에 loading 하는 방법에 대해 보고한다. 공진기 위에 자기 광 포획된 루비듐 원자 구름을 떨어트리고 원자의 공진기 도착 시간 히스토그램을 통해 원자 구름의 온도, 높이, 반지름을 계산하였다. 포획된 원자 구름을 떨어트린 뒤 중력 방향으로의 푸시 빔을 가한 경우, 도착 시간 히스토그램에서 평균 원자 도착 시간이 빨라지고, 도착 시간의 이차 상관 관계 함수를 계산하였다. 원자가 공진기에 도착했을 때 중력 반대 방향으로의 푸시 빔을 가한 경우, 원자가 중력 반대 방향으로 되돌아 가는 공진기 투과 신호를 실시간으로 관측하였다. 본 연구는 공진기 기반 양자 네트워크의 효율 증가에 기여할 것으로 기대된다.

Keywords:

Push beam, Cavity QED

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C5.03

Investigating velocity distribution effects on temporal correlation of photon-pair generated in atomic vapor cell

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Abstract:

Photon-pairs generated within atomic vapor cells is garnering attention as quantum communication light sources due to their narrow frequency spectrum, room temperature operability, system simplicity, and reproducibility. Nevertheless, the Maxwell-Boltzmann velocity distribution of atoms in such cells induces the Doppler effect, an understudied aspect in nonlinear processes. In this study, we investigates how this distribution affects temporal correlations in photon-pairs generated through Spontaneous Four-Wave Mixing(SFMW). Our investigation involves a comprehensive analysis of the second-order coherence function (G^(2)) under two distinct scenarios: one in which the difference in optical wavelengths between the pump and coupling beams is positive, and another in which it is negative. These scenarios are realized by utilizing two different excited states of 133 Cesium. The experiment results agreed well with simulation outcomes when considering the velocity distribution. We hope that this result will be d helpful in designing experiments based on atomic vapor cells by providing an understanding of the coherence phenomenon in atomic ensembles with velocity distribution.

Keywords:

cesium vapor, heralded single photon source, coherence and atomic vapor

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C5.04

Generation, Dynamics, and Interaction of Dipolar Excitations in a Bose-Hubbard System

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Abstract:

For a lattice system with a potential gradient, its Hamiltonian is fragmented when the tilt becomes the dominant energy scale. Such a system is expected to behave in a way that conserves its total dipole moment. Here, we report the experimental realization of a novel dipolar Bose-Hubbard Hamiltonian, which describes the physics of particles in a strongly tilted lattice. Starting from a unity-filled one-dimensional chain of ultracold atoms in an optical lattice, we generate individual dipolar and anti-dipolar excitations at desired pinpoints. We observe quantum walks of these dipolar quasi-particles as well as their scattering dynamics, which allows us to study this new type of Hamiltonian using a bottom-up approach.

Keywords:

Quantum Gas Microscope, Optical Lattice, Dipolar Bose-Hubbard Model

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C5.05

Observation on hydrodynamic behavior of a Bose-Einstein condensate with disordered spin texture

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Abstract:

We experimentally investigate the hydrodynamic properties of a turbulent spinor Bose-Einstein condensate (BEC). We generated turbulent BEC in a spinor ^{23}Na by applying a rf-field that couples between different spin states. The nature of spin turbulence is both stationary and long-lived, providing a time window for characterizing the hydrodynamic properties of the system [1, 2]. By a comprehensive measurement on the spectrum of sound waves and low-lying excitation, we compared the hydrodynamic properties of a turbulent and a non-turbulent BEC. Sound mode, excited by local perturbation and propagating with negligible damping, strongly suggests superfluid nature of the turbulence. Low-lying modes reveal extended temporal evolution dynamics where enhanced damping rates are observed. We propose a model presenting this higher damping rate within the turbulent state. Notably, the hallmark of superfluidity, observable via existence of quantized vortices, has not been identified in the turbulent sample. [3]

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[2] J. H. Jung, J. Lee, J. Kim and Y. Shin, Random spin textures in turbulent spinor Bose-Einstein condensates, arXiv preprint arXiv: 2308.01757
[3] A. Griffin, D. Snoke, and S. Stringari, Bose-Einstein Condensation, Cambridge University Press, Cambridge (1995)

Keywords:

Hydrodynamics, Superfluidity, Turbulence, Collective excitations, Spin excitations

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C6.01

물리·공학통합을 통한 실증로급 디버터 시스템 기반기술 선도연구: 1-2차년도 연구결과

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Abstract:

핵융합선도기술개발사업의 일환으로 한국연구재단의 지원(2022년-2026년)으로 연구를 수행하고 있는 본 연구센터(물리·공학통합모델 기반 디버터 기술 선도센터)는 1) 디버터-플라즈마 물리기반 기술 연구, 2) 디버터 설계/제작 기반 구축, 3) 디버터 성능평가 기술 확립의 세 가지 목표를 가지고 있다. 이를 위해 디버터 자기장 모사장치를 활용한 플라즈마 경계조건 분석, KSTAR텅스텐 디버터 실험을 통한 고성능 디버터 운전조건 제시, 노심-경계-SOL통합 코드 개발 및 전산해석을 통한 디버터 플라즈마 해석 등의 물리기반 기술 연구를 수행하고 있다. 또한, 통합 물리코드 개발을 통한 디버터 형상 설계 기반 확립, 이종재료 접합 기술 성능향상을 통한 디버터 제작 기반 확보, 진단계 및 냉각채널을 포함한 디버터 시스템 설계 및 제작 기반기술 개발 등을 바탕으로 디버터 설계/제조 기반을 구축한다. 디버터 성능평가 기술확립을 위해 입자속 및 열속 부하장치 성능향상, 디버터 구성요소 별 성능평가 기술 개발, 통합 디버터 시스템 성능평가 기술 등을 확보하고자 한다. 본 발표에서는 본 연구센터의 1차년도 및 2차년도 연구결과를 보고한다.

이 논문은 정부(과학기술정보통신부)의 재원으로 한국연구재단의 지원을 받아 수행된 연구임 (No. RS-2022-00155917)

Keywords:

핵융합, 디버터, 핵융합선도기술개발사업

C6.02

Development of new core technologies of heating and current drive for the extreme high temperature and stable sustainment of fusion plasmas

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Abstract:

The stable sustainment of extreme high temperature of plasmas is imperative for nuclear fusion advancement. To achieve this objective, three new core technologies should be developed successfully. The first is to develop H&CD (Heating & Current Drive) schemes and technologies applicable to such extreme fusion plasmas. The second is to develop key simulation tools capable of predicting and analyzing the H&CD effects. The third is to develop the scenario of such extreme plasma modes related with its generation and sustainment by utilizing the new H&CD schemes, simulations, and technologies. Four research groups have collaborated to achieve these goals through Advanced Nuclear Fusion Research Program initiated in 2021. The first group has developed a NIS (Negative Ion Source) based on volume production scheme by using novel two region plasmas for NNB (Negative Neutral Beam) heating, and a new RF current drive scheme and technology by using LHFW (Lower Hybrid Fast Wave) CD applicable to high density and high temperature plasmas. The second group has developed foundational technologies of multi-frequency Gyrotron for versatile EC (Electron Cyclotron) H&CD scenarios in high magnetic field and reactor grade environment using the millimeter-wave and a mirror type launcher. In particular, an innovative design technique has been pursued to ensure high purity of the multi-modes within the Gyrotron's mode convertor based on the meticulous measurement and mapping of the stray radiation. The third group has developed a new Fokker-Planck code in four dimensions capable of dealing with NB and RF H&CD simultaneously, including the synergetic effects. It also aims to predict the self-consistent H&CD effect in the extreme high temperature plasma with neoclassical effects such as bootstrap currents. The last group has developed a new scenario, the so-called FIRE mode, a high performance mode with high NICD (Non-Inductive Current Drive) fraction and without LH transition and related reactor-harmful ELMs (Edge Localized Modes) events. The fast-ion instabilities and turbulent transport in the mode have been analyzed in KSTAR and the stabilization techniques have been studied including NTM (Neo-classical Tearing Mode) suppression. Based on the results, the scenario of the FIRE mode in ITER or DEMO is to be suggested considering the new NNB, LHFW, ECCD schemes, simulation, and technologies. More details of the research status and progress will be presented in the Focus Session of the conference.

Keywords:

2023 KPS Fall Meeting
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C6.03

Advancement of an accelerator-based ion beam irradiation facility for testing and assessment of fusion reactor materials

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Abstract:

Nuclear fusion-based power production has the potential to make a big impact on the fight against climate change. High-energy neutrons generated from nuclear fusion reaction affect the material's substance. The long-term durability of the material suffers as a result. To do this, research facilities that can provide and analyze the experimental data of material damaged by high-energy particles are necessary.
Neutron irradiation research on materials is being carried out at a very-rarely huge facilities like research-reactors or accelerator-based high-energy neutron source, IFMIF. To compensate, heavy ion beam irradiation research has been steadily progressing.

The heavy ion beam irradiation experiment for the material of surface level about ㎛ can closely resemble the high-energy neutron irradiation experiment. The Korea Atomic Energy Research Institute (KAERI) has established a heavy ion beam irradiation facility capable of producing heavy ion beams with varying energies at the highest rate of dpa (displacement per atom) in Korea.

This paper introduces the KAHIF (KAERI Heavy-ion Irradiation Facility) facility that is based on ion-beam accelerator, and provides an advancement for testing and assessment of fusion reactor materials.
KEYWORDS

Keywords:

Ion-beam, Accelerator, KAHIF, material assessment, nucelar fusion

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C6.04

Development of plasma dynamic characteristics representation and analysis techniques for nuclear fusion digital twin

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Abstract:

This study develops a technology that can accurately express and analyze the dynamic characteristics of plasma in order to realize a digital fusion digital twin. We develop numerical schemes and grid technology to efficiently store and express simulation data of large-capacity fusion plasma, and research algorithms with AI and ML technologies to analyze and extract dynamic characteristics of fusion plasma. Also we develop technology to visualize the dynamic characteristics of fusion data for the digital twin platform, and integrate and implement developed algorithms and technologies into Virtual KSTAR.
The technology developed in this study can be used for analysis of nuclear fusion simulation data, experimental verification research, and development of next-generation imaging diagnostic technology for nuclear fusion. It can also be used to develop advanced digital twin technology that enables dynamic data expression and analysis in fields other than nuclear fusion. It is possible to activate interdisciplinary convergence research for nuclear fusion energy development and to secure core software technologies to accelerate the achievement of KSTAR and ITER's research goals and the demonstration of nuclear fusion energy.

Keywords:

Digital Twin, Nuclear Fusion Simulation, Plasma Turbulence Visualization, Virtual Reality, Artificial Intelligence

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C6.05

Permeation and retention of hydrogen isotopes in metal interfaces by experiment and computer simulation

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Abstract:

The transport and inventory of hydrogen isotopes (HIs) affect the safety and sustainability of nuclear fusion reactors. For radiation safety, tritium (T) is radioactive; thus, its leakage must be suppressed to protect workers and the environment. For the integrity of structural materials, HIs are known to cause embrittlement of materials. For the sustainability of the fuel cycle, we need to recover T as quickly as possible and use nearly all T efficiently with minimal loss. Therefore, to realize nuclear fusion power plants after the ITER project, we must establish methods to achieve accurate prediction and thorough management of transport and inventory of HIs.
For this, we need to understand HI behaviors in each component, such as (1) plasma-facing components (W and Cu alloys, including their interfaces), and (2) structural components (reduced activation ferritic-martensitic (RAFM) steels for blanket). However, reliable data related to the inventory and transport, such as diffusion coefficient (DC), solubility constant (SC), and permeability constant (PC), are rarely available for tritium. In addition, HI behaviors at the interfaces are yet to be understood. Therefore, our project aims to develop an efficient and accurate research system combining computer simulations and experiments to acquire HI transport and inventory data and then to acquire the data of important materials and components.
In this presentation, we will report several research results achieved in this project that started in May 2022 for around 3 years. First, we will present the atomistic simulation methods we constructed to accurately calculate the DC/SC/PC of HIs by combining path-integral molecular dynamics and machine-learning potentials. Comparison with experimental data demonstrated that this method can determine DC/SC/PC at an accuracy comparable to accurate experiments for both bcc and fcc metals. Second, we will present experimental results for hydrogen permeation behaviors through several materials, including W, Cu, Ni, and Cu/Ni interface as a model system. Both gas-driven permeation and plasma-driven permeation experiments were performed. Third, we will introduce a rate-theoretical model to quantify the hydrogen permeation rate and retention based on DC/SC/PC data and kinetic/thermodynamic parameters obtained by atomistic simulations for HIs at surfaces and interfaces. The model calculation agreed with the HI permeation experiments, and a significant impact of surfaces and interfaces on HI behaviors was indicated.
This study is supported by National R&D Program through the National Research Foundation of Korea (NRF) funded by the Korea government (Ministry of Science and ICT) (RS-2022-00156222).

Keywords:

Fusion Reactor Engineering, Tritium , Hydrogen Isotopes, W/Cu monoblock

C6.06

Development of Li-M-O-based ceramic pebble for tritium breeding containing high-concentration Li using LiOH precursor

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Abstract:

Tritium breeder, called a pebble, is a lithium-based ceramic material that produces tritium, one of the essential fuels for nuclear fusion.
Lithium has isotopes ^{6}Li and ^{7}Li, and the natural ratio is about 7.5:92.5. During tritium production, ^{7}Li absorbs thermal energy while ^{6}Li releases thermal energy. In order to minimize the loss of thermal energy generated by the nuclear fusion reaction, the ^{6}Li contents in the pebble should be improved.
In this study, it developed that a technology for separating and concentrating ^{6}Li from seawater, and to establish a pebble production technology using enrichment ^{6}Li as a precursor.
^{6}Li concentrated from seawater has the form of $^{6}LiOH$, and by using it as a precursor, Li_4SiO_4 and Li_2TiO_3, which are promising materials for breeder, were synthesized into powder with high lithium density. The pebbles manufacturing technology with physical and chemical stability at operating temperature was developed using the synthesized powders.

Keywords:

Tritium Breeder, High lithium density breeder, Core-shell pebble. Lithium isotope separation, 6Li enrichment

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C7.01

Simulation Study of Neutron Production for NDPS at RAON

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Abstract:

Nuclear Data Production System (NDPS) is one of the experimental systems at the Rare isotope Accelerator complex for ON-line experiments (RAON). It provides high-energy neutrons reaching up to several tens of MeV. The main goal of NDPS is to precisely measure cross sections induced by neutrons, focusing on the energy range that extends over tens of MeV for neutrons. The first beam commissioning of NDPS is planned for the year 2024. Ion beams, such as H, ^{2}H, ^{16}O, and ^{40}Ar, are accelerated using the SuperConducting Linac 3 (SCL3) and transported to the target room of NDPS. By bombarding an ion beam onto the neutron production target, high-energy neutrons will be generated and subsequently provided to researchers for conducting experiments.
For the preparation of the upcoming beam commissioning, simulation investigations are conducted to calculate neutron productions using Monte Carlo particle transport codes, specifically MCNPX, FLUKA and PHITS. By analyzing the simulation results of various combinations of the ion beams target materials and comparing with available benchmark measurements, an optimal combination of ion beam and target is proposed for the beam commissioning.

Keywords:

RAON, NDPS, Beam Commissioning, Neutron Production, Monte Carlo Simulation

Effect of Richardson-Lucy deblurring algorithm to the collective flow parameters in heavy-ion collisions

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Abstract:

Traditionally, the observables related to the collective-flow phenomenon in heavy-ion collisions have been analyzed relative to the estimated reaction plane direction. However, the quality of these observables might be deteriorated by the detection inefficiency and the uncertainty in the reaction plane determination. In optics, the degraded images, which represent the intensity distributions, can be restored by employing the deblurring algorithm. Inspired by the analysis technique in optics, we have analyzed the flow parameters in ^{132}Sn+^{124}Sn collisions at 270 AMeV recorded by the SPiRIT Collaboration and employed the Richardson-Lucy deblurring algorithm to restore the triple-differential particle distributions, which may exhibit different collective-flow features. In this presentation, we present the principle of the deblurring process and the status of the analysis.

Keywords:

Collective flow, Deblurring, Richardson-Lucy algorithm, Reaction plane, SPiRIT

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C7.03

Preparation of the STARK Silicon Detector Array for the Commissioning

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Abstract:

A new barrel type silicon detector array, STARK, has been developed by CENS to conduct experimental researches on the nuclear reaction, nuclear structure, and nuclear astrophysics. It is designed to detect the light charged particles emitted from nuclear reactions in inverse kinematics between radioactive ion beams and target nuclei placed at the center of the STARK array.

The development of the STARK is approaching to the commissioning phase. The detectors, their supporting frame, a dedicated vacuum chamber and the DAQ system have been prepared. When a new target supporting system is designed and manufactured soon, the detection efficiency, and the energy and position resolution of the array will be tested with the radioactive source. A noble Monte-Carlo simulation software utilizing GEANT4 and NPTool libraries is developed as well. Recent updates on its development and future plans will be presented.

Keywords:

Silicon Detector System, Nuclear Experiment, Nuclear Reaction, Nuclear Astrophysics, Nuclear Structure

C7.04

Deep learning to classify and restore particle signals from experiments

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Abstract:

In particle and nuclear experiments, signals recorded by the detector system are accompanied by noises and pile-ups. This feature complicates the data analysis, particularly if the data structure is complicated and has a large number of signals. However, the conventional rule-based methods have limitations for cases where no explicit rules exist. Here, we first utilize deep learning to classify signals into particle, noise, and pile-up (particle+noise) signals to eliminate the noise signals in the experimental data. Then, we use the idea of denoising autoencoder to restore the original signals from the pile-ups. By doing so, we achieved much higher energy and timing resolutions of signals. This is vividly shown in the PID plots and track images reconstructed from the signals.

Keywords:

deep learning, machine learning, time projection chamber, pile-up

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C7.05

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 to separate kaons from pions between 700 and 800 MeV/c. It identifies the kaon beam just upstream of the target. For high light collection efficiency, we use silica aerogel with a refractive index of 1.115, a parabolic reflector, and four MPPC arrays. We tested the prototype using a 1 GeV/c positron beam and verified the consistency of the beam test results with the optical simulation results using Geant4. To improve the signal-to-noise ratio level and facilitate the installation and operation, we upgraded the detector and tested it using 1.2 GeV/c kaon and pion beams at J-PARC. We will report on the current R&D status and the expected performance at the E72.

Keywords:

silica aerogel, Cherenkov detector, J-PARC

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C7.06

40Ar Beam Commissioning of KoBRA for Rare Isotope Production at RAON

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Abstract:

A multi-purpose experimental instrument, called KoBRA (Korea Broad acceptance Recoil spectrometer and Apparatus), was constructed at the Institute for Rare Isotope Science (IRIS), as a part of the RAON facility in Korea. Stable or rare isotope (RI) beams can be produced using Electron Cyclotron Resonance (ECR) ion sources or the Isotope Separation On-Line (ISOL) system at RAON, and these beams can be delivered to KoBRA at energies of 1 – 40 MeV per nucleon via the SuperConducting Linear accelerator 3 (SCL3).
Currently, KoBRA is undergoing beam commissioning phase for the purpose of producing rare isotope beams at an energy of about 20 MeV per nucleon. The first test with 40Ar stable ion beam was completed in June 2023. In this presentation, we report on the recent activities for beam commissioning of KoBRA, together with the result of rare isotope production.

Keywords:

RAON, KoBRA, Beam Commissioning, Rare Isotope Production

C7.07

Development of Low-pressure Gas TPC for Stellar Nucleosynthesis Reactions

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Abstract:

We develop an active-target Time Projection Chamber (aTPC) for stellar nucleosynthesis reactions. The aTPC will measure a low-energy ^{16}O recoil track in the $^{12}C(\alpha,\gamma)^{16}O$ reaction in a 2.5 T magnetic field. 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 cm^2 with 1000 3x3 mm^2 square pads. The construction of the detector is in progress, and the expected performance is verified using Geant4 and Garfield++ simulation. This talk will present the current R&D status and the results of several performance tests.

Keywords:

active-target time projection chamber, low-pressure, stellar nucleosynthesis, GEM

C7.08

Improvement of the analysis of the performance of the prototype Beam Drift Chamber (pBDC) for the LAMPS experiment with the beam from HIMAC

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Abstract:

The Beam Drift Chamber (BDC) is designed to reconstruct the beam trajectories for the Large Acceptance Multi-Purpose Spectrometer (LAMPS), which is the detector system for the investigation of the density dependence of the nuclear symmetry energy, with the rare isotope beam produced by the Rate isotope Accelerator complex for ON-line experiments (RAON).
To study the performance of BDC for LAMPS with irradiated beam, prototype BDC is made and tested with the proton and Carbon beams at HIMAC, Japan.
In this presentation, we present the improvement of the algorithm for a more precise analysis of data in BDC.

Keywords:

LAMPS, RAON, BDC, drift chamber, gaseous detector

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C7.09

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. We tested the performance of the prototype array using radioactive sources (60Co, and AmBe). We also measured capture gamma rays from Al(p,g)Si reaction from Ep=2.040 to Ep=2.080 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

Extreme-ultraviolet superradiance from helium atoms

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Abstract:

"Superfluorescence" is commonly understood as a form of superradiance which occurs in an extended medium following a rapid initial incoherent excitation, with the classic experimental realisation being emission of directional bursts of radiation following the passage of a short pulse of laser light through a gasous atomic sample. This was the setup for the first experimental observation of a superradiant process.
Free-electron laser sources are well-suited to this application since they offer intense ultrafast pulses which can be used to rapidly create a high density of excited atoms.
Following a brief overview of this and related work, we will present results observed using the EUV free-electron laser located at SPring-8, including:-

- visible wavelength superfluorescence following excitation of helium atoms to 1s3p or 1s4p states, revealing simple superfluorescence, cascade superfluorescence through multiple levels, and competitive superfluorescence
- superfluorescence at visible and EUV wavelengths following excitation of helium ions to 3p or 4p states, revealing cascade emission, backwards emission, and related effects such as free-induction decay
- 'yoked' superfluorescence in this system, understood to be due to the coherence in the initial excitation

prospects for extension to shorter wavelengths and different systems

Keywords:

superfluorescence, superradiance, free-electron laser, helium

C8.02

Coherent driving of superfluorescence by a continuous-wave laser

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Abstract:

Surperfluorescence (SF) is collective spontaneous emission wherein radiators spontaneously synchronize, resulting in an intense single-pulse emission. Because SF is driven by fluctuations in a vacuum field, its phase is random from shot to shot. We demonstrate that this phase can be controlled by driving the SF with a resonant continuous-wave (CW) laser. Using a femtosecond laser, rubidium (Rb) atoms contained in a heated glass cell were excited from the 5S ground state to the 6P state. The 2.73 μm and 1.37 μm SF fields were generated on the cascaded decay, 6P→6S→5P, which stimulated the 780 nm forward emission on the 5P→5S transition. By applying a CW laser resonant to the 6S→5P transition, the 1.37 μm SF field was coherently driven. At the same time, the peak intensity of the CW laser was amplified by eight orders of magnitude via SF, indicating that SF serves as a quantum optical amplifier.

Keywords:

Superfluorescence, Superradiance, Nonlinear optics, Cross-correlation measurements

C8.03

Super-radiance and fundamental physics

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Abstract:

Coherent phenomena have many potential applications in fundamental physics using atoms and molecules. For example, they are useful for EDM detection and APV measurement. We plan to determine neutrino masses and search for axions by applying coherent amplification techniques to rare processes. Solid targets with long decoherence time are desirable for these studies. Recently, observation of super-radiance from Er^{3+} ions doped in a Y_2SiO_5 crystal (Er:YSO) has been reported. This result indicates that an Er:YSO crystal is a solid target suitable for studying coherent phenomena. We found that the super-radiance pulses in an Er:YSO crystal have a quasi-periodic time structure. Focusing on the periodicity, we refer to this phenomenon as “periodic super-radiance”. We will report its detailed properties, such as a period and a photon number, along with a theoretical model which qualitatively reproduces these features. Future prospects of neutrino mass measurement and axion search will be also given.

Keywords:

super-radiance, rare-earth doped crystal, fundamental physics using atoms

Dynamic switching of neural oscillations in the prefrontal-amygdala circuit for naturalistic freeze-or-flight

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Abstract:

The medial prefrontal cortex (mPFC) and basolateral amygdala (BLA) are involved in the regulation of defensive behavior under threat, but their engagement in flexible behavior shifts remains unclear. Here, we report the oscillatory activities of mPFC-BLA circuit in reaction to a naturalistic threat, created by a predatory robot in mice. Specifically, we found dynamic frequency tuning among two different theta rhythms (~5 or ~10 Hz) was accompanied by agile changes of two different defensive behaviors (freeze or flight). By analyzing flight trajectories, we also found that high beta (~30 Hz) is engaged in the top-down process for goal-directed flights and accompanied by a reduction in fast gamma (60-120 Hz, peak near 70 Hz). The elevated beta nested the fast gamma activity by its phase more strongly. Our results suggest that the mPFC-BLA circuit has a potential role in oscillatory gear shifting allowing flexible information routing for behavior switches.

Keywords:

Neural oscillations, Neural synchrony, EEG, Brain, Oscillations

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C9.02

Human Brain Fluctuates between Internal and External Modes of Dynamics

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Abstract:

Although Internal or top-down oriented mode (where the information flow in the brain is from the higher-order hub area to the peripheral sensory area) and external or bottom-up oriented mode (where the information flows from the peripheral area to the hub area) and their transitions have been suggested using neuroimaging, their electrophysiological signatures are relatively unknown. We present results from multiple EEG (electroencephalography) data sets exhibiting phase dynamics that correspond to top-down or bottom-up modes for most of the time points during the conscious awake state. However, during the unconscious state induced by general anesthesia, the phase dynamics become random without distinct patterns, showing that these two modes only arise when the participant is conscious. We demonstrate canonical coupled oscillator models of large-scale cortical dynamics reproduce transitions between two distinct and dominant modes: one in which high-degree mid-line cortical regions phase-lag the network becoming sink of the directionality, and one in which they phase-lead the network and become the source of the directionality. Our EEG analysis and models suggest the working hypothesis that the relative phase of 4-20Hz oscillations switches rapidly across the human cerebral cortex in the conscious awake state, with opposite phase patterns corresponding to bottom-up and top-down modes. We conclude that the internal/external (top-down/bottom-up) modes are the basic constituents of human brain dynamics.

Keywords:

Human brain, State transition, Phase dynamics, EEG, fMRI, internal vs. external modes

Geant4 simulation of Single and Double Strand Breaks in a Human Fibroblast Cell due to Irradiation from Therapeutic Radiopharmaceuticals

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Abstract:

Modelling the damage to DNA molecules by ionizing radiation plays a crucial part in predicting the biological effects of any form of radiation therapy, but the creation of accurate damage models remains scientifically challenging. This study evaluated the frequency and severity of DNA strand breaks caused by direct and indirect radiation effects using the Geant4 DNA simulation toolkit. The DNA itself was represented as a continuous fractal Hilbert curve with a total length of approx. 6.4 Gbp, consisting of straight and twisted chromatin sections placed inside a simplified model of a human fibroblast cell. Using At-211 and Ac-225, both alpha-emitting radionuclides employed in radiopharmaceutical treatment, the results were compared to those from external irradiation with 1.5 MeV gamma rays. For each Gy of absorbed dose, the strand break yields were 103 ± 10 SSBs/Gbp and 15 ± 4 DSBs/Gbp for At-211, 96 ± 10 SSBs/Gbp and 15 ± 4 DSBs/Gbp for Ac-225, as well as 198 ± 14 SSBs/Gbp and 7 ± 3 DSBs/Gbp for the gamma rays. Thus, the radionuclides exhibited more than double the incidence of DSBs at the expense of SSBs compared to the gamma radiation. By demonstrating the feasibility of adapting the Geant4 DNA toolkit for in silico studies of the radiobiological effects of therapeutic radiopharmaceuticals at the DNA level, this study is the first step towards the development of a comprehensive simulation model for determining the relative biological effectiveness of radiopharmaceuticals.

Keywords:

DNA damage, Geant4-DNA, Monte Carlo simulaton, At-211, Ac-225

General Kinetic Model for GPCR-based Olfactory Sensing: Elucidation of Odorant Mixture Effects and Agonist–Synergist Threshold

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Abstract:

We present a general chemical reaction network theory for olfactory sensing processes that employ G-protein-coupled receptors (GPCRs) as olfactory receptors (ORs). The theory is applicable to general mixtures of odorants and an arbitrary number of ORs. Reactions of ORs with G-proteins, both in the presence and the absence of odorants, are explicitly considered. A unique feature of the theory is the definition of an odor activity vector consisting of strengths of odorant-induced signals from ORs relative to those due to background G-protein activity in the absence of odorants. It is demonstrated that each component of the odor activity defined this way reduces to a Michaelis-Menten form capable of accounting for cooperation or competition effects between different odorants. The main features of the theory are illustrated for a two-odorant mixture. Known and potential mixture effects, such as suppression, shadowing, inhibition, and synergy are quantitatively described. Effects of relative values of rate constants, basal activity, and G-protein concentration are also demonstrated.

Keywords:

Olfactory sensing, Reaction theory, Widespread inhibition, Competitive antagonism

C9.05

Bend-induced Phase Coexistence and Hysteresis of Heterogeneous Ring Polymers

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Abstract:

Semi-flexible polymers, such as microtubules, actin filaments, and DNA, often adopt a ring topology and play critical roles in both biological and synthetic systems. The flexural stiffness along these bio-polymers can be altered by various factors, leading to anisotropic shapes and mechanical instabilities. However, the presence of heterogeneity in polymer stiffness along their strands presents challenges in establishing an analytical theory. In this study, we propose an extension of Euler-Kirchhoff's theory to account for heterogeneous two-state polymers. Specifically, we provide an exact solution for ring polymer configurations, along with a methodology to address boundary condition problems. Focusing on the two-state polymer model, where the fraction of each state can dynamically change, we identify buckling and kinking transitions that drive various phases, displaying phase coexistence and hysteresis. The theoretical findings are validated through numerical simulations, and we demonstrate the applicability of our theory to a realistic polymer model, oxDNA. We envision our theory being used to estimate the bending energy and configurations of heterogeneous stiff polymers effectively.

Keywords:

ring DNA, heterogeneous polymer, theory of Elastica

C9.06

Modeling facilitated diffusion of DNA-binding proteins using Markov chains and Hi-C matrix with applications to E. coli DNA

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Abstract:

The precise binding of DNA-binding proteins to their target sequences is critical for various biological processes, including gene expression and DNA repair. Despite extensive research, understanding the in vivo target search mechanism that considers DNA structure and protein's facilitated diffusion remains a challenge. Here, we present a novel Markov chain model that investigates facilitated diffusion within the in vivo DNA structure, using *E. coli* DNA as a case study. Our model enables one to calculate the mean first passage time and mean recurrence time for DNA-binding proteins on all DNA segments, accounting for various association-dissociation rates between the protein and DNA segments. Our results demonstrate that the sequencewise target search mechanism is significantly affected by both the 3D structure of DNA and the association-dissociation strategy of DNA-binding proteins. By comparing our findings with experimental transcription data, we suggest that the association rate to target sequences cannot be solely explained by first passage dynamics, which has been a primary focus in previous studies. Instead, we propose that the collision frequency between proteins and target sequences is a primary factor for a transcription mechanism. Furthermore, our analysis shows excellent agreement between the theoretical transcription rate obtained from our model and experimental data. In conclusion, we highlight the importance of interplay between DNA structure and protein's facilitated diffusion to quantitatively understand the target search mechanism.

Keywords:

Target search, Markov chain, Hi-C, Facilitated diffusion

First-principles study of electronic structures and magnetic properties of $Pb_9Cu(PO_4)_6O$

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Abstract:

Copper-substituted oxypyromorphites, $Pb_{10-x}Cu_x(PO_4)_6O$, received attention very recently. Here we report electronic structures and magnetic properties of $Pb_9Cu(PO_4)_6O$ obtained by the density functional theory (DFT) and the DFT+U method. Considering nonmagnetic, ferromagnetic, and antiferromagnetic phases, we discuss their electronic band dispersions, magnetic moments, and differences in the total energy. We compare results of DFT and results of the DFT+U method to figure out effects of Coulomb repulsion among Cu *d* orbitals. We discuss very narrow bands near the chemical potential and the stability of magnetic phases. This work is supported by the 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:

oxypyromorphite, Pb9Cu(PO4)6O, density functional theory, electronic structure, magnetic property

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C10.02

First-principles study of atomic and electronic structures of nickelates

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Abstract:

It was reported that $Nd_{0.8}Sr_{0.2}NiO_2$, an infinite-layer nickelate, showed superconductivity with an onset at 14.9 K and $La_3Ni_2O_7$ showed superconductivity near 80 K at the pressure of about 20 GPa. These materials have two-dimensional square lattices of Ni atoms stabilized by O atoms. Here, we study atomic and electronic structures of nickelates such as $NdNiO_2$, $LaNiO_2$, and $La_3Ni_2O_7$ using the density functional theory (DFT) plus U method. We compare atomic and electronic structures of these materials with a focus on Ni d-orbitals in their electronic structures. This work is supported by the 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:

Superconductivity, Nickelates, Density functional theory

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C10.03

Three-dimensional flat bands in pyrochlore metal $CaNi_2$

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Abstract:

The investigation of complex atomic geometries in materials has attracted significant attention due to their ability to exhibit exotic electronic states. One of the most prominent example is the electronic flat band arising from the suppressed electron kinetic energy in such systems. So far, the experimental realization of electronic flat bands has been limited to (quasi) two-dimensional (2D) crystalline materials such as twisted bilayer graphene and the kagome lattice. Consequently, a question that naturally arises is whether the flat band can exist in the three-dimensional (3D) system while remaining dispersionless dispersion along all momentum directions k_x, k_y, and k_z. To answer these questions, we conducted angle-resolved photoemission spectroscopy (ARPES) experiments on the C15 Laves phase $CaNi_2$, which consists of a Ca diamond network and a Ni pyrochlore network. We observe a partial and nearly ideal 3D flat bands below the Fermi level. Moreover, we find that the energy of the flat bands and their dispersion can be modulated through chemical substitution, specifically by replacing Ni with Rh, ultimately resulting in the flat band aligning with the Fermi level. Interestingly, the emergence of superconductivity is observed in $CaRh_2$, where the flat band is located at the Fermi level. Although direct experimental evidence demonstrating flat-band induced superconductivity is still elusive, our results offer a promising material platform for investigating novel emergent phenomena originating from the divergent density of states associated with 3D flat bands in complex lattice systems.

Keywords:

Flat band, Geometrical frustration, Kagome, Pyrochlore, Superconductivity

C10.04

Higher-Order Topological Superconductivity for 1T'-MoTe2

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Abstract:

The metal dichalcogenides MoTe2 is known to be a second-order topological insulator when it is at the monoclinic 1T' phase. Below the critical temperature, this material shows zero-bias conductance peaks when using point-contact Andreev reflection spectra is used. The fitting of these experimental finding with the Blonder-Tinkham-Klapwijk model shows that the s+p wave pairing potentials are the most compelling candidate for the superconductive pairing functions. The purpose of this presentation is to present a theoretical interpretation of these experimental findings. Using a model tight-binding Hamiltonain and a surface Hamiltonian, which stems from the Dirac approximation of such Hamiltonian, we find numerical and analytical results of the 1T' MoTe2. This Hamiltonain of a second-order topological insulator is then, using the Bogoliubov-de-Gennes method, expanded to that of a superconductor. After calculations regarding all possible s- and p- wave pairing potentials, it is found that the hinge states of the second-order topological insulator will, for some p-wave pairing potentials, expand to become Majorana fermions. The tight-binding Hamiltonians of the superconductors will give density of states which give peaks at zero-energy, which also allign with experimental findings.

Keywords:

Higher-order topology

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C10.05

Reversible hydrogenic control of the superconducting state in La2-xCexCuO4 thin films

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Abstract:

High temperature superconductivity observed in cuprates originates from hole or electron doping of parent Mott insulators. Among the electron-doped cuprates, $La_{2-x}Ce_xCuO_4$ shows one of the highest superconducting transition temperature (T_c) of ~30 K to be reported in the electron-doped system [1], and their superconductivity emerges only at appropriate doping concentrations of Ce (x = 0.06 – 0.17) [2]. In this study, to investigate the variation of the superconducting states, we used the hydrogen spillover method to intercalate hydrogen ions into epitaxial $La_{2-x}Ce_xCuO_4$ thin films, which can induce an electron doping effect [3]. Since hydrogen ion has the smallest ionic size among existing ions, it facilitates reversible injection and extraction without causing significant structural collapse. We show that by annealing the thin film in a gaseous mixture of H_2 (5%) + N_2 (95%) at a temperature of 200℃, which is relatively lower than the conventional temperature window of oxygen vacancies formation, it is possible to realize electron doping effect which causes a large change in superconducting properties. Especially in the optimally doped sample (x = 0.11), the reversible superconductor-insulator transition is realized by the annealing process. Our aim is to systematically control the hydrogen ion concentration to modify the superconductivity and investigate whether it could establish or expand a new chemical doping window.

[1] M. Naito, et al., *J. Appl. Phys.* **39**, L485-L487 (2000)
[2] K. Jin, et al., *Nature*. **476**, 73-75 (2011)
[3] H. Yoon, et al,. *Nat. Mater.* **15(10),** 1113-1119 (2016)

Keywords:

hydrogenic control, reversible superconductor-insulator transition, electron-doped cuprate, high-Tc superconductor, La2-xCexCuO4 thin film

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C10.06

Electron-phonon coupling of Nb-doped $SrTiO_3$ by ab initio calculations using jellium model

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Abstract:

Doped $SrTiO_3$(STO) is a highly dilute bulk systems with a superconducting ground state. As such, the applicability of the BCS-Eliashberg paradigm is highly uncertain. However, recent experimental reports have observed the BCS pairing gap to T_c ratio for the superconductivity in Nb-doped STO. Motivated by these reports, we study Nb-doped STO by density functional theory. To describe low concentration doping, we adopt the jellium model which is in good agreement with experimental phonon data for Nb-doped STO. We obtain changes in frequency and electron-phonon coupling strength for each mode of the lowest transverse-optical phonon, which is actively investigated as the main source for the instability to superconductivity using EPW code. Furthermore, we discuss the effect of the doping concentration on the electron-phonon coupling in the jellium model

Keywords:

SrTiO3, n-type doping, superconductor, DFT, electron-phonon coupling

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C10.07

Current-driven motion of magnetic topological defects in ferromagnetic superconductors

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Abstract:

Recent years have seen a number of instances where magnetism and superconductivity intrinsically coexist. Our focus is on the case where spin-triplet superconductivity arises out of ferromagnetism, and we make a hydrodynamic analysis of the effect of a charge supercurrent on magnetic topological defects like domain walls and merons. We find that the emergent electromagnetic field that arises out of the superconducting order parameter provides a description for not only the physical quantities such as the local energy flux density and the interaction between current and defects but also the energy dissipation through magnetic dynamics of the Gilbert damping, which becomes more prominent compared to the normal state as superconductivity attenuates the energy dissipation through the charge sector. In particular, we reveal that the current-induced dynamics of domain walls and merons in the presence of the Gilbert damping give rise to the nonsingular 4π and 2π phase slips, respectively, revealing the intertwined dynamics of spin and charge degrees of freedom in ferromagnetic superconductors.

Ref: Se Kwon Kim and Suk Bum Chung, arXiv:2305.13564

Keywords:

ferromagnetic superconductor, emergent gauge field, domain wall, meron

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C10.08

Understanding Unconventional High Temperature Superconductivity in the Three-Band Hubbard Model for Cuprate Ladders: A Density Matrix Renormalization Group Study

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Abstract:

After the discovery of cuprate high-temperature superconductivity in 1986, the underlying mechanism in the cuprates remains one of the longest-standing mysteries in physics despite more than thirty years of comprehensive study and research. One feasible minimal model for real cuprates that can be considered by many theorists is the doped two-leg single band Hubbard model in which superconducting pair-pair correlations decay slower than $1/r$, implying that superconducting quasi-long range order dominates over charge and spin correlations. While the Luther-Emery superconductivity is known to be a dominant phase in the doped one-band ladder, recent numerical study of the more generic three-band model found the absence of superconducting phase on the realistic sets of parameters most relevant to the hole-doped cuprates. We present Density Matrix Renormalization Group (DMRG) calculations of the spin gap, pair-binding energy, and superconducting pair-pair correlation functions on the various three-band hole- and electron-doped Cu_2O_3 ladders. The strong doping asymmetry of superconductivity found in our DMRG calculations is opposite to the earlier experimental findings of hole- and electron-doped real cuprates. The validity of one-band Hubbard model to superconductivity is now being seriously questioned. We shall discuss that unconventional superconductivity in the two-dimensional and ladder cuprates can be understood in the valence transition approach closely associated with negative charge transfer gaps.

Keywords:

Hubbard model, strongly correlated system, unconventional superconductivity, density matrix renormalization group

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C10.09

Collective mode across the BCS-BEC crossover in Holstein model

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Abstract:

We present the collective mode emerging in bosonic spectra for the Holstein model with a superconducting state in terms of the variation of the electron-phonon coupling. The dynamical mean field theory (DMFT) was employed in combination with the numerical renormalization group (NRG) technique to investigate the phonon spectra and the density-density correlation function. In the superconducting state with a pairing gap Δ, the collective mode exhibits a gradual transition from the Bardeen-Cooper-Schrieffer (BCS) regime with a weak electron-phonon coupling to the Bose-Einstein condensation (BEC) regime with a strong coupling through the crossover regime with an intermediate coupling. In the BCS regime, the collective mode appears close to $\omega \simeq 2\Delta$ in the bosonic spectra with its frequency increasing as the electron-phonon coupling gets stronger. Conversely, in the BEC regime, the collective mode decreases with increasing coupling, proportional to the superfluid stiffness. This mode was interpreted as originating from the phase fluctuation of local pairs, referred to as the Anderson-Bogoliubov mode. In the crossover regime, the collective mode follows the soft phonon mode (ω_s) renormalized by the phonon self-energy, showing a decrease in frequency for $\omega_s < 2\Delta$. To our knowledge, this result is the first report to show the spectral evolution of the collective mode in the superconducting state across the BCS-BEC crossover. We also explore potential experimental methods such as inelastic X-ray scattering, Raman spectroscopy, and electron energy loss spectroscopy to observe the collective mode in condensed matter systems.

Keywords:

collective mode, BCS-BEC crossover, Holstein model

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C11.01

Engineering the Phonon Transport through Phase Discontinuity in Oxide Superlattices

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Abstract:

Nano-phononic material, such as a superlattice (SL) offers the promise of engineering nano-scale heat transport by adjusting their geometric parameters. By increasing the interface density in SLs, it is possible to achieve ultra-low thermal conductivity which is significantly lower than the alloy-limit. However, the wave interference effect resulting from the artificial periodic structure in SLs limits the lowest thermal conductivity in SLs due to the coherent nature of phonon transport. In this study, we demonstrate the modulation of coherent phonon transport in SLs by adjusting both the interface density and the phonon mean free path. We synthesized atomically flat SLs composed of metallic $SrRuO_3$ (SRO) and insulating $SrTiO_3$ (STO) with varying interface densities and investigated their structural phase and phonon transport using second harmonic generation, Raman spectroscopy, and time-domain thermoreflectance technique. By changing the interface density, we observed a coherent-incoherent crossover of phonon transport, accompanied by a structural phase transition. Furthermore, we discovered that the presence of a polar phase in the STO layer can reduce the phonon mean free path, resulting in the weakening of phonon coherence. Our findings will provide a new controllable degree of freedom for engineering the nano-scale heat transport in SLs. We believe that it could potentially overcome limitations in achieving ultralow thermal conductivity, thereby contributing to the development of highly efficient thermoelectric devices.

Keywords:

Superlattice, SrRuO3, SrTiO3, Thermal trasnport

C11.02

Epitaxial Growth and Electron Doping of WO_3 Thin Films by Hydrogen Annealing

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Abstract:

Tungsten trioxide (WO_3) exhibits a wide range of functionalities and can be modified through hydrogen or alkali-metals intercalation, resulting in various property changes [1, 2]. An interesting observation is that modification by doping with light elements can induce unexpected superconductivity [3]. However, the underlying mechanism remains unknown. To investigate this unexplored phenomenon, we study electron doping effects in H_xWO_3 thin films on $YAlO_3$ $(110)_o$ substrates. The films are synthesized by using pulsed laser deposition, and treated by hydrogen gas annealing at several selected temperatures. During the annealing process, electron doping is achieved, as identified by in-situ resistance measurements and coloration of the samples. X-ray diffraction analysis reveals larger lattice parameters and higher symmetry compared to the pristine. Moreover, the ferroelastic twin structure [4] observed via atomic force microscope disappears on the annealed thin films. DC resistance and magnetoresistance measurements of the annealed thin films exhibit Mott's variable-range hopping conduction and a crossover between negative and positive magnetoresistance states at low temperatures, depending on the annealing conditions. These findings demonstrate that electron-doped WO_3 can be achieved through hydrogen annealing. It contributes to a comprehension of electronic behaviors in doped WO_3.

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Keywords:

Tungsten oxide(WO3), Hydrogen annealing, Variable range hopping(VRH), Magnetoresistance(MR)

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C11.03

Observation of hidden domain and polar structures in Bi_2WO_6 thin films and their electric properties

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Abstract:

Topological polar textures have promise as alternative devices for future information technology [1]. Easy planar isotropy helps to promote rotating structures and, accordingly, to facilitate access to nontrivial textures. Unlike other textures which consist of spin or berry connection vectors in real or momentum spaces, the lack of ferroelectric model materials has made research difficult. For this reason, we investigate the domain structure of an epitaxial bismuth tungsten oxide (Bi_2WO_6) thin film which is a candidate for having polar structures. By using angle-resolved piezoresponse force microscopy [2-4] and scanning transmission electron microscopy, we find the existence of a hidden phase with ⟨100⟩-oriented ferroelectric polarizations in the middle of the four variant ⟨110⟩-oriented polarization domains, which assists in the formation of flux closure domains [5]. The results suggest that this material expands the research field and is one step closer to becoming an isotropic two-dimensional polar material. Furthermore, we made several epitaxial thin films that show atomically flat surfaces and were able to find locations showing current enhancement at suspected topological defect locations in the Bi_2WO_6 thin films by using conductive atomic force microscopy. Our findings provide a useful playground for using ferroelectric topological textures in next-generation memory.

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Keywords:

ferroelectric domain, topological polar structure, bismuth tungsten oxide, piezoresponse force microscopy, scanning transmission electron microscopy

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C11.04

Real-time measurement of structural and electrical properties of $PrBaCo_2O_{5+x}$ as a function of oxygen contents

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Abstract:

$PrBaCo_2O_{5+x}$(PBCO) is an A-site double perovskite that is well-known for fast oxygen diffusion at the moderate temperature. In this presentation, we show our measurement results of the structural and electrical properties of PBCO polycrystals in topotactic transition and elucidate oxygen diffusion pathway and effect of strain in the transition. With polycrystalline PBCO, we observed '(oxygen-rich) Tetragonal (T_1) – Orthorhombic (O) – (oxygen-deficient) Tetragonal (T_2)' phase transition depending on oxygen contents, and simultaneously probe the changes in the electrical properties using in-situ X-ray scattering/transport setup and real-time neutron scattering. Both in-situ X-ray diffraction and in-situ neutron scattering confirmed that the structural phase transition due to the redox reaction was reversible. In-situ dc transport was also performed to measure the electrical properties on PBCO. The resistance of PBCO shows colossal differences as a function of oxygen content. It also shows reversibility. The result of detailed analysis about structural information including information on oxygen diffusion will be discussed.

Keywords:

Double perovskite, Topotactic phase transition, In-situ XRD, In-situ neutron scattering, In-situ dc transport

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C11.05

Understanding oxygen defect transport in Ca-doped bismuth ferrite thin films

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Abstract:

A comprehensive understanding of defect transport is essential for numerous future applications. The unique properties of Ca-doped bismuth ferrite (BCFO) make it a promising material for investigating collective ion migration[1-3]. In this study, we employed both non-destructive and destructive techniques to determine the ionic conductivity of BCFO thin films grown on $SrTiO_3$(100). To unravel the ionic conduction mechanism of BCFO, we utilized electrochemical impedance spectroscopy with varying magnitudes of AC voltage. By employing the mixed conductor equivalent circuit model, we successfully determined the ionic conductivity, which exhibited converged conductivity at high electric fields and the lengthy channels. Moreover, we visualized the ionic conductivity of BCFO through electroforming experiments with DC voltages. The results obtained from these diverse methods provided valuable insights into the ionic conduction mechanism within solid materials.

References

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Keywords:

oxygen vacancy, ionic conduction, Electrochemical impedance spectroscopy, Electrochromism

C11.06

Optimization of voltage pulse train for conductance modulation through polarization switching control in a ferroelectric transistor for a neuromorphic computing

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Abstract:

The learning accuracy of neuromorphic computing which mimics the biological brain, is affected by the conductance-modulation characteristics of an artificial synapse. In ferroelectric-based devices, these characteristics are implemented using a distribution of polarization values. Therefore, we investigate the distribution in a ferroelectric thin film with various external voltage signals. As polarization switching proceeds, the domains of the switched polarization become larger. The channel layer assumed to lie beneath experiences a local conductance change, according to the polarization distribution of the ferroelectric layer. We find that small clusters with high conductivity become large clusters. Eventually, the high-conductive regions connect (i.e., percolate) in the channel layer and the conductance of the layer is greatly increased. Adjusting the height of the applied voltage can slow down or speed up this phenomenon. We demonstrate that conductance modulation is optimized with an appropriate voltage pulse train pattern.

Keywords:

neuromorphic computing, learning accuracy, ferroelectric transistor, conductance modulation, polarization switching

C11.07

Temperature dependence of S=1 EMR centers in a neutron irradiated diamond

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Abstract:

The S=1 centers in neutron or electron irradiated diamond have been extensively studied [1-5]. The electron magnetic resonance (EMR) spectra of a neutron irradiated diamond with a dose of 10^{18} neutrons/cm^2 were quite complicated, due to many EMR signals including strong and overlapping ones near g=2.0 and ones from two or more S=1 centers [5]. We investigated the temperature dependence of the EMR signal intensities of two S=1 centers, including the previously published results [5]. The EMR signal intensity of a S=1 center, R1 [5] or the N-V center [4], with the zero-field splitting (ZFS) parameter of $|D_{zz}|$ ~ 2.8 GHz and the principal Z axis parallel to [994], decreased monotonically as the temperature increased. However, the other S=1 center, R2 [5] with neary the same ZFS parameters as R1, and the principal Z axis of ZFS parallel to [100], had the maximum signal intensity near 270 K [5]. We will discuss possible models for the different EMR signal intensity behaviors of the two centers with respect to temperature.
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Keywords:

Defectes in neutron irradiated diamond, S=1 center.

C12.01

Accelerating materials discovery through machine learning approaches

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Abstract:

Searching for materials with targeted properties is a nontrivial task due to enormous search space, originating from infinitely many combinatorial possibilities of atomic species from periodic table. Such time-consuming effort can be subtantially expedited through machine learning (ML) approaches, which enables accelerated materials screening. In this talk, I will describe how ML can be efficiently utilized in discovering energy storate materials. As is well conceived, the demand for high performance energy materials is ever increasing for various applications including portable electronics, electric zero-emission vehicles and stationary energy storage systems. Among others, tremendous research efforts have been devoted to discovering next-generation battery cathode materials for secondary batteries. To provide useful insights towards developing post-Li cathode materials, we use a deep neural network (DNN) model and rapidly explore large materials space to identify novel Mg-ion cathode active materials. These efforts together with verification via first-principles density functional theory calculations result in new Mg-ion cathode active materials with high energy density and low volume change, which are important factors in designing batteries. Comparisons with other related materials will also be given.

Keywords:

Machine learning, Deep neural network

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C12.02

Material design of indium iodine compounds

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Abstract:

We apply material design methodology and find a new indium iodine compound, CsInI3, which is thermodynamically stable but is not reported in Inorganic Crystal Structure Database (ICSD) yet. By using the ab initio evolutionary algorithm, we find several meta-stable structures of CsInI3 and investigate their physical properties. The ideal cubic perovskite structure, which is one of meta-stable phases, shows the structural instability of the iodine breathing mode at zero temperature. However, the cubic perovskite is eventually stabilized at finite temperature due to the contribution of the phonon entropy. The cubic perovskite shows band inversion above the Fermi level, indicating that it is a topological material. Other meta-stable structures are derived from the cubic perovskite and have two different sizes of indium octahedrons, thereby presenting bond and charge disproportionation. The new compound of CsInI3 presents diverse physics including bond and charge disproportionation, topological nature, and a possible application for photovoltaics, thereby providing an ideal playground for these research fields.

Keywords:

Computational material design, Density functional theory, Topological material, Photovoltaics

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C12.03

Machine learning for dynamical mean-field theory

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Abstract:

We implement a machine learning algorithm for Dynamical Mean-Field Theory (DMFT) with an adaptive truncation employed for the impurity solver. The practical limitation of DMFT arises from the impurity solver, which encounters an exponentially increasing number of Slater determinants in the Hilbert space. To enhance performance by pruning redundant Slater determinants, we utilize an active learning algorithm. The efficient construction of the Hilbert space allows us to increase the number of orbitals in the impurity Hamiltonian.

Keywords:

Dynamcal Mean-Field Theory, Machine Learning

C13.01

Subwavelength Terahertz Resonance Imaging (STRING) for Molecular Fingerprinting

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Abstract:

We have developed a technique called subwavelength THz resonance imaging (STRING) that overcomes the limitations of weak light-matter interactions, allowing for highly sensitive detection of molecular fingerprints. This method involves the use of a ring-shaped single-gap resonator in conjunction with near-field spectroscopy, resulting in significant sensitivity improvements due to local field enhancement. Our studies include detailed spectral analysis of isomers of α-lactose and maltose monohydrates, where the sensitivity has been boosted by up to 10 orders of magnitude in comparison to traditional far-field THz measurements using pelletized samples. The findings indicate that the STRING technique may pave the way for the utilization of THz spectroscopy as a versatile and sensitive approach for the molecular fingerprinting and spectral imaging of molecules and nanoparticles.

Keywords:

THz near-field spectroscopy, Molecular fingerprint

Visualization of solitary spin wave localized in a canted antiferromagnet $YFeO_3$

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Abstract:

In this study, we present compelling empirical substantiation for an extraordinary magnon characterized by pronounced stability in both its temporal lifetime and energetic manifestations. Our approach entails a meticulous capture of the solitary magnon's dynamics, achieved through coherent precession facilitated by a precisely controlled picosecond magnetic field within the confines of a canted antiferromagnet, $YFeO_3$. We determine the lifetime and energy of the magnon by analyzing its coherent emission within the picosecond time frame and its precession frequency in the terahertz spectral range, which are unexpectedly independent of the temperature, magnetic field, and magnetic substitution. Our investigation reveals the confined spatial nature of the solitary magnon, rendered discernible through direct visualization facilitated by tip-assisted detection methodologies, thereby illuminating the delicate interplay between magnon stability and spatial localization phenomena.

Keywords:

near-field THz spectroscopy, solitary magnon, visualization of magnon, canted antiferromagnet

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C13.03

Terahertz field-driven hydrodynamic electron fluids in topological states

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Abstract:

Highly correlated electrons within solids are often analogized to hydrodynamic fluids like water. The transportation of these hydrodynamic electron fluids exhibits extraordinary behaviors, including Poiseuille distribution, vorticity, negative voltage, and superballistic transport that extends beyond the classical Drude model. Despite considerable recent strides, which include the utilization of diamond nitrogen-vacancy magnetometry, the direct observation of hydrodynamic fluids over macroscopic scales remains elusive. Furthermore, a significant challenge lies in disentangling between two intertwined hydrodynamic fluids. I will address these significant challenges through the utilization of terahertz hydrodynamic fluids, encompassing several key aspects: i) Exploring the role of topology in showcasing hydrodynamic electron fluids without relying on an ultraclean system, ii) Discussing the suitability of utilizing picosecond terahertz fields for investigating hydrodynamic electron fluids, iii) Highlighting the necessity of tip-assisted terahertz detection to visualize the transport of hydrodynamic electron fluids, iv) Establishing the principle to distinguish two types of hydrodynamic fluids with distinct viscosities in real space. Wrapping up the presentation, I bring into focus the exciting potential for the quantum transport of hydrodynamic electron fluids.

Keywords:

Near-field terahertz spectroscopy, Hydrodynamic electron fluids, Terahertz chromatography, Topological semimetals

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C13.04

Nonlinear photocarrier transport by THz field enhancement

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Abstract:

Terahertz (THz) waves have attracted significant attention due to their unique spectroscopic characteristics to molecular vibration and non-ionization by very low energy under the level of room temperature. Metamaterials, which are subwavelength optical resonators, have enabled the manipulations of electric permittivity and magnetic permeability beyond the characteristics of natural materials. Such capabilities have led to various applications, both in the manipulation of THz waves in the far-field and the exploitation of strong field enhancement in the near-field region. Enlargement of light-matter interaction by the near-field enhancement allows sensitive spectroscopy and molecular detection without labeling or chemical modification, even under extremely low concentrations. Additionally, extending this concept into two dimensions has facilitated advanced imaging techniques. This abstract introduces the applications of THz field enhancement by metamaterials with nanostructures, emphasizing the intriguing potential for inducing nonlinearity in semiconductors, despite their inherently low photon energy compared to the bandgap. Intense field localization leading to conductance change of the semiconductor substrate changed the resonance and transmittance of the metamaterial under a common oscillator-based THz spectroscopy system with a photoconductive antenna emitter. This approach can enable the realization of unattainable THz devices, bridging the gap toward practical applications.

Acknowledgments: This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korean government (MSIT) (No. 2022R1F1A1074851).

Keywords:

terahertz, metamaterial, imaging, impact ionization, nearfield enhancement

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C13.05

Design of Nanophotonic Structures with Binary optimization: Machine learning-Quantum Annealing Enhanced Approach

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Abstract:

The demand for multi-wavelength-scale, multifunctional nanophotonic structure is surging across applications, from smart mobility to opto-electronics. However, the challenge lies in identifying the optimal configuration within the vast parametric space. We propose a strategy: transforming nanophotonic design into a binary optimization, aided by machine learning and quantum annealing. This approach enhances efficiency and quality in finding optimal structures. By discretizing the nanophotonic structure into sub-wavelength-scale pixels (~1/10 of wavelength), and assigning binary states according to constituent materials, a nanophotonic structure is encoded as a binary vector. This vector has a figure-of-merit (FOM), quatifying structural proximity to the target. Machine learning, such as factorization machines, constructs a surrogate model using the binary vector-FOM dataset. Quantum annealing efficiently navigates the solution space to uncover the optimal binary vector. We present recent research progess achieved through our proposed binary optimization methodology, exemplified by advancements in transparenct radiative cooling and thin-film optical diodes

Keywords:

Nanophotonics, Optimization, Binary Optimization, Machine Learning, Quantum Annealing

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C14.01

Tip-enhanced cavity-spectroscopy to control excitonic behaviors at the nanoscale

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Abstract:

The tunability of the bandgap, radiative emission, and energy transfer in transition metal dichalcogenide (TMD) monolayers provides a new class of functions for a wide range of ultrathin photonic devices. Additionally, understanding and controlling the nanoscale transport of excitonic quasiparticles, such as excitons and trions, in atomically thin 2D semiconductors are crucial to produce highly efficient nano-excitonic devices. In this work, we present a dynamic nano-mechanical strain-engineering of naturally-formed wrinkles in a WSe_2 monolayer, with real-time investigation of nano-spectroscopic properties using tip-enhanced cavity-spectroscopy. We reveal the modified nano-excitonic properties by the induced tensile strain at the wrinkle apex, exhibiting the exciton funneling phenomenon. In addition, we demonstrate a nanogap device to selectively confine excitons or trions of 2D TMDs at the nanoscale, facilitated by the drift-dominant exciton funneling into the strain-induced local spot. Furthermore, 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 exploit propagating surface plasmon polaritons (SPPs) to localize hot electrons in a 2D TMD transferred on a metal–insulator–metal (MIM) waveguide. Our work provides a new strategy for robust, tunable, and ultracompact nano-excitonic devices using atomically thin semiconductors.

Keywords:

exciton, 2D semiconductor, surface plasmon polariton, tip-enhanced cavity-spectroscopy

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C14.02

Quantum Interference in Optical Möbius-Strip Microcavities: Experiment vs Theory

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Abstract:

A Möbius-strip resonator and a self-rolled asymmetric microcavity are representative nanostructured microarchitectures, which give rise to fascinating topological and quantum-interference effects by virtue of Möbiosity, optical spin-orbit coupling and non-Abelianism.
We represent the first experimental observation of a geometric phase in optical Möbius-strip microcavities. Two-photon polymerization-based laser writing is employed to fabricate dielectric Möbius-strip microrings with different aspect ratios (thickness-to-width) *T/W* at *T*=0.9 mm. 3D numerical simulations are carried out using "COMSOL Multiphysics Wave Optics" for different ratios *T/W*. In a Möbius strip, where the thickness is assumed smaller than the wavelength of light in the waveguiding medium, the optical electric field is strictly confined within the strip during propagation. In such Möbius-strip cavities, an odd number of antinodes is discerned indicating a constructive interference involving a half-integer number of wavelengths due to the presence of the geometric phase π.
However, the realistic thickness can be shrunk only to a finite value. Due to a finite aspect ratio, the twisted cross-section does not guarantee a strict in-plane confinement of the electric field. During the propagation along the twisted strip, the electric field tends to stay in its current orientation, while the tilted cross-section forces the electric field to rotate along the strip. As a compromise, the electric field orientation slightly biases away from the strip centerplane, resulting in in-plane and out-of-plane electric-field components manifesting a phase retardation due to the different effective refractive indices. As a result, an elliptically polarized resonating light occurs in the Möbius-strip cavities. The optical resonances revealed in the Möbius-strip resonators indicate that the occurring geometric phase depends on the ellipticity. The geometric phase extracted from measurements of transmission spectra of the resonators with continuously changing input polarization orientation, is slightly lower than that from simulations due to the strain-induced deformation during the fabrication. Leveraging the tunable strip cross section offers a way of manipulating the ellipticity of circulating light and the geometric phase from π to 0 in the Möbius-stripmicrocavities for emerging classical or quantum photonic applications.

Keywords:

Optical Möbius-Strip, Microcavity, topological quantum interference

C14.03

Ballistic diffusion of hot carriers in van der Waals layered materials

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Abstract:

One of the key-aims in enhancing the performance of advanced two-dimensional (2D) optoelectronic devices revolves around the effective conversion of photoexcited hot carriers into electrical energy. In pursuit of efficient applications involving hot carrier devices, it becomes imperative to gain insights into the rapid spatial expansion of hot carriers in van der Waals layered materials and to harness these carriers prior to their energy dissipation through carrier-phonon interaction. Here, we explore the spatiotemporal dynamics of hot carriers in monolayer and bulk $MoSe_2$ using transient absorption microscopy. The observed ultrafast expansion behavior of hot carriers exhibits quasi-ballistic motion, resulting in an exceptionally extensive diffusion length. Furthermore, we discuss the implications of these extended hot carrier travel characteristics for designing and developing next-generation optoelectronic devices.

Keywords:

spatiotemporal pump-probe microscopy, hot carrier expansion

C14.04

Cavity effects in perovskite nanostructures

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Abstract:

Perovskite nanostructures are capable of very efficient light emission covering a large range of wavelengths in the visible spectrum. They are relatively simple to produce and can be made into nanocolumns, nanocube arrays or single quantum dots. In this talk I will discuss recent work that we have undertaken looking at enhancing the emission from these structures by making use of natural optical cavities produced by the shape of the crystals themselves. I will discuss the first observation of triplet lasing in these materials and the waveguiding in perovskite nanowires.

Keywords:

Exciton, Cavity, Perovskite nanowire

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C15.01

Organic-based artificial synapses for artificial neural networks

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Abstract:

Biological nervous systems detect various external stimuli such as light, sound, pressure, and chemical molecules. In addition, they perform complex calculations and memorization activities, and manage the body's activities according to the processed information. To accomplish this, a tremendous number of nerve signals are transmitted through a neural network in which neurons and synapses are intricately entangled. In this process, synapses, which are connecting parts between preneurons and postneurons, play an important role in information flow, data processing, and memory functions thanks to a unique property of synaptic plasticity. Therefore, much efforts have been dedicated to emulating biological synapses in electronic devices, called artificial synapses. These devices have a wide range of applications, from neuromorphic computing and humanoid robots to neural prostheses. Here, research focused on organic-based artificial synapses for the construction of an artificial neural networks is introduced. Organic materials are promising due to their advantages such as low cost, mechanical flexibility, biocompatibility, and tunable electrical/optical/mechanical properties through molecular design. First, several approaches to achieve high uniformity and reliability of organic memristors are presented. Additionally, a photonic synapse that selectively detects and processes UV exposure information is introduced. This is achieved using a two-dimensional carbon nitride nanodot layer that responds to UV light as a floating gate.

Keywords:

Artificial synapses, Organic materials, Artificial neural networks

Investigation of hole transfer dynamic during charge separation in non-fullerene organic solar cells

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Abstract:

Despite a clear elucidation that the change in PM6:Y6 morphology with different solvents affects photovoltaic performance, the charge dynamics during the charge separation process resulting from these morphological changes have not been extensively studied. However, studies on mobility and photocurrent have shown that holes play a crucial role in charge generation and separation. In PM6:Y6 devices fabricated using chlorobenzene (PM6:Y6-CB), the reduced exciton dissociation probability is attributed to changes in hole transfer states due to morphological variations. In PM6:Y6 devices fabricated using chloroform (PM6:Y6-CF), the hole transfer state (${}^{h}E_{CT}$) and Y6 highest occupied molecular orbital (HOMO) were almost degenerate. Consequently, the formation of lower effective ${}^{h}E_{CT}$, which can interfere with hole transfer, was minimized. Conversely, in PM6:Y6-CB, the overlapping region of ${}^{h}E_{CT}$ and Y6 HOMO shifts to a lower energy side, creating a significantly lower effective ${}^{h}E_{CT}$, which is energetically unfavorable for hole transfer. These findings from electroluminescence deconvolution analysis were validated using time-resolved photoinduced absorption spectroscopy. Consequently, the decrease in fill factor and current density in PM6:Y6-CB can be attributed to compromised hole transfer from Y6 HOMO to PM6 HOMO. This analysis underscores the importance of morphological changes in nonfullerene acceptor solar cells on hole transfer levels, ultimately affecting the charge separation efficiency.

Keywords:

organic solar cells, hole transfer, charge separation

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C15.03

Interface Tailoring of Perovskite via Mesoporous Structured MoS_2 for Efficient and Photostable Perovskite Solar Cells

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Abstract:

Mesoporous electron transport layers (ETLs), particularly mesoporous TiO_2 ETLs, in perovskite solar cells (PSCs) increase surface contact with the perovskite, which enables effective charge separation and extraction and plays an important role in obtaining high-efficiency devices. However, a high sintering temperature of more than 500 °C and the photocatalytic reaction under incident illumination limit the application and operational stability of PSCs. Herein, we propose a newly developed mesoporous MoS_2 as an efficient and stable ETL material. We fabricated TiO_2-based and MoS_2-based PSCs and compared their various properties. The MoS_2 interlayer enlarged the surface contact area with the adjacent perovskite layer, improved charge dynamics, and realized the coupling between MoS_2 and the perovskite crystal lattice. This facilitated a preferential growth of perovskite crystals with improved crystallinity and relaxed residual strain. High-performance PSCs exhibiting 25.7% (0.08 cm^2, certified: 25.2%) and 22.4% (1.00 cm^2) efficiencies were thus obtained. Furthermore, owing to the suppressed photocatalytic reactions at the perovskite and ETL interface, the photostability was improved significantly and maintained for more than 2,000 h.

Keywords:

epitaxial growth, mesoporous structured molybdenum disulfide, perovskite solar cells, photostability, strain regulation

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C15.04

Electronic structure of metal halide perovskite and their interface study for optoelectronic device application

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Abstract:

To fully unlock the entire potential of metal halide perovskite (MHPs) for the optoelectronic device application, a comprehensive understanding of the electronic structure and energy level alignment at the interface is essential. However, it remains still challenging to figure out a comprehensive picture of the fundamental physical properties of these semiconductors so far. Especially, the presence of intrinsic and extrinsic defects, interface, and surface state make the electronic structure more complicated. In this talk, to expand the understanding of the electronic structure of MHPs, I will introduce the recent representative studies that oxygen-induced p-doping mechanism of MHPs, as well as the formation of 2D/3D MHPs interface.

Keywords:

metal halide perovskite, photoelectron spectroscopy, UPS, energy level alignment

2023 KPS Fall Meeting
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C16.01

Orbital fluctuation and superconductivity in Kagome metal

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Abstract:

Historically, the Kagome lattice structure is known to have emergent quantum phenomena such as flat bands, quantum spin liquids and etc. Particularly, recent experimental discovery of Kagome metal, AV3Sb5 (A=K,Rb,Cs), has been a subject of intense debate. It shows not only the exotic orbital fluctuations but also unconventional superconducting state. In this talk, we theoretically classify orbital current orders and discuss their influence in superconductivity with characteristic van Hove singularity. In addition, we also discuss the effect of intra-orbital and inter-orbital charge density wave and their role in determining orbital currents. Our analysis can be used to infer the superconducting order parameter when the orbital current order is identified and vice versa.

Keywords:

Kagome metal, orbital current, superconductivity, van-Hove singularity

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C16.02

Emergence of flat bands via orbital-selective electron correlations in Mn-based kagome metal

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Abstract:

Kagome lattice has been actively studied for the possible realization of frustration-induced two-dimensional flat bands and a number of correlation-induced phases. Currently, the search for kagome systems with a nearly dispersionless flat band close to the Fermi level is ongoing. Here, by combining theoretical and experimental tools, we present $Sc_3Mn_3Al_7Si_5$ as a novel realization of correlation-induced almost-flat bands in the kagome lattice in the vicinity of the Fermi level. Our magnetic susceptibility, ^{27}Al nuclear magnetic resonance, transport, and optical conductivity measurements provide signatures of a correlated metallic phase with tantalizing ferromagnetic instability. Our dynamical mean-field calculations suggest that such ferromagnetic instability observed originates from the formation of nearly flat dispersions close to the Fermi level, where electron correlations induce strong orbital-selective renormalization and manifestation of the kagome-frustrated bands. In addition, a significant negative magnetoresistance signal is observed, which can be attributed to the suppression of flat-band-induced ferromagnetic fluctuation, which further supports the formation of flat bands in this compound. These findings broaden a new prospect to harness correlated topological phases via multiorbital correlations in 3d-based kagome systems.

Keywords:

kagome lattice, nuclear magnetic resonance, magnetoresistence, ab-initio calculations, optic spectroscopy

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C16.03

Engineering flat bands in 1T-TaS_2 via atomic adsorption

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Abstract:

Strongly interacting electrons in 1T-TaS_2 with half-filled flat band exhibit rich phase diagrams of exotic quantum states, including Mott state, superconductivity and correlated topological orders intermixed with magnetic orders. In the context of manipulating flat bands, atomic adsorption offers an effect way for tuning localized states, especially in the presence of strong correlation effects. In the first part, I'd like to introduce an approach to realize artificial hexagonal and kagome lattices by metal adsorption on a 2D Mott insulator 1T-TaS_2. Alkali, alkali-earth, and group-13 metal atoms are deposited stably in $(\sqrt{3}x\sqrt{3})R30°$ and 2x2 TaS_2 superstructures of honeycomb- and kagome-lattice symmetries exhibiting Dirac and kagome bands, respectively. The strong electron correlation of 1T-TaS_2 drives the honeycomb and kagome systems into correlated topological phases. We further show that the band filling of these Mott Dirac and flat bands can be tuned by proper choice of adsorbates. Especially, the 2/3- or 3/4-filled system can be achieved with a proper concentration of Mg adsorbates, which can lead to unconventional superconductivity. Moving on to the second part, I'd like to show that the systematic tuning of a trivial insulator into a Mott insulator and a Mott insulator into a correlated metallic and a pseudogap state in 1T-TaS_2. The band structure evolution is investigated upon the surface doping by K atom adsorbates for two distinct phases occurring around 220 and at 10 K by ARPES. We find contrasting behaviors upon doping, which corroborate the fundamental difference of two electronic states: while the antibonding state of the spin-singlet insulator at 10 K is partially occupied to produce an emerging Mott insulating state, the presumed Mott insulating state at 220 K evolves into a correlated metallic state and then a psuedogap state.

Keywords:

flat band, CDW, TaS2, Mott insulator

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D2.01

Status of differential Drell-Yan cross section measurement with the CMS detector

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Abstract:

The Drell-Yan process holds a significant position in high-energy experiments owing to its characteristic of yielding a clean final state. Additionally, its differential cross-section serves as a vital parameter for inclusion in global PDF fitting. This presentation addresses the measurement of differential Drell-Yan cross-sections with the dimuon and dielectron channel, using pp collision data at a center-of-mass energy of 13 TeV, as recorded by the CMS detector during the the LHC Run2 from 2016 to 2018. This dataset corresponds to an integrated luminosity of 138 pb^-1. The background estimation and the various of corrections for precision measurement are discussed. The result are compared with the perturbative predictions of the standard model.

Keywords:

Drell-Yan, cross section, CMS

2023 KPS Fall Meeting
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D2.02

Direct measurement of Top quark width in tt Dilpeton decay channel in pp collisions.

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Abstract:

We present a preliminary MC study on the direct measurement of top quark in ttbar dilepton decay channel in pp collisions at LHC. In this study we consider including non-resonant regions in the lepton-b-jet invariant mass distribution as a proxy to the top mass distribution.
Our study expects a vastly improved measurement compared to previous measurements at LHC.

Keywords:

CMS

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D2.03

Study for measuring the CKM matrix component $|V_{ts}|$ directly in dilepton channel of top pair production at 13 TeV with the CMS detector

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Abstract:

Since the discovery of top quark, there have been many studies of its properties but there still exist parameters yet to be investigated. In the CKM matrix, describing charged weak interaction between quarks, V_{ts} is such a parameter. $|V_{ts}|^2$ can be interpreted as the branching ratio of decay of the top quark into a strange quark and the parameter is determined indirectly from precision measurements of other elements and the unitarity of the matrix under the assumption of the Standard Model (SM). The direct measurement of the component tests the SM and gives constraints on beyond-the SM scenarios. This work studies measuring the value directly by finding signal strange jets from top decays, discriminated from backgrounds through a machine learning-based jet discriminator in the dileptonic final state of top pair production events at CMS 13 TeV.

Keywords:

top quark, strange quark, Vts, CKM matrix, LHC

D2.04

A study of V_{cb} measurement in semi-leptonic decay channel of top pair events at the LHC

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Abstract:

We present the current status of CKM matrix element V_{cb} measurements using top-pair semileptonic decay at the LHC. The existing measurements show two different values with boundary tension. These values are measured using exclusive and inclusive decays of the B meson, respectively. We take a look at the hadronic decay top of the semi-leptonic decay of top pairs, which is free from non-perturbative effects of B meson formation. This analysis aims at analyzing the complete sqrt{s}=13TeV data collected with the CMS detector. With the most recent CMS jet flavor tagging algorithm, we have also introduced new MVA techniques. These techniques help achieve: 1. Improved reconstruction performance of the top pair events against high jet multiplicity. 2.Improved signal extraction performance by reducing contamination from heavy-flavored jets outside of the ttbar. Combining this result with our study of the background and signal, we will present the expected sensitivity on the V_{cb} parameter with the systematic uncertainties.

Keywords:

Vcb, CKM, LHC, CMS

D2.05

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

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Abstract:

The leading order calculation for the top pair production is charge symmetric in the Standard Model (SM). However, higher-order predictions lead to an asymmetry caused by the direction preference of top quarks by the initial quark momentum. Additionally, there are several beyond standard models that could enhance the asymmetry. Thus, measuring the charge asymmetry in top pair production gives a chance to test SM and new physics models. In this study, we present the measurement of charge asymmetry using the CMS Run 2 dataset in the LHC.

Keywords:

Top, LHC, CMS, Asymmetry

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D2.06

Search for Lepton Flavour Violation in the Top Quark Sector in events with single muon and tau at √s=13 TeV.

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Abstract:

The search for CLFV in the top quark interaction with a charged lepton (μ), a up-type quarks (u, c), and a tau lepton is performed.
This is the first time investigation of tau lepton in the final state with events where top quark decays with CLFV.
The search assumes the scale of new physics responsible for CLFV is larger than the energy scale available at the LHC.
The data corresponding to an integrated luminosity of 138₩fbinv is collected by CMS Experiment during Run 2.
A Multi class classification Deep neural network trained using MC is used for signal extraction.
The expected upper limits are calculated by combining the entire run 2 MC events with blinding the data.

Keywords:

Beyond SM physics, TOP quark, Lepton flavour violation

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D2.07

Identification of tqg FCNC process using machine learning techniques

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Abstract:

Flavor-changing neutral current interactions with a light quark, top quark and gluon vertex (tqg FCNC) is highly suppressed in the Standard Model (SM) but occurs in many new physics models. In this study, we investigate the tqg FCNC processes having the final state with one top quark and one energetic gluon jet, while processes in the SM with one top quark in the final state have only quark jets. Hence, we perform machine learning techniques using quark-gluon jet discrimination variables to distinguish the tqg FCNC events from the SM backgrounds. We compare the performance of Boosted Decision Tree (BDT) and a Self-Attention for Jet-parton Assignment (SaJa) that can use all jets. We show that the detailed jet information increases the signal-background separation power, and the enhancement of SaJa is larger than that of BDT.

Keywords:

FCNC, top quark, BSM

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D2.08

Search for the Rare Top Process t→sW in Dileptonic Top Pair Events Using Deep Learning

HEO Jeewon [1], JANG Woojin [1], LEE Jason Sang Hun[1], PARK Inkyu [1], ROH Youn Jung [1], WATSON Ian James*[1], YANG Seungjin [2]
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Abstract:

The Cabibbo Kobayashi Maskawa (CKM) matrix describes the flavor-changing interaction between quarks and is unitary in the Standard Model. One of the CKM matrix elements, Vts, showing the coupling between the top and strange quark has not been directly measured. The direct measurement of the |Vts| can be achieved by finding a strange jet from top quark 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 self-attention based deep learning model, which has advantages in handling various types of objects and different numbers of object per each event, to tag the strange jet.

Keywords:

ML, top

Probing Non-Standard Neutrino Interactions with Interference: Insights from Dark Matter and Neutrino Experiments

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Abstract:

Neutrino-electron scattering experiments play a crucial role in investigating the non-standard interactions of neutrinos. In certain models, these interactions can include interference terms that may affect measurements. Next-generation direct detection experiments, designed primarily for dark matter searches, are also getting sensitive to probe the neutrino properties. We utilise data from XENONnT, a direct detection experiment, and Borexino, a low-energy solar neutrino experiment, to investigate the impact of interference on non-standard interactions. Our study demonstrates that interference between standard and non-standard neutrino interactions can lead to a transition between different non-standard interaction models in the relevant energy range of XENONnT and Borexino experiments. This transition can be used to distinguish between the considered models if any signal is observed at direct detection or neutrino experiments. Our findings underscore the importance of accounting for interference and incorporating both direct detection and solar neutrino experiments to gain a better understanding of neutrino interactions and properties.

Keywords:

Non-Standard Neutrino Interaction, Solar Neutrino, Interference, Dark Matter Experiments, Neutrino Experiments

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D3.02

Search for axion dark matter in the laboratory and in the cosmos

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Abstract:

I would like to present a new experimental proposal, called LACME, to search for axion dark matter in the laboratory. If axions or axion-like particles are the main component of dark matter, they will modify the transport property of electrons and also the atomic spectra, which will give a new way of detecting axions ot axion-like particles. Finally I will discuss a topological soliton made of axions and discuss its observational consequences in the cosmos.

Keywords:

Axions, dark matter, electron transport, atomic spectra, soliton

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D3.03

Regurgitated Dark Matter

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Abstract:

We present an alternative production mechanism to thermal freeze-out for WIMP dark matter. In this model, GeV mass particles are shepherded into false vacuum pockets during a first order phase transition and trapped by a large mass gap. They form compact remnants that collapse into light primordial black holes, which subsequently regurgitates the initial constituent particles through Hawking evaporation. The WIMP mass density is nearly independent of the cross section and can constitue all of dark matter over a wide swath of parameter space. The dark matter particles in this unique model are responsible for creating the PBHs which later re-emit them.

Keywords:

PBH, WIMP, Dark Matter, First order phase transition, Hawking Evaporation

D3.04

Structure formation of a multi-component dark matter

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Abstract:

We present distinctive properties of multi-component dark matter from the structure formation on a small scale. We solve linear Einstein-Boltzmann equations and show how density perturbation and matter power spectrum change compared to the ΛCDM prediction. To incorporate non-linear effects, we use the above result to perform N-body simulation, and discuss various phenomenological aspects of the model. Finally, we give constraints to the model with observational data such as the matter power spectrum and maximum circular velocity function of the halos.

Keywords:

dark matter, N-body, structure formation, density perturbation

D3.05

Capture of Inelastic Dark Matter in white dwarves

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Abstract:

Weakly Interacting Massive Particles (WIMPs) can be captured in compact stars such as white dwarves (WDs). If they are in a Dark Matter (DM)-rich environment, the capture will lead to an increase in the star luminosity because of DM annihilation process. According to N-body simulation, we can assume that the core of the Messier 4 globular cluster (where plenty of WDs are observed) is rich of DM. With this, when DM whose mass is over a few tens GeV interacts with nuclei in the WD through inelastic scattering, the DM mass splitting can be probed up to around 40 MeV. This largely exceeds the mass splitting from direct detection, which is 200 keV. We also apply such constraint to the specific DM scenario of self conjugate bi-doublet in the left-right symmetric model, where the standard SU(2) left group with coupling g_L is extended by an additional SU(2) right group with coupling g_R. In such scenario, we show that bounds from WDs significantly reduce the cosmologically viable parameter space, especially requiring $g_R > g_L$

Keywords:

dark matter, white dwarf, indirect detection

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D3.06

Characterizing the hypercharge anapole dark matter particle

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Abstract:

We consider the case that dark matter (DM) is solely composed of a self-conjugate (Majorana) particle interacting with ordinary standard model (SM) matter exclusively through the so-called U(1) hypercharge anapole terms. Based on the general three-point vertices of a virtual photon γ and a massive gauge boson Z and two identical on-shell particles of any spin J and mass m, we evaluate the relic density and the direct detection cross sections. Combining the constraints from these experiments and those from the high-energy Large Hadron Collider (LHC) experiments, we perform a systematic investigation of whether the limits on the mass and coupling strengths depend on the spin of the anapole DM.

Keywords:

Dark matter, Self-conjugate particle, Majorana particle, Anapole moment

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D3.07

Non-thermal WIMPy Baryogenesis with Primordial Black Hole

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Abstract:

We consider the possibility that the weakly interacting massive particles produced from the evaporation of primordial black hole can explain both the relic density of dark matter and the baryon asymmetry of the Universe, through their annihilation which violate B and CP-symmetry. We find that the primordial black hole with mass 10^6 g (10^7 g) are good candidates for TeV dark matter with the total annihilation cross section $\langle\sigma_a v\rangle \simeq 5.4\times10^{-9}\ \mathrm{GeV}^{-2}$ ($\langle\sigma_a v\rangle \simeq 2.1\times10^{-7}\ \mathrm{GeV}^{-2}$) and the B-violating annihilation cross section $\langle\sigma_B v\rangle \simeq 8\times10^{-10}\ \mathrm{GeV}^{-2}$ ($\langle\sigma_B v\rangle \simeq 8\times10^{-8}\ \mathrm{GeV}^{-2}$). This large annihilation cross section of dark matter in this model would make it available to search them in the indirect search for dark matter such as gamma-ray or neutrino observations.

Keywords:

WIMP dark matter, baryon asymmetry, PBH

D3.08

Positivity bounds on Higgs-portal dark matter: Freeze-out vs Freeze-in

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Abstract:

We consider the positivity bounds for scalar dark matter with effective Higgs-portal couplings up to dimension-8 operators. We regard scalar dark matter as being WIMP or FIMP, depending on the cutoff scale for the effective couplings. Taking the superposed states for Standard Model Higgs and scalar dark matter, we show that 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. In the case of WIMP dark matter, 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. 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 Bound

D3.09

Dirac-Majorana neutrino type oscillation induced by a wave dark matter

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Abstract:

Whether the neutrinos behave like Dirac or Majorana particles are determined by the relative size of the Dirac and Majorana mass term in the Lagrangian. If these ratios change in time, the neutrino phenomenology may show time-dependent behavior, depending on the local Dirac/Majorana mass ratio at observed time. This may occur in the case the neutrino masses are affected by the wave dark matter. We showed the amplitude of the wave dark matter can be significant enough to oscillate the neutrino type between Dirac and Majorana while satisfying current constraints on the scalar dark matter. This model predicts periodic modulations in the event rates in various neutrino phenomena such as neutrinoless double beta decay. Also, as the energy density of the scalar dark matter evolves in the cosmic time scale, the oscillation amplitude changes accordingly and this may provide an important link between the present-time neutrino physics and early universe physics including the leptogenesis scenario. This talk is based on the recent paper (arXiv:2305.16900) by YeolLin ChoeJo, Yechan Kim, and Hye-Sung Lee.

Keywords:

Neutrino Physics, Dark Matter, Cosmology, BSM Physics, Dirac/Majorana Neutrinos

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D4.01

PAL-XFEL status and plan

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Abstract:

The PAL-XFEL is an X-ray free-electron laser facility that has supported more than 300 user experiments to date based on its outstanding performance regarding brightness and temporal stability. In its 6 years of user support since 2017, the accelerator has steadily increased the FEL output through continuous improvements. Besides, we present new possibilities in terms of the light source through new technologies such as self-seeding, two-color FEL generation, and multi-beamline operation modes. The beamline is constantly improving and specializing in 10 experimental techniques currently available to conduct in various sample environments. These are expected to reveal new physical aspects of molecules and materials.
We have been increasing available user beamtime shifts, and 24-hour-based support for hard X-ray experiments begins in the second half of this year, resulting in a more than 25% increase in total user beamtime shifts. However, due to the limited beamlines and the number of beamtime shifts to provide, the approval ratio was not increased significantly, and the user beamtime is still insufficient. If this is prolonged, the XFEL user pool may eventually be saturated or shrink, which will lead to a weakening of PAL-XFEL's competitiveness. We believe that the addition of the hard X-ray FEL line will provide a solution to these issues.
In this presentation, I will report the current status of PAL-XFEL and discuss the plan for the new hard X-ray FEL line construction.

Keywords:

PAL, XFEL, X-ray Free Electron Laser, Pohang Accelerator Laboratory

D4.02

Hard X-ray instrument at PAL-XFEL for the study of energy and quantum materials

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Abstract:

Research on energy materials and quantum materials has garnered significant interest in the fields of condensed matter physics and materials science due to their potential impact on everyday life, particularly in the areas of energy storage/conversion/transportation, and emergent functionality. In this presentation, I will provide an overview of the Femtosecond X-ray Scattering (FXS) instrument at the hard X-ray beamline of the PAL-XFEL and its applications in researching energy and quantum materials. From basic X-ray diffraction to state-of-the-art resonant X-ray scattering, the FXS instrument offers a wide range of X-ray probes capable of capturing intriguing out-of-equilibrium states involving charge, spin, orbital, and lattice physical degrees of freedom in the femtosecond time domain after photoirradiation. I will also discuss the current status and future development directions for this instrument.

Keywords:

quantum materials, energy materials, XFEL, pump-probe

D4.03

Evidence for fractional quasiparticles in frustrated square-lattice iridates

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Abstract:

Spinons are elementary excitations in quantum spin liquids carrying spin-1/2 fractional quantum number. Their existence in square lattices remains an open question with their possible role in unconventional superconductivity. Square-lattice iridates realizing effective S = 1/2 antiferromagnet (AF) in the strong spin-orbit coupling limit offer a new materials strategy to address this issue. In this presentation, I will talk about enhanced magnetic frustration in the Heisenberg square-lattice AF Sr_2IrO_4 heterointerfaced with its bilayer variant Ising AF $Sr_3Ir_2O_7$, evidenced by slow recovery of the AF order after its transient suppression by an optical pump, magnons confined to long wavelengths and low energies, and spin excitation spectra dominated by isotropic continua—a hallmark of spinons. Thus, our results pave a new route to frustrated magnetism in square lattices by combining distinct types of magnetic anisotropies in one material.

Keywords:

spinon, magnetic frustration, heterointerface, XFEL, RIXS

2023 KPS Fall Meeting
2023-10-24 - 2023-10-27

D4.04

Ultrafast and nanoscale imaging with XFELs

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Abstract:

Intense femtosecond optical laser pulses drive material phase transitions via kinetic reactions otherwise hidden in equilibrium measurements. This stimulates interest in uncovering reaction dynamics of individual atoms prompted by photoexcited electrons. However, our understanding on ultrafast atomic dynamics has been limited by the challenges in resolving irreversible processes at the relevant space–time resolution. By establishing single-pulse time-resolved diffraction imaging technique using an X-ray free-electron laser, we overcome this to directly observe the intermediate processes accompanied during the nonequilibrium phase transitions. Recent investigation of exotic kinetic transitions forbidden in thermodynamic equilibrium condition will be introduced to highlight the potential available with the diffractive imaging scheme. Emphasis of the talk will be made on the superior performance of the PAL-XFEL on its timing resolution with noncompromising stability. This inherits invaluable potential to lead internationally competitive research with the PAL-XFEL, and the extension of the facility to enable more access to this unique facility will significantly promote such researches.

Keywords:

XFEL, Ultrafast, Nanoscale, Imaging

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D4.05

HX-2 FEL line construction plan

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Abstract:

The PAL-XFEL X-ray free electron laser facility, which started user services since 2017, is a state-of-the-art scientific research facility that leads the atomic levels/femtoseconds spatio-temporal resolution in solving energy, environmental, bio, and quantum problems. However, with the very limited number of beamlines and beam time allocation, only a very small number of researchers' needs are being met due to only one hard x-ray undulator line (HX1) and soft X-ray undulator line (SX1) in operation. Therefore, we have proposed the new hard X-ray undulator line (HX2) to meet the demands of researches in various fields. This HX2 with a higher undulator parameter K is needed to make full use of the PAL-XFEL performance in the lower photon energies by increasing the resonant electron beam energy. Furthermore, HX1 and HX2 will operate in parallel without sacrificing the beam repetition rate of 60 Hz with the help of the advanced two-bunch mode operation, which effectively doubles the available beam time. In this presentation, I will present about construction plan of HX-2 FEL beam line at PAL-XFEL.

Keywords:

Second Hard X-ray FEL undulator, PAL-XFEL, Free electron laser, hard X-ray

2023 KPS Fall Meeting
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D5.01

Quantum mechanical methods for the reliable absorption spectra

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Abstract:

For more than a few decades, various quantum mechanical methods have successfully predicted or explained the absorption spectra of atoms and molecules. In this presentation, we provide qualities of well-known quantum mechanical methods for various ranges of absorption spectra. Several density functional theories (DFTs) and coupled-cluster (CC) are chosen to compare with the experiments. We will explore the valence, Rydberg, and core excitations for the first-row hydrides.
For the reliable spectrum of a wide energy range, we recently implemented the time-dependent equation of motion CC (TD-EOM-CC) in the ACES2 program. TD-EOM-CC is obtained from the time propagation of the moment operators expressed in the CC effective Hamiltonian form, which can be used as an alternative method to conventional EOM-CC. This enables the full spectra from UV to X-ray regions. We further developed the full second-order transition moments in EOM-CC for the correct spectra. Another example, K pre-edge spectra of transition metal tetrachlorides, show that TD-EOM-CC and EOM-CC can be used as an important tool for understanding the nature of the electron transitions in the core region.

Keywords:

excited state, coupled cluster, density functional theory

2023 KPS Fall Meeting
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D5.02

Manifestation of Laser Resonance Chromatography on Lu+ ions

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Abstract:

Optical spectroscopy of superheavy elements is experimentally challenging as their production yields are low, half-lives are very short, and their atomic structure is barely known. Conventional spectroscopy techniques such as fluorescence spectroscopy are no longer suitable since they lack the sensitivity required in the superheavy element research.

A new technique called Laser Resonance Chromatography (LRC) could provide sufficient sensitivity to study superheavy ions and overcome difficulties associated with other methods. In this contribution, I will introduce the LRC technique and report the progress and the results from inauguration experiments conducted on Lu+, the lighter chemical homologue of Lr+.

This work is supported by the European Research Council (ERC) (Grant Agreement No. 819957).

Keywords:

Laser Resonance Chromatography, Super heavy ion, Ion mobility separator, Heavy ion accelerator

2023 KPS Fall Meeting
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D5.03

Test of atomic charge-exchange cell for the collinear laser spectroscopy at RAON

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Abstract:

The performance of the vertical charge-exchange cell (CEC) was tested to evaluate the collinear laser spectroscopy (CLS) beamline that has been developed at RAON. The CEC is one of the key components of the CLS apparatus, allowing the laser spectroscopic measurements of the radioactive isotopes, in the form of neutral atomic beam, generated at the ISOL (Isotope Separation On-Line) facility. In order to evaluate the performance of the CLS beamline, a 20-keV Ar ion beam generated at the off-line ion source was sent to the CEC via 45-degree bender, in agreement with the results of the ion optics calculations. The neutralization efficiency was investigated as a function of the reservoir temperature used to control the rubidium vapor density, and the CEC exhibited similar neutralization performance to that developed at TRIUMF, Canada. The performance of the CEC will be tested further for the laser spectroscopy on the various rare isotopes, e.g. Al that will be produced at the ISOL facility in the near future.

Keywords:

RAON, Collinear Laser Spectroscopy, Charge Exchange Cell, Neutralization Efficiency

2023 KPS Fall Meeting
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D5.04

Development of the collinear laser spectroscopy system for the study of unstable nuclei at RAON

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Abstract:

In recent decades, laser spectroscopy techniques have made significant contributions in our understanding of exotic nuclei in radioactive ion beam facilities worldwide. Especially, high precision laser spectroscopy allows us to determine fundamental properties of nuclear ground and isomeric states, such as nuclear spins, magnetic dipole, electric quadrupole moments, and charge radii, via the measurement of hyperfine structures and isotope shifts in the atomic or ionic spectra of the nuclei of interest. The collinear laser spectroscopy (CLS) has been developed as one of the key experimental apparatus of the RAON (Rare isotope Accelerator complex for ON-line experiment) in the Institute for Rare Isotope Science (IRIS), Korea. Recently, the CLS beamline, based on the nuclear-spin-polarization beamline at TRIUMF in Canada, has been installed and tested using the offline ion source. We are now focusing on the light collection system on the CLS beamline and the laser system setup as well, to perform the laser spectroscopy on the rare isotope beams produced at the ISOL (Isotope Separation On-Line) facility in the near future.

Keywords:

Collinear Laser Spectroscopy, RAON, Nuclear properties, Hyperfine structure, Isotope shifts

2023 KPS Fall Meeting
2023-10-24 - 2023-10-27

D5.05

The isotope shift measurement in 6s2 $^1S0$ - 5d6p $^3D1$ transition of barium

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Abstract:

We present the isotope shifts of 6s2 $^1S0$ – 5d6p $^3D1$ transition in barium. The spectrum is directly measured from the laser-induced fluorescence of atomic beam excited by 413nm external-cavity diode laser. The experimental data well agrees with the fit model of King plot and hyperfine coefficient from the previous study, while we observed the discrepancy between the measured isotope shifts and indirect estimations from previous studies of nearby transitions. We will discuss the mismatch with the literatures and also feasibility of isotope-selective barium ion loading utilizing this transition.

Keywords:

photoionization, ion trap, isotope shift, atomic physics

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D5.06

Spectroscopy of a slow MgF buffer-gas beam

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Abstract:

An ultracold diatomic molecule is gaining prominence as an important platform for exploring various quantum phenomena due to its rich internal structure, long coherence time, and strong long-range interaction between molecules' large electric dipole moments. Among various diatomic molecules, MgF stands out due to its light mass, strong UV transition lines, and diagonal Frank-Condon factors, which collectively provide advantages for laser cooling. Additionally, its diverse isotopologues allow for studies involving both bosonic and fermionic properties.
We investigated the spectroscopy and optical cycling effects of the $P_{12}(1)$ and $P_{13}(1)$ transitions of ^{25}MgF and the $P_1(1)$, and $Q_{12}(1)$ transitions of ^{24}MgF. The measurements were conducted using fluorescence signals in the transverse direction of a slow buffer-gas beam located 35 cm downstream from the generation point of the MgF molecules. To observe optical cycling, for the case of ^{24}MgF, we employed EOM modulation to create sidebands corresponding to the hyperfine splitting at 120 MHz. In the case of ^{25}MgF, since the additional nuclear spin of Mg, the hyperfine structure is more complicated than in the case of ^{24}MgF. And also since the energy splitting between $P_{12}(1)$, and $P_{13}(1)$ is about 1 GHz, to cover all hyperfine structures and address both transitions simultaneously, we used two lasers whose frequency is modulated by a white-light EOM with multiple sidebands of 10 MHz interval.
We also measured the forward velocity distribution of the slow buffer-gas beam for capturing into a MOT (Magneto-Optical Trap) for ^{24}MgF. The forward velocity was measured to be 150 m/s using the Doppler shift. The measured forward velocity is slow enough for the molecules to be captured in a MOT with the aid of the laser slowing.

Keywords:

Diatomic molecule

D6.01

Development Progress of Proton Beam Diagnostics Using Tomography Technology at KOMAC

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Abstract:

This study aims to develop a diagnostic method to characterize a proton beam distribution in the phase space. The particle distribution in the phase space can be described by an emittance and Twiss parameters with an assumption that the particles are in the Gaussian distribution. Thus, beam diagnostics such as a quadrupole magnet (QM) scan method are widely utilized to measure those parameters. However, the QM scan method isn't able to explain the detailed beam distribution in the phase space since its assumption despite the very convenient and superior tool. Therefore, in this study, a computational tomography technique is introduced to compensate for this limitation of the quadrupole magnet scan method and still use the merits of the method such as its simple layout and non-intrusive property. In addition, a beam diagnostic simulator is also developed to improve the accuracy of the diagnostics. This simulator can return independent variables of the experiment, such as which QM will be operated in which current range. This method and the simulator were applied to the 100 MeV proton linac of KOMAC, and it was confirmed that this method could significantly improve the measurement of the beam distribution in the phase space.

Keywords:

Beam diagnostics, Beam phase space diagnostics, Computational tomography, Proton accelerator

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D6.02

Surface Wave Plasma 기반 저손상 고효율 반도체 제조 공정 적용에 관한 연구

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Abstract:

최근 반도체 소자의 미세화 및 3차원화에 따른 집적 공정 기술 난이도가 상승함에 따라, 3차원 적층 구조 생성을 위한 높은 종횡비의 식각 특성 및 우수한 단차 피복 성능을 가지는 박막 제조에 관한 공정 기술 개발이 요구되고 있다. 또한 고반복성 반도체 공정이 요구되는 3차원 적층 기술의 필요성이 증가함에 따라 저손상, 저온 공정에 관한 수요가 증가하고 있으며 이에 따른 플라즈마 공정 장비의 개선 및 개발이 필요한 실정이다. 본 연구에서는 원통형 평면 반도체 제조 공정에 적용이 가능한 Surface Wave Plasma 발생 장치의 응용 가능성에 관하여 기술하였다. 유전체 계면에서 slow wave 발생이 용이한 표면파 플라즈마는 유전체 계면 근처에서 높은 전자 온도를 가지며, 기판 근처에서는 낮은 ion bombardment energy를 통하여 저손상 고효율 플라즈마의 생성이 가능한 장치이다. 또한 수 mTorr ~ 수 Torr 까지 넓은 동작 압력 범위에서 구동이 가능하며, pulse 파 제어를 통한 eedf 제어는 특정 고반응성 라디칼 생성의 선택비를 높일 수 있는 장점이 있다. 최근 초고주파 발생에 사용되는 반도체 기반 전력 증폭 기술의 비약적인 발전으로 초고주파 플라즈마 장비 제어성 극대화가 용이하며, 이를 바탕으로 고속, 고수율 반도체 공정 적용 가능성을 검토하였다.

참고문헌 :
[1] “Transition of electron heating mode in a planar microwave discharge at low pressure”, H.Sugai et al, Appl.Phys.lett, **77**, 3523 (2000).
[2] “Advanced large-area microwave plasmas for materials processing”, I.Ganachev et al, Surface and Coatings Technology, **174**, 15 (2003)

Keywords:

초고주파 플라즈마, Surface Wave Plasma

D6.03

Leveraging physics-informed neural computing for plasma transport

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Abstract:

In this work, we propose a solution scheme for plasma transport problems in a tokamak, using physics-informed neural networks (PINNs). In contrast to adopting the traditional time-serial computations of finite difference methods (FDMs), this novel technique using PINN iteratively updates a neural network function that maps spatiotemporal coordinates to plasma states, systematically minimizing errors in transport equations. The required number of iterative updates in PINNs is several orders less than the time-ordered iterations in traditional FDM, which can significantly reduce the number of serial calls of the costly transport models and thus the elapsed wall time of the simulation. In this talk, we discuss the features and potentials of our newly proposed PINN-based tokamak transport solver.

Keywords:

Tokamak, Plasma transport, Physics-informed neural network, Computational simulation

D6.04

Supervised Machine learning development of parallel closures for a high-collisionality deuterium-carbon plasma

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Abstract:

In laboratory and space environments, numerous plasmas comprise multiple ion species. Notably, in tokamak edge plasmas, the presence of ionized impurities emitted from material surfaces significantly influences plasma transport. Precise closure relations are indispensable for describing multi-ion plasmas using fluid equations to complete the system. In this study, we present the creation of fitting formulas for parallel closures by employing a machine learning algorithm, incorporating recent advancements in multi-ion plasma closure theory [Plasma Phys. Control. Fusion 65, 075014 (2023)]. We illustrate the efficacy of this approach by applying it to a high-collisionality deuterium-carbon plasma. The machine learning-based method establishes itself as a practical and accurate approach for developing closure relations, with potential extensions to a wide array of plasma systems.

Acknowledgement :
This material is based upon work supported by the U.S. Department of Energy, Office of Science, Office of Fusion Energy Science under Award Numbers DE-SC0022048 and DEFG02-04ER54746 and by National R&D Program through the National Research Foundation of Korea (NRF) funded by Ministry of Science and ICT (2021M3F7A1084419).

Keywords:

Closure theory, Multi-ion plasma, Machine learning

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D7.01

Pseudorapidity densities of charged particles with ALICE

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Abstract:

The pseudorapidity density of charged particles ($dN/d\eta$) is a key observable to characterise the global properties of the collisions, such as the achieved energy density, and to provide constraints for model calculations. In this study, $dN/d\eta$ with minimum transverse momentum (p_T) thresholds of 0.15, 0.5, 1, and 2 GeV/c is measured in pp collisions at $\sqrt{s}$= 5.02, and 13 TeV with the ALICE Run 2 setup. The measurement is carried out for inelastic collisions with at least one primary charged particle within $|\eta| < 0.8$ and p_T larger than the corresponding threshold. $dN/d\eta$ with p_T thresholds provides an opportunity to compare with results from ATLAS and CMS. The results are also compared with PYTHIA and EPOS-LHC event generators. In addition, the recent progress on $dN/d\eta$ studies with the ALICE Run 3 setup will be shown.

Keywords:

ALICE, pseudorapidity density

2023 KPS Fall Meeting
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D7.02

Multiplicity dependence of $₩Xi_₩mathrm{c}^{+}$ baryon production in pp collisions at $₩sqrt{s}$ = 13 TeV with ALICE

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Abstract:

Recently measured baryon-to-meson production yield ratios between charm baryons (Λ_{c}^{+}, $\Sigma_{c}^{0,++}$, $\Xi_{c}^{0,+}$, Ω_{c}^{0}) and D mesons (D^{0}) in small collision systems show a significant enhancement with respect to the measurements performed in $e^{+}e^{-}$ collisions. These results were compared with various models implementing a modified hadronization of charm quarks in hadronic collisions, which enhance the production of baryons.
The models can describe the measurements of Λ_{c}^{+} and $\Sigma_{c}^{0,++}$, that don't contain a strange quark. However, the models cannot provide a precise description for the $\Xi_{c}^{0,+}$ and Ω_{c}^{0} measurements, which contain both charm and strange quarks, even though the models including hadronization via both coalescence and fragmentation show the similar trends in baryon-to-meson production yield ratios obtained from the data.
Therefore, more differential measurements are needed to unveil the hadronization of charm quarks.

The ALICE Collaboration also measured the Λ_{c}^{+} baryons as a function of charged particles multiplicity in pp collisions at $\sqrt{s}$ = 13 TeV. In this measurement, the production yield ratios between Λ_{c}^{+} and D^{0} show a remarkable dependence on multiplicity.
Similar measurements of $\Xi_{c}^{0,+}$ as a function of the charged particles multiplicity are expected to give additional constraints for describing the hadronization mechanism of charm quarks.

In this presentation, the measurement of Ξ_{c}^{+} for several charged particles multiplicity classes, reconstructed via the hadronic decay channel $\Xi_{c}^{+} \rightarrow \Xi^{-}\pi^{+}\pi^{+}$ at midrapidity in pp collisions, will be shown. The production yield of Ξ_{c}^{+} ratio to D^{0} will be shown as well. The results were obtained for pp collisions at ₩sqrt{s}$\sqrt{s}$ = 13 TeV, using minimum bias and high-multiplicity triggered data recorded by the ALICE detector.

Keywords:

Hadronization, charm baryon, multiplicity dependence

D7.03

Observation of $₩Upsilon(3S)$ in PbPb collisions at 5.02 TeV in CMS and sequential suppression of bottomonia

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Abstract:

Quarkonia are produced in the early stage of the heavy-ion collisions and propagate through the quark-gluon plasma. Within the QGP medium, the quarkonium states are dissociated depending on their binding energies, resulting in a sequential suppression pattern in yields. Previously, CMS has shown the evidence of the sequential suppression for the S-wave bottomonium states. However, the available statistics were limited, especially, for the Y(3S) mesons. In this presentation, the measurement of the s-wave excited bottomonium states in PbPb recorded during the Run 2 at LHC is given. The results are compared with some theoretical calculations, providing strong constraints to the dynamical QGP models.

Keywords:

Quarkonia, QGP, Upsilon, CMS

2023 KPS Fall Meeting
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D7.04

Diquarks and the production of charmed baryons

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Abstract:

Utilizing a quark model characterized by parameters that effectively replicate the masses of ground state hadrons, we illustrate that (us) or (ds) diquarks exhibit greater compactness in comparison to (ud) diquarks. Concretely, the binding energy of the (us) diquark - defined as the diquark's mass minus the combined masses of its individual quarks - is found to be more attractive than that of the (ud) diquark. This heightened attraction present in (us) diquarks could lead to enhanced production of Ξ_c/D ratio in high-energy pp or ultra relativistic heavy-ion collisions. In this talk, we show the pt distribution of Ξ_c consisting of us diquark and c quark calculated by the coalescence model. We then explain the measured Ξ_c/D ratio in pp collision at 5.02 TeV.

Keywords:

Coalescence, diquark, baryon to meson ratio

2023 KPS Fall Meeting
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D7.05

Heavy flavor jet tagging in ALICE using Run3 framework

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Abstract:

Heavy quarks are produced by the initial hard scattering of ultra-relativistic heavy ion collisions. Since their production time is earlier than the formation of the quark-gluon plasma (QGP), heavy quarks pass through and interact with the QGP medium, losing part of their energy via gluon radiation. The energy loss of heavy quarks via gluon radiation is expected to be smaller than that of gluons and light quarks because the gluon radiation is suppressed below a certain angle with respect to their origination quarks, the so-called dead-cone area, which is proportional to the parton mass. Thus, measuring the production of jets initiated by heavy quarks provides a test of the parton energy loss mechanisms, in particular the mass-dependent energy loss. As a result, heavy quarks are a useful tool to explore the energy loss mechanism inside the QGP.

Following its successful upgrade during the long shutdown 2, ALICE was able to collect a much larger data set in the first year of its Run 3 operation, with improved vertex and track pointing resolution. In addition, a new data processing framework, the so-called O2 framework, was introduced to work with the continuous readout and optimized to reduce the amount of data coming from the detector during data flow, which required significant changes in the physics analysis framework.

This contribution presents the study of heavy quark jet tagging under the O2 framework in ALICE. The feasibility of heavy flavour tagged jet measurement in pp collisions at sqrt(s) = 13.6 TeV with ALICE run3 data is also discussed.

Keywords:

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D7.06

Performance of the CMS muon reconstruction software for p+p, p+Pb, and Pb+Pb collisions

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Abstract:

The performance of the CMS muon reconstruction algorithm was investigated using the data samples for p+p and Pb+Pb collisions at $\sqrt{S_{NN}}$= 5.02 TeV and p+Pb collisions at $\sqrt{S_{NN}}$= 8.16 TeV at LHC. This study includes the evaluation of muon tracking, identification, triggering, momentum scale, and momentum resolution for various collision systems from p+p to Pb+Pb with different detector occupancy. The result demonstrates that the efficiency, larger than 90%, is possible from the current muon tracking, muon identification, and muon triggering even in the highest detector occupancy by Pb+Pb. In addition, the muon momentum scale and resolution are not affected by the occupancy. We conclude that the outstanding CMS muon reconstruction software allows us to proceed with a vigorous muon-based program, for example, the quarkonium and heavy-flavor analyses, in heavy-ion collisions.

Keywords:

muon reconstruction, heavy-ion collisions

2023 KPS Fall Meeting
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D7.07

Transverse single spin asymmetry for forward neutron production in polarized $p+p$ collisions at $\sqrt{s} = 510$ GeV

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Abstract:

In the high-energy $p+p$ collisions, the transverse single spin asymmetry for forward neutron production has been interpreted by an interference between π (spin flip) and a_1 (spin non-flip) exchange with a non-zero phase shift. The π and a_1 exchange model predicted the neutron asymmetry would increase in magnitude with transverse momentum ($p_{\scriptsize{\textrm{T}}}$) in $p_{\scriptsize{\textrm{T}}} < 0.4$ GeV/c. In June 2017, the RHICf experiment installed an electromagnetic calorimeter at the zero-degree area of the STAR experiment at the Relativistic Heavy Ion Collider and measured the neutron asymmetry in a wide $p_{\scriptsize{\textrm{T}}}$ range of $0 < p_{\scriptsize{\textrm{T}}} < 1$ GeV/c from polarized $p+p$ collisions at $\sqrt{s} = 510$ GeV. The RHICf data allows us to study the kinematic dependence of the neutron asymmetry in detail, which not only can test the π and a_1 exchange model in the wider $p_{\scriptsize{\textrm{T}}}$ range but also can enrich our understanding for the spin-involved diffractive particle production mechanism. We present the final result of the neutron asymmetry measured by the RHICf experiment. A new theoretical trial to understand the RHICf result based on the Reggeon exchange will also be discussed.

Keywords:

Single-spin asymmetry, RHIC, spin, polarized p+p collision

2023 KPS Fall Meeting
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D7.08

Femtoscopy with Bose-Einstein correlation at CMS

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Abstract:

Femtoscopy is a practical technique employed in high energy and nuclear physics to determine the size of emitting systems that result from particle collisions, especially those occurring in heavy ion experiments such as those conducted at the Large Hadron Collider (LHC). In this study, femtoscopy utilizes Bose-Einstein correlations with boson particles. By analyzing correlations among the emission points, this method reveals their intrinsic properties. This presentation will show the present 5.02 TeV PbPb results of the femtoscopy study in CMS experiment and future plans.

Keywords:

CMS, Femtoscopy, Heavy Ion, Bose-Einstein Correlation, CERN

2023 KPS Fall Meeting
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D7.09

The First Look at Charged-Particle Jet Production in pp Collisions at $\sqrt{s_{NN}}$ = 13.6 TeV with ALICE Run 3 Data at the LHC

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Abstract:

In this presentation, I report a first measurement of charged-particle jet properties using pp collisions of run 3 data at the center-of-mass energy per nucleon-nucleon collision $₩sqrt{s_₩mathrm{NN}}$ = 13.6 TeV of ALICE detector at the LHC.
Jets are cone-like sprays of hadrons fragmented from the high transverse momentum ($₩p_₩mathrm{T}$) partons which is produced by high momentum transfer (hard) QCD scatterings of partons in pp collisions.
The ALICE Collaboration started run 3 from 2022 with upgraded silicon detector Inner Tracker System (ITS2), enhanced collision energy and luminosity with higher statistics compared to the run 2.
Charged-particle jets are reconstructed using the anti-kT algorithm with jet resolution parameter R = 0.4 at the mid-rapidity ($|₩eta|$ < 0.9) tracks using ITS2 and Time Projection Chamber (TPC) in pp collisions.
The unfolded spectra of the transverse-momentum ($₩p_₩mathrm{T}$), eta, phi of the charged-particle-jets are presented using the data and the response matrix obtained from MC.
The results of the data are compared to the jet quenching models and the run 2 data of ALICE to check the agreement.

Keywords:

jet, pp collisions, LHC

2023 KPS Fall Meeting
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D8.01

Towards generation of an atomic array with optical tweezers

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Abstract:

An array of trapped netutral atoms is a promising candidate for scalable quantum computing and simulation. In this talk, we discuss our plan for constructing a neutral-atom-based quantum architecture. Comparing its performance with that of other hardware like trapped ions and superconducting qubits, we show a goal of our project, the gate-based quantum operations, and share the status of our experiment. In addition, we also present very recent results from other experimetnal settings of ion trap and cavity QED in our group.

Keywords:

neutral atom, quantum computing

D8.02

Interlayer coupling of Rydberg atom arrays

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Abstract:

Scalable and programmable Rydberg atom platforms are recently considered promising platforms for quantum simulations and quantum computations. Especially, three-dimensional(3D) Rydberg atom arrangements could implement arbitrarily connected Rydberg atom graphs [1-2], and they are also expected to be utilized for quantum simulations with various Hamiltonians. With the progress toward such a large-scale and 3D Rydberg atom quantum processor, we present an extended version of experiments observing quantum dynamics in 3D Rydberg atom arrays [1]. We consider bilayer Rydberg atom arrays up to N=20(N=10 in a plane), in which the interactions between intra and interlayer sites are expressed by the quantum Ising Hamiltonian. The unity-filled atomic arrays are prepared by an additional optical tweezer, controlled by a 2D-acousto-optic deflector. Their lowest-energy eigenstates are observed after adiabatic evolutions, and the spectral properties of the quantum quench dynamics are measured through Fourier-Transform spectroscopy. We expect that extending the experimental scheme to a system with several hundred atoms opens up possibilities in quantum simulations requiring 3D atomic arrays, for example, studying the many-body physics of twisted bilayers [3] and quantum spin ice [4].
[1] M. Kim, Y. Song, J. Kim, and J. Ahn, "Quantum Ising Hamiltonian Programming in Trio, Quartet, and Sextet Qubit Systems," PRX Quantum **1**, 020323 (2020).
[2] M. Kim, K. Kim, J. Hwang, E.-G. Moon, and J. Ahn, "Rydberg quantum wires for maximum independent set problems," Nature Physics **18**, 755-759 (2022).
[3] Z. Meng, L. Wang, W. Han, F. Liu, K. Wen, C. Gao, P. Wang, C. Chin, and J. Zhang, "Atomic Bose-Einstein condensate in twisted-bilayer optical lattices," Nature 615, 231-236 (2023).
[4] J. Shah, G. Nambier, A. V. Gorshkov, and V. Galitski, "Quantum spin ice in three-dimensional Rydberg atom arrays," arXiv:2301.04657

Keywords:

Rydberg atoms, Quantum simulation

D8.03

Towards Cs-atom arrays for quantum computing and simulation

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Abstract:

We report our progress towards building a cesium atom array system for quantum computing and quantum simulation. Specifically, we have generated two-dimensional bottle beam arrays that can trap both ground-state and Rydberg atoms. The possibility to trap Rydberg atoms in two angular momentum states may enable future quantum simulation of exotic spin models. We also demonstrated a simple and efficient Raman transition scheme for the realization of single qubit gates with an electric-optic modulator. We have locked two Rydberg excitation lasers to a high-finesse cavity to reduce their linewidths to ~100 Hz level. The two-photon excitation to 81 $S_{1/2}$ and 79 $D_{3/2}$ Rydberg states is demonstrated by the trap loss spectroscopy in a magneto-optical trap. The installation of the tweezer arrays in a new vacuum cell system is underway. Most updated results will be reported. Besides, the collaboration works with theorists to realize high-fidelity Rydberg controlled-phase (Cz) gate and the study on phase diagram of XY spin model in a square lattice will be discussed.

Keywords:

atom array, optical tweezer, quantum computing, quantum simulation, Rydberg atom, quantum gate

2023 KPS Fall Meeting
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D9.01

Fluorescence-based structural profiling for single-molecule protein sequencing

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Abstract:

Proteins serve as cellular workhorses, playing pivotal roles in various cellular functions. Numerous diseases, including cancer, often stem from protein malfunctions or regulatory breakdowns. Analyzing the precise protein composition and state within a cell or minute tissue sample offers invaluable insights and holds immense promise for diagnostic applications. However, a significant challenge in this pursuit of single-cell protein profiling lies in the absence of an experimental tool capable of comprehensively identifying individual proteins, particularly those present in limited quantities. In this study, we introduce a groundbreaking approach for single-molecule protein sequencing and identification. Leveraging a multiplex, FRET-based optical sub-nanometer detection framework, we obtain a 3D structural fingerprint of individual proteins. Through initial experimentation involving DNA-based designer nanostructures that mimic proteins, we showcase the proof-of-concept for our approach. Furthermore, we present the real-world application of our method by demonstrating the 3D structural profiling of select proteins. Our method offers ultimate sensitivity at the single-molecule level and a wide detection dynamic range. This innovation paves the way for enhanced comprehension of cellular processes and holds promise for transformative diagnostic applications.

Keywords:

Single molecule, Protein sequencing, protein Finger printing, FRET, Fluorescence

2023 KPS Fall Meeting
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D9.02

Conformational Dynamics of Human DNA Polymerase θ during Microhomology-Medicated End Joining

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Abstract:

DNA polymerase θ (Pol θ) is a proofreading-deficient family A polymerase involved in translesion synthesis and DNA repair. The error rate of the polymerase is 10~100 times higher compared to other family A members. Previous smFRET studies on Klenow fragment (KF), a high fidelity A-family polymerase, revealed three finger domain conformations: open, ajar, and closed. The Pol-DNA binary complex mostly adopts an open conformation, shifting to a long-lived closed conformation upon binding to a cognate nucleotide. An ajar conformation that examines the incoming nucleotide for complementarity is predominant in the presence of a noncognate nucleotide. In this work, smFRET measurements on DNA templates were performed, which revealed dynamics between discrete FRET states when the nucleotide at the ssDNA-dsDNA junction was labeled, presumably reporting the conformational changes of Pol θ. With the cognate nucleotide, Pol θ remained in the highly stable closed conformation similar to KF but it displayed the closed conformation as well as the ajar conformation with an incorrect nucleotide. smFRET and *in vitro* replication assay results suggest that two Pol θ proteins bound the DNA substrate with short homology region in a cooperative manner, possibly forming a transient dimer. Remarkably, at the ssDNA-dsDNA junction, the Pol θ dimer stabilizes the closed conformation of the ternary complexes only in the presence of the cognate nucleotide, revealing its unprecedented role in nucleotide selection. Our results suggest the intricate interplay of the conformational dynamics and dimer formation of Pol θ as the molecular basis for the low fidelity.

Keywords:

Polymerase θ, smFRET, DNA repair, Fidelity

2023 KPS Fall Meeting
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D9.03

Estimating the folding ‘speed limit’ of helical membrane proteins

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Abstract:

Single-molecule tweezers, such as magnetic tweezers, are powerful tools for probing nm-scale structural changes in single membrane proteins under force. However, the weak molecular tethers used for the membrane protein studies have limited the observation of long-time, repetitive molecular transitions due to force-induced bond breakage. The prolonged observation of numerous transitions is critical in reliable characterizations of structural states, kinetics, and energy barrier properties. Here, we present a robust single-molecule tweezer method that uses dibenzocyclooctyne cycloaddition and traptavidin binding, enabling the estimation of the folding ‘speed limit’ of helical membrane proteins. This method is >100 times more stable than a conventional linkage system regarding the lifetime, allowing for the survival for ~12 hr at 50 pN and ~1000 pulling cycle experiments. By using this method, we were able to observe numerous structural transitions of a designer single-chained transmembrane homodimer for 9 hr at 12 pN and reveal its folding pathway including the hidden dynamics of helix-coil transitions. We characterized the energy barrier heights and folding times for the transitions using a model-independent deconvolution method and the hidden Markov modeling analysis, respectively. The Kramers rate framework yields a considerably low-speed limit of 21 ms for a helical hairpin formation in lipid bilayers, compared to μs scale for soluble protein folding. This large discrepancy is likely due to the highly viscous nature of lipid membranes, retarding the helix-helix interactions. Our results offer a more valid guideline for relating the kinetics and free energies of membrane protein folding.

Keywords:

membrane protein folding speed limit

2023 KPS Fall Meeting
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D9.04

Mitochondrial Transcription Dynamics Revealed by Single Molecule FRET Measurement

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Abstract:

Precise coordination between mitochondrial RNA polymerase (RNAP) and initiation factors is required for the proper transition from the initiation to the elongation stage of transcription. Earlier studies have shown that transcription in bacteriophage and bacteria goes through a series of conformational transitions during the initiation stage. It is still unclear how mitochondrial RNAP collaborates with the initiation factor to recognize the promoter, creates an open initiation complex, and transitions to the elongation stage. We employed single-molecule fluorescence resonance energy transfer techniques to examine the conformational dynamics of the yeast and human mitochondrial transcription systems with single base resolution. Yeast mitochondrial transcription initiation complex was found to undergo dynamic transitions between closed, open, and scrunched conformations during the initiation stage, which is followed by an irreversible, sharp transition to an unbent conformation by freeing the promoter at position +8. Stalled initiation complex remained in dynamic scrunched and unscrunched states without dissociating the RNA transcript, suggesting that backtracking transition occurs, which may have regulatory role. Human mitochondrial transcription contains another initiation factor, TFAM, and it remains unknown how the initiation-elongation transition is coordinated in this system. TFAM was found to preferably bind LSP promoter, by bindings and bends upstream of the LSP promoter. This binding and bending preference explains how TFAM reserves space for RNAP binding at the transcription start site. RNAP failed to bend DNA in the absence of TFAM, suggesting that RNAP relies on TFAM for DNA sequence recognition. The transcription initiation complex became more stable as it progressed up to the +5 position. Based on these observations, mechanistic models of mitochondrial transcription initiation are proposed.

Keywords:

smFRET, Mitochondrial Transcription

2023 KPS Fall Meeting
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D9.05

Single-molecule analysis of RNA-dependent RNA polymerase (RdRp) associated nsp13 helicase

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Abstract:

The architecture of SARS-CoV-2 transcriptome (*1*) shows discontinuous transcription events. By means of this, we have inferred that the SARS-CoV-2 RNA-dependent RNA polymerase (RdRp) operates via mechanisms such as hopping or jumping, and based on prior structural papers (*2*), it is believed that the polymerase-associated nsp13 plays a significant role in hopping or jumping. This study is an exploration of nsp13's characteristics, which serves as a foundation for further in-depth investigation into RdRp's unique behavior. Initially, the known helicase attributes of nsp13 were reproduced using single-molecule fluorescence assays. We investigated directionality characteristics via various lengths and positions of overhangs, intermediate characteristics via ATP analogues and nsp13 mutant studies, as well as binding characteristics via directly observed fluorescence-labeled nsp13. The hlicase pattern of individual nsp13 molecules was observed using surface-immobilized nsp13. Additionally, we immobilized single-strand RNA or nsp13 on a surface and then introduced additional nsp13 through flow, allowing us to examine the binding characteristics between them. These single-molecule studies facilitated an understanding of various characteristics related to nsp13.

1. Kim, Dongwan, et al. "The architecture of SARS-CoV-2 transcriptome." ***Cell*** 181.4 (2020): 914-921.
2. Chen, James, et al. "Structural basis for helicase-polymerase coupling in the SARS-CoV-2 replication-transcription complex." ***Cell*** 182.6 (2020): 1560-1573.

Keywords:

Single-molecule study, SARS-CoV-2, nsp13, RdRp, helicase

2023 KPS Fall Meeting
2023-10-24 - 2023-10-27

D9.06

Single molecule counting: Towards determination of the absolute number concentration of free protein molecules in solution.

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Abstract:

Nanoparticle tracking analysis (NTA) has become an indispensable tool for the size and number concentration of mobile nanoparticles in solution. A conventional NTA primarily relies on the optical detection of purely scattered light from nanoparticles, offering the information about particle dynamics and interactions. Its sensitivity is, however, insufficient to detect nanoparticles smaller than 50 nm or non-metallic like proteins, whose index of refraction is not very different from that of surrounding medium. Recently, interferometric-scattering (iSCAT) microscopy has drawn much attention because of its superb sensitivity and label-free detection capability. It has been demonstrated that the mass of biological molecules such as proteins and nucleic acids can be measured by light scattering. Taking advantage of its highly sensitive interferometric detection, one can further push the limit of detection sensitivity and spatial resolution. In this work, we first demonstrate that we detect and track nanoparticles including protein molecules moving in solution for an extended period of time. From the iSCAT-based single particle tracking (SPT) assay, we succeeded in measuring particle size, number count, and holographic imaging depth, which leads to the determination of the absolute concentration of suspended nanoparticles. We envisage that our iSCAT-based SPT opens a new door to highly quantitative analysis of nano-scaled objects and accessing transient events occurring in dilute solutions, providing critical insights into nanometric systems.

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Keywords:

interferometric-scattering microscopy, single particle tracking, label-free single-molecule detection

2023 KPS Fall Meeting
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D9.07

A hidden route of protein aging

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Abstract:

Protein oxidation is a major factor contributing to the impairment of protein structure and function, closely linked to human aging and age-related diseases. Here, we describe a unique mechanism of protein oxidative damage, which we refer to as "O_2-trapping protein oxidation". Using a robust molecular tweezer approach, we found that contrary to expectations, the oxidative damage of maltose binding protein was facilitated even in its folded state concealing a substantial portion of oxidizable atoms. Molecular dynamics simulations showed that molecular oxygen (O_2) was frequently and tightly trapped within highly hydrophobic pockets of the protein. First-principles calculations suggest that the captured O_2 can be converted to singlet oxygen upon blue light exposure. The potent reactive oxygen species can then readily attack neighboring residues within the diffusion-suppressing, confined areas. This oxidation mechanism provides a design guideline for proteins more resistant to oxidative damage and may have a significant impact on the aging of tissues, such as skin and eyes.

Keywords:

protein oxidative damage, oxygen trapping, singlet oxygen conversion, novel oxidation pathway

2023 KPS Fall Meeting
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D9.08

RNA polymerase alone senses DNA double-strand breaks during transcription and generates R-loops for repair

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Abstract:

R-loop formation around double-strand breaks (DSBs) on transcription template DNA is critical for their repair but its mechanism of action remains poorly understood. In this single-molecule study using Escherichia coli RNA polymerase, we discovered that during transcription, translocating RNA polymerase by itself effectively senses DSBs and efficiently generates R-loops, without assistance from any factors. The R-loop formation efficiency highly depends on DNA end structures, ranging here from 2.8% to 73%. Evidently, R-loop formation is more efficient on sticky ends with 3' or 5' single-stranded overhangs than blunt ends without any overhangs, and the longer the overhangs are, the more efficiently the R-loops form. The R-loops expand unidirectionally upstream from DSB sites and can reach the transcription start site, interfering with ongoing-round transcription. Moreover, the extended R-loops can persist to preempt subsequent transcription rounds. Our findings would resolve several current controversies and provide insights into the general mechanism underlying transcription-coupled repair of DSBs across bacteria, archaea and eukaryotes.

Keywords:

R-loop, DNA double-strand break, DNA repair, Non-canonical nulceic acid structure, Single-molecule FRET

2023 KPS Fall Meeting
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D10.01

Ultrafast dynamics of correlated materials and coherent oscillations

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Abstract:

The development of ultrashort lasers enabled us to investigate various material properties in the ultrafast time domain. Ultrafast studies on correlated materials do not only show the dynamics inherited from the equilibrium properties but also reveal unique phenomena realized only in the nonequilibrium state.

In this tutorial, I will briefly introduce the ultrafast experimental techniques based on short pulse lasers and representative experimental results demonstrating the power of the ultrafast studies. I will discuss coherent oscillations in various cases in more details as one of the representative ultrfast phenomenoa.

Keywords:

Ultrafast phenomena, Coherent oscillations

2023 KPS Fall Meeting
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D10.02

Ultrafast X-ray spectroscopy and scattering using X-ray Free Electron Laser

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Abstract:

Quantum materials present various many-body and topological phenomena and offer possibilities for next generation applications. Among the external perturbations to understand and activate exotic quantum phases, ultrafast light-matter interaction is considered as one promising route. In addition to the widely used optical pump optical probe techniques, the innovative development of X-ray sources, in particular X-ray free electron lasers (XFELs), enables to utilize ultrashort and extremely bright X-ray pulses as probing agents.
In this tutorial, I will present how optical pump X-ray probe experiments are carried out in XFELs. Moreover several time-resolved X-ray spectroscopy and scattering research on quantum materials will be introduced, particularly done at Pohang Accelerator Laboratory X-ray Free Electron Laser (PAL-XFEL).

Keywords:

time-resolved X-ray spectroscopy and scattering, X-ray free electron laser, quantum materials

2023 KPS Fall Meeting
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D11.01

Tuning the phase transition of VO_2 thin films

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Abstract:

Adjusting the phase transition of thin films composed of vanadium dioxide (VO_2) holds considerable importance owing to its potential applications in intelligent windows, sensors, and diverse electronic devices. VO_2 displays a distinctive metal-insulator transition (MIT) that occurs around 68°C temperature which is accompanied by a structural transition and a dramatic change in the optical properties. During this transition, the material shifts between its low-temperature insulating monoclinic phase (M1) and its high-temperature metallic rutile phase (R). From application perspective it is highly imperative to stabilize VO_2 thin films with control on the transition temperature. We have stabilized VO_2 thin films via RF-sputtering technique and employed different routes to tune the phase transition in these films. The tuning of phase transition in VO_2 thin films was achieved by varying the disposition parameters, oxygen content and by ion-implantation. We were able to shift the transition temperature of VO_2 thin films toward room temperature. The modification in the structural, electrical, electronic and optical transition were investigated in different VO_2 thin film samples.

Keywords:

Phase transition, VO2, Thin Film

2023 KPS Fall Meeting
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D11.02

Strain-driven magnetic anisotropy in $La_{0.88}Sr_{0.12}MnO_3$ thin films on (110) $NdGaO_3$

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Abstract:

The $La_{1-x}Sr_xMnO_3$ has various electronic magnetic ground states depending on the hole doping. We focused on the ferromagnetic insulating (FMI) state in $La_{1-x}Sr_xMnO_3$ with x = 0.12 (LSMO). This low-temperature FMI phase is related to orbital ordering in the LSMO. In this presentation, we show magnetic anisotropy in the LSMO films by in-plane strain anisotropy and possibly orbital ordering. To create anisotropic in-plane strain states, an $La_{0.88}Sr_{0.12}MnO_3$ thin film was grown on (110) $NdGaO_3$. The growth of epitaxial $La_{0.88}Sr_{0.12}MnO_3$ is confirmed by X-ray diffraction, and scanning transmission electron microscopy. For investigating magnetic anisotropy, x-ray magnetic circular dichroism was adopted. It shows that different magnetic property by $NdGaO_3$ in-plane direction. Especially, at the lower temperature, the difference in magnetic moments gets larger. The difference in magnetic moments can be simply interpreted as a result of built-in strain by the substrate. However, as indicated above, the larger difference at the lower temperature infers other mechanism can be involved. In this respect, we tried to find information of charge localization, which is deeply related to orbital ordering. We adopt x-ray linear dichroism, the result will be discussed in detail at the presentation.

Keywords:

Thin film, Manganite, Ferromagnetism, Anisotropy

D11.03

Structural disorder in mixed hybrid lead halide perovskites: Impact of anion and cation modifications

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Abstract:

Mixed hybrid lead halide perovskites have attracted great interest in recent years as potential materials for a variety of optoelectronic applications. [1]. Varying the halide concentration and organic cation size can induce local structural disorder in the lattice, altering the properties of these materials [1]. Such changes in mixed halide perovskites are of fundamental importance and a detailed investigation is necessary to know the exact peculiarities caused by these cationic and anionic modifications. In this study, we have studied the effect of changing both anion and cation compositions. We synthesized two mixed hybrid lead halide perovskite systems, the first one is $MAPbBr_xCl_{3-x}$ with x = 0.5 and 1.5, and the second one is $DMAPbBr_xCl_{3-x}$ with x=1.5. We used Brillouin spectroscopy, Raman spectroscopy, X-ray diffraction (XRD), and dielectric measurements to characterize our materials.
The results indicate that in the $MAPbBr_{3-x}Cl_x$ system, by slightly changing the halide content (x) to 0.5, the phase transition shifts to lower temperatures as evidenced by temperature-dependent Raman and Brillouin spectroscopic measurements. However, when the halide content (x) is increased to 1.5, the difference in the anionic radii at the X site increases leading to the induced structural disorder in the lattice. A heterogeneous environment is created that disrupts the long-range order in the lattice, resulting in a glass-like behavior in x=1.5 as evidenced in the temperature-dependent Brillouin shifts. This result is further corroborated by the XRD peaks that do not show any splitting down to the lowest temperature (20 K), proving that the average structure of the material at room temperature (cubic phase) did not change. Dielectric scans at different frequencies give further validation of this hypothesis showing relaxor-like curves. Vogel Fulcher's law was to analyze the dielectric measurements that revealed the glassy phase of this composition with significantly high b values. Moreover, we studied the $DMAPbBr_xCl_{3-x}$ perovskite system, where we kept halide content x to be 1.5, to study the effect of changing the MA (methylammonium) cation with its longer derivative DMA (dimethylammonium). We observed that contrary to $MAPbBr_{1.5}Cl_{1.5}$, which showed an absence of phase transition, $DMAPbBr_{1.5}Cl_{1.5}$ showed a distinct phase transition from its room-temperature hexagonal phase to the low-temperature orthorhombic phase.
Overall, these findings highlight the importance of structural changes induced by incorporating different-sized A-site and X-site cations in mixed halide perovskites, that can help tailor specific properties for a range of optoelectronic applications.

[1] Li C, ACS applied materials & interfaces. 2016 May 11;8(18):11526-31.
[2] Shahrokhi S, Small. 2022 May;18(21):2200847.
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Keywords:

Raman spectroscopy , Relaxors, mixed halide perovskites, Brillouin spectropscopy, Glassy behavior

2023 KPS Fall Meeting
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D11.04

Clean realization of Hund physics near the Mott transition: NiS_2 under pressure

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Abstract:

In recent decades, the effect of Hund coupling *J* in multi-band systems has been studied with much attention. The strong correlation effects caused by Hund's interaction, usually contrasted with the Mott case, can appear dramatically in the case of Hund's metal having a large effective mass and local moments in a region far from the insulating limit. Recently, however, the Hund effect was revealed to be prominent also in the half-filled $NiS_{2-x}Se_x$ system, which is a prototypical Mott system. [1] A kink structure is observed from the ARPES experiment, and it was demonstrated by the DFT+DMFT study that the kink is produced by *J*.
Here, we studied pressure-induced metallic NiS_2 near the Mott metal-insulator transition (MIT) using first principles DFT+DMFT methods to investigate the underlying mechanism of how Hund interaction affects the quasiparticle's behavior in a half-filled multi-band system. Our main results consist of 1) a new interplay of correlations produced by Hund coupling together with Mott physics exhibited as the kink scaled by *J* times *Z* (quasiparticle residue), 2) that the Hund effect of enhancing the effective mass and quasiparticle scattering rate becomes apparent when *J* becomes to the quasiparticle half-bandwidth, and finally 3) the prediction of Hund's signature in optical conductivity – its non-Drude frequency dependence and the non-monotonic temperature evolution of optical spectral weight, possibly observed through experiment.

Keywords:

Hund physics, Mott physics, Metal insulator transition, DFT+DMFT

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D11.05

Role of non-local Coulomb interactions in $SrMO_3$ (M = 3d) perovskites: A DFT+U+V study

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Abstract:

Transition metal oxides represent a class of 'correlated systems' where simple Density Functional Theory (DFT) fails to accurately describe their properties. In our study, we investigate the effects of Coulomb interactions in $SrMO_3$ (M = 3d) perovskite materials by employing both local (U) and non-local (V) Coulomb interactions. The U and V values are calculated using the constrained random phase approximation (cRPA) method, which are then incorporated into the DFT+U+V method to study the electronic structure of materials. Our analysis from cRPA calculations reveals that the intricate interplay between t_{2g}-e_g and t_{2g}-O_p gaps, coupled with *pd*-hybridization, leads to a non-monotonic behavior of U along the 3d series. The calculated electronic structures using DFT+U and DFT+U+V methods demonstrate that the inclusion of V shifts the unoccupied band further up and narrows the bandwidth overall. Our study unveils that incorporating V synergistically enhances the effects of U. This work provides valuable insights into understanding the role of V in the electronic structure calculation of correlated systems.

Keywords:

Non-local Coulomb Interactions, DFT+U+V, ABO3 Perovskites, Correlated Systems, Electronic Structure

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D11.06

Orbital anisotropy of heavy fermion Ce_2IrIn_8 under crystalline electric field and its energy scale

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Abstract:

We investigate the temperature (*T*) evolution of orbital anisotropy and its effect on spectral function and optical conductivity in Ce_2IrIn_8 using a first-principles dynamical mean-field theory combined with density functional theory. The orbital anisotropy develops by lowering *T* and it is intensified below a temperature corresponding to the crystalline-electric field (CEF) splitting size. Interestingly, the depopulation of CEF excited states leaves a spectroscopic signature,"shoulder," in the *T*-dependent spectral function at the Fermi level. From the two-orbital Anderson impurity model, we demonstrate that CEF splitting size is the key ingredient influencing the emergence and the position of the "shoulder." Besides the two conventional temperature scales T_K and T^*, we introduce an additional temperature scale to deal with the orbital anisotropy in heavy fermion systems. Finally, we will discuss the application of the our study to understand the low-*T* behavior in heavy fermion systems.

Keywords:

heavy fermion system, crystalline electric field, dynamical mean field theory

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D11.07

Hall effect in quantum critical superconductor $CeCoIn_5$

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Abstract:

In quantum critical materials, the charge current is expected to be affected by quantum critical fluctuations associated with quantum critical point (QCP). However, while quantum criticality appearing in electrical resistivity has been extensively studied near QCPs, quantum criticality manifested in the Hall effect has not been as thoroughly investigated. Here, we investigate quantum criticality in $CeCo(In_{1-x}M_x)_5$ with M=Cd and Sn via electrical resistivity and Hall effect measurements. Hall effect measurements show the anomalous enhancement of the Hall coefficient (R_H) at quantum critical regime. Combining electrical resistivity and Hall effect results, we find that the complementary interaction between longitudinal and transverse resistivity leads to the universal temperature dependence of the Hall angle. We discuss the singular behaviors of the Hall coefficient and Hall angle coefficient in various cases of quantum critical materials, indicative of quantum criticality.

Keywords:

Hall effect, Quantum criticality, CeCoIn5

2023 KPS Fall Meeting
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D11.08

Orbital Selective Electronic Correlations and Topological Superconductivity of Iron Chalcogenide: A Dynamical Mean Field Theory Perspective

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Abstract:

The iron-based superconductor, $FeSe_{1-x}Te_x$ (FST), obtained significant attention due to two emergent phenomena of the material. The first is the topological superconductivity hosts Majorana Fermion in its boundary as a candidate of the topologically protected quantum bit [1,2]. The second is the orbital selective Mott transition, which is a selective localization of the $Fe(d_{xy})$ orbital while other orbitals, including $Fe(d_{xz/yz})$, remain as itinerant [3]. This talk shows that the topological superconductivity and the orbital selective Mott transition in the FST material are intimately connected [4]. We use the state-of-the-art linearized quasiparticle self-consistent GW plus dynamical mean-field theory framework with included spin-orbit coupling (LQSGW+DMFT+SOC), which enables the quantitative description of the topological Dirac surface state of the FST material. We show that the topologically non-trivial band has the $Fe(d_{xy})$ orbital origin experiencing a localization from the orbital selective Mott transition. From this identification, we show that the non-trivial Z_2 topology for the topological superconductivity could be realized only for the physical regime that is close but not too close to the orbital selective Mott phase. This observation enables understanding and manipulation of the topological superconductivity of iron-based superconductors. Also, more prominent electronic correlations at the topological surface state dominantly from the $Fe(d_{xy})$ orbital can be the origin of the experimentally observed time-reversal symmetry breaking at the surface of the FST material [5].

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Keywords:

Iron-based superconductor, topological superconductor, orbital selective Mott transition , dynamical mean-field theory, GW

2023 KPS Fall Meeting
2023-10-24 - 2023-10-27

D12.01

Multiple charge density wave phases of monolayer VSe_2 on graphene substrates

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Abstract:

Bulk VSe_2 presents a rare example of a three-dimensional (3D) CDW phase which is attributed to Fermi surface nesting with 4 × 4 × 3 periodicity. The CDW nature of VSe_2 undergoes dramstic changes when reducing the dimensionality and forming a heterointerface. A combined study of scanning tunneling microscopy (STM) and angle-resolved photoemission spectroscopy (ARPES) is conducted to understand the multiple charge density wave (CDW) phases of monolayer (ML) VSe_2 films manifested by graphene substrates. Submonolayer (~0.8 ML) VSe_2 films are prepared on two different substrates of single-layer graphene (SLG) and bi-layer graphene (BLG) on a 6H-SiC(0001). We find that ML VSe_2 films are less coupled to the SLG substrate compared to that of ML VSe_2/BLG. Then, ML VSe_2 grown on SLG and BLG substrates reveals a very different topography in STM. ML VSe_2/BLG shows one unidirectional modulation of √3 × 2 and √3 × √7 CDW in topography, which is completely different from the 4 × 4 × 3 CDW in bulk. On the other hand, ML VSe_2/SLG presents a clear modulation of 4 × 1 CDW interfering with √3 × 2 and √3 × √7 CDW. We explicitly show that the reciprocal vector of 4 × 1 CDW fits perfectly into the long parallel sections of cigar-shaped Fermi surfaces near the M point in ML VSe_2, satisfying Fermi surface nesting. Therefore, the 4 × 1 CDW in ML VSe_2/SLG is attributed to the planar projection of 4 × 4 × 3 CDW in bulk. Our result clarifies the nature of the 4 × 1 CDW in monolayer VSe_2 system and is a good example demonstrating the essential role of substrates in two-dimensional transition metal dichalcogenides.

Keywords:

scanning tunneling microscopy, charge density wave, transition metal dichalcogenide, angle-resolved photoemission spectroscopy

2023 KPS Fall Meeting
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D12.02

Multiple insulating phases in a van der Waals material 1T-TaS_2

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Abstract:

1*T*-TaS_2 experiences a metal-insulator transition at low temperatures by forming a charge density wave. This insulating state has long been believed to be due to charge localization. However, recent theoretical studies have shown that the vertical arrangement of the non-bonding layers determines the material's electronic structure. The dimerized configuration, which leads to the bonding-antibonding splitting, is energetically favored rather than the undimerized one. Although various surface-sensitive spectroscopy techniques have confirmed this, we still lack an understanding of the stacking faults and their impact on the surface electronic structure.

To address this, we used scanning tunneling microscopy (STM) to investigate the stacking-order-dependent electronic structure in a van der Waals material 1*T*-TaS_2. Our STM results reveal that the surface is divided into three band-insulating domains with different band edges. This strongly supports the idea that the surface reconstruction puts the non-bonding (undimerized) layer underneath the surface dimerized one. We will discuss the possible stacking configurations to explain the electronic structures of the multiple insulating domains and compare them with previous experimental results, which have shown some inconsistency.

Keywords:

STM, TaS2, Stacking order, Band insulator, Mott insulator

2023 KPS Fall Meeting
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D12.03

Multiband charge density waves in $NbTe_2$

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Abstract:

The electronic properties of low-dimensional materials can be influenced by interactions among electrons as well as between electrons and phonons. These collective interactions often lead to the formation of charge density waves (CDWs) in layered systems, causing significant alterations in the symmetry and shape of the Fermi surface. In this presentation, I will discuss the methodology for analyzing CDWs using scanning tunneling microscopy (STM) and spectroscopy (STS). To illustrate, I will examine the multiband electronic structure of $NbTe_2$ through an analysis of energy-dependent real and momentum measurements. The varying phase offset between CDWs will be demonstrated to produce a non-trivial energy-dependent phase shift. The real space information as well as the momentum space information of CDW can enhance our understanding of CDW formation.

Keywords:

charge density wave, Multiband, low-dimensional

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D12.04

Distinguishing ground state wavefunction of correlated insulator in twisted bilayer graphene

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Abstract:

Flat bands created by moiré band engineering in magic-angle twisted bilayer graphene(MATBG) host abundant emergent quantum phenomena such as correlated insulator, unconventional superconductors, and topological magnet phases [1-4]. Strong interactions between electrons are believed to play a major role to form these quantum phases, yet the microscopic mechanisms remain poorly understood.
To uncover the underlying fundamental physics of those correlated quantum phases, it is essential to identify the exact ground state wavefunction, for which a careful analysis of the real-space electronic structure may provide vital information.
In this talk, I will discuss about our recent Scanning Tunneling Microscopy (STM) results that manifest atomic scale electronic textures of correlated phases originated from coherently interfering electronic states in different valleys of MATBG [5]. I will also discuss our recent achievement in distinguishing the ground state of correlated insulating states in twisted bilayer graphene by using novel phase-sensitive analyzing technique enabling to extract key information of the many-body wavefunction from the atomic scale features.

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** These authors are equally contributed*

Keywords:

STM, Magic Angle Twisted Bilayer Graphene, MATBG, Correlated Insulator

2023 KPS Fall Meeting
2023-10-24 - 2023-10-27

D13.01

Bottom-up synthesis of 2D materials for future electronics

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Abstract:

Two-dimensional (2D) semiconductors have been intensively studied because of their potential in overcoming the limitation of current Si semiconductor technology. Applications in the semiconducting industry require the synthesis of high-quality 2D materials with a large scale. Also, engineering physical properties of 2D materials and their integration into various electronic devices should be addressed. To achieve these goals, a bottom-up synthesis is essential such as chemical vapor deposition. In this talk, I will introduce my three research themes on bottom-up synthesis of 2D materials, aiming to promote their industrial application.

I. Various 2D semiconductors can be synthesized at a wafer-scale with reasonable uniformity and crystallographic quality. The key lies in engineering the absorption energy between substrate and precursor.
II. Engineering physical properties of 2D materials through substitutional reaction allows for effective modification of carrier type, carrier density, and band gap.
III. Integrating 2D materials into various electronic chips, such as Back-End-Of-Line in silicon technology or solar cell devices, necessitates low-temperature deposition to maintain the original device structure. By introducing remote plasma, the reaction between precursors is significantly enhanced, enabling the deposition of 2D films even at room temperature.
IV. Studying the growth mechanism and controlled synthesis of two-dimensional materials using in-situ diagnostics as feedback for artificial intelligent driven autonomous bottom-up synthesis.

Keywords:

2D materials, Bottom-up synthesis

2023 KPS Fall Meeting
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D13.02

Negative Differential Interlayer Resistance Originating from Vertical Channel Migration of Multilayer WSe_2

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Abstract:

Various physical parameters, such as the Thomas-Fermi screening length effect, distribution of surface trap density, and thickness-dependent carrier mobility, have been attributed to vertical channel migration in two-dimensional (2D) van der Waals multilayers. In addition, previous theories and experiments have demonstrated that the interlayer resistance existing within neighboring layers triggers the migration of the conducting channel and spatial variation along the thickness. However, the precise direction of channel migration and the profound effect of interlayer resistance on the carrier density profile under different electrostatic drain and gate bias conditions have not yet been resolved. In this study, we report the direction of channel migration and the resultant negative differential interlayer resistance (NDIR) originating from the vertical channel migration of a multilayer WSe_2. The electrostatic bias-dependent shape modification of transconductance, closely related to carrier transport in 2D multilayers, clearly demonstrates the redistribution of the carrier density profile with different contact electrode configurations: i) bottom-contact (BC), ii) top-contact (TC), and iii) vertical double-side contact (VDC). Furthermore, the reversal of the conducting channel migration direction probed via VDC results in the presence of negative differential interlayer resistance within 2D WSe_2 multilayers, as revealed by employing four-probe measurements to exclude the contact resistance. Our results provide insights into an advanced device layout and a deeper understanding of the distinct carrier transport mechanism in 2D multilayers.

Keywords:

conducting channel migration, tungsten diselenide, negative differential interlayer resistance

2023 KPS Fall Meeting
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D13.03

P-Type Controllable Growth of Large Area MoS_2 with Vanadium Doping using Confined Space CVD

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Abstract:

2D Molybdenum Disulfide (MoS_2) has been a popular choice for researchers as an n-type semiconductor owing to the presence of the sulphur vacancies. The synthesis of 2D semiconducting materials, including MoS_2 with p-type behavior remains a challenge to date. One of the methods for achieving P-type response from CVD grown MoS_2 is the substitutional doping of Transition metal atoms like niobium (Nb), tantalum (Ta) and vanadium (V) into the MoS_2 crystal Lattice. Herein, we have successfully achieved p-type doping of Vanadium into Mos2 flakes using a Confined Space CVD approach. Large area crystals of P-Type MoS_2 were achieved by successful doping of vanadium (V) atoms with varying concentrations of Vanadium precursor in comparison with molybdenum precursor. The varying doping concentrations were verified using the EDX (Energy dispersive X-ray) and XPS (X-ray photoelectron spectroscopy). The electrical measurements of fabricated Field Effect Transistors (FETs) show ambipolar to P-Type behavior depending on the doping concentration. The synthesis of large area P-Type V-doped MoS_2 grown by our method provides the opportunity for its use in advanced material technologies including optoelectronics, photodetectors, and 2D materials-based devices.

Keywords:

2D Materials, CVD Growth, P-Type MoS2, Devices, Field Effect Transistors.

2023 KPS Fall Meeting
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D13.04

Gate dependent magnetoresistance and Hall resistance of polar semimetal WTe_2

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Abstract:

In conventional ferroelectric materials, polarization is weakened as we reduce the thickness of the materials. It has been reported that when the thickness of WTe_2, a polar transition metal dichalcogenide (TMD), is thinned enough, electric fields can penetrate the material and reverse its polarization (i.e., ferroelectricity). The polar semimetallic WTe_2 has perpendicular polarization; charge carriers are free to move in-plane, and the polarization is not completely screened. It has high conductance with the polarization unlike former conventional ferroelectric materials, which allows direct polarization-based transport measurements. It has been demonstrated in previous research that when an electric field is applied to WTe_2, ferroelectric polarization switching can occur, and abrupt changes in conductance and hysteresis appear. However, no clear mechanisms or origins for the hysteresis have been identified.
Here, we explored the origin of electrical conductance hysteresis in the polar semimetal (WTe_2)-based device. We confirmed ferroelectric hysteresis in the ferroelectric field effect transistor (Fe-FET) with WTe_2. To find out the specific origin of the conductivity change, carrier density and mobility were investigated by measuring magnetoresistance (MR) and Hall resistance with gating. The MR was measured as 2.3% and 250% at T=290 K and 1.5 K, respectively, with a non-saturating feature. We investigate electron or hole carrier density and mobility with polarization switching of WTe_2 channel. We note that the WTe_2 can be used as non-volatile memory, which can be extended to be Berry curvature memory and synaptic devices. The novel polar metal-based Fe-FETs are promising for next-generation memory devices.

Keywords:

polar metal, transition metal dichalcogenide, tungsten ditelluride, magnetotransport, ferroelectricity

2023 KPS Fall Meeting
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D13.05

Multi-level magnetoresistance in multi-phase $CrPS_4$ tunneling device

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Abstract:

As the magnetic van der Waals materials are discovered, the transportation properties depending on their magnetic phases are of interest for next-generation memory devices. The precedented research with the family of chromium trihalides ($CrCl_3$[1], $CrBr_3$, CrI_3[2]) demonstrate very large tunneling magnetoresistance with a change of magnetic ordering. In general, these materials change their phase continuously or abruptly between two stable states (interlayer antiferromagnetism, interlayer ferromagnetism). Hence there exist two distinguishable states and it can be possible to generate multi-level magnetoresistance with sequentially changing phase in multi-layer materials [2].

Here, we report the observation of three distinguishable levels (interlayer antiferromagnetism, interlayer ferromagnetism, canted antiferromagnetism) in $CrPS_4$ via tunneling current change with different magnetic field as it has been reported. The canted antiferromagnetic and interlayer ferromagnetic phases have smaller magnetoresistance than interlayer antiferromagnetic phase about 74% and 23% with respect to interlayer antiferromagnetic phase, respectively, at 2K. Such intrinsically distinguishable states [3] will be able to realize multi-level magnetoresistance device with just few layers structure.

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Keywords:

Multi-level magnetoresistance, Multi-magnetic phase, Spin-flop

2023 KPS Fall Meeting
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D13.06

Spin-selective memtransistors with magnetized graphene

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Abstract:

Spin-polarized bands in pristine and proximity-induced magnetic materials are promising building blocks for future devices. Conceptually new memory, logic, and neuromorphic devices have been conceived based on atomically thin magnetic materials and the manipulation of their spin-polarized bands via electrical and optical methods. A critical remaining issue is the direct probe and optimized use of the magnetic coupling effect in van der Waals heterostructures, which requires further delicate design of atomically thin magnetic materials and devices. Here, we report a spin-selective memtransistor with magnetized single-layered graphene on a reactive antiferromagnetic material, CrI_3. The spin-dependent hybridization between the graphene and CrI_3 atomic layers enables spin-selective bandgap opening in the single-layered graphene and the electric field control of magnetization in a specific layer of the CrI_3. The microscopic working principle is clarified by our first-principles calculations and theoretical analysis of our transport data. We achieved reliable memtransistor operations (i.e., memory and logic device-combined operations) as well as a spin-selective probe of Landau levels in the magnetized graphene by using the subtle manipulation of the magnetic proximity effect via electrical means.

Keywords:

Magnetized graphene, Memtransistors, CrI3, Magnetism, Landau levels

2023 KPS Fall Meeting
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D13.07

Investigating Temperature-Dependent Ferroelectric Behavior in Stacked Multilayered MoS_2

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Abstract:

Ferroelectric-based memory holds promise as a candidate for next-generation non-volatile memory. However, traditional three-dimensional ferroelectric materials, primarily oxide-based, face challenges in terms of circuit integration and durability [1]. To address these issues, researchers are exploring the use of two-dimensional ferroelectric materials as potential solutions [2-4]. Recent research has demonstrated that ferroelectric properties can be artificially induced using the tear-and-stack method. Stacking non-ferroelectric materials at a specific angle breaks the inversion symmetry, especially in the transition metal dichalcogenides (TMDs), which are known for their semiconductor properties [5-6]. This offers new possibilities for memory applications. Yet, most investigations have focused on theoretical models and local characterization techniques, such as scanning probe microscopy (SPM) [7]. Consequently, studies that utilize electrical measurements to analyze material properties and their practical applications remain limited.
In our study, we investigated the induced ferroelectric properties by stacking hexagonal (2H) MoS_2 into a rhombohedral (3R) phase with controlled angles. Using an edge contact method, we successfully detected ferroelectric signals from multilayered MoS_2 at room temperature. Contrary to conventional physical properties, ferroelectricity disappears at temperatures below approximately 200 K. In conclusion, our study demonstrates the potential to induce ferroelectric behavior in stacked multilayered MoS_2 layers and highlights the temperature-dependent characteristics. This research paves the way for further exploration and application of ferroelectric materials in advanced memory technologies.

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Keywords:

ferroelectricity, edge contact, rhombohedral stacked MoS2

2023 KPS Fall Meeting
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D13.08

Atomic-scale thermopower in TaS_2

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Abstract:

Thermoelectric power has been generated and used via macroscopic devices exposed to a temperature gradient. While thermopower generation has been investigated to design highly efficient thermoelectric materials, electronically ordered phases such as charge density waves (CDW), or correlated quantum states have not been explored for energy harvesting at the atomic scale. Here, we report on atomic scale thermopower and phonon puddles in the CDW states in 1T-TaS_2, probed by scanning thermoelectric microscopy. The Star-of-David in 1T-TaS_2 exhibits counterintuitive variations in thermopower with broken three-fold symmetry, originating from the localized nature of valence electrons and their interlayer coupling in the Mott-insulating CDW phase of 1T-TaS_2. Additionally, phonon puddles were observed with a spatial range shorter than the conventional mean free path of phonons, revealing the phonon propagation and scattering in the subsurface structures of 1T-TaS_2.

Keywords:

Thermoelectric power, Scanning thermoelectric microscopy, Correlated electronic systems, Phonon puddles, Charge density waves

2023 KPS Fall Meeting
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D14.01

Hydrothermal Synthesis of Round-Shaped Wet-Ceria in the 2-100 nm Scale for High-Performance, Scratch-Less CMP

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Abstract:

The continuous scaling-down of DRAM, 3D-NAND flash-memory, and logic devices necessitates a SiO_2-film chemical mechanical polishing (CMP) process with higher SiO_2-film removal rates (≥ 4,000 Å/min), reduced allowable scratch size, and minimal remaining scratches. Conventionally, ceria abrasive-based SiO_2-film CMP slurries have been employed. To achieve reduced scratch sizes and scratch-less surfaces, there has been a shift from dry-ceria abrasives to wet-ceria abrasives and a decrease in ceria abrasive size. However, this approach often leads to a trade-off by decreasing SiO_2-film removal rates, highlighting the need for solutions.

In order to achieve reduced scratch sizes and scratch-less surfaces, smaller wet-ceria abrasive sizes are desired. However, reducing the size of wet-ceria abrasives results in reduced facet area, introducing a trade-off where SiO_2-film removal rates are compromised. To address this challenge, a hydrothermal-based wet-ceria synthesis study was conducted, aiming to synthesize round-shaped wet-ceria abrasives with high Ce^{3+}/Ce^{4+} ratios (~30% and above) and devoid of {111}, {100}, {110} facets. Parameters such as synthesis temperature and time, source mole concentration, surfactant conditions, agitation speed, centrifugation, and homogenization were systematically controlled.

For achieving high SiO_2-film removal rates, the development of additives alongside particles is essential. Therefore, research on accelerator, dispersant, high selectivity, and slurry chemical design were pursued. This led to the design and synthesis of nano-scale (5-100 nm) round-shaped wet-ceria abrasives, including the optimization of the process and the design of dispersants (three types: picolinic acid, arginine, glutamic acid). Furthermore, a 3L scale hydrothermal synthesis reactor was designed and established for 100 nm-scale round-shaped wet-ceria abrasive synthesis, building upon the assessment of feasibility through a lab-scale (500 mL) demonstration setup.

In summary, we have developed a hydrothermal process-based wet-ceria synthesis technique, producing round-shaped abrasives with unique properties. This research addresses the challenges of high SiO_2-film removal rates and scratch-less CMP processes, contributing to the advancement of semiconductor device fabrication technologies.

Acknoweldgment:
This research was supported by a National Research Foundation of Korea (NRF) grant funded by the Korean government (MSIT) (No. 2021R1A4A1052085).

Keywords:

abrasive, Wet-ceria, CMP, chemical mechanical plarnarization, semiconductor, hydrothermal synthesis, SiO2-film CMP

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D14.02

Thermal analysis simulation of LEC/VGF method for the fabrication of a modular typed InP single crystal growth apparatus

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Abstract:

This research presents on a thermal optimization of the heater by the numerical analysis to fabricate a modular-typed single crystal growth apparatus, which is capable of growing InP using both LEC (Liquid Encapsulated Czochralski) and VGF (Vertical Gradient Freeze) methods in a single apparatus and it was studied to derive the optimal heater design. Controlling the internal temperature of the solid-liquid interface is crucial for defect-free growth of InP crystals. Growth conditions were obtained for temperature control in three regions during growth : the melting zone, the crystal growth zone, and the fully crystallized zone. The simulation results show that the axial temperature gradient at the solid-liquid interface depends on the heater design, which also affects the characteristics of the melt flow.

Keywords:

Indium phosphide, Single crystal, LEC, VGF, Modular-typed

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D14.03

Structure and optical porperties of InAs/$GaAs_{1-x}Sb_x$ sub-monolayer quantum dots

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Abstract:

Structure and optical properties of InAs/GaAsSb sub-monolayer quantum dots grown by molecular beam epitaxy (MBE) have been investigated through high-resolution X-ray diffraction (HRXRD) analysies and photolumindescence (PL) spectroscopy. The sub-monolayer quantum dot structure was introduced to increase the carrier escape efficiency. Also, the type-II band structure inhibits carrier recombination. The results were analyzed via HRXRD simulation and x values were 0, 0.075, 0.116, 0.12, and 0.134. The transition energies of quantum structures obtained the PL results were compared to the results by the HRXRD. With comparing the PL and XRHRD results, we confirmed an optical transition by the type-II band structure when the composition of Sb was increased.

Keywords:

type-II, monolayer, quantum dots, GaAsSb, InAs

Expanding Graphene Field-Effect Transistor (FET) Applications with Single-Layer Oxidized Graphene (SOG)

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Abstract:

This study investigates the potential of single-layer oxidized graphene (SOG) to expand the applications of graphene Field-Effect Transistor (FET) devices. SOG is explored as a gate-tunable dielectric layer, offering the flexibility to tailor electronic properties, rendering it suitable for a wide range of applications, including flexible electronics, sensors, communication devices, and chemical sensing. A novel approach employing SOG patterning is introduced to precisely define the channel design of graphene FETs, effectively confining the graphene channel within self-limited optimal SOG characteristics. Remarkably, the performance of SOG-patterned graphene FETs is found to be on par with graphene/hBN monolithic pattern synthesis. Moreover, this research provides a practical methodology for generating and accurately detecting optimized SOG, paving the way for the integration of SOG into graphene-based devices. This integration holds significant promise for advancing field-effect transistors, heralding transformative developments in electronics and sensing technologies.

Keywords:

Graphene oxide, UV, Super structure, Band gap., Graphene FET, Single-layer oxidized graphene, UV

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D14.05

LED efficiency according to the composition of the InAsP cladding layer

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Abstract:

In the semiconductor LED structure, a cladding layer is created to increase the luminous efficiency. The cladding layer increases the efficiency of the LED by adjusting the path of light emitted from the light emitting layer like an optical fiber in the structure. Therefore, we compared and analyzed the LED characteristics according to the cladding layer. We measured three LEDs to analyze the characteristics according to the composition of the cladding layer. The cladding layer was $InAs_xP_{1-x}$ (x = 0.63, 0.73, 0.81), and the light emitting layer was $InAs/InAs_{0.35}P_{0.60}Sb_{0.05}$ MQWs By Metal Organic Chemical Vapor Deposition (MOCVD).

To analyze LED the optical properties, Photoluminescence (PL) were measured, the wavelength of emitted light was confirmed through PL at 300K, temperature dependence photoluminescence (TDPL) was measured to analyze the temperature stability, and power dependence photoluminescence (PDPL) was performed to determine the emission coefficient.

To analyze the electrical properties, I-V and Transient photocurrent (TPC) were measured. Carrier dynamics were analyzed by measuring the operating voltage and dark current of the LED through I-V and the carrier lifetime through TPC.

We investigated the cladding layer conditions to increase LED efficiency by measuring the optical and electrical characteristics of three LED samples with different cladding layer compositions.

Keywords:

LED, PL, I-V

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D14.06

Characterization of Ion Implantation-Induced Modifications in Hexagonal Boron Nitride via Raman and Photoluminescence Spectroscopy

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Abstract:

Hexagonal boron nitride (hBN), an atomically thin two-dimensional (2D) material with a wide band gap, is extensively employed as a substrate layer in optoelectronic devices due to the removal of dangling bonds and surface charge traps by hBN substrates. Moreover, hBN is recognized for hosting optically active luminescent point defects, which hold promise as single-photon sources at room temperature.

Ion implantation serves as an effective technique for modifying material properties through mechanisms such as doping effects, defect generation, strain formation, and phase transitions. Therefore, an understanding of the changing characteristics of hBN after ion implantation using various ion species is essential for the development of the next generation of 2D material-based optoelectronic devices or single-photon sources.

In this study, we investigate the effects of ion implantation on h-BN using five different types of ions: hydrogen (H), nitrogen (N), copper (Cu), and iron (Fe). Our Raman analysis shows a phase transition from hBN to cBN, exclusively observed in the cases of N, Cu, and Fe ion beam implantation. However, such a transition is absent in H ion implantation. Photoluminescence (PL) emission around 800 nm indicates the generation of boron vacancies. After N and Fe ion implantation, the emergence of boron vacancies is evident, in contrast, H ion implantation fails to effectively generate boron vacancies, highlighting the ion-specific nature of defect formation. This study suggests effective ion species and ion beam fluences for inducing phase transition to cBN or creating boron vacancy.

Keywords:

hexagonal boron nitride, ion implantation, boron vacancy, c-BN, phase transition

D14.07

Study of InGaAs/InAlAs digital alloy using HRXRD and photoluminescence measurements

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Abstract:

The InGaAlAs quaternary alloy has gained significant attention as a promising alternative to existing InGaAsP, enabling the design of laser diodes (LDs) and light emitting diode (LED) that don't require cooling. However, employing the digital alloy method for growth, which results in the creation of numerous heterojunction interfaces and the inability to accurately match the optimal growth temperature of InAlAs, inevitably leads to non-radiative recombination. rapid thermal annealing(RTA) was used to mitigate non-radiative recombination. The InGaAs/InAlAs digital alloys are grown using molecular beam epitaxy(MBE). And the RTA temperature was changed form 700 ℃ to 850 ℃. A comparison of the optical and structural properties that changed according to RTA temperature was conducted using photoluminescence(PL) and high-resolution x-ray diffraction(HRXRD) analyses. The HRXRD simulation results obtained through triple crystal diffraction(TCD) measurements clearly showed compositional changes in the dominant InAlAs barrier and cladding layers due to RTA. Additionally, it is inferred that the compositional and changes induced by RTA have an impact on the optical outcomes of Photoluminescence.

Keywords:

PL, HRXRD, digital alloy, InGaAs/InAlAs, RTA

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D14.08

Transient photocurrent decay studies of p-i-n and nBn photodetector structures

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Abstract:

Transient photocurrent (TPC) decay measurements are performed with infrared photodetectors with p-i-n and nBn device structures. TPC decay with different behavior for photodetector structures is observed by employing a nanosecond pulsed laser with a 1024 nm wavelength without background illumination. As the laser power and cell area of the p-i-n photodetector were increased, the decay time gradually decreased concerning trap-assisted recombination, and it was observed that the steady state was maintained in the nBn structure concerning the saturation of the carrier lifetime and barrier. The purpose of this study is to examine the influence of carrier traps and recombination with TPC of p-i-n and nBn IR photodetectors and to understand better the play role of the barrier and the absorber region in nBn IR photodetector. Also, it can be assumed to have nearly a lack of the depletion region, so the generation-recombination (GR) to the net dark current from the absorber layer is limited. Thus, it is capable of high-temperature operation for IR detection.

Keywords:

Transient photocurrent, infrared photodetector, carrier lifetime

2023 KPS Fall Meeting
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D15.01

Experimental Observation of Three-Dimensional Vortex Ordering in Ferroelectric Nanoparticles

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Abstract:

During the early 2000s, predictions were made about the presence of unique polar structures with nontrivial topological features, such as vortices or skyrmions, within low-dimensional systems. The occurrence of these structures depended on the specific mechanical or electrical conditions at the boundaries. While these patterns were observed experimentally in thin film models, where they were deliberately created by balancing charges and distortions, their identification and categorization in general ferroelectric nanostructures have proven difficult. This is because it requires mapping the atomic-level polarization in three dimensions. In this study, we reveal the existence of these distinctive polar structures in ferroelectric $BaTiO_3$ nanoparticles. This breakthrough was made possible through atomic electron tomography, a technique that reconstructs the spatial arrangement of cation atoms in three dimensions. Our maps of polarization in three dimensions expose a clear pattern of vortices, and we also identify indications of size-dependent changes in the topological configuration – transitioning from a single vortex structure to multiple vortices. These findings not only enhance our comprehensive understanding of the intricate topological properties of nanoscale ferroelectrics but also hold promise for practical applications involving switchable toroidal moments that can be manipulated without physical contact.

Reference: Jeong et al., arXiv 2305.0418 (2023).

Keywords:

atomic electron tomography, topological polar ordering, ferroelectric nanoparticles

2023 KPS Fall Meeting
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D15.02

Mechanical strain-driven room temperature redox reactions in freestanding oxide membrane

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Abstract:

Rapid and reversible redox reactions in the solid system at low temperatures have been a key requirement for designing efficient and environmentally friendly energy materials and devices. Due to the multiple available oxidation states, transition metal oxide compounds have been a good material platform for redox reactions. For example, reversible topotactic phase changes from brownmillerite-$SrCoO_{2.5}$ to perovskite-$SrCoO_{3-\delta}$ and vice versa can occur via oxidation and reduction, respectively [1]. These reactions normally require elevated temperature (~300 ^{O}C) with a certain range of P_{O2} which depends on reaction directions. We have demonstrated that applying mechanical strain on the $SrCoO_x$ freestanding membrane can greatly reduce the activation energy for redox reactions in atmospheric pressure. Therefore, a phase transition from perovskite to brownmillerite structure is possible even at room temperature. Topotactic phase transition induced by mechanical strain provides a new, clean, and practical pathway for tuning the functional oxides.

[1] H. Jeen *et al.*, Nat. Mater., **12**, 1057–1063 (2013).

Keywords:

Oxide free-standing membrane, Mechanochemistry, Strain, Redox reaction, Structure transition

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D15.03

Light-induced enhancement of piezoelectricity in $BiFeO_3$

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Abstract:

Piezoelectricity, which is a conversion between mechanical and electrical energy, is one of the key functional properties that has attracted considerable attention for energy harvesting devices. Enhancement of piezoelectricity in ferroelectrics often has been realized mainly by synthetical approaches via structural engineering of materials, using a variety of processing methods and parameters. In this regard, $BiFeO_3$ is one of the most promising multiferroic materials due to its largely enhanced piezoelectricity when mixed with other materials, doped with other elements, or even epitaxially grown in compressively strained thin films by hosting morphotropic phase boundaries. While these structural approaches are well-known, enhancing piezoelectricity by external stimuli has yet to be clearly explored, despite their advantages of offering not only simple and in-situ control without prior processing requirement, but compatibility with other functionalities. Here, we show that light is a new pathway to enhance the piezoelectric property in $BiFeO_3$. Our results by piezoresponse force microscopy scans and spectroscopy measurements on $BiFeO_3$ reveal nearly a sevenfold enhancement of piezoelectric signal under laser illumination. This light-induced enhancement of piezoelectricity is attributed to two main contributions from the bulk photovoltaic effect and Schottky barrier effect, involving the key role of open-circuit voltage and photocharge carrier density. These findings provide fundamental insight to light-induced piezoelectricity enhancement, offering its potential for multifunctional optoelectronic devices.

Keywords:

Piezoelectricity, BiFeO3, The bulk photovolatic effect, Schottky barrier effect , Piezoresponse force microscopy

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D15.04

Engineering electronic structures on oxide interfaces

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Abstract:

Understanding electronic structures is vital to investigating exotic phenomena such as superconductivity, ferromagnetism, and metal-insulator transitions. Among various experimental techniques, angle-resolved photoemission spectroscopy (ARPES) stands out as particularly suitable for studying novel phenomena. By analyzing the electronic structures of materials, ARPES leads to an understanding of how these exotic phenomena manifest within solid-state systems from an electronic structure perspective. That being said, only a limited number of experimental results have so far addressed the manipulation of electronic structures.

In this talk, I will elucidate the examination of controlled electronic structures through the utilization of ARPES and oxide thin-film growth methods, which allow electronic systems of materials to be finely tuned. This presentation will shed light on how exotic phenomena can be studied and manipulated from the perspective of electronic structures.

Keywords:

ARPES, oxides, thin films

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D16.01

First-principles Study of the Atomistic Mechanism of Ferrocene-based Molecular Rectifier

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Abstract:

Being the fundamental building block of semiconductor devices, realizing large and robust diode effects has been a major goal in the field of single-molecule electronics. However, the device performance of the molecular device is still insufficient to replace silicon-based devices. Recently, ferrocene based molecular junction are widely studied as a candidate for molecular rectifier due to its large rectification ratio [1]. In this study, based on multi-space constrained search density functional theory (MS-DFT) we have recently developed [2-4], we carry out first-principles non-equilibrium quantum transport calculations of ferrocene-based molecular diode. We here emphasize that the electrode of the device structure is finite 2-dimensional graphene, which cannot be handled within conventional nonequilibrium Green's function (NEGF) due to the requirement of semi-infinite electrodes. Using MS-DFT, we first study the asymmetric current-voltage characteristics and rectifying property of the junctions coming from the bias-dependent electronic structure change. Next, by introducing the gate electrode, we investigate the effect of the gate bias on rectification behavior of the device. This study will offer a fundamental understanding toward the field of single-molecule electronics.

[1] H. Jeong et al. Adv. Funct. Mater., 24, 2472 (2014)
[2] J. Lee et al. Proc. Natl. Acad. Sci. U.S.A., 117, 10142 (2020)
[3] J. Lee et al. Adv. Sci., 7, 2001038 (2020)
[4] T.H. Kim et al., Npj Comput. Mater. 8, 50 (2022)

Keywords:

first-principles calculations, nonequilibrium quantum transport, molecular electronics, rectification, ferrocene

2023 KPS Fall Meeting
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D16.02

Low-temperature behavior of quantum hybridization negative differential resistance from one-dimensional halide perovskite

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Abstract:

Halide perovskites have garnered significant attention for their potential in optoelectronic and electronic applications coming from their excellent properties, including long charge carrier diffusion lengths and lifetimes. For the electronic device application of low-dimensional halide perovskites, we reported the negative differential resistance (NDR) property of the device based on 1-dimensional $(CH_3)_3SPbI_3$ and $(CH_3)_3SGeI_3$ within first-principle manner [1,2]. We revealed that the origin of NDR property is quantum-mechanical hybridization between left and right electrode states in the low-bias regime and its abrupt disruption in the high-bias regime, named quantum-hybridization NDR, or QHNDR. Since the electrode state is the key of QHNDR mechanism, the NDR performance can be adjusted by differing electron temperature that induces broadening. In this study, we carried out density functional theory-based non-equilibrium Green's function (DFT-NEGF) calculation with various electronic temperature to investigate the effect of temperature toward the device performance. By analyzing the nonequilibrium electronic structure of the device structure, we find that the hybridization between electrode states has been remained even in high bias at low temperature. As a result, we find that the peak-to-valley ratio improves about 7 times at low temperatures compared with room temperature.

[1] Khan, M. E. *et al.*, *Adv. Funct. Mater.* **29**, 1807620 (2019)
[2] J. Lee, Khan, M. E. & Y.-H. Kim *Nano Converg.* **9**, 25 (2022).

Keywords:

First-principles calculations, halide perovskite nanowires, nonequailibrium quantum transport, Quantum-hybridization negative differential resistance, low temperature

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D16.03

Carbon Substitutional Defects in Monolayer hBN and their Effects on Graphene/hBN Heterostructure

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Abstract:

Monolayer hexagonal boron nitride (hBN) has emerged as a fascinating object of study, primarily due to its characteristics as a single photon emitter in a wide range of wavelengths. The origin of this single-photon emission lies in the defect that triggers electron transitions within the original bandgap. This distinctive luminescence has been identified as a promising avenue for advanced quantum information technology. However, comprehending individual defect variations is necessary for practical applications, which has been challenging because experimental observations often capture collective signals rather than local properties. To surmount these inherent complexities, we carried out a comprehensive investigation using first-principles calculations based on density functional theory (DFT) within the hybrid functional approach, which is well known for accurate optical bandgap estimation. We have studied the formation energies of defects, a fundamental quantity reflecting their energetic stability, based on the atomic and electronic structures we have carefully examined. Here, we also propose a detailed approach to the carbon chemical potential, which could contribute immensely to the formation energy. We then compare the calculated transition energies through the defect-induced midgap states with the observed energies of the emitted photons to find the origin of the previously reported luminescence. Finally, we discuss the implications of defects in the graphene/hBN bilayer heterostructure, including the energetic, electronic, and magnetic properties of the system.

Keywords:

hBN, Defects

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D16.05

First-principles study of the sliding ferroelectricity in cellulose nanocrystals

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Abstract:

Sliding ferroelectricity is a unique property observed in non-centrosymmetric van der Waals (vdW) systems, where interlayer sliding induces a switch in spontaneous electric polarization. The different switching mechanism enables sliding ferroelectrics to have substantially low switching energy barriers compared to conventional ferroelectrics. In this study, using first-principles calculations, we reveal that cellulose nanocrystal (CNC), which is a metal-free, organic vdW material, displays sliding ferroelectric behavior characterized by reversible spontaneous electric polarization in both out-of-plane and in-plane orientations. We investigate two cellulose atomic structures, referred to as the 'vdW slab' and 'CNC slab', each possessing distinct surface orientations. We propose a comprehensive theoretical model to elucidate the switching dynamics within multilayer cellulose vdW slabs and the formation of intermediate polarization states. Furthermore, we discuss the transition states and kinetic pathways governing the motion of ferroelectric domain walls in cellulose CNC slabs. This study introduces a new dimension of tunability for the design of organic sliding ferroelectric devices, harnessing the unique sliding ferroelectric properties of cellulose.

Keywords:

cellulose nanocrystals, sliding ferroelectricity, density functional theory

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D16.06

First-principles analysis of curvature and strain energies of carbon nanotubes

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Abstract:

Carbon nanotubes (CNTs), while resembling rolled-up sheets of graphene, show subtle structural differences due to the curvature effect. When a CNT is made by rolling up a sheet of graphene and then its atomic structure is optimized by minimizing its total energy in the density functional theory (DFT), its curvature energy is decreased by the increase of its cylindrical radius while its strain energy is induced by the deviation of its atomic structure on the cylindrical surface from that of the rolled-up graphene. Using DFT calculations of armchair and zigzag CNTs of various radii, we analyzed their curvature and strain energies and found the dependence of the curvature energy on the cylindrical radius. Based on these results, we also discuss curvature and strain energies of chiral CNTs. 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:

carbon nanotube, density functional theory, curvature energy, strain energy

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D16.07

Exploring Tunable Magnetic Properties in Multilayerd Co/Pt Superlattices using DFT Analysis

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Abstract:

Recently, layered systems with 3d transition metals and 4d or 5d transition metals have been investigated for magnetic applications such as ultra-high density recording media and magnetic random access memories (MRAMs). In particular, Co/Pt(111) multilayer systems, which are artificially synthesized thin films, have attracted attention as spin-orbit torque-based spintronic memories because of their excellent thermal stability with low critical spin switching current density and perpendicular magnetization characteristics. Despite the great interest in this system, the mechanisms of magnetic anisotropy and the role of Co and Pt in the spin Hall effect are not fully understood. Therefore, we have systematically analyzed the magnetic properties of Co/Pt(111) multilayers composed of 18 layers using density functional theory (DFT), taking into account the spin-orbit interaction (SOI). The main cause of the change in the physical properties with the relative thickness of Co/Pt is due to interfacial effects. By controlling the individual thicknesses, we have demonstrated the potential for tunable magnetic properties tailored to specific applications.

Keywords:

CoPt alloy, magnetic anisotoropy , spintronics, magnetic property

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E2.01

Search for Very Light Fermiophobic Higgs boson in the type-I two-Higgs-doublet model

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Abstract:

The possibility of a light fermiophobic Higgs boson h_f in the type-I two-Higgs-doublet model remains viable. We explore the allowed parameter space that satisfies theoretical constraints and current experimental data under the mass degeneracy assumption $M_A = M_{H^\pm} = M_{A/H^\pm}$, which is motivated by the Peskin-Takeuchi oblique parameters. Our findings reveal that the mass of the light fermiophobic Higgs boson falls within the range of $[1, 20]\ \mathrm{GeV}$, with ₩$M_{A/H^\pm} < 335\ \mathrm{GeV}$.
We propose that $pp \to h_f H^\pm(\to W^\pm h_f) \to 4\gamma W^\pm$stands as the primary production channel at the HL-LHC, and subsequently perform a signal-background analysis. A notable challenge arises due to the boosted nature of light $h_f(\to \gamma\gamma)$, causing it to evade the conventional photon isolation criteria. we suggest that the jet substructure have important role, to address this predicament.

Keywords:

Beyond Standard model, Higgs Physics, HL-LHC

Exploring local and global feature integration in Multi-Modal Deep Neural Networks

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Abstract:

In this study, we present a new approach for incorporating both local and global features into the architecture of a multi-modal deep neural network.
Kinematic features as global features offer a broader contextual understanding for classification tasks, while the quantum chromodynamics (QCD) color structure as local features, provides decorrelated attributes that complement global features.
Our proposed methods facilitate the combination of these two distinct features, enhancing the effectiveness of the network.

Keywords:

Neural Network, Multi-modal model, color structure

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E2.03

A new decorrelation algorithm for high energy physics

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Abstract:

In high energy physics, creating a trustworthy classification model necessitates non-trivial regularizations to preserve the interpretability of the underlying physics and the relationships among observed features. We present a novel measure of variable association, accompanied by a new machine learning algorithm designed to estimate it. Using this, we build a distinctive classifier that incorporates attributes derived from the evaluated association. Through case studies in jet and Higgs physics, we demonstrate the improved robustness and interpretability this approach provides compared to other methods.

Keywords:

particle physics, collider data analysis, machine learning, classification, interpretability

2023 KPS Fall Meeting
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E2.04

Exploring lepton flavor violation phenomena of the Z and Higgs bosons at electron-proton colliders

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Abstract:

We explore the potential to detect lepton flavor violation (LFV) phenomena in the Z and Higgs bosons at electron-proton colliders, specifically the LHeC and FCC-he. These colliders have advantages such as reduced QCD backgrounds and fewer pile-ups in comparison to HL-LHC. We study an indirect method to investigate LFV in the Z boson through the $Z-e-\tau$ coupling and directly observe the on-shell decays of $H \to e \tau$ and $H \to \mu \tau$ through the charged-current production of H. To enhance the results, we apply the XGBoost method. We conclude by projecting the following 2 σ upper bounds that can be achieved at the LHeC with the configuration of $E_e=50$ GeV, $E_p=7$ TeV, and $\mathcal{L}=1 {\rm ab}^{-1}$: Br$(Z \to e^\pm \tau^\mp) < 2.2 \times 10^{-7}$, Br$(H \to e^\pm \tau^\mp) < 1.7 \times 10^{-4}$, Br$(H \to \mu^\pm \tau^\mp) < 1.0 \times 10^{-4}$.

Keywords:

Collider Phenomenology, Lepton Flavor Violation, LHeC, FCC-he, Machine Learning

2023 KPS Fall Meeting
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E3.01

Emergence of new scaling symmetry in holographic superconductor

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Abstract:

We develop holographic superconductor model by introducing non-linear electrodynamic interactions. Due to the non-linearity of the interaction, we can consutruc superconducting dorm in the phase diagram.
However, we observed that the superconducting phase does not fill all the region of the superconducting phase. And we find new scaling symmetry appear inside superconducting dorm. The numerical result shows that region corresponds to the LIfshitz geometry rather than AdS. We propose this regioin can detect quantum critical point at zero temperature.

Keywords:

holographic superconductor, quantum critical point, Lifshitz symmetry, non-linear electrodynamics

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E3.02

Prediction of Holographic Superconductor Dome

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Abstract:

We have developed an AI model that utilizes a transformer architecture to predict a holographic superconductor dome. This AI model is specifically designed to take the superconductor dome as input and produce the effective mass as output. In this paper, we focus on a holographic superconductor characterized by real scalar fields exhibiting momentum relaxation and an effective mass term that is dependent on the square of the field strength tensor.
To generate the training data for our AI model, we take a random selection process for the effective mass values. Subsequently, we analyze the resulting phase diagram of the holographic superconductor.

Keywords:

Transformer, Neural Network, Holography, superconductor, AI

2023 KPS Fall Meeting
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E3.03

Order parameter and spectral function in holographic superconductors

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Abstract:

Numerical investigations of the fermionic spectral function in the presence of a vector and tensor condensate yield a Fermi arc and a gapped behavior. We have verified the corrected order parameter for vector and tensor fields by comparing the fermionic spectral function with the order parameter that depends on momentum. Our work also introduces the calculation of the tensor condensate with matter's backreaction on the metric, addressing a missing part in the literature. In the holographic setup, we analyze the different orbital symmetries in the presence of a vector and tensor condensation. Moreover, we have examined the influence of various factors, including the coupling constant, chemical potential, and temperature, on the spectral function. We demonstrate the feasibility of achieving d-wave fermionic spectral function through two vector field condensates (p_x and p_y) combined with two fermion flavors. Combining $d_{x^2−y^2}$ and d_{xy}-wave condensation with two fermion flavors leads to a g-wave spectral function.

Keywords:

Gauge/Gravity duality, Holographic superconductors, Fermi arc, Spectral function

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E3.04

When the Analytic Fermions Spectral Function in Probe Limit Can Be Trusted?

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Abstract:

We investigate the symmetry-breaking effect on the spectral function of holographic fermions. Previously, we reported the probe limit analytic expressions for all Lorentz symmetry interactions and precisely determined the symmetry and singularity types of Green's functions. In this talk, we calculate the full backreacted spectral functions and then compare them with the previous analytic results. The probe limit is an appropriate approximation for scalar, polar(radial)-space-like vectors, and space-space-like antisymmetric 2-tensors interactions. On the other hand, in polar(radial)time-like vectors and time-space-like antisymmetric 2-tensors interactions, the probe limit and backreacted results are significantly different, causing the probe limit to be an unreliable approximation.

Keywords:

Holography and condensed matter physics (AdS/CMT),

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E4.01

Deep Learning for the HAWC Gamma Ray Observatory

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Abstract:

We present the results of applying a transformer-based deep learning neural network to the data from the HAWC Gamma-Ray Observatory. HAWC observes the extensive air showers produced by very high energy gamma rays, and registers the Cerenkov radiation produced by the shower by PMTs placed in 300 large water tanks. The deep learning model takes the charge and relative timing information of the PMTs and aims to reconstruct the incoming direction of the initiating gamma ray and to discriminate showers produced by gamma rays from the overwhelming cosmic-ray background. Both tasks are vital for source analysis, where better angular reconstruction allows better source localization, and improved cosmic-ray rejection improves the signal-to-noise ratio. We will present the results on simulation and the gamma-ray sky maps from applying the network to a subset of the HAWC data.

Keywords:

Gamma ray observatory, Deep Learning, HAWC

Analysis of the Very High Energy Gamma-ray Source eHWC J1850+001 Using Updated HAWC Data

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Abstract:

eHWC J1850+001 is one of the nine gamma-ray sources emitting energetic photons above 56 TeV discovered by the HAWC gamma-ray observatory reported by HAWC in the high energy catalog of 2020. Other gamma-ray observatories like H.E.S.S. and LHAASO have also detected sources near that location as HESS J1849-0001 and 1LHAASO J1848-0001u, respectively. Due to the spatial consistency between HESS J1849-0001 and PSR J1849-0001, the origin of the gamma rays has been identified as the pulsar wind nebula powered by PSR J1849-0001. A pulsar wind nebula typically produces TeV gamma rays through leptonic processes like inverse Compton scattering. Understanding the spectrum of the pulsar wind nebula is essential for determining whether gamma rays are of a purely lepton origin or require an additional mechanism. We present the up-to-date spectrum of eHWC J1850+001 by using about 2400 days of HAWC data. We also confirm that the HAWC observation is consistent with HESS J1849-0001 and 1LHAASO J1848-0001u in spectrum and position.

Keywords:

Pulsar Wind Nebula, TeV gamma-ray astrophysics, HAWC

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E4.03

In-ice measurements and sensitivities of the IceCube Upgrade Camera System

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Abstract:

The IceCube Neutrino Observatory is a world's first gigaton neutrino telescope consisting of 86 strings instrumented with over 5000 digital optical modules (DOMs), containing Cherenkov light detecting photomultiplier tubes, distributed over a cubic kilometer in the deep glacial ice below the South Pole in Antarctica. The primary objectives of this optical Cherenkov detector are to measure high-energy astrophysical neutrino fluxes and ascertain their sources. The IceCube Upgrade is an extension of the current detector by seven additional, denser-instrumented strings to be deployed in the lowest central region of the existing detector. The goals of the IceCube Upgrade are two-fold: to enhance sensitivity to neutrinos in the GeV range, and to improve the calibration of the IceCube detector as a means of reducing systematic uncertainties due to the ice's optical properties. Among other calibration devices designed to study ice properties, a novel camera system, designed and produced at Sungkyunkwan University, are being integrated into the Upgrade DOMs. The system includes three cameras, each paired with an illumination LED, included in each Upgrade DOM. In total, 2,300 cameras will be deployed. A combination of photographic images from transmitted and reflected light will measure optical properties of both the bulk ice in-between strings and the refrozen hole ice. We present the current operations plan for these two measurement types and preliminary sensitivities to the ice properties that can be expected with this new camera system.

Keywords:

neutrinos, , IceCube, optics, neutrino detector, cameras

Searches for dark matter signals with high-energy neutrinos in the IceCube Neutrino Telescope

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Abstract:

Even though numerous astrophysical observations imply the existence of dark matter, the nature of this invisible matter remains unknown. One way to overcome this unsatisfactory situation is to indirectly search for dark matter using high-energy neutrinos, which could in turn provide clues about the particle nature of dark matter. Neutrinos could be produced from annihilations or decays of dark matter in large dark matter reservoirs such as galaxy clusters, the Milky Way halo, or the Sun. Furthermore, high-energy neutrino fluxes from distant sources, like active galaxies, could be influenced by rare interactions with dark matter in galactic and extragalactic regions during their propagation. The IceCube Neutrino Observatory has been detecting high-energy astrophysical neutrino events which offers new opportunities to look for dark matter. By analysing the collected data, searches for signals of dark matter decay or annihilation or rare dark matter interaction signatures in a wide range of dark matter mass, in particular sub-GeV to TeV-PeV, are conducted. In this talk, the recent results and the status of dark matter searches in IceCube are presented.

Keywords:

IceCube, Neutrino, Dark Matter, Indirect Detection

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E6.01

A theoretical and numerical approach into high-efficiency plasma oscillator for next-generation THz-driven electron linear acceleration

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Abstract:

기존의 RF (radio-frequency) 선형 전자 가속기들은 대부분 30 ~ 50 MV/m 범위의 종방향 가속 전기장에서 operation 하는데 이는 RF cavity의 conductor waveguide의 vacuum breakdown limit이 낮아 전자 빔을 가속시키기 위한 가속장의 세기를 쉽게 높일 수 없다는 한계점이 있다. 이를 극복하기 위해 구동 주파수를 테라헤르츠 단위 (1 ~ 10 THz)로 높이고 펄스 길이를 늘려 threshold를 높이면 결론적으로 가속관의 전기장 세기를 GV/m 단위로 높일 수가 있다. 이러한 이유로 최근 해외에서 고체 기반의 테라헤르츠파 방출 소스를 사용하여 전자 가속을 하려는 시도가 보고되고 있다. 하지만 고체 기반의 방출원들은 대부분 레이저 에너지 대비 효율이 낮다는 단점이 있다. 본 발표에서는 앞서 언급한 단점들을 극복하기 위한 연구로 새로운 고출력 테라헤르츠 방출원인 “플라즈마 쌍극자 진동” [1,2]을 테라헤르츠 기반 전자 가속에 적용하는 연구를 진행하였다. 특히 테라헤르츠파 에너지를 2,3차원 시뮬레이션을 통해 레이저 에너지 대비 효율을 계산하였으며 또한 효율을 계산함과 동시에 플라즈마 쌍극자 진동에서 방출된 테라헤르츠파와 전자 빔의 상호작용을 Elegant simulation으로 전산 모사한 결과를 보고할 예정이다.

References

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Keywords:

laser-plasma interaction, Terahertz-driven acceleration, plasma dipole oscillation

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E6.02

Intense narrow-band THz emission from a density gradient plasma

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Abstract:

Tunable narrowband terahertz (THz) sources with GW-level power are of great importance in THz research. A new scheme is presented to obtain such THz emission, in which two co-propagating detuned laser pulses beat in a linear density gradient plasma. Using two- and three-dimensional particle-in-cell simulations, it is demonstrated that the radially-polarized THz emission originates from a localized region of plasma wave excited by the ponderomotive force. This occurs when the beat frequency exactly matches the plasma frequency, generating a plasma current, which drives electromagnetic radiation. In a vacuum, the emitted radiation has multiple cycles, with high-peak-field strength and a narrower spectrum, making it suitable for various ambitious applications.

Keywords:

THz emission, PIC simulation, Laser-plasma interaction

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E6.03

Heat transfer within non-equilibrium dense aluminum heated by a heavy ion beam

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Abstract:

Energetic laser-accelerated ions can heat a small solid-density sample homogeneously to temperatures over 10,000 K in less than a nanosecond. During this brief heating time, the electron temperature of the sample rises first, and then the ion temperature increases owing to the heat transfer between the hot electrons and cold ions. Since energy deposition from the incident heavy ion beam continues concurrently with the electron-ion relaxation process within the heated sample, the electron and ion temperatures do not reach equilibrium until the end of the heating. Here we calculate the temperature evolutions of electrons and ions within a dense aluminum sample heated by laser-accelerated gold ions using the two-temperature model. For these calculations, we use the published stopping power data, known electron-ion coupling factors, and the SESAME equation-of-state (EOS) table for aluminum. For the first time, we investigate the electron and ion temperature distributions within the warm dense aluminum sample and the heating uniformity throughout the entire heating period. We anticipate that knowledge of the temperature evolution during heating will allow for the study of the stopping power, thermal conductivity, EOS, and opacity of warm dense matter heated by an energetic heavy ion beam.

Keywords:

Heavy ion beam, non-equilibrium, laser-driven ion heating, electron-ion coupling

E6.04

Characterization of strongly coupled plasma produced in helium fluids

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Abstract:

The Sun's inner layers, including the photosphere and chromosphere, as well as white dwarfs, are characterized by abundance of helium in a plasma state with high electron density and relatively low temperature, satisfying strongly coupled plasma (SCP) states, where the Coulomb coupling parameter exceeds unity [1, 2]. While prevalent throughout space, it is difficult to access directly such SCP states or to produce uniform SCP states with sufficiently long lifetime in the laboratory, rendering the investigation of basic transport processes quite challenging. To surmount these obstacles and explore the realm of high-density SCP, we have developed an experimental setup utilizing a supercritical fluid (SCF) [3, 4]. Using a ns laser pulse to SCF helium at 100 bar, we create SCPs with the estimated electron density of approximately 10^{27} m^{-3} [5] and a temperature of about 1 eV, corresponding to a Coulomb coupling parameter of 2. This study shows the potential to facilitate precise measurements of thermodynamic transport parameters and equation of state for dense SCP states.
*This work was supported by the National Research Foundation of Korea (NRF) funded by the Ministry of Science and ICT (Nos. 2019R1A2C3011474, 2022M3H4A1A04074153, and RS-2022-00154676).

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Keywords:

Laser plasma, strongly coupled plasma, supercritical fluid

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E7.01

Collectivity in ^{86}Mo and ^{84}Mo: an implication of a sudden shape change

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Abstract:

The characteristics of the $N = Z$ nuclei are intertwined with proton-neutron correlations and quadrupole-quadrupole interactions. Consequently, the medium-mass nuclides show a significant shape change over the number of neutrons and protons. The collectivity of ^{80}Zr implies a large deformation, and the shell model calculation becomes sensitive to the different model spaces and a choice of interaction for ^{84}Mo. For example, a prolate-oblate shape competition is anticipated in a shell model calculation based on the Nilsson SU(3) scheme in ^{84}Mo. We studied the collectivity of ^{84}Mo and its neighbor isotope ^{86}Mo through a first 2^+ state lifetime measurement. A 140-MeV/u ^{92}Mo primary beam impinged on a 235-mg/cm^2 ^{9}Be target and produced the proton-rich nuclei. The TRIPLEX plunger setup coupled to the GRETINA HPGe array was employed to populate the low-lying excited states in ^{84,86}Mo and measure their first 2^+ state lifetime. The new lifetime measurement results for ^{84}Mo and ^{86}Mo are presented. A sudden change of the collectivity between ^{84}Mo and ^{86}Mo is discussed with a shell model calculation and a recently developed DNO-SM formalism.

Keywords:

nuclear structure, gamma-ray spectroscopy, nuclear shell model

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E7.02

독일 마인츠 대학에서 수행한 Fe 원자의 광이온화 과정과 Dy 원자의 optical pumping 연구

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Abstract:

방사성 동위원소 분석을 위한 기초 작업의 일환으로 마인츠 대학교 RISIKO 시설에서 2개의 레이저를 이용하여 Fe 원자를 대상으로 2단계 광이온화 과정을 통하여 Rydberg 준위와 자동 이온화 준위에 대한 연구를 실시하였다. 선택적 이온화의 효율이 4000배 이상임을 확인하였다. 또한, DY 원자를 대상으로 parity violation 연구를 위한 준비 과정으로 optical pumping 연구를 실시하였다. 하나의 EOM을 이용하여 5개의 동위원소 전이선과 일치하는 레이저를 발생시켰으며, 이를 이용하여 163Dy 동위원소의 조미세 준위들 사이에 거의 100% 효율에 달하는 pumping 효율을 얻을 수 있었으며 원편광 빔을 이용하여 Zeeman pumping도 동시에 이루어지는 것을 확인하였다.

Keywords:

원자 레이저 분광, 초미세 구조, 다단계 광이온화, parity violation

2023 KPS Fall Meeting
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E7.03

Exploring the nuclear structure towards around the N = 126 shell closure

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Abstract:

The investigation of neutron-rich nuclei near shell closures provides new insights into the strong nuclear interaction. The nuclear structure of nuclei far from the stability line near the N = 126 shell closure below 208Pb is important for understanding the evolution of nuclear interaction in heavy nuclei. Additionally, these nuclides are the last bottleneck in the r-process, forming an abundance peak near A = 195. Properties of those nuclei thus can also provide constraints to the astrophysical r-process scenario. However, exploring these nuclei around N~126 has been limited due to small production cross-sections involving conventional reactions to study neutron-rich nuclei, like in-flight fragmentation or fission.
There is a growing interest in using Multi-Nucleon Transfer (MNT) reactions near energies around the Coulomb barrier to access these nuclei, overcoming this difficulty. MNT reactions between a 7MeV/u 136Xe beam and 198Pt target was performed at GANIL to produce and characterize neutron-rich nuclei around the N = 126 shell closure. The outgoing projectile-like particles were identified by the large acceptance VAMOS++ spectrometer, and the Target-Like Fragments (TLFs) were detected by the newly installed second arm detector, CATLIFE (Complementary Arm for Target LIke FragmEnts). The excitation energy of the fragments and the mass number (A) of the TLFs before evaporation were then obtained. The prompt (Doppler corrected) and delayed γ rays from the excited states of the residues were detected by AGATA γ-ray array at the target position and 4 EXOGAM clover detectors at the end of CATLIFE, respectively.
One of the major challenges in the experiment is particle identification due to the large A and Z of the residues, as well as the wide range of charge states due to the use of energies around the Coulomb barrier. Therefore, a new calibration method for particle identification using several machine-learning techniques was developed. The complexity of the calculation of the ionic charge state was reduced, and the resolution (ΔQ/Q) was improved to 1/86 (FWHM) by regression of the ion energy using a deep neural network and gradient-boosted decision tree. The method for Z identification was also developed using semi-supervised learning with a deep neural network. Subsequently, the prompt and delayed γ-ray spectroscopy of the excited states of these nuclei was performed. Preliminary results of the above analysis will be presented.

Keywords:

AGATA, Machine learning, Multi-nulceon transfer reaction, VAMOS, Shell evolution near N=126

2023 KPS Fall Meeting
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E7.04

Lifetime measurements of low-lying excited states in ^{110}Sn and ^{206}Pb

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Abstract:

One of the well-established methods to investigate nuclear structure and shape evolution in rare isotopes is safe-energy Coulomb excitation. By ensuring the beam energy to be safely below the Coulomb barrier between the target and the beam nuclei, model-independent measurements of reduced electromagnetic transition strengths and spectroscopic quadrupole moments of excited states of interest are possible.

Due to limited beam intensity of rare isotopes, a high-Z target with sufficient thickness is often chosen for safe-energy Coulomb excitation in order to obtain necessary gamma-ray statistics. Under these conditions, beam energy straggling inside the target is significant and the Doppler-shifted gamma-ray spectrum is sensitive to state lifetimes. As a result, spectroscopic quadrupole moments of excited states can be constrained by experimental B(E2) values.

A Coulomb excitation experiment was carried out at HIE-ISOLDE, where unstable ^{110}Sn nuclei were excited on a 4.0-mg/cm^2 ^{206}Pb target with a beam energy of 4.4 MeV per nucleon. From comparisons with Geant4 simulation outputs, lifetimes of the 2^+ and 4^+ states in ^{110}Sn, and the 2+ state in ^{206}Pb were determined. The B(E2) values will be combined in the Coulomb excitation data analysis, and their implications on structural evolution of the Sn isotopic chain will be discussed.

Keywords:

Coulomb excitation, Doppler shift, Gamma-ray spectroscopy

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E8.01

Probing magnon bound states and Hilbert space fragmentation in Rydberg atom arrays

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Abstract:

Rydberg atom has emerged as a promising platform for exploring novel many-body phenomena. We recently develop a Rydberg dressing scheme that can access the extremely anisotropic regime of the Heisenberg model [1,2]. A many-body perturbation analysis reveals that the model can be mapped exactly onto a modified version of the folded XXZ model, possessing U(1) symmetries of the total magnetization and the domain wall number, while exhibiting the strong Hilbert space fragmentation (HSF). The effective Hamiltonian has distinct time scales for the motion of a magnon and a hole, which allows for a continuous tuning from the integrable regime, to the Krylov-restricted thermal phase, and eventually to the statistical bubble localization region. As a signature of the HSF, we experimentally identify the kinetically constrained frozen dynamics and the formation of a long-range magnon bound state in a Rydberg tweezer array setup [2].

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Keywords:

Rydberg atom, Heisenberg model, Hilbert space fragmentation, magnon bound state

Quantum Computation of Maximum Independent Set Problem on King's Graph of over Hundred Rydberg Atoms

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Abstract:

A neutral atom system with optical tweezers represents one of the most scalable quantum systems. When combined with the Rydberg state, which generates interatomic interactions, many-body quantum experiments can be executed. Several groups have recently conducted many-body quantum adiabatic computations on Rydberg atom systems [1-2]. Notably, the maximum independent set (MIS) problem experiment on the King's lattice, which has been proven NP-complete for the MIS on this lattice structure, is recognized in numerous studies highlighting the potential for a quantum advantage [2-4]. We conducted experiments on the MIS problem over the King's lattice involving hundreds of atoms, with the atoms being randomly loaded. This stochastic arrangement provides MIS experiment data for randomly generated graphs not previously examined. Our experiments explored varying sweep times, initial detunings, and final detunings. Across all tests, we found that the average error was linearly proportional to the graph size or number of atoms. This confirms the predictions based on bit-flip errors in state measurements and the universal quantum Kibble-Zurek mechanism. Furthermore, we observe defect scaling as a function of sweep rate, consistent with previous experiments [2], and identified defect convergence during slow sweeps. We expect that our experimental dataset could be used to analyze the quantum advantage of such adiabatic computation on the MIS problem of Rydberg atoms or serve as primary data for quantum error mitigation.

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[4] Cain, M. et al. "Quantum speedup for combinatorial optimization with flat energy landscapes," 10.48550/arXiv.2306.13123 (2023). 2306.13123.

Keywords:

Rydberg atom, Quantum computing, Combinatorial optimization, Maximum independent set

2023 KPS Fall Meeting
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E10.01

Aharonov-Bohm effect mediated by “massive” photons confined between conducting plates

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Abstract:

The vacuum electromagnetic field plays an essential role in understanding the fundamental nature of the Aharonov-Bohm (AB) effect [1]. An interesting question is how a modified spectrum of the vacuum photon would affect the AB effect. In particular, when the vacuum field is confined between two conducting plates, the photons satisfy 2-dimensional wave equation with finite mass (= Proca equation). We show that this results in a short-range interaction between a test charge and a distant magnetic flux and that the AB phase is drastically reduced as a function of the distance between the two bodies. On the other hand, we point out that a semiclassical description is also possible, and address a question on the reality of the vacuum field.

[1] K. Kang, "Gauge invariance of the local phase in the Aharonov-Bohm interference: Quantum electrodynamic approach." Europhysics Letters 140 (2022): 46001, and references therein.

Keywords:

Aharonov-Bohm effect, Massive photons, Reality of the vacuum field

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E10.03

PT-symmetric Non-Hermitian Hopf bundle matter

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Abstract:

Hopf bundle is a topological invariant, which plays an important role in various fields of physics. In Hermitian systems, there exists an interesting class of insulators, which are characterized by Hopf invariant, known as Hopf insulator. In this letter, we propose the generalization of the Hopf bundle in the non-Hermitian systems. We show that the Hopf bundle phases are stabilized in the presence of additional PT symmetry. In sharp contrast to the Hermitian counterpart, the non-Hermitian Hopf bundle possesses topologically protected surface degeneracy, and each point of the surface is described by the exceptional point. Finally, we show that by breaking PT-symmetry, the surface of exceptional points deforms into exceptional lines. Our work discovers new types of the non-Hermitian topological phase characterized by the Hopf invariant.

Keywords:

Non-Hermitian physics, Topological insulators/semimetals, Non-Hermitian topological phase.

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E11.01

Towards Physically Reliable Molecular Representation Learning

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Abstract:

Estimating the energetic properties of molecular systems is a critical task in material design. Machine learning has shown remarkable promise on this task over classical force fields, but a fully data-driven approach suffers from limited labeled data; not just the amount of available data lacks, but the distribution of labeled examples is highly skewed to stable states. In this work, we propose a molecular representation learning method that extrapolates well beyond the training distribution, powered by physics-driven parameter estimation from classical energy equations and self-supervised learning inspired from masked language modeling. To ensure the reliability of the proposed model, we introduce a series of novel evaluation schemes in multifaceted ways, beyond the energy or force accuracy that has been dominantly used. From extensive experiments, we demonstrate that the proposed method is effective in discovering molecular structures, outperforming other baselines. Furthermore, we extrapolate it to the chemical reaction pathways beyond stable states, taking a step towards physically reliable molecular representation learning.

Keywords:

Machine learning potential, Molecular Representation Learning, DFT, Machine learning

2023 KPS Fall Meeting
2023-10-24 - 2023-10-27

E11.02

First-principles study on electronic structure changes in $MA_3Sb_2I_9$ during annealing, cooling, and reannealing

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Abstract:

Perovskites are promising materials for solar cells, especially lead-free perovskites, which offer the possibility of making non-toxic and environmentally friendly solar cells. In addition, perovskites containing methylammonium (MA) undergo dynamic structural changes at low temperatures as well as at room temperature due to the rotational degrees of freedom of MA. These observations require more intensive studies for the potentially diverse applications of these materials in the future. Our experimental collaborators shared with us an interesting experimental result on $MA_3Sb_2I_9$, a material with a similar structural configuration to the perovskite. They utilized ultraviolet photoelectron spectroscopy (UPS) experiments and found distinct variations in the electronic structure of $MA_3Sb_2I_9$ during annealing and cooling. On the other hand, the electronic structure of the cooled samples did not change during reannealing. In order to understand their observations, we studied this material using density functional theory (DFT) calculations. However, there is an inherent limitation of DFT, which considers materials at absolute zero temperature. To overcome, this limitation, we performed molecular dynamics (MD) simulations, which allow dynamic averaging of various properties at finite temperatures, and thus the finite-temperature peculiarities of $MA_3Sb_2I_9$. Our analysis shows that $MA_3Sb_2I_9$ undergoes a structural change, such as phase transition and Sb atom migration, which affects the electronic structure, during annealing and cooling. The insights gained from this investigation contribute to a more comprehensive understanding of materials that undergo structural changes at room temperature, paving the way for the analysis of diverse material properties.

Keywords:

DFT, Perovskite, UPS, Electronic Structure

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E12.01

단일 물분자 제어를 통한 물-이온 상호작용 연구

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Abstract:

단원자 이온과 물의 상호작용은 복잡한 다원자 이온의 수화 및 이온과 관련된 다양한 반응에 중요하다. 대표적인 반응인 소금의 용해는 열역학적으로 정립되었지만, 미시적인 실험은 한계가 있어 다양한 이론적 접근을 통해 연구되어왔다. 본 연구는 저온 주사 터널링 현미경과 밀도범함수 이론을 통해 초극박막 NaCl에 흡착한 물 단분자의 거동을 조사했다. 우리는 탐침을 정교하게 조절하여 물 단분자를 NaCl 표면의 두 방향, 극성 및 비극성 방향으로 제어했다. 방향에 따른 탐침 높이의 변화로 물 분자가 비극성 방향으로 이동 시 회전해야 하는 것을 확인했다. 물 분자의 회전이 $H^{\delta+}\cdots Cl^{-}$ 결합을 유도해 물 분자와 기판의 거리가 가까워진다. 탐침의 수직 높이를 제어하여, 물 단분자와 탐침의 원자간 전위를 두 방향으로 측정했다. 이를 통해 방향에 따른 임계 마찰력과 해당 에너지 장벽을 비교했다. 탐침-물 상호작용을 통해 물-이온 상호작용이 원자 수준 마찰력에 미치는 영향을 확인했다.

Keywords:

Water molecule, NaCl, STM, Atomic-scale friction

2023 KPS Fall Meeting
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E12.02

Al_2O_3/ZnO 계면의 전자상태와 이차원 전자기체(2DEG) 형성에 관한 밀도범함수 연구

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Abstract:

반도체로 이루어진 이종구조의 계면에서 주로 형성되는 이차원 전자기체(2DEG)가 부도체로 이루어진 이종구조의 계면에서도 발견된다. 대표적인 물질로는 $SrTiO_3$(STO)와 $LiAlO_3$(LAO)로 이루어진 STO/LAO가 있으며, 2DEG 형성의 원인이 많이 연구되었다. 부도체인 ZnO와 Al_2O_3으로 이루어진 Al_2O_3/ZnO 이종구조 또한 계면에서 2DEG이 발견이 되나, 2DEG 형성의 원인과 계면 구조가 명확히 밝혀지지 않았다. Al_2O_3/ZnO 이종구조 계면의 2DEG 형성 원인을 밀도범함수 이론을 이용하여 연구하였다. Al_2O_3는 상온에서 가장 흔한 구조인 α-알루미나을 사용했으며, ZnO는 wurtzite구조를 이용하였다. 두 물질의 격자상수를 맞추기 위하여 Al_2O_3와 ZnO을 각각 2x2, 3x3으로 늘려서 사용하였다. 계면에는 O를 추가하여 Zn와 Al이 O를 매개로 결합하도록 하였고, 계면에 있는 O의 수를 조절하여 안정적인 계면구조를 찾았다. 형성 에너지를 비교하여 안정적인 구조를 찾았고, 안정적인 구조에서 Hubbard U값을 도입하여 전자구조를 계산하였다. 안정적인 구조 중 ZnO에서 산소 빈자리(oxygen vacancy)가 있는 구조에서 2DEG에 해당하는 빈자리 상태들(vacancy states)이 페르미 준위에 걸치고, 계면에 주로 분포하며 고체 안으로 들어갈수록 줄어든다. Vacancy level에 해당하는 전자밀도는 산소 빈자리 위치에 있는 것을 확인하였다. ZnO에서 생성된 산소 빈자리가 발생하여 Al_2O_3/ZnO 계면의 2DEG 형성에 기여한다고 볼 수 있다.

Keywords:

제일원리 연구, DFT+U, Al2O3/ZnO 이종구조, 이차원 전자기체

2023 KPS Fall Meeting
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E12.03

물 삼합체의 협력성을 통한 양성자 터널링 제어

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Abstract:

수소 결합을 통한 양성자 터널링은 양성자 매개 반응에서 중요한 양자 현상이다. 협력적 상호작용이 수소 결합을 강화하여 양성자 터널링을 촉진시킨다. 수소 결합의 조작은 안정적인 구조의 클러스터에서 제한된다. 협력성(cooperativity)이 양성자 터널링에 미치는 영향을 이해하기 위해 낮은 협력성, 즉 불안정한 구조를 가진 클러스터가 필요하다. 우리는 주사 터널링 현미경을 통해 NaCl 표면에서 고리형 물 삼합체의 집단적 양성자 터널링을 제어했다. 물-기판 상호 작용은 삼합체를 비대칭으로 만들어 협력성을 저해한다. 우리는 양성자 터널링을 촉진하는 기하학적 메커니즘인 “rotation-excited tunneling”을 밝혔다. 분자 간 회전은 비대칭의 삼합체를 재배열해 수소 결합을 단축시킨다. 이렇게 증가된 협력성으로 양성자 터널링은 향상된다. 우리는 양성자 터널링 분석을 통해 수소 결합 협력성의 제어를 원자수준으로 입증했다.

Keywords:

양성자 터널링, 협력성, 수소 결합, 주사터널링현미경

E12.04

Unraveling in-depth recombination mechanisms in flexible kesterite thin film solar cells

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Abstract:

Kesterite, $Cu_2ZnSn(S,Se)_4$ (CZTSSe), is a attracting material for earth-abundant and non-toxic light absorber in flexible thin film solar cells. Carrier recombination at the grain boundaries (GBs) is one of the main issues to lowering the device performance therefore, their mechanisms at the surface has been widely studied. However, carrier recombination mechanisms in the materials' bulk are scarcely known. In this study, in-depth carrier recombination has been investigated through atomic force microscopy-based characterization. A flexible CZTSSe solar cells using a Mo foil substrate was prepared and the samples was mechanically etched by focused-ion beam to reveal the plane at the specific depth. Kelvin probe force microscopy was utilized on the revealed plane and an upward potential bending was observed at the GBs at all depth. Specifically, at the surface and subsurface, both conduction (E_C) and valence band (E_V) upward bending was observed which repels electrons from the GBs suppressing the carrier recombination.[1] Upward band bending at the GBs was attributed to the widen band gap and increased charge defects than in the intra grains (IGs). On the other hand, in the center of the absorber, formation of E_C downward and E_V upward band bending was observed. This type of band bending can increase the recombination sites and hinder the current flow along the IGs. As a results, non-uniform band bending at the GBs in the vertical direction resulted in inhomogeneous recombination mechanism. Therefore, vertically uniform E_C and E_V upward band bending at the GBs is desirable to minimize the carrier recombination. [2]

[1] H. K. Park et al., npj Flexible Electronics, 6 (2022) 91.
[2] D.-H. Son, H. K. Park, and K.-J. Yang et al., Carbon Energy, Accepted.

Keywords:

flexible kesterite thin film solar cells, Kelvin probe force microscopy, grain boundaries, carrier recombination

Realization of non-layered 2D transition metal nitride films via chemical vapor deposition

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Abstract:

Different from 2D layered materials, such as graphene, transition metal dichalcogenides (TMDs), h-BN, 2D non-layered materials have high surface activity due to unsaturated dangling bonds on their surfaces, resulting in outstanding catalytic, sensing, and carrier transfer properties and show unique properties. Transition metal nitride (TMN), a non-layered material, is attracting attention as a substitute for noble metals because it shows catalytic and plasmonic properties similar to those of noble metals due to d band density variation and high DOS caused by N atoms inside the lattice. [1] However, the isotropic chemical bonding properties of TMN as a non-layered material, unlike layered materials, limit growth in the vertical direction, which limits 2D anisotropic growth. Here, we demonstrate intriguing method for the synthesis of non-layered 2D molybdenum nitride films by controlling the vapor pressure of the nitrogen source during the chemical vapor deposition process. Reducing the amount of nitrogen source supply through vapor pressure control can limit the vertical growth of non-layered 2D molybdenum nitride to synthesize films. Also, we demonstrate a feasible chemical vapor deposition strategy for selectively producing γ-Mo_2N or δ-MoN through modulating temperature as growth temperature. As a promising surface enhanced Raman scattering substate (SERS), δ-MoN films exhibit high level detection capabilities for R6G. Our work sheds light on the synthesis of 2D non-layered films and could open up exciting opportunities in electronics and electrochemical devices based on 2D non-layered materials.

References

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Keywords:

2D non-layered materials, chemical vapor deposition, lateral growth, surface enhanced raman scattering (SERS), transition metal nitrides (TMNs)

2023 KPS Fall Meeting
2023-10-24 - 2023-10-27

E13.02

Realizing High-Concentration Coalesced Vanadium Doping in Monolayer MoS_2: Toward High-Performance Hydrogen Evolution Catalysis

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Abstract:

The introduction of heteroatom is a widely employed strategy in the electrolysis of transition metal dichalcogenides (TMDs), which, by activating the inactive basal plane, effectively boosts the intrinsic catalytic activities. However, the effect of incorporated atomic configurations within the TMDs lattice on their catalytic activity is not thoroughly understood due to the lack of controllable synthetic approach for highly doped TMDs. Here, we demonstrate a facile approach to realize heavily doped MoS_2 with high doping concentration of above 16% through the intermediate-reaction-mediated chemical vapor deposition. As the V doping concentration was increased, the incorporated V atoms were configured in a coalesced manner in the MoS_2 lattice. The coalescence V doping enabled both the basal plane activation and electrical conductivity enhancement of MoS_2, accelerating the hydrogen evolution reaction (HER) kinetics through the reduced Gibbs free energy of hydrogen adsorption as evidenced by the experimental and theoretical analyses. Consequently, the coalesced V-doped MoS_2 exhibited superior HER performance with an overpotential of 100 mV at 10 mA cm^{-2}, surpassing the pristine and single-atom-doped counterparts. This study provides an intriguing pathway to realize highly doped TMDs with improved intrinsic catalytic activity as robust 2D electrocatalysts.

Keywords:

Chemical vapor deposition, Coalesced doping, Hydrogen evolution reaction, Transition metal dichalcogenides

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E13.03

Defects-Mediated Valley Polarization in Vertical Heterobilayer WS_2/MoS_2: From Vulnerable Edge to Mild Healed Interior

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Abstract:

Structural imperfections can have both beneficial and detrimental consequences on the excitonic characteristics of transition metal dichalcogenides (TMDs). Regarding valley selection, structural defects promote effective valley depolarization in intensively studied TMD monolayers, but the impact of these defects in vertical heterobilayers (VHs) is still unclear due to the possibility of restoring valley polarization via defect healing. In this study, we analyzed the valley polarization of center-nucleated and edge-nucleated Type-Ⅱ VHs (WS_2/MoS_2) grown using a controlled process and discovered that defect-related photoluminescence is strongly suppressed in center-nucleated VHs due to the mild defect healing effect. Additionally, the valley polarization of lower-lying, MoS_2 intralayer excitons is more sensitive to the inherent defect density of the sample than the high-lying, WS_2 intralayer excitons. Despite the defect healing in center-nucleated VHs, the temperature dependence of the PL study indicated that the valley depolarization of low-lying intralayer exciton is significantly facilitated by defect due to stronger hybridization below 100 K. Also, we conducted a comprehensive study on the excitation intensity dependency to decouple the carrier density induced Auger recombination mechanism from defect-related mechanism, which also contribute in loss of valley polarization of intralayer excitons in CVD-grown samples due to creation of intervalley trions. Our findings provide insight into the impact of growth mechanism on valley polarization of intralayer excitons in CVD-grown samples, which is critical for the development of VHs-based valleytronic devices.

Keywords:

defective 2D materials, vertical heterobilayer, Valleytronics, intralayer exciton

2023 KPS Fall Meeting
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E13.04

Visualization of local mechanical properties in Moiré graphene

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Abstract:

The moiré superlattice from magic-angle twisted bilayer graphene has been studied extensively with its unconventional electrical properties, such as superconductivity [1], topological edge states [2], and correlated insulator phases [3]. In addition, imaging local structures of twisted bilayer graphene by scanning tunneling microscope [4] and transmission electron microscope [5] has demonstrated intriguing local features.

Here, we report mechanical properties of local domains of magic-angle twisted graphene via atomic force microscopy. In particular, friction force and dissipation energy potential were carefully investigated at room temperature in our study. Thus, we observed periodic potential with a period much longer than the graphene lattice constant, and differences between the AA and AB sites by lateral force microscopy and non-contact microscopy. In addition, we observed the evolution of current image by changing the carrier density based on conductive atomic force microscopy. Such visualizations will enhance our physical understanding of the electronic states of magic-angle twisted graphene.

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Keywords:

Magic-angle graphene, Moiré graphene, Atomic force microscopy

2023 KPS Fall Meeting
2023-10-24 - 2023-10-27

E14.01

Plasmon expedited response time and enhanced response in gold nanoparticles-decorated zinc oxide nanowire-based nitrogen dioxide gas sensor at room temperature

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Abstract:

A highly sensitive and rapidly responsive nitrogen dioxide (NO_2) gas sensor based on gold (Au) nanoparticles (NPs)-decorated zinc oxide (ZnO) nanowires (NWs) is presented. The Au NPs decoration was conducted onto ZnO NWs with and without a (3-aminopropyl)triethoxysilane (APTES) layer on their surface by using the electrostatic force. The samples without the APTES layer exhibited high NO_2 gas sensitivity (i.e. expedited response time and enhanced gas response) due to localized surface plasmon resonance (LSPR) of the Au NPs; in particular, the NO_2 gas response and the response time were increased by three times and shortened by 86%, respectively, compared with the undecorated ZnO NWs. The presence of the APTES layer improved the Au NPs attachment, but hindering the gas adsorption on the ZnO NWs surface, as proven by the observed photocurrent and gas response. Our findings imply that the response time of semiconductor gas sensors can be remarkably expedited by the LSPR effect, which is useful for developing practical gas sensors.

Keywords:

ZnO nanowires , Au nanoparticles, Localized surface plasmon resonance, Gas sensor

2023 KPS Fall Meeting
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E14.02

The optical properties study of varied thickness for InGaAs/AlInAs superlattice structures

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Abstract:

The AlGaInAs quaternary alloy is a valuable material system for optoelectronic devices. However, the growth of quaternary alloy material has difficulties, such as a large miscibility gap and phase separation during the growth. The superlattice (SL) or digital alloy (DA) growth techniques have shown a new path to growing materials for avalanche photodiodes (APD) and a reduced ratio of impact ionization coefficients. The quality of the growth material is essential for APD structures.

We have investigated the optical properties of the InGaAs/AlInAs superlattice structure by Photoluminescence (PL) and Photoreflectance (PR) spectroscopy. For the AlGaInAs quaternary alloy, the difference thicknesses 4ML, 6ML, and 8ML of InGaAs/AlInAs SL PIN structures on InP were grown by Molecular beam epitaxy (MBE). At 20 K, the PL spectra show different emission centers: 1.37 eV for 4ML, 6ML, and 1.35 eV for 8ML. For the 6ML thickness of SL, the PL spectrum observed the shoulder. We observed differences in band optical transition dimensions at 6ML. We compared the internal electric fields for each structure.

Keywords:

Photoluminescence, Photoreflectance, Molecular beam epitaxy, AlGaInAs

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E14.03

희토류 없는 적색/적주황색 발광 페로브스카이트기반 형광체의 합성 및 특성

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Abstract:

최근 환경 및 에너지 문제가 대두되면서 기존 조명 장치에 비해 좋은 에너지 효율, 강한 밝기, 긴 작동 수명을 가진 고체조명이 새로운 광원으로써 각광받고 있다. 기존 상용화된 형광체 중 녹색과 청색 형광체는 높은 효율과 강한 발광 특성을 띄는데 반해 상용 적색 형광체는 낮은 발광 성능을 보인다. 따라서 이를 보완하기 위해 좋은 발광 성능을 가진 적색 형광체에 대한 연구가 필요하다. 일반적으로 형광체의 합성은 주로 희토류 물질을 activator로 하여 이루어지는데, 희토류 물질의 높은 가격은 형광체 합성 비용 효율을 좋지 않게 한다. 이를 해결하기 위하여 Mn, Bi 등의 activator를 이용하거나, host 물질 자체의 발광 특성을 이용하는 연구가 진행되고 있다. 이에 따라 현재 희토류 없는 적색 발광 형광체에 대한 연구를 진행 중에 있다. 본 발표에서는 페로브스카이트 물질을 host 물질로 하고, activator 이온을 도핑하여 적색/적주황색 발광 형광체를 합성하였다. 물질 합성은 고상법을 이용하였으며, 합성된 형광체 샘플은 다양한 물성분석을 통하여 그 특성을 확인하였다. 또한 합성된 형광체의 발광 특성을 분석하였고, 고온 환경에서의 열 안정성을 테스트하였다. 준비된 형광체는 그 특성에 따라 고체 조명을 위한 적색 형광체로서의 사용이 기대된다.

Keywords:

희토류 없는, 페로브스카이트, 형광체, 발광특성

2023 KPS Fall Meeting
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E14.04

A study on the optical transition in $InAs_xP_{1-x}$ metamorphic buffers structure by photoreflectance spectroscopy

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Abstract:

Recently, metamorphic buffers with progressively modified compositions have been employed to alleviate the strain caused by lattice mismatch in the active layer of *III-V* devices. This approach reduces the density of crystalline defects and threading dislocations, thereby enhancing the overall device quality. As a result, our focus is directed toward meticulous design and the high-quality optimization of optical and internal electrical properties for modified buffer structures. These structures are aimed for $InAs_xP_{1-x}$ (x=0.5, 0.55, 0.7) composition grade buffers on *InP* substrates, fabricated using the metal-organic chemical vapor deposition (MOCVD).
Conventionally, optical bandgap measurements rely on photoluminescence (PL) spectroscopy. However, PL measurements have limitations, as they struggle to provide a comprehensive view of the optical properties across all layers of a sample. To circumvent these limitations, this study employs photoreflectance (PR) spectroscopy to evaluate the optical properties of the $InAs_xP_{1-x}$ metamorphic buffer structure.
The PR measurements performed at 300 K reveal that the transition energy of the metamorphic buffer layer is aligned with the expected values for each *As* composition namely around 0.81 *eV*, 0.72 *eV*, and 0.61 *eV* for x = 0.5, 0.55, and 0.7, respectively. Furthermore, by utilizing the third derivative function form (TDFF) simulation, we confirm that the actual composition of the grown layers closely matches our designed composition indicating successful growth.
Interestingly, we observed a Franz-Keldysh oscillation (FKO) signal in the energy region above the optical bandgap. We subjected this FKO signal to analysis using the Fast-Fourier Transform (FFT) method to deduce the internal electric field at the sample interface.
In essence, this study investigates the optical properties of the $InAs_xP_{1-x}$ metamorphic buffer structure through PR spectroscopy, which offers a comprehensive view of the transition energy across all layers. These findings prove valuable insights into the *As* composition of each layer, allowing for a direct comparison with the target composition

Keywords:

Photoreflectance, metamorphic buffer

2023 KPS Fall Meeting
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E15.01

Unveiling potential of metallic delafossite oxide $PdCoO_2$ as a hyperbolic plasmonic medium

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Abstract:

Metallic delafossite oxides showcase remarkable electrical conductivity comparable to that of noble metals, along with intriguing transport behavior at low temperatures. Despite the established understanding of their conductive properties, their potential as excellent hosts for plasmonic phenomena has largely been disregarded. To address this research gap, our study takes a comprehensive approach to investigate the optical characteristics of metallic delafossite oxide $PdCoO_2$. Our findings demonstrate that this oxide acts as an extremely pure medium, enabling the presence of hyperbolic plasmon polaritons over a broad frequency spectrum spanning from mid-infrared to the telecommunication band. This material is distinguished by its remarkably high figure of merit. By employing high-energy resolution monochromated electron energy loss spectroscopy, we directly observe and analyze hyperbolic plasmon polaritons in finite-length nanogaps that are intricately carved in a single crystal of $PdCoO_2$. This study opens up a new avenue for expanding the utility of metallic delafossite oxides into the realms of plasmonics and nanophotonics.

Keywords:

Delafossite oxides, Hyperbolic polaritons, Optical properties, Nanospectroscopy

2023 KPS Fall Meeting
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E15.02

Multiferroic freestanding oxide membrane of heterogeneous integration

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Abstract:

Transition metal oxides display various electrical and magnetic properties governed by their order parameters. Ferroic orderings present a wide range of essential physics phenomena and practical applications. A successful approach to creating multiferroic oxides involves merging ferroelectric (FE) and ferromagnetic (FM) materials. The development of freestanding heterogeneous membranes containing these multiferroic oxides is highly desirable. This work used pulsed laser epitaxy to fabricate freestanding bilayer membranes of $BaTiO_3$ and $La_{0.7}Sr_{0.3}MnO_3$ with epitaxially combined [1]. These membranes exhibit ferroelectric and ferromagnetic properties at room temperature and a quantifiable magnetoelectric (ME) coupling coefficient. Our investigation underscores that the realization of the freestanding heterostructure can determine the structural and emergent properties. Without the strain effect originating from the substrate, the magnetic easy-axis undergoes reorientation, resulting in perpendicular magnetic anisotropy caused by modifications in the orbital occupancy of the magnetic layer. These discoveries pave the way for incorporating these flexible membranes into electronic applications.

[1] K. T. Kang et al., *Adv. Sci.* **10**, 15 (2023).

Keywords:

Heterogeneous integration, Transition metal oxides, Pulsed laser epitaxy, Ferromagnetism, Magnetic anisotropy

2023 KPS Fall Meeting
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E16.01

Capillary Force Microscopy Non-Contact Imaging Method

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Abstract:

Atomic force microscopy (AFM) often causes tip and sample damage due to tip scanning in nanometer-scale proximity to the sample surface. Although there are several non-contact working methods that exploit the dynamic properties of cantilevers, achieving truly non-contact, non-destructive imaging in AFM in air remains challenging. Here, we present a novel method for non-contact imaging 'capillary force microscopy'. We use a quartz tuning fork-based, shear-mode atomic force microscope and utilize a nanometric water bridge naturally formed between the tip and the sample. Prior to scanning, a capillary bridge is formed between the etched gold tip and the sample surface, and then the amplitude setpoint for feedback is set to an amplitude value that is changed only by capillary interaction without tip-sample mechanical hard contact. The resolution of the new mode is limited by the thermodynamics of the capillary bridge. The bridge grows or evaporates depending on the lateral velocity and vertical position of the tip, and the z-feedback fluctuates about 3 nm in our experiments accordingly. Capillary force microscopy can provide a truly non-contact, non-destructive imaging method in ambient air.

Keywords:

QTF, Capillary water bridge, AFM, Non-contact

E16.02

Linearization of atomic force microscope scans acquired using dual-stage lateral scanners

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Abstract:

Dual-stage scanners are used to increase the range of AFM lateral scanners in space and/or frequency. The displacement and frequency range of dual-stage scanners are extended by constructing the two stages using nanopositioners with significant difference in static and dynamic characteristics. In such cases, the positioning signal is split to meet the displacement and frequency limitations of each of the two stages. This split makes it challenging to linearize raster scans acquired using dual-stage scanners when displacement measurement sensors are not installed in the scanners. This work presents linearized raster scans acquired by adopting dual-stage scanners using a combination of model-based hysteresis inversion and the images acquired from trace and retrace scans. Our method involves reducing the effect of hysteresis in the images acquired using homemade dual-stage lateral scanner and high-speed AFM (HS-AFM). This method enhances the displacement and frequency range of lateral scanners without displacement measurement sensors.

Keywords:

Dual-stage scanners, atomic force microscopy, linearization

2023 KPS Fall Meeting
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E16.03

Wide-area piezoelectric scanner using mechanical amplification for applications in high-speed atomic force microscopy

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Abstract:

High-speed atomic force microscopy (HS-AFM) is known as a powerful tool for imaging and analysis of specimens at the molecular and atomic scales. It has been successfully used to study molecular dynamics, observe motions of biomolecules, and investigate various interactions occurring on surfaces. However, HS-AFM is typically limited to scanning small areas due to its high-speed operations. In this research, we report a design for a wide-area scanner that can record topographic images up to 27 μm by 27 μm at high speeds. We use the scanner to acquire images of optical disc data tracks and demonstrate its high-speed operations for large lateral dimensions.

Keywords:

atomic force microscopy, piezoelectric scanner, mechanical amplification

E16.04

Interaction of in-plane Drude carrier with c-axis phonon in $PdCoO_2$

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Abstract:

We performed polarized reflection and transmission measurements on the layered conducting oxide $PdCoO_2$ thin films. For the ab-plane, an optical peak near Ω $\approx$ 750 cm^{-1} drives the scattering rate $\gamma^*(\omega)$ and effective mass $m^*(\omega)$ of the Drude carrier to increase and decrease respectively for ω $\geqq$ Ω. For the c-axis, a longitudinal optical phonon (LO) is present at Ω as evidenced by a peak in the loss function Im[$-1/\varepsilon_C(\omega)$]. Further polarized measurements in different light propagation (q) and electric field (E) configurations indicate that the Peak at Ω results from an electron-phonon coupling of the ab-plane carrier with the c-LO phonon, which leads to the frequency-dependent $\gamma^*(\omega)$ and $m^*(\omega)$. This unusual interaction was previously reported in high-temperature superconductors (HTSC) between a non-Drude, mid-infrared band and a c-LO. On the contrary, it is the Drude carrier that couples in $PdCoO_2$. The coupling between the ab-plane Drude carrier and c-LO suggests that the c-LO phonon may play a significant role in the characteristic ab-plane electronic properties of $PdCoO_2$ including the ultra-high dc-conductivity, phonon-drag, and hydrodynamic electron transport.

Keywords:

PdCoO2, Electron-phonon interaction, Extended Drude, Polarized FTIR, Metal oxide

E16.05

Controlling Fe stoichiometry in Epitaxial FeTe Thin Films

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Abstract:

This work focuses on optimizing Fe stoichiometry of FeTe (001) epitaxial thin film on MgO (001) substrate using molecular beam epitaxy. Technique used to reduce Fe-excess FeTe is thoroughly described. We found that the best growth temperature for FeTe film is in range from 225 to 250 ^{O}C, whereas the optimum Te/Fe flux ratio is 4.66. The Fe-excess in FeTe films was effectively reduced using sequential Te annealing during the growth by controlling annealing time and deposition thickness. Temperature-dependent electrical resistivity showed a transition at around 70 K, attributed to the antiferromagnetic transition. Fe stoichiometry strongly affected the film's transport properties, especially at a low-temperature range where semiconducting to metallic behavior was observed for as-grown FeTe film. The semiconducting behavior reduced and completely changed to metallic behavior in the Te annealed films, indicating the reduction in Fe stoichiometry. This reduction was further confirmed by the changes in intensity and position of A_{1g} and B_{1g} Raman peaks. Our work demonstrated an effective way to control Fe excess in FeTe epitaxial thin films, which plays an important role in the physical properties of the material, especially in its superconductivity and magnetism. The technique can be applied to control defects in other materials, containing volatile elements such as As, Se, S, and P.

Keywords:

FeTe, Fe-excess, Fe-Stoichiometry, annealing, MBE

2023 KPS Fall Meeting
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F2.01

The Path Towards the Future Circular Collider at CERN

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Abstract:

The proposed Future Circular Collider (FCC) at CERN aims to continue the exploration of open questions in particle physics beyond the LHC and its high-luminosity upgrade in a staged research programme, integrating in sequence lepton (FCC-ee) and hadron (FCC-hh) collider programmes, and with the option of a hadron-electron collider (FCC-he), to achieve further understanding of the Standard Model and of electroweak symmetry breaking, and to maximise the potential for the discovery of phenomena beyond the Standard Model. This seminar will present the status of the FCC Feasibility Study, launched to address the recommendation of the update in 2020 of the European Strategy for Particle Physics with the objective to provide an analysis of the technical and financial feasibility of a new collider infrastructure at CERN through a global collaboration of universities, scientific institutes and high-tech companies.

Keywords:

CERN, FCC

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F2.02

Present and future of the CMS

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Abstract:

The Compact Muon Solenoid (CMS) is a particle detector operating at CERN’s Large Hadron Collider (LHC), situated 100 meters below the surface in France. The CMS experiment is one of the largest international scientific collaborations, with more than 3000 physicists and 1000 engineers from 255 institutes all around the world. Analysis of the experiment's data led to the discovery of the Higgs boson 11 years ago and it is still a unique tool for precisions measurements of parameters of the standard model of particle physics and the search for possible "new physics". The current status and the prospects for the High Luminosity LHC phase will be presented in this talk.

Keywords:

CMS, LHC

Precision timing with the CMS MIP Timing Detector (MTD) for High-Luminosity LHC (HL-LHC)

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Abstract:

The Compact Muon Solenoid (CMS) detector at the CERN Large Hadron Collider (LHC) is undergoing an extensive upgrade program to prepare for the challenging conditions of the High-Luminosity LHC (HL-LHC). A new timing detector in CMS will measure minimum ionizing particles (MIPs) with a time resolution of ~30-60 ps. The precision time information from this MIP timing detector (MTD) will bring new capabilities to the CMS detector for precision measurement and searches of rare processes. The MTD will be composed of an endcap timing layer (ETL), instrumented with low-gain avalanche diodes and a barrel timing layer (BTL), based on LYSO:Ce crystals coupled to SiPMs, read out with dedicated ASICs. In this talk we present the motivations and an overview of the MTD design, describe the latest progress towards prototyping and production, and show test beam results demonstrating the time resolution achieved.

Keywords:

CMS, HL-LHC, MTD

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F2.04

Beyond Collider Physics

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Abstract:

Firstly, I'll briefly report the current activities of CERN Korea Theory Collaboration.
Then I'll discuss possible future directions for productive collaborations with CERN based on current status of high energy physics and the composition of current/future theory community in Korea.
The topics include neutrino platforms, gbar, cosmology with gravitational waves, the 5th force and the axion search in addition to the LHC experiements.

Keywords:

CERN, LHC, Collider Physics, Beyond Collider Physics

F3.01

Supersymmetric Cardy Formula and the Weak Gravity Conjecture in AdS/CFT

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Abstract:

The Weak Gravity Conjecture (WGC) in anti-de Sitter spacetime (AdS) asserts the existence of an operator in the boundary conformal field theory (CFT) whose scaling dimension-to-charge ratio satisfies a certain upper bound. This bound is specified by the ratio of the conformal central charge c and the flavor central charge k_F. We propose a modified bound in AdS_5/CFT_4, determined by a combination of two central charges $3c-2a$ instead of c. This combination arises in the Cardy-like limit of the 4d superconformal index, which captures the Bekenstein-Hawking entropy of large BPS black holes in AdS_5. Using the new bound, we find that certain superconformal field theories (SCFTs) that are previously thought to violate the AdS WGC, including SQCDs in the conformal window, do satisfy the WGC. We check this version of the WGC against all possible superconformal gauge theories with SU(N) gauge group admitting a large N limit when the superpotential is absent. We conjecture the modified version of the WGC is a generic property of any 4d SCFT, regardless of the existence of a weakly coupled gravity dual or a large N limit.

Keywords:

Cardy-like limit, Weak Gravity Conjecture

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F3.02

Large N=1 Universality of 4d N=1 Superconformal Index and AdS Black Holes

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Abstract:

We study the large N limit of the matrix models associated with the superconformal indices of four-dimensional N = 1 superconformal field theories. We find that for a large class of N = 1 superconformal gauge theories, the superconformal indices of the large N limit of such theories is dominated by the 'parallelogram' saddle similar to the case of N = 4 Super Yang-Mills theory. This covers large classes of gauge theories, including quiver gauge theories, and the theories with rank-2 tensor matters. Our analysis works for most N = 1 superconformal gauge theories that admits a suitable large N limit while keeping the flavor symmetry fixed. This saddle corresponds to BPS black holes in AdS5 whenever holographic dual description is available. We also find 'multi-cut' saddle points, that corresponds to the orbifolded Euclidean black holes in AdS5.

Keywords:

AdS/CFT, Superconformal Index, Black holes

2023 KPS Fall Meeting
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F3.03

Strongly correlated Weyl semi metal in Holography

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Abstract:

type-I and type-II Weyl fermions have dispersion with tilted Dirac cone around the Dirac points. We will get effective matrix by Weyl fermions hamiltonian. Using this effective matrix, we can make holographic realization of Weyl fermion. And we can find dirac cone is tiling in the spectrum point of view by same parameter.

Keywords:

Weyl semi metal, Tilted Dirac cone, Holography, AdS/CFT

2023 KPS Fall Meeting
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F3.04

Pole-Skipping in Rotating BTZ Black Holes

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Abstract:

Motivated by the connection between pole-skipping phenomena of two-point functions and four-point out-of-time-order correlators, we study the pole-skipping phenomenon for rotating BTZ black holes. In particular, we investigate the effect of rotations on the pole-skipping point for various fields with spin s = 1/2, 1, 3/2, extending the previous research for s = 0, 2. We derive an analytic full tower of the pole-skipping points of fermionic (s = 1/2) and vector (s = 1) fields by the exact holographic Green's functions. For the non-extremal black hole, the leading pole-skipping frequency is $\omega_{leading} = 2\pi i T_h(s - 1 + \nu\Omega)/(1 - \Omega^2)$ where T_h is the temperature, Ω the rotation, and $\nu := (\Delta_+ - \Delta_-)/2$, the difference of conformal dimensions ($\Delta_\pm$). These are confirmed by another independent method: the near-horizon analysis. For the extremal black hole, we find that the leading pole-skipping frequency can occur at $\omega^{extremal}{}_{leading} = -2\pi i T_R(s + 1)$ only when ν = s + 1, where T_R is the temperature of the right moving mode. It is non-trivial because it cannot be achieved by simply taking the extreme limit ($T_h \to 0$, $\Omega \to 1$) of the non-extremal black hole result.

Keywords:

AdS-CFT Correspondence, Gauge-Gravity Correspondence, Holography and Condensed Matter Physics (AdS/CMT)

F3.05

Embedding a lattice into the Holography II : Kane-Mele model

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Abstract:

In this talk, we consider embedding the Kane-Mele model into Holography by postulating the relation between bulk Hamiltonian and tight-binding one. We find that the holographic spectral function provides broadening and intensity height as well as the dispersion relation so that it can provide information that is present in ARPES data but absent in the DFT result. Even though we apply a strong correlation by the AdS gravity, topology persists. By considering bulk fermion mass as an electron-electron coupling, we show that the system undergoes non-Fermi liquid to Fermi liquid transition within a conformal regime as the coupling changes.

Keywords:

Holography, Strongly Correlated System, AdS/CFT, Kane-Mele Model

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F3.06

Modeling of Physical Space and Time in Complex Domain

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Abstract:

<Abstract>
This paper presents a model of the physical space and time in the complex domain while mapping them in the complex planes. The model shows us to provide with very consistent and powerful ways to interpret the general phenomena in nature including negative and imaginary worlds and also wide applicability in a variety of areas including science, engineering and ordinary life.

1. Introduction

The universe space is the field filled with energy and matter including plasma. Energy and matter are equivalent in mass and conversionary to each other. Energy is always forced to gather together by its gravity and scatters via explosion at the ultimate density or disperses via thermal radiation. Energy changes features constantly such as in the forms of light, heat, electric, kinetic and potential, and structural densities as matters, while affecting the periphery by the feature of power and making wide variety of material worlds.

Energy maintains a stationary state if the gravity and the pressure by temperature are balanced. There are energies in the space that neither gather nor disperse. These energies are not only observed via light but also measured by electromagnetic waves, such that the dark matters do.

Examples of conglomerating of energy are the growths of black holes and those of scattering or dispersing are the explosion of supernovae and light emission from stars. The black holes, even though they emit thermal radiation and vapor out in the case of small ones according to Hawking's theory, absorb all surrounding materials and energies including light by their strong gravities. Energy circulates in modes continuously via these conglomeration and scattering processes.

All living beings including human are not able to live in the spatial region that all energy are taken from. They are not able to see at all as well as not able to maintain their lives because of no continuous acquiring of useful state energy from the surroundings.

Time is a measure of the interval between two events or the duration of an accumulated change made by sub-sequential changes. Every change, regardless of quality or quantity, has a direction relating to its observer's concern. If there is no change, motion or event at all, time cannot only be measured by any means but also be counted as passage. Time must be coupled with space while in the spacetime the visible and livable world for life is usually considered to be positive real world.

Keywords:

Space, Time, Complex Domain, Energy Field, Dark Energy

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F3.07

Poincaré invariance of binary dynamics in the post-Minkowskian Hamiltonian approach

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Abstract:

We constructed the global Poincaré algebra generators in the context of the post-Minkowskian Hamiltonian formulation of gravitating binary dynamics that is partly inspired by scattering amplitudes. We wrote down the Hamiltonian valid in an arbitrary inertial frame. Then we constructed the boost generator at the same order which uniquely solves all the equations required by the Poincaré algebra. Our results are exact in velocities and spins, at the first post-Minkowskian (1PM) order and exact in velocities at the second post-Minkowskian (2PM) order.

Keywords:

Post-Minkowskian, Binary Dynamics, Scattering Amplitudes, Poincaré algebra

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F3.08

W-algebras from non-Abelian Quiver Gauge Theories

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Abstract:

We present explicit relations between a class of affine W-algebra and a boundary Vertex Operator Algebra of a class of A-twisted N=4 SCFTs in 3d.

Keywords:

Vertex Operator Algebras, W-algebras, Supersymmetric Gauge Theory, String Theory

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F3.09

Mean-field and holographic models of the Kondo lattice

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Abstract:

We propose a holographic model of the Kondo lattice and compare it with the conventional mean-field approximation.

Keywords:

Kondo lattice, mean-field approximation, holographic duality

F4.01

Updates from the Parkes Pulsar Timing Array Project and towards the SKA

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Abstract:

I will describe the recent results relating to the gravitational wave background from the Parkes Pulsar Timing Array project and compare our results with those from the EPTA/InPTA, the CPTA and NANOGrav. I will highlight some of the current research and technical developments in pulsar timing array research in Australia and look towards the future with the Square Kilometre Array telescope.

Keywords:

gravitational waves, gravitational waves, pulsar timing array

F4.02

Pulsar Timing Array Experiments: Detection of low-frequency gravitational waves and some auxiliary sciences

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Abstract:

A Pulsar Timing Array (PTA) experiment monitors an ensemble of stable millisecond pulsars for several years to extract the signature of the low-frequency gravitational waves in the correlated timing irregularities of those pulsars. Such low-frequency gravitational waves are emitted by the inspiral of supermassive black holes as well as in the early universe. Hence, characterization of the observed low-frequency gravitational waves might shed light into these areas. This global effort to achieve this is known as the International Pulsar Timing Array and member consortia are the Australian Parkes Pulsar Timing Array (PPTA), the North American Gravitational Wave Observatory (NANOGrav), the European Pulsar Timing Array (EPTA), the Indian Pulsar Timing Array (InPTA, an Indo-Japanese collaboration) and associate members are the Chinese Pulsar Timing Array (CPTA) and the South African MeerTime collaboration. Recently, these consortia
noticed the hint of a stochastic background of low-frequency gravitational waves in their data. Moreover, PTA experiments might lead to various other significant results including a sudden change in the emission property of a pulsar, better characterization of the
interstellar medium, detection of solar events, improvements in planetary ephemeris, improvements in the models of binary pulsars leading to tests of gravity theory, etc. In the present talk, I will briefly describe the principle of PTA experiment and recent results.
Afterward, I will emphasize the uniqueness of InPTA and its role in better characterization of the interstellar medium and detection of solar events as well as in understanding the recent change in the emission property of one pulsar.

Keywords:

gravitational waves, pulsar timing array

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F4.03

Cosmological Gravitational Wave Background — with a focus on secondary gravitational waves —

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Abstract:

The evidence of stochastic gravitational waves at the nanohertz range has been recently found by pulsar timing arrays. In this talk, we discuss cosmological (or new physics) interpretations. In the first half, we briefly review various cosmological interpretations such as inflation, a first-order phase transition, cosmic strings, and domain walls. In the latter half, we focus on an interpretation based on the secondary gravitational waves induced by enhanced curvature perturbations and its possible relations with primordial black holes. The current data suggest the tensor spectral index about 2 around the nanohertz range, and we discuss three ways to explain it. For example, if we assume a sharply peaked spectrum for the curvature perturbations, we predict O(10^(-4)) solar mass primordial black holes and their binary mergers produce an additional gravitational wave peak around 100 megahertz, whose infrared tail may be detected by future gravitational wave observations.

Keywords:

Pulsar timing array, stochastic gravitational wave background, cosmological gravitational waves, new physics interpretations, scalar-induced gravitational waves, primordial black holes

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F5.01

Unlocking Multicolor and 3D Holography with Single-Cell Metasurfaces through Inverse Design

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Abstract:

Metaphotonics has revolutionized the field of advanced optical technologies by replacing conventional bulky optical devices with ultra-thin devices. However, the challenge of designing on-demand metaphotonic structures with specific optical properties still remains. This presentation introduces an innovative approach to address this challenge through an inverse design method based on gradient-descent optimization. The method focuses on developing single-cell metasurfaces that possess customized optical properties, particularly for multicolor and three-dimensional holography applications [1]. The technique exploits the gradient-descent optimization to consolidate multiple pieces of holographic information into a single phase profile. This achievement showcases the cutting-edge data capacity achievable with a phase-only metasurface composed of a single unit-cell.

To elaborate, we successfully engineer and experimentally validate the capabilities of our method in the realms of multiplane RGB color and 3D holography, using low-loss TiO_2 materials. This breakthrough not only establishes an effective and methodical means of designing metaphotonics with precise optical attributes but also holds promise for diverse domains such as imaging, sensing, and communication.

[1] S. So, J. Kim, T. Badloe, C. Lee, Y. Yang, H. Kang, J. Rho, "Adv. Mat. 35, 2208520" (2023)

Keywords:

metasurfaces, meta-photonics, nanophotonics, inverse design, optimization

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F5.02

육각형 마이크로 공진기에서 시공간 대칭성을 위한 새로운 엑시톤 폴라리톤의 커플링

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Abstract:

그룹 III-질화물 기반 반도체는 실온에서 가시광선에서 근자외선까지 넓은 스펙트럼을 제어 할 수 있기에, LED 및 레이저에서 쉽게 응용할 수 있다. 하지만, 기존의 평면 구조는 양자 광 연구에 중추적인 역할을 하는 마이크로 공진기 구조를 생성하는 데 한계가 존재한다. 이 문제를 해결하기 위해 우리는 Hermitian에서 non-Hermitian까지의 현상을 조사하기 위한 다양한 방법을 제공하는 독특한 육각형 마이크로 와이어 구조를 활용했다. Whispering gallery 모드를 생성하기 위해 이러한 육각형 와이어의 단면을 이용함으로써 우리는 엑시톤과 광자 사이의 강한 상호 작용의 결과인 엑시톤-폴라리톤 준입자 및 상온 응축 현상을 관찰했다[1]. 추가적으로 기판 엔지니어링을 활용하면, non-Hermitian 물리학 영역으로 확장할 수 있다. 이로 인해 상향 및 하향 삼각형 whispering gallery 폴라리톤 각각을 엑시톤-포톤 결합을 통해 커플링 시키고, 비대칭적인 손실을 인가하게 되면 non-Hermitian 영역의 대표적 현상 중 하나인 시공간 대칭성 및 붕괴를 제어할 수 있다. 특히, 시공간 대칭성 붕괴 영역에서 발생되는 축퇴 현상을 이용하면 손실이 커질수록 오히려 문턱 에너지가 더 내려가는 반 직관적인 특성이 관측된다. 이러한 특성을 이용해 극복해야 되는 대상이었던 손실을 오히려 유익한 방향으로 바꿔줄 수 있는 독특한 소자를 개발 하는데 활용 될 수 있다.

[1] H. G. Song et al, “Tailoring the potential landscape of room-temperature single-mode whispering gallery polariton condensate”, Optica, 19, 1313, 2019
[2] H. G. Song et al, “Room-temperature polaritonic non-Hermitian system with single microcavity”, Nature Photonics, 15, 582, 2021

Keywords:

strong coupling, exciton-polariton, non-Hermitian, Parity time-reversal symmetry

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F5.03

Strain balanced quantum cascade laser at 4700 nm wavelength

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Abstract:

In this presentation, growth optimization of strain-balanced InGaAs/InAlAs superlattices for quantum cascade lasers will be shown. The growth modes and properties of SB SLs are strongly affected by the growth conditions. The properties of the SB SLs were evaluated using AFM, HRXRD analysis and TEM measurements. Following the established growth conditions, SB QCL were grown and fabricated into a Fabry-Perot cavity with a double channel structure. The device operated in pulsed mode emitting ~4.7 μm at room temperature with a peak power of 650 mW and a slope efficiency of 870 mW/A.

Keywords:

Quantum cascade laser, MBE growth, Superlattice

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F5.04

Electrically tunable single plexcitonic emitter at room temperature

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Abstract:

Plexcitons are hybridized light-matter quasiparticles, with distinct optical characteristics compared to plasmons and excitons. Tunability of plexcitonic states is essential for manipulating quantum electrodynamic phenomena in the strong coupling regime, such as single-photon nonlinearity and quantum entanglement. Here, we demonstrate electrically-tunable single plexciton emitter operating at room temperature in electricfield tip-enhanced strong coupling (*e*-TESC) spectroscopy. For a single quantum dot in the nanoplasmonic tip-cavity with variable DC local electric-field, we dynamically control the Rabi frequency with the corresponding plexciton emission, crossing weak to strong coupling regime. We model the observed behaviors based on the quantum confined Stark effect in the strong coupling regime. Our approach paves the way to systematically engineer strongly coupled systems for room temperature operation and for a new class of optoelectronic and quantum devices.

Keywords:

Quantum dot, Strong coupling, Quantum confined Stark effect

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F5.05

Cavity magnonics with easy-axis ferromagnet: critically enhanced magnon squeezing and light-matter interaction

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Abstract:

Generating and probing the magnon squeezing is an important challenge in the field of quantum magnonics. In this work, we propose a cavity magnonics setup with an easy-axis ferromagnet to address this challenge. To this end, we first establish a mechanism for the generation of magnon squeezing in the easy-axis ferromagnet and show that the magnon squeezing can be critically enhanced by tuning an external magnetic field near the Ising phase transition point. When the magnet is coupled to the cavity field, the effective cavity-magnon interaction becomes proportional to the magnon squeezing, allowing one to enhance the cavity-magnon coupling strength using a static field. We demonstrate that the magnon squeezing can be probed by measuring the frequency shift of the cavity field. Moreover, a magnonic superradiant phase transition can be observed in our setup by tuning the static magnetic field, overcoming the challenge that the magnetic interaction between the cavity and the magnet is typically too weak to drive the superradiant transition. Our work paves the way to develop unique capabilities of cavity magnonics that goes beyond the conventional cavity QED physics by harnessing the intrinsic property of a magnet.

Keywords:

Cavity magnonics, Magnon, Cavity QED, Ferromagnet, Squeezing

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F5.06

Sampling a Laser Field near Nanostructures Using Tunneling

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Abstract:

Localized surface plasmon resonance can enhance the electric field of an incident laser in the vicinity of nanostructures, triggering electrons bound to metallic nanostructures to emit through tunneling. The sub-cycle nature of the tunneling event can be utilized to characterize the plasmonic near-field in a nanostructure array. Here, we demonstrate that the laser field can be directly sampled by measuring the tunnel-emitted electrons. We also perform extinction spectra measurement using transmission spectra of an incoherent white light source. A numerical electrodynamic simulation reproduces both of the experimental results in good agreement.

Keywords:

localized surface plasmon, near-field, femtosecond laser

F6.01

Frontiers in Ultrafast Laser Plasmas: Challenges and Opportunities

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Abstract:

Laser power has increased dramatically with the development of chirped pulse amplification (CPA) technology to amplify ultrashort laser pulses. High-power femtosecond lasers and plasmas have made it possible to achieve higher energy densities and pressure states on a small laboratory scale than any other existing method. It is becoming a platform for pioneering new basic science and applications such as high-energy light source and particle beam development, laser nuclear fusion, astrophysics and planetary physics, and extreme physics.
In this talk, I will present the current status and new opportunities in laser-plasma physics and the recently launched "Ultrafast Laser Plasma Basic Research Laboratory" at GIST. Through this program, we plan to explore uncharted territory by combining the expertise of plasma, laser, and condensed matter physics, and make impacts in this emerging field.

This work received support from the National Research Foundation of Korea (NRF-2019R1A2C2002864, RS-2023-00218180).

Keywords:

laser-plasma, femtosecond laser

F6.02

X-ray Imaging and Ionization dynamics in ultra-relativistic laser plasmas using X-ray free electron lasers

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Abstract:

The of heating and ionization dynamics determine crucial plasma parameters such as plasma temperature and density in ultra-short relativistic laser-solid target interactions. We have experimentally demonstrated fs-resolved x-ray imaging, small angle x-ray scattering, and (resonant) probing of radiative transitions in Cu foils and wires as a promising method to study spatial and temporal ionization and relaxation dynamics, as well as hydrodynamics.

Data on these dynamics are in demand to improve particle-in-cell simulations, as the widely applied Thomas-Fermi approximation lacks these and thus usually overestimates the ionization degree.

Opportunities at HED instrument at the European XFEL (Schenefeld, Germany) with its 25-fs x-ray pulses, together with the demonstrated 20-30 fs timing synchronization to the 400-Terawatt ReLaX short-pulse laser, allows unprecedented studies of relativistic laser plasmas. The talk will give an overview about the x-ray diagnostics which can be added to fs ultrarelastivistic laser-plasma research, and what parameter constraints these provide.

Keywords:

European XFEL, phase contrast imaging, resonant x-ray spectroscopy, ultrarelativistic laser plasmas, Cu K-alpha emission, HED science.

F6.03

Current and future opportunities for high energy density laboratory plasma and dynamic compression science at LCLS

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Abstract:

In 2009, LCLS became the world's first hard X-ray free electron laser, providing light over 1 billion times brighter than any previous light source. It was evident early on that this source would be a transformative tool for high energy density laboratory plasma and dynamic compression science, owing to its ultrafast nature, penetrating X-ray energies, and high brightness. The Matter in Extreme Conditions (MEC) instrument was built to foster this science, and LCLS has delivered impactful science in this area and inspired similar end stations at other XFELs, using higher power lasers. Now a new project at SLAC, MEC-U, aims to bring a new world leading capability, combining a kilojoule shock drive laser and high average power petawatt and long pulse lasers with LCLS, greatly expanding the range of conditions that can be addressed. I will present about recent MEC work at LCLS, and the MEC-U project.

Keywords:

High Energy Density Laboratory Plasmas 1, Dynamic Compression 2, X-ray science 3, Ultraintense Laser Matter Interaction 4, Non-LTE plasmas 5, Spectroscopy 6, Scattering 7, Diffraction 8, Fusion Energy Science 9, Laser Particle Accelerators 10

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F7.01

EIC and LHC forward physics; complementary and similarity on QCD study

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Abstract:

For the LHC Run 4 (2029-2032), a Forward Calorimeter (FoCal) is planned to take data in ALICE. This is a new instrumentation to detect isolated photons, hadrons and jets at a very forward region ($3.4 < \eta\eta < 5.8$) in hadronic collisions at LHC. FoCal enables to probe an unexplored kinematic region of small-x (~10^{-6}) and low Q^2 where a gluon saturation is expected. Around 2032, the Electron-Ion Collider (EIC) at BNL will be operated. One of the main goals of EIC is to find a signature of CGC and to study its evolution in e-A. EIC and Forward LHC is complementary to each other because they probe different kinematic region in different collisions systems with a same underlaying physics (QCD). We expect to see a universality on QCD in different x-Q^2 spaces probed by EIC e-A and LHC hadron collisions. In this talk, we will present a current status of FoCal and EIC with a focus on ZDC, physics goals in both projects and similarities, and future plans.

Keywords:

Electron Ion Collider (EIC), Large Hadron Collider (LHC), Forward Physics, ALICE, Forward Calorimeter (FoCal), ePIC, Zero Degree Calorimeter (ZDC), Color Glass Condensate (CGC), Gluon Saturation, QCD

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F7.02

Exclusive electroproduction of vector mesons with a Regge model

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Abstract:

We investigate exclusive electroproduction of vector mesons off the proton target wirh a Regge model. We consider the available data on the electroproduction of light vector mesons at various kinematical ranges of Q^2, W, and t. Our model predictions can be very valuable at the future EIC.

Keywords:

electroproduction, vector meson, Regge model

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F7.03

Perturbative QCD approach to the nucleon structure at EIC

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Abstract:

The investigation of the nucleon internal structure in high energy scatterings has been one of the central subjects in basic science since quantum chromodynamics(QCD) was established as a fundamental theory of the strong interaction. A lot of knowledge has been accumulated in the past half century through the perturbative QCD analysis of experimental data. However, in spite of tremendous theoretical and experimental effort, a lot of mysteries still lie in the proton structure. The measurement of the gluon total spin inside the proton at relativistic-heavy-ion-collider(RHIC) is one of the most important observations made in the past couple of decades.
Further investigation will be inherited by the next-generation electron-ion-collider(EIC) experiment. In this talk, I will introduce some major theoretical work related to the EIC experiment.

Keywords:

Electron-Ion-Collider, Nucleon structure, Perturbative QCD

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F7.04

Electroproduction of phi meson at EIC

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Abstract:

We investigate the electroproduction of the ϕ-meson from a proton target, $e\,p \to e\,\phi\,p$, based on the effective Lagrangian approach. For the part of the process, $\gamma^* p \to \phi\,p$, in addition to the t-channel process including Pomeron exchange and axial-vector Regge and etc., we introduce the contribution of the exotic pentaquark molecular state K^*₩Sigma, assigned as Ps^{+}(2071, 3/2^{-}). The analysis on the differential cross section for the unpolarized and polarized electrons and protons, taking into account the energy up to ₩sqrt{s} = 126 GeV, which is relevant for the Electron-Ion Collider (EIC) experiment, will be provided.

Keywords:

phi-meson, electroproduction, pentaquark,EIC

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F8.02

Rydberg-atom implementation of quadratic unconstrained binary optimization problems

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Abstract:

Solving combinatorial optimization problems using classical resources is a well-known complex computational problem. In many cases, combinatorial optimization problems are mapped to graph problems [1]. Optical tweezer-arranged neutral atoms, which are coupled with the Rydberg state, could implement ``graphs” [2,3]. These Rydberg-atom graphs inherently hold the information, maximum independent set(MIS), which is a special kind of graph-coloring problem [2]. Rydberg-atom quantum wire, a recently developed method, could make remote coupling between two distinct atom pair so that there is no restriction of geometry and topology of the Rydberg-atom graph [4,5]. Here, we experimentally find the solutions of the quadratic unconstrained binary optimization problem (QUBO) using the Rydberg-atom graph. We implement several two- and three-variable QUBO problems using fewer than N=15 atoms. We extend the concept of the Rydberg quantum wire so that under the condition that the Rydberg-atom graph represents MIS, every interactions in the Rydberg-atom graph are effectively formulated as quadratic ZZ interaction of the Ising model, which could represent QUBO cost function. QUBO-programmed Rydberg-atom graph prints the optimal of the QUBO cost function after adiabatic control. QUBO has the simple quadratic form of the cost function, so the QUBO-programmed Rydberg-atom graph could represent many complex optimization problems in the real world.

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[2] H. Pichler, S.-T. Wang, L. Zeo, S. Choi and M. Lukin, ``Quantum Optimization for Maximum Independent Set Using Rydberg Atom Arrays,” ArXiv:1808.10816 (2018).
[3] M. Kim, Y. Song, J. Kim, and J. Ahn, ``Quantum Ising Hamiltonian Programming in Trio, Quartet, and Sextet Qubit Systems,” PRX Quantum 1, 020323 (2020).
[4] M. Kim, K. Kim, J. Hwang, E.-G. Moon, and J. Ahn, ``Rydberg Quantum Wires for Maximum Independent Set Problems,” Nat. Phys. 18, 755–759 (2022).
[5] A. Byun, M. Kim, and J. Ahn, ``Finding the maximum independent sets of Platonic graphs using Rydberg atoms,” PRX Quantum 3, 030305 (2022).

Keywords:

Rydberg-atom, Optical tweezer, Rydberg-atom graph, Quantum computing, Quadratic unconstrained binary optimization(QUBO)

2023 KPS Fall Meeting
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F8.03

Computational complexity of integer factorization by Rydberg atoms

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Abstract:

Integer factorization is key element in modern cryptographies such as RSA [1]. Recent Rydberg atom quantum annealing maximum independent set experiments [2] reveal the possibility of solving integer factorization problem by such experiments. We introduce integer factorization problem solved by Rydberg atom quantum annealing maximum independent set experiments. To show efficiency of such scheme we discuss the computational complexity in terms of classical and quantum part. For integer of interest (e.g. N=6, 15, 35, etc.), the classical computation complexity translated to the number of required SAT clauses scales as $O\left(\frac{8}{3}(\log_2 N)^3\right)$ and the quantum computational complexity translated to the number of atoms required in single experiment scales as $O\left(3.3\,(\log_2 N)^4\right)$.
[1] Rivest, Ronald L., Adi Shamir, and Leonard Adleman. "A method for obtaining digital signatures and public-key cryptosystems." *Communications of the ACM* 21.2 (1978): 120-126.
[2] Ebadi, Sepehr, et al. "Quantum optimization of maximum independent set using Rydberg atom arrays." *Science* 376.6598 (2022): 1209-1215.

Keywords:

Maximum Independent Set, Quantum Annealing, Rydberg atom, Integer Factorization, 3SAT

F8.04

Floquet-tailored Rydberg interactions

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Abstract:

Programmable interactions are a basic ingredient for generating entanglement and controlling dynamics in quantum processors. In Rydberg atom arrays, the atom spacing relative to the Rydberg blockade radius has so far mostly governed whether the atoms experience Rydberg blockade or anti-blockade. Here we demonstrate the ability to tailor Rydberg interactions using Floquet frequency modulation, with which we achieve Rydberg-blockade entanglement beyond the traditional blockade radius. Further, we find that the Floquet frequency modulation protects the entangled state coherence and enables new pathways to strongly-interacting states. Our Floquet work opens the door to realizing more connected, coherent, and versatile neutral atom processors with a single approach.

Keywords:

Rydberg atom, Floquet frequency, quantum entanglement, quantum information processing

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F8.05

Raman driving of atomic hyperfine qubits with an electro-optic modulator

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Abstract:

Hyperfine atomic qubits with a transition frequency of several GHz can be driven by microwave fields or by two-photon stimulated Raman transitions. Microwaves allow high-fidelity single-qubit control but lack the function of local addressing of individual qubits separated by micrometer range. Raman transitions with a given laser zone for single-qubit gate operations with the transportable qubits scheme, in addition with the Rydberg transitions for two-qubit gates, enable large-scale implementation of quantum algorithms. Various schemes have been used to drive stimulated Raman transitions of hyperfine qubits. Here, we report a simple and efficient Raman transition scheme based on an electro-optical modulator (EOM). A Raman laser beam is phase modulated by an EOM with its polarization at q=45^{o} with respect to the optical axis of the EOM. The beam component with its polarization parallel to the optical axis of EOM can generate sidebands while the beam component with its polarization orthogonal to the optical axis has no sideband. The sidebands with the orthogonally polarized carrier can induce the Raman transition. We have used cold cesium atoms to characterize this scheme. Rabi frequencies versus the angle □ and the modulation index are measured. The stability of Rabi frequency versus the temperature drift of the EOM will be discussed.

Keywords:

quantum gate, Raman transition, qubit, electro-optic modulator, microwave

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F9.01

Discrimination of fast-time scale temporal sequences based on a Pavlovian-conditioned spiking neural network

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Abstract:

Brain activity spans a wide range of timescales, from milliseconds to hours. The ability of neural networks to discern sequences of events occurring within the fast timescale of milliseconds, as required in tasks like precise timing events in sports or music performances, remains a topic of ongoing research. Here we propose and investigate a temporally Pavlovian conditioned spiking neural network to model this ability. Through numerical simulations and graph-theoretical analyses, we demonstrate that the conditioned model network effectively distinguishes various pairs of (model) sensory inputs occurring sequentially with distinct time intervals. Furthermore, the same network can be conditioned to discriminate triplets of events, formulated with a set of two time intervals, from other triplets with different time intervals. Interestingly, the encoding process generates a structured feed-forward network. And the decoding process is based on the deformation and overall shift of population burst profiles. Our study sheds light on the neural mechanisms involved in discriminating fast temporal events and may have implications for understanding time perception and cognitive processing in real-world scenarios where precise timing is essential.

Keywords:

spiking neural network, sensory signal perception, learning and memory

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F9.02

Unveiling the Odor Representation in the Inner Brain of Drosophila through Compressed Sensing

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Abstract:

The putative dimension of a space spanned by chemical stimuli is deemed enormous; however, when odorant molecules are bound to a finite number of receptor types and their information is transmitted and projected to a perceptual odor space in the brain, a substantial reduction in dimensionality is made. Compressed sensing (CS) is an algorithm that enables the recovery of high dimensional signals from low dimensional data compressed through a sensing matrix when the representation of such signals is sufficiently sparse in the vector space. Here, we use the recent Drosophila connectomics data to show that the sensing matrix defined from two interneuronal synaptic interfaces effectively fulfills the prerequisites for CS to work. We demonstrate the activity profile of projection neurons (PNs) can be faithfully recovered from a lower dimensional response profile of mushroom body output neurons (MBONs) constructed using the experimentally measured electrophysiological responses to a wide range of odorants. By leveraging the residuals calculated between the measured and the predicted MBON responses, we visualize the perceptual odor space in terms of residual spectrum and discuss the differentiability of a given odor. The simultaneous introduction of many different odorants saturates the activity profile of PNs, significantly degrading the capacity of signal recovery, resulting in a perceptual state analogous to "olfactory white." Our study that applies CS to the connectomics data of the Drosophila olfactory system provides novel and quantitative insights into the structure of perceptual odor space and odor representation in the brain.

Keywords:

Compressed sensing, Drosophila olfactory system, Perceptual odor space, Projection neurons, Mushroom body output neurons

F9.03

Decoding neural connections from activity data

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Abstract:

Neural signaling relies on intricate connections between neurons, but identifying the physical connections is a challenging task. However, recent advances in experimental techniques make it increasingly feasible to measure the activities of many neurons simultaneously. Thus, inferring a neural network from a time series of neural activities becomes a vital problem in neuroscience. To tackle this challenge, we use the kinetic Ising model, a physics-based model that assumes the future activity of binary variables is probabilistically determined based on their linear interactions. By optimizing the interaction weights between variables to enhance the consistency between observed and expected activities, we can infer the underlying network structure. However, network inference faces challenges such as hidden variables and missing data that may lead to incomplete and biased results. To address these issues, we use the expectation-maximization method, which iteratively estimates hidden or missing values and optimizes the interaction weights. In this talk, we demonstrate the effectiveness of our approach in inferring neural networks from time series of neural activities and predicting future neural activities.

Keywords:

Kinetic Ising model, Neural network inference, Expectation-maximization method, Neural activity prediction, Hidden variables and missing data

F9.04

Relationship between Phase Dynamics Patterns of Human Brain Waves and the Level of Consciousness

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Abstract:

The human brain consists of billions of neurons interacting with each other. Neural interactions lead to the appearance of consciousness. During anesthesia, the brain shows random firing patterns because the anesthetic interrupts the interactions between neurons. Despite accumulating studies focusing on the underlying mechanism, it is still unclear how anesthetics alter the neural dynamics to cause loss of consciousness. In this study, we analyze human anesthesia electroencephalography (EEG) recording data from 9 participants. We find that the level of consciousness is related to the phase dynamics pattern of brain waves. First, our results show that the brain forms two dominant modes during the conscious state-the anterior part phase leading the posterior part, and the posterior part phase leading the anterior part. Second, we find that the dominance of these two patterns disappears with increasing the anesthesia depth. Third, we observe that the dominant modes return as the level of consciousness recovers. We interpret that the phase dynamics patterns reflect the information flow dynamics across the brain network which becomes weaker during the general anesthesia. In conclusion, our results show that the dominant modes discovered in our study may be neural correlated of consciousness and play a crucial role in brain state transition.

Keywords:

Human brain, Relative phase dynamics, Consciousness

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F9.05

Effect of Adult-Born Immature Granule Cells on Pattern Separation in A Biological Network of The Hippocampal Dentate Gyrus

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Abstract:

Young immature granule cells (imGCs) appear via adult neurogenesis in the hippocampal dentate gyrus (DG). In comparison to mature GCs (mGCs) (born during development), the imGCs exhibit two competing distinct properties such as high excitability (increasing activation degree) and low excitatory innervation (reducing activation degree). We develop a spiking neural network for the DG, incorporating both the mGCs and the imGCs. The mGCs are well known to perform "pattern separation" (i.e., a process of transforming similar input patterns into less similar output patterns) to facilitate pattern storage in the hippocampal CA3. In this paper, we investigate the effect of the young imGCs on pattern separation of the mGCs. The pattern separation efficacy (PSE) of the mGCs is found to vary through competition between high excitability and low excitatory innervation of the imGCs. Their PSE becomes enhanced (worsened) when the effect of high excitability is higher (lower) than the effect of low excitatory innervation. In contrast to the mGCs, the imGCs are found to perform "pattern integration" (i.e., making association between dissimilar patterns). Finally, we speculate that memory resolution in the hippocampal CA3 might be optimally maximized via mixed cooperative encoding through pattern separation and pattern integration.

Keywords:

Hippocampal dentate gyrus, Adult neurogenesis, Immature granule cells, High excitability, Low excitatory innervation

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F10.01

Braiding of anyons at a quantum point contact

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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 a new type of anyon braiding, which happens when a dilute anyon beam is partitioned at the quantum point contact in the fractional quantum Hall regime. In the effect, an anyon excited at the quantum point contact braids (in time domain) the anyons of the dilute beam arriving at the quantum point contact within the time window of the excitation. Recent experimental results [3], observed at quantum Hall filling factor 1/3, agree with the braiding with a braiding phase 2π/3, providing an evidence of the fractional statistics of Abelian anyons.

[1] B. Lee, C. Han, H.-S. Sim, Phys. Rev. Lett. 123, 016803 (2019).
[2] J.-Y. M. Lee and H.-S. Sim, 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, Nature 617, 277 (2023).

Keywords:

anyon, fractional quantum Hall effects, quantum point contact, braiding

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F10.02

Topological edge modes and band-crossings from compact localized states

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Abstract:

A compact localized state (CLS) is a characteristic localized eigenstate of a flat band [1,2]. A CLS has nonzero amplitudes only inside a finite spatial region while precisely zero outside due to the quantum destructive interference a specific lattice structure provides. While the CLS explains the origin of completely flat bands, which are dispersionless over the whole Brillouin zone, the localization mechanism for partially flat bands ubiquitous in surfaces of topological semimetals has been unknown. We show that a partially flat band is characterized by a non-normalizable CLS featuring a quasi-localization nature. In this band, one can have the Wannier obstruction even if the band is topologically trivial. We also discuss a novel type of band-crossing protected by symmetry properties of the compact localized states.

[1] J.-W. Rhim and B.-J. Yang, Phys. Rev. B **99** 045107 (2019).
[2] J.-W. Rhim and B.-J. Yang, Advances in Physics: X **6** 1901606 (2021).

Keywords:

flat band, compact localized state, topological, band-crossing

F10.03

Topological Magnonics: Hall, Spin Hall, and Orbital Hall Effects of Magnons

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Abstract:

In this presentation, I will discuss my recent findings on topological magnon transport, specifically focusing on the magnon Hall effect, magnon spin Hall effect, and magnon orbital Hall effect. First, I will explain how the well-known magnetoelastic interaction driven by Kittel enables the nontrivial topology of magnon-phonon hybrid excitations, even though each magnonic and phononic system is topologically trivial. Because the magnetoelastic interaction is ubiquitous in magnetic materials, our result indicates that the topological magnon-polaron's existence is not restricted to specific conditions but is a quite generic phenomenon. Next, I will discuss that the magnetoelastic interaction allows giant spin Nernst effect of magnon-polarons in the antiferromagnetic systems. Additionally, I will introduce a novel transport phenomenon: the magnon orbital Hall effect. Investigating honeycomb antiferromagnet, we discovered that the magnon orbital Berry curvature remains finite even in the absence of spin-orbit coupling-related effects. This intrinsic transport property solely relies on the exchange interaction and lattice structure. Interestingly, due to the intrinsic nature of the magnon orbital Hall effect, the magnon orbital Nernst conductivity is estimated to be orders of magnitude larger than the predicted values of the magnon spin Nernst conductivity that require finite spin-orbit coupling. Because the magnetoelectric effect couples the magnon orbital and electric polarization, for the experimental detection of the magnon orbital Hall effect, I suggest the local voltage measurement which allows to detection of the magnon orbital accumulation.

Keywords:

magnon Hall effect, topological magnon, magnon spin Nernst effect, magnon orbital Hall effect

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F10.04

Strong interlayer coupling and stable topological flat bands in twisted bilayer photonic Moiré superlattices

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Abstract:

The alignment of atomic bilayers creates a moiré superlattice, which can be used to design materials with adjustable properties. This study introduces a two-dimensional photonic crystal version of the moiré superlattice using dielectric resonator quasi-atoms. Unlike van der Waals materials with weak interlayer coupling, our moiré superlattice realizes a strong coupling regime, resulting in robust flat bands at large twist angles. These flat bands exhibit non-trivial band topology, which arises from the moiré pattern of the resonator arrangement. The flat band topology manifests as a one-dimensional conducting channel on the edge, protected by the reflection symmetry of the moiré superlattice. By breaking the underlying reflection symmetry on the boundary terminations, we demonstrate that the first-order topological edge modes transform into higher-order topological corner modes. This work pioneers the physics of topological phases in the designable platform of photonic moiré superlattices, going beyond the weakly coupled regime.

Keywords:

Topological photonic crystal and flat bands, Twisted bilayer photonic Moiré superlattices

F10.05

Revealing inverted chirality of hidden domain wall states in multiband systems without topological transition

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Abstract:

Chirality and topology are concepts of great importance that lead to novel physical properties and potential applications in various fields.
We investigate the emergence of hidden chiral domain wall states using a double-chain Su-Schrieffer-Heeger model with interchain coupling specifically designed to break chiral symmetry. We found that we can manipulate the gap with interchain coupling and dimerization displacement not bringing any topological phase changes. We identify hidden chiral domain wall states exhibiting opposite chirality to the domain wall states in the single-gap phase, where the opposite chirality is confirmed through spectrum inversion
and charge pumping as the corresponding domain wall slowly moves.
By engineering gap structures, we demonstrate control over hidden chiral domain states.

Keywords:

Chirality, Charge pumping, Domain wall state

F11.01

Breakthroughs in material synthesis and characterization at extreme conditions

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Abstract:

In recent years, high pressure research has made breakthrough progress in many fields of science mainly due to significant improvements in both types of high-pressure vessels (diamond anvil cell and large volume press), high x-ray energy sensitive detectors and developments of advanced *static and dynamic* probes including, high spatial and energy resolution synchrotron-based and optical techniques. Most of the experiments at ultra-extreme pressure and temperature conditions are very challenging and require dedicated synchrotron beamlines, where state-of-the-art high-pressure on- and off-line techniques have been implemented and are currently being developed. Such unique capabilities at ultra-high P-T conditions approaching the warm dense state of matter will open an entire new research area creating a bridge between shockwave and DAC experiments that provides fundamental structural, thermodynamic, and transport property information essential for understanding the composition, origin and evolution of planetary systems.
With this technique we have successfully studied a number of unique properties of elements and their compounds synthesized at ultra-extreme pressure-temperature conditions such as transition metals, silicates, various polyhydrides, super-ionic phases of ice etc. Details of recent results and future developments of cutting-edge synchrotron and laser techniques for complex synthesis and comprehensive characterization of materials in-situ at extreme conditions in view of planned APS diffraction limited storage ring upgrade will be discussed.

Keywords:

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F11.02

Current studies on the discovery of low-pressure-based superconductors

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Abstract:

Recently, a possibility of low pressure-based high-temperature superconductors [1] and even room-temperature superconductor at ambient conditions have been reported, but whether to reproduce or verify through experiments is still under discussion [2]. In this study, the structure and transport properties of Lu-based nitrogen-doped hydrides were measured at high pressure using a diamond anvil cell. Contrary to what was reported by Dias et al., superconductivity was measured at low temperature of 5.6 K at 2 GPa, which is responsible for the superconductivity characteristic of LuH_3 instead of nitrogen doping.
In addition, the up-to-date results on synthesis, structure and electronic resistance properties of LK-99 [3], claimed to be exhibiting superconductivity at ambient condition, will be reported.

[Reference]
1. Nathan Dsenbrock-Gammon et al., "Evidence of near-ambient superconductivity in a N-doped lutetium hydride", Nature Vol. 615, 244 (2023).
2. Xue Ming et al., "Absence of near-ambient superconductivity in $LuH_{2\pm x}N_y$",
Nature Vol 620, 72 (2023).
3. Sukbae Lee et al., "The First Room-Temperature Ambient-Pressure Superconductor", Axive and following reports.

Keywords:

High pressure,, Superconductor, Hydrides

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F11.03

The Wondrous World of Carbon Under High Pressure

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Abstract:

Carbon forms a wide variety of allotropes. High pressure is a unique tool to create new carbon materials and to characterize physical properties of these materials. In this talk, I will present results from several recent collaborative studies (which involve too many coauthors to list here) on selected carbon materials and their unique mechanical properties. Examples are: (1) Type-II glassy carbon has tunable mechanical properties, such as zero Poisson's ratio and exceptional compressibility, under compression. (2) Compressional strength of nanopolycrystalline diamond (NPD) synthesized from pure graphite is as high as 20 GPa when deformed at >10 GPa and 1200 °C. Such a strength is 2-3 times greater than conventional polycrystalline diamonds. NPD deforms primarily by twinning and lattice rotation, instead of dislocation mediated mechanisms. (3) Diamond synthesized from carbon onions contains extremely high density of twins. Such nanotwinned diamond has even higher hardness and thermal stability at 1 bar.

Keywords:

Carbon allotropes, multi-anvil, diamond-anvil cell, high pressure, synchrotron, hardness, strength, elastic properties, nano-twinning

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F12.01

Probing resonating valence bond states in artificial quantum magnets using ESR-STM

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Abstract:

Designing and characterizing the many-body behaviors of quantum materials represents a prominent challenge for understanding strongly correlated physics and quantum information processing. We constructed artificial quantum magnets on a surface by using spin-1/2 atoms in a scanning tunneling microscope (STM) [1]. These coupled spins feature strong quantum fluctuations due to antiferromagnetic exchange interactions between neighboring atoms. To characterize the resulting collective magnetic states and their energy levels, we performed electron spin resonance (ESR) [2] on individual atoms within each quantum magnet. This gives atomic-scale access to properties of the exotic quantum many-body states, such as a finite-size realization of a resonating valence bond state. The tunable atomic-scale magnetic field from the STM tip allows us to further characterize and engineer the quantum states [3]. These results, combined with pulsed ESR, open a new avenue to designing and exploring quantum magnets at the atomic scale for applications in spintronics and quantum simulations.

[1] K. Yang et al., *Nat. Commun.* **12**, 993 (2021).
[2] S. Baumann et al., *Science* **350**, 417 (2015).
[3] K. Yang et al., *Phys. Rev. Lett.* **122**, 227203 (2019).

Keywords:

STM, electron spin resonance, resonating valence bond state

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F12.02

Molecular quantum sensor on a scanning probe tip for sensing electric and magnetic fields with single-atom sensitivity

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Abstract:

Artificial nanostructures, fabricated by placing atoms or molecules as building blocks in well-defined positions, are a powerful platform in which quantum effects can be studied and exploited. Here I will show that the manipulation capabilities of the scanning tunneling microscope (STM) can be used to place aromatic molecules in a standing configuration on a surface or STM tip. These standing molecular nanostructures are spin 1/2 systems, which exhibit a strong decoupling from the metal and mechanical flexibility. These properties even allow coherent control of the spin state using STM-based electron spin resonance (ESR) when the nanostructures are fabricated on the metallic tip. This enables the use of these nanostructures as quantum sensors on the movable tip for electric and magnetic fields with single-atom sensitivity, since these fields cause a change in the transition energy between the different quantum states, which can be detected with the high energy resolution of ESR.

Keywords:

Scanning tunneling microscope (STM), Electron spin resonance (ESR), Molecular nanostructure, Quantum Sensor

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F12.03

Superconductivity in atom-by-atom crafted quantum corrals

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Abstract:

Gapless materials in electronic contact with superconductors acquire proximity-induced superconductivity in a region near the interface. Here, we investigate the most miniature example of this so-called proximity effect on only a single quantum level of a surface state confined in a quantum corral on a superconducting substrate, built atom-by-atom using a scanning tunneling microscope. Whenever an eigenmode of the corral is pitched close to the Fermi energy by adjusting the corral's size, a pair of particle-hole symmetric states is found to enter the superconductor's gap. By comparison to a resonant level model of a spin-degenerate localized state coupled to a superconducting bath, we identify the in-gap states as scattering resonances theoretically predicted in 1972 which had so far eluded detection. We further show that the observed anticrossings of the in-gap states indicate proximity-induced pairing in the quantum corral's eigenmodes. Finally, we study how magnetic adatoms interact with the corral's eigenmodes.

Keywords:

Superconductivity, Superconducting proximity effect, Quantum dots, Quantum corral, Scanning tunneling microscopy, Scanning tunneling spectroscopy

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F12.04

Exploring topological superconductors and emergent quantum states

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Abstract:

In this invited talk, we delve into the forefront of quantum science by investigating topological superconductors and emergent quantum states using advanced atomic manipulation techniques. By employing Scanning Tunneling Microscopy (STM), we design, synthesize, and characterize magnetic nanostructures with tailored electronic properties. We explore the interaction between designed structures on superconducting surfaces, unraveling the emergence of exotic states. Through differential conductance measurements, we validate theoretical predictions and probe quantum topological phase transitions induced by magnetic impurities. Our results shed light on Majorana bound states and their non-Abelian exchange properties, vital for the development of topological quantum computation. This talk highlights our efforts to bridge the gap between theory and experiment, advancing our understanding of quantum phenomena and paving the way for innovative quantum technologies.

Keywords:

Topological superconductivity, quantum states, scanning tunneling microscope (STM), quantum topological phase transitions

Exploration of interlayer stacking configurations and new polymorphs in van der Waals crystals using transmission electron microscopy

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Abstract:

Transmission electron microscopy (TEM) has emerged as a powerful tool for identifying and discovering new nanomaterials. In this talk, I will survey various examples of the identification of new materials via TEM characterizations. In particular, various studies on the new polymorphic configurations of van der Waals materials will be introduced. Each layer in these crystals is stacked together via a relatively weak van der Waals interaction and can be isolated as an atomic-thin layer. Various meta-stable stacking configurations can be realized in these systems, including twisted stacking configurations, which can be also exploited for tuning physical properties. Moreover, new intralayer structures can be also obtained by new synthetic methods for some layered crystals.

Keywords:

Transmission electron microscopy, nanomaterials, van der Waals crystals, new polymorphs

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F13.02

방사광 기반 광전자분광현미경 기법의 활용 및 응용

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Abstract:

광전자 분광 현미경(SPEM)은 방사광 기술과 주사현미경을 융합한 혁신적인 기술로, 나노스케일에서 물질의 표면과 내부 구조를 고해상도로 조사하고 분석하는 데 중요한 역할을 하는 측정 기법입니다. 주로 물질 표면의 화학적 조성을 높은 공간적 해상도로 분석하는 데 사용됩니다. 이를 통해 결함, 결합, 구조 변화 등을 정밀하게 분석하고 이해할 수 있습니다. 또한, 분광 정보를 획득하여 물질의 화학적 성질과 상호 작용을 연구하는 데에도 활용됩니다. 본 분석기법은 강한 세기의 방사광 광원을 사용할 때 그 효과를 극대화할 수 있어 세계적으로도 가속장치 빔라인의 실험장치로 활용되고 있습니다. 현재 국내에서는 포항 방사광가속기 1기 빔라인으로 운영중에 있으며, 최근 각광받고 있는 저차원 물질, 반도체 소자 및 이차전지 등 다양한 분야에 응용되고 있습니다. 또한 실시간 분석기법을 접목한 연구 적용 범위를 넓히고자 많은 시도들이 이뤄지고 있습니다. 따라서 본 발표를 통하여 광전자 분광 현미경 분석기법의 기본적 원리와 함께 그 응용 연구분야에 대해 소개하고자 합니다.

Keywords:

방사광 가속기, 광전자 분광 현미경

2023 KPS Fall Meeting
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F13.03

Operando Surface Techniques to Detect Photon and Chemically Excited Hot Electrons

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Abstract:

The detection of hot electrons and understanding the correlation between hot electron generation and surface phenomena are crucial tasks in the surface science and catalysis community. It has been found that the hot electron flux generated under photon absorption and exothermic chemical reaction is the major mediator of energy conversion process. In this talk, I introduce the research direction to attempt to detect the surface plasmon driven hot carrier at the nanometer scale. Photoconductive atomic force microscopy has been utilized to observe photoinduced hot electrons on a triangular Au nanoprism on n-type TiO2 under incident light. We observed surface plasmon induced hot hole on Au nanoprism / p-type GaN. I will discuss the impact of hot carriers in the photocatalytic activity under photoelectrochemical water splitting by using Au-based plasmonic nanostructures. In addition, I will describe operando surface characterization on metal-oxide interfaces and hot electron flows under catalytic conditions.

Keywords:

scanning probe microscopy, hot carriers, surface plasmon, chemicurrent, photoconductive atomic force microscopy

2023 KPS Fall Meeting
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F13.04

Atomic force microscope-based analysis of the low-dimensional materials and their applications

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Abstract:

Just as we observe the vast world of the universe, people have paid great attention to observing the microscopic world of atoms. Optical microscopes have difficulty distinguishing objects smaller than a few hundred nanometers, but an alternative, the atomic force microscope (AFM), has been developed that allows observation of the nanoscale world. This has allowed us to dig into the realm of nanoscience. In particular, when objects are reduced to the nanoscale, liquids exhibit solid-like properties, and solids exhibit liquid-like properties, leading to an interesting phenomenon. This phenomenon was observed using an AFM. In this study, we will discuss how to analyze nanomaterials using AFM and how it can be used in various fields. Uniquely, we will discuss the technology that enables 3D printing at the nanoscale using custom atomic force, and how to implement nanoscale 3D printing based on the unique properties of low-dimensional liquids. Furthermore, the capabilities of AFM extend to the study of two-dimensional materials. This allows us to understand the properties and behavior of matter, which has enormous implications for materials science and electronics. As an important component of AFM, the fabrication of cantilevers is also discussed. These cantilevers play an important role in the functioning of AFM. Exploring how to fabricate and optimize these cantilevers becomes a fundamental aspect of pushing the limits of AFM technology [1-3].

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Keywords:

Atomic force microscope, low-dimensional materials, analysis, nanoscale 3D printing

2023 KPS Fall Meeting
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F14.01

High-Performance Polymer Field-Effect Transistors Enabled by Self-Aligned Nanopatterning

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Abstract:

Polymer nanowire field-effect transistors (PFETs) integrated on highly aligned large-area flexible substrates are promising structures for the advancement of flexible electronics with high performance. In semiconducting polymers, charge carriers primarily transport through either interchain hopping or intrachain transport. Intrachain transport has been known to be a few times faster than interchain hopping. Thus, aligning polymer chains in a desired direction enhances intrachain transport.
This study presents the fabrication of PFETs using a simple stamp method based on semiconducting polymer nanowires. The alignment of chains within the polymer nanowires was confirmed using various measurement techniques. The PFETs based on P-type and N-type polymer nanowires demonstrated exceptional carrier mobilities. Additionally, the polymer nanowire-based complementary inverter logic circuit exhibited a high voltage gain, ideal trip voltage, and exceptional large noise margins.

Keywords:

PFETs, Nanowire, Interchain, Stamp

2023 KPS Fall Meeting
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F14.02

Vertical Organic Transistors: Overcoming Limitation of Next Generation Semiconductor Devices

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Abstract:

The current record for high-speed organic transistor is reached by the vertical organic thin film transistor (VOTFT) with very short vertical carrier paths and 3D nano structures. Despite their advantages, device fabrications need highly delicate techniques such as multiple photolithography and vacuum evaporation processes to control the nanoscale structure and vertical current path of VOTFT. An anodizing process is introduced in the various types of VOTFT and the optoelectronic and informatic devices based on VOTFT by using the nanoscale oxide architecture with excellent dielectric properties using simple electrochemical fabrication. Therefore, the soft, high-performing and convergence electronics such as communications, skintronics and synaptics are intensively developing based on VOTFT.

Keywords:

vertical, organic, transistors, votft

2023 KPS Fall Meeting
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F14.03

A Distinctive Persistent Photocurrent Effect in MoS_2-$LaAlO_3$ Heterostructure

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Abstract:

Heterostructures typically consist of similar structural families due to epitaxial lattice matching advantages. However, since the emergence of 2D van der Waals (vdW) materials like graphene, mixed-dimensional vdW heterostructures with non-2D vdW materials have become appealing due to the avoidance of lattice mismatch issues. Despite their potential, few studies have explored heterostructures combining 2D vdW materials and functional metal oxides. In this study, we introduce the first mixed-dimensional vdW heterostructure using 2D MoS_2 and 3D lanthanum aluminate (LAO), demonstrating a unique persistent photocurrent (PPC) phenomenon. This PPC behavior allowed for an optoelectronic memory based on MoS2/LAO, WSe_2/LAO, and graphene/LAO heterostructures, with distinct differences in the photo-induced doping effect. We highlight the role of the heterointerface in these effects and offer insights into designing next-gen optoelectronic devices, emphasizing both the individual and combined attributes of 2D vdW materials and functional metal oxides.

Keywords:

Persistent Photocurrent, Optoelectronic Memory, 2D van der Waals Heterostructure, Functional Oxides

2023 KPS Fall Meeting
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F14.04

Electrode Design of Aqueous Zinc-ion Batteries for Low-cost Energy Storage Systems

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Abstract:

In the realm of renewable energy and the pressing global climate objectives, integrating efficient renewable energy sources with cost-effective energy storage systems (ESS) is vital. Aqueous Zinc-ion batteries (ZIBs) have emerged as a promising solution for expanding renewable energy utilization in modern power grids. ZIBs offer benefits like high capacities, low redox potential, affordability, and inherent safety from aqueous electrolytes. Yet, ZIBs encounter hurdles that impede their advancement. Challenges include Zn anode dissolution, corrosion, limited nucleation sites, and low wettability, impacting the Zn plating process and leading to uneven charge density and dendrite growth. Additionally, Zn anodes suffer stability issues in mildly acidic electrolytes, causing corrosion and unwanted byproduct formation. Consequently, innovative strategies are imperative to surmount these obstacles in order to realize the full potential of ZIBs for economical ESS solutions tailored to renewable energy integration.

Keywords:

Zn-ion battery, Anode, Protective layer

2023 KPS Fall Meeting
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F15.01

Negative Photo Responsive 2D Heterostack FETs and 220 GHz Schottky Diode with Graphene/MoSe2/Pt Vertical Assembly

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Abstract:

The first and most applications of two dimensional (2D) semiconductors have been much oriented to using the lateral in-plane mobility. Plain field effect transistors are the representatives of the 2D electron devices, but much more functional devices have been reported taking advantage of 2D characteristic channels. They include multivalue logic, multilevel memory, negative differential resistance devices. Beyond those devices, we here demonstrate negative photo responsive (NPR) FETs with p-MoTe2 channel but n-SnS2 layer on it, which results in SnS2/MoTe2 type III junction. As a result, normal photo-response in the photo transistor has been measured under the photons with the energy below 2.1 eV (higher than 1.3 eV), however interestingly negative photo response (NPR) effects was observed with the energetic photons (>2.1 eV). It is attributed to the recombination between hole carriers (MoTe2) and photo-excited electrons (SnS2) at their 2D/2D heterojunction.

Second category of device applications might be vertical diode or barrister action with thick 2D-layered TMDs. Here, we have demonstrated vertical Schottky diodes, which has relatively large contact area and low contact resistance, aiming at high cutoff frequencies. ITO/60 nm-thick p-WSe2 (with bottom Pt Ohmic) and Pt/160 nm-thick n-MoSe2 (with graphene/Au Ohmic) Schottky diodes are those. The p-type Schottky diode showed 27 GHz (5G use) but n-type diode with graphene demonstrated 220 GHz cutoff in maximum performance. We attribute these excellences to least contact resistance and contact capacitance.

In summary, both lateral and vertical device applications are to be shown and discussed in the focused session for "Status and Prospective of van der Waals Materials Research".

Keywords:

2D heterostack, NPR FET, vertical Schottky diode

2023 KPS Fall Meeting
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F15.02

High-Performance & Low-Power 2D Heterojunction FETs

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Abstract:

Two-dimensional (2D) semiconductors such as transition metal dichalcogenides (TMDs) have emerged as promising materials for implementing beyond-CMOS electronics due to excellent gate coupling and immunity to short-channel effects at the ultimate scaling. In addition, owing to a van der Waals layered structure, they hold great potential for non-conventional electronics capable of heterogeneous integration and deformation. To achieve high-performance 2D field-effect transistors (FETs), it is highly required to control the electronic states and energy band profiles at various heterointerfaces among the semiconductor channel, the gate dielectric, and metal electrodes. In this talk, I will present two types of proof-of-concepts 2D FETs enabled by interface band engineering: 1) modulation-doped FETs (MODFETs) and 2) metal-semiconductor FETs (MESFETs). In a MODFET, we demonstrated remote modulation doping in the type-II band-modulated channel, enabling us to achieve high mobility by suppressing dopant-induced charge impurity scattering. The 2D MESFETs were also demonstrated using the Fermi-level pinning-free metal Schottky gate, whose device characteristics approach the Boltzmann switching limit.

Keywords:

2D materials, Electronics, Device Physics

F15.03

Current status and challenges in hBN growth by chemical vapor deposition

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Abstract:

Hexagonal boron nitride (hBN) is a promising two-dimensional (2D) material owing to its unique optical properties in the deep-UV region, mechanical robustness, thermal stability, and chemical inertness. hBN thin films have gained significant attention for various applications, including nanoelectronics, photonics, single photon emission, anti-corrosion, and membranes. Thus, wafer-scale growth of hBN films is crucial to enable their industrial-scale applications. In this regard, chemical vapor deposition (CVD) is a promising method for scalable high-quality films. To date, considerable efforts have been made to develop continuous hBN thin films with high crystallinity, from those with large grains to single-crystal ones, and to realize thickness control of hBN films by CVD. However, the growth of wafer-scale high crystalline hBN films with precise thickness control has not been reported yet. The hBN growth is significantly affected by substrate, in particular the type of metals, because the intrinsic solubilities of boron and nitrogen depend on the type of metal. In this talk, state-of-the-art strategies adopted for growing wafer-scale, highly crystalline hBN are summarized, followed by the proposed mechanisms of hBN growth on catalytic substrates. Furthermore, various applications of the hBN thin films are demonstrated, including a dielectric layer, an encapsulation layer, a wrapping layer of gold nanoparticles for surface enhanced Raman scattering, a proton-exchange membrane, a template for growth of other 2D materials or nanomaterials, and a platform of fabricating in-plane heterostructures. Finally, the inherent challenges are summarized, and future research directions for the facile CVD-based growth of single-crystal hBN are proposed.

Keywords:

Hexagonal Boron Nitride, Chemical Vapor Deposition

2023 KPS Fall Meeting
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F15.04

New phosphorus polymorph: Wavy Packing of Twisted Pentagonal Tubes in Type-II Red Phosphorus

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Abstract:

Elemental phosphorus exhibits fascinating structural varieties and versatile properties. The unique nature of phosphorus bonds can lead to the formation of extremely complex structures, and detailed structural information on some phosphorus polymorphs is yet to be investigated. In this study, we investigated an unidentified crystalline phase of phosphorus, type-II red phosphorus (RP), by combining state-of-the-art structural characterization techniques. Electron diffraction tomography, atomic-resolution scanning transmission electron microscopy (STEM), powder X-ray diffraction, and Raman spectroscopy were concurrently used to elucidate the hidden structural motifs and their packing in type-II RP. Electron diffraction tomography, performed using individual crystalline nanowires, was used to identify a triclinic unit cell with volume of 5330 Å^3, which is the largest unit cell for elemental phosphorus crystals up to now and contains approximately 250 phosphorus atoms. Atomic-resolution STEM imaging, which was performed along different crystal-zone axes, confirmed that the twisted wavy tubular motif is the basic building block of type-II RP. Our study discovered and presented a new variation of building blocks in phosphorus, and it provides insights to clarify the complexities observed in phosphorus as well as other relevant systems.

Keywords:

Red Phosphorus, Structure Elucidation, Twisted Pentagonal Tubes, Wavy Packing Motif, Electron Microscopy

2023 KPS Fall Meeting
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F16.01

Visualizing quantum materials using hard x-ray techniques

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Abstract:

Quantum materials originated from electron-electron correlation have been intensively investigated due to their scientific interests. Many researchers have tried to search for new insight and intriguing material systems, such as antiferromagnet-based spintronics and energy conversion in transition metal oxides. Here, we introduce an experimental approach based on resonant x-ray scattering [1-3]. Using the techniques, we systematically investigated emergent properties of quantum materials, e.g., ruthenate and iridate. Our studies also can offer a comprehensive understanding based on the theoretical calculations combined with advanced hard x-ray scattering techniques. Moreover, we were able to visualize structural and (anti)ferromagnetic domains of thin films and single crystals. We propose that the techniques combined with electric field can explore and create new phases and emergent physical properties.

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Keywords:

Antiferromangets, Resonant x-ray scattering, Iridate

2023 KPS Fall Meeting
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F16.02

Resolving Surface and Electronic Ambiguities in Kagome Metal FeSn

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Abstract:

Transition metal kagome lattices are promising candidates for exploring electron correlation effects. Among these, FeSn, recognized as an ideal antiferromagnetic kagome metal, has garnered significant research interest. Despite this, ambiguities persist in identifying its distinct surfaces—specifically, the kagome (Fe_3Sn) and honeycomb (Sn_2) surfaces. Moreover, the energy position of the kagome flat band remains ill-defined. This study aims to address these issues by offering unambiguous evidence for both the existence and energy position of the kagome flat band. Utilizing scanning tunneling microscopy and spectroscopy, measurements were conducted on FeSn crystals. These crystals were cleaved at low temperatures under ultrahigh vacuum conditions. The investigation successfully identified two distinct cleaved surfaces, each displaying a unique electronic structure. Notably, on the kagome surface, two pronounced spectroscopic features were observed, conclusively indicating the presence of flat bands. This study eliminates prior uncertainties concerning the surface and electronic structures of kagome metal FeSn. The results lay a solid foundation for subsequent theoretical and experimental inquiries.

Keywords:

kagome metal, FeSn, scanning tunneling microscopy, flat band

2023 KPS Fall Meeting
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F16.03

Resonant elastic x-ray scattering(REXS) study on polar topological structures and their ultrafast dynamics.

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Abstract:

Recently, polar topological structures emerging in ferroelectric superlattices have attracted much attention. These exotic structures are challenging to characterize because their unit structures are one order of magnitude smaller than their magnetic counterparts and are formed by the three-dimensional distribution of polarization vectors in each crystal lattice. Furthermore, two-dimensional cross-sectional TEM cannot distinguish the chiral nature or helicity of the polar topological structure. Here, circular dichroism of x-ray resonant scattering will be introduced as a solution to this problem. The results and analysis methods of REXS experiments will be presented, and the ultrafast dynamic behavior of polar vortices for acoustic phonons using XFEL will be discussed.

Keywords:

Resonant elastic x-ray scattering, Polar topology, Time-resolved resoanant elastic x-ray scattering

2023 KPS Fall Meeting
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F16.04

Exotic Z_N Generalizations of 3D Z_2 Stabilizer Models

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Abstract:

In this work, we introduce a set of Z_N generalizations of a few 3D Z_2 stabilizer models, known as the toric code, X-cube model, and Haah code. We carefully investigate their elementary excitations and ground state degeneracies on a three-torus T^3 and find that the Z_N generalizations exhibit unusual excitations and ground state degeneracies, which are strongly dependent on the system sizes. For example, the immobile excitation in the original Z_2 X-cube model becomes mobile in some Z_N generalizations. We present an entirely new 3D model without an apparent Z_2 counterpart, implying that many interesting 3D exactly-solvable models and “topological" phases are still waiting to be discovered.

Keywords:

3D exactly-solvable model, ZN generalization, ground state degeneracies, unusual excitations

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F16.05

Flat bands and real-space topology in photonic honeycomb lattice made of circuit QED system with triple-leg stripline resonators

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Abstract:

In circuit QED system, a flat band has been observed in Kagome Lattices and Lieb Lattices with tunable hopping strengths coupled superconducting resonators. In this study, we investigate various geometric aspects of a graphene-like hexagonal optical lattice which has upper and lower flat band with Triple-leg stripline resonators (TSRs). The inherent two-fold degenerate modes of the TSR resemble a behavior of orbitals in 2D lattice systems. Our analysis reveals how the system leverages the destructive interference to establish flat bands via stabilized compact localized states (CLSs). We further explore the real-space topology corresponding to the flat bands by finding proper non-contractible loop states (NLSs). Additionally, in a zigzag-structured hexagonal lattice, we demonstrate the induction of flat edge modes at zero energy by calculating the Zak phase. We also elucidate the origin of other dispersive edge bands that arise from the singular point of the flat band.

*This work is supported by the National Research Foundation of Korea (grant number NRF-2022M3K2A108385811 and RS-2023-00257561).

Keywords:

Circuit QED, Flat bands, Zak phase

2023 KPS Fall Meeting
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F16.06

External field induced metal-to-insulator transition in disspative Hubbard model

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Abstract:

The strongly correlated electron systems driven out of equilibrium by external fields has been one of the most challenging subject in condensed matter physics for long time. And with the recent development of technology the theoretical understanding of the subject is much desired. Multiple studies of this phenomenon have been performed in semiconductors and oxides and there are strong indications that the Joule heating mechanism occurs in some binary oxides such as NiO and VO_2; the electric field-driven current locally heats up the sample which experiences a temperature-driven resistive switching. Using non-equilibrium steady state dynamical mean field theory with non-crossing approximation impurity solver, we investigate strongly correlated electron systems described by the Hubbard model under electric field. Both electric field and the electronic Coulomb interaction treated in non perturbative manner. By building the dissipative Hubbard model where the additional energy acquired from the field is dissipated by the fictitious free Fermion reservoir attached to each correlated electrons, and calculating physical quantities such as current induced by the electric field, local distribution functions which gives effective local temperature we observe the electric field induced metal-to-insulator transition and the phase coexistence region in the phase diagram. We argue that the electric field near the criticality takes the role of thermal energy in equilibrium and the metal-to-insulator transition by the field is qualitatively similar as in equilibrium MIT by using more sophisticated impurity solver. We expect these results will describe correctly the behavior of compounds such as NiO, Cr doped V_2O_3. This is, in part, to validate whether the developed non-equilibrium steady state DMFT and NCA algorithms work properly before tackling the more complex cluster type systems. Furthermore, the formalism given here is relatively easy to extend to EDMFT, where the bosonic degree of freedom, such as phonon, is accounted for hence giving more accurate electric current description of the system. It should also be possible to incorporate the formalism with the density functional theory.

Keywords:

Non-equilibrium, SCES, Field Driven, MIT, DMFT

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G2.01

Impact of the Korea CMS on the CMS results

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Abstract:

The Korea-CMS team consists of around 120 researchers from 10 institutes in Korea. The team has been contributing to building the CMS (Compact Muon Solenoid) detector at the LHC (Large Hadron Collider). The CMS machine allows us to explore nature and solve many unanswered questions such as the Higgs mass, dark matter, and matter-antimatter symmetry, etc. The Korea-CMS is heavily involved in those broad physics programs of the Higgs boson, top quark, and beyond standard model searches. The team has been also taking a leading role in the muon system of the RPC (Resistive Plate Chamber) and GEM (Gas Electron Multiplier) since the beginning of the LHC and recently started to contribute to the MTD (MIP Timing Detector), which requires cutting-edge technology. In this talk, I will present the achievements and prospects of the Korea-CMS up to now.

Keywords:

KCMS, CMS, LHC, Muon

G2.02

The Future of ALICE

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Abstract:

The ALICE experiment currently underway at the CERN Large Hadron Collider is one of the largest and most challenging scientific enterprises ever realized in the field of nuclear and subnuclear physics. Its main mission is to characterize the properties of the quark-gluon plasma, the state of matter that is thought to have existed in the early instants of the Universe after the Big Bang. Such a state of matter can be created in the laboratory by colliding beams of heavy nuclei, which are accelerated to reach a velocity close to the speed of light, and its properties are studied by measuring with complex detectors the thousands of particles that flyout from the collision region. The progress in this research field strongly relies on the continuous improvement of particle colliders and detectors, with increasing collision energies and rates and with higher precision, respectively. In my talk, after a brief introduction on the ALICE's experiment, I will present its long-term plans and the scientific and technological opportunities they open.

Keywords:

CERN, ALICE

G2.03

The footprint of the Korean ALICE experiment team

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Abstract:

Next year marks the 70th anniversary of the CERN. From 1990’s, Korean researchers participated in CERN experiments individually from 1970’s and the government officially made a MoU to support group research at CERN in 1906. In this talk, the activity of the Korean ALICE experiment team (KoALICE) will be reviewed and the current status of the KoALICE group will be reported. Also the future project leading by the KoALICE group and its contribution will be discussed.

Keywords:

CERN, ALICE

2023 KPS Fall Meeting
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G2.04

Physics at FCC

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Abstract:

The Future Circular Collider (FCC) is CERN's flagship proposal for a post-LHC accelerator facility. Similarly to the LEP/LHC sequence, it foresees the sequence of an e+e– collider (optimized for precision measurements of Higgs, EW and top quark properties), and a successive 100 TeV pp collider, both hosted in a new ~100km tunnel. A process is ongoing to assess its feasibility (from the technological, technical, financial and political perspectives), and to fully explore its overall physics potential. This talk discusses the science motivations supporting the need for a future generation of high-energy colliders and outlines the physics opportunities offered by the FCC.

Keywords:

LHC, FCC

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G3.01

A study on the visitor's characteristic of space science by statistics analysis in the exhibition data

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Abstract:

On 5th.(Korea standard time) Aug. last year, Korea's first lunar orbiter called 'Danuri'(Officially know as the Korea Pathfinder Lunar Orbiter) was launched. In response to this scientific achievement, the National Science Museum held a special exhibition with the aim of enhancing public understanding and engagement. Among the special exhibition contents, there was an activity where participants were asked to make their own predictions and write down coordinates for the landing site of Korea's first lunar lander, scheduled for the 2023. Thousands of visitors participated in this acticity, using information from previously landed lunar missions, to determine and record their own estimated landing coordinates for Korea's first lunar lander.
In this study, show the results of the analysis of exhibition data, and to infer visitor's knowledge of space science using this data.

Keywords:

National Science Museum, Scientific culture, DANURI(KPLO), Visitor's data

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G3.02

담당 큐레이터가 바뀌는 과정에서 과학관 특별전시 준비 활동 사례 연구

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Abstract:

과학관은 대표적인 비형식과학교육환경의 하나로 전시활동을 통해 시민이 과학을 만날 수 있는 기회를 제공한다. 여기서, 큐레이터는 전시의 공간과 디자인, 콘텐츠의 배치, 관람객의 체험활동 등을 설계하는 핵심적인 실무 기획자이다. 이 연구에서는 물리와 영화를 주제로 하는 과학관 특별전시 준비과정에서 담당 큐레이터가 바뀌면서 벌어지는 특별전시 활동 사례를 기술하고 분석하여 시사점을 도출하고자 한다. 발표에서는 3세대 문화역사활동이론을 적용하여 과학관의 특별전시 준비 활동체계를 마련하고, 활동주체로서 큐레이터의 전공과 배경이 바뀜에 따른 활동요소가 어떻게 변화하는지 논의하고자 한다.

Keywords:

과학관, 특별전시, 큐레이터, 활동

미래형 교수학습모델 개발: 디지털시대 물리교사의 과학 실험 역량

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Abstract:

디지털 전환 사회는 미래에 필요한 역량을 갖추기 위한 교육을 제공할 수 있는 교사 양성 프로그램과 교수학습 모델의 개발 및 실행을 요구합니다. 디지털 혁신은 교육자들에게 새로운 기회와 도전을 제시합니다. 학생들이 디지털 기기와 온라인 플랫폼을 능숙하게 활용하는 가운데, 교사들은 교수법을 조정하고 디지털 도구를 효과적으로 활용해야 합니다. 이러한 요구를 충족하기 위해서는 과학적 연구를 기반으로 사회의 변화에 유연하게 대응할 수 있는 교사 양성 체계를 구축하는 것이 필요하며, 이에 대한 효과를 검증하기 위한 지속적인 연구가 필요합니다. 최근 한국교원 대학에서 디지털 전환과 기후 변화와 같은 전지구적인 문제에 대처하기 위한 능력을 기르기 위한 교사 양성 모델을 개발하는 프로젝트가 시작되었습니다. 이 프로젝트는 예비 교사 대상으로 다양한 학습 이론에 기반한 초기 교수학습 모델을 개발하고, 이를 검증하기 위한 평가 방법을 모색하고 있습니다. 이 과정에서 "물리 교사로서 필요한 역량은 무엇이며, 물리 교사 교육을 위한 교수학습 모델의 특징은 무엇인가?"라는 질문이 나왔습니다. 이 발표는 연구 결과를 제시하는 것이 아니라 연구 문제를 제기하는 것을 목적으로 합니다. 디지털 리터러시, 온라인 협업, 데이터 리터러시, 기술의 윤리적 사용과 같은 주제에 대해 물리교육에서 활용하거나 기여할 수 있는 내용을 논의하며, 이와 관련된 교사의 역할과 필요한 역량에 대해서도 논의하고자 합니다. 이러한 논의를 통해 물리 교사 교육에 포함되어야 하는 역량 내용 및 그 역량을 발전시키기 위한 교수학습 전략에 대한 다양한 아이디어를 모아보고자 합니다. 이러한 노력의 궁극적인 목표는 물리 교사 교육질을 향상시키는 것뿐만 아니라 교육 체계 내에서 연구 기반 혁신과 지속적인 개선 문화를 조성하는 것입니다.

Keywords:

물리교사교육, 교사역량, 물리교육, 디지털 역량

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G3.04

개념적 혼성 이론에 기초한 물리교육 연구 유형

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Abstract:

이 연구에서는 개념적 혼성이론에 기초한 기존의 물리교육 연구를 유형 별로 나누어 보고, 각 유형의 연구 내용과 결과를 종합적으로 고찰하고 앞으로 물리교육 연구에서 개념적 혼성 이론을 어떻게 활용할 수 있을지 그 방향성을 탐색하고자 하였다.
2005년 이후 발표된 20개의 논문이 분석 대상으로 하였고 이들의 연구 주제는 '학생의 물리 현상 추론에 관한 연구', '물리 개념 분석 연구', '물리와 수학의 혼성에 관한 연구', '물리 개념에 대한 은유 및 존재론에 관한 연구', '물리의 시각적 표상 활용에 관한 연구', '테크놀로지 활용 물리 학습에 관한 연구' 6가지로 구분되었다. 각 연구 주제 별로 연구 내용과 결과를 종합적으로 살펴본다.

Keywords:

개념적 혼성 이론, 물리 교육 연구

G3.05

물리 전공이 아닌 중학교 과학 교사가 물리 영역을 가르칠 때의 어려움과 대응

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Abstract:

오늘날 과학교육은 점점 ‘통합성’을 강조하고 있다. 하지만, 중학교 과학 교사는 본인의 세부 전공을 넘어 과학의 모든 영역을 지도하기 때문에 타전공 영역에 대한 낮은 자신감 및 교수 불안을 갖는 경우가 많다. 이는 학생들의 과학 학습에 큰 영향을 미치기 때문에 이에 대한 철저한 이해가 필요하다. 본 연구에서는 중학교 과학 교사 중 비전공 교사가 물리 영역을 가르칠 때의 어려움과 그에 대한 대응을 살펴보았다. 이를 위해 물리 전공이 아닌 중학교 과학 교사 37명을 대상으로 개방형 문항의 설문조사를 실시하고, 그중 7명을 대상으로 반구조화된 면담을 실시하였다. 수집된 자료를 통해 물리 영역 단원별 어려움, 교사의 전공별 어려움, 어려움에 대한 대응의 유형을 분석하였으며 다음의 결과를 도출하였다. 첫째, 물리 영역을 가르칠 때 가장 큰 어려움을 느끼는 내용 부분은 ‘전기와 자기’ 단원이었다. 교사들은 이 단원에서 특히 추상적인 개념의 정의를 이해하고 설명하며, 교과서 밖 질문에 대처하고, 공식 없이 물리 현상을 설명하는 데 어려움을 보였다. 둘째, 화학 교사는 다른 타전공 과학 교사에 비해 물리 내용 이해의 어려움보다 교수의 어려움이 많은 것으로 나타났다. 생물, 지구과학, 공통과학 교사는 물리 개념이 추상적이고 수식을 많이 활용하며 이상적인 상황을 가정한다는 인식 때문에 물리 내용을 이해하는 데 어려움을 느낀다고 응답하였다. 게다가 단편적인 교과서 서술과 교사의 부족한 실험 경험은 이들의 어려움을 더욱 가중시켰다. 셋째, 어려움에 대한 교사의 대응은 개선형, 대체형, 최소형, 포기형의 4가지 유형으로 나눌 수 있었다. 교사는 협력을 통하여 자신의 수업을 교육과정의 의도대로 보완하거나(개선형), 자신의 전문성을 바탕으로 수업을 재구성하기도 하였다(대체형). 또는 교과서에 있는 내용만 고수하거나(최소형), 교과서를 재구성하려는 시도를 했지만 자신감 부족으로 포기하기도 하였다(포기형). 이를 종합할 때 교사용 지도서의 상세한 서술, 실험 연수, 그리고 전공별로 차별화된 타전공 영역 수업에 필요한 지원이 필요하며, 물리 용어에 대한 연구, 과학 현상에 대한 간학문적인 접근에 대한 연구가 필요함을 알 수 있다. 본 연구는 물리 영역 수업에서의 어려움과 대응을 타전공 교사의 구체적인 사례를 통해 살펴봄으로써 중학교 과학 교실 현장을 이해하고 중등 과학교사교육에 시사점을 주는 데 의의가 있다.

Keywords:

Middle school science teacher with non-physics major, Difficulties in teaching physics

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G3.06

물리교육 이론과 수업 실행간 연결을 위한 학교(교사)-대학(교사교육자)간 협업의 방향

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Abstract:

교육학자들은 교육학적 이론과 학교에서의 지도 실행간 격차가 교사의 전문성 발달과 학교의 혁신을 가로막는 주요 요인 중의 하나로 지적해 왔다. 그러면서 이를 해결하기 위한 방안의 하나로 초중등 학교와 대학간, 또는 교사의 교사교육자간 협업을 제안해 왔다. 본 발표에서는 학교와 대학간 협업의 필요성에 대해 소개하고, 문헌조사에 기반하여 개발한 학교와 대학간 협업 모델과 조건을 소개하고자 한다.

[학교(교사)-대학(교사교육자)간 협업의 조건]
1. 상호이애
1-1. 상대의 상황/목적/주요 관심 등의 이해가 잘 되었는가?
1-2. 상대에 대한 이해를 통해 자신의 변화를 꾀하였는가?
1-3. 상호이익이 되었는가?
2. 상호관계
2-1. 서로 평등한 관계로 공유하고 공감하는가?
2-2. 서로에게 신뢰를 주고 좋은 관계를 가지고 있는가?
2-3. 의사소통이 원활하게 일어나고 있는가?
3. 시간
3-1. 충분한 시간을 확보하여 오랜 기간에 걸쳐 협업이 진행되는가?
4. 실행
4-1. 실행을 위해 기반이 되는 이론을 고려/반영하는가?
4-2. 실행에 기반하여 이론화하고 형식화하려고 시도하는가?
4-3. 실행에 대한 반추가 이루어지고, 반추에 의한 개선이 있는가?
4-4. 교육적 상황에 따라 실행이 유연하게 변화하는가?
5. 지원
5-1. 적절한 예산지원이 있는가?
5-2. 협업을 위한 인프라 조성과 학교장/교육청으로부터 행정적 지원이 적절한가?
5-3. 코디네이터가 협업과정을 원활하게 도와주고 있는가?

Keywords:

이론과 실행, 협업, 교사 전문성 발달

G4.01

Nano-Hz gravitational waves: first evidence and implications

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Abstract:

The EPTA+InPTA, NANOGrav, PPTA and CPTA independently reported evidence of a nano-Hz gravitational wave (GW) signal in their data. While the exact origin of the signal cannot be currently established, it is consistent with the expected 'murmur' of a cosmic population of supermassive black hole binaries (SMBHBs). In this talk, I will introduce the pulsar timing array (PTA) techinque and how it is used to detect GWs, I'll describe the signal found in the data and discuss future directions and implications for the astrophysics of SMBHBs and galaxy formation at large.

Keywords:

gravitational waves, pulsar timing array

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G4.02

New detection methods with PTA

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Abstract:

A second wave of gravitational wave (GW) astronomy is coming as pulsar timing arrays (PTAs) around the world provide strong evidence for a GW background. We review the principle of PTA in depth and propose various new GW observation methods. Firstly, we present an observational method using the perturbations of the Stokes parameters. Secondly, we propose an extension of the observational frequency range of PTAs. Lastly, we investigate the feasibility of detecting GWs through electromagnetic invariants.

Keywords:

pulsar timing array, gravitational waves, Stokes parameters, electromagnetic invariants

G5.01

The introduction of medical laser systems and related applications developed by LASEROPTEK

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Abstract:

The medical laser can be used in various medical field for diagnosis and treatment purposes by using the principle of causing thermal damage and chemical reactions in cells or tissues as the laser is absorbed by tissues and converted into thermal energy.
Due to the characteristics of the laser, when incident on human tissue, special changes occur in a specific tissue layer and can be applied to treatment.
In particular, in dermatology, since the penetration depth of the skin differs depending on the wavelength of the laser, a special wavelength is required depending on the skin disease. Therefore, dermatologists use various lasers to treat melasma, tattoo removal, scar removal, acne, and vitiligo.
LASEROPTEK can develop and manufacture various medical laser systems, and these laser systems are used in many hospitals for skin treatment and skin care.
In this presentation, we are going to introduce LASEROPTEK laser systems for the skin treatments.

This work was supported by the Technological Innovation R&D Program (S3272695) funded by the Ministry of SMEs and Startups (MSS, Korea).

Keywords:

Solid state laser, Fiber laser, Pulse laser, UVB, Dermatology

G5.02

고출력 Yb 첨가 광섬유 레이저 광원 개발

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Abstract:

회절한계 특성을 갖는 수 kW 급 Yb 첨가 광섬유 레이저는 기존의 고체, 액체, 기체 레이저를 대체하여 많은 응용분야에서 사용되고 있다. 특히 청정 가공, 생산 자동화 등이 중요시되는 산업 및 공업 분야뿐만 아니라 드론, 미사일, 지뢰 등 갈수록 정밀화, 소형화, 무인화, 첨단화가 되어가는 국방 분야에서는 최소 수 kW에서 수백 kW에 이르는 고출력 광섬유 레이저 시스템의 필요성이 증대되고 있고 이와 관련된 많은 연구 개발이 보고되고 있다.

과거에는 단순히 레이저 단일 채널의 출력을 증대시키는 방식이 사용되어왔으나, 최근 단일 레이저 빔 결합 기술 발달로 인해 출력뿐만 아니라 결합성이 우수한 레이저 모듈에 대한 연구 및 요구가 증대되고 있다. 레이저 모듈의 결합성은 광학 특성뿐만 아니라 기계/전자 등 모든 사항들이 종합적으로 고려되어야 한다. 특히 광학적으로 협대역 선폭이 요구되기에 고출력 구현시 유도 블릴루앙 산란(Stimulated Brillouin scattering)에 의해 출력이 결정되기 때문에 이를 극복하기 위한 레이저 구성 및 최적화에 대한 연구가 활발히 진행 중이다.

이에 본 그룹은 Yb 첨가 광섬유 레이저의 출력 증강뿐만 아니라 협대역 선폭 특성을 갖는 우수한 결합성의 광섬유 레이저에 대한 연구를 진행 했으며, 본 논문에서 이에 대해 보고하고자 한다.

Keywords:

광섬유 레이저, 고출력 레이저, 이터븀(Ytterbium, Yb)

2023 KPS Fall Meeting
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G5.03

Ultra-high-speed repetition of wavelength-swept fiber-optic laser

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Abstract:

Recently various swept sources have achieved commercial success, owing to their fast-tuning speed, compact size, ease of use, wide bandwidth, and long coherence length. As a result, these sources have been widely applied across various fields, including 3D biomedical imaging, source-based spectroscopy, and fiber optic sensors. Fourier domain mode locking (FDML) and microelectromechanical systems (MEMS)-tunable vertical-cavity surface-emitting lasers (VCSEL) are cutting-edge mechanical wavelength selection methods for creating wavelength-swept sources, but there has been a limitation for increasing repetition speed around hundreds kHz and phase stability around tens nm due to the mechanism of physical movements of optical components. Achieving both ultra-high-speed (multi-MHz repetition rates) and ultra-phase stability (sub-nm) simultaneously has been reported based on the stretched-pulse active mode locking (SPML) configuration The long and continuous chirped pulse with a broad spectral bandwidth is achieved through the repeated stretching, amplification, and compression of the optical pulse in the SPML laser cavity. The all-fiber-based laser cavity and precise pulse modulation techniques facilitate stable mode-locking and easy synchronization with other devices because the mechanism is free from physical movement.

Keywords:

Ultra-high-speed repetition, wavelength-swept laser, fiber-optic laser

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G5.04

Computational adaptive fluorescence microscopy based on the incoherent reflection matrix

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Abstract:

Reflection matrix microscopy is an innovative adaptive optics method designed for coherent imaging, providing the capability to correct aberrations induced by samples. In this presentation, we introduce the extension of the aberration correction technique based on the reflection matrix to encompass incoherent imaging systems. Theoretical and experimental investigations show that optical transfer functions in the excitation and emission pathways of a fluorescnece microscope can be identified from an incoherent reflection matrix. This approach allows for super-resolution fluorescence imaging even in the presence of significant sample-induced aberrations.

We first discuss an incoherent reflection matrix and an image reconstruction algorithm. We then show super-resolution imaging of fluorescent beads located beneth an aberrant medium. Unlike conventional fluorescence imaging impeded by blurred excitation and emission point-spread functions, our method overcomes these limitations, leading to sub-diffraction-limited resolution. We also showcase the application of this technique in aberration-free high-resolution fluorescence imaging within complex biological samples.

Keywords:

computational adaptive optcs, fluorescence microscopy, incoherent reflection matrix

G5.05

고출력 방사형/방위형 레이저 빔 생성

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Abstract:

축 대칭 편광 상태의 원통형 벡터 빔(CVB)은 편광 상태에 따라 방사형 또는 방위형으로 구분되며 횡 단면 중심에서는 편광 특이성을 가지기 때문에 도넛 모양의 빔 세기 분포를 가진다. 이러한 빔은 원형 또는 선형 편광 빔보다 높은 절단 품질과 효율성을 지니고, 열에 의한 복굴절이 발생하지 않으며, 높은 NA로 집속시킬 때 TEM_{00} 모드 빔보다 작은 스폿 사이즈를 가질 수 있다는 특징으로 인해 재료 가공, 광학 리소그래피, 고해상도 이미징, 플라즈몬 포커싱 및 나노입자 조작과 같은 다양한 분야에서 많은 관심을 받고 있다. CVB의 생성 방법으로는 Q-파장판, S-파장판, 방사형/방위형 편광 변환기 등을 사용하여 TEM_{00} 모드 빔에서 원하는 편광을 가진 레이저빔으로 변환시키는 방법과 복굴절 열렌즈 공진기, 편광 혼합 공진기 등의 구조에서 직접 방사형/방위형 편광을 가진 CVB를 레이저로부터 직접 생성하는 방법 등이 있다.

본 논문에서는 S-파장판이 삽입된 Yb:YAG 디스크 레이저 공진기에서 직접 발진된 CVB을 보고하고자 한다. 펌핑 광원으로는 969 nm 중심 파장을 가지는 다이오드 레이저를 사용하였고, 이득 매질은 215 um 두께와 12 mm 직경을 가진 Yb:YAG 디스크를 사용하였다. 이때, s-파장판의 광축 각도에 따라 출력 레이저 빔의 방사형 혹은 방위형 편광 상태를 결정할 수 있었다. 그 결과, 입사된 펌프 출력이 131 W 일 때, 방사형 편광된 빔의 최고 출력은 10.8 W, 빔질은 2.3, 광-광 효율은 22.9%로 측정되었고, 방위각 편광 빔의 최고 출력은 10.2 W, 빔질은 2.3, 광-광 효율은 23.7%로 측정되었다.

Keywords:

Laser, Cylindrical Vector Beam, Thin disk laser

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G6.01

Theory and Simulations on Laser Pulse Compression in a Plasma

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Abstract:

In this special presentation, I would like to talk on the latest advancements in plasma optics and photonics, with a specific focus on diverse methods of pulse compression in plasmas. The plasma photonics is a nascent yet rapidly evolving field in plasma physics, aiming to the manipulation of high-power photons through the utilization of the dispersive properties of plasmas. This novel concept proves particularly useful when the intensity of the laser surpasses the damage threshold of conventional optical devices made from solid materials. As the plasma is in an already ionized state, it is free from the constraints of 'damage', thereby enabling the control of highly intense electromagnetic fields in substantially reduced dimensions. This feature is in contrast to traditional Chirped Pulse Amplification (CPA) techniques, which necessitate compression gratings spanning hundreds of meters to attain exawatt or zettawatt level laser pulses. In contrast, plasma-based compression schemes like Raman or Brillouin backscatter hold the potential, in principle, to achieve comparable levels of compression within plasmas of less than a centimeter. In this presentation, I will introduceand discuss an innovative pulse ompression concept that has been conceived from collaboration between UNIST, GIST, and the Univ. Strathclyde, its inherent potential, and the direction for its future research trajectory.

Keywords:

plasma photonics, pulse compression

2023 KPS Fall Meeting
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G6.02

Current status of the on-going experiment for laser pulse compression using a density-gradient plasma

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Abstract:

Recently the novel idea for laser pulse compression using a density-gradient plasma was proposed (accepted for publication in Nature Photonics), which is a close collaboration result of three universities (UNIST, GIST and Univ. of Strathclyde). In this idea, a negatively frequency-chirped long laser pulse is sent into a plasma with a special density profile in the longitudinal direction, where the high-frequency components in the front part are reflected more deeply in the overdense plasma compared with the low-frequency componests. As a result, the incident negatively frequency-chirped long laser pulse can be compressed after reflection from the overdense plasma. This idea may provide a new way for realization of the future untra-high power lasers which are not possible with the current CPA (chirped-pulse amplification) technique. In our laboratory, we are performing the laser pulse compression experiment to demonstrate the idea. So far we have developed some special solid targets based on extensive hydrodynamics simulation results. Besides, the development of diagnostic tools for measurement of the overdensity plasma is also underway. In this talk, the on-going progress for the laser pulse compression experiment is reported.

Keywords:

laser pulse compression, density gradient plasma, ultrahigh power laser

Plasma photonics at high intensities

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Abstract:

High power lasers have become large because they are based on relatively low damage-threshold optical media, which pose a constraint on the development of exawatt to zettawatt ultra-short pulse lasers. A more robust and much more compact medium for manipulating intense laser pulses is plasma. Here we demonstrate that intense ultrashort probe pulses can scattering off robust plasma photonic structures with high intrinsic efficiency. These volume plasma Bragg gratings are formed by ballistically evolving ions that gain momentum from space-charge fields created by the ponderomotive force of the beat waves of intercepting laser pulses. Electrons bunched by the forces produce space-charge fields that impart phase correlated momenta to ions, which then evolve into a plasma photonic structure that can efficiently scatter a probe pulse. This two-step, inertial bunching mechanism can be used to create robust media for manipulate intense laser pulses. We will present the latest results of experiments to demonstrate the properties of plasma photonic structures.

Keywords:

Plasma photonics

G7.01

Imaginig Calorimeter for the Electron-Ion Collider

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Abstract:

The Electron-Ion Collider (EIC), which will be built at Brookhaven National Laboratory, is a powerful accelerator facility with polarized electron and light ion beams to study the partonic structure of hadrons. The versatility of the accelerator allows to use of heavy nuclei like gold and uranium to study nuclear medium effects on the partonic structure and hadron production. The ePIC collaboration has formed to design and construct the general-purpose detector to be ready at the beginning of the operation of the Electron-Ion Collider. The imaging calorimeter has been selected for the barrel electromagnetic calorimeter. It consists of four silicon pixel layers interleaved with five Pb/SciFi layers, and a bulk section of Pb/SciFi is behind of the imaging layers. The configuration satisfies the requirement of charged pion suppression, energy resolution for photon energy reconstruction, and fine granularity for $\pi^0-\gamma$ separation. Several Korean institutions will significantly contribute to developing and building the detector system. In this presentation, I will introduce the imaging calorimeter for the ePIC experiment at the EIC and discuss future plans from Korean institutions.

Keywords:

Electron Ion Collider, Imaging Calorimeter

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G7.02

Electron-Ion Collider (EIC) and the ePIC experiment

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Abstract:

The Electron-Ion Collider (EIC) is an electron-proton and nuclear collider with electron-polarization and proton-polarization capabilities. The EIC will perform the world's first collider experiments of polarized electrons and polarized protons, and electron-nucleus collisions. The EIC is a next-generation large accelerator that will open up new areas of quantum chromodynamics (QCD) physics and expand the richness of nuclear and hadron physics. The process to construct the EIC is proceeding at a rapid pace at Brookhaven National Laboratory in the United States. The first EIC experiment has been named the ePIC experiment, and the integrated collision point and detector are being designed and developed to maximize physics results. In this talk, I will give a brief overview of the physics that the EIC aims to achieve and the current status of the project, an overview of the ePIC experiment, and the status of detector design and development, including activities in Japan.

Keywords:

QCD, hadron physics, collider, polarized electron-proton collision,electron-nucleus collision, nucleon structure, spin, mass, gluon saturation

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G7.03

QCD relations for gravitational form factors

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Abstract:

Study of gravitational form factors (GFFs) as the hadron matrix element of the energy-momentum tensor is a hot topic related to EIC physics. Using QCD constraints for the corresponding matrix elements, the GFFs at large and zero momentum transfers are discussed. In particular, the new results for the latter are derived for the twist-four GFF for quark as well as for gluon, $\bar{C}_{q,g}$, at NNLO QCD from the trace anomaly constraints. For the nonperturbative matrix elements arising in the corresponding three-loop formulas, we use the results from experiment and lattice QCD. We show the quantitative results for nucleon as well as for pion, leading to a model-independent determination of the forward value of $\bar{C}_{q,g}$. We also mention that the same framework based on the trace anomaly constraints indicates quite different pattern in the mass structures between the nucleon and the pion.

Keywords:

gravitational form factors, energy-momentum tensor, QCD, trace anomaly, NNLO calculation, mass structures of nucleon and pion

Exclusive electroproduction of J/psi off nuclei and the electron endcap tracker

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Abstract:

The Electron Ion Collider (EIC) to be built in Brookhaven National Laboratory plans to investigate the structure of the proton, the neutron, and the nuclei with polarization via deeply-inelastic scattering (DIS) of the polarized electrons at very high luminousity, and study the strong nuclear force inside the mentioned target dictated by Quantum Chromodynamics (QCD).

The perturbative QCD calculations, assuming two guon exchange with the target, was applied to the exclusive electroproduction of J/psi off proton, and gave decent descriptions of the measurements so far. The EIC will offer opportunities for new measurements and studies at another level if enhanced with the state of the art detectors.

ITS3, new vertex detector developed for the ALICE collaboration at CERN, is based on the wafer-scale ultra-thin silicon pixel sensors which has very low material budget of 0.05% radiation length and ultimate spatial resolution of about 5 micron. These characteristics are important for the eletron endcap detector at EIC and will play an important role to the mentioned measurement.

Keywords:

EIC, J/psi, perturbative QCD, electron endcap, ITS3

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G8.01

Progress of KRISS Yb-atom array

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Abstract:

Neutral atoms in optical tweezer array have emerged as one of powerful tools for implementing quantum technology and, more recently, tweezer array of Alkaline-earth-like atoms (AEA) of two valence electrons is rapidly developing to seek new opportunities, like in atomic clocks. The two electrons offer richer structure including intercombination lines, meta-stable states, and ion-core transitions, which allows better coherent controls and measurements for ground and Rydberg qubits. Especially, Yb atoms uniquely provides a stable element of 1/2 nuclear spin, which helps to implement qubits. In this talk, I will review these recent advances in AEA array. Then, I will present progress of building a new Yb-atom tweezer array at Korea Research Institute of Standards and Science (KRISS), where Yb optical clock and quantum gas experiments have been conducted before.

Keywords:

neutral atoms, tweezer traps, Alkaline-earth atoms, Rydberg atoms, quantum information

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G8.02

Controlling nuclear spin qubit of Ytterbium atoms in an optical tweezer array

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Abstract:

Neutral atoms trapped in an optical tweezer array are one of the promising platforms for quantum computing. Recently, the two-electron atom system is attracting much attention because it has many advantages over alkali atoms used in conventional experiments. In this presentation, we report the experimental results of Raman sideband cooling and nuclear spin control of the fermionic isotope 171-ytterbium trapped in the optical tweezers at a wavelength of 532nm. We successfully cooled the atoms to the mean vibrational level of $\bar{n}_x = 0.21(4)$ and $\bar{n}_y = 0.19(3)$ in the radial direction of the tweezers with the trapping depth of 1.7 mK and the Lamb-Dicke factor of 0.22. We also observed the Rabi oscillation between the nuclear spin states by Raman transition with a frequency up to 1.3 MHz, corresponding to the X gate in the quantum computation.

Keywords:

Optical tweezer array, Ytterbium, Quantum computing, Nuclear spin qubit

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G8.03

Motion of atoms in optical tweezers: from thermal to squeezing and entanglement

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Abstract:

I will discuss progress on controlling the motion of atoms in optical tweezers. A series of seminal work by the group of C. Regal have demonstrated, close to 10 years ago, the preparation of atoms in the motional ground-state of optical tweezers as well as textbook experiments such as tunneling or quantum interference between tweezers [1].
Here, I will consider the case of well-separated tweezers (no tunneling) where the individual atoms and their motions are coupled to each other following excitation of the atoms to strongly interacting Rydberg orbitals. I will make use of the “ultrafast” capabilities demonstrated in our research group [2], where atoms are excited simultaneous to Rydberg states (no Rydberg blockade) to introduce a strong mechanical force and thus a momentum kick on the relative motion of the two atoms. I will present how to create squeezed state of motions and use them to either suppress or enhance this effect with applications for the realization of an ultrafast Rydberg gate and for quantum simulation of “spin-motion” coupled systems. One could also envision to extend the “throw-and-catch” experiments recently demonstrated [3] by using squeezed states of motion to improve the control over the free-flying atom trajectory.
More generally, the preparation of atoms in the motional ground-state of tweezers or in squeezed motional states will gain importance as the “atoms in tweezers” platform matures and we push its limit for higher fidelity of gates and simulations.

[1] A. Kaufman et al., Science 345, 306 (2014)
[2] Y. Chew et al., Nature Photonics 16, 724 (2022)
[3] H. Hwang et al., Optica 10, 401 (2023)

Keywords:

Rydberg atom, quantum entanglement, optical tweezers

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G8.04

Rydberg atom collisions by optical tweezer accelerator

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Abstract:

Neutral atom collision is one of the focusing areas of physics research. Until recently, neutral atom collision was implemented with atom cloud which was made by Magneto-Optical-Trap(MOT) [1]. Because it uses an atom cloud, a single atom's speed, direction or position is uncontrollable. About this, we reported controllable neutral atom collision, by using atom throw and catch method [2]. The experiment was implemented by colliding two Rydberg state atoms, one is stationary and the other one is accelerated and thrown by a dynamical optical tweezer. Colliding Rydberg atom's principal number was n=53 and the controlled fly atoms velocity was 0.5(1) m/s by accelerated and released by optical tweezer. Furthermore, in this work we performed we expanded our experimental regime n=53 to n=36 also n=45. Even more, using the advantage of the atom throw and catch method which is the controllable speed of fly atom, we controlled colliding atoms velocity value with 0.5(1) m/s and 3.0(5) m/s. By changing the collision atoms' position in one dimensional of each data set n=36, 45, and 53 with two cases of velocity 0.5(1) m/s and 3.0(5) m/s, we achieved 6 value of collision cross section depending on Rydberg states principal number and velocity. Analysis of 6 data shows depend on principal number n and speed v with cross-section is increasing with an order of $n^{2.34(98)}$ and decreasing with an order of $v^{-0.5(2)}$. This proof-of-principle analysis of Rydberg atom controlled collision shows the milestone of the controlled 3-particle collision experiment.

[1] Yoshida, S., Burgdörfer, J., Fields, G., Brienza, R., & Dunning, F. B. "Giant cross sections for L changing in Rydberg-Rydberg collisions." Physical Review A 102.2 (2020): 022805.

[2] Hwang, H., Byun, A., Park, J., de Léséleuc, S., & Ahn, J. (2023). Optical tweezers throw and catch single atoms. *Optica*, *10*(3), 401-406.

Keywords:

Rydberg atom, Collision, Atom Throw and Catch, Trapped Atom

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G8.05

Slingshot throw and catch of single atoms by optical tweezers

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Abstract:

Optical tweezer is widely used to hold and guide atoms, molecules and biological objects. Recently, it has been demonstrated that optical tweezer can throw and catch atoms between two spatial positions [1]. Here we propose and experimentally demonstrate a slingshot throw-and-catch method, which utilizes a linearly increasing acceleration (i.e, d*x/dt = constant*$d\ddot{x}/dt = \mathrm{constant}$), instead of the previous constant acceleration (i.e, *x = constant*$\ddot{x} = \mathrm{constant}$) and deceleration method. In our preliminary experiment and analysis, the slingshot throw-and-catch achieves faster free-flying atoms up to a speed of 1.5 m/s, a longer travel distance up to 20 um, a higher success of the throw and catch, and most importantly minimal heating. The minimal heating mechanism of the slingshot atom throw-and-catch can be understood that the atom in the accelerating and decelerating optical tweezers maintains minimal oscillation amplitude, which results in expectedly sending an atom in the ground vibrational energy level to a distance up to about 200 um.

Keywords:

Optical tweezer, Slingshot acceleration method, throwing and catching

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G9.01

A brief introduction to our research achievements in percolation and synchronization

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Abstract:

In this presentation, we introduce our findings in the fields of percolation and synchronization. At first, we introduce the explosive percolation model with a very small order parameter critical exponent and summarize our findings related to it. These results include unified framework to understand origin of discontinuous percolation transitions, the first model showing hybrid percolation transitions in cluster merging processes, and critical behaviors of information entropy of cluster size distribution. Next, we introduce our theoretical framework applicable to an arbitrary symmetry-induced cluster synchronization and show that a stable finite-sized chimera state can be found using the theoretical framework.

Keywords:

discontinuous percolation transition, entropy, cluster synchronization

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G9.02

Oscillating synchronization order parameter of the Kuramoto model with inertia

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Abstract:

Coupled oscillators with inertia are commonly observed in various natural systems, including power-grid systems with alternating current. The governing equation for these systems is often described by the second-order Kuramoto model. The distribution of natural frequencies, representing the interplay between power demand and generation, significantly influences the synchronization stability of these power-grid systems. It is well-known that the second-order Kuramoto model exhibits hysteresis, accompanied by a discontinuous transition, in the presence of uniform and Lorentzian distributions of natural frequencies. Furthermore, prior research has unveiled that secondary synchronized groups of oscillators with substantial inertia emerge as the coupling strength K increases. In this study, we delve into the K region where these secondary synchronized clusters manifest. We explore scenarios where the natural frequency follows a normal distribution. Our investigation reveals that the temporal standard deviation of the synchronization order parameter r assumes a pivotal role in detecting the emergence of these secondary synchronization groups. A significant deviation implies the coexistence of a prominent synchronization cluster and smaller clusters. Through suitable visualization techniques, we validate the presence of a globally synchronized oscillator alongside secondary synchronized clusters.

Keywords:

second-order Kuramoto model, secondary synchronized clusters, oscillating synchronization order parameter

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G9.03

Revisiting small-world network models: Exploring technical realizations and the equivalence of the Newman-Watts and Harary models

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Abstract:

We address the relatively less known facts on the equivalence and technical realizations surrounding two network models showing the "small-world" property, namely the Newman-Watts and the Harary models. We provide the most accurate (in terms of faithfulness to the original literature) versions of these models to clarify the deviation from them existing in their variants adopted in one of the most popular network analysis packages. The difference in technical realizations of those models could be conceived as minor details, but we discover significantly notable changes caused by the possibly inadvertent modification. For the Harary model, the stochasticity in the original formulation allows a much wider range of the clustering coefficient and the average shortest path length. For the Newman-Watts model, due to the drastically different degree distributions, the clustering coefficient can also be affected, which is verified by our higher-order analytic derivation. During the process, we discover the equivalence of the Newman-Watts (better known in the network science or physics community) and the Harary (better known in the graph theory or mathematics community) models under a specific condition of restricted parity in variables, which would bridge the two relatively independently developed models in different fields. Our result highlights the importance of each detailed step in constructing network models and the possibility of deeply related models, even if they might initially appear distinct in terms of the time period or the academic disciplines from which they emerged.

Keywords:

small-world network, Newman-Watts model, Harary graph

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G9.04

Decomposition and Scaling of Complex Networks

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Abstract:

Network decomposition is used to find the important nodes and communities by removing the least important parts of the network. To decompose the network, we measured the properties of edges and removed the least important edge first in real-world networks and model networks. Properties of edges are edge betweenness centrality, the product of degree of nodes attached to both ends, and the product of hub centrality of nodes attached to both ends. When edges are removed, which is the case of the product of hub centrality, there is a critical point contrary to cases of edge betweenness centrality and product of degree. Based on the critical point, we decomposed the network and removed edges again. Interestingly, at the decomposed network, there is also a critical point. Therefore, we sequentially decomposed the network and found the critical point at each decomposed network. In real-world networks, the average degree, critical point, and other properties change as the network is decomposed. However, in model networks, the properties of the network do not change. Properties of real-world networks such as average degree and critical point show the power-law relationship, and the network is scaled according to the relationship. In conclusion, the network is decomposed by the edge removal based on hub centrality product, and the real-world network and its decomposed networks are scaled.

Keywords:

complex network, network decomposition

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G9.05

Percolation transitions in spatial multiplex networks with long-range links

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Abstract:

Spatial multiplex networks can exhibit continuous transitions even in one-dimensional systems if long-range connections are allowed. We revisit such transitions in the context of the dynamical process of cascading failures. In particular, we focus on the transition types and scaling properties as the range of interlayer and intralayer connections varies. Moreover, we adopt localized attacks to explore the metastability. Our study can help understand the mechanisms of phase transitions with various types in an integrated view.

Keywords:

multiplex network, network geometry, percolation, scaling analysis

2023 KPS Fall Meeting
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G9.06

Detecting breakdown nodes in power grids via Graph Neural Networks

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Abstract:

The power grid is an important infrastructure to sustain society. However, it is sometimes broken by various causes, such as power demand-supply fluctuation or disaster. Moreover, this breakdown can propagate to the system's other parts. Therefore, detecting the breakdown parts is important to prevent spreading the outage. Many studies have tried to address the power grid's weak part by predicting the node's stability with machine learning. However, low-stability nodes are not always broken by perturbation, although the breakdown probability is high. Therefore, they can predict the system's state about perturbation but can not find breakdown nodes. In this study, we show that not only predicting the system's stability but also detecting the breakdown node via graph neural networks.

Keywords:

Power grid, Graph Neural Networks

2023 KPS Fall Meeting
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G9.07

Semi-supervised pruning optimization with modularity-based hierarchical clustering

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Abstract:

Clustering or community detection is one of the most popular unsupervised learning techniques and is used in many areas of data analysis. We introduced an optimization technique to find statistically more meaningful clusters when community detection has labels or objective values. We call this new method Semi-Supervised Pruning Optimization (SSPO). SSPO can be applied to traditional hierarchical clustering, and given a tree structure, it goes through two merging steps to merge clusters from the bottom of the hierarchy according to two variables: threshold N_{th} and resolution r. We apply our optimization technique to food intake in bibliometric data and diabetes data to compare it with existing clustering techniques. We show that our optimization technique is effective for certain datasets where the data and labels are not highly correlated.

Keywords:

hierarchical clustering optimization, clustering, network analysis, community detection

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G9.08

Searching for more effective CNN-based architecture with different preprocessed dataset in SER

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Abstract:

음성 감정 인식은 사람의 음성 속에 내포된 감정을 컴퓨터의 모델을 통해 자동적으로 알아내는 일이다. 최근 딥러닝 기반의 모델이 비약적으로 발전함에 따라 감정 음성 인식의 정확도 또한 향상되었다. 그 중에서도 CNN 모델 기반의 감정 인식 모델은 적은 학습 파라미터와 간단한 학습만으로 높은 성능을 보여 보편적으로 많이 사용되어진다. 하지만 이들은 대부분은 자신들의 독자적인 구조를 사용할 뿐 감정인식 문제에 적합한 CNN 구조의 모델을 찾는 일은 잘 이뤄지지 않았다.
그렇기에 우리는 음성 감정인식에서 보다 효과적이고 일반적인 CNN 구조를 찾고자 연구를 진행하였다. 특히 그 중에서도 음성감정인식에 있어서 Channel 특징이 가지는 의미에 주목하였다. Channel의 크기는 합성곱 계산에서 서로 다른 공간적 특징을 학습할 수 있는 수용성을 의미한다. 우리는 다양한 크기의 channel 크기와 서로 다른 전처리 방식의 데이터셋을 사용한 실험을 통해 감정인식에서 Channel 크기의 변화에 따라 인식 성능의 급변한다는 사실을 알게 되었다. 또한 channel을 통해 보다 복잡한 특징을 학습하고자 음성 감정인식에 효과적인 깊은 층의 모델 구조에 찾는 실험을 진행하였다. 이를 위해 적은 수의 파라미터로 보다 깊은 층을 설계할 수 있는 bottleneck module 구조를 통한 CNN 모델을 다양하게 실험하였다. 또한 bottleneck 구조의 단점인 channel 크기가 작아 짐에 따라 감정 특징 표현력이 떨어지는 것을 보완하기 위해 매우 적은 파라미터 개수로 효과적인 channel 특징 학습을 할 수 있는 Bottleneck-ECA 구조를 제안한다. 이를 통해 깊은 층의 CNN 구조를 사용하면서 효과적인 감정 특징을 학습할 수 있음을 보였다.

Keywords:

감정인식 , 인공지능, Channel

G9.09

Knowledge Transfer and Innovation in Complex Systems

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Abstract:

In an era of rapid technological development and globalization, understanding the structure of knowledge transfer within complex corporate systems has become crucial. This research plan seeks to explore the interface between knowledge diversity and corporate innovation, with a special focus on the implications of information flows across diverse industrial groups. We aim to refine the method to quantify knowledge diversification within corporations leveraging the concept of entropy. To ensure robustness, we deploy the two-stage least squares estimation, thereby addressing potential endogeneity issues. Our hypothesis is that greater diversity within board networks, where the integration of influential directors from historical backgrounds, can act as a trigger for corporate innovation. Through this lens, our research aims to illuminate the competitive strategies of companies.

Keywords:

Knowledge Transfer, Innovation, Influential Directors, Complex systems, Corporate Networks

2023 KPS Fall Meeting
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G10.01

Effect of mechanical boundary condition on actin-myosin network dynamics

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Abstract:

the presence and absence of lipid membrane that can provide mobility to motor protein myosin. We demonstrated how actin networks contraction depend on relative concentration of proteins and mechanical boundary condition. In order to elucidate the mechanism of the network contraction, we developed the computational model that is able to track the components of network such as actin, actin binding protein and myosin. We revealed how the altered dynamics of cytoskeleton-motor protein network is related to diseases development. Our study provides an intuition into not only the mechanism of cell dynamics but the design of biomimetic systems.

Keywords:

Cytoskeleton, Boundary Condition, actin-myosin network, Biomimetic, Mobility

Engineering Microfluidic Vascularized Organ Systems for Clinical Utility

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Abstract:

Developing sophisticated in vitro microfluidic devices is a crucial endeavor to bridge the gap between basic research and clinical applications. Our focus is on engineering advanced in vitro models, particularly vascularized organ systems, utilizing various fabrication methods, such as 3D printing, laser processing, and soft lithography. These microfluidic platforms expand the boundaries of traditional basic research, enabling emulation of complex morphological and functional aspects. Our objective is to revolutionize translational research by seamlessly transitioning from decoding biological mechanisms and biophysics to practical clinical applications. In this presentation, we will discuss the development of microfluidic devices using diverse engineering approaches and their clinical applications with patient-derived cells. These efforts not only shed light on the clinical utility of this platform but also extend its value to various basic research domains, including biophysics.

Keywords:

Microfluidics, Microphysiological systems (MPS), 3D Vascular Modeling, Clinical Applications

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G10.03

Functional Color Materials with Bio-Inspired Structural Colorations

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Abstract:

This presentation navigates through fundamental principles and practical applications of functional color materials with bio-inspired structural colorations. The principles of structural coloration, including Mie scattering, Bragg scattering, and the intriguing interplay of scattering-based and absorption-based colors are presented. Based on the principles, the fabrication techniques and characterization methods employed in the synthesis of functional color materials is explored. Furthermore, the potential practical applications of these materials are discussed, including their integration into electronics, textiles, sensors and beyond. The versatility of bio-inspired color materials extends beyond static coloration, paving the way for responsive, tunable, and even programmable color effects, leading to transformative advancements in various industries.

Keywords:

bio-inspired, structural coloration, functional materials, nanotechnology

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G10.04

3D Printed Fiber-Infused Gel Scaffolds for Recapitulating Cardiac Muscle Anisotropy in Engineered Ventricle Models

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Abstract:

Hydrogels have been identified as a compelling material in the tissue engineering field. Current efforts have limited success in producing the microstructural features required for cellular self-organization into 3D organ models. Here, we developed gelatin fiber-infused gel inks for printing ventricular scaffolds of 3D cardiac models with anisotropic muscular tissues in vitro. The infused gelatin fibers to the hydrogel matrix enhance the sol-gel transition properties, enabling precise 3D printing of structures. During ink extrusion, fibers formed aligned microstructures that promote the self-organization of cardiomyocytes into anisotropic muscular tissues in vitro. The 3D-printed in vitro ventricle model demonstrated functional syncytium with anisotropic electrophysiology and synchronous contractions.

Keywords:

3D printing, Cardiac tissue engineering, Hydrogel, Biomanufacturing, In vitro models

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G11.01

Large-Volume High-Pressure Research at GSECARS, Advanced Photon Source

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Abstract:

The development of synchrotron-based large-volume high-pressure (LVP) techniques for studying earth, planetary, and other materials under extreme pressure and temperature (PT) conditions has been an ongoing effort at the GeoSoilEnviroCARS (GSECARS) of the Advanced Photon Source (APS). Over nearly 30 years, these developments have enabled scientists over the world to conduct coordinated research on materials in both the solid and liquid states. In this presentation we will show a few applications of our state-of-the-art techniques to scientific studies: (1) high PT ultrasonic velocity measurements on solids and liquids, (2) rheological properties of materials at high PT, (3) 3D imaging of composite materials using the high-pressure x-ray tomographic microscope, and (4) structure studies of non-crystalline materials using a Paris-Edinburgh Press combined with a multi-channel collimator. These techniques have provided the high-pressure community with a complete suite of tools for structure, density, elasticity, and viscosity measurements of earth materials

Keywords:

Large-volume, high-pressure, high-temperature, synchrotron, X-ray, Earth Science, GSECARS, APS

Compositional Dependence of Silicate Melts: Towards Understanding the Amorphous Structural Modification in Extreme Conditions

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Abstract:

The study of amorphous materials is fascinating due to their exceptional properties in various domains such as mechanics, chemistry, biology, and magnetism. Understanding the melts and/or glass transition and their structural changes at extreme pressure and temperature conditions has been a challenging task and requires meticulous observation and analysis. There is currently insufficient experimental data to convincingly describe the densification and evolution of local structures in amorphous materials and/or Earth-related disordered system. Here we report the structural dynamics of $Ca_2Si_2O_6$, $Mg_2Si_2O_6$, $CaMgSi_2O_6$ under high pressure and high temperature at around ~13 GPa and ~3000 K. Angle dispersive X-ray scattering, Brillouin spectroscopy and Raman spectroscopy were utilized to delve into the relationship between the structure of melts and glasses. Such information is vital in covering missing links between structure and physical properties of silicate melts and may pave the way for the synthesis of more advanced technological materials for potential applications.

Keywords:

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G11.03

Glasses and Diamond above Multi-Megabar Pressures

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Abstract:

Proper inference of the chemical and physical processes in planetary systems requires an atomic scale understanding of how constituent materials (minerals and melts) behave under extreme compression deep inside Earth and other planets. Advances in element-specific probes, including solid-state nuclear magnetic resonance (NMR) and inelastic x-ray scattering (IXS) shed light on a unique opportunity to unravel the pressure-driven transitions in planetary materials under pressure [1, 2]. In this talk, we provide an overview of the latest experimental breakthroughs and insights achieved through mainly NMR into structures of planetary materials under pressures reaching megabars. Correlation NMR techniques allow us to identify pressure-induced changes in short-to-medium range structures of complex oxide glasses upon compression [3]. The first high-resolution NMR spectra of oxide glass compressed using diamond anvil cells extends the pressure record of such studies from 24 to 65 GPa [4], quantifying how such structural modifications increase the configurational entropy of melts with increasing density. The detailed electronic bonding nature of compressed materials, inclduing diamond above megabar pressures enable us to propose the atomic origins of its enhanced hardness upon compression up to 2 Mbar and the nature of compressed diamond in carbon-rich super-Earth bodies [5]

[1] Lee, S. K., Lee, A. C. and Kweon, J. J., *Journal of Physical Chemistry Letters*, 12 1330-1338 (2021)
[2] Lee, S. K., Mosenfelder, J., Park, S. Y., Lee, A. C., and Asimow, P., *Proceedings of the National Academy of Sciences*, 117 21938-21944 (2020)
[3] Li, Shujia., Kweon, J. J., Lee, S., Lee, A. C., Lee, S. K., *Journal of Physical Chemistry Letters* 14 (8), 2078-2086 (2023)
[4] Kim, Y., Yi, Y. S.., Kim, H., Chow, P., Xiao, Y., Shen, G., Lee, S. K., *Journal of the American Chemical Society* 144 10025–10033 (2022)
[5] Lee, S. K., Yi, Y., Kim, Y., Kim, H., Chow, P., Xiao, Y., Eng, P., Shen, G., *Science Advances* 9 eadg4159 (2023)

Keywords:

solid-state NMR, Inelastic x-ray scattering, glass, diamond, high pressure

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G12.01

Optical heterodyne imaging of spin dynamics at nanoscale

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Abstract:

The ability to directly observe the spin dynamics in a real space is crucial for investigating the spin-related phenomena in confined structure. The optical detection is one of the promising approaches in this regard. So far, micro-focused Brillouin light scattering technique, time-resolved magneto-optical Kerr effect (MOKE), and stroboscopic MOKE have been established. In this talk, we will introduce an optical heterodyne imaging method with a vector network analyzer and a high-speed photodetector which enables to measure both the intensity and phase of the spin dynamics in a simpler way. By utilizing this technique, we revealed the inhomogeneous magnetic properties (inhomogeneous broadening and damping constant) in the device structure commonly used in the spin-torque ferromagnetic resonance experiments. In addition, the dispersion relations for quantized coherent magnons in narrow waveguide and hybridization of synthetic antiferromagnetic magnon modes have been investigated. Our technique is a powerful tool to investigate the spatial distribution of spin dynamics.

Keywords:

Spintronics, Spin dynamics, Magneto-optical Kerr effect, Ferromagnetic resonance, Magnons, Synthetic antiferromagnets

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G12.02

Universal hopping motion of skyrmion bubbles

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Abstract:

The motion of magnetic interfaces in various geometries shows rich physics ranging from universality to dimensional crossover [1, 2]. In this work, we experimentally investigate the unique transport properties of skyrmion bubbles, which form a closed-loop magnetic interface. We statistically examine over 700 thousand skyrmion bubbles in the W/CoFeB/Ta/MgO multilayer to reveal a hopping-like scaling law for the motion of skyrmions in a weakly-driven regime. Such behavior deviates from the conventional motion of the magnetic domain wall which typically shows stochastic hopping only at the 1D limit where the width of the wire is comparable to the domain wall segment length. We use collective segment theory and the bottleneck process to reveal the role of structural topology, distinguished from the skyrmion number. In addition to a physical insight into the properties of magnetic skyrmion transportation, this result also suggests a new factor to consider for using skyrmions in racetrack technology.

Keywords:

skyrmion motion, skyrmion bubble, universal scaling, hopping motion

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G12.03

Three-dimensional observation of magnetic microstructures by scanning X-ray magnetic tomography

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Abstract:

Magnetic domain structures reflect the fundamental magnetic properties of materials. Imaging techniques of magnetic domain structure have been an essential tool for studying magnetic properties. However, most conventional techniques are applied only to the sample surface and can only obtain two-dimensional (2D) magnetization distribution images, i.e., 2D magnetic domains. Thus, three-dimensional (3D) observation of magnetic domain structure has long been challenging. We have recently developed a scanning X-ray magnetic micro-tomography technique using a focused hard-X-ray beam at SPring-8 [1,2]. In this talk, we will present our recent results in directly visualizing the 3D shape of skyrmion strings [3] and the evolution of magnetic domains in a high-performance Nd-Fe-B sintered magnet [4].

[1] M. Suzuki *et al.*, Appl. Phys. Express **11**, 036601 (2018).
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[3] S. Seki *et al.*, Nat. Mater. **21**, 181 (2022).
[4] T. Takeuchi *et al.*, NPG Asia Mater. **14**, 70 (2022).

Keywords:

X-ray magnetic imaging, magnetic domains, skyrmions, permanent magnet

2023 KPS Fall Meeting
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G12.04

Role of the 3D topological singularity in magnetization dynamics

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Abstract:

Topology is a cornerstone in condensed matter physics and applied phusics, playing a pivotal role in understanding emerging phenomena like the Kosterlitz-Thouless transition, quantum Hall effect, topological insulators, and Weyl semimetals.

Bloch points (BPs), three-dimensional (3D) topological singularities in ferromagnets, have long intrigued theorists but remained elusive in experiments due to their stability challenges. BPs uniquely feature local magnetization vanishing (0D). They're theorized to impact the dynamics of one- and two-dimensional spin textures, yet remain experimentally unexplored.

Our study establishes stable BPs in asymmetric $Ni_{80}Fe_{20}$ nanostructures using Magnetic Transmission X-ray Microscopy (MTXM) and micromagnetic simulations. We reveal their topological stability against field-driven lateral motions and their crucial role in vortex-core dynamics. We directly observe the atomic-scale nature of BPs.

Our work marks a significant scientific breakthrough, providing insights into magnetic topological singularities' static and dynamic aspects.

Keywords:

Topology, Singularity, Skyrmion, Magnetic Vortex, Spin Dynamics, Bloch point, Magnetic monopole

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G13.01

Photonic neuromorphic devices in low dimensional materials

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Abstract:

최근 인공지능 컴퓨팅을 효과적으로 가능하게 하는 뉴로모픽 소자의 개발이 각광을 받고 있다. 생체 시스템은 대부분의 정보를 빛의 형태로 받기 때문에, 특히 시각적 정보를 처리하는 광 뉴로모픽 소자의 개발이 중요하다. 본 연구에서는 1차원 나노선 실리콘을 사용한 나노그레인 네트워크 메모리 소자를 소개한다. 솔리드 코어/다공성 쉘 세그먼트가 있는 단일 실리콘 나노선에서 전류 침투 경로 형성 메커니즘을 이용하여 메모리 특성을 시연하였으며, 전류 침투 경로의 전기적 및 광자적 제어를 통해 아날로그 및 가역적 방식으로 전류 가중치를 제어, 강화 및 약화 프로세스와 같은 시냅스 동작을 보여주었다. 특히 다공성 나노선 쉘에 빛을 비추어 광학적 약화 프로세스를 수행하엿으며, 더 나아가서는 두 인접한 메모리 소자 간의 뉴런 상호작용을 모사하였다. 그 외에도 오직 빛을 사용한 강화 및 약화 프로세스를 그래핀/양자점 소자에서 시연하였다. 이는 발표에서 더욱 자세하게 논의하도록 한다.

Keywords:

뉴로모픽, 실리콘, 나노선, 그래핀, 양자점

2023 KPS Fall Meeting
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G13.02

Chiral charge transport properties in topological material GdB_4 and NdAlGe

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Abstract:

Emergent state quantum materials with topological order, such as topological insulators or topological semimetals, whose bulk or surface electronic bands are protected by symmetry, exhibit distinctive properties due to Berry curvature and chiral phenomena. In particular, the relativistic nature of Weyl fermions near the Fermi level plays a role in charge transport, and as a result, emergent phenomena such as weak antilocalization, extremely large magnetoresistance, chiral anomalies, and intrinsic anomalous Hall effect, etc. are experimentally observed.

In this talk, we will show how the chiral charge transport properties of Weyl fermions can be demonstrated in solid single crystals through the topological semimetallic materials in GdB_4 and NdAlGe. GdB_4 has a Shastry-Sutherland structure with spins lying in the ab-plane. As a magnetic field is applied in the c-axis direction, the time-reversal symmetry breaks due to the tilting of the spins, lifting the band, but the C_4, C_{2z} symmetry is preserved, creating Weyl nodes along the M-A line (tau band). The tau band was observed to have a very small effective electron mass of $0.07m_0$ compared to other Fermi surfaces with ~$0.2m_0$ by quantum oscillation experiments. Furthermore, the phase analysis of the quantum oscillation showed the presence of an additional phase factor of $2\pi\Gamma$ in the tau band due to the Berry curvature. Moreover, chiral anomalies were observed via negative longitudinal MR, indicating the transport properties of the Weyl state. NdAlGe is an interesting Weyl material with simultaneously broken time-reversal and inversion symmetries. NdAlGe has an anomalous Hall conductivity of ~607 S/cm, which is very close to the ~605 S/cm that occurs when considering the intrinsic Berry curvature. These results exhibit the exotic charge transport properties of chiral charges. If these exotic charge transport properties can be utilized in a variety of devices, unexpected next-generation technologies could be achieved.

Keywords:

Chiral charge transport, Weyl semimetal, Topological materials, NdAlGe, GdB4

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G13.03

Low-dimensional materials, mixed-dimensional heterostructures, topological materials, and device applications

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Abstract:

In this talk, I review my studies on low-dimensional materials, mixed-dimensional heterostructures, topological materials, and device applications. We have employed two-dimensional (2D) transition-metal dichalcogenides (TMDs) for mixed-dimensional heterostructures, useful for optoelectronic and energy-harvesting device applications. Particularly, I focus on moiré superlattices produced by heterojunction of two TMD monolayers (MLs) and their optical properties. I report blue shift of energy and strong enhancement of intensity in light emission by twisted heterojunction of TMD MLs in a particular range of twist angle. We have also successfully fabricated 2D Janus MoSSe and WSSe layers by NaCl-assisted CVD. The MoS_2 layer is shown to still exist at the bottom of the Janus MoSSe, resulting in actual formation of a MoSSe/MoS_2 heterostructure, thereby exhibiting interesting *I-V* characteristics. We have also employed zero-, one-, and even three-dimensional materials in 2D-materials-based mixed-dimensional heterostructures. As another issue, the intriguing electronic structure of topological semimetals, representing a novel class of condensed matter, is of fundamental interest because of their exotic quantum nature and potential for next-generation device applications. I discuss our recent findings on a Dirac- to Weyl-semimetal (WSM) phase transition in $Bi_{0.96}Sb_{0.04}$ single crystals by Au-ion implantation and 2D WSM states achieved by a thickness-dependent topological phase transition of MBE-grown $Bi_{0.96}Sb_{0.04}$ thin films.

Keywords:

2D materials, low-dimensional, mixed-dimensional, heterostructure, moire superlattice, twisted, 2D Janus materials, topological semimetal, phase transition

2023 KPS Fall Meeting
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G14.01

Ultrafast exciton transport in semiconductor thin films revealed via fs-microscopy

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Abstract:

Carrier transport dynamics in semiconductors play a pivotal role in achieving high device performance. A deep understanding of how charge carriers transport in bulk/thin semiconductors will shed light on developing next-generation semiconductors. Nevertheless, the observation of true charge carrier transport has hardly been reported due to limitations in time- and space-resolved techniques. This necessitates a new type of integrated time- and space-resolved technique. In this talk, I will first introduce a new type of time- and space-resolved spectroscopy technique called transient absorption microscopy (TAM), which offers dual capabilities: femtosecond time resolution and nanometer-scale spatial resolution. I will then discuss the application of TAM to perovskite thin films, which exhibit ballistic transport of non-equilibrium charge carriers with transport lengths of up to 150 nm. I will further explore how the non-equilibrium charge carrier dynamics are influenced by the nanoscale chemical heterogeneity, as revealed by fs-microscopic measurements on alloyed perovskite thin films.

Keywords:

fs-Microscopy, Exciton transport, Perovskite, Semiconductor, Thin films

2023 KPS Fall Meeting
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G14.02

Electronically tunable exciton confinement probed with nonlinear spectroscopy

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Abstract:

Optical spectra of semiconductors display resonances below the absorption edge, which are attributed to the excitons, i.e. pairs of electrons and holes, correlated by the Coulomb interaction. For decades, epitaxial growth provides modulated nano-structures, where a smaller bandgap material is surrounded by a higher bandgap one. Such growth-designed, static potentials restrict the motion of the charge carriers in one, two or three dimensions in so-called quantum wells, wires and dots, respectively, and their energies consequently become quantized. Engineering the quantum confinement of excitons is a key to control the light-matter interaction dynamics in semiconductors, where the electron-hole overlap integral along with the Fermi golden rule govern the radiative lifetime T1, spanning from ~100 fs to μs. Another relevant optical observable is coherence, describing the phase relation within the exciton polarization, vanishing beyond the dephasing time T2. Recently, electrically controlled quantum confinement of neutral excitons has been achieved in a $MoSe_2$ monolayer, by exploiting strong interactions between excitons and free charges, on top of gate defined in-plane electric fields. Using such a device, we here demonstrate control of the exciton coherent dynamics and inter-exciton couplings via dynamical tuning of their quantum confinement. To this aim, we perform ultrafast nonlinear spectroscopy, in particular heterodyne-detected four-wave mixing (FWM) microscopy. This approach permits us to focus onto a carrier-depleted region of the gate-induced lateral p-i-n junction with a 300nm resolution and distinguish the response of the 1D and 2D excitons via their drastically distinct radiative decay rates, and thus overcoming the limitations of linear absorption largely dominated by the response of the 2D excitons. With increasing the gate voltage, and thus generating the in-plane potential well, we clearly observe an increase of the exciton T1 and T2 times, indicating the crossover from the 2D to 1D quantum confinement regime. The subsequent decrease and modulations could be due to increased exciton ionization at higher in-plane electric fields. For higher gate voltages, several 1D confined exciton states can be formed. Their coherent coupling is indicated by quantum beats observed in the coherence dynamics. Our work thus opens the field of exciton coherent control under tunable confinement.

Keywords:

Exciton, MoSe2, Coherence time

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G14.03

Unprecedented exciton-polariton coupling in 6-folded microcavity for PT symmetry

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Abstract:

While group III-nitride based semiconductors exhibit robust emission across the visible to UV spectrum at room temperature, readily finding application in LEDs and lasers, conventional planar structures encounter limitations in producing essential low-dimensional quantum and cavity structures pivotal for quantum photonics research. Addressing this, we have harnessed a distinctive hexagonal microwire configuration, offering a versatile avenue for investigating quantum phenomena encompassing the spectrum from Hermitian to non-Hermitian dynamics. By exploiting the cross-sectional geometry of these hexagonal wires to generate whispering gallery modes, we have observed the emergence of exciton-polariton hybrids—a result of the intimate interaction between excitons and photons. Remarkably, we have achieved control over polaritonic condensation even at room temperature [1]. Leveraging advanced substrate engineering, we have extended our exploration into the realm of non-Hermitian physics. This has led to the identification of non-Hermitian degeneracies within parity-time reversal symmetry, facilitated by coupled upward- and downward-triangular whispering gallery polariton pairs. The intriguing counterintuitive effect of loss behaving as gain has been realized, marking an unprecedented advancement [2]. With these developments, we anticipate that our room-temperature polaritonic non-Hermitian system will kindle a new era in optical sensing, harnessing its unique physical attributes to unlock novel capabilities.

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[2] H. G. Song et al, “Room-temperature polaritonic non-Hermitian system with single microcavity”, Nature Photonics, 15, 582, 2021

Keywords:

Strong coupling, exciton-polariton, non-Hermitian, Parity time-reversal symmetry

2023 KPS Fall Meeting
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G14.04

Bright ultrarrow-linewidth perovskite single-photon sources

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Abstract:

Bright ultranarrow-linewidth single-photon sources are essential for optical quantum technologies, including distributed quantum networks, quantum cryptography and sensing. One of the challenges these devices face is ambient-condition operation, which poses a barrier to scaling and industrial use. Here we show a room-temperature single-photon source operating in air and generating polarised photons at a rate of 6 MHz based on inorganic $CsPbI_3$ perovskite quantum dots embedded in an optical micro-cavity. The ultranarrow bandwidth emission under ambient conditions is achieved by coupling to the cavity's fundamental mode, which narrows the dot's emission spectrum by an order of magnitude and offers performance compatible with the stringent requirements of quantum technology applications. The single-photon purity of the source is 94% under pulsed and continuous mode operation.

Keywords:

Single photon, perovskite

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G15.01

Spin dynamics of two-dimensional van der Waals ferromagnet CrI_3

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Abstract:

Chromium tri-iodide (CrI_3) is a prototypical ferromagnetic van der Waals insulator with its genuinely two-dimensional (2D) long-range order below 45 K demonstrated recently. The underlying magnetic anisotropy has not been completely understood while both the Dzyaloshinskii-Moriya (DM) interaction and the Kitaev-Γ-type interaction have been proposed for the relevant magnetic Hamiltonian. In this connection, we performed the temperature- and magnetic field-dependent terahertz spectroscopy on bulk CrI_3 single crystals, focussing on the dynamics of ferromagnetic resonances (FMRs) in the terahertz (THz) frequency region from 4 to 120 cm^{-1} (from 0.5 to 15 meV). Based on the variation of the FMR frequencies measured under an external magnetic field aligned along various crystallographic axes, we set the possible ranges of the combination of the important exchange interactions such as the off-diagonal symmetric term and the single-ion anisotropy. The accurate values of these parameters significantly help to constrain the range of magnitude of possible Kitaev exchange interactions and the topological magnon gap, in addition to the g-factor anisotropy.

Keywords:

Chromium tri-iodide, CrI3, terahertz spectroscopy

2023 KPS Fall Meeting
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G15.02

Room temperature valley polarization of the B-exciton in monolayer MoS_2

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Abstract:

Transition metal dichalcogenides (TMDCs) have recently attracted a lot of attention with respect to potential application for valleytronics. Although achievement of high degree of valley polarization (DoVP) is essential for valleytronics, it still requires a low-temperature environment, especially for monolayer TMDCs. In this work, we observed valley polarization at room temperature for the B-exciton in monolayer MoS_2 under a near perfect resonant excitation condition. DoVP for the B-exciton remained almost constant as the temperature was raised from 4 K up to 250 K, where the excitation laser energy exactly matched with the B-exciton peak energy, then it gradually decreased as the temperature increased up to 400 K. The observed DoVP at room temperature, achieved by carefully controlling resonant excitation condition, provides an exciting possibility for valleytronics at room temperature.

Keywords:

valley polarization, exciton, resonant excitation

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G15.03

Sublattice pseudospin in quantum materials

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Abstract:

Van der Waals two-dimensional materials are a great platform to study various aspects of condensed matter physics. For example, surface doping on black phosphorus can be used to modulate the band gap over the energy range even greater than its intrinsic gap size [1], leading to the topological phase transition to a Dirac semimetal phase with a pair of Dirac fermions protected by spacetime inversion symmetry [2]. This topological phase transition is accompanied with the order of relative phases between sublattices, that is, sublattice pseudospin [3]. These materials have been used to study the unusual electronic structure of liquid metals predicted in the 1960s [4] and to disclose the microscopic mechanism of order-disorder phase transitions [5]. In this talk, after briefly reviewing recent works, I will introduce our angle-resolved photoemission spectroscopy (ARPES) study on the electronic structure of quantum materials with two pairs of sublattices [6]. The message I would like to deliver is that the sublattice degree of freedom should be carefully considered as much as the atomic orbital degree of freedom, in the study of condensed matter physics.

References

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Keywords:

Pseudospin, Sublattice, ARPES, Quantum materials

2023 KPS Fall Meeting
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G16.01

Ultrafast generation of acoustic chiral phonons

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Abstract:

Here, we propose a simple but effective approach to observe the dynamics of the thermalized chiral phonons by synthesizing a superlattice composed of ferromagnetic metal $SrRuO_3$ and non-magnetic insulator $SrTiO_3$. Following the photo-induced ultrafast demagnetization in the $SrRuO_3$ layer, we observed an additional magneto-optic signal in the superlattice, which is absent in the single $SrRuO_3$ films. This emerged magneto-optic signal shows thermal-driven dynamic properties and a clear correlation with the thickness of the non-magnetic $SrTiO_3$ layer, evidencing that it originates from thermalized chiral phonons. From the numerical calculation considering the magneto-elastic coupling, we present an evolution of lattice angular momentum in excellent agreement with our experimental observations. We anticipate that our findings can provide a deep understanding of thermalized chiral phonons and suggest a new platform for investigating angular momentum transfer in ferromagnetic materials.

Keywords:

chiral phonon, oxide superlattice, time-resolved MOKE

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G16.02

Nonadiabatic quantum molecular dynamics study of the ultrafast laser melting of germanium

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Abstract:

Nonadiabatic quantum molecular dynamics simulations have been carried out to quantify the ultrashort laser-driven lattice disorder in germanium. By utilizing a quantum molecular dynamics method that describes, in condensed phases, the electronic excitations and their inter-band transitions under nonadiabatic electron-ion interaction we were able to separate the time-evolving lattice disorder into elemental components, thereby identifying the main driver of the disordering at each time stage. We find that although the bond softening effect dominates in the beginning irrespective of the excitation density, the eventual ultrashort laser-driven phase transition involves both the thermal and nonthermal elements in it, with the level of their effects regulated by the electronic excitation density. Our novel findings should provide not only a fundamental insight into the underlying mechanism of the laser-driven ultrafast phenomena but invaluable information for choosing optimal laser parameters in materials processing.

Keywords:

Ultrafast phenomena, Nonadiabatic quantum molecular dynamics, Laser melting

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G16.03

4D visualization of a nonthermal coherent magnon in a laser heated lattice by an X-ray free electron laser

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Abstract:

The ultrafast optical control of magnetic phenomena represents a remarkable achievement, expanding our understanding of functional nonequilibrium states. Operating on extremely short timescales, this research pushes the limits of detection, revealing intriguing interactions between light and matter that lead to the nonthermal creation of effective magnetic fields. While some cases manifest emergent transient behaviors set apart from thermal effects, otherwise identifying nonthermal influences remains challenging. In this study, we introduce a femtosecond time-resolved resonant magnetic X-ray diffraction experiment that employs an X-ray free-electron laser (XFEL) to distinguish between the effective field and the thermal effects induced by light. Our observations focus on a multiferroic Y-type hexaferrite, where we observe magnetic Bragg peak intensity oscillations that reveal the intertwined antiferromagnetic (AFM) and ferromagnetic (FM) Fourier components of a coherent AFM magnon. The trajectory of this magnon, mapped in 3D space and time, provides crucial evidence of ultrafast field formation before lattice thermalization. We also uncover the remarkable impact of photoexcitation across the electronic bandgap, which enhances the photomagnetic coupling—a characteristic that ranks among the highest among AFM dielectrics. Leveraging this above-bandgap photoexcitation, our research suggests an energy-efficient optical process for novel photomagnetic control of ferroelectricity in multiferroic materials.

Keywords:

XFEL, multiferroic, hexaferrite, pump-probe

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G16.04

Direct Observation of Acoustic Shape Deformation of Gold Nanorods via Localized Surface Plasmon Control

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Abstract:

Ultrafast light–matter interaction invigorates research activities on light induced quantum control of materials properties by providing routes to explore new phases of matters in nonequilibrium states. With the exclusive excitations of electrons through femtosecond IR laser pulses, various physical processes can be accessed mode selectively, which enables the way to tackle fundamental science issues including the role of electrons in driving crystal phase changes. Au nanorod, are elongated gold single nanoparticle that has longitudinal localized surface plasmon (LSP). Understanding this surface plasmons in Au nanorod is essential, which enables to control optical properties in metal nanostructures. Despite the significance of surface plasmons in the light-matter interaction in metallic nanoparticles, the role of the localized surface plasmon in ultrafast melting has remained elusive. We studied the impact of surface plasmons dynamics in ultrafast phase transition of Au nanoparticle using femtosecond pump-probe X-ray imaging at PAL-XFEL. To study further, we directly imaged the reaction dynamics of photoinduced Au nanorod with femtosecond X-ray pulses. Shape distortion caused by LSP and further investigation of laser fluence and polarization direction dependence was carried out to result in various melting reaction in reaction in response to the surface plasmon excitations in metallic nanoparticles.

Keywords:

LSP, XFEL, Coherent Diffraction Imaging, Single-particle imaging, Au nanorod

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G16.05

Probing the Role of A-site Cations to Charge Density Wave (CDW) Order in kagome metal AV_3Sb_5 (A = K, Rb, Cs) through X-ray Scattering

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Abstract:

The vanadium-based kagome metal, AV_3Sb_5 (A=K, Rb, Cs), exhibits significant effects of A-site cations on the Charge Density Wave (CDW) phase and superconductivity. Notably, (K, Cs)V_3Sb_5 differs from Rb counterparts, showing distinct properties, such as nematicity and various CDW domains involving 2×2×1, 2×2×2 structure. Utilizing X-ray scattering, CDW structures in AV_3Sb_5 (A=K, Rb, Cs) were identified. Moreover, through time-resolved X-ray scattering, we examined the influence of A-site cations on the CDW phase in CsV_3Sb_5 which has a relatively elevated T_c, going beyond the limitations of previous doping and pressures studies. This revealed contrasting dynamics between 2×2×1 and 2×2×2 CDW orders after the photoexcitation of conduction electrons near the Fermi surface. Especially, the 2×2×2 CDW order exhibited complex behavior involving coherent phonon linked to the A-site cation's displacement. These findings offer strong support to the hypothesis that A-site ions significantly impact the 2×2×2 CDW phase in CsV_3Sb_5.

Keywords:

Kagome metal, Charge Density Wave, Strongly correlated material, X-ray scattering, XFEL

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G16.06

Direct measurement of electron phonon coupling with 2D spectroscopy

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Abstract:

Electron phonon coupling underlies intriguing phenomena in quantum materials, as well as most of properties of conventional solids. However, the electron phonon coupling matrix elements have been inferred rather in indirect ways. Two dimensional optical spectroscopy has unique advantages of specificity and quantification in elementary excitations. In this talk, I'll introduce our recent theoretical and experimental development of a new 2D spectroscopic approach to directly measure and quantify electron phonon coupling matrix elements. We will discuss how the matrix element is connected to the 3rd order optical response function; how the desired set of quantum pathways are isolated theoretically and experimentally; how to quantify the matrix element from the experiment; and how mode-specific electron phonon coupling strength behaves in different environments in a benchmark system.

Keywords:

electron phonon coupling, two dimensional optical spectroscopy

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H1.01

Exploratory research of the impact of the CHIPS and Science Act: Focusing on the organizational changes of NSF and OSTP

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Abstract:

Historically, the United States has linked its science and technology workforce policy to national security, a perspective consistently backed by bipartisan support. This research delves into the CHIPS and Science Act, examining both its historical and political contexts. The study further investigates the evolving roles of the National Science Foundation (NSF) in fostering innovation and the White House Office of Science and Technology Policy's shifting responsibilities in coordination and planning. The research concludes by analyzing the potential ramifications on the science and technology workforce and drawing insights relevant to South Korea's policy landscape.

Keywords:

STEM education, the CHIPS and Science Act, S&T Policy

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H1.02

과학교사들의 실험 개발 경험 공유

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Abstract:

정규 교육 과정에서 수업 시간에 과학교사들과 함께 실험을 개발하고 SCI급 저널에 논문을 게재하면서 경험한 것들을 공유하고자 한다. 수업의 진행 방법과 연구 주제의 선정, 실험 개발 과정에서 교사들이 배우는 내용, 동료 교사들의 상호작용, 논문 게재 과정에서 일어났던 상황 등에 대하여 논의하고자 한다.

Keywords:

과학교사, 논문게재

2023 KPS Fall Meeting
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H1.03

마이크로비트를 이용한 무선 데이터 자동기록 시스템 개발 및 물리탐구에의 활용

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Abstract:

마이크로비트가 V2로 업그레이드되면서 수집된 데이터가 기록되는 공간이 컴퓨터에서 마이크로비트로 변경되었다. 본 연구에서는 이러한 변화에 맞추어 마이크로비트를 이용한 무선 데이터 자동기록 시스템을 개발하여 소개하고자 한다. 개발된 시스템을 활용한 탐구를 예시하고 학교에서의 물리탐구 활동이나 실험 활동 개발에 활용할 때 주의할 점을 논의하였다. 마이크로비트를 활용하는 무선 데이터 자동기록 시스템은 기술적으로 어려웠던 원격 데이터 수집을 용이하게 하여 생활 속 과학원리를 탐색하는 좋은 도구가 될 수 있을 것이다.

Keywords:

마이크로비트, 물리탐구, 무선 데이터 자동기록

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H1.04

물리학 기초학력 보장을 위한 진단도구 개발 및 타당화

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Abstract:

코로나19로부터의 회복을 위한 교육계의 가장 큰 과제로 학생들의 기초학력 보장이 떠오르고 있으며, 이를 위해 기초학력 진단을 통한 교육적 지원이 선제되어야 한다. 따라서 본 연구에서는 물리학에서 기초학력 진단을 위한 도구개발을 위한 기초연구를 수행하였다. 2022 개정 교육과정에 기반한 도구개발을 위한 영역으로 운동과 에너지, 열, 전기, 빛과 우리 생활의 네 가지 영역 구분하여 학습진전과 개념학습의 측면에서 평가준거를 개발하였다. 학습진전을 고려한 준거로, 영역별 성취기준을 분석하여 각각 상, 중, 하의 평가준거를 개발하였으며, 과학개념 학습을 위한 오개념 분석을 실시하여 영역별 학생들의 오개념을 분석하였다. 평가준거를 토대로 타당한 진단도구를 개발함으로써 학교현장에서 물리학 기초학력 보장에 기여를 할 것이라고 기대된다.

Keywords:

기초학력, 오개념, 진단문항, 성취수준, 물리교육

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H1.05

과정 중심 실험 평가 방안 탐색

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Abstract:

중등과학올림피아드 진행 과정에서 우리나라 학생은 공통적으로 '지시하는 글을 꼼꼼하게 읽고 이에 따라 실행하는 능력'이 부족하다는 점과 '측정 도구를 적절한 방법으로 사용하여 정확하게 측정하여 데이터를 얻고 이를 처리하는 능력'이 부족하다는 점을 발견하였다. 이러한 약점은 과학고등학교나 영재학교에 진학하는 과학 우수학생에게도 공통적으로 볼 수 있는 특징이다. 이를 해결하는 방안 중의 하나로 학교 과학 수업에서 '정확하게 측정하기' 및 '데이터를 적절하게 처리하기' 능력을 구체적으로 평가하고 학생에게 적절한 피드백을 제공하는 것을 들 수 있다. 본 연구에서는 학생의 기초 측정 능력을 신장하기 위한 '알루미늄의 두께 측정하기' 활동의 채점 방법을 제안하고, 실제 실험 교실을 통해 이 활동에 참여한 학생의 실험 보고서 평가를 통해 학교 교실에서의 적용 방안에 대해 논의하고자 한다.

Keywords:

물리실험, 중학생, 과정중심평가

특수 상대성 이론에 대한 예비 물리교사의 개념 이해와 확신도

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Abstract:

이 연구의 목적은 예비 물리교사를 대상으로 특수 상대성 이론의 기본 개념에 대한 이해를 조사하고 그 결과를 분석하여 물리교사교육 맥락에서 상대성 이론 교수 학습에 대한 시사점을 도출하는 것이다. 이를 위해 Aslanides & Savage (2013)가 개발한 상대론개념조사(Relativity Concept Inventory)를 적용하여 사범대학에서 물리학을 전공하는 예비 물리교사 51명의 응답을 수집하였으며, 응답 자료를 바탕으로 특수 상대성 이론의 개념별 이해도와 확신도의 분포와 관계, 응답자의 개인 변인에 따른 차이 등을 분석하였다. 분석 결과를 요약하면 다음과 같다. 첫째, 예비 물리교사들은 동시성, 속도 합성, 인과성 개념 영역에서 개념 이해에 어려움을 보이며, 특히 시간 지연과 동시성의 상대성에서는 일부 오개념이 발견된다. 둘째, 응답자의 개념 이해와 확신도는 서로 정적 상관관계가 있으며 개념 이해에 비해 확신도가 대체로 높다. 셋째, 개념 이해에서는 응답자의 성별에 따른 차이가 없으나, 확신도에서는 남성의 확신도가 여성에 비해 상대적으로 높다. 넷째, 응답자의 학년 또는 관련 선수학습 정도는 개념 이해와 관련있으나 확신도와는 무관하다. 이 연구의 결과는 물리교사교육과 중등과학교육 맥락에서 상대성 이론 교수 학습에 대한 시사점을 제공한다.

Keywords:

특수 상대성 이론, 예비 물리교사, 개념 이해, 확신도

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H2.01

기계학습 기반 미래 전자-양전자 충돌빔에서 암흑광자 탐색 연구

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Abstract:

기계학습을 기반으로 미래 전자-양전자 가속기/검출기에서 암흑광자를 탐색하였다. 미래 전자-양전자 가속기/검출기는 Circular Electron Positron Collider (CEPC)/CEPC, Future Circular Collider (FCC-ee)/Innovative Detector for Electron-positron Accelerator (IDEA), International Linear Collider (ILC)/International Large Detector (ILD)을 사용하였다. 신호사건 모드는 e+e- → A'A'와 e+e- → A'A'γ로, 암흑광자 A'가 뮤온 쌍으로 붕괴한다. Simplified model을 사용하여 MadGraph5로 시뮬레이션 몬테카를로(MC) 이벤트를 생성하였다. 각 실험에서 암흑광자의 질량을 스캔하여 산란단면적이 최대가 되는 암흑광자의 질량을 찾고, 이 값을 적용하여 Delphes 툴킷으로 검출기 시뮬레이션을 수행하였다. 그에 따라 각 가속기/검출기에서 이중 암흑광자 모드의 신호사건 효율을 구하였다. 주요 배경사건은 e+e- → μ+μ-μ+μ-와 e+e- → μ+μ-μ+μ-γ 이다. 이들 배경사건은 표준모형을 사용하여 MadGraph5로 생성하였다. Toolkit for Multivariate Analysis (TMVA)을 사용, 기계학습을 수행하여 가속 결정 트리 방법으로 배경사건 대비 신호사건의 비율을 향상시켰다. 결과로서 각 가속기/검출기의 검출기 효율을 구하였다. 이 연구의 결과는 미래 전자-양전자 충돌 실험에서 암흑광자를 찾는 데 도움이 될 것이다.

Keywords:

기계학습, 암흑물질, 암흑광자, 전자-양전자 충돌가속기

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H2.02

Status and plan of dual-readout calorimeter R&D for future e^+e^- collider

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Abstract:

In high-energy physics experiments, calorimeters have played an important role, 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 read calorimeter (DRC) is a good option for this requirement. The Korea Future Collider Dual-READout Method calorimeter (KFC-DREAM) collaboration performed test beams with several copper-fiber calorimeters at CERN in 2022 and 2023. In this talk, we will present the status and plan for the upcoming test beams.

Keywords:

Dual-readout Calorimeter, FCC-ee, High energy physics, Detector, calorimeter

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H2.03

Module assembly and the plan for full-size module of the dual-readout calorimeter for the future e^+e^- colliders

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Abstract:

The dual-readout calorimeter(DRC), consisting of scintillating and čerenkov fibers, is one of the calorimeter candidates in future e+e- colliders. The Korea DRC team built various module types and had a beam test at T9 in CERN with 2 configurations. We are now building a full-size module that consists of 9 modules for the next beam test. For the full-size module, we are performing various trials for fiber bundling, optical contact, and assembly optimization. In this talk, we present the process of assembly module for the 2023 beam test, and current status and the plan for the full-size module for the next beam test.

Keywords:

FCC, Calorimeter, Dual-readout

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H2.04

Readout bundling optimization of dual-readout calorimeter for particle identification 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. Its particle identification can be performed via signal differences in scintillation and Cerenkov channel and also spatial information of shower shape. However, there are limitations to attaching readouts to each fiber for maximum position resolution. This study compares the performances of particle identification at different readout bundling for an efficient readout bundling plan of the dual-readout calorimeter.

Keywords:

Dual-readout calorimeter, Particle identification, Deep learning

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H2.05

Overview on the 2023 test beam with dual-readout calorimeter at CERN

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Abstract:

The dual-readout calorimeter (DRC) is one of the calorimeter candidates for future e+e- colliders such as FCC-ee and CEPC. Using both Cerenkov and Scintillation fibers, it shows excellent performance with measuring energy of both electromagnetic and hadronic processes. The Korea DRC collaboration constructed single copper-fiber DRC module, and had test beam at CERN on this July. In this talk, we present general overview on the test beam including preparation, test setup and prompt analysis results.

Keywords:

Calorimeter, Future collider, Dual-readout, CERN, Test beam

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H2.06

Experimental setup of the Dual-Readout Calorimeter test beam (2023) at CERN

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Abstract:

Future lepton collider experiments (FCC-ee and CEPC) require great energy resolution of hadronic particles for their purpose to understand the Higgs. The dual-readout calorimeter (DRC), by using two different readout channels (Scintillation and Cerenkov), meets this condition greatly. In 2023, the Korea DRC team made prototype modules of DRC and had a test beam at T9 in CERN. The prototype DRC are made in several different methods, including metal 3D-Printing and heatsink. In this talk, we present the experimental setup of this test beam.

Keywords:

Dual-Readout Calorimeter, Dual-Readout, Testbeam, Future Collider, FCC

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H2.07

The DAQ system of the dual-readout calorimeter for future e^+e^- colliders in 2023 test beam at CERN

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Abstract:

Dual-readout calorimeter(DRC), which detects both electromagnetic and hadronic particles, is included in IDEA detector conceptual design report(CDR). It also has been proposed both in Fcc-ee & CEPC with high energy resolution. DRC is a combination of several types of modules made of copper and two types of fiber - cerenkov and scintillation. Each fiber bundle is connected to each detector, especially the center of module is connected to MCP-PMTs for high granularity. And we construct our own data acquisition system (DAQ system) to take data of them and verified the performance of DRC in this test beam by using it. In this talk, we will present how we construct and operate our DAQ system.

Keywords:

test beam, Dual-readout calorimete, calorimeter, DAQ, future e+e- colliders

H2.08

R&D and 2023 test beam of wireless DAQ system 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 & MCP-PMT multi readout system and readout system connected to DAQ using ribbon cables, but it`s have big volume & noise. so, we design the wireless Data transfer system. It consist of server & client communication using WIFI wireless device and UDP socket protocol..We will present the progress of designed wireless DAQ system R&D and 2023 test beam at CERN in this presentation.

Keywords:

future e+e- colider , dual-readout calorimeter, wireless DAQ system, 2023 testbeam

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H2.09

Data qulity monitoring procedure and analysis status of the Dual-Readout Calorimeter test beam (2023) at CERN

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Abstract:

The Dual-Readout Calorimeter (DRC) stands as a strong candidate for future e+e- colliders like FCC-ee and CEPC. It uniquely employs Cerenkov and scintillation channels to simultaneously measure electromagnetic and hadronic particle energies. Compensating for hadronic energy with the electromagnetic fraction in the hadronic shower, DRC achieves high-quality energy resolution for both particle types. Our team constructed a set of DRC module, tested at CERN last July. This presentation, we present our data quality monitoring procedure and prompt analysis results.

Keywords:

Calorimeter, Future collider, Dual-readout

R&Ds in Axion Research at IBS-CAPP

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Abstract:

IBS-CAPP has established a state-of-the-art axion detector facility in Korea with multiple dilution refrigerator systems of which four axion detectors are taking physics data in parallel on the low-vibration pads now. 12 T big bore (32 cm) Nb_3Sn superconducting magnet system was added to the line-up with quantum noise-limited amplifiers to collect the axion dark matter physics data with a DFSZ level sensitivity.

This milestone reflects the CAPP's effort of successfully applying cutting-edge technologies and innovative R&D to reach the leadership position in the axion dark matter search internationally for frequencies over 1 GHz. The critical R&Ds include the development of quantum noise limited amplifiers and the high-temperature superconducting cavity that sustains a high Q-factor even at 8 T. We are now collecting axion dark matter physics data with quantum amplifiers in the frequency range of 1 to 2 GHz and a superconducting cavity will be added within this year. I will present the status of CAPP's axion search and R&D efforts, including future plans.

Keywords:

Axion, IBS, CAPP, dark matter, DFSZ, experiment

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H3.02

High-Temperature Superconducting Cavities for CAPP's Main Axion eXperiment (MAX)

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Abstract:

The axion haloscope, known as the most sensitive method for searching axion dark matter, employs axion-to-photon conversion within a resonant cavity immersed in a high magnetic field. Enhancing the experimental efficiency of an axion haloscope involves the utilization of high-quality factor cavities that sustain long-lived converted axion signals while minimizing thermal dissipation. However, the challenge arises with the unavailability of high-Q superconducting cavities within the context of multi-tesla scale magnetic fields. The Center for Axion and Precision Physics Research (CAPP) at the Institute for Basic Science (IBS) has achieved a breakthrough by fabricating high Q-factor superconducting cavities with a narrower bandwidth compared to that of axion signals. This achievement has been realized by incorporating high-temperature superconductor (HTS) rare-earth BCO (ReBCO) tapes onto the inner walls of cylindrical microwave cavities, even under an 8T magnetic field. This HTS cavity development technology is currently being applied to large-scale (>30L) axion haloscope cavities for the CAPP's Main Axion eXperiment (CAPP-MAX), which is currently the world's most sensitive haloscope. The detailed discussion of the performance measurements of the HTS cavity at both room temperature and cryogenic conditions, along with the resulting enhancement in axion search capabilities, will be presented at the conference.

Keywords:

Axion haloscope, 12 Tesla, HTS cavity, CAPP-MAX

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H3.03

Data analysis for phase 2 of the CAPP-MAX experiment

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Abstract:

The CAPP-MAX experiment from IBS-CAPP is searching for QCD axions, which can reveal two big mysteries in our universe: the strong CP problem and dark matter. The experiment takes power spectrum data of a microwave cavity where the axion-to-photon conversion can be resonantly enhanced. If axion exists, the signal appears on top of the noise power spectrum given by the thermal noise photons from the cavity and the receiver chain. Over the decades the analysis procedure for such data has been optimized and standardized to maximize the detection efficiency of the axion signal. That being said, the details of the analysis procedures in each haloscope experiment are subject to change, and hence additional development of methods for dealing with different circumstances of experiments is needed. In this presentation, the analysis procedure for science data taken in phase 2 of the CAPP-MAX experiment will be discussed in detail. It includes the standard procedures of combining the spectra, as well as estimation of parameters for the signal-to noise┐ratio of the axion-photon conversion signal power, strategy for combining the signal and idler data which are highly correlated, characterization of additional source of systematic uncertainties, and so on.

Keywords:

Axion , Dark matter, Haloscope, Data analysis, CAPP

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H3.04

High-temperature superconducting cavities for axion dark matter search

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Abstract:

The axion is a hypothetical particle that can resolve the strong charge-parity (CP) problem in quantum chromodynamics (QCD) and uncover the unknown constituent of our universe, dark matter. The axion haloscope is the most sensitive method designed to search for dark matter axions. The experiment utilizes the cavity resonant enhancement of the axion-to-photon signals converted by a multi-tesla magnetic field. While the current axion haloscope experiment employs a strong magnetic field with a big bore magnet and quantum amplifiers to achieve high sensitivity, it has yet to implement a cavity with a high quality (Q) factor due to the substantial loss of superconductivity in a magnetic background. This talk will present the high-temperature superconducting (HTS) cavity developed by the Center for Axion and Precision Physics Research (CAPP). A recently developed version has reached a Q factor of 13 million in an 8 Tesla field, which is the highest known value in this field. These HTS cavities will dramatically increase the scanning speed of the experiment, helping to unveil the mysteries of physics. The first axion haloscope with one of the HTS cavities at around 9.5 μeV will also be reported in this talk.

Keywords:

Dark matter, Axion, Axion haloscope, High-temperature superconductor, Superconducting radiofrequency cavity

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H3.05

CAPP 12-Tesla experiment for axion dark matter search at 25-mK temperature

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Abstract:

Axion search experiments are desire to address fundamental questions in physics: the strong CP problem and the nature of dark matter. One of the leading experiments at the Center for Axion and Precision Physics Research (CAPP) of Institute for Basic Science (IBS) in South Korea is the CAPP-MAX experiment. This experiment features a 12-T Nb3Sn+NbTi superconducting magnet with a big bore (32 cm), a 37-liter cylinder copper cavity and a state-of-the-art microwave readout system with a Josephson Parametric Amplifier (JPA) that approaches the quantum noise limit. We describe the technical details of the detector chain, the features of the dilution refrigerator immersed into the liquid He dewar, and the operation of the closed cycle helium recovery system. The system temperature is kept near to 25 mK, which is the lowest temperature achieved by axion experiments to date. Using JPAs has opened up new possibilities for exploring plausible axion masses with high sensitivities by reaching the system noise temperature lower than 250 mK. Our results demonstrate the potential of the CAPP-MAX experiment to significantly improve the speed of axion dark matter search, contributing to our understanding of the fundamental nature. In this presentation, we discuss the current status of the experiment and outline future plans

Keywords:

axion haloscope search, axion dark matter search, quantum noise limit detection, Josephson parametric amplifier in haloscope axion search, high quality cavity

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H3.06

High-frequency cavity designs for the CAPP-12TB experiment

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Abstract:

The axion is a hypothetical particle that could offer a solution for both the strong CP problem and the dark matter mystery in the universe.The cavity haloscope experiment is the most sensitive method among various experiments designed to search for axion dark matter. Recently, CAPP-12TB, the flagship experiment at CAPP, has reached DFSZ sensitivity around 1.1 GHz (~ 4.55 ueV). The experiment plans to extend the search range up to 3 GHz (~ 12 ueV) while maintaining sensitivity. In this presentation, we present several a series of novel cavity designs suitable for high-frequency axion searches with CAPP-12TB.

Keywords:

Axion, Haloscope, Microwave cavity

H3.08

New haloscope design with an array of horn antenna for volume-efficient broadband search for dark matter axions

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Abstract:

Offering a solution to the strong CP problem, the axion, with a mass below meV, stands as a strong candidate for cold dark matter. A haloscope utilizing a dish antenna excels at broadband searches for axions in the THz region. Under a strong magnetic field, axions convert into photons, their conversion rate is tied to the surface area of the dish antenna, not the magnet volume. To enhance the volume efficiency, we propose an innovative design consisting of an array of horn antennae that fills the magnet volume and a reflector that focuses the converted photons onto a photo-detector. Numerical simulations of axion electrodynamics verify the efficacy of our proposed geometry. The experimental sensitivity surpasses previous designs for a given magnet. This presentation will outline the conceptual framework of our novel horn antenna array and quantify its projected sensitivity.

Keywords:

Axion, Dark Matter, Axion Haloscope

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H3.09

Experimental test of axion cosmology around 22 μeV with a multi-cell cavity and a Josephson parametric amplifier

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Abstract:

A theoretical solution to a long-standing puzzle in quantum chromodynamics, known as the strong CP problem, have led to the proposition of a hypothetical pseudo-Goldstone boson, the axion. Additionally, axions have growing attention due to their potential role as cold dark matter in our Universe. Interestingly, theoretical estimates from different research groups overlap notably in the mass range between 20 and 30 μeV. We performed an experimental search to test axion cosmology in this particular mass range with KSVZ sensitivity. The experiment features a multiple-cell cavity in a 12 T magnetic field and a high-performance Josephson parametric amplifier at 30 mK. In this talk, we will present the first experimental results around 22 μeV.

Keywords:

Axion, Hasloscope, Dark matter, Josephson parametric amplifier

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H5.01

Exploring Superconductivity with Terahertz Time-Domain Spectroscopy

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Abstract:

Terahertz time-domain spectroscopy (THz-TDS) is a powerful experimental technique used to investigate the physical properties of materials in the terahertz region. This frequency range lies between the microwave and infrared regions, and it is particularly interesting because it corresponds to the energy scale of superconducting gaps in many materials. We applied THz-TDS to study superconductivity in Nb, a well-known s-wave superconductor suitable for studying superconducting properties. By extracting the real and imaginary parts of the optical conductivity, we were able to gain insights into the behavior of the superconducting gap and superfluid density of Nb. This kind of research contributes to our understanding of the fundamental properties of superconductors and could potentially have implications for the development of new quantum devices based on superconducting materials.

Keywords:

Terahertz time-domain spectroscopy, Nb

Graphene-based THz metasurfaces for electrical control of polarization states

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Abstract:

Polarization control in the terahertz region is important for telecommunication and biotechnology. However, at terahertz frequencies, the relatively small anisotropy of naturally existing materials impedes the miniaturization of optical components and devices. In this talk, we demonstrate electrically controllable polarization states at the THz waves by different designs of metasurfaces with strong chirality, anisotropy, and non-Hermitian chiral degeneracy. Continuous control polarization states may provide a wide range of opportunities for the development of compact THz polarization devices and polarization-sensitive THz technology. Moreover, we anticipate that electrically controllable non-Hermitian metasurface platforms can serve as an interesting framework for the investigation of rich non-Hermitian polarization dynamics around chiral exceptional points.

Keywords:

Graphene metasurfaces, Polarization, THz technology

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H5.03

고속 시분해 테라헤르츠 분광법을 이용한 비파괴영상 및 센서 응용

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Abstract:

테라헤르츠 분광학은 비파괴 검사, 신소재 분석, 바이오·환경 센서 등 다양한 분야에서 응용범위가 넓어지고 있다. 특히, 테라헤르츠 시분해 (THz-TDS) 분광법은 실시간 주파수 분석 및 3차원 (3D) 영상측정 등에 강점이 있는 반면, 느린 측정속도로 인해 큰 제약이 있어왔다. 최근 진보된 광지연법의 도입을 통해, 고속 (100 Hz/scan 이상) THz-TDS 분광법이 개발되어 그 응용 가능성이 높아지고 있다. 일례로 고속 ToF(time-of-flight) 영상 측정법을 통해 반도체 패키징, 자동차·인프라, 식품·의약품 내에 존재하는 결함을 비파괴적으로 관측하는 것이 가능하며, 새로운 광학계 및 분석법의 도입을 통해 해상도가 지속적으로 향상되고 있다. 한편, 실시간 THz 분광법은 신물질의 인라인 특성 평가 및 새로운 바이오센서의 개발을 가능하게 한다. 특히, 박테리아와 같은 미생물을 검출하기 위해, 메타물질을 기반으로 하는 고감도 센서의 개발이 진행중이며, 감도 및 측정속도의 향상을 위한 연구가 활발히 이루어지고 있다. 최근에는 온도에 따른 메타센서 공명주파수 변화가 미생물 종의 성장·파괴와 같은 생리학적 특징을 잘 반영함을 밝혀내고, 이를 이용한 독창적인 비표지자 센서를 성공적으로 개발하였다.

Keywords:

테라헤르츠파, 비파괴영상, 바이오센서

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H5.04

10-nm 이하의 금속 나노틈에 갇힌 물의 테라헤르츠 굴절률 연구

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Abstract:

나노 미터 수준의 틈에 갇힌 물의 거동은 우리가 일상에서 마주하는 물과는 다른 특성들을 보인다는 것이 여러 분야에서 보고된 바 있다. 그러나 실험적 구현의 한계로 이에 대한 정량적 분석은 대부분 이론적 연구에 의존하고 있었으며 최근, 나노미터 수준에 갇힌 물의 정적 유전율이 약 40배가량 낮아 질 수 있다는 것이 실험적으로 확인되었다. 반면 물 분자 사이 수소결합에 의해 발생하는 물의 거동은 장파장 대역에 해당하며 이에 대한 실험적 연구는 아직까지도 미진하다. 본 연구에서는 계면 물(interfacial water)에서 거대 물(bulk water)에 이르는 2~20nm 폭의 금속 틈에 갇힌 물의 테라헤르츠(THz) 유전율을 조사하였다. 물 분자를 둘러싸고 있는 이 직사각형 루프 나노갭은 광물질 상호 작용을 크게 향상시켜 나노미터 두께의 물 층의 실수부와 허수부 모두에 대한 굴절률을 정밀하게 측정할 수 있다. 영하 20도부터 상온까지 온도를 달리하며 측정한 THz 투과실험, Effectivie Medium Theory 및 분자 역학 시뮬레이션을 통하여 우리는 나노 물의 두 가지 별개의 영역: (1) 금속 표면의 계면 물과 (2) 부피 제한에 의해 억제된 장거리 집단 역학을 갖는 물 로 구분되어야 함을 확인하였다. 본 연구는 물을 매개로 하는 분자 수송, 전기 화학 등의 분야에서 물 분자의 장거리 집단 역학을 이해하는 중요한 통찰력을 제공할 것이라 기대한다.

Keywords:

Nano Confinement, THz, Water Dynamics, Refractrometry

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H5.05

Tunable Q-factor guided-mode resonance with quasi-bound states in the continuum

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Abstract:

We present a tunable all-dielectric metasurface where ridges are affixed on both sides of the upper and lower core waveguides, transforming between symmetrical and asymmetrical configurations based on their positioning. By altering the symmetry and asymmetry of this dual-ridge metasurface, the Q-factor can be maximized or minimized at a specific frequency. This manipulation of the Q-factor leverages the variations in quasi-bound states in the continuum (BIC) and leaky modes resulting from the metasurface's structural changes. Our proposed metasurface design was designed using rigorous coupled wave analysis (RCWA) and finite difference frequency domain (FDFD) methods, and was experimentally verified in the terahertz frequency band.

Keywords:

Metasurface, Guided-Mode Resonance, Bound States in the Continuum

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H6.01

Microwave-driven miniature plasma plume for space propulsion

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Abstract:

Microwave-driven Coaxial Transmission Line Resonator (μ -CTLR) produces a small-volume high-density plasma plume. When operated at low pressure, the γ discharge mode, characterized by increased electron temperature, electron density, and gas temperature, was achieved even at low power levels [1]. These characteristics of the μ -CTLR show promise for low-power micro-propulsion systems. In this study, we investigated the propulsion capability of the μ -CTLR operating at 900 MHz and 8W power, with argon gas. At the gas flow rate of approximately 100 SCCM, the measured plasma parameters are electron density of $3.8 \times 10^{20} m^{-3}$, electron temperature of 2.3 eV, and gas temperature of 3300 K in the center of the plasma plume. It is noted that the density of the μ -CTLR plasma is significantly higher than similar research cases using RF power [2]. The estimated minimum thrust is about 2 mN, surpassing the power-to-thurst efficiency of recent micro-propulsion systems [2-4].
*This research was supported by Basic Science Research Program through the National Research Foundation of Korea(NRF) funded by the Ministry of Education(RS-2023-00273696) and the BK21+ program of the National Research Foundation of Korea (NRF)

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Keywords:

Microwave-driven plasma, plasma thruster, stark broadening method, Boltzmann plot method, Plasma diagnostics

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H6.02

Numerical Study on the Runaway Electron Mitigation Effect by the Plasma Inhomogeneity

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Abstract:

For avoidance or mitigation of runaway electron (RE) beam in tokamak devices, several methods have been developed, such as the magnetic perturbation induced by the Deuterium pellet injection [1, 2] or passive 3D field coils [3, 4], to induce scattering the pitch angle of the RE beam. In our previous study, we conducted 2-dimensional particle-in-cell (PIC) simulations and studied the resonant interaction between the uniform plasma and the uniform RE beam. As a result, we observed that: (1) the electrostatic waves in magnetized plasma are generated accompanying the parallel diffusion of the RE momentum distribution, (2) the whistler waves are generated accompanying the perpendicular diffusion of the RE momentum distribution, and (3) the resonance condition depends on the initial kinetic energy of the RE beam. In the present work, we study the effect of the plasma inhomogeneity on the pitch angle scattering. For varying profiles of the background plasma density and magnetic fields, we calculate the “friction” due to the pitch angle scattering by the interaction between the inhomogeneous plasma and the RE beam.

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Keywords:

runaway electron beam, pitch angle scattering, inhomogeneous plasma, particle-wave interaction, particle-in-cell simulation

2023 KPS Fall Meeting
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H6.03

Beam manipulations and measurements in the injectors of proton and ion linear accelerators

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Abstract:

Proton and ion accelerators are frequently employed as neutron sources for both basic scientific research and numerous practical applications. The repetition time of the neutrons depends on that of the beam, which is typically in the order of tens of nanoseconds. However, such a short repetition time might be inadequate for certain high-resolution neutron time-of-flight (TOF) experiments. As a solution, we propose a method involving the selection of a single bunch beam in the low-energy beam transport (LEBT) section through the utilization of a fast chopper and a double gap buncher. This technique aims to facilitate high-resolution neutron TOF experiments.
Furthermore, ensuring successful beam manipulation requires careful monitoring of beam quality within the LEBT section. Emittance, a crucial parameter directly associated with beam quality, quantifies the beam's spread in both position and momentum. Multiple methods exist for emittance measurement, including the Allison-type scanner, pepper pots, slit-scan methods, and quadrupole scan methods. In this presentation we discuss the application of emittance tomography using wire scanners to reconstruct the two-dimensional phase space of a beam. Additionally, we explore the Allison-type emittance scanner and elaborate on the associated data processing techniques.

Keywords:

Single Bunch selection , Emittance, Tomography, Double gap buncher

2023 KPS Fall Meeting
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H6.04

Beam Characteristics of RAON Injector using Ne Beams

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Abstract:

RAON linac is designed to accelerate proton beams to uranium beams. We used argon beams in the initial beam commissioning of RAON injector and a superconducting linac, SCL3. Next year's KoBRA experiment will require Neon and Oxygen beams along with Argon beams. As a preparation for the SCL3 beam acceleration, we are conducting an experiment to measure the characteristics of Neon beams in a RAON injector. This is a brief summary of the beam test results for Neon beams in RAON LEBT, RFQ, and MEBT.

Keywords:

RAON, Injector, Neon Beams

2023 KPS Fall Meeting
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H6.05

Two-color hard X-ray free-electron laser with flexible pulse duration at PAL-XFEL

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Abstract:

Recently, two-color hard X-ray free-electron laser with flexible pulse duration is used for user beamtime at PAL-XFEL. To generate two-color hard X-ray free-electron laser pulse with single electron bunch, we utilize variable gap undulator and dipole magnet located at self-seeding section. Time delay between pump and probe XFEL pulses can be controlled by changing the current of the dipole magnet. However, due to the limitations of the maximum current of the dipole magnet and the chamber size of the self-seeding section, the maximum time delay between the pump and probe pulses is approximately 120 fs. Since the pulse duration of XFEL pulse is typically on the order of tens of femtoseconds, therefore, it is necessary to be able to control the pulse duration for obtaining sufficient pump-probe experimental data within the given time delay. In this presentation, we introduce the method for generating two-color hard X-ray free-electron laser pulse with single electron bunch and the slotted foil scheme at bunch compressor to control the pulse duration. Experimental results of two-color hard X-ray free-electron laser with flexible pulse duration are presented.

Keywords:

Two-color XFEL, PAL-XFEL

2023 KPS Fall Meeting
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H7.01

Study of multiplicity-dependent ρ^0(770) production in pp collisions with ALICE

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Abstract:

Short-lived resonances are ideal probes to study the properties of the hadron gas phase created in heavy-ion collisions in the post-hadronization phase. Since the resonance lifetime is comparable to that of the hadron gas phase, their yields are affected by the competing rescattering and regeneration effects. These can be studied experimentally by measuring the yield ratio of resonances to the corresponding long-lived hadron as a function of the charged-particle multiplicity, which is related to the lifetime of the hadron gas phase. In this context, the ρ^0(770) resonance is particularly interesting due to its very short lifetime of about 1.3 fm/c, so it is suitable to study the hadron gas phase even in small collision systems. In addition, we may also study how the effects change with daughter particle species by comparing $\rho^0 \rightarrow \pi^+\pi^-$ and $K^{*0} \rightarrow K^+\pi^-$. This talk will present the analysis status of the ρ^0(770) production in pp collisions as a function of multiplicity with ALICE.

Keywords:

Resonance, ALICE, Hadron gas phase

2023 KPS Fall Meeting
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H7.02

Status of the upgrade activities of FAZIA in Korea

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Abstract:

The FAZIA (Forward A and Z Identification Array) detector system is designed to identify fragments of reaction products from heavy-ion collisions in the range of several tens to a hundred MeV per nucleon. One basic unit of FAZIA consists of three layers of silicon sensors of two different thicknesses and one CsI scintillator detector, called FAZIA telescope, which allows the charge identification of nuclei with Z up to 54 and the isotropic nuclei discrimination with Z up to 25 by using the Delta E - E information and the pulse shape analysis.
The FAZIA detector system has been successfully operated at GANIL since 2019.

Recently, the FAZIA upgrade project aims to extend the beam-energy coverage and increase the acceptance capabilities. The Korean FAZIA team is working on developing silicon sensors and improving the front-end electronics board.

Specifically, The silicon sensor characteristics have been investigated using TCAD (Technology Computer Aided Design) simulation tool. Based on the simulation result, our prototype of sensor designs were optimized and produced in collaboration with a domestic fab. Currently, Fabricated sensors have been measured detector response to a radiation source and undergone radiation hardness assurance.
In this talk, we presents the current R&D of the FAZIA upgrade project, focusing on the activities of the Korean team.

Keywords:

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H7.03

Study on the cluster size of the silicon pixel detector

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Abstract:

The ALPIDE (ALice PIxel DEtector) is a silicon pixel detector, which is based on the MAPS (Monolithic Active Pixel Sensor) technology and developed for the ITS (Inner Tracking System) of the ALICE at the LHC. The electrons produced in the epitaxial layer of the ALPIDE through ionization by the incident charged-particles are collected to the pixel diodes of the ALPIDE, and the converted signals are digitalized via the integrated inner circuitry implemented on each pixel. The number of the fired pixel - the cluster size - depends, therefore, on the number of electron, which is proportional to the energy loss of the incident particle, and detector parameters. We present and discuss the cluster size distribution obtained in the source experiments with various conditions.

Keywords:

ALPIDE, MAPS, Cluster Size

2023 KPS Fall Meeting
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H7.04

Searching for medium-induced jet quenching effects in small collision systems with ALICE

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Abstract:

Small system collisions exhibit signatures suggesting collective flow, a phenomenon associated with QGP formation observed in heavy-ion collisions. Jet quenching is also related to QGP formation, but there remains no clear evidence within small systems. Understanding jet quenching's extent in small systems is crucial to set QGP formation limits. The ALICE collaboration undertakes a comprehensive search for jet quenching in pp and p-Pb collisions, using several observables: the semi-inclusive acoplanarity distribution of jets recoiling from high-p_T hadrons (h+jet) and intra-jet measurements. In HM events, a distinct broadening of the h+jet acoplanarity distribution compared to MB events suggests potential jet quenching. Both data and PYTHIA simulations indicate that this broadening may arise from the event selection bias of HM selection. This bias of HM selection must also be taken into account for the interpretation in terms of QGP of other phenomena seen in small collision systems. To further investigate disentangling parton showering and hadronisation in the jet evolution process, we analyzed the transverse momentum (j_T) distributions of charged-particle jet constituents for several z ranges within pp collisions. The results are expected to set good constraints on current theoretical models. Continuing our investigation through HM pp and p-Pb collisions might open an exciting avenue to delve into jet quenching within small systems. These findings have substantial implications for our comprehension of collective effects and the concept of jet quenching within the specific context of small systems.

Keywords:

ALICE, Small system, Jet modificaiton

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H7.05

Probing event-structure dependence of strange hadron production in small systems with ALICE at the LHC

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Abstract:

Probing event-structure dependence of strange hadron production in small systems with ALICE at the LHC High-multiplicity proton-proton (pp) and proton-lead (p-Pb) collisions at the LHC have revealed that small collision systems show the onset of phenomena typical of heavy-ion collisions. Some of these signatures, such as strangeness enhancement and collective flow, suggest that light-flavor hadron production arises from a set of complex mechanisms whose relative contributions evolve smoothly from low to high multiplicity collisions. This implies that proton-proton collisions cannot be seen as a simple incoherent sum of parton-parton collisions, an idea that is central to most proton-proton Monte Carlo event generators, for example, PYTHIA. Studies on multi-differential strange particle production in small systems can be utilized to discriminate among the various final state effects at play and represent an important baseline for heavy-ion studies.

This talk presents new results from ALICE on light-flavor particle production as a function of the (unweighted) Transverse Spherocity (S_{₩text{O}}^{₩pt=1}}₩xspace) in pp collisions measured at 13 TeV. Utilizing narrow selections on S_{₩text{O}}^{₩pt=1}}₩xspace, the observable allows for a topological selection of events that are either "isotropic" (dominated by multiple soft processes) or "jet-like" (dominated by one or few hard scatterings). The experimental results are discussed in context with predictions from various Monte Carlo generators.

Keywords:

ALICE, quark-gluon plasma, small systems, strangeness enhancement, event-shape engineering

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H7.06

Handling of the underlying event in jet mass and di-jet mass measurements in heavy-ion collisions

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Abstract:

Jets are a unique tool to study a hot and dense QCD medium created in relativistic heavy ion collisions. Among several jet observables, modification of jet mass and di-jet mass in heavy-ion collisions relative to those in proton-proton collisions provides insights into understanding the jet quenching phenomena particularly regarding gluon radiation and the depletion of parton virtuality. However, jet measurements often encounter significant contamination by large underlying event in heavy-ion collisions. In this talk, we present the performance of various methods for managing such underlying event in jet mass and di-jet mass measurements, including conventional area-based approach, jet-by-jet and whole-event based constituent subtraction methods, and iterative constituent subtraction method. Hard-process PYTHIA events are embedded into a thermal model designed to approximate the heavy-ion underlying event, and jet mass and di-jet mass resolutions achieved with these methods are compared. In addition, theoretical predictions for jet mass and di-jet mass at sqrt(s_NN) = 5.02 TeV Pb-Pb collisions using the JEWEL (Jet Evolution With Energy Loss) event generator will be provided. This study will serve as a basis for forthcoming experimental measurements at RHIC and the LHC.

Keywords:

Jet mass, Di-jet mass, Heavy-ion underlying event, Jet, Relativistic heavy ion physics

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H7.07

Overview of recent CMS heavy ion results.

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Abstract:

The overview of latest results from the CMS heavy ion program is presented.
This report highlights the recent accomplishments across diverse domains, including heavy quark dynamics, quarkonia production, jet-hadron correlation, and the elliptic flow of the f_0 particle.
These studies have been conducted using the LHC Run II dataset.
Moreover, new results for the particle multiplicity and collective flow, freshly analyzed using the 5.36 TeV PbPb Run III data, will be presented as well.

Keywords:

cms, heavy ion, LHC, Run III

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H7.08

Production of the X(6900) meson in heavy ion collisions

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Abstract:

We study a fully-charmed tetraquark state, the X(6900) meson in heavy ion collisions by focusing on its production from both cases, one from two charm and two anti-charm quarks in a quark-gluon plasma by quark coalescence and the other from two J/ψ mesons in the hadron medium by hadron coalescence. Starting from the investigation on the transverse momentum distribution of charm quarks, we calculate the transverse momentum distribution of the J/ψ meson. Then, we evaluate the yield and transverse momentum distributions of the X(6900) produced from both charm quarks and the J/ψ meson in heavy ion collisions. We show that the yield and transverse momentum distributions of the X(6900) are strongly dependent on its structure, and thereby we propose that we can discriminate the internal structure of the X(6900) by measuring the yield and transverse momentum distributions of the X(6900) meson.

Keywords:

heavy ion collisions, the X(6900)

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H7.09

Correlation study using RHICf and STAR detectors to understand the finite transverse single spin asymmetry for very forward neutral pion production

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Abstract:

Transverse Single-Spin Asymmetry (TSSA) provides insights into the particle production mechanism in terms of perturbative and non-perturbative strong interaction. The RHICf detector collected data for polarized $p+p$ collisions at $\sqrt{s}$ = 510 GeV, with STAR detector system during 2017 runs. The previous RHICf results showed that asymmetries of the very forward π^{0}, A_{N}, were measured to be non-zero for values in the range of $\eta > 6$, $p_{\mathrm{T}} < 1$ GeV/c. To further understand the origin of this result, we will analyze the correlation between activities of very forward-rapidity and mid-rapidity regions, which are measured by RHICf and STAR detectors, respectively. In this talk, we will report the current status and future plan for this analysis.

Keywords:

RHICf, Transverse Single Spin Asymmetry, very forward neutral pion

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H8.01

Nonlinear Bosonic Control with Qubit-Oscillator Gates

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Abstract:

Quantum gates between qubits and oscillators provide promising opportunities for advanced quantum nonlinear control of bosonic systems, including mechanical motion and superconducting circuits. Our team at Palacky University has already proposed diverse methods to achieve such a challenging target [1-3]. In this talk, I will present our advanced approaches, the qubit acting as an ancilla facilitates Rabi-type interactions for photons or phonons and enables the preparation of highly squeezed oscillator states [4], bosonic error correction codes [5], slowing of decoherence [6], new methods of estimation of bosonic systems [7], and efficiently interfacing them with qubits [8], all highlighting the nonlinear enhancement of quantum control. These results pave the way for high-fidelity quantum control of mechanical motion and superconducting circuit oscillators, providing an experimentally feasible path for developing bosonic quantum technologies.

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Keywords:

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H8.02

T-depth-optimized Quantum Search with Quantum Data-access Machine

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Abstract:

Quantum search algorithms offer a remarkable advantage of quadratic reduction in query complexity using quantum superposition principle. However, how an actual architecture may access and handle the database in a quantum superposed state has been largely unexplored so far; the quantum state of data was simply assumed to be prepared and accessed by a black-box operation—so-called oracle, even though this process, if not appropriately designed, may adversely diminish the quantum query advantage. Here, we introduce an efficient quantum data-access process, dubbed as quantum data-access machine (QDAM), and present a general architecture for quantum search algorithm. We analyze the runtime of our algorithm in view of the fault-tolerant quantum computation (FTQC) consisting of logical qubits within an effective quantum error correction code. Specifically, we introduce a measure involving two computational complexities, i.e. quantum query and T-depth complexities, which can be critical to assess performance since the logical non-Clifford gates, such as the T (i.e., π/8 rotation) gate, are known to be costliest to implement in FTQC. Our analysis shows that for N searching data, a QDAM model exhibiting a logarithmic, i.e., $O(\log N)$, growth of the T-depth complexity can be constructed. Further analysis reveals that our QDAM-embedded quantum search requires $O(\sqrt{N} \times \log N)$ runtime cost. Our study thus demonstrates that the quantum data search algorithm can truly speed up over classical approaches with the logarithmic T-depth QDAM as a key component.

Keywords:

Quantum algorithm, Quantum data search, quantum data-access

2023 KPS Fall Meeting
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H8.03

Quantum error correction in continuous time

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Abstract:

Quantum error correction is an essential element for achieving universal quantum computing. While conventional error correction protocols have been designed to operate in discrete time domains, recent research has been conducted on their continuous-time extensions. We propose a protocol that effectively reverses the noisy dynamics of encoded quantum states, thereby realizing error correction/suppression in continuous time. We highlight that our approach can be realized via the precise engineering of dissipative dynamics.

Keywords:

open quantum system, quantum computing, quantum error correction, Lindblad equation

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H9.01

How to apply entropy inequalities and extend to quantum entropy

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Abstract:

Fluctuation theorem reveals the symmetry of stochastic entropy production and this fundamental result leads to interesting consequences including the estimation of free energy from a nonequilibrium process and extension of the 2nd law of thermodynamics in information thermodynamics. Over the past few decades, many physicists inspired by the finding participate have actively engaged in research on stochastic thermodynamics.

Recently, a new wave named entropy inequality occurs in stochastic thermodynamics. Entropy inequality is an informative version of the 2nd law of thermodynamics and bounds entropy production with a positive real number. For example, the thermodynamic uncertainty relation shows that entropy production can be bounded by the relative error of any observable. Speed limit shows that entropy production can be bounded by distances in probability space and activity. These inequalities are applicable to estimating entropy production with a neural network and finding optimal protocol.

In this talk, I will present applications of these fundamental bounds. In addition, I will introduce our recent work on quantum-entropy estimation utilizing the combination of a quantum circuit and a neural network [arXiv:2307.13511]. This algorithm is inspired by entropy inequalities and can be employed to discern phases of a quantum system that accompany the change of entanglement entropy. We verify the algorithm on the XXZ chain.

Keywords:

Entropy production, Quantum entropy, Stochastic thermodynamics, quantum circuit, neural network

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H9.02

Active transport in a tilted periodic potential

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Abstract:

The study of Brownian particles in a tilted periodic potential has been a focal point of research due to its wide-ranging applications in various fields, including Josephson junctions and superionic conductors. Moreover, this intriguing problem exhibits notable physical phenomena, such as stochastic resonance and giant diffusion. In this study, we extend this subject into the realm of active transport by investigating active Ornstein–Uhlenbeck particles in a tilted periodic potential. Using numerical simulations and analytical approximations, we explore the non-equilibrium steady-state distributions, current, and diffusivity in the tilted periodic potential varying tilting forces and self-propulsion strengths. Our findings offer profound insights into active dynamics and responses of self-propelled particles navigating through heterogeneous environments, with potential implications for diverse scenarios, including the concept of a ratchet driven by active particles.

Keywords:

Active Matter, Peridic Potential, Giant Diffusion, Nonequilibrium Steady States

2023 KPS Fall Meeting
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H9.03

Nonequilibrium heterogeneous diffusion dynamics for active particles in disordered biopolymer network

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Abstract:

Activeness of particles and heterogeneity of the system play a fundamental role in comprehending the diverse biological processes within living cells, particularly with respect to diffusion dynamics. Despite extensive experimental and computational studies for nonequilibrium heterogeneous systems, our understanding for the intricate interplay between activeness and heterogeneity with regard to diffusion dynamics remains incomplete. 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 interplay between activeness and heterogeneity gives rise to rich, distinct diffusion dynamics for varying particle size. 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, showing active but subdiffusive and non-gaussian behavior. We provide computational investigations of dynamics observables such as the trapped time distribution, hopping length distribution, mean squared displacement, and long-time diffusivity. For mesh-sized tracer, we find tracer's non-gaussian behaviors show Laplace distribution at a certain timescale of $O(\tau_A)$. Notably, observed Laplace distribution originates from the hopping dynamics in heterogeneous media. For large tracer, we found activeness makes heterogeneous diffusion remarkably persistent beyond $O(\tau_A)$. Our results provide important implications for understanding relevant biological processes such as intracellular transport.

Keywords:

Heterogeneous diffusion, Active Ornstein-Uhlenbeck particle, Disordered polymer network, Non-gaussian behavior, Trapping-and-hopping dynamics

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H9.04

Anomalous relaxation of a Brownian particle in active bath

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Abstract:

We investigate the relaxation dynamics of a Brownian particle confined within a harmonic trap and immersed in an active heat bath. We unveil a non-monotonic relaxation behavior as the system converges towards a nonequilibrium steady state. This phenomenon becomes particularly pronounced when the correlation time of the active noise surpasses the characteristic time of the damped harmonic oscillator, prevailing amidst an otherwise thermal environment. This unconventional behavior finds its foundation in the assimilation of the Brownian particle within the active bath. Through adept manipulation of the initial correlation between the particle's position and the active noise, we gain the ability to exert control over the relaxation properties, including the presence and dimensions of a distinctive overshoot. This discovery holds significant implications, shedding light on the art of fine-tuning noise characteristics within an active medium. Such mastery offers prospects for optimizing the performance of microscopic devices, potentially revolutionizing the manipulation of stochastic systems within intricate active environments.

Keywords:

relaxation, active bath

H9.05

A stochastic target search by active particle

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Abstract:

Random target search by a run-and-tumble particle in a confined one-dimensional space is investigated in the presence of a partially absorbing target. We analytically obtain the mean searching time, which shows a non-monotonic behavior as a function of the propulsion speed of the active particle. It clearly indicates the existence of the optimal speed, when the absorption strength (reactivity) of the target is finite. However, as increasing the diffusivity of the particle, the mean searching time changes into monotonic behavior on propulsion speed dependence, resulting in transitional behaivor of optimal speed from finite to zero. We also figure out the initial distribution dependence for the transitional behaivor of optimal speed, and obtain the condition for initial distribution to have finite optimal speed, in spite of large diffusivity.

Keywords:

Random Target Search, First Passage Time, Active Particle, Partially absorbing target

H9.06

The Jarzynski's equality for the microcanonical ensemble.

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Abstract:

Jarzynski's equality (JE) proves that the average energy change occurring through a non-equilibrium cyclic process should not be less than zero if the process begins with canonical initial states. So far, whether JE is true also for microcanonical initial states is yet to be proven, despite it having long been anticipated in view of the ensemble equivalence. In this study, we numerically test JE for a quantum spin-1/2 system initially prepared in the microcanonical ensemble. We consider a cyclic quench to perturb only a small part of the system and calculate work cumulants using the exact diagonalization technique. We show that JE is roughly true and explain how the temperature scales of the microcanonical ensemble, such as the Boltzmann and Gibbs temperatures, can be amalgamated in JE.

Keywords:

Jarzynski's equality, Microcanonical ensemble, Exact diagonalization technique

Precise Stoichiometry Control of Complex Oxide Using Hybrid Molecular Beam Epitaxy

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Abstract:

Complex oxides are of great interest in condensed matter physics and material science due to the interesting physical properties that arise from the interactions between lattice, charge, spin, and orbital degrees of freedom. The interaction has been influenced not only by the crystal structure, and cation type but also by the stoichiometry of the complex oxide. Recent advances in deposition equipment have enabled the growth of high-quality complex oxide thin films. However. there remain synthesis challenges including stoichiometry control for metals with low vapor pressure and low oxidation potential (i.e. difficult to oxidize).

In this study, I will introduce a novel growth approach using elemental source, reactive oxygen, and metal-organic sources-hybrid molecular beam epitaxy (*h*MBE). The *h*MBE approach has the following advantages: 1) it produces complex oxide film with precise stoichiometry control, and 2) it removes the issue of difficulty in oxidation and low vapor pressure by utilizing metal-organic precursors. Using this approach, I will present the first *h*MBE growth of $DyTiO_3$, a rare-earth titanate, grown on $LaAlO_3(001)$ and $DyScO_3(110)$ substrates. The $DyTiO_3$ film grown under optimized stoichiometric conditions shows clear ferromagnetism with a bulk-like T_c = 60 K. By systematically tuning the Dy cell temperature, we find that small deviations in the cation stoichiometry lead to the simultaneous disappearance of the crystal structure and ferromagnetism of the $DyTiO_3$. Based on these results, we will discuss the correlation between the stoichiometry, crystal structure, and ferromagnetic ordering of $DyTiO_3$ films.

This research is supported in part by NRF Korea (RS-2023-00210625).

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Keywords:

complex oxide, hybrid molecular beam epitaxy, DyTiO3

H10.02

Oxide semiconductor $BaSnO_3$ as a new platform for perovskite oxide electronics

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Abstract:

$BaSnO_3$ perovskite oxide semiconductor system provides a new platform to put together many interesting properties of various perovskite oxides and create new functions that have not been possible before.

In combination with the lattice matched polar perovskite oxide $LaInO_3$, a high density 2DEG can be created. Its formation mechanism, namely the "interface polarization" created by the inversion symmetry breaking at the orthorhombic $LaInO_3$ and the cubic $BaSnO_3$ interface, is a very unique property of perovskite oxides. We will discuss its scientific and technical implications. In combination with the lattice matched and highly insulating $SrHfO_3$, a complex multilayer structure such as double-gate FETs can be demonstrated. Furthermore, when a new high-k dielectric $BaHf_{0.6}Ti_{0.4}O_3$ is used as a gate oxide, 2D charge density larger than 10^{14} cm^{-2} can be modulated by field effect. Lastly, when a lattice matched ferroelectric $PbZr_{0.7}Ti_{0.3}O_3$ is used as a gate oxide, ferroelectric FET can be realized. We will discuss the implications of the ferroelectric material parameters on the device performance.

Keywords:

Perovskite oxide, BaSnO3, LaInO3, 2DEG, SrHfO3, FET, high-k Ba(HfTi)O3, ferroelectric Pb(ZrTi)O3

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H10.03

High quality 2DEG in $BaSnO_3$ based system

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Abstract:

The two-dimensional electron gas (2DEG) at $LaInO_3$(LIO)/$BaSnO_3$(BSO) interfaces is understood to originate from a polarization discontinuity at the interface and the conduction band offset between LIO and BSO. We investigate the role of the terminating layer at the LIO/BSO interface in creating the 2DEG. Based on electric transport measurement of our in-situ grown LIO/BSO heterostructures, we report in this work that the SnO_2 termination is the key of forming 2DEG. We controlled the terminating layer with several method on top of the BSO surface. We show that the as-grown BSO surface has a mixed terminating layer of BaO and SnO_2 while the BSO surfaces prepared with additional SnO_2 deposition are terminated mainly with the SnO_2 layer. And lastly, as a proof of 2DEG layer in this system, we present angle dependent Hard X-ray Photoemission Spectroscopy (HAXPES) data. It shows a clear conducting fermi edge together with angle dependent behavior as a 2D conduction channel. Our finding can provide a key parameter to build 2DEG LIO/BSO system and enhance understanding of characteristic properties of BSO based 2DEG system.

Keywords:

BaSnO3, oxidesemiconductor, 2DEG, FET, XPS

Oxide Superlattices and Hybrid Heterostructures

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Abstract:

Heterostructures let us exploit the properties of both constituent materials. The physical and chemical behaviors of the heterostructures are not just simple average of those of the constituent materials, but are often unexpected emergent behavior. Interface, dimensionality, proximity are some of the keywords associated with heterostructures. Moreover, when the excitonic wavelength is larger than typical length scale of the lattice unit cell, one might create artificial materials that do not exist in nature.
In this talk, I present some of our recent studies on oxide superlattices and hybrid heterostructures. Complex oxides host strong electronic correlation, which prevail when they heterostructure with other materials with various bonding characteristics. Some strategies of obtaining artificial materials for magnetoelectric, optical, and thermal functionalities will be introduced.

Keywords:

oxide superlattices, hybrid heterostructures

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H11.01

Andreev bands in three-terminal graphene Josephson junctions

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Abstract:

Multiply connected electronic networks were 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). In this work, we investigate the artificial topological band structure of three-terminal graphene Josephson junctions by using superconducting tunneling spectroscopy. Differential tunnelling conductance shows the characteristic features of Andreev bound states (ABS) formed in graphene. We controlled the superconducting phase configurations by applying the flux gates and obtained the ABS energy spectrum as a function of two independent phase differences and energy. Such quasi-momentum v.s. The energy map of ABS unveils the transition between gapped and gapless states, corresponding to the topological band structure of 2D-Dirac semimetals. Our results show the potential of graphene-based MTJJ for engineering the band topology.

[1] J.E Avron Rev. Mod. Phys., 60, 873 (1988).
[2] Roman-Pascal Riwar, Manuel Houzet, Julia S.Meyer & Yuli V. Nazarov. Nature Comm. 7, 11167 (2016)

Keywords:

graphene, Josephson junction, Andreev bound state

2023 KPS Fall Meeting
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H11.02

Manipulation of topological superconductors: electron-doped topological superconductors and chiral magnet-superconductor heterostructure

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Abstract:

Topological superconductors, which host Majorana bound states as low-energy excitations, have attracted much interest as they are ideal candidates for fault-tolerant qubits with non-abelian exchange statistics. The search for topological superconductors is therefore one of the central topics in condensed matter physics. Despite the great interest in both fundamental research and industrial applications, only a few materials or specially designed systems have been experimentally verified as candidates for topological superconductors. To date, one of the most promising approaches toward the realization of topological superconductors is using *s*-wave superconductors to induce superconducting pairing on topological insulators in the presence of magnetic fields with significant Rashba spin-orbit coupling. In addition, electrons such as the Cu, Sr, Nb ion-doped topological insulator Bi_2Se_3 have been intensively studied to understand the nature of topological superconductivity. In this talk, I will focus on how the research on topological superconductivity in doped Bi_2Se_3 has developed. In the end, I will also give a brief introduction to the chiral magnet-superconductor heterostructure as a newly proposed topological superconducting system, where the coupling of the *s*-wave superconductor to a spatially rotating magnetic field could create a *p*-wave topological superconductor.

Keywords:

topological superconductor, electrons-doped Bi2Se3, chiral magnet-superconductor heterostructure

Superconducting diode effects in vertical van der Waals heterostructures

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Abstract:

Engineering non-reciprocal currents, commonly referred to as diode effects, have found widespread applications in modern electronic devices. However, the conventional diode encounters limitations when operating at ultralow temperatures due to increased resistivity and heat emission, primarily arising from the composition of p- and n-type semiconductors. Consequently, superconducting diodes, enabling zero-resistance supercurrent in one direction while enduring resistive ohmic currents in the opposite direction, emerge as potential candidates for expanding device functionalities in the quantum regime. In this presentation, we will present superconducting diode effects (SDE) using vertically stacked van der Waals (vdW) Josephson junctions (JJ), which consist of a two-dimensional (2D) superconductor $NbSe_2$ and a semiconductor MoS_2. Benefiting from atomically clean vdW interfaces and precise twist-angle controls in $NbSe_2$–MoS_2–$NbSe_2$ JJs, we observe that JJ characteristics are sensitive to the twist angle of the superconducting $NbSe_2$ layers and the number of MoS_2 insulating layers. We tentatively attribute the intriguing twist-angle-dependent SDE to the unique structural and electrical properties of all-2D-vdW JJs, including spin-orbit couplings, layer-number-dependent spin-valley locking, and Ising superconductivity in 2D layered materials.

Keywords:

Superconducting diode effects, two-dimensional superconductor, van der Waals Josephson junctions

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H11.04

Tunable Josephson diode effects in Al/InAs SQUID

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Abstract:

We report a non-reciprocal superconducting quantum interference device (SQUID) composed of two gate-tunable Al/InAs Josephson junctions. The non-reciprocity results from the breaking of inversion and time-reversal symmetries due to spin-orbit coupling and magnetic fields, and it manifests as the difference between the forward and backward critical currents, referred to as the Josephson diode effect [Nat.Nanotechnol. 17, 39 (2022)]. The device demonstrates Josephson diode effects clearly when the critical current maximizes with respect to the flux through the SQUID loop. The diode effect is tunable by controlling gate voltages which change the carrier density and spin-orbit strength, and even reverses its polarity as the in-plane magnetic field increases. The tunable Josephson diode effect could be utilized in developing superconducting quantum circuits with unique non-reciprocal properties.

Keywords:

Al/InAs heterostructure, non-reciprocal devices, symmetry breaking, Josephson diode effect, superconducting quantum interference device (SQUID)

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H12.01

Spin-orbit torques by magnon dissipation

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Abstract:

Efficient control of magnetization in ferromagnets is key for advancing high-performance spintronic devices[1,2]. Conventionally, the focus of research efforts has been directed towards optimizing spin transport to minimize energy loss, as it's commonly believed that dissipation impedes effective control of magnetization[3,4]. In contrast to this prevailing view, we introduce an innovative approach that harnesses dissipation as a tool for magnetization control. This intriguing idea is demonstrated by employing a magnetic heterostructure composed of a ferromagnetic metal and an antiferromagnetic insulator and exploiting an intrinsic spin current within the ferromagnetic metal[5,6]. By incorporating an antiferromagnetic insulator that allows broken symmetry in spin transport while preserving charge transport symmetry, we are able to achieve significant spin-orbit torques (SOT) comparable to those observed in non-magnetic metals, enabling magnetization switching. Intriguingly, our findings demonstrate that these SOTs scale with the amount of spin angular momentum lost to surrounding via magnon dissipation, in stark contrast to the conventional approach where the spin dissipation process diminishes their magnitude. These results not only provide novel insights into the dissipation but also open up new degree of freedom for developing energy-efficient spintronic devices.

Keywords:

magnon, spintronics, spin-orbit torques, spin transport

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H12.02

Low-dissipation and ultrafast transport of antiferromagnetic magnons over nm-distances

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Abstract:

Magnons, quasiparticles of spin waves, are the low-energy collective excitation in magnetically ordered systems. Antiferromagnetic insulators (AFMIs) have garnered attention since they host THz-frequency magnons carrying angular momentums without moving charges and the absence of stray fields in the AFMIs is desirable to make further compact spin devices than their ferromagnetic counterparts. Interestingly, the magnon transport efficiency through AFMIs often increases at several to a few tens of nm distances, which corresponds to the points near the magnetic transition, and thus can be associated with the magnon fluctuation enhanced near the magnetically disordered state. This is practically useful in engineering nanometer-thick spin devices such as magnetic tunnel junctions, in which angular momentums propagate along the film thickness direction rather than the in-plane motion. On the other hand, not much is known about the propagation of magnons in AFMIs over nm distances. Particularly, the magnon propagation speed, a key parameter for data operation time, still remains elusive, particularly at nanometer distances due to the lack of sufficiently fast probes. Here, we use THz emission measurements and identify THz magnon currents through an AFMI NiO layer (≤ 100 nm). We find the AFM magnons in NiO carry sufficient spin angular momentums and thus manipulate the magnetization in an adjacent ferromagnet, enabling low-dissipative operation of spin devices [1]. In addition, we measure the AFM magnon velocity in nm-thin NiO. We find the AFM magnons propagate at a superluminal-like velocity (up to 650 km/s) at nanoscales in NiO (≤ 50 nm), which exceeds far beyond the bulk magnon group velocity (~40 km/s). We attribute these findings to a finite magnetic disorder near the AFM transition at nanoscales. Our observations suggest the prospects of energy-efficient (low-dissipative and ultrafast) nanodevices using AFMIs even when considering finite dissipation in real materials.

[1] Y. Wang *et al.*, "Magnetization switching by magnon-mediated spin torque through an antiferromagnetic insulator" Science 366, 1125–1128, 2019.
[2] K. Lee *et al.*, "Superluminal-like magnon propagation in antiferromagnetic NiO at nanoscale distances" Nat. Nanotechnol. 16, 1337–1341, 2021.

Keywords:

Terahertz spintronics, Antiferromagnetic magnon

2023 KPS Fall Meeting
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H12.03

Intrinsic Orbital Hall Effect of Magnons

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Abstract:

We theoretically investigate the transport of magnon orbitals in a honeycomb antiferromagnet [1]. We find that the magnon orbital Berry curvature is finite even without spin-orbit coupling and thus the resultant magnon orbital Hall effect is an intrinsic property of the honeycomb antiferromagnet rooted only in the exchange interaction and the lattice structure. Due to the intrinsic nature of the magnon orbital Hall effect, the magnon orbital Nernst conductivity is estimated to be orders of magnitude larger than the predicted values of the magnon spin Nernst conductivity that requires finite spin-orbit coupling. For the experimental detection of the predicted magnon orbital Hall effect, we invoke the magnetoelectric effect that couples the magnon orbital and the electric polarization, which allows us to detect the magnon orbital accumulation through the local voltage measurement. Our results pave a way for a deeper understanding of the topological transport of the magnon orbitals and also its utilization for low-power magnon-based orbitronics, namely magnon orbitronics.

[1] G. Go, D. An, H.-W. Lee, and S. K. Kim, "Intrinsic Magnon Orbital Hall Effect in Honeycomb Antiferromagnets," arXiv:2303.11687

Keywords:

orbital, magnon, Hall effect, antiferromagnet

H12.04

Long-Distance Coherent Transmission and Highly Efficient Controllable Interference of Magnons using a Photon-Magnon Hybrid System

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Abstract:

A hybrid system, characterized by a strong coupling between multiple distinct excitations such as photons, phonons, spins, and magnons, has been pivotal in uncovering captivating coupled dynamics that hold the potential for an efficient interface in quantum information processing [1]. Magnons, or spin waves, which are collective excitations within ordered spin systems, can encode information into their phase or amplitude and the information can be manipulated through interference among the magnons. However, achieving long-distance transmission and highly efficient magnon interference in real magnetic material systems is challenging due to the fundamental issue of the significant magnon dissipation. In this study, we demonstrate the realization of long-distance coherent magnon propagation and nearly perfect controllable interference of magnons using a photon-magnon hybrid system. Our experimental setup comprises a pair of Yttrium Iron Garnet (YIG) spheres positioned 12 mm apart on a silicon substrate, connected through a superconducting NbN coplanar waveguide (CPW) microwave resonator circuit [2]. Two vertical antennae are assembled adjacent to each YIG sphere to excite and detect Kittel magnon modes in the YIG spheres. Through Vector Network Analyzer (VNA) measurements, a clear avoided crossing of the two magnon bands is observed, with a hybridization gap of around 29.5 MHz at a frequency of approximately 5.4 GHz. This indicates the strong coupling between magnon modes of the two YIG spheres through the microwave resonator. Using microwave pulse excitation and real-time detection with an oscilloscope, we measured coherent energy exchange between the two coupled magnonic resonators through the microwave circuit, with a period of 34 ns, corresponding to the frequency gap between the two eigenmodes (34 ns ~ [29.5 MHz]$^{-1}$). Also, by injecting two consecutive microwave pulses with varying time delays and carrier frequencies, perfect constructive and destructive interference of the two magnon excitations can be achieved, enabling arbitrary manipulation of states encoded by the eigenmode amplitudes. Our findings provide significant insights into the coherent dynamics inherent in strongly coupled hybrid systems. This understanding also presents promising opportunities for advancing quantum-compatible coherent information processing through the strategic utilization of magnons.

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[1] G. Kurizki *et al., Proceedings of the National Academy of Sciences* **112**, 3866 (2015)
[2] Y. Li *et al., Physical Review Letters* **128**, 047701 (2022)

Keywords:

Magnon, Hybrid magnonics, Magnon-photon coupling, Superconducting circuit, YIG sphere

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H12.05

Nonlocal Relaxation of Magnons via Ballistic Acoustic Phonons

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Abstract:

In a normal metal, electrons scatter inelastically with phonons to give rise to an electrical resistance. Usually these phonons are incoherent and the change is equivalent to a temperature rise. In strongly coupled spin-phonon systems, the magnetic precession can efficiently emit coherent phonons in the GHz range. These phonons have usually very little interaction with a dielectric crystal supporting the thin magnetic film and are able to travel inside almost unattenuated. Here we report experiments injecting these ballistic phonons into a thin metal sheet placed on the back-side of the substrate. We observe the emergence of a nonlocal relaxation of magnons by these phonons through a resistance rise as the magnetic precession becomes nonlinear. This is distinct from the temperature induced by incoherent phonons. Our finding points to the unexplored regime on the interaction between electrons and ballistic phonons.

Keywords:

Magnon, Acoustic phonon, Coherent coupling

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H13.01

Channel length dependence 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 characteristics of TMDC heterostructure field-effect transistors (FETs).
We fabricated hBN/WSe_2/hBN heterojuction 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. hBN plays a role in reducing hysteresis in the transfer curve caused by charge trap and moisture adsorption. In addition, resistance and mobility vary according to the channel length between the source and drain, which are important parameters for the flow of current. The shorter the channel length, the lower the resistance of the channel, allowing current to flow easily. The performance of the fabricated device can be confirmed by calculating the mobility according to the channel length through the measured transfer curve. However, if the channel length is too short, problems such as leakage current occur due to the short channel effect.
By analyzing the gate-dependence of the transfer curve and output curve of the FETs, we find the changing in the mobility and resistance according to the WSe_2 channel length.

Keywords:

Transition-metal dichalcogenide, Field-effect transistor, Transfer curve, Output curve, Mobility

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H13.02

Novel quantum states by steering ultrafast mixing of exciton and Floquet states

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Abstract:

Via the light-matter interaction, Floquet replicas are generated mimicking themselves in the electronic structure and simultaneously excitons are also excited with a considerable Coulomb interaction between electron and hole. Ultrafast mixing and coupling between exciton and Floquet states could be steered in an all-optical coherent fashion under the weak optical pumping, which is investigated through the theoretical description of the time- and angle-resolved photoemission spectroscopy (tr-ARPES). In this vision, two branches of novel quantum states, i.e., exciton-Floquet composites, the quasiparticle invoking an exciton dressed with the Floquet replica or vice versa, are found to be formed. This finding suggests a unique platform to delve into the real-time build-up and dephasing of novel quasiparticles in terms of a coherent modulation of exciton and Floquet states and to pursue reconfigurable optoelectronic and nanophotonic devices based on two-dimensional semiconductors.

Keywords:

Exciton, Floquet, tr-ARPES, entanglement

2023 KPS Fall Meeting
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H13.03

The Investigation of p-type Two-Dimensional Tellurium and Its Applications

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Abstract:

The size of semiconductors continues to decrease like to Moore's Law and has been reduced to the sub-nanometer scale. Conventional silicon-based semiconductors are limited in size due to the short channel effect. Therefore, new materials are needed for the next generation of semiconductors.
The 2-dimensional (2D) semiconductors have been studied in optoelectronic and electronic fields due to excellent optical and electrical properties. In 2D materials, p-type semiconductors are just as rare as in three dimensions. The black phosphorus (BP) is a p-type material with excellent properties, but it oxidizes very quickly in air. Therefore, a glovebox must be used during the process and passivation is required after the process.
The field effect transistor with hydrothermally synthesized 2D Tellurium have been reported in 2018[1]. The 2D Tellurium demonstrated high field effect mobility (~500 cm2/Vs) with p type semiconducting property (Eg ~ 0.4 eV), comparing with BP, it also showed outstanding stability under ambient.
The PVP, which is widely used as a capping ligand in the synthesis of nanomaterials, is known to give an n-doping effect due to the electron donating group of long carbon chain. In the case of 2D Tellurium synthesized by hydrothermal method, PVP is used as capping ligand, indicating the interaction of PVP and 2D Tellurium existed. In this work, the unique electrical changes in hydrothermally synthesized 2D tellurium transistors were observed.

Keywords:

two dimensional, P-type semiconductor, 2D tellurium, PVP

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H13.04

Chiral transport of valley-polarized exciton-polaritons in h-BN/WS_2/h-BN waveguide cavities

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Abstract:

We demonstrate the chiral transport of valley-polarized exciton-polaritons in h-BN/WS_2/h-BN waveguide cavities. The large spatial overlap between the WS_2 excitons and the guided photon modes enables the formation of the exciton-polaritons in the h-BN/WS_2/h-BN waveguide cavities. By directly imaging the far-field emission from the waveguide structures under a focused excitation, we show that the chiral transport of valley-polarized exciton-polaritons, resulting in the spatial separation of oppositely polarized valley exciton polaritons at the ends of the waveguide. The valley polarization ratio is measured to be as large as 30 % at the waveguide ends for the propagation length of ~10 μm, and the valley contrast is controlled according to the circularly-polarized excitation conditions with opposite handedness. This finding can open up a route for realizing practical valleytronic optical devices.

Keywords:

Valley-polarized exciton-polaritons, Chiral transport, Valley polarization

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H13.05

Approach for reproducible and high-quality perovskites in workable temperature region

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Abstract:

Metal halide perovskites have been recognized as a light-emitting material for the next generation of high-efficiency and low-cost optoelectronic applications due to their near unity quantum yield. Their tri-colors emitted from tuning composition are crucial for the optoelectronic devices, and further finding new approaches to obtain high quality nanocrystals and understanding their formation process are essential for fundamental research and technological fields. However, a fast defocusing phenomenon of the size distribution in a short time can lead to difficult results as obtained samples with standard deviations and existence of surface trap states on colloidal inorganic halide perovskite can allow to occur PL loss. In this work, we try to develop highly reproducible synthetic process and consider workable temperature range of Cs-based all inorganic perovskites with different reaction parameters. These results provide the practicable platform for controllable synthesis and excellent support for evaluating the validity of synthetic design.

Keywords:

Metal halide perovskite, Light-emitting material, Reproducible synthetic process, Workable temperature range, Reaction parameters

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H13.06

Defect-related strain and doping characteristics in monolayer MoS_2

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Abstract:

화학 기상 증착 방법으로 성장된 단일 층 MoS_2에서 황 공극 결함에 의한 변형 및 도핑 특성 변화를 연구하기 위해서 공간 분해된 라만 산란 및 광발광 실험을 수행하였다. 성장된 MoS_2는 영역에 따라서 삼각형 모양의 단일 조각, 이러한 조각들이 일부 합쳐진 필름, 그리고 연속적인 필름 형태를 지닌다. 이들 각각의 영역에 대한 라만 산란 실험 결과 전자 밀도와 변형 수치가 영역에 따라서 다르게 나타남을 확인할 수 있었다. 광발광 실험을 통해 얻어진 전자 밀도 변화 또한 라만 실험 결과와 일치하였다. 이론적인 계산을 통해서 작은 조각들로 이루어진 필름 형태에 가까워질수록 황 공극 결함이 더 많이 형성 될 수 있음을 알 수 있었다. 흥미롭게도, 성장된 MoS_2 필름을 화학 처리한 결과 전체 영역에 걸쳐 전자 밀도가 거의 균일하게 되었다. [이 연구는 정부(과학기술정보통신부)의 재원으로 한국연구재단의 지원을 받아 수행되었음 (과제번호: 2019R1A2C1003366, 2022R1A4A1033358)]

Keywords:

Molybdenum disulfide, Raman spectroscopy, Strain, Doping, Sulfur vacancy

2023 KPS Fall Meeting
2023-10-24 - 2023-10-27

H13.07

Exciton-polariton condensation in perovskite microwire cavities

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Abstract:

The polariton devices with conventional III-V or II-VI semiconductors have demonstrated lots of remarkable results in the field of polariton physics in a few decades thanks to their exceptional quality of quantum-well-based microcavities grown through molecular beam epitaxy. Yet, it is hard to overcome their inherent small exciton binding energy and thus develop room-temperature working polaritonic devices. Lead halide perovskites are regarded as emerging materials in this field due to their large exciton binding energy, strong oscillator strength, and easily achievable synthesis methods. Furthermore, by combining their physical characteristics such as birefringence and spin-orbit interaction with polaritons, our understanding of polariton physics can be expanded to unexplored areas. Here, we fabricated one-dimensional $CsPbBr_3$ microwire single crystals embedded in between two distributed Bragg reflector mirrors to produce polaritons. In this structure, the behaviors of photons and polaritons vary with in-plane propagating direction in the cavity and appear with distinctive energy-momentum dispersions. Moreover, these geometrical properties give rise to the occurrence of non-zero momentum condensation and its coherent transport. These results propose a straightforward approach for manipulating the dynamic properties of polaritons.

Keywords:

Exciton-polartions, Perovskites, Microcavities

2023 KPS Fall Meeting
2023-10-24 - 2023-10-27

H13.08

Manipulating Rashba Excitons in Ferroelectric Two-Dimensional Perovskites

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Abstract:

The manipulation of excitons stands as a pivotal focus in recent research for controlling qubits by utilizing photon polarizations. Rashba spin-orbit coupling (or Rashba effect), which originated from the inversion symmetry breaking in halide perovskites, emerges as a promising approach for exciton spin manipulation. A splitting of the spin degeneracy of the exciton band can be induced into the momentum direction, thereby leading to improved spin coherence and modified spin-momentum locking. In this study, we explore the exciton characteristics of the two-dimensional Dion-Jacobson phase perovskite (4-AMP)MAPb2I7. Notably, the 2-D perovskites exhibit both of the ferroelectricity and the Rashba effect, providing the controllability of Rashba splitting by switching external electric fields. Through temperature-dependent and electric field-dependent spectroscopic measurements, we uncover the distinct manipulation of Rashba excitons. These observations can pave the way toward the realization of exciton-polariton qubits.

Keywords:

Rashba spin-orbit coupling, 2-D perovskites, ferroelectricity, exciton

2023 KPS Fall Meeting
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H14.01

Gate-tunable synaptic devices based on conductive bridges in two-dimensional $CrPS_4$

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Abstract:

In modern von Neumann architecture, there is a bottleneck problem where the processing speed decreases as the amount of data increases. In response to this, various forms of in-memory synaptic devices inspired by our brain's synapses have been proposed to perform parallel and concurrent calculations while consuming minimal energy.[1] Among these, Conductive Bridge Random Access Memory (CBRAM) is a promising synaptic device due to its fast operation speed and capability for low-voltage operation, which utilizes the formation and collapse of a cation bridge. However, it faces challenges such as low reliability, nonlinearity, limited multi-level resistance, and a small dynamic range. [2],[3]
To address these problems, this study implemented synaptic devices based on CBRAM using the two-dimensional magnetic material $CrPS_4$ instead of the commonly used h-BN or metal oxides.[4] CBRAM based on $CrPS_4$ exhibited distinct resistance states for on and off, even at a low voltage of 0.2 V. It also achieved 200 linear synaptic weights with a dynamic range of 42. Furthermore, this study demonstrated that the on-current of the cation bridge can be modulated through charge injection via a graphene electrode. This gate-tunable on-current can expand the range of conductance, and it has been revealed that this is attributed to a change in the conductance of graphene. These results suggest the potential of using the 2D material $CrPS_4$ to overcome existing issues in CBRAM. By achieving on-current modulation, the study also proposes the feasibility of implementing a greater number of resistance levels for dense circuits.

[1] Ielmini, Daniele., *Microelectronic Engineering*, 190, 44-53, 2018.
[2] Abbas, Haider, Jiayi Li, and Diing Shenp Ang., *Micromachines*, 13(5), 725, 2022.
[3] Cha, Jun-Hwe, et al., *Nanoscale*, 12(27), 14339-14368, 2020.
[4] Lee, Mi Jung, et al., *NPG Asia Materials*, 10(4), 23-30, 2018.

Keywords:

Gate-tunable synaptic devices, CBRAM, on-current modulation, CrPS4

2023 KPS Fall Meeting
2023-10-24 - 2023-10-27

H14.02

Ultrathin Skin-attachable TiO_2 Synaptic Array Integrated with an Organic Proximity Sensor for Real-time Finger Gesture Recognition

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Abstract:

Human gestures and motions recognition technology have attracted great attention with the growing industry of Metaverse platforms and robot technology that requires in-depth human-computer interaction. Among them, especially, finger gesture recognition has been becoming important due to its high degree of freedom for effective and direct communication between human and computer. To accelerate the realization of real-time gesture recognition and to promote seamless communications, one of the suggestions is integrating recognition function with sensory devices that can be adhered to skin and tissue surfaces, proving their long-term operational stability under mechanical and environmental changes. However, unlike ultra-flexible organic sensory devices that have long proven their moderate tolerance to mechanical changes, the unstable performances of artificial synapse under mechanical deformation has been an obstacle to developing the integration. Here, we realize finger gesture recognition in free space via integration between artificial synapse array and proximity sensors attached on skin surface. We integrated organic photodiodes used as proximity sensors with 8 × 8 crossbar array titanium oxide (TiO_2) based artificial synaptic device and on a one-micrometre-thick ultra-flexible substrate. It is revealed that synaptic array was stably maintained under severe mechanical deformation at 60 % strain with 6400 repeated input pulses. Via device-to-device integration, the finger motion to draw numeral with an Eulerian trail in the free space of 25 cm^2 was successfully recognized with maximum accuracy of ~ 95 %. Also, the arbitrary motion gestures at generalized sensing condition of organic proximity sensor device were well recognized presenting accuracy of ~82.5 % even in interpreting of different persons. Our finds suggest a future avenue of interacting wearables for human-machine interactions in extended reality.

Keywords:

ultra-flexible device, gesture-recognition sensor, neuromorphic system, organic photodiode, device integration

Vertical ZnO Nanotubes on Graphene Films for Applications in Flexible Photonic Synapses

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Abstract:

In this work, we present the fabrication of flexible photonic synapses utilizing vertically grown zinc oxide nanotubes on graphene layers. These ZnO nanotubes were heteroepitaxially grown on multilayer graphene substrates, achieved through precise control over their position and morphology. The device's behavior was characterized via current-voltage measurements under various illumination conditions, unveiling its intrinsic characteristics. Exploring the temperature-dependent transient photocurrent revealed the mechanism behind sustained photoconduction, a pivotal aspect underlying the device's operation. Upon exposure to light pulses, the device exhibited remarkable synaptic properties, effectively generating excitatory postsynaptic currents along with paired-pulse facilitation. Additionally, the successful implementation of long-term plasticity mechanisms was demonstrated through potentiation-depression characteristics, marked by high linearity and reliability. These features retained their integrity even under different bending conditions, affirming the device's flexibility. Simulation-based investigations underscored the seamless integration potential of the device into neural network structures, showcasing its promise in advancing neuromorphic systems via flexible optoelectronic synaptic devices.

Keywords:

Photonic synapse, ZnO device, Neuromorphic devices

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2023-10-24 - 2023-10-27

H14.04

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.

Furthermore, We fabricated HZO/graphene/SiO_x heterostructure and investigated the capability of electrostatic gating to reorient the polarity and polarization direction of HZO, as well as the switching characteristics of SiOx memristors fabricated on graphene. As a result, the SiO_x memristor exhibited an electroforming process and current-voltage (I-V) curve, indicating abrupt switching behavior at ~3.5 V (V_{SET}). The observed hysteresis curve reflected typical unipolar switching behavior with an impressive ON-OFF ratio of ~3.97×10^8 at V_{READ} = 1 V. In conclusion, our research highlights the potential of doped HfO_2 thin films and innovative graphene barristor devices for next-generation electronic applications. The results, including the V_{SET} modulation characteristics of the graphene barristor device, will be presented in the upcoming conference.

Keywords:

Neuromorphic computing, Artificial synapse, Synaptic barristor, Ferroelectric HZO, Rebound depolarization

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2023-10-24 - 2023-10-27

H14.05

Artificial synaptic device utilizing 2D heterostructure of PtS_2 and CrSBr for neuromorphic applications

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Abstract:

Neuromorphic computing, inspired by the human brain, holds great promise for a wide range of artificial intelligence tasks. Transition metal dichalcogenides (TMDCs), such as chromium sulfide bromide (CrSBr) and platinum disulfide (PtS_2), have gained significant attention due to their unique electronic properties, including high mobility, expansive surface area, and flexibility. In this study, we introduce a heterostructure comprising CrSBr and PtS_2, with PtS_2 serving as the channel layer, unveiling remarkable memory attributes. These encompass a significant memory window of 76 V in the back gate voltage, robust retention (5.7×10^4 s), high endurance (2000 cycles), and a notable current ON/OFF ratio (2.71×10^6) for program and erase operations. The synaptic behavior and memory window can be manipulated by capturing and releasing electrons through gate voltages, a phenomenon linked to sulfur vacancies in CrSBr. Furthermore, successful demonstrations of paired-pulse facilitation (PPF) and paired-pulse depression (PPD) emphasize the replicable nature of the outcomes. These discoveries set the stage for brain-inspired neuromorphic computing and advanced artificial intelligence systems.

Keywords:

Synaptic Transistor, PtS2, CrSBr, Neuromorphic Computing

2023 KPS Fall Meeting
2023-10-24 - 2023-10-27

H14.06

Excitation Spot Size Dependence of Photonic and Exciton Polaritonic Modes in GaN Microwire

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Abstract:

Due to high oscillator strength and large exciton binding energy, GaN hexagonal microwire has been used for generating room-temperature polaritons. But when laser applied to GaN microwire, various photonic modes and polariton modes such as whispering gallery modes made by total internal reflection and Fabry-Perot modes made by two parallel reflecting surfaces can be generated simultaneously. Here, we investigated a method about extracting specific mode which we want to analysis. Excitation spot size dependence of angle-resolved photoluminescence was studied to investigate tendency of photonic and polaritonic modes. We can suppress Fabry-Perot mode by narrowing excitation spot size. Besides different polariton condensation behavior with excitation spot size are investigated. Also separating whispering gallery polariton modes by using interference pattern in far-field are presented.

Keywords:

III-nitride 1D microcavity, Exciton-polariton, Whispering gallery mode, Fabry-Perot mode

2023 KPS Fall Meeting
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H15.01

Space Charge Redistribution of Modified $FAPbI_3/SnO_2$ Interface via Fermi Level Tuning in Highly Efficient Perovskite Solar Cells

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Abstract:

Lead halide perovskites $APbX_3$ (A = methylammonium (MA) or formamidinium (FA); X is Cl, Br or I), have garnered attention as potential energy-harvesting materials for optoelectronic devices due to their remarkable photovoltaic properties. Among these, the FA cation demonstrates the most promising performance and attributes to the 3D formamidinium lead triiodide ($FAPbI_3$) perovskite, which has a narrow bandgap (Eg) and greater thermal stability in comparison to its MA counterpart. This enhanced stability is owed to the higher activation energy of the FA cation relative to the MA cation. Despite $FAPbI_3$ perovskite displaying greater stability as an absorber layer for perovskite solar cells in contrast to $MAPbI_3$, issues of device instability persist due to the ionic migration of iodine vacancies with absorbed Pb^{2+} at the oxide surface. This phenomenon gives rise to the hysteresis loop in photovoltaic measurements. In this study, we have customized the charge-selective interfaces and controlled the Fermi level at the FAPI/SnO_2 junction to enhance charge transport. The built-in potential at the space charge zone of $FAPI_3/SnO_2$ was explored using Ultraviolet Photoelectron Spectroscopy, and the ionic and electronic conductivities, as functions of film thickness with a passivated interface, were analyzed through D.C polarization measurements. The space charge zone of cation and anion-treated SnO_2 (NH_4^+-SnO_2 and Cl^--SnO_2) [1] was found to exhibit reduced zones under induced light. Based on our findings, it is evident that interfaces modified with cationic and anionic treatments lead to a decrease in Pb^{2+} absorption at the oxide surface. Additionally, these modifications enhance charge transport while significantly minimizing the occurrence of interfacial defects. This collective effect considerably amplifies the device performance of perovskite solar cells.

[1] J. H. Kim, J. H. Park, Y. H. Kim, and W. Jo, "Improvement of Open-Circuit Voltage Deficit via Pre-treated NH_4^+ Ion Modification of Interface between SnO_2 and Perovskite Solar cells", Small, 2204173 (2022)

Keywords:

FAPbI3 Perovskite, Space charge, Fermi level tuning, Interface

2023 KPS Fall Meeting
2023-10-24 - 2023-10-27

H15.02

Advanced Method for Scalable Fabrication of Sub-10 nm Nanogaps with High Yield

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Abstract:

Nanogaps are widely employed as crucial components in diverse fields including sensors, optoelectronics, and energy harvesting. Despite various demonstrated methods for fabricating sub-10 nm nanogaps, achieving simultaneously high productivity and high-resolution characteristics remains challenging. Furthermore, despite several attempts to fabricate nanogaps in large areas, limitations persist including low yield, limited available metal species, and pattern shapes. Here, we present an advanced method for fabricating sub-10 nm featured nanogap on a wafer-scale with a high yield. We employ a patterned photoresist layer as a protecting and sacrificial layer for the ion milling and lift-off process. With the advantages of our fabrication procedure, we successfully achieved defect-free nanogap structures on a 4-inch wafer, leading to an almost 100% yield due to the elimination of manual handling seen in previous methods. Additionally, our method allows for utilizing various metals, including copper, silver, aluminum, vanadium, platinum, palladium, and more. Furthermore, it enables the creation of various patterns on a wafer-scale, including periodic patterns with dimensions ranging from tens to hundreds of nanometers. To validate the efficacy of our approach, we performed terahertz time-domain spectroscopy (THz-TDS) to investigate THz waves transmitted through the nanogap structure manufactured by the method. The results reveal excellent agreement with the previous findings, affirming the effectiveness of our advanced fabrication process. Overall, our approaches offer a straightforward, scalable, and innovative way of preparing a nanogap platform with sub-10 nm features across an entire wafer. This method is easily integrated into the ultraviolet (UV) lithography-based semiconductor fabrication processes, paving the way for the widespread commercialization of nanogap-based devices.

Keywords:

Nanogap fabrication, THz-TDS, wafer-scale fabrication, High Yield

H15.03

Improved Hole Injection in Hybrid Light-Emitting Transistors Incorporating Lithium and Copper(II) Poly(Styrene Sulfonate)

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Abstract:

Light-emitting transistors (LETs) are optoelectronic devices that perform switching and light-emitting functions in a single device. Hybrid LETS (HLETs) using inorganic metal oxide semiconductors as the transport layer with organic emissive layers and hole-injection layers (HILs) combine the excellent switching performance of metal oxides with the flexibility and tunability of organic semiconductors. However, the efficiency of n-HLETs typically suffers from unbalanced electron and hole injection. To overcome this issue, two hybrid polyelectrolytes—lithium poly(styrene sulfonate) (Li:PSS) and copper(II) poly(styrene sulfonate) (Cu:PSS)—are investigated as HILs in HLETs. HLETs employing Cu:PSS interlayers exhibit significantly enhanced brightness values of up to 4.89 × 103 cd m^{-2} and an external quantum efficiency (EQE) of 0.45%, compared to HLETs without HIL (no emission) and pristine poly(3,4-ethylenedioxythiophene):poly(styrene sulfonate) (PEDOT:PSS) (2.17×10^2 cd m^{-2} with an EQE of 0.01%). To understand how the HILs influence the performance, ultraviolet photoelectron spectroscopy (UPS) analysis and photoluminescence (PL) quenching studies are performed, which reveal improved energy band structure and reduced quenching using metal:PSS HILs. This work provides useful information about the function that polyelectrolyte HILs perform in HLET devices which may be exploited to develop new materials and applied in other types of optoelectronic devices.

Keywords:

Hybrid light-emitting transistors, Zinc-oxinitride, Copper(II) poly(styrene sulfonate), Lithium poly(styrene sulfonate), Super yellow

2023 KPS Fall Meeting
2023-10-24 - 2023-10-27

H15.04

Investigation of Interfacial Electronic Structure and Performance Enhancement of Optoelectronic Devices using Cytosine of Nucleobases

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Abstract:

Nucleobases, which are fundamental constituents of DNA and RNA, have received considerable attention as promising semiconductor materials for future applications due to their unique biological properties, such as biocompatible and biodegradable. Furthermore, studies on nucleobases in the past decade have shown that these can also exhibit unique electronic properties. However, there is still a lack of understanding of charge transport mechanisms in electronic devices. The charge transport properties are dependent on the electronic structure of the interface between nucleobase materials and any contact materials. Therefore, the understanding of interfacial electronic structure is significantly important in terms of enhancing device efficiency and functionality.

In this study, we investigated the interfacial electronic structure between Cytosine, one of the nucleobases, and organic materials and metals using in situ ultraviolet, X-ray, and inverse photoelectron spectroscopy measurements. Subsequently, we employed Cytosine as an electron injection layer (EIL) in various optoelectronic devices, including perovskite solar cells, organic light-emitting diodes, and organic solar cells. As a result, the device performances were highly enhanced by adding Cytosine EIL. Absolutely, the interfacial electronic structure plays a key role in determining the properties and performance of the device. Consequently, these results would provide insights into interface engineering strategies for utilizing Cytosine as an electronic material in bio-electronic devices.

Keywords:

Nucleobases, Cytosine, Interfacial electronic structure, In situ photoelectron spectroscopy, Perovskite solar cells

2023 KPS Fall Meeting
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H15.05

Towards highly emissive, thermally stable and low threshold amplified spontaneous emission from halide perovskite thin films

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Abstract:

Over the past decade, perovskite semiconductors have gained significant attention for their potential use in lasers due to their favorable characteristics like high mobility, modal gain coefficient, and oscillator strength. Different types of perovskites, including (quasi) two-dimensional, nanocrystals, and Dion-Jacobson structures, have already shown impressive lasing properties. While there has been extensive research aimed at improving perovskite solar cells and light-emitting diodes (LEDs), most existing studies have mainly focused on demonstrating amplified spontaneous emission (ASE) or lasing effects, which has left a critical gap in developing a comprehensive strategy to lower lasing thresholds and enhance both photo- and thermal-stability.
To attain population inversion in a perovskite gain medium, you need a carrier density threshold of roughly around 10^{18} cm^{-3}, which is at least three orders of magnitude higher than what's needed for LEDs. As a result, when the perovskite layer operates as a laser, it generates a significant amount of heat. In our research, we substituted the glass substrate with sapphire and used graphite and copper to manage and dissipate this heat. By taking this approach, we noticed enhanced photo-stable ASE properties, especially when subjected to intense excitation conditions.
To control the lasing modes in the perovskite layer, you need to ensure that the film has a minimum thickness, known as the cutoff thickness. Moreover, having a thicker film is beneficial for improved optical confinement. However, because perovskite strongly absorbs light, having films that are overly thick leads to higher lasing or ASE thresholds. Therefore, there's an ideal film thickness that offers the lowest threshold for achieving the desired outcome. In our study, we conducted investigations to identify this optimal film thickness, which provides the lowest ASE threshold while still delivering a high output intensity.

Keywords:

Perovskite, Lasing, Amplified Spontaneous Emission

2023 KPS Fall Meeting
2023-10-24 - 2023-10-27

H15.06

Practical issues on all-polymer passive daytime radiative cooling paint

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Abstract:

Applying passive daytime radiative cooling (PDRC) paint on building surfaces has gained significant interest as a sustainable method for cooling without energy consumption or carbon emissions. Recently, porous polymer coatings (PPC) have emerged as a promising option due to advantages like efficient cooling, cost-effectiveness, flexibility, and scalability. Nonetheless, maintaining consistent performance across diverse outdoor conditions remains a challenge due to the morphology of PPC developed through the evaporation-induced phase separation method (EIPS), which heavily relies on environmental factors such as temperature and humidity during evaporation. In this research, we identifies the sensitivity of PPC to humidity during its drying process and introduces a straightforward approach to alleviate this concern. Specifically, the study reveals that the solar reflectance capability of PPC declines significantly with rising humidity levels beyond 30% RH. At 45% RH, the PDRC ability of PPC is completely lost, and at higher humidity levels, it even transforms into a material that absorbs solar heat. However, by incorporating a small quantity of fumed silica into PPC, the PDRC performance can be preserved up to 60% RH, leading to a remarkable 1050% increase in coverage area for the United States. This investigation sheds light on a crucial consistency challenge related to PPC-based PDRC paint, an aspect that has been previously disregarded. The study also provides practical guidance for addressing this fundamental obstacle in the development of dependable PDRC paint for industrial utilization.

Keywords:

Raditive cooling, Porous polymer coating, Evaporation-induced phase seperation, Light scattering in a random media

2023 KPS Fall Meeting
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H16.01

The first reported altermagnet RuO_2: Density functional theory study

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Abstract:

In condensed matters, a collinear spin-order can lead to either ferromagnetic or antiferromagnetic states, depending on whether the net moment is compensated or not. The typical antiferromagnet has two magnetic sublattices with magnetic moments antialigned against each other, resulting in a band structure that is not spin-polarized across the entire Brillouin zone. Recently, a novel atypical antiferromagnet was reported and dubbed the altermagnet. This exhibits a spin-polarized band structure in specific regions of the Brillouin zone, while remaining with a precise zero net moment as in a typical antiferromagnet.
In this presentation, I will focus on the Rutile RuO_2 that shows itinerant antiferromagnetic characters. Through calculations based on the density functional theory, we found that the RuO_2 with the magnetic sublattice coupled by π/2-rotation leads to an unprecedented spin-polarized band structure in the antiferromagnetic state. This indicates that this system is the first altermagnet.

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Reference

[1] K.-H. Ahn, A. Hariki, K.-W. Lee, and J. Kunes, Phys. Rev. B **99**, 184432 (2019).

Keywords:

Altermagnet, RuO2, Density functional theory, first principles calculations

H16.02

Spin group and Space group: a necessary ingredient for altermagnetism

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Abstract:

Altermagnetism [1-4], recently proposed new phase in condensed matter, has recalled attentions but one obstacle is symmetry arguments used to distinguish it from other already recognized magnetic phases, ferromagnetism and antiferromagnetism. Hence, here we provide a pedagogical introduction on symmetry arguments necessary to understand altermagnetism. As other fields of physics, condensed matter physics also heavily exploits symmetry, most likely space group or point group symmetry. Furthermore, recent research has applied magnetic space group as well. On the other hand, to identify altermagnetism, spin group [5], introduced in 70's, is used which is distinct from aforementioned groups. Therefore, introductory classification and distinction among spin group, space group, and magnetic space group are necessary.

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[4] Pengfei Liu, Jiayu Li, Jingzhi Han, Xiangang Wan,and Qihang Liu "Spin-Group Symmetry in Magnetic Materials with Negligible Spin-Orbit Coupling " Phys. Rev. X **12**, 021016 (2022).
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Keywords:

altermagnetism, spin group, space group, magnetic space group

Spin Coherence Length of Antiferromagnets

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Abstract:

Spin-transfer torque (STT) is one of the most important phenomena in spintronics. Spin transfer from conduction electrons to localized moments is governed by the absorption of spin currents. In ferromagnets, spin majority and minority bands are clearly distinct so that a spin current polarized transverse to a localized moment experiences strong dephasing in ferromagnets, resulting in a very short spin absorption length (or called spin coherence length). This short spin coherence length is responsible for the surface-torque characteristic of STT for ferromagnets; it makes the STT efficiency inversely proportional to the ferromagnet thickness. In this talk, we will discuss distinct features of spin-current absorption in various classes of antiferromagnets (AFMs) – namely, collinear AFM, non-collinear AFM, and altermagnet. They have qualitatively different spin degeneracy in the momentum space, resulting in different spin coherence length and associated STT characteristics.

Keywords:

Spin-transfer torque, Spin coherence length

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H16.04

Broken Kramers' Degeneracy in Altermagnetic MnTe

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Abstract:

Altermagnetism is a newly identified fundamental class of magnetism with vanishing net magnetization but has time-reversal symmetry broken electronic structure. Probing the unusual electronic structure with nonrelativistic spin splitting would be a direct experimental verification of altermagnetic phase. By combining high-quality film growth and in situ angle-resolved photoemission spectroscopy, we report the electronic structure of an altermagnetic candidate, α-MnTe. Temperature dependent study reveals lifting of Kramers' degeneracy accompanied by magnetic phase transition at TN = 267 K with spin splitting of up to 0.5 eV, providing direct spectroscopic evidence for altermagnetism in MnTe.

Keywords:

altermagnetism, time reversal symmetry breaking, spin split bands

I1.01

EinsteinFirst – A timely, theoretically-informed Years 3-10 curriculum initiative

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Abstract:

Einstein-First is an Australian Research Council funded initiative, designed to modernise the school science curriculum by introducing students in Years 3-10 (aged 7-16 years) to 21st century physics. Over the past six years, a seamless spiral curriculum for introducing topics and concepts of Einsteinian physics encompassing quantum physics, relativity and gravitation has been developed and taught in Years 3-10 in a large sample and wide variety of classes in Western Australian schools. This curriculum initiative introduces our best modern understanding of physical reality at age-appropriate levels using toys, simple experiments and role plays. There is also an associated mathematics program. The curriculum is based on six educational principles for effective learning and guided by the Model of Educational Reconstruction. In this presentation, we introduce each of these aspects – the spiral curriculum, educational principles for effective teaching and learning, and the Model of Educational Reconstruction within the context of Einstein-First.

Keywords:

Primary school curriculum, junior high school curriculum, modern physics, educational principles, effective teaching and learning

I1.02

Evaluating secondary student conceptual understanding of light behaviour

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Abstract:

Quantum physics (QP) concepts, that are increasingly being included in Australian secondary curricula, typically ignore foundational conceptual understanding. Einstein-First is addressing the issue by developing a modernised progression of learning from Years 3-10 encompassing Einsteinian physics concepts in an accessible and fun way. The program began national implementation this year, 10 years after the initial trial. Here, we investigate changes in Year 9 (aged 14-15) students' understanding of foundational QP concepts from a series of lessons taught by the researcher and teachers across 4 trials. The research involved a pre-post design and mixed method analysis to measure students' test responses. Our findings show that concepts relating to QP (e.g. quantum probability, photon properties) are initially challenging for students but outcomes improved after instruction. Test scores and a thematic analysis of responses indicate that the language used by students evolved from classical to Einsteinian and that activity-based instruction improved student outcomes.

Keywords:

Einsteinian physics, Assessing knowledge and understanding, Secondary education, Photons, effective teaching and learning

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I1.03

A Critical Consideration of Teaching Modern Physics in Primary and Middle Schools: Focus on Einstein-First project

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Abstract:

In line with the rapid development of science and technology, many researchers have been conducting research on how to introduce modern physics into elementary and secondary science curriculum. In Korea, with the revision of the new curriculum, in-depth discussions have been ongoing. On the other hand, the Einstein-first project led by the Australian team can be a world-known project that promotes the modernization of the elementary and secondary science education curriculum through long-term planning and practice. Therefore, understanding the Einstein-first project and deriving its implications can be of great help in modernizing the physics curriculum in Korea. As part of such an effort, this presentation will focus on the premise behind the argument, especially along with the core argument of the Einstein-first project, to analyze it and discuss the meaning of the analysis results.

Keywords:

modernization of physics curriculum, Einstein-first project, modern physics, elementary and secondary science curriculum

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I2.01

Developing 1ton LAr Coherent Elastic Neutrino Nucleus Scattering detector

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Abstract:

In 2020, coherent elastic neutrino-nucleus scattering (CEvNS) was detected by CENNS-10, 24-kg single-phase liquid argon detector. The measured result of CENNS-10 is consistent with the Standard Model prediction with 30% statistical uncertainty. CENNS-1ton, a ton-scale single-phase liquid argon detector, is under construction at Seoul National University and will be commissioned next year at Neutrino Alley at Oak Ridge National Laboratory. We will present the current status of CENNS-1ton detector development.

Keywords:

CEvNS, COHERENT

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I2.02

SND@SHiP as tau neutrino short-baseline experiment

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Abstract:

In this study, we interpret SHiP experiment as new short-baseline experiment for tau neutrino, hence it could constrain $₩nu_s-₩nu_₩tau$ mixing. With prior uncertainty of parton distribution function of proton, the uncertainty of tau neutrino flux is ~20%. Therefore, we can constrain $₩theta_{34}$ by current SHiP design. Meanwhile, if we install new SND that follows after HS(hidden sector) detector, it could give sensitive constraints as uncertainty of tau neutrino flux is controlled by the first SND. We are going to show how much the sensitivity is changing.

Keywords:

neutrino oscillation, SHiP experiment, sterile neutrino

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I2.03

Observation of Collider Muon Neutrinos with the SND@LHC Experiment

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Abstract:

SND@LHC is a new 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 the ATLAS interaction point in the unused TI18 tunnel. The detector is composed of a hybrid system based on a 800 kg target mass of tungsten plates, interleaved with emulsion and electronic trackers, followed downstream by a calorimeter and a muon system. In this talk, we will report the first direct observation of muon neutrino interactions with the SND@LHC detector at the LHC, using a dataset collected by SND@LHC in 2022, corresponding to an integrated luminosity of 36.8 fb^{-1}. We will also report the current status of the SND@LHC experiment.

Keywords:

Collider Neutrino, SND@LHC , Nuclear emulsion

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I2.04

Status of JSNS^2-I & JSNS^2-II experiment

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Abstract:

The JSNS^2 (J-PARC Sterile Neutrino Search at the J-PARC Spallation Neutron Source) experiment aims to search for sterile neutrinos with Δm^2 near 1eV^2. A 3 GeV J-PARC proton beam incident on a mercury target produces an intense neutrino beam from muon decay at rest. The JSNS^2 detects the neutrino oscillation to electron antineutrinos via the inverse beta decay reaction. JSNS^2-I has a fiducial volume of 17 tons filled with gadolinium-loaded liquid scintillator to detect electron antineutrinos efficiently and is expected to provide the ultimate test of the LSND anomaly by replicating nearly identical conditions with a much better signal/noise ratio. JSNS^2-I located at 24 m baseline from the target starts the physics run in 2021 and JSNS^2-II having 32 tons of fiducial volume at 48 m baseline is under construction. The second detector will improve sensitivity on low Δm^2 region for sterile neutrino search. In this presentation, we will summarize the current status, preliminary analysis results, and the prospect of the JSNS^2-II experiment.

Keywords:

sterile neutrino, JSNS2

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I2.05

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 5×10^{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. This summer, the experiment received the final approval from J-PARC and KEK. The status of SUBMET will be discussed in this talk.

Keywords:

millicharge, J-PARC, dark photon

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I2.06

Module construction and tests for SUBME

YOO Jae Hyeok *[1], WON Eunil [1], CHOI Suyong [1], CHO Sungwoong [1], MOON Hyunki [1], JEONG Hoyong [1], SEO Chang Hyun [1], HWANG Insung [1]
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Abstract:

The detector of the SUBMET is composed of long scintillators that allow the particles with a small electric charge (Q) to produce photons by ionization energy loss. One detector module is composed of a scintillator bar with an optically coupled PMT. In this talk, the status and the results of the module assembly and tests will be discussed.

Keywords:

SUBMET, millicharge, scintillator, PMT

I2.07

Study of B^0 -> l^+ τ^- rare decay at Belle experiment

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Abstract:

We study lepton-flavor-violating decay B0 → l τ with leptonic τ decay channels. Samples simulated by Belle detector of KEKB electron-positron collider were used. An Upsilon(4S) meson is created by an 8 GeV electron and 3.5 GeV positron collision and decays into two B mesons. One B meson is considered as a signal decaying with lepton and τ, and the other is reconstructed by semileptonic B meson. It is reconstructed by full-event interpretation (FEI). Basic quality control to suppress background events 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 pl*, which is the primary lepton momentum of the CM frame, is used. From the shape of the signals and the background distribution of pl*, 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.

Keywords:

Belle, KEKB, B meson, LFV, BDT

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I2.08

Status of BESIII experiment and Korean-BESIII group activities

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Abstract:

BESIII is a unique electron positron collider experiment, located in Beijing, China, based on scan-data taken at CM energies from ~2GeV to ~5GeV.
These energies range from the production threshold of tau pairs at the lowest energies to the production of Lambda_c pairs at the highest energies, and also include the production of various Charm mesons in the middle as well as XYZ mesons.
We introduce recent Physics highlights from the BESIII group and the activities of CAU group.

Keywords:

I3.01

status of NEOS-II experiment

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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. In this talk, we report the analysis status and preliminary results of the experiment

Keywords:

NEOS, neutrino, reactor, oscillation, short baseline

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I3.02

Measurement of Reactor Antineutrino Spectra from ^{235}U and ^{239}Pu Fission at RENO

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Abstract:

We report the measured reactor antineutrino spectra from the fission of ^{235}U and ^{239}Pu using 2,500 days of RENO near detector data. The change of fission fraction and thus reactor neutrino yield during a fuel cycle is used to separate ^{235}U and ^{239}Pu fission contributions to the observed inverse beta decay (IBD) yield spectrum. The antineutrino spectra from the ^{235}U and ^{239}Pu fission are obtained from unfolding the detector effects from the separated prompt spectra. The IBD yield from the ^{235}U (^{239}Pu) fission is measured as 6.31 ± 0.13 (4.66 ± 0.19) cm2/fission. This corresponds to a deficit of (6.4 ± 3.2)% ((-5.8 ±5.2) %) with respect to the prediction by Huber. The deficit in the 235U fission is alleviated in comparison with the Kurchatov Institute (KI) conversion model and the Estienne-Fallot (EF) summation model. The prompt (antineutrino) spectrum from the ^{235}U fission shows a clear excess at 5 MeV (6 MeV) of prompt (neutrino) energy with 4.3 σ significance while such a clear excess is not seen in the ^{239}Pu spectrum.

Keywords:

RENO, reactor antineutrino, neutrino oscillation

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I3.03

Combine measurement of θ_{13} using reactor antineutrino events rates with neutron capture on hydrogen and Gadolinium at RENO

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Abstract:

The RENO Collaboration reports a measured value of the smallest neutrino mixing angle (θ_{13}) based on ~2800 days of reactor electron antineutrino events with a delayed signal of neutron capture on hydrogen (H). The neutron captures on H emitting a 2.2 MeV γ-ray are not easily detected because of high environmental radioactivity below 3.5 MeV, Due to the satisfactory purification of liquid scintillator, use of low–radioactivity photomultiplier tube (PMT) glass, and effective selection criteria, it is possible to extract the reactor neutrino signal against the high backgrounds and observe a clear deficit of the reactor neutrino rate. Based on a rate-only analysis, we obtain $\sin^2(2\theta_{13})$ =0.0815±0.006(stat)±0.011(syst). This corresponds to a more precisely measured θ_{13} value of the n-H IBD candidates than the previous measurement from 1500 days of data. With the increased data sample, the statistical error of this measurement is reduced by roughly 40%. Based on improved background uncertainties and additional removal of PMT noise events, the systematic error is reduced by roughly 60%. We also measured the $\sin^2(2\theta_{13})$ value from the n-H analysis combined with that from the most recent n-Gd measurement at RENO. A combined result is obtained by a simultaneous fit of the n-H and n-Gd data sets. Correlations between the two analyses are estimated for the uncertainties of detection efficiencies, backgrounds, $(\Delta m_{ee})^2$, and reactor-related parts. The combined result uncertainty is ~7% lower than the n-Gd rate-only result. Furthermore, the ratio of $\sin^2(2\theta_{13})$ between the n-H and n-Gd rate-only analyses is also reported.

Keywords:

RENO, reactor neutrino, neutrino oscillation, reactor neutrino oscillation, neutrino

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I3.04

Developing a prototype detector for the Reactor Experiment for Neutrinos and Exotics

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Abstract:

Reactor Experiment for Neutrinos and Exotics (RENE) aims to probe sterile neutrino oscillation at Δm_41^2 ~ 2 eV^2 region. The prototype detector consists of a cuboid gamma catcher filled with liquid scintillator (LS) and a cylindrical target with Gd-loaded LS. The detector will be located at the tendon gallery of a reactor in Hanbit Nuclear Power Plant. In this presentation, we will report on the current status of detector development and background study details.

Keywords:

Neutrino oscillation, Reactor neutrino, Liquid scintillator, Sterile neutrino

Experimental Design for Korea Experiment on Magnetic Monopole (KAEM) in Low-mass, Low-magnetic Charge Region: GEANT4 Simlulation Results of a Magnetic Bottle to Offset Reduced Generation Efficiency from a Thin Target

LEE Junghyun *[1], BYEON HeeJeong [1], DO HyeonSeok [1], HUH Changgi [1], KIM Bobae [1], LEE Sehwook [1], HAUPTMAN John M[2], RYU MinSang [3]
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Abstract:

After Paul Dirac's introduction of the quantization condition in 1931, extensive research was undertaken to search magnetic monopoles in the region where the mass exceeds that of an electron and the magnetic charge is greater than 68.5e. However, evidence of the existence of monopoles has remained elusive. Revisiting the historical trajectory of this research focus, we aim to explore in the opposite direction: searching for monopoles in the region previously unexplored in experiments, specifically where the mass is less than or equal to that of an electron and the magnetic charge is less than 68.5e.

In our search region, monopoles can potentially be generated through the annihilation of positron-electron pairs in their rest state and may possess a notably short radiation length. To prevent the absorption of the monopoles in the target, we designed a thin aluminum target. Concurrently, considering that a thin target could reduce the probability of annihilation, we implemented a magnetic bottle to confine the positron within a specific region, thereby enhancing the likelihood of annihilation. In this presentation, I will discuss the validation results for the magnetic bottle and, through simulation outcomes, predict the potential annihilation efficiency when a target is present. Consequently, I aim to forecast the signal generation efficiency that can be anticipated under our experimental design.

Keywords:

magnetic monopole, low magnetic charge monopole, GEANT4, magnetic bottle

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I3.06

A measurement of the properties of the tetrabutyltin-loaded liquid scintillator for the double beta decay experiment

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Abstract:

The tin-loaded liquid scintillator has a great advantage for the double beta decay experiment because of the high solubility of organo-tin in octane. Tetrabutyltin (TBSn, 34% tin by weight) was used to load tin in the liquid scintillator composed of linear alkylbenzene (LAB), 2,5-diphenyloxazone (PPO, 3g/L) and 1,4-bis(2-methylstyryl)benzene (bis-MSB, 30 mg/L). Optical properties such as relative light yield were measured as a function of tin concentration in the Teflon vessel. In addition, samples of TBSn that had been purified by vacuum distillation were also tested in order to assess the effect of impurities. Measurement of internal radioactivity caused by impurities in TBSn is now performed at the Yemi Underground Lab (Yemilab) in Jeongseon.

Keywords:

tetrabutyltin, double beta decay, underground physics, liquid scintillator

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I3.07

Efficiency analysis of GEM detector with boron converter

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Abstract:

This study explores a cost-efficient neutron detection technique using Gas Electron Multiplier (GEM) detectors with boron converters. We investigated the performance of a neutron detection system consisting of two types of boron-based converters: a sheet of natural pure boron (0.5 mm) and a cathode coated with B-10 isotope-enriched boron carbide(1 μm). Geant4 simulation is used to estimate the detection efficiency by analyzing the energy deposition of particles generated by neutron capture inside the detector and we compare it with the neutron beam test results.

Keywords:

GEM, Boron, neutron, detector

I3.08

Pulse Shape Discrimination of Organic Scintillation in a Phoswich Detector

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Abstract:

The scintillations of organic scintillators are similar in shape, posing a challenge in signal discrimination.
However, employing a machine learning technique enables the distinction of these signals.
We made a single-readout phoswich detector by optically coupling the plastic scintillator and the liquid scintillator, and received data using Co-60 (gamma source) and AmBe (neutron and gamma source).
Utilizing the Boosted Decision Tree algorithm, we achieved a discrimination power of 3.01σ in classifying the gamma radiation signals from two scintillators.
Also, we seperated neutron and gamma signals from each scintillator using the same approach.

Keywords:

machine learning, pulse shape discrimination, organic scintillator, phoswich

Measuring the matter-radiation equality scale using eBOSS quasars

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Abstract:

The position of the peak of the matter power spectrum, the so-called turnover scale, is set by the horizon size at the epoch of matter-radiation equality. It can easily be predicted in terms of the physics of the Universe in the relativistic era, and so can be used as a standard ruler, independent of other features present in the matter power spectrum, such as baryon acoustic oscillations (BAO). We use the distribution of quasars measured by the extended Baryon Oscillation Spectroscopic Survey (eBOSS) to determine the turnover scale in a model-independent fashion statistically. We use the measured equality scale to make inferences about the matter density of the Universe, and combine with other late-time standard candles and standard rulers to infer the value of the Hubble expansion rate at redshift zero (H0). We find that H0 = 74.7 ± 9.6 km/s/Mpc, combining with the Pantheon supernova (SN) sample, and H0 = 72.9 +10/-8.6 km/s/Mpc combining with the eBOSS LRG and Lyman-α BAO. These results are closer to the low-redshift SH0ES estimated value for H0 over the value from the Planck satellite, though consistent with both. Furture large-scale galaxy surveys such as DESI will refine the measurment of this scale significantly, providing more information on the very early Universe.

Keywords:

cosmology, large-scale structure, early universe, dark energy

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I4.02

Late-time Cosmology without Dark Sector but with Closed String Massless Sector

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Abstract:

We propose to solve the dark energy problem by postulating the massless sector of closed strings. This sector constitutes the gravitational multiplet of string theory in four-dimensional cosmology and predicts that the expansion of an open Universe defined in string frame is readily accelerating. We confront the prediction with the late-time cosmological data of Type Ia supernovae and quasar absorption spectrum, which probe the evolutions of the Hubble parameter and possibly the fine-structure constant. We report that the observations are in agreement with the prediction without any dark sector. We estimate the Hubble constant, $H_0 \simeq 71.2 \pm 0.2\ \mathrm{km/s/Mpc}$.

Keywords:

String, Cosmology, Dark Sector, Hubble, Fine-Structure Constant

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I4.03

Formation of the first supermassive black holes in ultralight dark matter halos

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Abstract:

We suggest that seeds for supermassive black holes can form from collisions of cold gas in ultralight dark matter halos. In this scenario, the first supermassive black holes with mass $O(10^5)$ M_s can form in the early universe. This scenario also explains the absence of intermediate massive black holes in large galaxies.

Keywords:

ultralight dark matter, supermassive black holes

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I4.04

Final parsec problem of black hole mergings and ultralight dark matter

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Abstract:

When two galaxies merge, they often produce a super massive Binary Black Hole (BBH) at their center. Numerical simulations show that BBHs typically stall out at a distance of a few parsecs apart, and take billions of years to coalesce. This is known as the final parsec problem. We suggest that Ultralight Dark Matter (ULDM) halos around BBHs can generate dark matter waves due to gravitational cooling. These waves can effectively carry away orbital energy from the black holes, rapidly driving them together and solving the final parsec problem. To test this hypothesis, we performed numerical simulations of BBHs inside ULDM halos. Our results imply that ULDM waves can indeed lead to the rapid orbital decay of BBHs.

Keywords:

Final Parsec Problem, Binary Black Hole, Ultralight Dark Matter, Gravitational Cooling

I4.05

Quantum radiation from the collapse of a dust cloud

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Abstract:

In three-dimensional low-energy string theory, we study the gravitational collapse of a dust cloud and then investigate the quantum radiation from the cloud by employing the functional Schrödinger formalism. In the formation of the black string, the interior geometry of the cloud can be chosen as an appropriate inhomogeneous dust distribution consistent with the Israel junction conditions. In the incipient black hole limit, we calculate the wave function from the time-dependent Schrödinger equation for a massless scalar field.

Keywords:

Black strings, Black holes, Gravitational collapse, Inhomogeneous dust

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I4.06

Cauchy horizon from numerical computations

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Abstract:

We revisit numerical simulations of charged black holes and see the dynamics of the inner horizon. We relate this numerical observation and the recent progress in Cauchy horizon theorems.

Keywords:

Cauchy horizon, Numerical simulations, Charged black holes

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I4.07

Effects of metric fluctuations on higher-dimensional black holes

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Abstract:

We investigated the influence of metric fluctuations on the higher-dimensional black hole geometry. By generalizing the previous four-dimensional model to higher dimensions, we introduced a simple model for a classical treatment of quantum vacuum fluctuations. Our model is described by a higher-dimensional ingoing Vaidya-type metric with a spherically oscillating source. Assuming the amplitude of the fluctuations to be minuscule compared to the black hole mass, we used a perturbation method to obtain a radially outgoing null geodesic equation in arbitrary D-dimensions. Considering up to second order in the fluctuation, we investigated the dimensional dependency in the correction terms of the position of a perturbed event horizon and the time-averaged values of thermodynamic quantities defined at the black hole horizon. We then calculated a general solution for the perturbed radial rays propagating outward near the horizon. Finally, we found that the perturbation terms are significantly simplified in the large D limit, enabling a complete solution to be obtained in a compact form.

Keywords:

Black Holes, Classical Theories of Gravity, Large Extra Dimensions

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I4.08

Steady heat flow around a black hole

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Abstract:

When a system is in thermal equilibrium with a black hole, the local temperature of the system satisfies the Tolman's law.
In this case, the local temperature at an event horizon diverges.
We study a steady state around a black hole background and find the configuration of number, entropy densities and heat.

Keywords:

black hole, steady state

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I4.09

Properties of Maxwell field in a charged rotating wormhole spacetime

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Abstract:

We study a charged rotating wormhole. In particular, we analyze the solutions of Maxwell equations in this geometry. We also analyze the properties of the geometry.

Keywords:

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I5.01

Monolayer semiconductors with high luminescence efficiency

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Abstract:

Two-dimensional (2D) transition metal dichalcogenide (TMDC) monolayers such as MoS_2, WS_2, and WSe_2 have aroused significant attention among researchers over past years due to their unique properties which possess the promise for future optoelectronic applications. Atomically thin TMDC monolayers exhibit the tunability of their properties through electric field and strain as well as the capability to achieve van der Waals heterostructures free of lattice mismatch. While these advantages enable their application for various optoelectronic devices including light-emitting diodes (LEDs) and photodetectors, one of the main constraints for their implementation in practical applications is the low photoluminescence (PL) quantum yield (QY), which is reported in the range of 0.01 to 6% at room temperature. PL QY is a key figure of merit in optoelectronic applications because it directly determines the maximum efficiency that the device can achieve.

In this work, 2D TMDC monolayers with high optoelectronic quality were demonstrated in both mechanically exfoliated and synthesized samples through proper material processing. Moreover, we achieved near-unity PL QY in monolayers at all exciton densities, which paves the way for developing LEDs that will retain high efficiency at all brightness.

Keywords:

Two-dimensional semiconductors, Photoluminescence

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I5.02

Terahertz field-induced transparency in graphene-integrated slot antennas

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Abstract:

In two-dimensional graphene, massless Dirac fermions exhibit interesting optical and electron transport properties. These remarkable characteristics of graphene have spurred the exploration of novel possibilities in the advancement of optoelectronic and photonic devices spanning a broad light spectrum range, including optical modulators, microwave bolometers, and ultrafast transistors. In single-layer graphene, terahertz (THz) waves drive intraband transitions that lead to significant intraband absorption and show a Drude response but still encounter inadequate modulation depth. In order to overcome this problem, graphene integrated with plasmonic structures exhibits enhanced light-matter interactions, which can improve modulation under localized field areas. Furthermore, when stronger THz waves are applied to graphene, hot carriers are generated, resulting in a reduction in conductivity due to electron-electron scattering and phonons, while simultaneously increasing the transmission through graphene. Here, we present THz field-induced transparency boosting in a slot antenna structure combined with graphene, concentrating electric fields up to around 1.8 MV/cm and reaching the device's modulation depth by up to 100%. We observe a four-fold reduction in the effective refractive indices of graphene atop the slot antenna structure compared to the bare graphene sample. Our optical pump-intense THz probe spectroscopy also confirmed that hot electrons triggered by the intense THz pulse could be settled within the conduction band by suppressing interband transitions.

Keywords:

single layer graphene, slot antenna, nonlinear optics, intense terahertz pulse, ultrafast dynamics

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I5.03

Plasmonic polymer nanoantenna arrays for electrically tunable and electrode-free metasurfaces

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Abstract:

Plasmonic polymer poly(3,4-ethylenedioxythiophene) (PEDOT) can switch the optical properties depending on its redox state. We present a PEDOT nanostructure fabrication technique, which can form various nanostructure arrays including nanorod arrays or their inverted structures. In addition, we investigated the origin of plasmon resonances in the nanorod arrays using the finite-difference time-domain (FDTD) simulations. Further, we realized electrode-free plasmonic polymer metasurfaces which enable tuning their doping and dedoping electrochemically.

Keywords:

Optical nanoantenna arrays, Conductive polymers, SANE-RIE, PEDOT, electrically tunable metasurfaces

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I5.04

Inverse design of nano-photonic devices for high electric field enhancement in the terahertz frequency range

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Abstract:

In this study, we have achieved the previously unattainable task of applying the inverse design approach to terahertz nanophotonic device design, which was hindered by the wavelength-structure size mismatch. Furthermore, by integrating analytical solutions, our method dramatically reduces computational costs compared to simulation-based inverse design techniques. This high efficiency enables the inverse design to be completed within 2 days even on standard middle-level PCs. As a result, we successfully designed a terahertz loop nanogap structure with about 29,000 times enhanced field enhancements, a result validated through simulations and the terahertz time-domain spectroscopy measurement. In the experiments, we achieved an electric field enhancement of about 32,000 times and observed a blue-shifted peak position. To explain the discrepancies between the fabricated device and the computed results, we conducted simulations based on a TEM image. Our research holds significant promise for applications involving strong electric field enhancements, such as sensing and nonlinear optical effects.

Keywords:

terahertz, nanophotonics, inverse design

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I5.05

Electron-hole decoherence accessed by high harmonic generation in monolayer MoS_2

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Abstract:

Experimental determination of decoherence time T_2 is a significant and challenging problem, and the physical origin of the recently reported short T_2 of a few femtoseconds time scales remains still an open question. Here, we use the quantum master equation to investigate the dephasing dynamics with various T_2 values in monolayer MoS_2. Under a linearly polarized pulse, which is rotated by a specific angle between 0 and 30 degrees with respect to the crystal mirror plane, we find that a rotation angle along the $\hat{x}$ (zigzag) direction of the polarization direction of the even-order HHG signals varies with T_2. This rotation is because the dominant quantum pathways of monolayer MoS_2 differ along the parallel and perpendicular directions to the pulse. The vectorial character of transition dipoles supports the results and is related to the real-space structure of monolayer MoS_2 designed in different forms along zigzag and armchair directions with broken inversion symmetry. These findings present an understanding of quantum decoherence in momentum-space and imply that they are connected to the electron dynamics in real-space.

Keywords:

Polarization, High harmonic generation, Monolayer MoS2, decoherence

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I5.06

Effective design of scattering-based reservoir computing for efficient real-time intelligence

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Abstract:

Realizing a real-time intelligent system is essential for understanding and replicating the perception of sentient life forms. Recurrent neural networks (RNNs) have traditionally been the mainstream approach for implementing such real-time intelligence. However, their excessive time and energy consumption due to gradient-based optimization has remained a persistent drawback.
Reservoir computing (RC) was proposed as an alternative to achieve real-time cognitive functions with minimal training of RNNs. RC leverages the intrinsic signal propagation within a randomly wired RNN that exhibits fading memory—the ability to retain a finite amount of input history. Given that fading memory is present not only in RNNs but also in physical systems, researchers have successfully demonstrated physical RC, showcasing its potential efficiency. Nonetheless, many previous implementations of physical RC have had limited tunability, rendering the design guidelines of RNN-based RCs inapplicable.
In this study, we implement a tunable physical RC system based on light scattering. We conduct extensive scans of reservoir properties to achieve benchmark cognitive tasks. Our system comprises a display and an imaging system with a scatterer in the aperture, where pixels represent the reservoir nodes. In each sequence, the reservoir state combines with the input signal, is projected onto the display, scattered, and then imaged to update the reservoir state. By exploring the memory capacity of the system, we identify optimal ranges for reservoir properties, including dynamic strength, input distribution, and connectivity. Furthermore, we employ these configurations to excel in high-memory cognitive tasks, specifically predicting a chaotic time series and recognizing spoken words.
Our demonstration provides practical insights into realizing physical RC and underscores the potential of scattering-based RC for efficient real-time intelligence.

Keywords:

Reservoir computing, Scattering, Real-time intelligence

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I5.07

Terahertz Wave Applications via Electrically Tunable Graphene Metasurface

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Abstract:

Active control of optical properties in terahertz (THz) regime is an important role in advancing next-generation wireless communication, medical equipment, and spectroscopy. However, the lack of natural materials exhibiting strong anisotropy poses a challenge at terahertz frequencies. In this study, we experimentally validated the gate-controllable states of THz wave through the integration of an isotropic metasurface with graphene. Our approach involves designing an isotropic metallic metamaterial to optimize capacitive coupling between adjacent meta-atoms. By adjusting the optical conductivity of graphene, we demonstrate that the capacitive coupling between adjacent meta-atoms can be weakened, leading to a change in the refractive index or beam splitting. For the graphene metasurface incorporating bilayer graphene micro-ribbons, we achieved a relative phase retardation of 90 degrees, enabling its application as a tunable quarter-wave plate. Furthermore, our approach exhibits near non-dispersive split ratios across a broad operational frequency range, spanning from 0.5 to 1.5 THz. These studies mark a substantial breakthrough in achieving efficient and tunable manipulation of THz waves. This accomplishment holds the potential to drive the development of compact terahertz devices and to advance the field of THz technology.

Keywords:

Metasurfaces, Graphene, Graphene metasurfaces, Terahertz applications

I6.01

Progress in Accelerator Research and Education at Korea University, Sejong

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Abstract:

Department of Accelerator Science at Korea University, Sejong was established in 2014 to promote accelerator science research and train accelerator scientists and engineers for the growth of domestic accelerator projects in Korea. In addition, Accelerator Research Center and Small Accelerator Application Core Facility Research Center under the department hood were also organized to foster in-depth research on accelerators. Since 2017, several small accelerators have been introduced on our campus. These accelerators include a 14GHz ECR Ion Source for heavy ion accelerator research, a 7 MeV microtron with an undulator for terahertz radiation application research, a 150 keV proton accelerator for ion implantation applications, a 50 MeV microtron for a variety of low energy electron applications, and 60 MeV electron linac with an RF photoinjector gun for electron injector linac research. This work presents the results of recent progress in construction and commissioning of these accelerators, as well as educational programs for graduate students in our own department and users in various fields.

Keywords:

terahertz radiation, 14GHz ECR Ion Source, 7 MeV microtron, 50 MeV microtron, 60 MeV electron linac

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I6.02

KOMAC MeV-grade Accelerators and their Applications

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Abstract:

In addition to the 100-MeV proton linac as a flagship machine in KOMAC, we have operated a few MeV-grade accelerators including a 1.7-MV tandem, 1-MeV/n RF linac, and 1 MV single-end electrostatic accelerators, as well as a 3-MV tandem in preparation. These small-scale accelerators can be useful for both scientific and practical purposes. A brief induction to the small-scale accelerators operated in KOMAC along with their exemplary applications will be given in this presentation.

This work was supported through KOMAC operation fund of KAERI by the National Research Foundation of Korea (NRF) grant funded by the Korean government (MSIT) (KAERI-524320-23).

Keywords:

KOMAC, small-scale accelerator, tandem, RFQ

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I6.03

The status of PAL-eLABs and its opportunities for future R&D and user community.

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Abstract:

The high brightness of electron beams are highly valuable, and useful resource for various fields such as research for advanced accelerator technology, and science user community. The injector test facility (ITF) at PAL have successfully completed the mission for PAL-XFEL to generate high quality electron beams with a high brightness, a low emittance that leads to successful PAL-XFEL operation. This high quality electron beam are extremely applicable in diverse ways. Therefore, the PAL-ITF was reconfigured to include two beam lines, GUN-I and GUN-II for various applications, so recently renamed as the Electron Linear Accelerator for Basic Science (e-LABs). The GUN-I beam line produces electron beams with energy up to 5 MeV and duration of few hundred of femtoseconds which is dedicated to ultrafast electron diffraction (UED) experiments. The GUN-II beamline produces electron beams having an energy up to 70 MeV, a low emittance (<0.5 mm-mrad), and low jitter between electron and an external optical laser which is optimized for advanced accelerator experiments. Furthermore, the eLABs has provided great educational opportunities such as hands-on experiments to cultivate future young accelerator researchers. In this presentation, I will present about status of eLABs and our ongoing R&D activities and plans.

Keywords:

LINAC, Bright electron beam, PAL-eLABs, PAL-ITF, UED

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I6.04

Industrial applications using small-scale electron accelerators

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Abstract:

The high energy possessed by electrons accelerated in an electron accelerator can be utilized in a wide range of industrial applications. The X-ray tube used by Roentgen to discover X-rays, despite being a very simple and primitive accelerator, remains a widely used representative radiation device. Through various improvements, X-ray tubes are currently used in medical diagnosis, X-ray security inspection, non-destructive testing, and more. For an inspection of a large object like cargo container, RF linear accelerators are used to obtain a higher energy X-ray. Electron beams can easily destroy the molecular structure of pollutants like odors or wastewater, making them useful in environmental applications. In this applications the electron beam with high current is required in order to treat a large volume of pollutants. Electron beams can easily destroy the molecules or DNA structure of living organisms. Thus, they are applied in sterilization of medical equipment and food, as well as cancer treatment. Electron beams are also employed in processes like cross-linking and polymerization of polymer materials, offering advantages like more uniform and faster processing compared to heat-based treatments. Here we will discuss the various industrial applications of electron accelerators and strategies for their utilization.

Keywords:

industrial accelerator, electron beam, X-ray, irradiation

Suppression of the elastic scattering cross section for 17Ne + 208Pb system

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Abstract:

We investigated the elastic scattering, inelastic scattering, breakup reaction, and total fusion reactions of 17Ne + 208Pb system using the optical model (OM) and a coupled channel (CC) approaches. The aim of this study is to elucidate the suppress of the elastic cross-section that is invisible in proton-rich nuclei such as 8B and 17F projectiles but appears in neutron-rich nuclei such as 11Li and 11Be projectiles.

Keywords:

optical model, coupled channel, low-energy reaction, near the Coulomb barrier, elastic scattering

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I7.02

Status of isospin dependency of collective flow in 129,124Xe + 124,112Sn collisions at 100AMeV

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Abstract:

Nuclear symmetry energy is important to understand the complicate properties of nuclear matter that depend on the neutron-to-proton ratio (N/Z). Understanding the symmetry energy as a function of the baryon density is the prime interest of the current research in nuclear physics. Theoretically, the collective flow, among other observables, is predicted to be sensitive to the nuclear symmetry energy, but no N/Z dependency has been observed yet. To shed some lights on this subject, we have analyzed the directed and elliptic flow parameters of the various light nuclei in 129,124Xe+124,112Sn collisions at 100AMeV. (These data sets were recorded in the fourth INDRA Campaign experiment.) In this talk, we present the status of the analysis to search for any N/Z dependency of the flow parameters.

Keywords:

Nuclear symmetry energy, Nuclear Physics, Collective flow, INDRA detector

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I7.03

Cross sections for $^{nat}Zr(n,xn)^{88}Zr$ and $^{nat}Zr(n,xn)^{89}Zr$ reactions at neutron energies from 29 to 42 MeV

CHAVAN Vivek Raghunath[2], MOON Dalho [2], HAM Cheolmin [1], OH Seyong [3], PARK Byunghyun [4], BHORASKAR Vasant [2], HONG Seung Woo [*1,2]
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Abstract:

Cross sections of $^{nat}Zr(n,xn)^{88}Zr$ and $^{nat}Zr(n,xn)^{89}Zr$ were measured at six neutron energies in the energy range of 29.4–42 MeV by irradiating natural zirconium (^{nat}Zr) samples. The neutrons were produced via $^{9}Be(p,n)^{9}B$ reaction induced by bombarding a 0.25 mm thick beryllium target with 35, 40, and 45 MeV protons. The neutron spectrum produced at each proton energy was simulated by using the PHITS code. Two neutron peaks were observed in the simulated spectra for each proton energy. By using the estimated activity ratio factor for each neutron peak and experimentally measured γ-ray activities of ^{89}Zr and ^{88}Zr, the cross sections of $^{nat}Zr(n,xn)^{89}Zr$ and $^{nat}Zr(n,xn)^{88}Zr$ reactions were obtained, respectively. These experimentally measured cross sections were compared with the cross sections estimated by the TALYS-1.95 and those from the EAF library. For natural zirconium, these cross sections are reported here for the first time in the neutron energy range of 29.4–42 MeV.

Keywords:

Natural zirconium, TALYS, EAF, Cross-section, PHITS

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I7.04

Performance test of CsI(Tl) crystals for the Subthreshold Pion Production Experiment at RAON (SUPER)

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Abstract:

Subthreshold pion production in pA reactions leads to a low-lying nuclear state so that it involves large momentum transfer even close to the threshold. Therefore, this reaction is sensitive to nuclear dynamics at short distances. However, the existing experimental data sets on the excitation function near 20 MeV are not consistent. In AA 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. This experiment will employ a gamma-ray detector array with 768 CsI(Tl) crystals.
This talk will present the KEK test bench results for the performance of CsI(Tl) crystals and Geant4 simulation results on the pi0 reconstruction.

Keywords:

Subthreshold pi0 production, RAON, SUPER, CsI(Tl) Array

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I7.05

Probing multi-chance fission in proton induced fission of thorium

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Abstract:

Thorium is considered as a fertile fuel for thorium ADS and breeder reactors. In the ADS systems, spallation and multiple collision produces secondary protons which will still significantly contribute to the proton induced reactions. With the increase in the excitation energy, due to a reduced importance of shell effects, the transition to predominantly symmetric (liquid-drop) type fission should occur. The asymmetry of the mass (charge) distribution at high excitation energies can be only caused by multi-chance fission, hence from the measurement of the ratio between the symmetric and asymmetric yields we can probe the multi-chance fission. In the present work, by using the off-line gamma spectrometry method together with a belt-driven system, the excitation functions of short- and long-lived fission products were measured for proton-induced fission of thorium in the energy range from threshold to 45 MeV.

Keywords:

Thorium, Multi-chance fission, Proton, Gamma spectrometry, Belt-driven system

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I7.06

Excitation energy of primary fragment in projectile fragmentation

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Abstract:

Projectile fragmentation is a complicated scheme to produce rare isotopes. One can understand the fragmentation through a two-step process: the production of primary fragments by colliding and de-excitation of these fragments. The excitation energies of primary fragments are essential to understanding the connection between two processes. In this study, we discuss the method to define the excitation energy of primary fragments from QMD calculation and compare the de-excited fragments using a statistical model. Then, we compare the rare isotope production methods IF with U fragmentation and IF+ISOL with neutron-rich isotope fragmentations.

Keywords:

projectile fragmentation, QMD, statistical model

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I7.07

Low-energy K^+N scattering experiment at J-PARC

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Abstract:

The kaon–nucleon (K^+N) interaction has attracted considerable interest because of the possible existence of the Θ^+ pentaquark. The K^+N system constitutes the only open hadronic decay channel for that resonance and, therefore, can be used to impose constraints on its width. In this talk, we will discuss the idea of the K^+N scattering experiment at low energies near p_{lab}= ~0.5 GeV/c at J-PARC to explore the possible existence of an S=+1 exotic resonance in the I=0 channel. A large acceptance Hyperon Spectrometer, which consists mainly of a time projection chamber (HypTPC) and a 1-T superconducting magnet, will be utilized to exclusively measure the decay products of Θ^+, such that $\Theta^+ \rightarrow K^0p$, followed by $K^0 \rightarrow \pi^+\pi^-$, if it exists. The experiment will also provide the high-quality data of the total cross section of the I=0 and I=1 K^+N channel with the liquid hydrogen and deuterium targets in the HypTPC with almost 4π acceptance.

Keywords:

K+N interaction, J-PARC, pentaquark

I7.08

Low-energy $K^-p \to \Lambda\eta$ reactions with the J-PARC E72 detector

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Abstract:

We are preparing for an upcoming $K^-p \to \Lambda\eta$ scattering experiment (J-PARC E72) at J-PARC Hadron Experimental Facility [1]. In this experiment, a K^- beam momentum is poised at the vicinity of 730 MeV/c, while the Hyperon Spectrometer detects the scattered Λ with $\Lambda \to p\pi^-$ decay [2]. Our primary goal is to search for a new Λ^* resonance, the traces of which have been seen in the previous scattering data by Crystal Ball [3-5]. With the anticipated beamtime scheduled for 2024, we plan to acquire 100 times more data than in the previous experiments, thus identifying the new hyperon clearly. In this talk, we will report on the preparation status and plan of J-PARC E72. Furthermore, the physics impact and topics will be discussed.

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[5] H. Kamano et al., Phys. Rev. C 92, 025205 (2015).

Keywords:

J-PARC E72, Kaon beam, hyperon, exotic hadron, scattering

I7.09

Cross-section Measurement for K-p->K+Ξ(1535)- Reactions at √s = 2.15 GeV/c²

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Abstract:

We present preliminary results for differential cross-sections of Ξ(1535)- production in the (K-, K+) reaction at a center-of-mass energy of √s = 2.15 GeV/c². The J-PARC E42 utilized a polyethylene target and the time projection chamber (HypTPC) for charged particle reconstruction. A forward dipole spectrometer tagged forward K+ outgoing particles from 0 to 20 degrees. We identified Ξ(1535)- production in the missing-mass spectra for p(K-, K+)X and p(K-, K+Ξ-)X reactions. We will discuss possible reaction mechanisms for K-p--> K+Ξ(1535)-)X reaction and also the feasibility of observing a radiative decay Ξ(1535)- --> Ξ-γ.

Keywords:

TPC, J-PARC, Xi baryon

2023 KPS Fall Meeting
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I8.01

Characterization of 20-qubit superconducting quantum system at KRISS

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Abstract:

Superconducting qubit system is one of the most promising platforms for practical quantum computing. As the size of multi-qubit system grows, it becomes important to characterize superconducting qubits efficiently, including the precise calibrations of single and two qubit gates and the measurement of both classical and quantum crosstalks. In this talk, I will present some recent progress on the experimental characterization of fixed-frequency 20-qubit superconducting circuit at KRISS.

Keywords:

Quantum computing, Superconducting qubit

2023 KPS Fall Meeting
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I8.02

Initial qubit operation runs performed in linear 5-qubit devices in $^{28}Si/SiGe$

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Abstract:

We report fabrication, charge occupancy tuning, and initial qubit addressing experiments performed in linear quintuple quantum dot devices in isotopically purified silicon. Following the pioneering linear 6 qubit experiments recently performed in TuDelft, we discuss the main points in device design and fabrication recipe that are helpful to improve production yield. We next present our solution to some challenges we encountered in device tuning, tunnel coupling adjustment, and single-shot readout in this device geometry. We report typical single-qubit coherence times that are in line with reported values for micro-magnet integrated silicon devices along with a discussion of measurement techniques to improve coupling tunability and two-qubit gate quality without redesigning gate geometry.

Keywords:

Qubit, Silicon, quantum dot, coherent shuttling

2023 KPS Fall Meeting
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I8.03

Recent progress on building a trapped-ion quantum computer in SKKU

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Abstract:

An ion trap is an exotic quantum system that reveals novel quantum phenomena and has become one of the leading quantum computing platforms. Its promising features include long qubit coherence time, low SPAM (state-preparation and detection) error, high gate fidelity, and all-to-all qubit connectivity. In this presentation, we deliver recent progress on building a full-stack trapped ion quantum computer targeting 5-qubit operation. The presentation will include our system design, construction progress, control hardware/software and recent achievements in trapping ytterbium ions in the chamber.

Keywords:

ion trap, quantum computing, quantum information, atomic physics

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I9.01

Examining Social Connections of Black American College Students Pre and Peri-COVID-19 Pandemic: Social Network Analysis

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Abstract:

We aim to examine whether there are any differences in the social network characteristics (during the pre-COVID versus peri-COVID periods) of Black American college students that have posted a depression-related tweet or retweet on their timeline and those who have not during the pandemic period to understand the collective patterns of the group. We analyzed the social networks (i.e., friendship networks) of Historically Black Colleges and Universities (HBCU) students, an intersectional minority group, on their online social behaviors on Twitter by comparing pre- (collected in May 2019) and peri-COVID (collected in July 2022) data. For the two periods, the depression-related group includes 508 users, and the non-depression-related group contains 512 users.

Online social activities of HBCU students with depression-related tweets are significantly different from those without depression-related (d-r) tweets. Users with d-r tweets tend to seek more mutual relationships and try to connect with other d-r tweet users. Collectively, HBCU students' online friendship networks are congruent with their institutional affiliation and their networks cluster according to their affiliations. Given the echo-chamber effect, which can amplify depressed emotions and homogenizing the information in the community, understanding Black American college students' online social behaviors during the pandemic may help to inform future social media interventions to support their mental health.

This study analyzed the changes in Black American college students' online social behaviors over the pandemic and compared the structural differences between users with depression-related tweets and without depression-related tweets. The macroscopic changes in this group's online social networks can provide insights to plan proper interventions for Black American college students in social disasters such as COVID-19.

Keywords:

health, online behavior, network, HBCU, depression

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I9.02

Understanding the filoviral entry efficiency by an epidemic spreading model

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Abstract:

The filovirus including Ebola and Marburg viruses are highly dangerous, causing large-scale outbreaks. The interaction between glycoprotein in the virus and single nucleotide polymorphisms (SNPs) in humans is a key to the successful settlement and then pervasion of the virus into the human body. The SNPs are contained in a membrane protein in host cells and the efficiency of viral entry hinges on the protein type. Since every individual has her/his own unique protein possessing the SNPs, the entry efficiency of the virus and the resulting degree of severity are different from individual to individual. That is, the effective transmission rate of the virus, or equivalently the entry efficiency can be varied along with the protein type. The most common protein in human cells is the Niemann-Pick disease, type C1 (NPC1), but other variants also exist. Albeit the protein type plays a crucial role in the assessment of the entry efficiency, the effective transmission rate or the entry efficiency has hardly been explored quantitatively in various proteins except for the NPC1, so the previous study has proposed a mean-field compartment model based on an epidemic spreading model. In this study, we implement an agent-based model for realizing the short-range interaction in the experimental setting. Comparing the experimental results including the plaque size, we measure the effective transmission rate in the various proteins.

Keywords:

epidemic spreading, viral efficiency, filovirus

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I9.03

Inter-country Relations Based on Content Consumption Trends in Netflix

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Abstract:

Netflix, a leading OTT platform, is widely used across various countries. In our study, we analyzed Netflix data to understand the relationship between these countries, grouping them accordingly and assessing their influence as content producers and consumers. Our findings revealed an observable correlation between content consumption tendencies and both geographical and cultural factors. From a content production perspective, the U.S., South Korea, and Colombia exert significant influence globally. Aside from the Middle East, countries seemed to favor content from nations with similar consumption patterns. Through our analysis of influence as content consumers, we observed that the Asian cluster actively distributes content trends to other groups, yet is less inclined to adopt trends from them. While this analysis might not capture every subtlety, it offers a valuable perspective on approximate inter-country dynamics of cultural influences.

Keywords:

Netflix, Inter-country Relations, Cultural influences

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I9.04

The price of Stern Judging: segregation and slow relaxation

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Abstract:

The theory of indirect reciprocity provides us with a dynamical framework to study how to assess other players based on their actions, as well as how to act toward them based on the assessments. Well-known are the `leading eight' from L1 to L8, the eight pairs of assessment rules and action rules that resist the invasion of mutants having different action rules. In this work, we focus on macroscopic dynamics due to Stern Jundging (also known as L6 or `Kandori' among the leading eight) in a few tractable structures. The first example is a fully connected graph, on which we show that this norm segregates the system into two mutually hostile clusters, although error hinders this process substantially. The second example is a triangular lattice, and here we argue that the system can be mapped to an Ising system with three-spin interaction on the kagome lattice, which fails to reach a consensus state. The last example is a hierarchically constructed graph, for which we have applied the renormalization-group transformation with a decimation rule and found that the system becomes disordered. Our analysis demonstrates that individuals who follow this simple norm may induce counter-intuitive patterns at a societal level.

Keywords:

indirect reciprocity, Heider balance, evolutionary game theory

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I9.05

Population density reveals core-periphery structure in commuting mobility networks

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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? 이 연구에서 우리는 KT 이동전화 사용자에서 추출한 통근 이동 데이터를 이용하여 노드를 행정동으로, 행정동 사이의 통근자 수를 링크 가중치로 정의한 방향성 있는 통근 네트워크를 만들어 분석하였다. 먼저 네트워크 분석을 통해 두 종류의 노드 집단이 통근 네트워크에 존재함을 관찰했다. 첫 번째 노드 집단은 연결선 수(degree)와 연결 강도(strength)가 높으며 특정 문턱값 이상의 인구밀도를 갖는다. 이에 반해 두 번째 집단은 낮은 연결선 수와 연결 강도를 보이며 특정 문턱값 이하의 인구밀도를 갖는다. 이 결과는 통근 네트워크에서 인구밀도가 높은 노드들은 다른 노드들과 연결이 잘 된 중심을 이루고 인구밀도가 낮은 노드들은 서로 느슨히 연결된 주변부를 이루는 일종의 중심-주변 구조(Core-periphery structure)가 있음을 암시한다. 우리는 통근 네트워크의 노드의 인구밀도와 k-shell 수를 비교하여 이를 확인하였다. 우리 연구는 지역의 인구밀도가 통근 패턴에 스위치와 같은 영향을 미치며, 도시화 정도에 따라 지역의 통근 패턴이 중심과 주변으로 나누어 질 수 있음을 시사한다.

Keywords:

Human mobility, Core-periphery structure, Mobility networks

I9.06

Percolation-based analysis of polycentric structure in real-time population distributions of metropolitan areas

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Abstract:

최근 도시들이 대도시권(metropolitan area)을 이루면서 도시의 구조를 단핵(Monocentric)구조 같은 간단한 형태로 설명하기 어려워졌다. 도시에서 인구가 많이 모이는 중심지역인 센터를 통해 도시구조가 시간에 따라 변화하는 다핵구조(Polycentric structure)임을 확인할 수 있지만, 대도시권에서 인구가 어떻게 공간적으로 배치되고, 연결되어 있는지를 아는데 한계가 있다.

이에 따라 우리는 스미기 이론(Percolation theory)을 이용하여 도시내부 영역들을 인구 클러스터의 관점으로 분석하였다. 즉 개별 센터가 아닌 도시내부의 권역 수준에서 다핵구조를 바라보고자 한다. 특히 인구 클러스터를 계층적으로 분석함으로써 도시 내부의 경계가 자연경계와, 지역의 기능에 따라 나뉘는 것을 확인했고, 시간에 따라 인구 클러스터의 경계가 기능에 따라 바뀌는 것을 확인할 수 있다.

이는 인구 클러스터가 대도시에서 다핵(polycentric)구조로 나뉘어진 주거지역과 직장지역으로 나타나는 사람들의 출퇴근 패턴을 잘 반영한다는 것을 의미한다. 또한 센터들이 모여있는 특정 클러스터를 식별하여 도시내부에서 중심지역이 만들어내는 주요 생활권역을 식별해볼 수 있다.

또한 이전에 다핵구조를 확인하기 위해 측정한 값들에서 확인하지 못한 특징을 인구 클러스터를 계층적으로 분석함으로 알 수 있다. 대표적으로 출근전과 퇴근후의 인구의 분포는 유사하지만, 클러스터를 통해 계층적으로 분석했을 때 클러스터의 경계구조가 다른것을 확인했다. 이는 하루동안 대도시에서 인구 구조는 사람들의 출근과 퇴근 패턴은 대칭적이지 않은 대도시 사람들의 생활패턴을 이해하는데 도움이 된다.

Keywords:

Percolation, Polycentric structure, Cities

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I9.07

Exploring the relationship between the spatial distribution of roads and universal pattern of travel-route efficiency in urban road networks

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Abstract:

Urban road networks are well-known to exhibit universal characteristics and scale-invariant patterns, despite the different geographical and historical contexts of cities. Previous studies on the universal characteristics of urban road networks have mostly focused on their network properties but have often ignored the spatial network structures. To address this research gap, we explore the underlying spatial patterns of road networks. We examine the travel-route efficiency in a given road network across 70 global cities, which provides information on the usage pattern and functionality of the road structure. The efficiency of travel routes is measured by analyzing the detour patterns, as determined by the detour index (DI). The DI is a long-standing popular measure, but its spatial pattern has been barely considered so far. In this study, we investigate the behavior of DI with respect to spatial variables by scanning the network radially from a city center. Through empirical analysis, we first discover universal properties in DI throughout most cities, which are summarized as a constant behavior of DI regardless of the radial position from a city center and a clear collapse into a single curve for DIs for various radii with respect to the angular distance. Especially the latter enables us to determine the scaling factor in the length scale. We further reveal that the universal pattern is induced by the center-periphery spatial structure of urban roads through the model study of an artificial road network. In addition to exploring the universality of DI, we delve into the specific characteristics of DI associated with the unique internal structure of individual cities. By visualizing the spatial DI network on city maps, we identify distinct city-specific DI characteristics. The case studies of selected cities demonstrate that our proposed method of spatial DI networks has the potential for practical implications in analyzing individual cities.

Keywords:

Urban road network, Detour index, Core-periphery structure, Universal behavior

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I9.08

Distinguishable Cash, Bosonic Bitcoin, and Fermionic Non-fungible Token

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Abstract:

Modern technology has brought novel types of wealth. In contrast to hard cashes, digital currencies do not have a physical form. They exist in electronic forms only. Yet, it has not been clear what impacts their ongoing growth will make, if any, on wealth distribution. Here we propose to identify all forms of contemporary wealth into two classes: 'distinguishable' or 'identical'. Traditional tangible moneys are all distinguishable. Financial assets and cryptocurrencies, such as bank deposits and Bitcoin, are boson-like, while non-fungible tokens are fermion-like. We derive their ownership-based distributions in a unified manner. Each class follows essentially the Poisson or the geometric distribution. We contrast their distinct features such as Gini coefficients. Further, aggregating different kinds of wealth corresponds to a weighted convolution where the number of banks matters and Bitcoin follows Bose-Einstein distribution. Our proposal opens a new avenue to understand the deepened inequality in modern economy, which is based on the statistical physics property of wealth rather than the individual ability of owners. We call for verifications with real data.

Keywords:

Distinguishable Identical Bitcoin NFT

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I10.01

van der Waals integration of oxide thin film and 2D layered materials for hot carrier diffusion

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Abstract:

Two-dimensional van der Waals layered materials have been successfully employed in various optoelectronic applications. Notably, in a high-k dielectric environment, the transport properties of 2D materials are expected to undergo significant enhancement. Despite previous achievements, a discernible gap remains in comprehending their underlying characteristics, particularly concerning carrier diffusion. In this study, we study hot carrier diffusion in MoS_2 on high-k dielectric films, resulting in room-temperature, long-range carrier diffusion. This enhanced diffusion coefficient, surpassing tens of thousands of square meters per second, arises from elevated carrier mobility, extended carrier relaxation time, and minimized impurity scattering within the heterostructure. Our findings open up new possibilities to approach previously inaccessible physical limits, thereby enabling novel devices with unprecedented performance beyond 2D materials and applications.

Keywords:

hot carrier diffusion, van der Waals integration

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I10.02

Evolution of half-metallic ferromagnetism in (111)-oriented manganite superlattices

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Abstract:

Oxide heterostructures can host exotic phenomena – such as flat bands, magnetic anisotropy, exchange bias and spin-glass, only latent in bulk – and interesting phase competition in thin films and superlattices, because of symmetry breaking and quantum confinement. Research in these topics can reveal the potential of oxides for future applications. The (001)-oriented superlattice of two anti-ferromagnetic insulators $LaMnO_3$ and $SrMnO_3$ is found to be a half-metallic ferromagnet with short periodicity and an antiferromagnetic insulator with 2 or more unit cells. Our ab-initio work predicts a (111)-oriented $LaMnO_3|SrMnO_3$ superlattice is a half-metallic ferromagnet in spite of its large thickness due to strain and charge transfer across the interface, contrary to results reported in (001)-oriented superlattices. We compare the two ground state space groups of bulk $LaMnO_3$ ($R\bar{3}c$) and bulk $La_{2/3}Sr_{1/3}MnO_3$ (Pnma), finding that their competition is tuned by in-plane strain and superlattice thickness. The $R\bar{3}c$ supports breathing distortions coupled to charge/spin oscillations. The space group competition plays also a role in the Mn magnetic coupling, as Pnma promotes A-type antiferromagnetism. Computed within the Heisenberg formalism via the magnetic force theorem, it stays strongly ferromagnetic in the La region but progressively shifts towards antiferromagnetic in the Sr region as thickness grows, suggesting mixed magnetic orders.

Keywords:

Manganite, Superlattices, Electronic structure, Density functional theory

2023 KPS Fall Meeting
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I10.03

Quantification of local and nonlocal Coulomb interactions in transition metal oxides

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Abstract:

The electronic structure and magnetic properties of transition metal oxides are determined from physical parameters such as crystal field splitting, bandwidth, and Coulomb interactions. The energy scales of such parameters are similar, which sometimes cooperatively present unprecedented emergent phases. Especially, when employing DFT-based computational approaches, the correct enumeration of the Coulomb interaction is crucial for an accurate description of the material properties in transition metal oxides. In this presentation, I will show the importance of correctly estimating the local and nonlocal Coulomb correlation parameter, *U*, which is sensitive to the structural and material-specific details, and I will discuss the implications.

Keywords:

Transition Metal Oxides, DFT, Coulomb interaction

2023 KPS Fall Meeting
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I11.01

A superconducting quantum simulator based on a photonic-bandgap metamaterial

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Abstract:

While majority of scalable quantum simulation and computation architectures to date feature nearest-neighbor interactions limited by their local nature of coupling, long-range interacting quantum systems—exhibiting fast build-up of quantum correlation—provide new approaches for studying quantum many-body phenomena and investigating quantum error-correction schemes in the near term. Utilization of extensible quantum bus such as a photonic waveguide provides a natural direction to investigate such many-body quantum systems where qubits interact non-locally by exchange of photons along the bus. Following this idea, here we demonstrate a 10-qubit superconducting quantum simulator constructed from a photonic-bandgap metamaterial. The simulator realizes Bose-Hubbard model with tunable long-range hopping and on-site interaction, whose Hamiltonian is learned using a novel protocol based on quantum many-body chaos. Our work enables study of different regimes of quantum chaos and thermalization, and more broadly, provides a novel class of accessible Hamiltonians for analog quantum simulation in superconducting circuits.

Keywords:

Superconducting circuit, Quantum simulation, Metamaterial, Quantum chaos

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I11.02

Development of the 10+ Qubit Superconducting Quantum Processor in SKKU – Progress Report

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Abstract:

양자프로세서는 양자회로를 적용하여 양자계산을 수행할 수 있는 디바이스를 지칭한다고 할 수 있다. 초전도 큐비트 기반 양자프로세서는 현재 가장 널리 사용되는 방식으로서, 기업들에서는 수백 개 수준의 조셉슨 접합을 포함하는 양자 프로세서 소자 및 이를 완전히 자동화하여 운영하는 NISQ 시스템을 완성도 높게 선보이고 있는 수준이다. 이번 발표에서는 현재 성균관대 실험실에서 본 연구팀이 진행하고 있는 10개+ 큐비트 규모의 초전도 양자소자 연구 내용과 연구성과를 공유하려고 한다. 초전도 회로는 설계에서 매우 자유도가 크기 때문에 10-큐비트급을 넘어가는 경우에는 컴퓨터 설계 도구가 반드시 필요하며, 많은 회로 변수의 최적화와 공정 마진이 매우 중요하게 된다. 따라서 웨이퍼 스케일의 조셉슨 접합의 균일도 및 수율이 중요한 변수가 된다. 특히 큐비트 소자의 저온특성평가는 매우 시간이 오래 걸리는 작업이기 때문에 연구개발의 병목이 대부분 평가에서 발생하게 되고, 따라서 효율적인 설계 및 공정, 그리고 특성평가 루틴이 매우 중요하다. 본 연구에서는 회로양자전기동역학(circuit QED) 방식의 고정 주파수 트랜스몬 회로와 에코교차공명(Echoed Cross-Resonance)방식의 얽힘 게이트를 사용하는 회로를 기본으로 사용하였으며, 다양한 방식의 초전도 큐비트 회로에 대한 프로세스 전반을 충분히 확립하였다. 이 발표에서는 다중 큐비트 프로세서에 필요한 설계, 측정, 분석, 교정, 최적화 및 알고리즘 수행까지 전 과정의 연구개발성과와 대규모 큐비트 소자에 대한 연구개발 과정을 소개한다. 시스템 차원의 적용을 고려한 현재의 양자소자 성능평가 및 이를 활용한 연구결과들을 간단히 소개하기로 한다.

Keywords:

Quantum Computer, Superconducting Qubit, Quantum Processor, Entanglement, Quantum Algorithm

I11.03

Solving Crosstalk Problem in Multi-JPA Amplifiers for Axion Search Experiments

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Abstract:

In the CAPP MAX experiment, we conduct a series of scans to search for axion signals within the 1-2 GHz frequency range using the haloscope method proposed in reference [1]. To amplify the minute haloscope signals, we employ a flux-driven Josephson Parametric Amplifier (JPA), which exhibits noise characteristics approaching the quantum limit and is known for its exceptional performance [2]. In an effort to expand the frequency coverage of the amplifier, we developed the Dulcimer Amplifier (DA) by combining six JPAs [3]. However, due to the overlapping frequency bands of the individual amplifiers, crosstalk is introduced during their operation, leading to an impact on the noise of the DA. In this report, we present methods to mitigate this crosstalk-induced noise effect on the amplifier and its implications for axion search experiments.

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Keywords:

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I11.04

Magnetic proximity-induced superconducting diode effect and infinite magnetoresistance in a van der Waals heterostructure

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Abstract:

We report unidirectional charge transport in a NbSe₩textsubscript{2} noncentrosymmetric superconductor that is exchange-coupled with a CrPS₩textsubscript{4} van der Waals layered antiferromagnetic insulator. The NbSe₩textsubscript{2}/CrPS₩textsubscript{4} bilayer device exhibits bias-dependent superconducting critical-current variations of up to 16%, with magnetochiral anisotropy reaching ~ $10^{5} T^{–1} A^{–1}$. Furthermore, the CrPS₩textsubscript{4}/NbSe₩textsubscript{2}/CrPS₩textsubscript{4} spin-valve structure exhibits the superconducting diode effect with critical-current variations of up to 40%. We also utilize the magnetic proximity effect to induce switching in the superconducting state of the spin-valve structure. Finally, it exhibits an infinite magnetoresistance ratio depending on the field sweep direction and magnetization configuration. Our result demonstrates a novel route for enhancing the nonreciprocal response in the weak external field regime (< 50 mT) by exploiting the magnetic proximity effect.

Keywords:

superconducting diode effect, noncentrosymmetric superconductor, nonreciprocal transport

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I11.05

Observation of bimodal switching current distributions in topological Josephson junctions made of Cd_3As_2 Dirac semimetal nanowire

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Abstract:

Topological Josephson junction (JJ) hosting Majorana zero modes is anticipated to exhibit a 4π-periodic current-phase relation, leading to the emergence of fractional Josephson effects. The fractional Josephson effect becomes evident through the absence of odd-integer Shapiro steps when subjecting the topological JJ to microwave radiation. Non-topological JJ, however, can also yield similar Shapiro-step behavior via Landau-Zener transition. To reliably distinguish the topological supercurrent, we investigated switching current distributions (SCDs) in addition to the abnormal Shapiro steps. In our experiment, we fabricated topological JJs utilizing Cd_3As_2 Dirac semimetal nanowires, which were then contacted with PbIn superconducting electrodes. Our observations of bimodal SCDs strongly indicate the existence of topological supercurrent attributed to Majorana zero modes. Our experimental results, including variations of SCDs in temperature, magnetic fields, and gate voltages, will be discussed.

Keywords:

Josephson Junction, superconducting device, Topological superconductor, Dirac semimetal

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I12.01

Magnetic-Field Controllable Non-Reciprocal Negative Refraction in Photon-Magnon Coupling

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Abstract:

Research on metamaterials [1,2] has unveiled unparalleled electromagnetic properties, most notably negative refraction. This phenomenon enables light to bend counterintuitively upon entering a medium with a negative refractive index (NRI), holding immense promise for innovations such as superlensing and advanced electromagnetic wave control. In this study, we explored the occurrence of negative refraction within a photon-magnon hybrid system, endowed with the ability for magnetic-field controlled on-off switching and nonreciprocity. We utilized a photon-magnon hybrid composed of yttrium iron garnet films and inverted split-ring photon resonators [3,4]. Through the development of an analytical circuit model grounded in transmission line theory and in conjunction with experimental findings, we have gained deeper insights into the negative refraction and nonreciprocal mechanism inherent in this hybrid system, particularly in relation to coherent and dissipative photon-magnon coupling [4,5]. Furthermore, this research presents a new paradigm for the advancement of practical NRI materials within both the microwave optics and magnonics communities. The findings may pave the way for the design and implementation of advanced communication networks, information processing systems, and other cutting-edge quantum technologies.

This research was supported by the Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Science, ICT, and Future Planning (No. NRF-2021R1A2C2013543).

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Keywords:

Photon-Magnon Coupling, Negative Refraction, Nonreciprocity, Quantum Technology, Circuit Model

2023 KPS Fall Meeting
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I12.02

Magnonic Characteristics of Epitaxial Cr/Fe Bilayers

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Abstract:

Magnon refers to the spin-wave quantum associated with the flip of a single spin which gives rise to exotic phenomena such as quantum Bose-Einstein condensation [1], spin pumping [2], spin Seebeck effect [3], and magnon-related transports [4]. Therefore, the ways of observing magnonic behaviors are an intriguing topic to study such magnon-related phenomena. In this presentation, focusing on the Cr/Fe epitaxial bilayers, I will discuss about two major topics; 1) high energy magnons giving rise to the non-linear magnetoresistance, and 2) spin dissipation at the interface as a function of the crystalline direction. Ising character with (211) planes and possibility of orbital pumping in the Cr/Fe bilayer will be mainly discussed

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Keywords:

Cr/Fe epitaxial bilayer, high energy magnon, orbital pumping

2023 KPS Fall Meeting
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I12.03

Magnon-mediated thermal phonon control in magnetic insulators

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Abstract:

Phonons, the quanta of lattice vibrations, are usually considered insensitive to the magnetic field [1]. However, in this work, we observed change of thermal excitation and thermal transport of phonons in the magnetic insulator thulium iron garnet (TmIG) with respect to the external magnetic field via optical reflectometry. We show that this change of thermal excitation is originated from the enhanced low energy magnon excitation at the small magnetic field. Furthermore, from the results of time-resolved measurements, we observed that rising and decay time of thermal phonon excitation are reduced at the low magnetic field. We expect that there is a reduction of relaxation time of phonons in the presence of non-equilibrium magnon density [2], resulting the enhancement of phonon thermal conductivity. Numerical calculation of heat equation reproduces the enhancement of thermal phonon excitation and the reduction of rising and decay time of phonons as a function of the thermal conductivity of magnetic insulator.

[1] A. Baydin, *et al.*, Phys. Rev. Lett. **128**, 075901 (2022)
[2] S. M. Rezende, *et al.*, Phys. Rev. B **103**, 144430 (2021)

Keywords:

magnon, phonon, thermal conductivity, magnon-phonon non-equilibrium

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I12.04

Detection of Nonlinear Acoustic-to-Optic Magnonic Interaction in a Synthetic Antiferromagnetic System

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Abstract:

Understanding the nonlinear aspects of magnonic behavior arising from three-magnon or four-magnon processes in ferromagnetic metals and insulators plays a crucial role in advancing our comprehension of intricate magnon interactions [1-4]. Furthermore, the ability to manipulate magnonic systems within a nonlinear realm holds the potential to drive innovative advancements in hybrid magnonic systems. Harnessing nonlinear magnon-polariton anti-crossing gap closure and bi-stability in dispersion are the representative examples [5, 6]. A recent study has spotlighted tunable magnon-magnon interaction within synthetic antiferromagnets, where introducing a novel magnonic platform [7]. Nevertheless, the phenomenon of nonlinear magnonic excitation in the synthetic antiferromagnets (SAFs) remains largely unexplored, despite their distinctive attributes that encompass both ferromagnetic and antiferromagnetic spin wave characteristics.
In this study, we delve into the intricacies of nonlinear magnon-magnon interaction within an SAF consisting of two ferromagnetic CoFeB layers, coupled antiferromagnetically through a Ru insertion layer by the Ruderman-Kittel-Kasuya-Yoshida (RKKY) interaction. Within this system, two distinct magnon modes coexist: the acoustic mode (in-phase rotation) and the optic mode (out-of-phase rotation). These propagating magnons exhibit an anti-crossing gap within the spin wave resonance spectra at an approximate angle of 45 degrees between the in-plane magnetic field and the magnon wave vector [7]. Through a range of RF-excitation powers spanning from -20 dBm to +10 dBm, we identify an anomalous distortion in the magnonic dispersion. This distortion stems from a sudden transition between the acoustic and optic modes in the vicinity of the anti-crossing gap. Remarkably, this transition occurs discontinuously in both directions, underscoring the bistable nature between the acoustic and optic modes. Moreover, the magnonic dispersion displays hysteresis in response to changes in external magnetic field direction, unveiling the coexistence of bistability. This intriguing observation unveils the robust and nonlinear acoustic-to-optic magnonic interaction within SAFs, carrying significant potential for magnonic applications such as frequency shifters, magnon transistors, and next-generation hybrid magnonic devices.

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Keywords:

Synthetic antiferromagnet(SAF), acoustic/optic magnons, nonlinear, hysteresis, bistability

2023 KPS Fall Meeting
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I12.05

Control of photon-magnon coupling in physically separated dual hybrids by traveling waves

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Abstract:

Photon-magnon coupling, which is crucial for spintronics and magnonics, holds the potential for innovative information processing technologies[1-3]. As the demand for expansive quantum networks continues to grow, ensuring extended information transfer and maintaining coherence remains paramount [4]. To address these challenges, our study delves into both coherent and dissipative couplings between photons and magnons, with a particular emphasis on hybrid quantum systems and their capacity for efficient information exchange between distinct physical entities. Here we utilized planar-geometry samples consisting of physically separated inverted split-ring resonators (ISRRs), indirectly coupled through traveling waves flowing along a shared microstrip line. Additionally, each YIG film is positioned at the center of its respective ISRR, but on its opposing side. Our experimental observations reveal alternations in coupling behaviors compared to our standard single YIG/ISRR hybrid [1]. It indicated that the traveling waves, serving as an additional radiation channel to ISRR and YIG subsystems, have the capacity to transform the photon-magnon coupling strength from a real to a complex value. This suggests that traveling waves, spanning the distances between these components, can influence the nature of coherent and dissipative coupling[5]. Conclusively, this research provides a novel approach for manipulating strong couplings in physically separated systems through the utilization of traveling waves. The implications of these findings could be far-reaching, especially in the realm of communication networks using photon-magnon coupling applications.

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Keywords:

photon-magnon coupling, Inverted split ring resonators, Magnons, traveling waves, coherent and dissipative coupling

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I13.01

HMG Solar Energy Research for Future Mobility

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Abstract:

climate change, has developed integrated solutions for a sustainable future beyond mobility to the entire city. In this presentation, we will introduce why HMC is working on solar energy and what is HMC's strategy for solar energy research for carbon neutrality.

Keywords:

Transparent Solar cells, Hyundai Solar roof

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I13.02

Fluidic-assisted self-alignment transfer (FAST) method of micro-chips and its application

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Abstract:

perfect single alignment of micro-LEDs simultaneously by using simple sweeping process. In addition, FAST can also be applied to large displays (TVs) and small, high-resolution displays (Watch, mobile) applications. Furthermore, its potential to be employed in various types of semiconductor chips transfer is expected to significantly contribute to the advancement of heterogeneous integrated devices.

Keywords:

Micro-LED display, Micro-LED, Fluidic transfer method, FAST

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I13.03

A Brief Introduction to EUV Lithography and Related Issues for DRAM HVM

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Abstract:

EUV(extreme ultraviolet lithography) is becoming widely applied in logic and memory semiconductor industry. Compared to the previous lithography technologies, EUVL uses the shortest wavelength of around 13.5nm to enhance resolution. However, due to the high energy of EUV photon (~92eV) and lower number of photons (~14 times fewer photons than the previous ArF 193nm lithography), EUVL has confronted many different new issues to be handled. In this presentation, a brief introduction to EUVL and related issued from the perspective of DRAM HVM, such as stochastics, mask 3D effect will be covered.

Keywords:

EUV, Lithography, DRAM

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I13.04

Advanced novel optical stack technologies for high SNR in CMOS Image Sensor

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Abstract:

Smaller pixels with high resolution are widely used for CMOS image sensor (CIS) and it needs technologies to reduce the size of the chips while performance or quality of image is even more enhanced. However, the decrease in pixel size inevitably causes degradation of optical properties. In this paper, we introduce a new technique to improve the sensitivity and signal-to-noise ratio (SNR) by using new color filter material and optical structure which is necessary to implement high resolution. These development of new optical pixel structures are able to overcome the degradation of characteristics resulting from pixel shrink and guarantee the possibility of pixel shrink in the future.

Keywords:

CMOS image sensor, high resolution, singnal-to-noise

2023 KPS Fall Meeting
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I13.05

Artificial sensory system for personal care products

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Abstract:

Artificial sensory systems are an emerging field of technology that are designed to mimic the way human sensory organs work. We have developed a system that can measure tactile sense in a manner similar to the way that humans perform. This system has the ability to acquire, process, and interpret information for personal care products. We obtain quantitative sensory data for attributes such as spreadability, stickiness, coolness, etc., for more than 100 products using this device. Furthermore, we have built a reliable AI simulation system by connecting this data with human sensory and rheological data. By utilizing the developed system, it is possible to dramatically reduce the time and costs required compared to the conventional methods for product development and to predict sensory experiences.

Keywords:

Artificial sensory system, AI simulation, Skin surfaces, Personal care products

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I14.01

Neuromorphic Devices based on 2D Materials for SNN

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Abstract:

The conventional von Neumann computing architecture has confronted substantial challenges in achieving desirable energy efficiency and efficient data processing capabilities, particularly when dealing with the demands of extensive datasets in diverse application domains. Therefore, several novel computing methods including neuromorphic computing have been investigated from materials to algorithm perspectives. Neuromorphic computing is designed to adopt and mimic the parallel processing methods of the brain's neural network, composed of a large number of neuron and synaptic devices.

In this talk, I will first give a brief introduction on neuromorphic devices, and then present some of the 2D materials-based neuromorphic device research results performed in my group.

Keywords:

2D material, neuromorphic, neuron, synapse

I14.02

Next Generation Spintronic Device

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Abstract:

In the very near future, artificial intelegence(AI) will be one of the most important keyword in electronics. To treat hugh amount of the data, neuromorphic device has drawn a lot of interests. Spintronics is one of the possible approach to reach this goal due to the distinct advantages such as nonvolatility, high endurance, extremely low power consumption[1], etc.. Recently, based on our methods for the generation of magnetic skyrmions, we have shown many devices based on this magnetic skyrmion. In this special session, we will show our recent results on neuromorphic device based on magnetic skyrmion.

[1] *Communications Materials* **volume 1**, Article number: 24 (2020)

Keywords:

Probabilistic computing based on random MTJs for invertible logics

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Abstract:

A new computing paradigm that fundamentally increases computational efficiency is required than ever before in order to overcome the energy consumption, miniaturization problems in the nanofabrication process, and computational limitations of current CMOS technology. In particular, non Von-Neumann computing technologies that go beyond existing logic circuit technology, such as Neuromorphic computing and quantum computing, are being studied with greater intention in academy and industry. In the meantime, a new computing method based on the randomness at the physical property level was proposed, which offers excellent possibilities for solving problems that are difficult with conventional computing. The proposed method, called as probabilistic computing (*p-computing*) [1,2], shows a promising candidate to provide novel non-Boolean computing schemes. More importantly, invertible logic functions, integer factorization, and emulation of quantum bits are unique possibilities where the *p-computing* might have advantages compared to conventional digital computing [1 and references therein].
In this presentation, we will introduce the basic concepts of *p-computing* and our initial works on random MTJs that can be used for recently proposed p-computing scheme. In addition, we will discuss our primitive results from p-computing circuits.

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Keywords:

Probabilistic computing

2023 KPS Fall Meeting
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I15.01

Reversible air-induced doping in two-dimensional tin halide perovskite transistors

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Abstract:

In recent years, metal halide perovskites (MHPs) have gained attention due to their low cost, facile fabrication, excellent optoelectronic properties, and intrinsically high charge transport properties. Among these, Sn-based perovskites have been considered promising alternatives to conventional Pb-based perovskites, offering favorable properties with achieving lead-free. However, the utilization of Sn-based perovskites still faces significant constraints due to their low stability upon exposure to ambient air, primarily attributed to interaction with oxygen. In our study, we demonstrated the reversible air-induced *p*-doping in two-dimensional phenylethyl ammonium tin iodide ($(PEA)_2SnI_4$) perovskite field-effect transistors (FETs). Electrical measurements showed that exposure to ambient air induces *p*-doping in $(PEA)_2SnI_4$ FETs, and subsequent exposure to vacuum conditions recovers the electrical properties to the pristine state. Through first-principles density functional theory calculations, we identified that oxygen molecules at interstitial sites act as acceptors and cause *p*-doping, supporting the results of electrical measurements. Our findings enhance the comprehension of behaviors of Sn-based perovskites under various conditions and contribute to the further development of stable and reliable perovskite devices.

Keywords:

perovskite, air stability, reversible doping, field-effect transistor

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I15.02

Photoinduced surface degradation mechanism of two-dimensional Ruddlesden-Popper perovskite and its passivation by charge extraction

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Abstract:

For recent several years, organometal halide two-dimensional Ruddlesden-Popper (2D RP) perovskites have brought a plenty of accomplishments in perovskite-based photovoltaics including solar cells, light emitting diodes, and photodetectors. Their reduced dimensionality is raised by incorporation of organic spacer molecules that is intercalated between metal halide octahedra layers, resulting in 2D van der Waals structure. This structure of 2D RP perovskites provide significantly superior thermal and humidity stability compared to 3D perovskites, owing to the hydrophobicity of the organic spacers and their low thermal conductivity. Moreover, the presence of organic moieties and their potential distinction to inorganic layers induces periodic quantum-well structure which constituent carriers are hard to escape from. Thus, 2D RP perovskites are far relieved from ion migration phenomenon that has been problematic in 3D counterparts under electric fields, enhancing the operational stability of devices. However, overshaded by these advantages, the low photostability of 2D RP perovskites has not received enough attention although their usage as light absorption material. Herein, we would like to present our recent works on surface photodegradation of 2D RP perovskites. Widely used PEA_2PbI_4 films were chosen for model system in the studies. The degree of photodegradation was controlled by laser source with various wavelengths, and its evolution was monitored comprehensively, employing photoelectron spectroscopy, photoluminescence spectroscopy, SEM, and AFM. We observed that the photodegradation of PEA_2PbI_4 occurs when light sources with photon energy higher than the band gap are irradiated, inducing loss of iodine ions accompanied by under-coordinated lead ions. We furthermore suggest the importance of light control during film fabrication process by showing the degradation process is accelerated at that moment. Significantly, we also propose an efficient passivation method to prevent the photodegradation of 2D RP perovskite surfaces which utilizing molecular acceptors. We anticipate that our findings can provide meaningful perspective to understand fundamental natures of 2D RP perovskites and their related applications.

Keywords:

perovskite, 2D perovskite, photoelectron spectroscopy, degradation, passivation

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I15.03

A Graphene Neuron based Spiking Neural Network

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Abstract:

Graphene based electronic devices have gained wide attention due to their novel transport properties, and scalable device attributes. Neuromorphic computing envisages to mimic the biological computing paradigm and thereby accelerate data processing by parallel vector matrix multiplications. However, the huge area and energy consumption of conventional CMOS based artificial neuron circuits act as a drawback for the development of compact neuromorphic architectures. Neuron circuits based on graphene devices can act as a viable alternative due to their scalable and low power operation. Further, spike based neuromorphic computing hardware can also benefit from the unique electrical properties of graphene devices. Here, we present a nanoporous graphene (NPG) based memristor device fabricated from sugar cane bagasse (Saccharum officinarum) using a dry transfer technique. The device exhibited reproducible threshold switching characteristics with excellent ON/OFF ratio of greater than 10^6. The threshold switching is due to the oxygen ion accumulation at the interface between the anode and NPG channel. The threshold switching characteristics of the device was further utilized for the demonstration of a leaky integrate and fire (LIF) neuron circuit using SPICE based simulations. The graphene based LIF neuron circuit demonstrated interesting bio-realistic responses like leaky membrane integration, threshold spiking and distinct reset behavior with optimizable spike frequency response. A spiking neural network (SNN) was simulated based on the optimized spike frequency response of the LIF neuron circuit. The SNN model achieved a high pattern recognition accuracy which demonstrates the feasibility of the graphene neuron device for spike based neuromorphic applications. Our results suggest that the fabricated NPG device can be a potential candidate for future neuromorphic chip development.

Keywords:

Graphene, Neuromorphic Computing, Memristor, Spiking Neural Network, LIF Neuron

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I15.04

Compact Modeling of Organic Negative-Transconductance Transistors for Advancing Their Circuit Integration

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Abstract:

Organic negative-transconductance (NTC) transistors are considered as one of the important devices in the field of organic electronics research area. This remarkable device depends on the development of a parallel thin film p-n heterostructure which enacts an anti-ambipolar charge transport that engraves a descending bending (developing peak and valley) in a turning-on transfer curve. To overcome the upcoming technological progress, analytical investigations into the organic NTC transistors are needed. However, there is no standard model for NTC transistors available in circuit simulator. Here, we propose the new compact current-voltage model based on equivalent organic thin-film NTC transistors. This compact model illustrated details of the modeling method and development. Afterward, experimental data from a high-performance device is used to thoroughly validate the model. The flexibility to determine how abruptly inter-regime transitions occur is highlighted as a crucial benefit of the model for the precision of fitting results. The device- and circuit-level perspectives of organic NTC transistors are bridged by this compact, and analytical model that accounts for all operational regimes, fostering the incorporation of organic NTC transistors into useful electronics technologies. The simulation and experimental results showing the precision of model. The experimental and modeling results were overall in good agreement over a wide range of applied *gate voltage and drain voltage*. We made a further detailed analysis of the transition parameters. It was found that inclusion and careful control of these parameters allows for the precise tuning of the transition behaviors, which are critical to the reproduction of the measured electrical characteristics of organic NTC transistors in simulations.

Keywords:

Flexible electronics, Organic transistors

I16.01

Time-Resolved Rheometry of Complex Fluids

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Abstract:

There has been a resurgence of interest over the past decade in complex aging and time-dependent fluids which exhibit a wide range of rheologically challenging phenomena including thixotropy, elastoplastic creep below yield and an age-dependent yield stress. We illustrate how modern oscillatory rheometric techniques can be used to help distinguish the distinct contributions to what may be referred to broadly as *mutating materials* with rheological properties that are typically both time– and rate–dependent. In this tutorial we show how frequency-modulated techniques such as the *optimally-windowed chirps* and amplitude-modulated techniques such as the *Gabor transform* (a Short Time Fourier Transform that utilizes a Gaussian window) can be used to provide optimal time-frequency resolution of the local viscoelastic properties of mutating materials.

Keywords:

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I16.02

Drop-based microfluidics

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Abstract:

This tutorial will focus on the use of drop-based microfluidics to create new functional materials that can be created through using drops as templates on which to construct more complex structures. In addition, the talk will describe the use of drop-based microfluidics for lab-on-a-chip applications that enable very high throughput screening for biotechnology applications.

Keywords:

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J1.01

좋은 과학(물리)교육론 수업을 위한 도전과 반성

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Abstract:

물리교육론은 물리교육과에서 개설하는 핵심 교과 교육론 수업 중의 하나이다. 좋은 물리교육론 수업은 예비교사들이 향후 좋은 물리 수업을 하기 위한 하나의 모델이 될 수 있기 때문에 물리교육론 수업을 잘 구성해서 실행하는 것은 매우 중요하다고 할 수 있다. 하지만 물리교육 전공 예비교사들은 이과 계열 성향이 강하기 때문에 인문학적 소양이 필요한 물리교육론 수업을 낯설어 하는 경향이 있으며, 이 수업에서 임용시험을 대비하기 위한 방대한 지식을 가르쳐야 한다는 부담감이 있기 때문에 "좋은 물리 교육론 수업"은 실현하기 힘든 측면이 있다. 연구자는 국립 사범대에 임용된지 이제 갓 만 3년이 지난 연구자로서 그동안 물리교육론, 과학교육론 등의 수업을 가르치며 좋은 물리교육론 수업은 무엇인지, 물리교육론 수업에서는 어떤 내용을 다루어야 하는지, 물리교육론 수업 내용의 구성은 어떻게 하면 좋은지 많은 고민을 거듭해 왔다. 본 연구에서는 좋은 과학(물리)교육론 수업을 위한 한 연구자의 약 3년간의 도전 사례와, 현 시점에서 그 연구자의 스스로의 반성에 대한 내용과 함께, 향후 더 좋은 과학(물리)교육론 수업을 위해 함께 나누고 싶은 내용들을 발표할 예정이다.

Keywords:

좋은 수업, 물리교육론, 과학교육론, 도전, 반성

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J1.02

물리교육론 수업에 대한 반성과 개선방안 모색

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Abstract:

물리교육론은 물리교육학의 입문 학문으로서 중요성이 크다. 물리교육론의 내용 및 교수 방법에 관한 개선 요구는 많았지만, 다양한 이유로 구체적인 개선 방안을 모색하는 것은 쉽지 않다. 본 발표에서는 물리교육론 수업을 담당했던 경험을 되돌아보고 물리교육론 수업의 목표와 지향점에 대한 고민을 나눌 예정이다. 이를 통해 물리교육학의 입문이자 기반이 되는 과목인 물리교육론의 개선방안을 제시할 것이다.

Keywords:

물리교육론, 반성, 개선방안

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J1.03

이론/연구와 수업 실행간 연결을 위한 물리교육 교과활동

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Abstract:

본 발표에서는 예비 물리교사들이 물리교육 교과 수업에서 배우는 물리교육 이론과 연구결과들을 실제 수업지도에 활용할 수 있는 역량을 기르기 위한 방법을 소개하고, 이와 관련된 다양한 노하우를 공유하고자 한다.

(1) 유의미 학습 이론 – 실사성(substantiveness)이 있는 물리개념을 다양하게 표현하기, 추상적이고 익숙하지 않은 용어에 구속성(non-arbitrariness) 부여하기, 선행조직자 역할을 할 수 있는 비유 만들기
(2) 경험-귀추적 순환학습 모형 – 3단계 귀추적 사고 활동지(설명할 현상의 특징들 나열하기-설명할 현상과 유사한 현상을 찾아 특징 나열하기-두 특징간의 유사성을 이용하여 가설 제안하기) 만들기
(3) 과학적 설명의 구조 – 과학적 설명을 하기 전에, 원인, 현상(결과), 배경이론, 조건/가정별로 적고, 그들을 모아 인과적 관계로 과학적 설명하기
(4) 개념도 – 개념도를 쉽게 활용하기(개념과 연결어 채워넣기, 미완성 개념도 완성하기 등)
(5) 탐구문제 발견 – 교과서 탐구활동 후에 탐구문제 발견하기를 안내하는 활동 단계 추가하기
(6) 시범장치 만들고 시연하기 – 시범의 목적 인식하기(교과서 학습목표/내용과 연관지어), 시범장치 만들기, 잘 보이게 시연하기, 이해할 수 있도록 쉽고 분명하게 설명하기, 질문하고 답하기
(7) 실생활 상황 – 실제값으로 바꾸어 설명하기/문제만들기, 실제 사례 이용하기

Keywords:

이론과 실행, 물리수업 지도 역량, 물리교육론

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J2.01

Review of Volume Free Electron Lasers

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Abstract:

We give a review of a new type of vacuum electronic devices named Volume Free Electron Lasers (VFEL). VFEL is operating on the radiation of relativistic electrons moving through a spatially periodic resonator (photonic crystal) in synchronism with one or more electromagnetic waves, for which the Bragg diffraction conditions are satisfied near the intersection of the roots of dispersion equation. The main ideas and principles of VFEL operation provide a radical decrease in the threshold conditions of generation. VFEL principles are valid for all frequency ranges and various mechanisms of spontaneous emission.

The VFEL linear stage was investigated theoretically. The nonlinear stage of instability in the X-ray, optical and microwave wavelength ranges under VFEL conditions was simulated. VFEL chaotic dynamical properties are investigated by methods of mathematical modelling.

Currently VFEL experimental studies are carried out in gigahertz and subterahertz ranges with resonators made of metal threads or foils.

Keywords:

vacuum electronic device, volume free electron laser

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J2.02

Simulation study for measuring position and energy of few hundreds MeV carbon beam used in therapy

YOO Hwidong *[1], EO Yun [1], CHO Guk [1], HA Seungkyu [1], HWANG Kyuyeong [1], JANG Haeun [1], JANG Seoyun [1], KIM Dongwoon [1], KIM Sungwon [1], KIM Tongil [1], PARK Hyesung [1], DO Hyunsuk [2], HUH Changgi [2], KIM Bobae [2], LEE Junghyun [2], LEE Sehwook [2], RYU Min Sang [3], KO Sanghyun [4], KWON Hyejin [4], KIM Doyeong [5], LEE Hyupwoo [5], LEE Jason [5], LEE Yunjae [5], SON Youngwan [5], KIM Dongwook [6], KWON Nahye [6], LEE Woochan [6], KIM Yongjun [7], LIM Sanghoon [7], RYU Jaehyeok [7], BAE Joonsuk [8], KIM Beomkyu [8], LEE Hyungjun [8], PARK Hyebin [8], JANG Yoonjun [9], JEONG JinYong [9], KIM Minsuk [9], CHOI Suyong [10], CHEON Byunggu [11]

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Abstract:

Our aim is to get 1 % energy resolution at 400 MeV/u carbon beam and 1 mm^2 position resolution. So with several scintillation crystals(LYSO, BGO, CsI), the energy resolution could be satisfied under 1 % requirement. And using the fiber tracker, the reconstructed position could get 1 mm^2 resolution. The prototype of the detector is designed with 2 x 2 x 12 cm^3 scintillation crystal(LYSO, BGO, CsI) and 2 layers of square type scintillation fiber tracker. We present the result of the Geant4 simulation compared to our requirements.

Keywords:

Crystal Scintillator, fiber tracker, Geant4

New results of the Project TRILLION: Geant4 model of X- and gamma-rays production in oriented crystals

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Abstract:

We present the new Geant4 model to simulate X- and gamma-rays production in oriented crystals by ultrarelativistic electrons and positrons. This radiation model is an essential step towards the simulations of X-ray and gamma radiation source for radiotherapy and nuclear physics, a positron source for future lepton colliders and an ultracompact electromagnetic calorimeter for high-energy experiments. The Geant4 simulation models of these applications are developed in the frame of Marie Curie Individual Global Fellowships project TRILLION.

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Keywords:

Geant4, Oriented crystal, X-ray, Gamma-ray

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J2.04

KOTO 실험의 표본형 열량계 전산모사 연구

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Abstract:

J-PARC KOTO 실험은 이론적 불확정도가 적은 $K_L \rightarrow \pi^0 \nu\bar{\nu}$ 사건을 검출하여 표준모형 너머 새로운 물리 현상을 찾고자 한다. 검출이 어려운 중성미자를 제외하고, $K_L \rightarrow \pi^0 \nu\bar{\nu}$가 붕괴하여 생긴 두 개의 광자가 검출되면 사건이 발생하였다고 판단한다. K_L의 붕괴모드를 결정하는데 검출된 광자의 개수가 중요하기 때문에 검출기의 광자 검출효율이 중요하다. 최근 KOTO 데이터 분석에서 비효율 사건의 발생 빈도가 Geant4 버전에 따라서 달라지는 것이 확인되었다. 본 연구는 Geant4 버전들의 차이가 발생하는 이유를 알기 위한 것이다. 비효율 사건의 원인으로 생각되는 광핵 상호작용 과정을 Geant4가 어떻게 다루고 있는지, 이로 인한 버전 의존성이 있는지, 검출기 내부에서 발생하는 입자들의 반응을 추적하여 알아보고, 광핵 상호작용이 발생하여 비효율 사건을 만드는 과정에 대해 연구하여 검출기의 비효율성을 줄일 수 있는 방법에 대해서 알아보고자 한다.

Keywords:

KOTO, Kaon, Sampling Calorimeter, Monte Carlo Simulation

Lineshape analysis of a new narrow peak structure near the Λη threshold in the pK⁻ system at Belle

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Abstract:

We observe a narrow pK^- peak near the $\Lambda\eta$ threshold in $\Lambda_c^+ \to pK^-\pi^+$ events collected by the Belle detector. Through lineshape analysis of this peak structure, we identify it as a threshold cusp enhanced by the Λ(1670) pole nearby, as opposed to signifying a new hadron resonance. This result has recently been published in Physical Review D [1]. In this talk, we will give a detailed explanation of this analysis method and the result.

References
[1] S. B. Yang, K. Tanida, and J. K. Ahn et al. (Belle Collaboration), Phys. Rev. D 108, L031104 (2023).

Keywords:

Belle, Flatté model, cusp, charmed baryon, hyperon

J3.01

Neutrino Cross Sections: Interface of shallow- and deep-inelastic scattering for collider neutrinos

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Abstract:

Neutrino experiments in a Forward Physics Facility at the LHC can measure neutrino and antineutrino cross sections for energies up to a few TeV. Although a large fraction of LHC neutrinos is distributed above 100 GeV, there will be thousands of neutrinos in the 10’s of GeV energies. For neutrino energies below 100 GeV, the inelastic cross section evaluations have contributions from weak structure functions at low momentum transfers (Q^2) and low hadronic final state invariant mass (W). In this work, we evaluate the neutrino deep-inelastic scattering (DIS) cross sections using theoretically motivated and phenomenologically constructed structure functions for low Q^2, and investigated contributions of the W and Q^2 outside the DIS region. We also compare our results with other approaches to account for this kinematic region in neutrino cross section for energies between 10–1000 GeV.

Keywords:

Neutrino cross sections, DIS scattering

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J3.02

CP violation and mass hierarchy in the neutrino sector from T2HK and KNO

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Abstract:

Long-baseline neutrino experiments play a crucial role in investigating neutrino oscillations. The study of neutrino oscillations can provide solutions to some puzzles including CP violation (CPV) phase and mass hierarchy in the neutrino sector. In neutrino oscillations, matter effect (or MSW effect) is important, especially for baseline experiments, and can be the key point to identify the sign of the mass squared differences. Thanks to long baselines, T2HK (L=295 km, Japan) and T2HKK (L~1100 km, KNO in Korea) are good next-generation experiments to explore the puzzles in the neutrino sector. We will discuss how to find the CP violation phase and mass hierarchy using neutrino oscillations with the MSW effect focusing on T2HK and KNO experiments.

Keywords:

neutrino oscillation, neutrino mass hierarchy , CP violation, MSW effect, Long-Baseline Neutrino Experiment

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J3.03

Dark Z boson and the W boson mass anomaly

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Abstract:

The dark Z boson is a new vector particle induced by an additional Abelian gauge symmetry. It interacts with the SM fermions via kinetic and mass mixings and provides a new source of parity violation. It is known that such a parity-violating effect can be tested by future precious measurements of the weak mixing angle at low energies. In this talk, we discuss the effect of the dark Z boson on the W boson mass measurement. Mixings between dark Z and the electroweak gauge bosons induce deviations in the SM gauge couplings, and it gives a possibility of explaining the W boson mass anomaly reported by the CDF collaboration. We will show that the dark Z model can explain the W boson mass anomaly while satisfying other experimental constraints within 2σ; on the other hand, the simple dark photon model cannot. We also discuss how to verify such a dark Z boson in future experiments.

Keywords:

New gauge boson, Dark Z boson, The W boson mass

J3.04

Uncovering doubly charged scalars with dominant three-body decays using machine learning

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Abstract:

We propose a deep learning-based search strategy for pair production of doubly charged scalars undergoing three-body decays to Wtb in the same-sign lepton plus multi-jet final state. This process is motivated by composite Higgs models with an underlying fermionic UV theory. We demonstrate that for such busy final states, jet image classification with convolutional neural networks outperforms standard fully connected networks acting on reconstructed kinematic variables. We derive the expected discovery reach and exclusion limit at the high-luminosity LHC.

Keywords:

BSM, LHC, ML, DNN

2023 KPS Fall Meeting
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J3.05

Surface code and 3-dimensional Z(2) gauge theory

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Abstract:

A threshold probability provides a maximum, tolerable quantum error rates of quantum circuits that any quantum computer should allow for sustained quantum computations. Thus, finding a threshold probability for a quantum code is important for the realization of quantum computer. Expanding on our previous study of the threshold probability for 1-D repitition code via Quantum Error Correction (QEC) - Statistical physics Model (SM) mapping, we study the threshold probability for the surface code. For a realistic quantum circuit error model, we find that the error pattern of the surface code can be mapped into a 3-dimensional Z(2)xZ(2) gauge theory, and here we report on our progress.

Keywords:

qauntum computing, surface code, quantum error correction, statistical physics model

2023 KPS Fall Meeting
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J3.06

Dynamical Generation of Matter-Antimatter Asymmetry from a Large Scale Hierarchy

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Abstract:

We propose a simple scheme of baryogenesis in which the observed baryon asymmetry in the Universe originates from a large hierarchy between the two fundamental scales, the weak scale and the Planck scale.
The model is based on the neutrino portal Affleck-Dine (AD) mechanism, in which the asymmetry is generated from the dynamics of a Standard Model (SM) singlet complex scalar field that carries a lepton number. The related phonomenology will be also discussed.

Keywords:

Dark matter, Baryogenesis, beyond the Standard Model

Complete spectrum of Sp(4) gauge theory in the quenched approximation

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Abstract:

We have performed numerical studies of Sp(4) gauge theory using lattice Monte-Carlo techniques. When the theory is coupled to two fundamental and three antisymmetric Dirac fermions, it could serve as a ultra-violet theory which realizes SU(4)/Sp(4) composite Higgs as well as top-quark partial compositeness in the context of physics beyond the standard model. In the quenched approximation, namely no dynamical fermions in the sea, we calculate the complete mass spectrum of the theory including flavor-non-singlet mesons, chimera baryons, and glueballs.

Keywords:

Composite Higgs, Top-quark partial compositeness, Sp(4) gauge theory, Chimera baryon, physics beyond the standard model

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J4.01

Gravitational Waves and the effective mass of wormholes in the Newtonian Approximation

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Abstract:

In this study, we considered a Newtonian approximation of the gravitational potential of a wormhole. We need a definition of the effective mass of a wormhole, including tension due to the 'flare-out condition'. The gravitational interaction of a wormhole with another mass, such as a wormhole or a black hole, can be easily calculated similarly to a two point-particle system, provided the effective mass remains constant. If the effective mass is negative, a sophisticated approach is needed. Also we get the gravitational wave generation by a point particle around the wormhole as the extreme limit of the hybrid binary system.

Keywords:

gravitational waves, wormhole binary system, effective mass

2023 KPS Fall Meeting
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J4.03

Atomic structure characterization of potential coating material of A+LIGO using ePDF and FEM

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Abstract:

The Advanced Laser Interferometer Gravitational-wave Observatory (aLIGO) detectors have successfully observed the gravitational wave (GW) signals since the first detection in 2015. Despite its success, current detectors' sensitivity to detect GW from various astronomical sources is limited by coating Brownian noise in the most sensitive frequency range, around 100 Hz. In order to push the sensitivity limit, reducing coating Brownian noise by optimizing the performance of future detector's mirror coating with lower mechanical loss materials is crucial to further reduce coating Brownian noise. For efficient investigation of new candidate material, atomic structure characterization study is in progress to find the correlation between mechanical loss and local atomic structure of amorphous metal oxide material. To accomplish this goal, electron pair distribution function (ePDF) analysis or fluctuation electron microscope (FEM) analysis are applied to diffraction data acquired from transmission electron microscope (TEM) to extract short-range order (SRO) or medium-range order (MRO) structural information. In this talk, recent analysis results on SRO and MRO are presented for one of the promising future coating materials: Titania-doped Germania.

Keywords:

Advanced LIGO, Atomic structure characterization, Electron pair distribution function (ePDF), Fluctuation electron microscopy (FEM), Transmission electron microscope (TEM)

2023 KPS Fall Meeting
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J4.04

Classification and Analysis of KAGRA Glitch

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Abstract:

We analyzed noises of the KAGRA detector, a gravitational wave detector based upon the cryogenic underground laser interferometer, during the O3GK run, a joint observation run of KAGRA and GEO 600. Our analysis was carried out with two tools, hierarchical veto (hveto) and omicron, which have been commonly used for the noise analysis of the LIGO and VIRGO data. We present the results of our analysis according to each channel group of the KAGRA detector. KAGRA is a gravitational wave detector based on an interferometer in Kamioka prefecture, Japan. It is similar in design to other gravitational wave detectors LIGO and VIRGO but is located underground in a mountain. And by maintaining a cryogenic temperature, vibration caused by the environment is minimized. The data analysis team uses a variety of computer tools to verify that KAGRA can properly detect gravitational waves and increase its sensitivity to detect distant cosmic distances. KAGRA, like LIGO and VIRGO, is extracting actual data, such as pilot operation and engineering implementation (ER) for gravitational wave observation. For that, KAGRA actually observed from April 7, 2020, to April 20, 2020, and this period is called O3GK. We proceed by linking the methods and results of the above study. The Q spectrograms from the KAGRA main channel are collected and broadly classified into Blip, Blip-like, Line-related, Whistle, and other glitch, and reclassified into small groups with detailed naming(Blip, Dot, etc.). And, in the noisy part of the main channel, extract the Q spectrogram for the time period that is considered to be highly related (Hveto) and classify the AI rather than classifying it by eye to make classification faster.

Keywords:

KAGRA, Hveto, Omicron, O3GK, Detector Characterization

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J4.05

A LIGO detection at 5.5σ of the central engine of GRB170817A by multimessenger calorimetry and event timing

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Abstract:

We discuss a recent identification of the central engine of GRB170817A following the double neutron star merger GW170817A in the detection of a contemporaneous emission of a descending chirp in gravitational radiation. This observation has a significance of 5.5σ by event timing applied to LIGO H1 and L1 data. For the first time, this observation shows the spin-down of a Kerr black hole produced in the delayed gravitational collapse of an initial hyper-massive neutron star. During O4-5, LVK is expected to similarly probe cosmological GRBs from mergers and, possibly, core-collapse supernovae. (van Putten & Della Valle, 2023, A&A, 669, A36, https://doi.org/10.1051/0004- 6361/202142974.)

Keywords:

GRB170817A, Central engines, LVK O4

2023 KPS Fall Meeting
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J4.06

LIGO-Virgo-KAGRA O4: Observing the restless Universe in Transient and Stochastic gravitational waves

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Abstract:

The universe is replete with vide range of Extreme Transient astrophysical sources. So far LIGO-Virgo_KAGRA (LVK) gravitational-wave (GW) observations produced a catalog of about 90 signals from compact binary mergers (CBC) and 1 from the central engine of the short GRB17081A. Possibly powerful GW signals are also expected from core-collapse supernova (CC-SNe) representing the parent population of long GRBs. Collectively, these astrophysical transients will contribute to a stochastic gravitational wave foreground (SGWF) of interest to LVK. This outlook poses some novel challenges to the development of advanced searches for un-modeled GWs signals at sensitivities significantly beyond conventional LIGO-searches and their extension to searches for SGWF. Preliminary results indicate show a promise to detecting SGWF in the LVK band of sensitivity.

Keywords:

Gravitational waves, Stochastic gravitational waves, Transients

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J4.07

Detecting Gravitational Wave Background by Electromagnetic Cavity

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Abstract:

Gravitational wave (GW) detection using electromagnetic (EM) cavities has garnered significant attention in recent years. With ongoing experiments on axion detection using highly sensitive electromagnetic cavity, there is potential to apply these existing facilities to GW detection, opening up a new channel of GW observation. In this talk, we comprehensively examine the principles of GW detection using EM cavities within the framework of general relativity. Furthermore, we propose a detection method for the GW background.

Keywords:

Gravitationa Waves, Electromagnetic Cavities, Gravitational Wave Background

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J6.01

4GSR Hard X-ray NanoProbe (HXNP) Beamline

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Abstract:

Hard X-ray NanoProbe (HXNP) Beamline is an X-ray nanoprobe operating in the energy range from 5 keV to 25 keV, offering scanning and full-field imaging modalities. Scanning capability will use a nano-focused beam size down to ~30 nm with a fly-scanning range up to ~100 um. Owing to the coherent bright source of 4GSR and the optical scheme optimized for the KB nano-focusing, HXNP will produce a significantly higher focused flux density (~10^{12} photons) at sample position. Using the intense nano-beam, HXNP will make dramatic enhancements for 3D ptychographic imaging both in the transmission and Bragg channels, enabling sub-10 nm resolution for a broad range of material systems. HXNP will also provide a wide range of correlative imaging capabilities such as XRF, XRD and XANES. KB-based nano-focusing gives a much longer working distance than any other focusing optics. HXNP aims to achieve a working distance of 50 mm to offer flexibility in adapting to a range of in-situ environments. In addition to these scanning-probe capabilities, HXNP will offer full-field imaging in the form of projection imaging. The intense nano-focusing beam serves as a point source for the magnified projection of the sample at the detector gives real-time high-resolution images.

Keywords:

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J6.02

Real-Time XAFS beamline at Korea-4GSR and its applications

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Abstract:

The Korea-4GSR, a 4th generation storage ring-based synchrotron, is being constructed in Ochang. As part of this project, a beamline called the Real-Time XAFS beamline is under development. The beamline will be dedicated to X-ray absorption fine structure (XAFS) experiments, allowing for an understanding of the local and electronic structures of atoms that absorb X-rays. Thanks to an advanced light source from the Korea-4GSR, the beamline is expected to provide X-rays with increased brilliance by about 10 to 100 times compared to the several XAFS beamlines at Pohang Light Source-II (PLS-II). With this increased brilliance, the beamline plans to incorporate two 'photon-hungry' measurements: quick X-ray absorption fine structure (QXAFS) and X-ray emission spectroscopy (XES). This presentation will overview the beamline design and demonstrate applications in various scientific fields for XAFS, QXAFS, and XES that will be available on the Real-Time XAFS beamline.

Keywords:

Korea-4GSR, Real-Time XAFS beamline, Beamline design goal, X-ray absorption fine structure, Quick X-ray absorption fine structure, X-ray emission spectroscopy

결맞음 소각산란 빔라인 (Coherent Small Angle X-ray Scattering Beamline)

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Abstract:

CoSAXS (Coherent Small Angle X-ray Scattering) beamline is planned to be built in Korea-4GSR, and μSAXS (Small Angle X-ray Scattering) and XPCS (X-ray Photon Correlation Spectroscopy) experimental techniques are to be implemented.
The μSAXS setup using μm-sized beams enables structure analysis at the sub-nm to hundreds of nm level and in-situ experiments at the msec level. Many studies, including those of nano-patterning materials, organic semiconductors, are related to this experimental technique.
XPCS is an experimental technique to study the dynamics of materials at the nm level using coherent beams. It is based on measuring the time correlation function of the speckle pattern which appears when a coherent X-ray beam is scattered from a sample with a disordered structure. The XPCS setup aims to enable sub-msec dynamics experiments.
This presentation will show the design values of CoSAXS beamline, the XPCS and μSAXS setup and applicable studies using these setups

Keywords:

4GSR, Coherent SAXS, XPCS, μSAXS, Dynamics, In-Situ SAXS

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J6.04

Thermal Analysis on X-ray Optics in Beamlines of Korea Fourth-generation Storage Ring

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Abstract:

The Korean fourth-generation storage ring (Korea-4GSR) has a low electron beam emittance of 60 pm-rad and provides photon flux density several times larger than the third-generation Pohang light source (PLS-II). However, the new source imposes a higher heat load on beamline optics. In particular, in the case of soft x-ray beamlines, the heat load is concentrated on the first mirror (M1), which receives the broad-bandwidth white beam, while in the hard x-ray beamline, it is concentrated on the monochromator. Therefore, efforts to reduce the heat load were reflected in each beamline design, and based on this, we calculated the absorption power density and temperature rise in each optics. In this paper, the results are compared quantitatively.

Keywords:

Korea-4GSR, Heat load, Thermal analysis

Nuclear spctroscopy projects at CENS

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Abstract:

Center for Exotic Nuclear Study in the Institute for Basic Science was recently founded to study fundamental questions in astrophysics and nuclear physics by investigating radioactive atomic nuclei. The center comprises four groups: experimental nuclear structure, experimental nuclear reaction, experimental nuclear astrophysics and nuclear theory.
In the experimental groups, many detectors are currently under development/planned which can be applied for the nuclear spectroscopic study at new accelerator facility RAON, such as Clover HPGe detector array (ASGARD), Co-axial Ge detector array, Si detector array (STARK and STARK-Jr), LaBr3 detector array (KHALA), conversion electron detector array (SCEPTER) and neutron detector array (PANDORA II). Several projects utilizing detectors, such as decay station and in-beam gamma-ray spectroscopy, have recently started for low-energy branches at RAON. Also, many international collaboration projects are ongoing such as the IDATEN project utilizing the LaBr3 detector array from Korea and UK, forming the largest LaBr3 array at RIBF RIKEN. The current status of the detector system development for nuclear spectroscopy and possible setups will be presented.

Keywords:

J7.02

Performance test of LAMPS ToF array with cosmic muons

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Abstract:

We tested the performance of the LAMPS time-of-flight (TOF) array with cosmic rays. We employed custom-made electronics (TOFDAQ from NOTICE Co.) to develop the integrated trigger and data acquisition system. The TOF array comprises 46 Barrel TOF (BTOF) and 48 Forward TOF (FToF) detectors. This talk will focus on the cosmic test results with the TOFDAQ system compared with the beam test results at HIMAC.

Keywords:

LAMPS, RAON, Time-of-Flight, Cosmic muon, SiPM

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J7.03

GEANT4 simulation study of the Start Counter for the LAMPS experiment at RAON

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Abstract:

Start Counter is a scintillator detector designed to measure the reference time of the incident beam at the Large Acceptance Multi-Purpose Spectrometer (LAMPS). The performances of the Start Counter have been evaluated using radioactive sources and 100 MeV proton beams at KOMAC and HIMAC. To understand the test results, timing resolution as a function of light yield (ADC count), and estimate the performance in the circumstance of LAMPS, a simulation framework with GEANT4 has been developed. The generation, propagation, and detection of scintillation photons are described by optical physics implemented in GEANT4. Through the simulation study, we have understood the detailed performance, such as the light collection efficiency of the current design. In this presentation, we will report on the simulation framework's development and the simulation study's results.

Keywords:

GEANT4, Start Counter, LAMPS

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J7.04

Module assembly of segmented sampling calorimeter for the KOTO experiment

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Abstract:

The KOTO experiment is one of the major experiments at J-PARC, and it aims to search for experimental signatures beyond the standard model. Based on the theoretical calculation of the standard model, the branching ratio of $K_L \rightarrow \pi^0 \nu \bar{\nu}$ is very small (3×10^{-11}), and the KOTO experiment aims to perform a precise measurement of the $K_L \rightarrow \pi^0 \nu \bar{\nu}$ decay channel using the KL beam provided by the J-PARC facility. The primary detector system at the KOTO experiment is an electromagnetic calorimeter to measure γ energy from π0 decay and reject hadronic background. The experiment plans to upgrade the electromagnetic calorimeter system by placing a segmented sampling calorimeter upstream to achieve better energy resolution and signal purity. The segmented sampling calorimeter module comprises five layers of a thin tungsten sheet and scintillating fibers to measure shower shape more accurately in front of the current CsI calorimeter. This presentation will overview the segmented sampling calorimeter used to upgrade the KOTO experiment and present the module production procedures, current status, and plans.

Keywords:

KOTO, Sample calorimeter

J7.05

Early investigation of the MVTX commissioning

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Abstract:

The sPHENIX experiment has achieved a major milestone with the construction and installation of the cutting-edge three-layer Monolithic-Active-Pixel-Sensor (MAPS) based VerTeX detector (MVTX) in 2023. The MVTX is the innermost tracking detector, boasting a remarkable spatial resolution of 5um, covering 2.5-4.0cm radially and a pseudorapidity range of $|\eta|<2$ and consisting of 432 ALPIDE sensors with 27 um x 29 um pixels in an area of 1.5cm x 3.0cm.
We make an early diagnosis of the data collected in the sPHENIX MVTX commissioning, collect a few indicators for the successful operation of the detector, and identify the next milestones for the operation of the detector and the analysis of the resulting data.

Keywords:

MVTX, sPHENIX

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J7.06

Development of the Forward Tracker Prototype for the LAMPS experiment at RAON

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Abstract:

The LAMPS experiment, one of the nuclear physics experiments at RAON, targets studying the symmetry energy of neutron-rich systems by measuring the id and energy of particles from exotic nuclei reactions. The main detector of the measurement, especially for the tracking is the TPC (Time Projection Chamber) which encloses around the target. However, due to its structural characteristics, the tracking capability in the forward downstream direction is relatively less powerful. Therefore, an additional tracking system that makes up the forward tracking capability would be a meaningful upgrade for the future operation of the LAMPS experiment. The LAMPS Forward Tracker, which currently under conceptual design and prototype test stage, consisting of multiple layers of scintillating fiber array combined with MPPC (Multi-Pixel Photon Counter) readout. In this talk, we report the general concept and status of 1st prototype development of the LAMPS Forward Tracker.

Keywords:

RAON, LAMPS, Tracking, Scintillator, MPPC

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J7.07

DPTS test beam analysis 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. ITS3 is a cylindrically bent silicon vertex detector based on stitched wafer-scale monolithic active pixel sensors with a 65 nm CMOS technology, and it will improve the trajectory and vertex measurement precision of charged particles. Various silicon sensors, such as DPTS, ATPS, and CE65, were developed and tested with existing ALPIDE to evaluate their performance in test beams at PS, SPS, and DESY. The beam test in December 2022 focused on the performance study with inclined DPTS sensors following a similar study with bent ALPIDE chips. In this test beam, DPTS sensors were rotated up to 75 degrees to vary the beam incident angle, and we tested different configurations for the threshold value for hit digitization. In this presentation, we will introduce the test beam of prototype silicon sensors for the ITS3 and present the test beam analysis results of the inclined DPTS setup.

Keywords:

ALICE, ITS3, Silicon tracker, Beam test

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J7.08

Development tracking algorithm of AT-TPC at HIMAC

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Abstract:

The development for active target time projection chamber(AT-TPC) to measure quasi-elastic scattering of proton off Carbon is presented. The experiment was carried out using the 200 MeV/u Carbon beam at the Heavy Ion Medial Accelerator in Chiba (HIMAC) facility in Japan. Using this dataset, we measured the drift velocity of electrons in the chamber, and calibrated the energy deposition and timing offset for the readout system.
We also developed our own multi-track reconstruction algorithm based on Hough transform, which was optimized for the rectangular shaped pads.
Based upon this, we will discuss the utility of AT-TPC detector for the rare isotope accelerator experiment at RAON.

Keywords:

LAMPS, TPC, HIMAC, RAON

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J8.01

Generation of three-dimensional continuous-variable cluster state

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Abstract:

Measurement based quantum computing is a promising paradigm of quantum computation, where universal computing is achieved through a sequence of local measurements. The backbone of this approach is the preparation of multipartite entanglement, known as cluster states. While a cluster state with two-dimensional (2D) connectivity is required for universality, a three-dimensional (3D) cluster state is necessary for additionally achieving fault tolerance. However, the challenge of making 3D connectivity has limited cluster state generation up to 2D. Here we experimentally generate a 3D cluster state in the continuous-variable optical platform. To realize 3D connectivity, we harness a crucial advantage of time-frequency modes of ultrafast quantum light: an arbitrary complex mode basis can be accessed directly, enabling connectivity as desired. We demonstrate the versatility of our method by generating cluster states with 1D, 2D, and 3D connectivities. For their complete characterization, we develop a quantum state tomography method for multimode Gaussian states. Moreover, we verify the cluster state generation by nullifier measurements, as well as full inseparability and steering tests. Finally, we highlight the usefulness of 3D cluster state by demonstrating quantum error detection through syndrome measurements. Our work paves the way toward fault-tolerant and universal measurement-based quantum computing.

Keywords:

measurement based quantum computing, optical quantum computing, cluster entangled state, quantum error detection

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J8.02

Quantum computation using Rydberg atom graphs

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Abstract:

Rydberg atoms are being widely used for quantum simulation and quantum computing applications. The key advantages of Rydberg atom systems are the programmable interaction of individual atoms utilizing the strong dipole interactions of highly excited energy states and almost arbitrary three-dimensional spatial arrangements of the atoms utilizing optical tweezers. In that regards, Rydberg atom graphs, which are the arrangement of atoms of which the interaction through Rydberg state excitation can be represented by a mathematical graph, have emerged as a promising qubit platform through implementing quantum gates and circuits, probing quantum phase transitions in designed atom arrays, and solving the classically diffcult class of computational problems. In this presentation we briefy review the latest progress of the related techniques and research activities involved with the Rydberg atom graphs.

In recent years, Rydberg atoms are used in the fields of quantum simulation and quantum computing. The key advantages of Rydberg atom systems include their ability to program the interaction of individual atoms by leveraging the strong dipole interactions of Rydberg energy states. Additionally, they allow for nearly unrestricted three-dimensional arrangements of atoms through the use of optical tweezers. Within this context, the concept of Rydberg atom graphs has emerged as a promising foundation for quantum information processing. These graphs represent the spatial arrangement of atoms, with their interactions via Rydberg state excitation depicted as mathematical graphs. This approach holds potential for implementing quantum gates and circuits, investigating quantum phase transitions in exotic arrays of atoms, and tackling computationally challenging problems that are difficult to address classically. This presentation provides a brief overview of the recent advancements in techniques and research activities related to Rydberg atom graphs.

Keywords:

Rydberg atom, Quantum computing, Quatum simulation

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J8.03

Progress of neutral atom quantum computing at KRISS

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Abstract:

We report the progress toward building neutral atom computers at KRISS. Neutral atoms have emerged as versatile platform for quantum computation and metrology. To engineer quantum state of neutral atoms, we use two different optical techniques: 1. Optical lattice, 2. Optical tweezer. Optical lattices realize a quantum simulation platform for solving strongly-correlated condensed matter problem such as Hubbard model. Optical tweezer provides analog and digital quantum computation opportunities for solving optimization problem and realizing quantum circuits. In both configurations, ytterbium species are utilized as qubits. The properties of ytterbium and its unique opportunity for quantum computations will be discussed in this talk.

Keywords:

2023 KPS Fall Meeting
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J9.01

Crossover phenomena of the Ising Spin model on scale-free network

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Abstract:

We studied crossover phenomena in the Ashkin-Teller (AT) model and the hidden Potts (HP) spin model defined on the scale-free network.

In general, the critical phenomena near the critical temperature are well known to us; however, the study has not been implemented exhaustively for the crossover phenomena.

Thus, we have determined whether the crossover phenomena occur in the system and then investigated the critical properties of the crossover phenomena.

In the AT and HP models, we find that the temperature dependency of the order parameter (magnetization) diverges at CP.
From the CP, we can introduce the Widom line where the temperature dependency of the order parameter is locally maximum.

It notes that the Widom line can be regarded as the crossover point because analytical properties of the (Landau-Ginzburg) free energy differ according to whether the temperature is higher or lower than the crossover point.

If the temperature is lower than the crossover point, the system behaves similarly to a system with strong strength of the interaction among spins. Otherwise, when the temperature is near the critical value, the strength of the spin interaction weakens, so the system shows a different behavior from the system with solid interaction.
These crossover phenomena originated from the 'hub' structure, so the crossover phenomena do not appear in the case of lattice or random graphs where there is no hub.

We found a crossover point in the spin interaction system, like the case of the water, and the AT and HP model's properties change when the temperature goes through the crossover point.

Keywords:

Crossover phenomena, Critical point, Widom line, Scale-Free network, Ashkin-Teller model

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J9.02

Renormalization Group-Motivated Data Anaysis

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Abstract:

We introduce a new method for coarse-graining data that is inspired by the renormalization group (RG). Our method is able to effectively reduce the dimensionality of data while preserving the essential features. The key to our method is to find appropriate pairs of data sets to coarse-grain. We do this by considering both the overall information loss in the coarse-grained data and the proximity of the data points in the original data set. For weakly correlated data, we use the correlation of data as a metric for the proximity of data points. However, we also concern about minimizing an overall projection error to ensure that the coarse-grained data is as informative as possible. We show that our method can be extended to incorporate non-linear features by replacing correlation measures with mutual information. This results in an information-bottleneck-like trade-off: maximally compress the data while preserving the information among the compressed data and the rest. We examine our method with random Gaussian data, the Ising model, and the glass system to demonstrate its validity. Our approach has potential applications in various fields, including machine learning and statistical physics.

Keywords:

renormalization group, machine learning, coarse-graining

2023 KPS Fall Meeting
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J9.03

Divergence of Differential Capacitance at Electrodes: A Statistical Field Theory Approach with Coulomb and Yukawa Potential

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Abstract:

Ionic liquids (ILs) are appealing materials because of low volatility, good solvent properties, high thermal stability, and environmental sustainability. Though they have used for decades, understanding their behavior in the vicinity of charged interface is still challenging in high concentration. One of the obstacles is a formation of electric double-layer (EDL). Most studies on EDL use phenomenological approaches such as Landau-Ginzburg free energy. In this study, we develop a modified Poisson equation to explore the structure of ILs near the charged surface, from the statistical field theoretical analysis employing the long-range Coulombic interaction and short-range the Yukawa interaction between ILs. We find a differential capacitance diverges, indicating first-order transition and surface instability, upon EDL formation. The asymmetric Yukawa interaction enhances a charge separation near the electrodes, hence the divergence occurs at lower surface charge density.

Keywords:

Statistical Field Theory, Electric Double Layer

J9.04

Cargo velocity hauled by multiple kinesins in crowded environments

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Abstract:

The kinesin motor is a dimer protein that walks along the microtubule and plays an essential role in intracellular transport. Despite this, the velocity of cargo in cells is still not well understood due to the complex cell environment. To investigate, we perform the in vitro experiments in crowded environments and determine the number of motors on cargo using the fluctuation theorem. We observe that cargo velocity keeps constant regardless of the number of kinesins at the low concentration of crowing agents. For a high concentration of crowding agents, the cargo velocity carried by a single kinesin is slower than that for a low concentration. However, as the number of kinesins increases, the cargo velocity increases and reaches the single motor velocity. Our findings suggest that kinesins tethered to cargo share the load on the cargo and, therefore, move faster than a single motor in a crowded environment.

Keywords:

molecular motors, kinesin, intracellular transport

J9.05

Poisson distribution in stochastic gene expression: What independent events do they count?

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Abstract:

The Poisson distribution is the probability distribution of the number of independent events in a given period. Although the Poisson distribution appears ubiquitously in various stochastic dynamics of gene expression, both as time-dependent distributions and stationary distributions, underlying independent events that give rise to such distributions have not been clear, especially in the presence of the degradation of gene products, which is not a Poisson process. I show that the variable following the Poisson distribution is the number of independent events where biomolecules are created, destined to survive until the end of a given time. This new viewpoint not only allows us to rederive time-dependent solutions of various Markovian and non-Markovian models of stochastic gene dynamics for arbitrary initial distributions but also to derive a novel series expansion form of a time-dependent distribution for a model with a stochastic production rate.

Keywords:

Gene Regulatory Network, Stochastic fluctuation, Poisson distribution

2023 KPS Fall Meeting
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J9.06

Algorithmic Approach to the Optimal Computation of Chain Propagators in Polymer Field Theory Simulations

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Abstract:

Polymer field theory simulations are an efficient theoretical tool for investigating the self-assembly of branched block copolymers as well as linear block copolymers. The main computation in these simulations is to solve the modified diffusion equations to obtain the chain propagators. In principle, the cost of the computation increases linearly with total chain length. When the same branches exist in the polymer chain architectures, the computational demand can be significantly reduced by avoiding redundant chain propagator calculations. This optimization is crucial for performing simulations with branched polymers. Until now, it has been done by human intervention, and not algorithmically. This situation has prevented the development of open-source software that efficiently performs simulations with arbitrary branched polymers. In this talk, I will introduce an algorithmic approach to optimize the computation for an arbitrary mixture of acyclic branched block copolymers.

Keywords:

Open-source Software , Branched Polymer , Polymer Field Theory Simulation, Chain Propagator , Block Copolymer

2023 KPS Fall Meeting
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J9.07

Investigation of Fluctuation Effects in Diblock Copolymer and homopolymer mixture through Langevin Field Theoretic Simulation

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Abstract:

In the polymer community, it is well known that Block Copolymer (BCP) melts can form microphases at a sufficiently high χN, and related research is actively pursued. Researchers have put considerable effort into controlling this phenomenon, and blending random copolymers (RCPs) or homopolymers (HPs) is one of those strategies. Under experimental conditions, a BCP melt usually forms a randomly directed lamellar structure referred to as the "Fingerprint pattern." Mixing short RCPs or HPs into the BCP melts often helps the system gradually achieve long-range ordered microstructures.

Theoretically, Self-Consistent Field Theory (SCFT) has demonstrated such a possibility by reducing the energy barrier for the removal of defects. However, due to the limitations of the SCFT, which is based on mean-field theory, the consideration of fluctuation effects that help the system escape from metastable states has been lacking. Consequently, theoretical methods that overcome this limitation of the SCFT method have been developed, and Langevin Field Theoretic Simulation (L-FTS) is one of them.

In this study, we employ L-FTS, a method known to incorporate fluctuation effects into the polymer field theory, to investigate the influence of fluctuations when mixing RCPs or HPs into BCP melts. In particular, we explore the shift of the order-to-disorder transition point by comparing the results of SCFT and FTS.

Keywords:

Fluctuation, Fields Theoretic Simulation, Polymeric System, Block Copolymer

J10.01

Investigation of magnetic ground state in antiferromagnetic Dirac material candidate $TaCoTe_2$

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Abstract:

Magnetic Dirac materials are attracting significant attention for their potential spintronic application due to high mobility and versatile magnetotransport phenomena related to non-trivial Berry phase contribution under broken time reversal symmetry. Intensive efforts for decades have been made to search magnetic Dirac materials, however, only few are identified as magnetic Dirac materials mainly due to the difficulty in realizing low-dimensional crystal structure with magnetic orders. Recently $TaCoTe_2$ has been theoretically proposed to be another candidate of two-dimensional antiferromagnetic (AFM) Dirac materials possessing unique topological property of controllable Dirac point depending on the AFM spin direction. While an angle resolved photoemission spectroscopy (ARPES) study[1] has confirmed a Dirac band structure in $TaCoTe_2$, the magnetic ground state remains still controversial due to the absence of experimental evidence.
Here, we report experimental investigation of magnetic ground state in $TaCoTe_2$. X-ray absorption spectroscopy experiments confirmed the 2+ valence of Cobalt indicating that a S=3/2 spin state in the tetrahedral environment of Co ions. Interestingly, temperature-dependent magnetization measurements do not show any magnetic ordering down to 2 K, with a very small value of 15×10-4 emu/moleOe at 2 K. Instead, the van Vleck like paramagnetic behavior appears above 70 K, suggesting that Co ions are close to non-magnetic spin states.

[1] Federico Mazzola et al. Nano Lett. 2023, 23, 902-907

Keywords:

TaCoTe2, van Vleck like paramagnetism, Antiferromagnetic Dirac material, 2D magnetic Dirac material

J10.02

Using Cr_2X_3 (X= S, Se, Te) a non-vdW material as a base material for discovery of new magnetic materials

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Abstract:

Non-van der Waal magnetic materials have recently been of great interest for the research community with the possible novel application. Recent investigation has shown Cr_2X_3 (X=S, Se, Te) as being a non-van der Waal magnetic 2D material is a promising candidate, because of rich magnetism, high T_c (Compared to 2D van der Wall materials), and their excellent air-stability. A unique structure of self-intercalated covalently bonded magnetic layers was used as basis for proposing new materials as Cr_4MX_6. Here we tried to investigate the possibilities of engineering the intercalating layer by systematically substituting the magnetic atom in the intercalating layer. Our calculation reveals very promising results thereby unveiling the magnetism interaction in the base material and also giving a way to manipulate electronic and magnetic properties of the base material. The ground magnetic state was investigated and the corresponding electronic band structure is studied. The anti/ferromagnetically coupled layers of Cr-M atoms were closely carefully considered for a detailed picture of the magnetism in which directional local movement of M atoms in the *c*-axis of the crystal is used as a tuning control. The results of the insight we got in the coupling of magnetic layers and stability of structures are all discussed.

Keywords:

Cr2X3, non-van der Waals, Ferrimagnet, self-intercalated, Spintronics, High-Tc

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J10.03

A new type of cluster magnetism in the trimer-based hexagonal antiferromagnets

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Abstract:

Mott insulators can be generally understood by a single magnetic ion picture with a well-defined local moment. In the other extreme limit, one can consider the molecular orbital state, where the electrons are delocalized over the lattice by losing their atomic properties. In between, cluster magnetism is a new concept in quantum magnetism, where a set of collective magnetic ions behaves as a single magnetic ion, which is magnetically coupled with other clusters. With this novel property, the cluster magnet is considered a new playground in searching for an exotic state of matter, such as quantum spin liquids. Thus, it has initiated a strong research interest in understanding the nature of the cluster magnet: the interplay between the localised and delocalised electron.

This talk presents our recent results in growing and characterizing new candidate materials for cluster magnetism, Ba4MMn3O12 (M = Ta, Nb) polycrystalline samples, via systematic solid-state reactions. We report the new compound, Ba4TaMn3O12, and the improved powder, Ba4NbMn3O12. They form the trimer unity of Mn ions with different valence states along the c-axis, which are connected via the triangular lattice within the ab-plane. Results of magnetic susceptibility and heat capacity measurements suggest the novel cluster-based S = 2 magnetic moments, which is consistent with ab-initio calculations.

Keywords:

Quantum magnetism , Cluster magnets , Trimer hexagonal lattice , Susceptibility , Heat capacity

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J10.04

Observation of unconventional room-temperature carriers in the triangular-lattice Mott insulator $TbInO_3$

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Abstract:

Geometrically frustrated magnetism emerges from the intricate interplay among various magnetic interactions, preventing a system from developing long-range order even at low temperatures. A remarkable scenario occurs when long-range order is suppressed even at absolute zero temperature due to quantum fluctuations, giving rise to what is known as quantum spin liquids (QSL). Within this presentation, we introduce $TbInO_3$, a quasi-2-dimensional triangular lattice system, proposed as a potential QSL material. A range of experiments, such as inelastic neutron diffraction, muon spin rotation, and specific heat measurements, provide evidence for the presence of fractionalized spin excitations and the absence of magnetic long-range order down to extremely low temperatures [1]. More recently, our observations using terahertz time-domain spectroscopy reveal a quadratic frequency-dependent behavior in the optical conductivity. In addition, we detect Fano asymmetry in an optical phonon mode, showcasing a strong interaction with the excitation continuum [4]. These distinct power-law feature and Fano asymmetry strongly support to the QSL characteristics of $TbInO_3$, although further detailed examination of the model system is necessary. Intriguingly, these observations remain robust over a wide temperature range (1.5 K – 300 K) and under magnetic fields up to 7 T, suggesting an interesting possibility to manipulate highly entangled quantum many-body states even at room temperature.

[1] L. Clark *et al.* Nat. Phys.15, 262 (2019).
[2] M. G. Kim *et al.* Phys. Rev. B 100, 024405 (2019).
[3] J. Kim *et al.* Phys. Rev. X 9, 031005 (2019).
[4] T. Jung *et al.* Nat. Phys. published online (2023). DOI: 10.1038/s41567-023-02174-5

Keywords:

Frustrated magnetism, Quantum spin liquid, Optical conductivity, TbInO3

2023 KPS Fall Meeting
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J10.06

Electronic structures and spin-defect states in quasi-one-dimensional $MoBr_3$

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Abstract:

The interplay between charge, spin, and lattice in solids gives rise to emergent elementary excitations that are intricately connected. Particularly in one-dimensional systems with spontaneous symmetry breaking, the abrupt phase shift in the order parameter or soliton can be considered as low-energy excitations. We present a theoretical study of soliton formation and its contributions to the electronic and magnetic properties in quasi-one-dimensional $MoBr_3$ within the framework of density functional theory. Bulk $MoBr_3$ consists of weakly coupled one-dimensional chains in which each Mo^{3+} ion is surrounded by a Br octahedron, face-sharing with neighboring octahedra. We find an insulating antiferromagnetic ground state with dimerization of Mo-Mo pairs, exhibiting alternating short and long bonds. The insulating phase is stabilized by the combination of dimer-induced bonding-antibonding splitting and antiferromagnetic ordering, depending on orbital character. Further, we find that antiferro-coupled localized spin-defect states with a total spin of S=3/2 formed at the soliton site of the Mo-Mo dimer, leaving a single undimerized spin site. Our findings suggest that the creation of spin defects within the quasi-one-dimensional magnetic $MoBr_3$ system may offer potential applications in developing high-density data storage devices.

This work is supported by the National Research Foundation of Korea grant (No.2021R1C1C1009494) and (No.2021R1A6A1A03043957)

Keywords:

Quasi-one-dimensional, soliton, DFT, spin-defect, antiferromagnet

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J10.07

Investigation of Magnetic and Optical properties of intrinsic bulk $Ga_{0.50}V_{0.50}As$ for Transparent Spintronics Applications

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Abstract:

The pursuit of intrinsic magnetic semiconductors has been a focal point of research over the past few decades, with a particular emphasis on achieving these properties at room temperature. However, despite continuous efforts, the fabrication of an intrinsic magnetic semiconductor operating at room temperature has remained elusive. Similarly, the challenge of creating optically transparent magnetic materials under ambient conditions has proven to be a formidable task. In this study, we investigate the magnetic and optical properties of $Ga_{1-x}V_xAs$ (x = 0.25, 0.5, and 0.75). It is found that only the $Ga_{0.50}V_{0.50}As$ structure meets all the structural stability criteria. The $Ga_{0.50}V_{0.50}As$ has a semiconducting ferromagnetic ground state with a Curie temperature of 478 K. In addition to its magnetic properties, the $Ga_{0.50}V_{0.50}As$ alloy displays remarkable optically transparency within the visible frequency spectrum. Based on our findings, we propose that the $Ga_{0.50}V_{0.50}As$ can be a potential candidate as a magnetic semiconductor in the realm of transparent spintronics applications.

Keywords:

GaAs, bulk magnetic semiconductor

2023 KPS Fall Meeting
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J11.01

Electronic bipolar states in a Janus van der Waals semiconductor Nb_3TeI_7

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Abstract:

Janus materials, a novel class of materials with two distinct surfaces of different chemical compositions and structures, have strong potential for a wide range of applications with catalytic reaction, chemical sensing, and optical or electronic responses. The key aspect for such functionalities is electronic bipolarity, depending on the types of surfaces, which has rarely been exploited in electronic devices. Here we report the coexistence of the bipolar states in a van der Waals (vdW) semiconductor Nb3TeI7 with the surfaces of iodine-only (I) and iodine-tellurium (I+Te) terminations. We found distinct *n*-type and *p*-type field-effect transistor behaviours in the I and I+Te surfaces, respectively, which is attributed to a built-in electric field across the layers due to unique coherent stacking structure of Janus layers in Nb3TeI7. Our findings highlight that the naturally-grown Janus vdW materials provide a promising material platform for utilizing strong electronic bipolarity in two-dimensional-material-based applications.

Keywords:

Janus, Kagome, electronic bipolar states

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J11.02

Abnormal emergence of coherent and dissipative photon-magnon coupling in dual ISRR/YIG Hybrids

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Abstract:

Coherent and dissipative couplings in diverse systems have gained interest due to their potential in understanding quantum information processes [1, 2]. In this study, we examine photon-magnon coupling (PMC) in a unique dual hybrid system of two coupled ISRR/YIG resonators with differing split-gap orientations [3]. Here, ISRR refers to an inverted pattern of a split ring resonator, while YIG denotes a Yttrium Iron Garnet film. Unlike a single ISRR/YIG hybrid [1], our system presented unconventional PMC dispersion and linewidth types. To elucidate these abnormal PMC types, an analytical model was developed, facilitating the estimation of damping constants across three hybridized modes. Our model calculations aligned closely with experimental data, especially regarding coupling strengths from photon hybrid mode-magnon interactions and photon-photon engagements. Crucially, the interactions between the dual ISRRs, influenced by their relative split-gap orientations [4, 5], were found to be central to these coupling dynamics. One ISRR/YIG resonator displayed significant anti-damping, suggesting considerable dissipative coupling. This discovery underscores the tunability within PMC systems, emphasizing the potential of manipulating split-gap orientations in ISRR resonators for applications in quantum telecommunication technologies.

References
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[2] Harder M, Yang Y, Yao B M, Yu C H, Rao J W, Gui Y S, Stamps R L and Hu C-M. Phys. Rev. Lett. 121, 137203 (2018)
[3] B. Bhoi, S.-H. Jang, B. Kim, and S.-K. Kim, J. Appl. Phys. 129, 083904 (2021)
[4] Liu, N., Liu, H., Zhu, S. et al. Nature Photon 3, 157–162 (2009)
[5] S. S. Seetharaman, C. G. King, I. R. Hooper, and W. L. Barnes. Phys. Rev. B 96, 085426 (2017)

Keywords:

photon-magnon coupling, photon-photon interaction, many-body system, light-matter interaction

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J11.03

Order-Disorder Charge Density Wave Phase Transition in the Kagome Metal CsV_3Sb_5

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Abstract:

The origin of the charge density wave (CDW) formations in AV_3Sb_5 (A = K, Rb, Cs) remains elusive, whether it is due to a Fermi surface nesting or a phonon softening. Here, using first-principles density-functional theory calculations, we demonstrate that the triple-Q 2×2×2 CDW order in CsV_3Sb_5 is decomposed into the multiple degenerate 2×1×1 charge orders above T_{CDW}, which are composed of V-V dimer chains along the Q_1, Q_2, and Q_3 directions. It is revealed that for $T > T_{CDW}$, the free energy of the high-temperature CDW phase becomes lower than that of the triple-Q 2×2×2 CDW phase mostly due to an emerging configurational entropy. We further show that the dynamic fluctuations of degenerate 2×1×1 charge orders condense to the triple-Q 2×2×2 CDW phase, indicating an order-disorder-type phase transformation. Our findings resolve a strong debate on the origin of the CDW formation in CsV_3Sb_5 by identifying the nature of the experimentally observed order-disorder CDW phase transition without a Fermi surface nesting or a phonon softening.

Keywords:

Kaggome metal, CDW fluctuation , CsV3Sb5

2023 KPS Fall Meeting
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J11.04

Nature of charge density wave in kagome metal ScV_6Sn_6

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Abstract:

Understanding the origin of the quantum phases in kagome metals is often challenging, owing to the intertwined electronic and structural degrees of freedom. The √3×√3 charge order observed in kagome metal ScV_6Sn_6 has also led to controversial interpretations on its origin, Fermi surface nesting or phonon instability. To this end, we conducted multimodal investigations to figure out the origin of charge order. First, we confirmed that the surface termination of ScV_6Sn_6 strongly rendered its electronic structure. Spatially resolved ARPES measurements and slab DFT calculations revealed a band gap opening is significant at V_3Sn domain that possesses rich planar Sn character. Further, phonon dispersion analysis suggests generic phonon instabilities of Sc and planar Sn atoms. Our results consistently supports phonon instabilities of Sc and planar Sn atoms as the origin of √3×√3 charge order in ScV_6Sn_6, proposing a noteworthy contribution of a structural degrees of freedom to charge order ground states in kagome metals.

Keywords:

ARPES, DFT, charge order, kagome

2023 KPS Fall Meeting
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J11.05

Ultrafast dynamics of charge ordered states in $Ir(Te,Se)_2$

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Abstract:

$IrTe_2$ exhibits a number of charge-ordered phases in different temperature ranges. Our previous study has revealed three distinct charge ordered phases in bulk $IrTe_2$ and suggested that the (1/6 0 1/6) modulated state is the ground state based on the temperature dependence although the phase has mostly been reported by the surface sensitive probes.

We have further investigated the ultrafast dynamics of $Ir(Te,Se)_2$ under various polarization conditions. Coherent lattice vibrations can be detected by measuring a transient reflectivity change induced by pump excitation. We find that not only the oscillation frequencies but also the polarization dependence of the coherent phonon modes allows us to distinguish the three charge ordered states of $IrTe_2$. Lastly, we compare the results with the coherent oscillations of $IrTe_{1.6},Se_{0.4}$, which is known to have the (1/6 0 1/6) charge ordered state already at room temperature. We find that $IrTe_{1.6},Se_{0.4}$ shows coherent phonon modes at 1.15 THz and 2.45 THz in agreement with the ground state response of $IrTe_2$, supporting our previous conclusion.

Keywords:

IrTe2, Ground state, polarization conditions, IrTe1.6,Se0.4

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J11.06

Interplay between linear and nonlinear couplings in non-equilibrium steady states

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Abstract:

Deepening our understanding in non-equilibrium steady states becomes more and more important in quantum many-body systems. Despite numerous research endeavors, many areas in this field remain unexplored. Here, we study non-equilibrium steady states within a single cavity with both linear and non-linear couplings to environments. Employing a mapping that connects the Lindbladian to a doubled non-Hermitian Hamiltonian, we show intriguing connections between non-equilibrium steady states and Bose-Hubbard model in terms of numerical and analytic results.

Keywords:

Non-equilibrium, Keldysh Field Theory

Emergent inductance from spin fluctuations in strongly correlated magnets

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Abstract:

Recently, the intriguing phenomenon of emergent inductance has been theoretically proposed and experimentally observed in nanoscale spiral spin systems subjected to oscillating currents. Building upon these recent developments, we put forward the concept of emergent inductance in strongly correlated magnets in the normal state with spin fluctuations. It is argued that the inductance shows a positive peak at temperatures above the ordering temperature. As for the frequency dependence, in systems featuring a single-band structure or a gapped multi-band, we observe a Drude-type, while in gapless multi-band systems, a non-Drude inductance with a sharp dip near zero frequency. These results offer valuable insights into the behavior of strongly correlated magnets and open up new possibilities for harnessing emergent inductance in practical applications.

Keywords:

strongly correlated systems, ferromagnetic system, emergent inductance, transport phenomena

2023 KPS Fall Meeting
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J12.01

First-principles theory of quantum spin decoherence in transition metal dichalcogenides

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Abstract:

A comprehensive understanding of qubit decoherence, is pivotal for its development as quantum devices. Here, we investigate the decoherence of spin defects in MX_2 transition metal dichalcogenide (TMDC) materials (M=Mo, W and X=S, Se, Te), which have recently emerged as potential candidates to host defect-based qubits with long coherence times [1, 2, 3]. By combining density functional theory (DFT) and cluster-correlation expansion (CCE), we computed the Hahn-echo decoherence time (T_2) of spins associated with a carbon radical ion (C_X^-; S=1/2) and with a neutral antisite defect (M_X^0; S=1) in the presence of the TMDC nuclear spin bath. First, we found that the spin decoherence significantly differs in Mo-based TMDC and W-based TMDC due to the nuclear spin property of spinful W and Mo isotopes. The longest T_2 was found for W_S defect in monolayer WS_2, which reaches 40 ms. Notably, the spin decoherence in the Mo-based TMDC hosts exhibits several unusual features, which are distinct from the W-based TMDC hosts. These include a rapid degradation of the coherence in a short time scale (~ μs) followed by the nuclear spin flip-flop induced decay. In addition, we found that the T_2 time as a function of magnetic field exhibits significant drops at certain magnetic field strengths. We show that these unusual features are attributed to the interaction of the spin qubit with local Mo nuclear spins, which have a large nuclear spin number (I=5/2). Our study provides an extensive and valuable information of spin decoherence in the TMDC host materials. We also showed that the precise prediction of the spin decoherence in the TMDC materials requires a proper inclusion of the electronic structure of the defect that the qubit is based on and its local nuclear spin environment.

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Keywords:

Quantum Information, Spin Decoherence, First-principles, Transition Metal Dichalcogenide, Quantum Technology

2023 KPS Fall Meeting
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J12.02

Stability of defect candidates of single-photon emitters in hexagonal boron nitride wrinkles: an ab-initio study

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Abstract:

Hexagonal boron nitride(hBN) is a two-dimensional material with a large band gap and has recently attracted attention as a host material for single photon emitters (SPEs) that can operate at room temperature. Various studies have attempted to elucidate the atomic origin of these SPEs, but they remain elusive. In this study, we use density functional theory (DFT) calculations to investigate the defect formation energies (DFE) of two different types of defects that are strong candidates of h-BN SPEs. The first type is carbon-based defect clusters, which are promising candidates for SPEs with zero phonon lines (ZPL) ranging from 2 eV (visible) to 4 eV (ultraviolet) [1]. The other type is oxygen vacancy-based defects, including *VBON*-$V_B O_N^-$, which has been reported in a previous study [2] to have a small Huang-Rhys factor (HRF) and excellent optical properties in good agreement with experimental results. In addition, we examined the stability of the defects in the presence of wrinkle-induced inhomogeneous strain. As shown in our previous study [3], h-BN wrinkles significantly affect the position and the optical property of SPEs. By using a supercell method, we change the size of hBN wrinkles to explore the strain-induced structural and electronic reconstruction occurring in the defect models. We show that the coupling of the defects to the wrinkle largely depends on the defect type. We believe that our study provides valuable information on the stability of SPEs on hBN wrinkles, contributing to the identification and control of hBN SPEs.

Reference

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Keywords:

Hexagonal boron nitride, single photon emitters, oxygen vacancy-based defects, carbon-based defect clusters, defect formation energy

2023 KPS Fall Meeting
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J12.03

Experimental setup to individually address trapped-ion qubits using multi-channel acoustic optical modulators and diffractive optics

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Abstract:

Control and optimization of how to Individually address ion-qubits is one of key components to build an universal quantum information processor.
Here, we use a 355nm pulsed laser in order to operate quantum gates on individual ion qubits and this requires us to split the pulsed laser into five independent beams using diffractive optical elements (DOE). In the experiment, we are setting up a multi-channel acoustic optical modulator (AOM) combined with the DOE and a RF driving system and performed beam profile analysis of five beam spots after passing 5ch AOM to check laser beam spacing and spatial mode of each beam. Then we need to match ion spacing and laser beam spacing for individual addressing of five qubits. Also, we checked individual beams of the AOM are well controlled via ARTIQ system. We currently drive single qubit Rabi Oscillation using a single beam and plan to incorporate this multi-channel setup and perform quantum gates individually.

Keywords:

Trapped Ion, Quantum Computer, Multi-channel AOM, Diffractive Optical Element, Individual Control qubit

2023 KPS Fall Meeting
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J12.04

Studies of polarization-dependent cooling of trapped Yb ions

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Abstract:

The first step of building a trapped-ion based quantum computing system is to trap ions in stable manner via optimizing Doppler cooling. In our experiment, we first performed the experiments for trapping Yb174 ions to test our trap performance, optical alignments, and laser systems. The Doppler cooling beam requires to cover all optical transition paths for a given quantization axis and three principal axes given by RF and DC potentials. In order to cover all possibilities as mentioned above, we introduced an additional Doppler cooling beam into the trapping device. However, we found out that the ions appear to be stretched in the axial direction of the trap, which may reflect the ions being heated instead of cooling. In order to understand this effect, we applied two orthogonally propagating cooling beams to the ion while changing their relative polarization and found out the polarization dependence for ions being heated. We speculate that the optical interference and/or combined optical polarization may not satisfy efficient Doppler cooling conditions. This may be useful to optimize the Doppler cooling of ions at the beginning stage of the experimental setup.

Keywords:

Quantum computing, Ion trap, Doppler cooling

2023 KPS Fall Meeting
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J12.05

Optimization for Optical Setup for Trapping Yb171+ in a Blade Trap

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Abstract:

We are using Ytterbium 171+ as a qubit for trapped ion-based quantum computing experiments since we can utilize two hyperfine ground states as a qubit which is robust against external magnetic field fluctuation. Trapping Yb171+ requires modulation of laser frequency using EOM and AOM. Also, proper optical addressing to individual ions is highly important to operate quantum gates with high fidelity. In order to do so, we are setting up a DC segmented blade trap which could control the spacing between the ions. In this talk, we would like to introduce the basic optical components and setup for trapping Yb171+ as well as development of the blade trap.

Keywords:

Trapped-Ion, Quantum Computing

2023 KPS Fall Meeting
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J12.06

Theoretical investigation of the spin decoherence of carbon-related defects in hexagonal boron nitride

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Abstract:

Optically active spin defects in hexagonal boron nitride have recently attracted a great amount of attention as excellent quantum sensing platforms owing to its two-dimensional (2D) form factor. Qubit sensors in 2D materials hosts can be close to the surface and the target sample of interest, while maintaining its coherence property. It could be also integrated into various van der Waals heterostructures to enable advanced functionalities such as electric-field control of qubit frequencies. The most studied system is the negatively-charged boron vacancy (V_B^-), which has been developed to the first 2D quantum sensors applied to various applications. However, the control of single V_B^- spin has yet been realized. Notably, single-spin optically detected magnetic resonance (ODMR) spectra at room temperature were recently demonstrated in h-BN. Several recent studies showed that the observed single-spin is associated with carbon-related defects. Here, we theoretically investigate the decoherence of electron spins associated with several carbon-related defects (C_N, C_B, C_2C_N, C_2C_B, $C_B(C_N)_3$ and $C_N(C_B)_3$) in the presence of the dense nuclear spin bath of h-BN by combining density functional theory (DFT) and cluster correlation expansion (CCE) method. We calculate the spin Hamiltonian parameters of each defect by using DFT at the hybrid density functional level of theory. We then compute the Hahn-echo decoherence depending on external magnetic field. We compare and discuss results obtained with different models of the hyperfine interaction to better understand the decoherence mechanism and features in carbon-related defects in h-BN. Our results contribute to laying a solid foundation for the development of the carbon-related defects in h-BN toward high-resolution solid-state quantum sensing applications.

Keywords:

2023 KPS Fall Meeting
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J12.07

Qubit manipulation of trapped Yb^+ ions

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Abstract:

Quantum computers are expected to solve certain problems more efficiently than conventional computers. Among the various architectures implementing quantum computer, trapped ion-based systems have been one of the promising architectures for building a scalable and practical quantum computer since long coherent time and high gate fidelities of the system. In this work, we trapped ^{171}Yb ions with a 4-rods trap and performed a single qubit rotation using microwave and a Raman pulsed laser system. We demonstrate single qubit rabi flopping and successfully scan qubit motional modes by a two-photon Raman transition. In future, we plan to implement laser pulse shaping to improve a gate fidelity and perform scalable quantum entanglements.

Keywords:

trapped ion, 171Yb, qubit manipulation, single qubit gate

2023 KPS Fall Meeting
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J12.08

Nano-gravimetry for soft matter by using Quartz Tuning Fork sensor

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Abstract:

mass and density are fundamental characters of soft matter. so, measurement of these characters are important for any analysis such as chemical reactions and chemical or biological synthesis. Using quartz crysral microbalances are well known for nano-gram gravimetry but they are hard to applicate to all substances or surfaces. Here, we introduce quartz tuning fork(QTF) based nano-gram gravimetry for soft matter. this gravimeter use QTF as force sensor which can measure mass by dynamic force specstroscopy which used in atomic force microscopes. also we can calculate density of samples by analysis volume from image of samples.
priority, we measure mass and density of glycerol aqueous solution from pure water to glycerol to modulate the density. furthermore, We choose colloidal and biological samples (aqueous humor and mice egg) to measure the mass of various soft matter. from these measurement, we could only weigh the solid contents of colloidal solution and conjecture organic contents and cell maturity of biological samples.

Keywords:

Gravimetry, Soft matter, Quartz Tuning Fork

2023 KPS Fall Meeting
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J14.01

All Solid-State Synapse Device Arrays Using 2D Channel/LiSiOx Electrolyte for Next-Generation Neuromorphic Edge Computing

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Abstract:

High-precision artificial synaptic devices compatible with existing CMOS technology are essential for realizing robust neuromorphic hardware systems with reliable parallel analog computation beyond the von Neumann serial digital computing architecture. However, critical issues related to reliability and variability, such as nonlinearity and asymmetric weight updates, have been great challenges in the implementation of artificial synaptic devices in practical neuromorphic hardware systems. Herein, a robust three-terminal 2D-MoS_2 artificial synaptic device combined with a lithium silicate (LSO) solid-state electrolyte thin film is proposed. The rationally designed synaptic device exhibits excellent linearity and symmetry upon electrical potentiation and depression, benefiting from the reversible intercalation of Li ions into the MoS_2 channel. In particular, extremely low cycle-to-cycle variations (3.01 %) during long term potentiation and depression processes over 500 pulses are achieved, causing statistical analog discrete states. Thus, a high classification accuracy of 96.77 % (close to software baseline of 98 %) is demonstrated in the Modified National Institute of Standards and Technology (MNIST) simulations. These results provide a future perspective for robust synaptic device architecture of lithium solid-state electrolytes stacked with 2D van der Waals layered channels for high-precision analog neuromorphic computing systems.

Keywords:

Molybdenum disulfide, electrochemical transistor, ion intercalation, lithium ion, solid-state electrolyte

2023 KPS Fall Meeting
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J14.02

Quantum optical quantum computerors and simulators

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Abstract:

Quantum computing has attracted a lot of attention. However, the full implementation of a working quantum computer in the near future appears to be challenging. On the other hand, the rapid development of noisy intermediate-scale quantum (NISQ) technologies has opened a new avenue for implementing classically intractable information processing devices and discovering their useful applications. Quantum computres and quantum simulators can be implemented by varioius physical platforms including superconducting circuits, ions or neutral atoms, photonic systmes, etc. In this talk, I will introduce a quantum optical approach to implement NISQ devices. Specifically, I will discuss recent achievements in discrete variable and continuous variable quantum optics based quantum computers and simulators. I will also present the KIST efforts to implement practical quantum optical quantum computers and simulators.

Keywords:

Quantum computer, Quantum simulator, Quantum optics

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J15.01

Ultrafast Polaronic Lattice Distortions in Perovskite-oxide Nanocrystal byTime-resolved Bragg Coherent Diffraction Imaging

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Abstract:

Polarons are quasiparticles that emerge within polarizable materials as a result of the interaction between excess electrons or holes and ionic vibrations. These quasiparticles exhibit diverse characteristics and significantly influence the properties and functionalities of materials. However, our understanding of the temporal and spatial aspects of polarons remains limited. To address this, we aim to utilize pulse X-ray and laser technology provided by XFEL to employ BCDI techniques on a picosecond time scale, allowing us to investigate the generation and propagation of polarons. Our findings have revealed that polarons begin to form in time scales shorter than 10 picoseconds, well before the time domain of acoustic phonons, and interact with phonons. This interaction has been detected through the BCDI technique, which monitors changes in particle shape and strain.

Keywords:

SrTiO3, XFEL, time-resolved, BCDI, polaron

2023 KPS Fall Meeting
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J15.02

Raman and infrared spectroscopic studies of oxygen defects in $CoNb_2O_6$

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Abstract:

Transition metal oxides (TMOs) have been utilized for their catalytic activity and have attracted interest for optoelectronic, photocatalytic, and/or magnetic characteristics. It is known that oxygen defects are often made in transition metal oxides and affect their functional properties. In this study, we were focused on the monitoring these oxygen defects by using Raman scattering spectroscopy. We conducted Raman spectra of $CoNb_2O_6$ microfibersgrown by electrospinning method. As a result, a new phonon mode at 782 cm^{-1} was observed in Raman spectra that might be associated with oxygen defects. We also used Fourier transform infrared (FTIR) spectroscopy for the purpose of using the complementarity with Raman spectroscopy for centrosymmetric $CoNb_2O_6$. We discuss how we can get defect information by comparing the two (Raman and FTIR) spectroscopic data.

Keywords:

Transition metal oxide, Raman, Defect study

2023 KPS Fall Meeting
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J15.03

Raman and Photoluminescence Spectroscopic studies of single-phase ZnV_2O_6 Nanorods

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Abstract:

The bivalent metal vanadates MeV_2O_6 (Me = Mg, Ca, Mn, Co, Ni, Cu, Zn, Cd, Hg) exhibit fascinating properties in electrochemical energy storage/conversion, photocatalysis, and gas sensing etc. Among them, zinc vanadate (ZnV_2O_6) with the brannerite structure has attracted extensive attention as a material for new high-efficiency energy storage batteries, enhanced photocatalysis, and supercapacitance and so on. However, during the synthesis of ZnV_2O_6, there is a potential for the formation of V_2O_5 as a secondary product. V_2O_5 shares the same oxidation state +5 as vanadium, and is thermodynamically more stable under the specific synthesis conditions and methods. We have carefully investigated the differences between ZnV_2O_6 and V_2O_5 nanorods, which were fabricated using a facile acid-base reaction followed by the thermal treatment. Using Raman and photoluminescence (PL) spectroscopy, we have effectively characterized and distinguished the crystal structures and chemical compositions of both ZnV_2O_6 and V_2O_5 nanorods. Our primary goal is to optimize the growth conditions and utilize spectroscopic techniques to gain a deeper understanding of and fully exploit pure ZnV_2O_6 nanorods as a versatile material in various applications.

Keywords:

Transition Metal Oxide, ZnV2O6, Raman, PL, TMOs

2023 KPS Fall Meeting
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J15.04

High-temperature Chemiresistive and Gaschromic Hydrogen Gas Sensor Using Vanadium Oxide Film

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Abstract:

In this study, we explore the modulation of VO_X film properties for hydrogen sensing under a high-temperature environment by using their reversible response to different oxidation states. The physical property variations of Pt/V_2O_5 /Al_2O_3(0001) structured films were within a temperature range of 300 ~ 500°C under alternating hydrogen and air (20% O_2, 80% N_2) environments. As a result, a significant reduction in electrical resistance was observed in the vanadium oxide films under a high-temperature hydrogen environment. However, the response was fully reversible upon subsequent exposure to air. The *in-situ* XRD measurements showed that these resistance variations were closely related to oxidation state changes of vanadium from V_2O_5 to V_2O_3 in a hydrogen environment. On the other hand, the oxidation state of vanadium in-air shifted from V^{3+} (i.e., V_2O_3) to V^{4+} (i.e., VO_2) to V^{5+} (i.e., V_2O_5), unlike in a hydrogen environment. In addition, these gaschromic properties of the films were evident through distinct color changes, transitioning between yellow and black during the sensing and recovery processes.

Keywords:

High-temperature Hydrogen gas sensor, Gaschromic, Vanadium oxide

Optoelectronic Synapse Behaviors in Tb^{3+}/Al^{3+} Co-doped $CaSnO_3$ with long persistent luminescence

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Abstract:

Neuromorphic computation draws inspiration from the remarkable features of the human brain including low energy consumption, parallelism, adaptivity, cognitive, and learning ability. These qualities hold the promise of unlocking groundbreaking computational techniques that surpass the limitations of traditional computing systems. Considerable research attention has focused on the potential of synaptic behaviors in oxide materials as a next-generation neuromorphic material due to many advantages neuromorphic engineering [1]. The long persistent luminescence (LPL) in rare earth ion doped oxides is a phenomenon in which the emission of light persists long after the excitation source is turned off [2]. Since the LPL can be enhanced by serial photoexcitation pulses, luminescent materials utilizing long-lasting luminescence can be used to develop light-emitting synaptic devices. In this work, we prepared Tb^{3+}/Al^{3+} doped $CaSnO_3$ (CSO:Tb/Al) perovskite oxides that show a good LPL property under UV-excitation. To investigate the synaptic plasticity of CSO:Tb/Al, we examined the light-emitting responses while varying various factors, including pulse number and pulse timing. Major synaptic behaviors such as paired-pulse facilitation, pulse number/timing dependent potentiation, and pulse number/timing dependent short-term to long-term plasticity transition were successfully demonstrated. Finally, we simulated a neural network for hand-writing digit recognition using synaptic activation function obtained by CSO:Tb/Al.

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Keywords:

Photoluminescence, Long persistent luminescence, Synaptic behaviors, Artificial synapses

2023 KPS Fall Meeting
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J15.06

Raman Spectroscopic Study of NZP Family Ceramics at Low Temperatures

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Abstract:

NZP family ceramics, including compounds such as $NaZr_2(PO_4)_3$ (NZP), $RbZr_2(PO_4)_3$, $Ca_{0.5}Zr_2(PO_4)_3$, and $KZr_2(PO_4)_3$, possess low thermal expansion properties. This makes them promising candidates for solid oxide fuel cells (SOFCs) operating at high temperatures for efficient power generation. SOFCs offer greater efficiency compared to traditional power generation methods, are environmentally friendly by utilizing hydrogen as fuel, and involve a single energy conversion process. Despite previous xperiments, comprehensive fundamental research on NZP ceramics is crucial for their further advancement. In this study, Raman spectroscopy was employed to investigate phonon modes of NZP ceramics at low temperatures. The study confirmed changes at different temperatures were consistent with previous experiments. In fact, certain phonon modes exhibited distinct patterns that directly reflect negative thermal expansion behavior, correlating with phonon dispersion from DFT calculations. These findings offer insights into NZP ceramics and aid in fuel cell development. Raman spectroscopy emerges as a valuable tool, offering immediate insights into material characteristics.

Keywords:

Raman, NZP family ceramics

2023 KPS Fall Meeting
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J15.07

Optical property database of inorganic phosphor

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Abstract:

Developing inorganic phosphor with desired properties for light-emitting diode application has traditionally relied on time-consuming and labor-intensive material development processes. Moreover, the results of material development research depend significantly on individual researchers' intuition and experience. Thus, to improve the efficiency and reliability of materials discovery, machine learning has been widely applied to various materials science applications in recent years. However, the prediction capabilities of machine learning methods fundamentally depend on the quality of the training datasets. In this work, we constructed a high-quality and reliable database that contains experimentally validated inorganic phosphors and their optical properties, sourced from the literature on inorganic phosphors. Our database includes 4,110 combinations of 27 dopant elements in 2,231 host materials from 586 articles. The database provides material information, optical properties, measurement conditions for inorganic phosphors, and meta-information. To validate this database, we performed preliminarily machine learning on the database and evaluated the prediction results.

Keywords:

database, inorganic phosphor, optical property, machine learning

2023 KPS Fall Meeting
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J16.01

$PdCoO_2$ as a new interconnect material: Prediction of its size-dependent conductivity based on size- and momentum-dependent mean free path

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Abstract:

As modern CMOS devices continue to decrease in size, addressing the issue of increasing interconnect resistance has become paramount. Although copper is known for its low bulk conductivity, its resistivity undergoes a rapid increase as device size diminishes. This increase is attributed to a higher likelihood of scattering from the surface, stemming from copper's long mean free path. Delafossite materials, such as $PdCoO_2$, are being proposed as a new alternative for interconnects. $PdCoO_2$ exhibits remarkable anisotropic electronic properties due to its 2D-like Fermi surface resulting in strong in-plane conductivity. However, predicting the size-dependent conductivity of $PdCoO_2$ is still challenging since most existing models that describe thin-film metal resistivity are heavily reliant on empirical fits to experimental data. Regrettably, these models fall short in predicting anisotropic conductivity. Here, we propose a novel methodology to predict size-dependent resistivity using modified relaxation times derived from momentum-dependent mean free paths. This methodology yields accurate predictions of the electrical properties of $PdCoO_2$ across different thicknesses. Thank to its 2D-like feature, the conductivity of $PdCoO_2$ remains less influenced by reductions in thickness. Our findings demonstrate that anisotropic materials offer superior conductive properties in thin film conductors, opening avenues for their adoption in future electronic applications.

Keywords:

delafossite, conductivity, size-dependent conductivity, thin film, mean free path

2023 KPS Fall Meeting
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J16.02

Phonon Decoupling in Brownmillerite $SrFeO_{2.5}$ and $CaFeO_{2.5}$

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Abstract:

Brownmillerite has emerged as a promising candidate for innovative ferroelectric applications, and it can be obtained by topotactically reducing the perovskite structure. Due to the distinct alignment of oxygen vacancy channels, unusual properties manifest, including ferroelectricity. Theoretically, BO_4 tetrahedral distortion could induce inversion symmetry breaking within the crystal structure, and both ionic displacement and rotation of the FeO_4 tetrahedra can be combined in brownmillerite $SrFeO_{2.5}$ (SFO) and $CaFeO_{2.5}$ (CFO), revealing a unique one-dimensional collective distortion. In these intriguing brownmillerite structures, phonons exhibit unique behaviors that have not yet been fully explored. This study investigates the decoupling of phonon modes associated with oxygen-octahedra from those with oxygen-tetrahedra in brownmillerite oxides. We find that such localized oxygen-tetrahedral phonons enable site-selective control of the unit cell-wide domain. By combining simple 2D modelling and density functional theory (DFT) calculations, we have uncovered the underlying mechanism responsible for phonon decoupling. Our findings demonstrate that specific structural characteristics within the brownmillerite framework lead to the independent vibration of oxygen-octahedra and oxygen-tetrahedra. In this presentation, we will detail our results regarding 2D modeling, phonon band structure, and the implications for ferroelectricity in brownmillerite oxides.

Keywords:

brownmillerite, phonon decoupling, SrFeO2.5, flat band, ferroelectricity

Superconductivity of metastable LaH_2 with partial occupation at ambient pressure

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Abstract:

Since a near room-temperature superconductor (SC) was experimentally founded in lanthanum hydride (LaH_{10}) at 200 GPa, many studies have been investigated to find other room-temperature SCs. However, those room-temperature SCs have a required condition, which is extreme pressure of megapascal order. For the commercialization of hydride SC, it is necessary to reduce pressure manifesting superconducting state. Here, we propose metastable hydrides in an attempt to reduce the pressure. We have found that $LaH_x^OH_{2-x}^T$ composed of partially occupied in octahedron (O) and tetrahedron (T) sites has dynamically stable, but also superconducting properties even at ambient pressure unlike parent compounds (LaH and LaH_2). We have found that the electron phonon coupling strength of $LaH_x^OH_{2-x}^T$ increases approaching x=1, which induces the increment of Tc up to 10.8 K. Thus, we propose that partial occupation of hydrogen within LaH_2 induces the superconductivity. Furthermore, we suggest that the metastable binary superconducting phases would also exhibit in all lanthanide series.

Keywords:

hydride, superconductor, density funtional theory

2023 KPS Fall Meeting
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J16.04

Role of Symmetries on Surface Band Gap in $MnBi_2Te_4$ with Antisite Defects: A First-Principles Study

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Abstract:

$MnBi_2Te_4$ (MBT) shows great promise in spintronics due to its exceptional magnetic and topological properties. Despite the lack of conventional time-reversal symmetry, MBT exhibits distinct topological surface features that arise from its intriguing properties under nonsymmorphic time-reversal symmetry with a combination of time-reversal and half-translation. While theory suggests a potential surface gap, experimental observations reveal an unexpected gapless surface state. Using density functional theory, we unravel the specific conditions under which the system tends to adopt the in-plane spin orientation and whether these conditions coincide with the emergence of the gapless surface state. Our analysis reveals that MBT with antisite defects exhibits negative magnetic anisotropy energy. Moreover, despite these defects, the protective influence of mirror symmetry preserves the surface Dirac state. We elucidate this phenomenon in terms of the mirror symmetry M_x (k_x = 0) and the effective magnetic field possessed by MBT. In addition, we predict the defect concentration by considering the Fermi level shift due to electron doping, which is directly related to the result of angle-resolved photoemission spectroscopy (ARPES).

Keywords:

2023 KPS Fall Meeting
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J16.05

Theoretical Investigation of Perovskite-inspired Structures for Novel Inorganic Solar-cell Absorbers

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Abstract:

In the past decade, there has been a remarkable surge in the efficiency of perovskite-based solar cells, while the performance of silicon-based solar cells has plateaued due to approaching their theoretical efficiency limits. Nonetheless, hybrid organic-inorganic perovskites (HOIP) which are responsible for the rapid advancement in photovoltaic efficiency are hampered by their limited long-term stability. To counteract this instability, which often stems from their organic constituents, a viable strategy for next-generation solar cell materials could involve the development of entirely inorganic perovskites that exhibit comparable performance. This study delves into an exploration of the extensive collection of ABX_3 inorganic compounds cataloged in structural databases, aiming to unearth innovative materials for solar energy harvesting.
Inspired by the diverse merits of the perovskite structure as an exceptional photovoltaic material, we adopt a systematic approach to screen and categorize materials featuring octahedral connectivity. Employing a sequential screening methodology, we meticulously investigate critical properties such as band gap, optical absorbance, and effective masse within the subset of perovskite-inspired crystal structures identified. The outcome of this thorough analysis unveils a selection of prospective materials suitable for deployment as fully inorganic photovoltaic absorbers. Additionally, we conduct an in-depth examination of specific attributes contingent upon the diverse structural classifications established earlier. The insights garnered from this research hold the potential to offer invaluable guidance for the exploration and design of promising novel materials sourced from the expanded reservoir of available substances. As a result, our efforts contribute to the ongoing quest for innovative solar cell materials, driving the advancement of renewable energy technologies.

Keywords:

Perovskite, Solar-cell, first-priciples calculation, photovoltaic

2023 KPS Fall Meeting
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J16.06

Unconventional hidden Rashba effects in two-dimensional InTe

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Abstract:

The exploration of the hidden Rashba (R-2) effect has shed new light on the previously unnoticed spin polarization phenomena in crystals with centrosymmetric symmetry, leading to the emergence of a fascinating spin-layer locking phenomenon in two-dimensional materials. In this study, we present a novel approach to manipulate the spin helicity inherent in the R-2 effect. Conventionally, both the R-1 and R-2 effects exhibit distinct spin helicities in their inner and outer bands. However, in our newly proposed R-2 system, we introduce the possibility for the spin helicities of these inner and outer bands to align and share the same polarization direction. To realize this novel form of the R-2 effect, we employed the inversion-symmetric InTe monolayer as a model system, utilizing first-principles density functional theory. Through our investigation, we found that InTe possesses two sets of R-2 Rashba bands and exhibits unconventional spin helicity characteristics, with the inner and outer bands exhibiting identical helicities. Furthermore, we uncovered the pivotal role played by band inversion between the two distinct sets of R-2 Rashba bands in the creation of this extraordinary spin texture. Our findings not only provide evidence for the existence of unconventional R-2 bands within the InTe monolayer, but also establish an exciting foundation for exploring the intriguing spin polarization physics associated with hidden Rashba effects.

Keywords:

hidden Rashba effects, spin-layer locking, two-dimensional van der Waals materials

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J16.07

Density-functional-based investigation of the electronic structures of $LaInO_3/BaSnO_3$ heterostructures

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Abstract:

Using first-principles density functional theory (DFT) and tight-binding modeling, we investigate the atomic and electronic structures of heterostructures composed of two band insulators $LaInO_3$ (LIO) and $BaSnO_3$ (BSO). We find that in LIO/BSO heterostructures, as LIO thickness increases, a charge transfer from the uppermost LIO layer to the interfacial BSO layer occurs, which in turn introduces the conducting interfacial electron gas. The spatial distribution of the interfacial charge density profile as a function of LIO thickness is investigated. Based on the DFT results, we introduce a tight-binding model with a self-consistent Hartree potential, where the model parameters, including the effective mass of Sn-s bands and dielectric constants, are determined by fitting the charge density profile to that from the first-principles calculations and find that the tight-binding band structures are in excellent agreement with DFT results. Our model-based calculations of thicker LIO/BSO slab 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 of frontier orbitals for LIO/BSO heterostructures in large-scale LIO/BSO heterostructures, which could be useful for understanding the optical and transport properties of the quasi-two-dimensional electron at the LIO/BSO interface.

Keywords:

Oxide heterostructure, Transition metal oxide, Density functional theory, Electronic structures, First-principles calculation

2023 KPS Fall Meeting
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J16.08

First-Principles Investigation of Phonon Transport Properties of Monolayer Fluorographene

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Abstract:

Materials with high thermal conductivity and low electrical conductivity are of interest for heat management in nanoscaled electronic devices. Fluorographene, a fluorinated derivative of graphene, is a promising candidate due to its structural resemblance to graphene and limited electrical conduction (band gap about 3.6 eV). Here we investigated the thermal transport properties of monolayer fluorographene in detail, based on density functional theory and density functional perturbation theory. We obtained the room-temperature in-plane lattice thermal conductivity of monolayer fluorographene: 222 and 272 W m^{-1} K^{-1} by using the single mode relaxation time approximation and the full linearized Boltzmann transport equation (LBTE) solutions, respectively. These results are an order of magnitude smaller than the LBTE solution of graphene, which can mainly be attributed to the heavy substituent fluorine atoms. We calculated the scattering rate of each phonon mode to reveal the relationship between the crystal structure and the thermal transport properties. Our work provides a guideline to design two-dimensional materials for heat management purposes.

Keywords:

first-principles calculations, thermal conductivity, 2D materials, fluorographene

2023 KPS Fall Meeting
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T8.01

박막 태양전지의 실험 기반 분석 기술 - $Cu(In,Ga)Se_2$ 박막 태양전지를 중심으로

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Abstract:

태양전지는 p-n 접합을 이루는 반도체 다이오드에 빛을 쪼이면 전자가 생성되는 광기전효과를 이용하여 태양광을 직접 전기로 변환하는 반도체 소자이다. 현재는 결정질 Si을 기반으로 한 태양전지 기술이 주류를 이루고 있지만, 더 높은 효율과 가격 경쟁력을 확보할 수 있는 수준을 목표로 하여 다양한 종류의 박막 태양전지들이 개발되고 있다. 박막 태양전지를 개발하는데 실험 기반 분석 기술은 박막 태양전지 소재의 물성을 분석하고, 소자의 성능을 평가하여 태양전지 효율을 향상하는데 필요한 기술이다. 다양한 실험적 기법으로 박막의 구조, 화학 조성, 물리적 특성 등을 평가하여 태양전지의 효율 저하 요인을 분석하고 성능을 향상하기 위한 연구가 진행되고 있다. 이를 통해 박막 태양전지 상용화를 위한 기술적 문제를 해결하고 산업적 경쟁력이 향상될 것으로 기대된다. 본 발표에서는 $Cu(In,Ga)Se_2$ 박막 태양전지를 중심으로 실제 사례를 통한 실험 기반 분석 기술을 소개하고자 한다.

Keywords:

박막 태양전지, 분석 기술, Cu(In,Ga)Se2

T9.01

Semiconductor quantum dot: physics and applications to quantum light sources

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Abstract:

Semiconductor quantum dot is a zero-dimensional system and exhibits novel properties not possible in finite dimensional semiconductors. In this tutorial, I will introduce fundamental properties of semiconductor quantum dots and novel devices taking advantage of those new properties. As a solid state atom, the quantum dot has discrete energy levels and the complete spatial isolation, which enables realizing high quality deterministic single photon and entangled photon sources for quantum computing, communications, and sensing.

Keywords:

Quantum dot, Single photon source, Quantum computing

TT2.01

Basics of collider physics

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Abstract:

Since the new record of particle collisions at the highest energy in the Large Hadron Collider (LHC) experiment, physicists are ushering in a new era of exploration and advancement in particle physics. The forthcoming decades hold great promise for particle physics, with the potential to finally unveil the mysteries that lie beyond the confines of the Standard Model. In this session, I will delve into the motivations driving particle collider experiments, elaborate on the methods developed for measuring the properties of elementary particles within specific decay topologies of various physics processes, and explore the analysis of new physics signals anticipated to emerge from the LHC.

Keywords:

LHC, particle collider experiments

2023 KPS Fall Meeting
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TT2.02

Deep Neural Networks in the Search for New Physics from Terrestrial to Cosmological Colliders

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Abstract:

What if new particles are hidden in final states that were neglected due to our theoretical bias, or just too heavy to directly probe? The lack of indications of new physics at the LHC motivates us to challenge some of the assumptions and paradigms we have been holding and to start testing new hypotheses in different ways and with new perspectives. Given the increasing number of events at the LHC, to efficiently explore this wide spectrum of new hypotheses, the task requires reducing complex and high dimensional raw data into a handful of parameters in Lagrangians.

Today, deep learning-based strategies have become more common in high-energy physics, because they can efficiently exploit a matrix-element information from the data and are excellent at interpolating between parameter values, which increases the power of searches for new particles. However, important questions still remain regarding how to apply this tool best. Should we give a neural network the lowest level data, and ask it to figure out the matrix-element information at once? Is it more sensible to give it human-engineered data reflecting various symmetries of Lagrangian, and then ask it to solve the problem? Or should we take a middle ground to both approaches? How do we quantify uncertainties with this procedure? In this talk, we will showcase the potential of deep neural networks to search for various physics beyond the standard model.

Keywords:

Deep Neural Networks, Colliders, New Fundamental Physics

TT2.03

Collider Phenomenology Tutorial – Hands-on

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Abstract:

In this tutorial session, we will explore statistical data processing techniques in the area of collider physics phenomenology, a discipline at the intersection of theory and experiment. This session is structured as a hands-on session and is targeted to graduate students and early career researchers who have interests in collider physics phenomenology. The goal of this hands-on session is to learn a series of processes for obtaining and analyzing data through Monte Carlo simulation. We will learn how to obtain analysis results by practicing step by step. We hope that this hands-on session can be utilized by graduate students and early career researchers who research to find new physics beyond the Standard Model in accelerators such as LHC, Belle2, FCC.

Keywords:

LHC, Collider Physics Phenomenology, FCC, Belle2, Beyond the Standard Model

Fundamentals and Applications of AlphaFold 2

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Abstract:

Recent developments in AlphaFold 2 have demonstrated that the machine learning model can accurately predict the structure of most proteins in the proteome. Due to the unprecedentedly high reliability of the predicted structures, AlphaFold 2 is becoming an essential research tool for both experimental and computational biophysicists. In this tutorial, I will walk through the AlphaFold 2 program from a novice's perspective. First, I will introduce the basic principles, such as multiple sequence alignments and structure modeling, which played a crucial role in enhancing the reliability of AlphaFold 2. Then, I will explain the hardware and software requirements for AlphaFold 2 and how to install it for in-house applications. Finally, I will demonstrate how to predict monomer and multimer structures using AlphaFold 2 using several examples.

Keywords:

Protein structure, AlphaFold 2

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W15.01

우주의 비밀을 캐고자 하는 물리학자들이 지하로 가는 이유

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Abstract:

암흑물질 중성미자와 같이 일반 물질과 잘 반응하지 않는 입자를 연구하기 위해 일부 물리학자들은 지난 반세기 이상 깊은 지하에 대규모 검출기를 설치하여 새로운 물리 현상을 찾기 위한 연구를 수행하고 있습니다. 본 강연에서는 물리학자들이 지하로 가는 이유를 통해 국내외의 지하 실험실을 소개하고, 이를 통해 우주의 비밀에 다가가고자 하는 물리학자들의 노력을 보여주려고 합니다.

Keywords:

암흑물질, 지하 실험

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W15.02

물리학자의 청각, AI 그리고 스타트업

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Abstract:

자연에 존재한다고 알려진 4가지 힘을 측정하기 위해서는 노이즈를 딛고 약한 힘을 측정할 필요가 있었다. 물리학자들은 약한 힘을 측정하기 위해서 많은 노력을 해왔고 본인도 그 방법의 이론적 배경을 연구하던 물리학자이다. 인간의 청각은 이러한 면에서 매우 뛰어난 능력을 가졌는데 그것을 모사하기 위해 인간 청각을 연구하였다. 이러한 연구를 하던 중에 인간의 청각은 하드웨어보다 소프트웨어적인 면이 중요하다는 것을 알게 되었고 그 이유로 인공지능 모델을 청각 연구로 사용하기 시작하였으며 나중에는 스타트업을 창업하였다. 현재 난청과 소음의 문제를 해결하는 회사를 운영하게 되기 까지 물리학을 공부한 것이 어떻게 쓰였는가를 소개하고 연구와 창업에 관한 이야기를 나누려 한다.

Keywords:

암흑물질, 지하 실험

2023 KPS Fall Meeting
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Y1.01

Black Hole Thermodynamics: Then and Now

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Abstract:

Black hole thermodynamics started with the work of Bekenstein and Hawking in the early 1970's, interpreting the area of a black hole horizon as a form of entropy. This is a thermodynamic entropy which obeys a generalized second law of thermodynamics. In modern developments, a microscopic or fine-grained von Neumann entropy is increasingly important. Under unitary evolution, it is constant even though thermodynamic entropy may increase. A fundamental step in understanding fine-grained entropy in gravity was the Ryu-Takayanagi formula, discovered in 2006. In this lecture, I will review some of the old and new developments.

Keywords:

black hole, thermodynamics, entropy, Ryu-Takayanagi formula

포스터발표논문

Poster session abstract

2023 KPS Fall Meeting
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P1-ap.101

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.102

Giant hole-doping in 2H-WSe2 by Ta substitution

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Abstract:

Two-dimensional (2D) transition metal dichalcogenides (TMDs) have emerged as promising candidates for future electronics and optoelectronics. While most of TMDs are intrinsic n-type semiconductors due to electron donation which originates from chalcogen vacancies, obtaining intrinsic high-quality p-type semiconducting TMDs has been challenging. Here we report an experimental approach to obtain p-type WSe2 film by substitutional Ta doping. Using angle-resolved photoemission spectroscopy (ARPES), we found that Ta-substituted WSe2 shows a giant hole-doping as well as moderate decrease of spin-split at K point. Our findings suggest a powerful strategy to realize p-type WSe2 and half-metallicity in TMDs.

Keywords:

Angle-resolved photoemission (ARPES), Molecular beam epitaxy (MBE), Transition metal dichalcogenides (TMDs), 2H-WSe2

2023 KPS Fall Meeting
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P1-ap.103

Development of polymer free transfer process of CVD grown large-area TMDCs

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Abstract:

We investigated a transfer technique for exfoliating large-area 2D TMDCs synthesized by chemical vapor deposition (CVD) on various substrates without substrate etching. It is a method that induces peeling by a solution by using the difference in hydrophilicity between the hydrophobic two-dimensional material and the substrate used. This method has advantages in that the substrate can be recycled and the two-dimensional materials synthesized on a substrate that is difficult to etch can be transferred.

In order to confirm the effect of the process on the material, we conducted a comparative experiment between the liquid assisted peeling method and the general wet-transfer method of etching the substrate. We prepared WS_2 thin films synthesized on SiO_2 and sapphire substrates using the CVD method. The WS_2 thin film was transferred using a method of etching an oxide film using BOE and peeling using a NaOH solution. The surface morphology of the transferred the WS_2 thin film was compared using an optical microscope and an electron microscope, XPS spectra were measured to confirm contamination according to the transfer method, and quality of sample were compared by measuring Raman and electrical characteristics.

Keywords:

Transfer Technique, CVD, WS2, TMDCs

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P1-ap.104

Study on ReS_2 homo-bilayers with various structures 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. Furthermore, the two faces of a monolayer ReS_2 are not equivalent. 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 twist angle. We systematically studied homo-bilayers of ReS_2 which can have various kinds of crystal structures, starting from the case with near 0° twist 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 0° twist 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 the incident beam polarized Raman spectroscopy. 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:

ReS2, Raman, SHG, TMD, interlayer vibration mode

2023 KPS Fall Meeting
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P1-ap.105

Influence of AlO_xN_y overlayer on Mobility in 2D FET Channels

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Abstract:

The allure of semiconductors lies in the ability to modulate their electrical characteristics through doping. However, conventional doping methods like ion implantation in 2D semiconductors come with the burden of lattice damage. Therefore, the surface charge transfer doping (SCTD) method has been proposed as an alternative doping method with change of mobility. In this work, we analyzed the carrier scattering before and after SCTD through low-temperature I-V measurements. The device used in the experiment is a MoS_2 field effect transistor (FET), with AlO_xN_y utilized as the doping layer. And we conducted XPS (chemical analysis) and UV-Vis (optical bandgap measurement) of AlO_xN_y. We examined how SCTD affects changes in mobility, with a focus on scattering factor variations. Through this study, we can contribute to the understanding of interrelationship between SCTD and mobility for MoS_2 based devices.

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Keywords:

2D Materials, MoS2, Scattering mechanism, Doping, 2D Field-effect transistor

2023 KPS Fall Meeting
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P1-ap.106

Ferroelectric $HfZrO_2$–based atomically-thin two-dimensional semiconductor MoS_2 field effect transistor working at low temperature.

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Abstract:

Ferroelectric materials exhibit inherent polarization without external electric fields, driving active research due to high dielectric constants, low power usage, and non-volatile traits. HfO_2-based ferroelectrics, especially, stand out for their compatibility with CMOS processes and persistent ferroelectricity in thin films and low temperatures, making them promising for future semiconductors. However, the ferroelectric behavior and properties of HfO_2-based materials have mainly been studied at room temperature, with limited research on device performance at varied temperatures. This study created ferroelectric field-effect transistors using Zr-doped HfO_2(HZO) and atomically thin 2-dimensional semiconductor MoS_2. Analyzing these transistors at temperatures between 80 K and 300 K revealed temperature-dependent hysteresis due to ferroelectric gate dielectric (HZO). Memory parameters like subthreshold swing and current on/off ratio showcased the potential of these devices in cryogenic memory applications. Additionally, temperature-related ferroelectric traits of HZO capacitors were explored, along with their impact on transistor performance, enhancing understanding of specific ferroelectric influences.

Keywords:

Ferroelectrics, 2D materials, MoS2, HfZrO2, Field-effect transistors

2023 KPS Fall Meeting
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P1-ap.107

Research and development of rapid chemical vapor deposition of graphene for efficient production

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Abstract:

Graphene is an atomically thin layer of material with a two-dimensional honeycomb lattice. It has excellent electrical, optical, mechanical and thermal properties. Based on these excellent properties, many studies on the application of graphene have been reported, and expectations for industrialization are high. On the other hand, it is not easy to find practical industrial application cases yet. To realize this, mass production of high-quality graphene is important.

In order to increase the productivity of graphene and control its properties, we developed a conveyor-type CVD system and our own recipe. Our system can produce 12 graphene sheets within one hour. The liquid hydrocarbon source has a high dehydrogenation rate, which is conducive to the rapid synthesis of graphene. Nitrogen-doped graphene was synthesized using an organic solvent containing nitrogen as a precursor. Synthesized graphene under various growth temperatures and times was evaluated using Raman spectroscopy, XPS, and electrical properties. In particular, in the electrical characterization, it was confirmed that the nitrogen-doped graphene had high n-type characteristics through the confirmation of the position of the charge neutral point (Dirac point).

Keywords:

Graphene, CVD, Mass production, nitrogen doped

2023 KPS Fall Meeting
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P1-ap.108

Te-deficiency induced hidden phase in 1T-$TaTe_2$ thin film

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Abstract:

Transition metal dichalcogenides (TMDs) have attracted extensive rich electronic phases and superstructures, which can be controlled by the growth conditions. Among them, 1*T*-$TaTe_2$ thin films have been reported to have multiple charge density wave (CDW) orders including 3×3, $\sqrt{13} \times \sqrt{13}$, and $\sqrt{19} \times \sqrt{19}$ superstructures, which can be selectively obtained by post-growth annealing treatment.
Here, we report a hidden phase in 1*T*-$TaTe_2$ thin film, which can be only achieved by higher post-annealing process. A combined study on angle-resolved photoemission spectroscopy (ARPES) and reflection high-energy electron diffraction (RHEED) found that the hidden phase shows totally different electronic and structural phases compared to 1*T*-$TaTe_2$ films and Te-deficiency is related to the formation of new phase in 1*T*-$TaTe_2$ thin film.

Keywords:

Angle-resolved photoemission spectroscopy (ARPES), Molecular beam epitaxy (MBE), Reflection high-energy electron diffraction (RHEED), Transition-metal dichalcogenides (TMDs), 1T-TaTe2

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P1-ap.109

Thickness dependence and laser thinning of $CrPS_4$

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Abstract:

Chromium thiophosphate ($CrPS_4$) is a well-known 2D van der Waals material. Single crystals of $CrPS_4$ were prepared by chemical vapor transport (CVT) method. After exfoliation on a Si substrate, each thickness was analyzed through Raman spectroscopy and atomic force microscopy (AFM) measurement. During Raman measurement, it was found that the sample was damaged depending on the laser power and exposure time, and it was expected that there would be a possibility of thickness control through laser thinning like transition metal dichalcogenides (TMDs). In this study, through the mapping mode of Raman spectroscopy, laser thinning of $CrPS_4$ was analyzed.

Keywords:

Chromium thiophosphate, CrPS4, laser thinning

2023 KPS Fall Meeting
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P1-ap.110

Photoluminescence Excitation Measurements on Quantum Emitters in hBN

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Abstract:

Finding quantum emitters in emerging materials and characterizing their origin is one of the important tasks in quantum information science. In this context, quantum emitters in hexagonal Boron Nitride (hBN) are good candidates due to their bright intensity, high chemical stability, and ability to operate at room temperature.

In this presentation, we created a single photon emitter in hBN using plasma treatment and an annealing process. We conducted photoluminescence excitation (PLE) measurements on these emitters using a tunable supercontinuum laser. We tuned the excitation energy over a broad range, corresponding to a few hundred eV difference from the zero phonon lines (ZPL), in order to study the effects of the intermediate electronic state. Furthermore, we observed that emission photon energy depends on the excitation energy. This could be attributed to the interactions with other nearby defects which are optically inactive. We performed detailed spectroscopic measurements on these quantum emitters to understand the origin of this behavior.

Keywords:

2D material, Quantum Emitter, Quantum Information

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P1-ap.111

Enhanced Trapped-Charge Memory Effect in Graphene Field Effect Transistor with Al_2O_3/SiO_2 Gate Insulator Stack

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Abstract:

Graphene is a single layer of carbon atoms arranged in a honeycomb lattice, and it has attracted significant attention thanks to its intriguing electronic, thermal, and mechanical properties. This work explores the influence of an Al_2O_3 overlayer deposited on the SiO_2 gate insulator of a conventional back-gated graphene field effect transistor (GFET) on its operational characteristics. A graphene film is synthesized via chemical vapor deposition on a copper foil (Graphenea) and transferred onto the SiO_2 and Al_2O_3/SiO_2 gate insulators by using the semi-dry transfer method [1]. The Al_2O_3 layer is relatively thin with its thickness of 12nm while the SiO_2 layer is 100nm thick. Raman spectrum measurements are performed to figure out the doping type and density of graphene channel just after the transfer process. The 2D peaks for graphene on SiO_2 and Al_2O_3/SiO_2 surfaces are found at ~2681 and ~2673 cm^{-1}, respectively, while the G peaks are found at ~1591 and ~1585 cm^{-1}, respectively. These peak positions, blue-shifted compared with those of intrinsic graphene confirm p-type doping on both surfaces with a higher hole concentration on SiO_2 surface being expected. The graphene channel is patterned through photolithography processes preceded by the formation of Au/Ti electrodes (50nm/20nm) near the opposite edges of channel serving as source and drain contacts. The noticeable hysteretic behaviors in the transfer curves revealing drain-to-source current (I_{DS}) vs. gate voltage (V_g) are observed for both SiO_2 and Al_2O_3/SiO_2 gate insulators, considered to originate from the electron trapping and detrapping in the insulators. This hysteretic behavior indicates that the carrier type and density in the graphene channel are modulated by the degree of electron trapping in the gate insulator (memory state). The memory retention measurements are followed by applying triangular pulses of +60 and -60 V to the back gate of GFET and measuring the I_{DS} at V_g = 0 V over an observation period of ~ 60,000 seconds. The GFETs with Al_2O_3/SiO_2 gate insulator stack exhibit significantly stronger memory effects compared to SiO_2 gate insulator. Our work suggests that the GFET adopting the back-gate configuration with Al_2O_3/SiO_2 gate insulator stack can be a promising alternative charge-trapping memory structure to the conventional Oxide-Nitride-Oxide structure.

[1] Sungchul Jung, *et al.*, Journal of Applied Physics 125, 184302 (2019)

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Keywords:

Graphene Field-Effect Transistor, Charge-Trapping Memory, Raman Spectroscopy, Transfer Curve, Aluminum Oxide

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P1-ap.112

Optical Characterization of MoS_2 Transistor by Hyperspectral Imaging

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Abstract:

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Transition metal dichalcogenides (TMDCs) are representatives of two-dimensional semiconductors. We fabricated field-effect transistors (FETs) using monolayer MoS_2 grown by metal-organic chemical vapor deposition (MOCVD). We used hyperspectral imaging analysis to characterize MoS_2 FETs fabricated by different processes. Photoluminescence (PL) has proven as an invaluable tool for characterizing the monolayer TMDs. The PL spectrum can sensitively probe doping, strain, and defects. While confocal PL is widely used to characterize MoS_2 FETs, it has limitations in obtaining spectra from multiple areas of the samples simultaneously. We utilized hyperspectral line imaging to characterize the MoS_2 FETs, enabling simultaneous measurements of the gate response of the PL signal from several hundred positions. Using this method, we statistically analyzed how the fabrication process affects the performance of the MoS_2 FETs both optically and electrically.
This work provides an important tool for characterizing large-area TMD-based electronic devices.

Keywords:

TMDC, MOCVD, hyperspectral imaging, MoS2 FET

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P1-ap.113

Optical frequency doubling in WS_2 nanoscroll

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Abstract:

Second harmonic generation (SHG), also called frequency doubling, is a nonlinear optical process that generates new photons with twice the frequency compared to the initial photons. Monolayer semiconducting transition metal dichalcogenides (TMDCs) exhibit a large nonlinear susceptibility, however, their thickness scalability is limited due to the stacking angle-dependent inversion symmetry. To overcome this issue, we performed a systematic optical study on the WS_2 nanoscrolls (NS), which can be easily scaled in terms of thickness.

In this presentation, we analyzed the scroll thickness and direction-dependent SHG of WS_2 NS. WS_2 was grown via MOCVD, and WS_2 NS was fabricated by solvent evaporation. Polarized SHG was used to identify the scroll direction with respect to the monolayer. The relative thickness was confirmed by dark field (DF) optical image, and atomic force microscope (AFM). We then analyzed the relative enhancement of SHG after the scroll process, to determine the optimal conditions for a highly efficient frequency conversion process.

Keywords:

WS2, nanoscoll, second harmonic generation

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P1-ap.114

Impact of Quantum Confinement on Second Harmonic Generation in Ge-based 2D Ruddlesden-Popper Perovskite Series

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Abstract:

Metal halide perovskites have drawn tremendous attention for their great potential towards solar cells, light-emitting diodes, radiation detection, etc. However, they have barely been considered as candidates for second harmonic generation (SHG) applications, a frequency-doubling process, because common metal halide perovskites crystallize in centrosymmetric structures. Recently, it has been reported that the centrosymmetry in 3D perovskites can be broken by engineering octahedral cages with Ge, allowing the resultant crystals to exhibit SHG response [1, 2]. Here, we report on nonlinear optical properties of Ge-based 2D Ruddlesden-Popper perovskite (RPP) series, $BA_2MA_{n-1}Ge_nI_{3n+1}$ (n = 1–3). The existence of the SHG response indicates that the Ge-based 2D RPP series still have noncentrosymmetric structures as its 3D counterpart, $MAGeI_3$. In experiments, wavelength-, size- and excitation intensity-dependent SHG responses were measured in order to examine the operating range, SHG efficiency with phase matchability, and laser-induced damage threshold (LIDT), respectively. Particularly, we focused on changes in the SHG efficiencies and LIDTs owing to quantum confinement effects in 2D RPP series; the SHG efficiency tends to decrease with reducing the layer number (n), while the LIDT tends to increase, which can be explained by well-known relations between each corresponding coefficient, second-order susceptibility $\chi^{(2)}$ and two-photon absorption coefficient β, vs. bandgap [1, 3]. We show that n = 2, 3 compounds can be used for SHG applications as they are phase matchable with good SHG coefficients, together with the enhanced LIDTs, compared with the 3D counterpart.

References

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3. F. O. Saouma et al., Nat. Commun. 8, 742 (2017).

Keywords:

Metal halide perovskite, Germanium, Second harmoic generation, 2D Ruddlesden-Popper perovskite series, Quantum confinement effects

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P1-ap.115

Direct Visualization of Charge Density Wave Domains in Rippled $GdTe_3$ Using Transmission Electron Microscope

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Abstract:

Rare-earth tri-tellurides (RTe_3; R = la-Nd, Sm, Gd-Tm) have recently emerged as interesting two-dimensional systems with charge density wave (CDW) order. Here, we investigate CDW in $GdTe_3$ by transmission electron microscopy (TEM). The typical unidirectional CDW ordering is observed in the flat regions of $GdTe_3$. On the other hand, the domain structures with alternating CDW directions are identified in rippled $GdTe_3$ membranes. The visualization of CDW domains and three-dimensional (3D) rippling structures are performed by dark field TEM imaging under various sample tilting conditions. The observed strong correlation between CDW domains and rippling structures directly confirm that the CDW order can be effectively tuned by external strain engineering.

Keywords:

Rare-earth tri-tellurides, charge density wave, transmission electron microscopy, 2d materials, gadolinium tri-telluride

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P1-ap.116

Raman investigation of substrate-induced strain in epitaxially grown graphene on low/high miscut angled silicon carbide and its application perspectives

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Abstract:

The remarkable properties of graphene/SiC heterostructures have demonstrated promise for use in future power electronics; however, the substrate-induced strain is detrimental to the optimal yield. Epitaxial graphene (EG) grown on nominally low miscut angled (0.05∘ off-axis) SiC (0001) intensely suffers from substrate-induced biaxial strain via a buffer layer. Buffer layer-free quasifreestanding graphene (QFSG) grown on high miscut angled (8∘ off-axis) vicinal SiC using the one-pot synthesis, as compared to EG/SiC (0001), exhibits contrasting Raman 2D-peak features. In this study, the substrate-induced strain exerted on graphene grown on both nominal and vicinal SiC was quantitatively investigated using Raman 2D mapping, and the unstrained feature of QFSG was demonstrated on vicinal SiC. Furthermore, metal-graphene-metal devices were fabricated and photocurrent enhancements of 430- and 150-fold were observed in QFSG/vicinal SiC devices, as compared to EG/SiC (0001), with and without gold nanoparticles, respectively. The significantly increased conductivity and photoresponse of the QFSG/vicinal SiC heterostructure, as compared to that of EG/SiC (0001), will increase the potential of graphene/SiC heterostructures in practical SiC microelectronics applications.

Keywords:

Epitaxial graphene (EG), Quasi-free-standing graphene (QFSG), Gold nanoparticles (AuNPs), Micro-Raman spectroscopy, Strain

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P1-ap.117

Optical spectroscopy 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. Low-frequency 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

2023 KPS Fall Meeting
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P1-ap.118

Investigation of Electrical Properties of SiP-based Field-Effect Transistor

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Abstract:

Silicon phosphide (SiP), a member of group IV-V 2D semiconductors with unique in-plane structure, is one of the emerging materials for electronics and optoelectric applications. Although previous studies have investigated in-plane electrical anisotropy, the detailed electrical characteristics and the feasibility of practical electrical device applications are unexplored. Here, we fabricate the SiP-based field-effect transistors with electrode deposition via shadow mask and explore the intrinsic electrical properties of SiP. Our results confirm that SiP exhibits n-type semiconductor behavior, in contrast to the previous reports showing p-type behavior. Moreover, we study the vacuum-pressure-dependent electrical properties and the ambient-exposure-induced device degradation. Our study provides fundamental insights into the electrical performance of SiP.

Keywords:

Silicon phosphide, group IV-V, 2D material, Field-effect transistor, Pressure sensor

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P1-ap.119

Characterization of Atomically Thin HfX_2 (X=S, Se) by Using Low-Frequency Raman Spectroscopy

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Abstract:

Two-dimensional transition metal dichalcogenides, HfX_2 (X=S, Se), possess intriguing properties such as extremely high photoresponsivity, well-balanced carrier mobility and suitable band gap for optoelectronic devices. Raman spectroscopy is an effective and non-destructive technique for characterizing the properties of 2D materials. In this study, optical properties of atomically thin layers of these materials were investigated by using low-frequency micro-Raman spectroscopy with two excitation energies (1.96 eV, 2.33 eV). We observed several interlayer modes in $HfSe_2$ when the 2.33-eV excitation energy was used. The in-plane E_g and out-of-plane A_{1g} optical phonons of $HfSe_2$ are located at ~150 cm^{-1} and ~200 cm^{-1}, respectively. The A_{1g} peak becomes more intense at thinner layers for 2.33-eV excitation energy, while it is reversed for 1.96 eV. Additionally, a broad peak is observed between 53 cm^{-1} and 94 cm^{-1} and six more Raman peaks are observed for 1.96 eV at higher regions including the in-plane and out-of-plane Raman peaks. In HfS_2, only one interlayer peak is observed by the 2.33-eV energy, while no mode is resolved by 1.96 eV. The in-plane E_g and out-of-plane A_{1g} optical phonons are observed at 256 cm^{-1} and 337 cm^{-1}, respectively. These results provide valuable information on materials parameters for device designs using atomically-thin layer HfX_2 (X=S, Se).

Keywords:

Hafnium dichalcogenides (HfX2), Interlayer vibration modes, Raman spectroscopy

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P1-ap.201

ZnTe ovonic threshold switching modulation by bottom electrode.

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Abstract:

Electrical switching materials have attracted renewed attention for next- generation artificial intelligent (A.I.) or neuromorphic computing devices. The neuromorphic computing devices requires development of highly integrated memory architecture. Ovonic threshold switching (OTS) selector device serves an essential role to prevent leakage current generated in the high- density memory cells with the cross-point array structure. Chalcogenide materials, such as GeSe, GeTe, and ZnTe, have shown OTS properties with mostly amorphous phases. Microscopic amorphization is considered as main driving mechanism of such threshold switching. Recently, however, polycrystalline ZnTe films also show the OTS behavior. The crystalline state of bottom electrode should influence that of overlaid switching materials. However, the effect of crystalline state of bottom electrode has not been examined in connection with the OTS properties. Here, we investigated ZnTe-based OTS devices with varied crystalline states of bottom TiN electrodes. The TiN electrode layers are fabricated with different crystalline states of (001), (111), and polycrystalline orientations on MgO(001), Al2O3(001), and silicon substates by using sputtering, respectively. The OTS devices are prepared with TiN top electrodes on top of ZnTe films. We found that the different bottom electrodes influence forming and threshold voltages, and especially the epitaxial TiN electrodes increases the ratio of on-off current values. For deeper understanding, we compared the I-V characteristics with local electrical characteristics by using conductive atomic force microscopy (C-AFM).
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Keywords:

Ovonic threshold switching(OTS), ZnTe

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P1-ap.202

Ferroelastic phase transition as the origin of Rashba-like band splitting in $MAPbBr_3$

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Abstract:

Due to heavy atoms in lead halide perovskites (LHPs), the existence of the Rashba effect has been suggested as a promising contender for a long recombination lifetime in optoelectronic devices. Despite the extensive studies based on optical, STM, ARPES, and theoretical band calculations, the presence of the Rashba effect and its impacts on optoelectronic properties are still uncertain. Even among studies that reported its existence, Rashba parameters differed from one another, leaving ununified explanations for inconsistent band structures. In this work, we confirmed surface microstructures developed upon the ferroelastic phase transition as an origin of the Rashba-like band splitting in $MAPbBr_3$. We observed chevron-like twin domains using optical microscopy and measured angles between adjacent domains by means of Cryo-SEM. Simple band structure calculation incorporating the structure showed consistent results of previous band structures. This distinctive surface microstructure could be a suitable candidate for explaining the splitting features in ARPES, even without considering the Rashba effect.

Keywords:

Rashba effect, Lead halide perovksites, Ferroelasticity, Twin domain, Angle-resolved photoelectron spectroscopy

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P1-ap.203

Morphological and Optoelectronic Properties of 2D Semiconductor AgSePh Grown on Varying Substrates

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Abstract:

2D organic metal chalcogenides (OMCs) are hybrid organic-inorganic semiconductors with natural multiple-quantum-well structures resulting in quantum and dielectric confinement. In addition to their promising optoelectronic properties, the conformal growth of OMCs grants facile routes for novel device fabrication. However, more study is necessary to implement this growth mechanism in real-world device architecture. Specifically, the conversion of OMC films on substrates other than wafer or glass is yet to be confirmed.
In this work, we synthesize silver benzeneselenolate (AgSePh), a 2D OMC renowned for its robust blue luminescence, on varying substrates. We investigate the resulting differences in morphological structures through SEM imaging and surface profiling. We also study the corresponding optical and electronic properties of the AgSePh films by UV-vis, Photoluminescence (PL), and photoemission spectroscopy.

Keywords:

Organic metal chalcogenide, 2D material, AgSePh, Surface morphology, Optoelectronic property

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P1-ap.204

The Analysis of Hole Injection Improvement when Utilizing Metal Fluorides(BiF3) on Hole Injection Layer

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Abstract:

Organic light emitting diodes (OLEDs) have been extensively studied because of their superior characteristics, such as fast response time, wide color gamut and wide viewing angle. Since device efficiency is contingent upon electronic properties such as carrier injection and transport, the investigation on energy level alignment between electrode and transport layers is of crucial importance for optimizing device performance.
Here, we focused on hole injection layer (HIL) to facilitate effective hole injection. We explored the influence of metal fluoride which is co-deposited with organic materials to aid the injection of hole from anode. The electronic properties of co-deposited films were evaluated with ultraviolet photoemission spectroscopy (UPS) measurements without breaking vacuum.

Keywords:

OLED, HIL, HTL, Anode Buffer Layer , UPS

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P1-ap.205

In situ electrical aging system designed for precise research of interfacial layers of optoelectronic devices

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Abstract:

Despite the development of various optoelectronic devices such as light-emitting diodes and solar cells, understanding the degradation mechanisms of the devices is still lacking. Particularly, despite the importance of comparing the buried interface energy levels and structure before and after imposing bias, which strongly affected the device's stability, the studies have been so far limited to destructive methods such as peeling-off with tapes or sputtering with high-energy atoms. Since it is difficult to obtain the surface of the target layer precisely or cause damage to the samples, a more accurate and non-destructive analysis method is urgently needed.
In this study, we designed a system that enables the research of the electronic properties of interfacial layers before and after biasing. Using this system, we can impose bias on the device structure and non-destructively separate the layers to investigate the electronic structure of the layers without breaking the vacuum. This will benefit studying the degradation mechanics; the studies directly on device layers can be more under control.

Keywords:

optoelectronic devices, degradation mechanics, bias, interfacial layers

2023 KPS Fall Meeting
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P1-ap.206

Fabrication of circular and hexagonal shapes of nanotubes by anodic aluminum oxide.

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Abstract:

During the decade, the synthesis of nanotubes may offer great potential for applications. The nanotubes have been prepared by template-directed methods which utilize a template such as the porous alumina membrane (PAM) to fill the pores of the template with a solution or precursor followed by thermal annealing and selective etching of the template. However, the nanotubes have normally circular shape because of the limits of the PAM fabrication method using nanotube templates. Unlike the circular shaped nanotube, the hexagonal nanotube would be expected to have a complex dispersion, resulting from spin-wave modes localized to the flat facets or to the extremely curved regions between the facets [1]. We believe that the magnetic hexagonal nanotube makes the spin-wave transport possible in 3D, related to the dipole-dipole induced magneto-chiral effects. So, we will show the fabrication of the nanotube with circular and hexagonal shape by the anodic aluminum oxide (AAO), and compare them.

Keywords:

Nanotube, Anodic Aluminum Oxide (AAO), Hexagonal shape

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P1-ap.207

Unraveling the Electronic structure of the 2D/3D Perovskite Heterostructure with halogenated organic spacer cations

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Abstract:

Organic-inorganic halide perovskites (OIHPs) have rapidly emerged as promising materials for high-efficiency solar cells due to their favorable optoelectronic properties such as balanced charge carrier mobility and high absorption coefficient. However, the instability in ambient conditions of the perovskites remains an obstacle to industrialization. One of the several proposed strategies to improve stability is the development of Ruddlesden-Popper (RP) phase 2D halide perovskite structures.

RP phase 2D halide perovskites comprise inorganic metal-halide layers separated by organic spacer cations. The bulky organic cation spacers prevent the inorganic layers from moisture and oxygen and passivate the surface defects that cause non-radiative recombination. Due to these merits, RP phase 2D halide perovskites have been used as a capping layer in Perovskite Solar Cells (PSCs) to improve efficiency and stability.

Although there have been many studies on advances in power conversion efficiency and stability, the role of RP perovskites capping layer in electronic structures is not well understood. Here, we synthesized a series of 2D(X-PEA_2PbI_4)/3D($MAPbI_3$) perovskite heterostructure films with different organic spacer cations (H-PEA, F-PEA, Cl-PEA). We present investigations on the interfacial electronic structure between the 2D perovskites and the electron transport layer using direct and inverse photoemission spectroscopy. These results provide a fundamental understanding of the role of the RP perovskite capping layers in terms of electron injection.

Keywords:

Electronic Structure, Ruddlesden-Popper phase halide perovskite, Photoemission Spectroscopy

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P1-ap.208

First-principles study of remote epitaxy through 2D materials on GaN and GaAs wafers

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Abstract:

In recent years, various experimental and theoretical studies have been conducted on the layer transfer process through two-dimensional (2D) materials such as graphene and hexagonal boron nitride (hBN) sheets on single wafers. The layer transfer process has been proposed as a mechanical lift-off method due to weak van der Waals interactions between 2D and overlayer materials. However, it is difficult to obtain a substantial quantity of single-crystalline overlayer from conventional epitaxial methods. Remote epitaxy, combined with the layer transfer process, could offer a promising alternative method for growing a single-crystalline overlayer.

In this study, we have performed density functional theory (DFT) calculations to examine the remote epitaxy in both cases: (i) BN sheet on GaN substrate and (ii) graphene on GaAs substrate. 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 by the projector augmented wave (PAW) potentials, and the cutoff energy for the plane-wave basis is set to 400 eV.

For BN on GaN, the Ga-terminated surface of wurtzite GaN(0001) is used, with a rectangular (8×8) BN unit cell placed on top of both pristine and defective configurations. The single-crystalline hBN layer remains flat on GaN(0001), while the defective BN exhibits slight rippling. We find no charge transfer from GaN substrates to the surface of single-crystalline hBN, whereas partial charge transfer is observed in the case of defective BN. On the other hand, in the case of remote epitaxy on GaAs, we also examine two types of atomic configurations of pristine and defective graphene with same geometrical configurations as the hBN case. It is found that partial charge transfer occurs from the GaAs substrate to both pristine and defective graphene. Our theoretical studies well explain the experimental results. [1]

[1] H. Kim *et al.*, Nature Nanotechnology ***18***, 464 (2023).

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Keywords:

DFT, remote epitaxy, 2D materials, GaAS, GaN

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P1-ap.209

Application and Development of Boron Nitride Porous Materials

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Abstract:

With the recent popularity of the space industry, the development of space radiation shielding materials become more important. For the success of the aerospace industry, it is crucial to develop shielding materials that can prevent exposure to ionizing radiation (proton, X-ray, etc.) present in space. This study deals with the development of lightweight radiation shielding materials using composite materials of boron nitride nanomaterials and bismuth halides. Boron nitride has a thermal neutron absorption cross-sectional area of 4,017 barn, which is a good neutron shielding agent. In addition, bismuth halide has excellent properties as an X-ray shielding material. By combining these two materials, we have successfully demonstrated a new material that X-ray can shield protons and x-rays at the same time.

Keywords:

Boron nitride, X-ray, ionizing radiation, bismuth halide

P1-ap.210

Multicomponent X-ray Shielding Using Sulfated Cerium Oxide and Bismuth Halide Composites

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Abstract:

Lead is the most widely used X-ray-shielding material, but it is heavy (density ≈ 11.34 g/cm^3) and toxic. Therefore, the replacement of Pb with lightweight, ecofriendly materials would be beneficial, and such materials would have applications in medicine, electronics, and aerospace engineering. However, the shielding ability of Pb-free materials is significantly lower than that of Pb itself. To maximize the radiation attenuation of non-Pb-based shielding materials, a high-attenuation cross-section, normal to the incoming X-ray direction, must be achieved. In this study, we developed efficient X-ray-shielding materials composed of sulfated cerium oxide (S-CeO_2) and bismuth halides. Crucially, the materials are lightweight and mechanically flexible because of the absence of heavy metals (for example, Pb and W). Further, by pre-forming the doped metal oxide as a porous sponge matrix, and then incorporating the bismuth halides into the porous matrix, uniform, compact, and intimate composites with a high-attenuation cross-section were achieved. Owing to the synergetic effect of the doped metal oxide and bismuth halides, the resultant thin (approximately 3 mm) and lightweight (0.85 g·cm^{-3}) composite achieved an excellent X-ray-shielding rate of approximately 92% at 60 kV, one of the highest values reported for non-heavy-metal shielding materials.

Keywords:

sulfated, cerium oxides, porous matrix, bismuth halides, X-ray shielding

Cu_2O나노 구조체의 구조적, 광학적 특성 연구

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Abstract:

제일산화구리 Cu_2O는 높은 광흡수계수와 더불어, 낮은 생산원가와 무독성으로 인해 광전지, 광촉매와 같은 광전기화학 소자의 응용 가능성이 높은 물질이다. 현재 다양한 방법으로 제작되는 Cu_2O 박막은 대부분 제이산화구리 CuO 상을 함께 가지고 있거나 다결정 박막이라는 단점이 존재하여 결정성을 높일 필요가 있으며, 광전기화학 반응의 효율성을 위해 나노 구조체 형성도 주된 연구 주제 중의 하나이다. 본 연구에서는 RF-스퍼터링 및 고온 열처리 방법을 활용하여 Cu_2O(111) 구조체 박막을 제작하였다. 구조적 특성, 표면 상태, 그리고 광흡수도를 X-선 회절, 주자 전자 현미경, 원자힘 현미경, 그리고 UV-Vis 분광기를 활용하여 조사하였으며, 이를 토대로 Cu_2O(111) 구조체 박막의 광전기화학 소자로의 응용 가능성을 제시한다.

Keywords:

Cu2O

SPEM-based Study of Contact Hole Connectivity for 3D Semiconductor Inspection

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Abstract:

As the demand for high-density memory devices increases rapidly, formation of high aspect ratio contact holes is required. Accordingly, the development of contact hole electrical condition inspection methods is necessary. Here, we developed a scanning photoelectron spectroscopy (SPEM)-based inspection method to investigate the electrical connectivity of contact holes. Samples are prepared with an array of holes of different sizes of holes in 500 nm-SiO_2. To model the electrically disconnected state, the etching process was controlled to leave residual SiO_2, while the electrically connected holes were etched to the substrate surface. Both W-filled (WF) and W-unfilled (WU) structures were considered. Si 2p and W 4f core level spectra were measured for WF and WU structure, respectively. Since the emission of photoelectron accumulates positive charges on the surface of electrically disconnected contact holes, the electrical state of each contact hole can be identified from the peak position. We achieved detection of 0.4 μm contact hole. Several considerations will be discussed for SPEM to be used in the field.

This work is supported by MOTIE (The Ministry of Trade, Industry and Energy, Korea) and the KSRC (20020927). This work is also supported by the National Research Foundation of Korea (NRF-2020R1A2C200373211) and Innovative Talent Education Program for Smart City by MOLIT.

Keywords:

Scanning Photoelectron Spectroscopy (SPEM), Contact hole, 3D NAND Flash memory

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P1-ap.213

Gd-MOF based Bismuth Halide Composite for Efficient X-ray Shielding Application.

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Abstract:

Recently, research on aerospace is a competition all over the world. Radiation is one of the vital challenges to the success of the aerospace industry. In particular, X-rays and neutrons are the main radiation in space. In this work, we have successfully developed efficient X-ray shielding materials by compositing gadolinium (Gd)-based metal-organic framework (MOF) and bismuth halides. The Gd-MOF and bismuth halides formed an intimate interface and composites, thereby resulting in high attenuation cross-section for X-ray radiation. Consequently, the developed materials exhibited highly efficient X-ray attenuation. In addition, they are also lightweight, flexible, and environmentally friendly.

Keywords:

Gd-MOF, PDMS, Bismuth halides, X-ray shielding, Aerospace

P1-ap.214

Two Full-Spectrum Responsive Catalysts: $SnFe_2O_4$ QDs and Heterojunction $SnFe_2O_4/\gamma\text{-}Fe_2O_3$ QDs.

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Abstract:

$SnFe_2O_4$ (SFO) is considered a promising candidate for full solar spectrum photocatalysis due to its narrow bandgap energy, non-toxic and non-polluting nature, and room-temperature magnetization. However, the synthesis process of SFO presents several challenges, such as much lower Sn content than the stochiometric value (Sn: Fe << 1:2) and impurity phases, which have not been investigated in detail. This work reports a systematic study on $SnFe_2O_4$ nanoparticles synthesized under two distinct preparation conditions and evaluations of their photocatalytic properties. We have observed that variation in Sn content within $SnFe_2O_4$ significantly influences its photocatalytic performance. Both syntheses initially yield $SnFe_xO$ and $FeSnO(OH)_5$ phases, which transform to different phases upon annealing: pure spinel-structured $SnFe_2O_4$ or a mixture of $SnFe_xO$ and $\gamma\text{-}Fe_2O_3$ phase depending on the initial reaction conditions. We employ EDX, XRD, XPS, and TGA-DSC techniques to analyze the structural transitions. These findings provide valuable insights for various applications of $SnFe_2O_4$ nanoparticles.

Keywords:

Photocatalyst, Tin Ferrite, Spinel structure

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P1-ap.215

The effect of the trailing edge of the pulse on the reset operation in Phase change memory

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Abstract:

Phase Change Memory (PCM) is a non-volatile memory technology that has gained significant attention in the field of computer technology. PCM utilizes specific materials with thermal properties that can transition into a reconfigurable state for data storage and retrieval. This technology offers advantages such as high speed, durability, density, and low power requirements. The process of melting-quenching plays a crucial role in PCM, involving the use of high currents to reset specific regions and induce structural changes in the material. In this experimental study, we investigate the effect of the trailing edge of the pulse on the reset operation in PCM. The experimental setup includes a pulse generator, power divider, bias tee, and oscilloscope. By adjusting the trailing edge length while keeping the pulse amplitude fixed, we assess its impact on the reset operation. The results reveal that the T-shape PCM cell exhibits different resistance states depending on the trailing edge length. These findings contribute to our understanding of PCM behavior and provide insights into optimizing its performance for future non-volatile memory applications

Keywords:

Pulse, PCM, PRAM, Trailing edge, Quenching

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P1-ap.216

Lightweight, high electrically conductive CNT/Cu Hybrid yarn

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Abstract:

The demand for lightweight, high-conductivity materials has grown due to their unique properties and potential applications. In this study, we propose a novel composite material made by electroplating copper onto carbon nanotube sheets and twisting the resulting sheets into biscrolling yarns. Through current annealing, the resulting CNT/Cu hybrid yarns are significantly improved in terms of electrical conductivity and compactness. The resulting composite combines the lightweight nature of carbon nanotubes with the excellent electrical conductivity of copper, making it an attractive candidate for replacing commercial metal wire in various applications. The electroplating process used in this study is versatile, cost-effective, and scalable for industrial production, making it highly promising for creating advanced composites.

Keywords:

Carbon nanotube, Electroplating, Electrical conductivity, Biscroll

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P1-ap.218

Structural identification of $GeSe_{2-x}Te_x$ nanowires: interlayer twist and twinning

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Abstract:

The interlayer stacking configuration and the intralayer connectivity are the critical features for effectively tuning the properties of van der Waals layered structures. Here we investigate the morphology and structures of $GeSe_{2-x}Te_x$ nanowires synthesized by the chemical vapor deposition method. Raman and energy dispersive X-ray spectroscopy confirm that the synthesized nanowires are $GeSe_2$ with a few percent Te doping. The newly identified phase of nanowires exhibits coexisting growth modes: thick helical nanowires with axial screw dislocation and thin bicrystal feather-like rod with mirror symmetry across twin boundaries. Electron diffraction and dark field imaging confirm the continuous twisting of interlayers due to the existence of a screw dislocation in the core of relatively thick nanowires. Electron diffraction and atomic resolution TEM imaging confirm that the nanowire growth transits to the twin-symmetry bicrystal growth mode in the thin wire regions. The newly identified structures in $GeSe_{2-x}Te_x$ provide interesting way to tune the interlayer stacking configuration and the intralayer connectivity in this system and warrant further studies on their physical properties.

Keywords:

Nanowire, Twisted nanowire, Vapor–Liquid–Solid method (VLS), Chemical Vapor Deposition(CVD), germanium diselenide

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P1-ap.219

Binder-free supercapacitors for reducing leakage currents

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Abstract:

Graphene-based supercapacitors (SCs) hold the potential to become integral components of the portable electronics sector due to their high power output, advantageous electronic and mechanical properties, as well as long-lasting durability. One of the primary challenges in SC research is enhancing electrochemical performance while reducing leakage currents. The addition of polyvinylidene fluoride (PVDF) binder during SC fabrication introduces electronegative fluoride ions to the graphene active material, impeding ion adsorption and desorption processes in the SC and leading to increased leakage currents. In this study, binder-free SC electrodes were developed using three types of solvents; ethylene glycol (EG), dimethyl sulfoxide (DMSO), and N-Methyl-2-pyrrolidone (NMP). Among the fabricated SCs, those produced with NMP solvent exhibited low leakage and high mechanical stability. Our study demonstrates that a binder-free SC with decreased leakage current can be achieved by employing the NMP solvent.

Keywords:

graphene, supercapacitor, solvent effect, leakage current

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P1-ap.220

Effects of ionic impurities on leakage currents of graphene-based supercapacitors

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Abstract:

We undertook this investigation due to the limited body of research concerning leakage current in graphene supercapacitors. Establishing a clear causal link between the extent of impurities and the occurrence of leakage current has proven challenging. Previous research suggests that impurities in metallic materials tend to elevate leakage current, a phenomenon potentially linked to Gibbs free energy. Our aim is to conduct a series of experiments to ascertain the impact of both ionic compounds and metals on leakage current, and subsequently, their relationship with Gibbs free energy. To achieve this, we will compare the behavior of the reduced graphene oxide (rGO) electrode with a basic rGO electrode, as well as an rGO electrode exposed to a comparable quantity of ion chemical within the electrolyte. This comparative analysis will shed light on the fate of ion chemical dissolution in the electrolyte. Furthermore, by employing a three-electrode system, we will measure and compare the cyclic voltammetry (CV), galvanostatic charge-discharge (GCD), and chronoamperometry (CA) values. Our objective is to identify any potential correlation between these values and Gibbs free energy, offering deeper insights into the underlying mechanisms governing leakage current in graphene supercapacitors.

Keywords:

Graphene, supercapacitor, Gibbs free energy, impurity, leakage current

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P1-ap.221

Enhanced Chage Trap Characteristics in MOIOS Flash Memory Structure by Silicon Quantum Dots in SiN_x

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Abstract:

In this study, we fabricated a Metal/Oxide/Insulator/Oxide/Semiconductor (MOIOS) structure with a silicon nanostructure as a charge trapping layer. To investigate the performance of the device with and without silicon quantum dots (Si-QDs) in the insulator layer (charge trapping layer), we fabricated SiNx and SiNx-QDs samples. Si-QDs were formed by increasing the temperature during the RF-sputtering deposition of the charge trapping layer. The formation of Si-QDs was confirmed by photoluminescence spectroscopy (PL) and X-ray photoelectron spectroscopy (XPS). We confirmed the improvement of the memory window of the Si QDs-containing device by capacitance-voltage (C-V) measurements. To analyze the chemical states of charge trapping layer, we conducted XPS measurements. As a result, we interpret that enhancement of charge trap characteristics is attributed to the change in the chemical state of the sample depending on the SiN_x formation conditions.

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Keywords:

silicon quantum dots, charge trapping flash memory, silicon nitride, silicon nanostructure

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P1-ap.222

Influence of diverse acidic and mixed electrolytes on the electrochemical characteristics of graphene supercapacitors

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Abstract:

Electrolytes play a crucial role in determining the performance of electrochemical supercapacitors. Particularly, aqueous electrolytes (acid electrolytes) are known for their high ionic conductivity and mobility, resulting in high power rate capabilities and swift charge/discharge cycles. Recognizing the significance of the specific type of electrolyte ions involved in the charge/discharge process for the performance of graphene supercapacitors, this study investigated the effects of various acid electrolytes and mixed electrolytes on the electrochemical behaviors of graphene supercapacitors. Pouch-type graphene electrodes in a symmetric two-electrode configuration were fabricated using a ball mill to mix source materials (reduced graphene oxide (RGO, 90 wt. %), polyvinylidene fluoride (PVDF, 10 wt. %) and dimethyl sulfoxide (DMSO) solvent). Subsequently, we conducted electrochemical measurements using different acid electrolytes such as 1 M H_2SO_4, 1 M H_3PO_4, 1 M H_2SO_4 mixed with 1 M H_3PO_4, 1 M H_2NO_3 and 1 M HCl. This study primarily focused on analyzing specific capacitance and leakage currents of graphene supercapacitors. Our results may contribute to the advancement of graphene supercapacitors as a next generation energy storage device.

Keywords:

two-electrode system, reduced graphene oxide, acid electrolytes, supercapacitor

역광전자 분광기술을 이용한 유기 태양 전지의 전압 손실 측정

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Abstract:

유기 태양 전지(OPV)에서는 엑시톤의 결합과 전하의 빠른 재결합으로 인해 전하 수송 상태와 전하 분리 상태를 거치며 다른 유형의 태양 전지에 비해 낮은 Voc를 갖는다. 그러나 LUMO 레벨을 독립적으로 측정하기 어려워 인해 Voc의 손실을 정확하게 알아내기 힘들다.
우리 그룹은 고감도 역광전자 분광법(IPES) 장비를 사용해 유기 반도체의 LUMO 레벨을 측정하고 있다. 기존의 자외선 광전자 분광기(UPS)와 결합하여 모든 유기 반도체 표면 및 계면에서의 HOMO, 페르미 레벨 및 진공 레벨 역시 측정할 수 있어 수송 갭 확인이 가능하였다. 이 모든 측정이 동일한 샘플에 대해 두께의 함수로 수행될 수 있음을 입증했다. 또한 C60/CuPc 계면에서의 에너지 준위를 결정하여 이종 접합 유기 태양 전지의 Voc 값을 관찰 후, 태양광 시뮬레이터를 이용해 유기 태양 전지의 손실된 Voc와 외부 양자 효율과의 관계를 파악했다.

Keywords:

IPES, Interface, OPV

Family-Vicsek scaling in the XX Heisenberg Model

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Abstract:

Family-Vicsek(dynamic) scaling has been thoroughly studied in classical hydrodynamics and surface dynamics. Recent studies report that Family-Vicsek scaling also emerges in quantum spin systems[1,2], and in some cases, the scaling exponents are expected to be unconventional[3]. In this poster, we introduce our progress in finding the unconventional scaling exponents in the XX Heisenberg model. In the limit of low filling and strong on-site interactions, the Bose-Hubbard model is mapped to the XX Heisenberg model. With the single-site resolving quantum gas microscope, we prepared a domain-wall state where the 1D spin chain is halfway filled with up spins and halfway filled with down-spins. The relaxation dynamics of magnetization was measured and compared with exact calculations to confirm that the dynamics is governed by the XX model. We plan to observe the relaxation dynamics of a staggered spin state where unconventional scaling exponents are expected.

Keywords:

Quantum gas microscope, Family-Vicsek scaling, Spin dynamics

2023 KPS Fall Meeting
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P1-at.002

Towards Degenerate Fermi Gases of Ultracold Lithium-6

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Abstract:

In this poster, we introduce the progress toward Degenerate Fermi Gases (DFG) of ^{6}Li atoms. The Gray Molasses (GM) cooling scheme is employed to produce degenerate Fermi gases efficiently into the optical dipole trap [1]. We collect approximately 10^8 atoms in the magneto-optical trap (MOT) in 6 seconds, and then apply blue-detuned D1 laser light for additional sub-Doppler cooling. Here, we have integrated the D1 and D2 laser beams, which can produce D1 and D2 pumping and cooling beams by two TAs, which results in a compact optical setup [1,2]. The temperature of the atoms drops to about 100 μK after the GM, which is cold enough to trap the atoms in the optical potential with a trap depth of a few mK. We also present a developed system for phase-stabilized optical lattice that exhibits versatile lattice geometry.

[1] A. Burchianti, G. Valtolina, J. A. Seman, E. Pace, M. De Pas, M. Inguscio, M. Zaccanti, and G. Roati, Phys. Rev. A **90**, 043408 (2014)
[2] C. L. Satter, S. Tan, and K. Dieckmann, Phys. Rev. A **98**, 023422 (2018).

Keywords:

Ultracold atoms, Degenerate Fermi Gas, Optical lattice

2023 KPS Fall Meeting
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P1-at.003

Quantum Kelvin-Helmholtz instability in a ferromagnetic superfluid

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Abstract:

In this poster, we will present an experimental demonstration of quantum Kelvin Helmholtz instability (KHI) in a two-dimensional ferromagnetic spinor Bose-Einstein condensate [1]. After preparing a single magnetic domain wall in the easy-axis ferromagnetic phase, we imprint a spin current onto the domain wall using a magnetic field gradient. The flutter-finger pattern of domain wall waves is generated as a result of quantum KHI instability. When the spin current exceeds a critical value, we observe the formation of a fractional skyrmion, accompanied by the presence of a spin singularity. To verify the skyrmion spin texture, we employ matter-wave interference using Raman transition. We observe a fork-shaped interference pattern at the center of the isolated spin up (down) domain in the background of spin down (up) domain. We will also discuss our progress toward a homogeneous box trap using a digital micromirror device.

[1] H. Takeuchi, Phys. Rev. A **105**, 013328 (2022)

Keywords:

ferromagnetic spinor Bose-Einstein condensate, quantum Kelvin-Helmholtz instability, fractional skyrmion, homogeneous trap

2023 KPS Fall Meeting
2023-10-24 - 2023-10-27

P1-at.004

Towards the Creation of Degenerate Fermionic/Bosonic NaK Molecular Gases with Long-range Dipolar Interactions

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Abstract:

Ultracold quantum gases offer a versatile platform for investigating complex quantum phenomena. In particular, the creation of degenerate gases of polar molecules, by virtue of the strong anisotropic and long-range dipolar interactions, can give access to exotic many-body physics with nontrivial correlations such as Wigner crystallization and topological superfluidity. In the presence of an optical lattice, quantum simulation studies of extended Bose- and Fermi-Hubbard models are allowed.

At POSTECH, we are constructing an apparatus to produce degenerate gases of strongly dipolar bosonic $^{23}Na^{41}K$ and fermionic $^{23}Na^{40}K$. Specifically, the experiment is designed such that the quantum statistics of the molecular gas can be chosen by adjusting a few experimental parameters. In regards to creating bosonic ground state molecules, we first demonstrated efficient sympathetic cooling of ^{41}K with Na atoms and have subsequently created weakly bound $^{23}Na^{41}K$ Feshbach molecules. Further spectroscopy on excited molecular states will reveal a suitable two-photon pathway down to the tightly bound absolute ground state. For the creation of fermionic molecules, we have recently succeeded in cooling ^{40}K, and Feshbach molecule association followed by ground-state conversion via the established STIRAP pathway [1] are to be performed. Future plans involve implementing optical transport to an additional science cell, where quantum gas microscopy of strongly dipolar molecules in an optical lattice can be performed.

[1]Jee Woo Park *et. al.,* 2015, *New J. Phys.* **17,** 075016

Keywords:

Ultracold molecules, Feshbach molecules

2023 KPS Fall Meeting
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P1-at.005

Hydrodynamic approaches to spin turbulent Bose-Einstein condensate

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Abstract:

This poster presents our investigation on the hydrodynamic behaviors of spin-driven turbulent Bose-Einstein condensates. In recent works, a stationary turbulence with isotropic but spatially irregular spin texture is observed in antiferromagnetic spin-1 BEC under continuous spin driving [1, 2]. Despite the existence of local density flow due to its irregular spin texture, there were no significant differences in the static density profiles between turbulent and uniform BEC. On the other hand, to investigate the hydrodynamic properties of the turbulent BEC, we measure the responses of turbulent and uniform BECs to external density perturbations: quadrupole oscillation, one of the lowest-lying collective modes of trapped BEC, and sound propagation. In both BECs, well-defined collective behaviors are observed, while we cannot observe significant difference in the frequency of the quadrupole mode and the speed of sound. However, the damping of collective modes is observed to be larger in the turbulent BEC, and we attribute this increase to the coupling between different spin components and internal flow.

[1] D. Hong, J. Lee, J. Kim, J. H. Jung, K. Lee, S. Kang and Y. Shin, Spin-driven stationary turbulence in spinor Bose-Einstein condensates, Physical Review A 108, 013318 (2023)
[2] J. H. Jung, J. Lee, J. Kim and Y. Shin, Random spin textures in turbulent spinor Bose-Einstein condensates, arXiv preprint arXiv: 2308.01757

Keywords:

collective modes, sound propagation, spin turbulent BEC, hydrodynamics

2023 KPS Fall Meeting
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P1-at.006

Floquet 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 band structure of a one-dimensional optical lattice system, which is periodically modulated via resonantly shaking its amplitude or phase. Not only numerically but also experimentally, we demonstrate that the Bloch bands of the periodically driven system can be coupled by a variety of channels. Finally, we discuss the effect of a global trapping potential and topological properties of the Bloch bands in the shaken lattice system.

Keywords:

Floquet engineering, optical lattice, topology

2023 KPS Fall Meeting
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P1-at.007

Optimization of Resolved Sideband Cooling Pulse Sequence using Reinforcement Learning

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Abstract:

Resolved sideband cooling is an essential technique to allow trapped ions to reach near their motional ground state [1,2]. This enables high-fidelity quantum operations and increases qubit's coherence time, which is necessary for quantum computing and quantum information processing. In this work, we present an innovative approach to optimizing the resolved sideband cooling pulse sequence by leveraging the power of reinforcement learning. Compared to a previous work [3], we have developed an optimization procedure that achieves lower average phonon state without any parameter restrictions. We will discuss the experimental verification of the optimized sequence in our trapped ion quantum computer setup, and the possibility of applying reinforcement learning to other aspects of the trapped ion experiment.
[1] H. Che, K. Deng, Z. T. Xu, W. H. Yuan, J. Zhang, and Z. H. Lu, Efficient Raman Sideband Cooling of Trapped Ions to Their Motional Ground State, Phys. Rev. A 96, 013417 (2017).
[2] C. Monroe, D. M. Meekhof, B. E. King, S. R. Jefferts, W. M. Itano, D. J. Wineland, and P. Gould, Resolved-Sideband Raman Cooling of a Bound Atom to the 3D Zero-Point Energy, Phys. Rev. Lett. 75, 4011 (1995).
[3] A. J. Rasmusson, M. D'Onofrio, Y. Xie, J. Cui, and P. Richerme, Optimized Pulsed Sideband Cooling and Enhanced Thermometry of Trapped Ions, Phys. Rev. A 104, 043108 (2021).

Keywords:

trapped ion, quantum computing, atomic physics, laser cooling

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P1-at.008

루비듐 원자를 이용한 광집게 배열 실험 진행 상황

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Abstract:

최근 급속히 발달한 중성 원자의 광집게 배열은 대규모 양자컴퓨터 및 시뮬레이터의 기반 기술이 되고 있다. 본 발표에서는 루비듐을 이용한 광집게 배열 형성과, 이를 이용한 중성 원자 양자 컴퓨터 개발 과정을 보고한다. 극고진공의 진공 챔버를 제작하였고, 완만한 자기장 기울기를 가지는 자기장 시스템을 개발하였으며, NA=0.42 이상의 광학계를 설치하였다. 또한 FPGA 기반의 rf 주파수 생성 장치를 이용하여 음향 광학 변조기가 광집게 배열을 형성함을 보였다. 본 실험 장치는 게이트 기반 양자컴퓨팅을 염두에 두고 있으며, 추후 실험 계획에 대해 심도있게 논의한다.

Keywords:

양자컴퓨터, 루비듐, 광집게

2023 KPS Fall Meeting
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P1-at.009

Progress on Construction of Cryostat-based Yb ion Quantum Computer

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Abstract:

In this presentation, we present our progress on building a trapped ytterbium-ion based quantum computer, which has been constructed using a mechanically stable cryostat and modular component design. The overall system is consisted of the compact core chamber, CW lasers and modulation optics, and Raman lasers systems to realize quantum gates on Yb ion qubits.We aim to achieve a stimulated Raman transition with two continuous-wave lasers, accomplished by phase-locking of their frequency difference to the qubit's transition frequency for resonant interaction. Our establishment of a optical phase-locked loop ensures synchronized phases and a fixed frequency difference between the lasers. The presentation will deliver the current status of system construction and the near-future goals.

Keywords:

Trapped Ion, Quantum Computer, Quantum Information

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P1-at.010

극저온 이온 포획 시스템의 개발과정

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Abstract:

본 발표에서는 4K의 극저온 환경에서 작동하는 이온 포획 시스템의 개발 과정에 대해 상세히 다룬다.
이온 포획을 위한 칩은 알루미나 기판에 금 코팅을 적용하였으며, micromotion compensation을 위한 레이어를 추가해 제작되었다.
또한 저온에서의 NA 렌즈의 이동을 위한 스테이지와 Helical Resonator가 시스템 내부에 통합되어 설계되었다.
이런 구성 요소들은 초고진공(UHV) 환경에서 낮은 motional heating rate을 보장함으로써, 정밀한 양자 컴퓨팅을 실현할 수 있는 기반을 제공한다.

Keywords:

Ion trap, Quantum computer

P1-at.011

Simulating the energy levels of optical trapped-ion qubit

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Abstract:

본 그룹에서는 자체 제작한 이온 트랩 장치를 이용하여 칼슘 이온을 포획하였다. 본 포스터에서는 포획한 칼슘 이온의 density matrix와 system, environment을 정의하고, Quantum Tool box in Python(QuTiP)을 이용하여 master equation을 해석한 결과를 보인다. 또한, $S_{1/2} - P_{1/2}$ 전이를 일으키는 laser의 세기에 따른 off-resonant excitation 빈도 변화에 대해 논의한다.

Keywords:

Ion trap, QuTiP, 40Ca+

2023 KPS Fall Meeting
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P1-at.012

Exploring third-order exceptional point in an ion-cavity system

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Abstract:

We theoretically explore third-order excpetional point (EP3) in an ion-cavity system and a method to observing EP3. In the lambda-type level configuration, the ion is pumped by a laser from the cavity side, and the cavity is probed with a low intensity laser field. We utilize the highly asymmetric branching ratio of an ion's excited state, which allows us to neglect a quantum jump operator and obtain the non-Hermitian Hamiltonian. By fitting the cavity transmission spectrum, the three eigenvalues emerge at a point 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 for $^{40}Ca^{+}$.

Keywords:

Exceptional point, third-order exceptional point, ion-cavity system

2023 KPS Fall Meeting
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P1-at.013

Estimation of velocity distribution of a laser-cooled single atoms in a cavity

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Abstract:

레이저 냉각된 단일 ^{87}Rb 원자는 고휘도의 공진기로 자유 낙하하면서 공진기 축방향으로 힘을 받는다. 축방향 움직임으로 인해 원자는 공진기 모드의 배/마디를 반복해서 지나며, 이에 따라 원자와 공진기 간의 결합 세기가 변화한다. 본 연구에서는 공진기를 투과한 광자의 이차상관함수 $g^{(2)}(\tau)$를 통해 원자-공진기 결합 세기 변화를 분석하여 원자의 공진기 축방향 속도 분포를 도출하였다. 또한 원자가 공진기를 지남에 따른 이차상관함수의 변화로부터 속도 분포의 변화 양상을 파악하였으며, 이는 약한 공진기 조사광에 따른 양자 효과와 관계됨을 논의한다.

Keywords:

Cavity QED, 87Rb, Second-order correlation function, Ensemble velocity

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P1-at.014

Room-temperature transduction and amplification of infrared photons into visible photons

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Abstract:

Electromagnetic wave transduction is essential to bridge quantum devices operating in different frequency regions. Here, we report on experiments utilizing a lambda-type atomic transition to convert and amplify near-infrared photons at 1500 nm into visible light at 553 nm. The three-level system of 138 barium atoms consists of the ground state $^1S_0$, the excited state $^1P_1$, and the metastable state $^1D_2$. The transition linewidths between $^1S_0$- $^1P_1$ and $^1P_1$- $^1D_2$ are 18.9MHz and 48kHz, respectively, different by about 400 times. By employing a strong 553- nm pump laser driving the $^1S_0$- $^1P_1$ transition, most atoms in the $^1S_0$ state can be optically pumped to the metastable $^1D_2$ state. When 1500-nm photons resonant with the $^1P_1$- $^1D_2$transition are incident, they interact with the atoms in the $^1D_2$state, returning some of them to the $^1S_0$ state. These atoms in the $^1S_0$ state can generate about 400 photons per atom at 553 nm when they are driven by a weak 553-nm cycling laser. As a result, the transduction and amplification of 1500-nm photons into the visible region takes place at room temperature. In this presentation, we will discuss the observed efficiency of conversion, amplification, linearity, and other relevant factors.

Keywords:

optical pumping, optical transduction, optical amplification, room-temperature, Lambda system

2023 KPS Fall Meeting
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P1-bp.101

Prism-based spectral analysis for single-molecule FRET measurement

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Abstract:

Single-molecule fluorescence Resonance Energy Transfer (smFRET) has been a versatile tool for kinetic and structural analysis of biomolecules. By measuring energy transfer efficiency from a donor fluorophore to acceptor, both labeled on the biomolecules of interest, it is feasible to ascertain the inter- and intra-molecular distances between the two fluorophores in nanometer scale. Here, inspired by recent advances in single-molecule spectral analysis, we present a simple and efficient smFRET detection scheme. Unlike the conventional smFRET setup, in which a dichroic mirror is used for segregating emitted light from the donor and acceptor, a dispersive prism is used to utilize the full spectral information of the two fluorophores. This design is easy to implement and enables higher throughput by allowing detection of 1.5x more molecules per field of view. Moreover, it can accommodate fluorophore pairs in different spectral region and even multicolor FRET scheme without necessitating any optical configuration modifications.

Keywords:

single molecule, fluorescence, Total internal reflection microscopy, Single molecule spectrum, FRET

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P1-bp.102

Tracking mouse USV origins with functional beamforming on sparse arrays

LEE Gyu-Hwan [1,2], JEONG Iljoo [3], PARK Keonhyeok [3], LEE Kangmin [1,5], LEE Seungchul [4], CHOI Jee Hyun *[1], PARK Choonsu *[3]
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Abstract:

To understand the neural mechanisms underlying social behaviors, pinpointing the speaker within a group is essential. In this study, we employ the mouse, a popular animal model in neuroscience, to identify vocalizations within group conditions. A primary challenge in localizing mouse vocalizations is the sensor inter-distance requirement—less than half of 1.9 cm—to satisfy the Nyquist condition. However, reducing the sensor dimensions inadvertently diminishes sensitivity.
To address this, we designed an optimal sparse sensor arrangement and adopted the functional beamforming method. Two parameters were our primary focus: the maximum side-lobe level (MSL) for estimating the image distortion and the half-power bandwidth (HPB) of the main lobe, indicating the spatial resolution.
First, we optimized a 2D arrangement for twelve sensors through a genetic algorithm, targeting a minimized MSL whilst preserving the main lobe's HPB. Through simulations and experiments with various source locations and frequencies, we observed that source localization improves with increasing frequency and decreasing target distance. Intriguingly, frequency and distance had a negligible impact on the MSL stemming from an identical main lobe.
Secondly, we enhanced the image resolution by adjusting the eigenvalues linked to the beam pattern's side-lobe distribution via eigenvalue analysis, termed functional beamforming. This approach, compared with conventional beamforming, yielded a 30% enhancement in HPB and a decrease of 10 dB in MSL, thus increasing the spatial resolution for a given sensor array system.
Lastly, we presented a proof-of-principle by applying this methodology to socially engaged mice. A novel CBRAIN technique was employed to enable concurrent recording of neural and vocal signals from freely interacting mouse groups. We expect that these advancements will contribute to unveil the intricate neural mechanisms underpinning vocalizations, furthering our understanding of the neural origins giving rise to social behavior.

Keywords:

social brains, animal communication, functional beamforming, ultrasonic sound, random sparse array

2023 KPS Fall Meeting
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P1-bp.103

Physical properties of anti-CD3 antibodies conjugated with magnetic nanoparticles for immunotherapy

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Abstract:

An optimal Fc-directed conjugate of a humanized monoclonal anti-CD3 antibody (Foralumab mAb) for COVID-19 immunotherapy and amine-silica coated magnetic nanoparticles (MNPs) with an average particle diameter of 35 nm was prepared. This was done using the SiteClick Antibody Labeling Kit, which included antibody concentration adjustment, buffer exchange, antibody carbohydrate domain modification, azide attachment, azide modified antibody purification and concentration steps. The conjugation of mouse monoclonal anti-CD3 antibody (CD3ε mAb (145-2C11), rabbit anti-hamster IgG (H+L)) and dextran-coated MNPs with an average particle diameter of 50 nm was made by adding glutaraldehyde as a crosslinking agent. Glutaraldehyde can act as a cross-linking agent that binds to the amine groups of amino acids (Arg, His and Lys) and MNPs of antibodies by amide bonds. Brownian motions of two conjugates in phosphate-buffered saline (PBS), were observed using a nanoparticle tracking analyzer (NTA). In the case of silica-MNPs, the average values of the drift velocities were measured as +3.16 pix/frame and 0.76 pix/frame in the x-axis and y[1]axis, respectively. In the case of the Foralumab mAb-MNPs conjugate, those were measured as +6.70 pix/frame and +1.98 pix/frame in the x-axis and y-axis, respectively. This means that the mAbs with a biocompatible ligand functional group attached to the surface of the MNPs have a two-fold improved fluidity in PBS. Meanwhile, in the case of the CD3ε-MNPs conjugate, the average values of the drift velocities were almost similar to the case of dextran-MNPs. The binding characteristics of MNPs conjugated with humanized Foralumab antibody and mouse antibody were observed using field emission-transmission electron microscope (FE-TEM). The CD3 mAbs conjugated to the MNPs were analyzed by surface element analysis of energy dispersive spectrum (EDS). The decrease in iron and oxygen (wt%) of two mAb-MNPs conjugates is pure MNPs as the carbon (C) component constituting the mAb in mAb-MNPs is relatively increased compared to MNPs. In addition, we confirmed the therapeutic effect by injecting the conjugated mAb-MNPs into the tail vein and the back of mouse with increased inflammation through a microneedle. These results are expected to be used as an immunotherapeutic agent for suppressing cytokine storm based on the characteristics of MNPs that enable drug delivery and target induction.
Acknowledgments: This research was funded by the Brain Pool (BP) program (2022H1D3A2A01094484) of the Ministry of Science and ICT, and the Basic Science Research Program (2021R1I1A3054773) of the Ministry of Education through the National Research Foundation of Korea (NRF).

Keywords:

magnetic nanoparticles (MNPs), monoclonal anti-CD3 antibody, nanoparticle tracking analyzer (NTA), microneedle patch

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P1-bp.104

GIGANTEA phase separation modulates thermosensitive flowering in Arabidopsis thaliana

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Abstract:

To efficiently organize different biochemical events in certain physicochemical settings, cells feature non-membranous compartments known as 'biomolecular condensates.' Biomolecular condensates are formed via **liquid-liquid phase separation (LLPS)** and act as novel milieus 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. Here, we report that one of the plant flowering pathway components, **GI (GIGANTEA)** undergoes LLPS to form biomolecular condensates of which the phase properties can be altered by ambient temperature. We report that increased ambient temperature disrupts GI condensate formation in FKF1 (FLAVIN-BINDING, KELCH REPEAT, F-BOX1) dependent manner thereby induces degradation of floral repressor protein SVP (SHORT VEGETATIVE PHASE). The study using plant flowering pathway component GI 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, Arabidopsis thaliana

2023 KPS Fall Meeting
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P1-bp.105

CRISPR RNP Transfection for Live-Cell Imaging of Heterochromatin under DNA Damage Response

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Abstract:

CRISPR system is widely used to visualize genomic loci in living cells by tagging the dCas9 protein or RNA-binding protein with a fluorescence protein (FP). However, low quantum yield and poor photostability of FP's hamper the application of CRISPR imaging technique to small, non-repeat targets and also limits the duration of tracking. To overcome such limitation, we constructed recombinant CRISPR RNA-protein (RNP) complex with purified dCas9 protein and synthetic guide RNA labeled with organic fluorophores. Injected into cells by electroporation, the RNP complex successfully labeled the pericentromeric domain of chromosome 9, C9-1. The gRNA could be further modified with photo-detachable capping to implement vfCRISPR on a chromosomal domain with repetitive sequence, which allows observing how chromatin changes structure upon DNA double strand break with temporal control. It provides a valuable tool to study the effect of DNA damage response on the chromatin structure in living cells.

Keywords:

CRISPR, Live-cell imaging

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P1-bp.106

Visualizing PABPC1-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:

Translation, live cell, PABPC1

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P1-bp.107

Monitoring open-ended tunneling nanotubes using photoactivatable motor protein

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Abstract:

Tunneling nanotubes (TNTs) are plasma membrane protrusions that contain filamentous actin (F-actin) and establish direct connections between cells, facilitating the transfer of materials between them. Small ions can pass across the gap junction in close-ended TNTs. Open-ended TNTs, on the other hand, carry larger molecules such as mRNA, proteins, organelles, and so on.
To identify the open-ended TNTs, we constructed a photocatalytic molecular motor system that unidirectionally moves along F-actin. This system utilizes a myosin XI motor modified with Cry2olig that triggers myosin XI oligomerization in response to blue light. Using Halo-tag, in addition to fluorescent proteins, enables enhanced visualization of this motor within live cells, thus offering a clearer and more precise observation.
In this study, we present the kinetic behavior of the myosin XI-Cry2olig system as it interacts with F-actin within living cells. This investigation sheds light on the mechanisms underlying molecular transport through TNTs and provides valuable insights into cell-to-cell communication and material exchange.

Keywords:

tunneling nanotube

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P1-bp.108

Formation and regulation of phase-separated UBQLN2 biomolecular condensate in vitro

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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. Here, we propose that the multivalency of UBQLN2 is provided by hydrophobicity, which enforces UBQLN2 LLPS *in vitro*. Our research also suggests that the material property or formation of phase-separated UBQLN2 condensate can be altered by regulating the hydrophobicity or solubility of UBQLN2 by point mutation, tag, and linker proteins. This data will clarify the pathogenic mechanism of UBQLN2 LLPS, which was previously unclear.

Keywords:

Liquid-Liquid Phase Separation, Biomolecular condensate, UBQLN2

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P1-bp.109

Two-color single-molecule cryo-fluorescence microscopy

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Abstract:

For fluorescence imaging, cryogenic conditions have a number of benefits, such as making most fluorophores brighter and keeping the native ultrastructure of target better than chemical fixation. However, cryogenic microscopy limits to use a low numerical aperture (NA) objective lens (NA < 1). To achieve high signal-to-noise ratio for single-molecule visualization, a high NA objective is required. To overcome this limitation, we developed a microscope with a high NA system (NA=1.8) using a 3 mm solid immersion lens and a low NA (0.6) objective under cryogenic conditions. Based on our microscope, we can observe the blinking of EGFP, the change in FRET efficiency of cy3 and alexa647 at 77K. we expect our microscope to contribute to the study of photophysics of fluorophore, which has never been previously reported at 77K.

Keywords:

Two-color single-molecule cryo-fluorescence imaging, Cryo-FRET, Solid immersion lens

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P1-bp.110

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 misamtch repair, Single moelcule biophysics, DNA Sky-bridge

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P1-bp.111

Single-Molecule Studies on The Mechanism of Intrinsic Termination

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Abstract:

Although extensive studies on intrinsic termination have proposed various models, such as hyper-translocation, shearing, and hairpin invasion, to explain the process, it remains elusive which specific model triggers the termination. To answer this question, we adopted the single-molecule fluorescence measurements to unravel this issue. Initially, we observed the common characteristic over terminators that decomposing and recycling termination exhibited similar population ratios and termination times. Notably, the longer termination times compared to run-off times implied a deactivation state following the determination of termination. To understand the U-track in intrinsic terminator, we introduced various point mutations to observe changes in termination efficiency and kinetics. Lastly, we conducted several mismatch experiments affecting DNA rewinding. The results revealed a sharp drop in termination efficiency near the termination site for all terminators in decomposing termination, while recycling termination exhibited diverse patterns by the terminator. This suggests that decomposing termination occurs via displacing, similar to Rho-termination's decomposing termination (*1*), while recycling termination require further studies. In summary, we discovered deactivation state and DNA rewinding's different effects on each termination route.

1. Song, Eunho, et al. "Rho-dependent transcription termination proceeds via three routes." ***Nature communications*** 13.1 (2022): 1-12.

Keywords:

Single-molecule study, Transcription termination, intrinsic termination, DNA rewinding, U-track

P1-bp.113

Single-molecule studies of translesion DNA synthesis: the role of PAF15

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Abstract:

DNA repair processes are critical to maintaining DNA integrity, but appropriate DNA damage tolerance (DDT) mechanisms are necessary to ensure accurate and timely replication of DNA. During DNA replication, cells encounter various types of DNA lesions, and one of the key DDT pathways, translesion DNA synthesis (TLS), enables the cell to bypass these lesions and resume stalled replication forks. TLS utilizes two different polymerases, polymerase δ, and polymerase η, to efficiently bypass typical DNA lesions, with proliferating cell nuclear antigen (PCNA) serving as the main mediator of polymerase switching. Although several models have been suggested to explain how PCNA switches partners when it collides with a DNA lesion, the underlying mechanisms remain unclear. Recent studies have suggested that PCNA-associated factor 15 (PAF15) plays a significant role in polymerase exchange, as most PCNA on DNA diffuses together with PAF15. However, fundamental information about PCNA-Polymerase-PAF15, such as processivity, switching time, and synthesis rate, has not been fully investigated. In this study, we constructed the FRET system to investigate how PAF15 affects the PCNA-Polymerase complex during its replication on CPD (cyclobutene pyrimidine dimer). Our results show that PAF15 binding to PCNA fundamentally changes the TLS ability of two polymerases.

Keywords:

Single-molecule, Translesion, FRET, PAF15

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P1-bp.114

DNA hanger: novel surface-free/multiplexed single-molecule blotting platform

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Abstract:

All blotting techniques require the surface immobilization of target molecules or substrates, which inevitably leads to nonspecific (off-target) binding to the surface. This nonspecific binding generates noise that can hinder precise analysis, especially in single-molecule blotting due to its high sensitivity. Stringent surface passivation is required to minimize nonspecific binding; however, it cannot entirely solve the problem. Here, we present a novel single-molecule blotting platform called the "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 in DNA hanger compared to conventional PEGylated quartz. We will show that DNA hanger would be a promising single-molecule blotting assay.

Keywords:

Single-molecule, immuno blotting, fluorescence microscopy

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P1-bp.115

High-speed force-fluorescence setup for studying single-molecule dynamics under load

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Abstract:

Magnetic tweezers (MT) have been widely used to study the mechanical properties of single biomolecules and their complexes in the piconewton regime. However, due to the limited speed in the image-based tracking of beads, the technique has been used mainly for the investigation of slow dynamics at relatively low forces. Here, we combined high-speed magnetic tweezers with a total internal reflection fluorescence (TIRF) microscope to enable correlative force-fluorescence measurements on single molecules. We demonstrate the power of this method by probing the high-force response of nucleic acid and protein molecules, such as DNA melting and protein unfolding.

Keywords:

Magnetic tweezers (MT), TIRF, Single molecules

P1-bp.116

Enhancement of radiotherapeutic Effect by flagellin in sarcoma cell-bearing mouse brain tumor models

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Abstract:

Although radiotherapy (RT) as an adjuvant therapy to surgical resection in CNS sarcomas shows local control, their radioresistance is bound to limit the therapeutic efficacy. Synergistic therapeutic effects of radiation treatment and flagellin were investigated in sarcoma cell-bearing mouse brain tumor models. In vivo radiation treatment were performed using a self-fabricated stereatactic system that can be mounted on the Gamma Knife unit. Irradiation coordinates were set based on CT images. In vitro studies have shown that combination therapy increases radiosensitivity, expression of DNA double-strand breaks and programmed cell death. In addition, tumor growth delay and elimination were demonstrated in an intracranial mouse model from FACS analysis. The migration and infiltration of CD8+ T cells and macrophages was enhanced and the proportion of M1 macrophage polarization was increased. Compared to radiotherapy alone, combined treatment with Flagellin may enhance the radiosensitivity, promote the recruitment of immune cells at the tumor site and prevente tumor recurrence.

Keywords:

Sarcoma, radiotherapy, Flagellin

Study on allostery of the human dopamine D3R receptor in complex with an eckol

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Abstract:

Dopamine receptors are well-known drug targets for the treatment of Parkinson's disease (PD), schizophrenia, and drug abuse. Dopamine receptors belong to the G protein-coupled receptor (GPCR) superfamily. They are classified into two classes, D1-like (D1R and D5R) and D2-like (D2R, D3R, D4R) depending on the coupling to stimulatory/inhibitory of G-protein. D2R, D3R, and D4R couple to the inhibitory G-protein alpha subunit. Eckol is a phlorotannin with a dibenzo-p-dioxin skeleton, which is abundant in brown algae (Lessoniacea). Cell-based functional GPCR assay shows that eckol acts as an agonist on D3R. "Allosteric communication" between the residues in the agonist-binding pocket of the eckol at the orthosteric site (cavity formed by transmembrane helices) and the G-protein interface provides information on the mode of action of eckol. In this study, we apply network and information theory to D3R-eckol complex system to search for important biological residues in the allosteric communication pathway across the transmembrane.

Keywords:

GPCR, Allostery

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P1-bp.118

Efficient labeling of vesicles with lipophilic fluorescent dyes via salt-change method

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Abstract:

Lipophilic fluorophores are widely used to stain the lipid membranes of vesicles for their investigation by fluorescence microscopy. However, incorporation of lipophilic molecules into vesicle membranes is generally limited by their poor solubility in water, which in turn makes the fluorescence imaging and analysis at the single-vesicle level challenging. Here, we describe a simple, fast, and highly effective procedure for the fluorescent labeling of vesicles. By using several types of lipophilic dyes and cell-derived vesicles including natural extracellular vesicles (EVs), we show that the ionic strength of the labeling buffer can be strategically adjusted with NaCl so that the lipophilic dyes are induced to aggregate or disperse reversibly, thus improving the labeling efficiency and also facilitating the removal of excess dyes. The integrity of selected membrane proteins in vesicles after labeling were checked by their binding to antibodies. We expect that the method will be useful in diverse applications of fluorescence-based analysis of vesicles.

Keywords:

Fluorescent labeling, Extracellular vesicles, Lipophilic dyes

High-Speed Magnetic Tweezers for Nanomechanical Measurements on Force-Sensitive Elements

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Abstract:

Magnetic tweezers (MTs) have served as powerful tools to forcefully interrogate biomolecules such as nucleic acids and proteins. Since the method commonly relies on image-based tracking of magnetic beads, the speed limit in recording and analyzing images has long hampered its application in observing fast structural changes. In this work, we describe in detail how to construct and operate a simple MT setup for high-speed tracking of beads, thus resolving the millisecond dynamics of target molecules. As examples, we demonstrate how transient states of DNA hairpins and SNARE complexes, the membrane-fusion machinery, can be detected in the presence of piconewton-scale forces. We expect that high-speed MTs will continue to enable high-precision nanomechanical measurements on molecules that sense, transmit, and generate force in cells, and thereby deepen our molecular-level understanding of mechanobiology.

Keywords:

Magnetic tweezers

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P1-bp.120

Role of Histone Tails in Inter-Nucleosome Stacking Interaction

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Abstract:

Nucleosome is thea building block of chromatin fiber. It comprises a histone octamer and DNA that wraps around it. Strong positive charge of histone octamer enables DNA to wrap around it and form a stable nucleosome structure.Chemical Various modifications on the histone tails are known to modulate the rigidity and openness of the nucleosome array and thus regulate the conformation of the chromatin and gene expression. As a result, the rigidity and openness of the nucleosome array is modulated along the chromatin fiber. In this study, we used magnetic tweezers were used to investigate histone unwrapping and unstacking dynamics in single nucleosomes and nucleosome arrays. We prepared long chain of nucleosome arrayss with 1 to 16by multiple repeats of Widom 601 sequence. By controlling the spacer sequence between Widom 601 sequences, distance between nucleosome was controlledhas been regulated. Methylation of CpG motifs in nucleosome positioning sequence was also controlled.Chemical modification has been applied to both histone monomers and/or DNA. Histonee monomer tails were either chemically altered as: Wild-type histones, histones with its tails deleted or site-specifically , histones with its tails acetylated using native chemical ligation. Each different sets of histone components were assembled to build nucleosome array. DNA has been CpG methylated on nucleosome positioning sequences. Different compositions of nucleosome array has been tested on magnetic tweezers to specify their physical properties under tension. We observed and compared the nucleosome stacking interactions Aat low-force regime, the unstacking dynamics of nucleosome arrays was observed while and the nucleosome unwrapping dynamics of individual nucleosomes was observed at high-force regime. Fitting the force-extension curves to a physical model of nucleosome array revealed the dependence of the stacking interaction and unwrapping behavior on the epigenetic modifications and nucleosome positioning.to understand the dynamics of inter-nucleosome stacking interaction under different context of epigenetic markers. We want to further study the dynamical features of chromatin fibers of when they would form phase separated condensates, and how would the epigenetic markers affect the dynamics.

Keywords:

Magnetic Tweezers, Nucleosome

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P1-bp.121

SUPER-RESOLVED HETEROCHROMATIN STRUCTURE DURING DNA DAMAGE RESPONSE REVEALED BY CRISPR IMAGING

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Abstract:

Heterochromatin is essential for the molecular cell as it plays an important role in gene expression regulation. Heterochromatin undergoes a DNA damage repair process distinct from that of euchromatin, involving large-scale rearrangement coupled to nuclear membrane and motor proteins. Revealing the nanoscale structure and dynamics of heterochromatin during its repair is necessary to understand the detailed mechanism of the wholeness DNA repair process, and the role of the distinct compaction and reorganization of heterochromatin. Here, we observed the novel structure and dynamics of heterochromatin in super resolution using CRISPR labeling techniques. Dense labeling of a pericentromeric region with CRISPR prevented cell cycle progression and induced DNA damage response accompanied by domain expansion and fiber-like extension beyond its chromosome territory. This structural change correlates with the DNA damage repair proteins. Also, the thinnest part of the heterochromatin fiber was found to be thinner than 70 nm, suggesting that it represents a fully-extended single chromatin fiber rather than hierarchically folded bundles of DNA. Our work highlights the DNA damage response in heterochromatin induced by molecular blockades and the resulting structural changes, providing a platform to study heterochromatin DNA repair process and its dynamics with high spatiotemporal resolution.

Keywords:

CRISPR Imaging, Heterochromatin, DNA repair, DNA structure and dynamics

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P1-bp.122

Single-molecule ubiquitination

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Abstract:

Ubiquitination is a crucial post-translational modification process that involves the covalent conjugation of small protein ubiquitins to target proteins. Mammalian cells contain thousands of ubiquitylated proteins, each with multiple ubiquitination sites and various types of poly-ubiquitination chains [1]. This structural variety of ubiquitination influences many cellular processes, including protein homeostasis through proteasomal degradation, DNA repair, translesion synthesis, epigenetic regulation, cell cycle regulation, etc [2].
The importance of the vast range of functions of ubiquitination and their spatiotemporal regulation has led to numerous biochemical studies on ubiquitylated proteins and their corresponding enzymes. However, conventional ensemble-based observations of ubiquitination are limited in their ability to distinguish heterogeneity in chain types and sites of ubiquitination and kinetics in various microenvironments.
To address these limitations, we developed a single-molecule assay that visualizes the processes of ubiquitination using total internal fluorescence microscopy. This approach has the potential to reveal new insights into the spatiotemporal regulation of ubiquitination in the cellular environment and its functional consequences.

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Keywords:

Single-molecule biophysics, Ubiquitination, TIRF

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P1-bp.201

Investigating Autophagosome Motion through Single Particle Tracking by Employing Clustering Methods

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Abstract:

Understanding the importance of understanding the dynamics of autophagosomes, essential organelles in autophagy, is vital since they play a key role in the intricate processes of cellular degradation and recycling. In our research, we utilized fluorescence-combined interferometric scattering microscopy (F-iSCAT) designed for single particle tracking (SPT) to capture the pattern of autophagosome movements within cells. This allowed us to characterize their motions based on various criteria such as mean square displacement (MSD), absolute moving direction, its variance, and autocorrelation time of moving direction. To delve deeper into the key aspects of autophagosome behavior, we examined the fluctuations and the persistence time of moving direction in relation to the diffusion exponent (α) acquired from the MSD evaluation. We then applied the K-means and hierarchical clustering methods to categorize the motional behavior of autophagosomes based on their inherent dynamics. This clustering process enabled us to identify distinct groups of autophagosomes according to their motional behaviors. From our analysis, we propose that their dissimilar dynamics originate from their interactions with different cellular organelles such as microtubules (MT) and the endoplasmic reticulum (ER) and their spatial arrangement and behaviors should be largely governed by these physically different cellular networks.

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Keywords:

iSCAT, Microtubules, ER

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P1-bp.202

Assessment and Correction of Non-Bonded Interaction Parameters in the Amber ff19SB Force Field Using Experimental Osmotic Pressure Data

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Abstract:

Accurate force fields (FFs) play a crucial role in attaining quantitative agreements between molecular dynamics (MD) simulations and experimental observations. However, most FFs are limited in accuracy, resulting in artifacts such as unrealistic aggregation. Here, we examine the accuracy of non-bonded interactions in the Amber ff19SB FF and OPC water models through osmotic pressure simulations including a range of different model chemicals. Moreover, we employ the NBFIX (Non-Bonded FIX) correction method, pair-specific modifications in Lennard-Jones parameters, to enhance intermolecular force descriptions. Comparative analysis of our refined FF against other standard force fields (e.g., ff99SB-ildn-phi, ff19SB-OPC3, and original ff19SB-OPC) underscores the efficacy of our approach. Finally, we demonstrate that our newly calibrated parameter sets can improve various biomolecular simulations such as protein folding, protein-DNA interactions, and intrinsically disordered proteins.

Keywords:

Molecular dynamics simulation, force field, non-bonded interactions, NBFIX, Amber ff19SB

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P1-bp.203

MegaFold: Multi-GPU Implementation of AlphaFold2

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Abstract:

The prediction of protein structures is of great significance in the understanding of protein functions, yielding extensive consequences across a variety of fields. The field of structural biology is experiencing an increasing demand for precise predictions of protein structures. The AlphaFold2 model represents a significant advancement in the field of protein structure prediction, applying artificial neural networks and obtaining ideas from the transformer architecture commonly employed in natural language processing. This novel approach enables the accurate prediction of protein structures at the atomic level, surpassing previous benchmarks and establishing a new standard of precision. Nevertheless, the computational requirements and memory constraints associated with the training and inference processes of AlphaFold2 pose significant problems. This study introduces MegaFold, a novel modification of the AlphaFold2 model that effectively overcomes memory constraints by employing a distributed computation strategy. The MegaFold platform offers solutions for addressing computational challenges. The experimental results show that the first version of MegaFold showed the capability of predicting structural conformations over a total of 3584 residues. Significantly, this result exceeds the limitations present in the original AlphaFold2 implementation. Remarkably, this accomplishment can be achieved without the need to utilize costly graphics processing units (GPUs) in state-of-the-art data centers.

Keywords:

Computational biophysics, Machine learning, Protein structure predictions, Structural biology, Distributed computing

수지상세포의 이동 경로에 기계학습을 적용하는 분석 방법에 대한 고찰

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Abstract:

수지상세포는 포유류의 항원제시세포로써 면역체계에서 시발점이 되는 아주 중요한 세포이다. 수지상세포의 이동 현상에는 많은 연구가 이루어지고 있으나 아직 정량적, 정성적으로 기술하는 데에는 어려움이 많다. 최근 발표된 연구에서, 기계학습을 활용하여 이동 경로를 분석한 결과 세가지 운동 모드가 있음을 확인하였고, 나아가 모드 간의 변화가 세포의 성숙도에 따라 달라진다는 보고가 있었다 [1]. 기계학습 방법론은 본질적으로 훈련 데이터, 입력 값의 전처리 및 다양한 조건들을 임의로 설정하게 되는데 이것이 선행연구에 어떠한 영향을 주는지에 대한 추가 연구가 필요하다. 따라서 본 연구에서는 훈련데이터를 무작위로 추출하고, 데이터의 전처리 과정에 다양한 변화를 고려하여 앞서 제시된 기계학습을 적용한 분석 결과의 견고성에 대하여 확인하였다. 본 연구에서 확인한 이동성(motility)과 방향성(directionality)을 토대로 이동 경로를 분석하는 기계학습 기법은 비단 수지상 세포뿐이 아닌 다양한 세포의 이동 현상에 적용 가능할 것으로 기대된다.

Keywords:

수지상세포, 기계학습, 경로분석

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P1-bp.205

췌장의 항상성 모델을 통한 랑게르한스섬의 크기에 따른 인슐린 분비능 고찰

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Abstract:

췌장의 내분비기관에서 혈당의 항상성을 위해 방출하는 호르몬은 글루카곤, 인슐린, 그리고 소마토스타틴이 있다. 각각의 호르몬은 알파, 베타, 그리고 델타 세포에서 방출되며 서로의 분비에 관여하는 특별한 상호작용 구조를 갖는다. 혈당 항상성의 실패는 만성질환인 당뇨병의 기전으로 내분비 세포의 구성비, 공간적 분포, 특히 인슐린의 분비능은 매우 활발히 연구되고 있다. 흥미롭게도, 크기가 작은 섬은 큰 섬에 비해 인슐린 분비능이 높다는 선행 연구결과가 보고되었다. 본 연구에서는 이러한 인슐린 분비능의 차이를 알아보기 위해 혈당 항상성 모델을 활용하여 영향을 미치는 요인을 분석하였다. 랑게르한스 섬의 인슐린 분비능은 섬을 구성하는 세포의 수 보다 각 내분비 세포의 조성비가 영향을 크게 미친다는 것을 확인하였다.

Keywords:

췌장의 항상성 모델, 인슐린분비능, 내분비 세포의 구성비

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P1-bp.206

Tracking and single-trajectory analysis of transport dynamics of SCOTIN condensates on ER network in living cells

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Abstract:

The Scotin protein, located within the endoplasmic reticulum (ER) network, plays a significant role in cellular apoptosis due to the cellular stress. Despite its importance, the mechanisms and dynamics governing Scotin remain open question. Recent experimental investigations have unveiled a phenomenon wherein Scotin proteins make condensation on the ER network, exhibiting directed diffusive motion along its structure. Employing quantitative analyses, we have scrutinized the intricate movement patterns of Scotin and derived a distinctive diffusion exponent. Our findings serve as a foundational step towards constructing a theoretical framework aimed at elucidating the underlying physical principle of transport dynamics.

Keywords:

semi-flexible chain, transport diffusion, viscoelastic media

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P1-bp.207

Molecular Dance with CUFIX-AMBER Forcefield: Leading-edge Coarse-Graining Illuminates Protein Binding & Phase Separations

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Abstract:

The rise of machine learning models, exemplified by Alphafold, has seemingly brought us closer to resolving the challenges of protein folding. However, this success casts a shadow over a crucial area: proteins that resist typical folding. These proteins, known as Intrinsically Disordered Proteins or Regions (IDPs/IDRs), exhibit an ensemble of conformations rather than having a native structure. Despite their pivotal roles, from mediating protein-protein interactions to facilitating phase separation, no machine learning model can properly predict the ensemble conformations of IDPs.
Conventional experimental methods are limited in the characterization of IDP ensembles because experimental data is ensemble-averaged. This highlights the importance of physics-based computational methodologies, providing detailed insights into the diverse conformational ensembles of IDPs. Molecular Dynamics (MD) simulations have drawn attention for their ability to provide structural dynamics at an atomistic scale. However, utilizing MD simulations for IDP research presents two challenges. Firstly, established forcefields like CHARMM or AMBER often misrepresent IDP dynamics due to inaccurate parameterizations. Secondly, MD simulations of IDPs demand extensive computational resources.
To overcome those challenges, we developed a coarse-grained (CG) model based on the CUFIX-AMBER force field that improves the agreements with experiments for both folded and unfolded conformations. First, we computed the potential of mean force (PMF) for all pairs of amino acids. Using the PMF and MD trajectory data, we then optimized the parameters of the Martini coarse-grained force field to ensure that the modified Martini force field reproduces the PMFs. This enhanced CG model provides a robust tool for generating ensemble conformations of IDR with greater speed and accuracy than conventional all-atom forcefields.

Keywords:

Molecular Dynamics Simulation

P1-bp.208

A computational model of basal ganglia circuitry: neuronal dynamics and network properties

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Abstract:

The basal ganglia (BG) are a collection of subcortical nuclei implicated in a variety of functions, including cognition, emotion, learning, and voluntary motor control. Existing BG models are primarily based on the abstract connectivity information between the subregions of BG and between BG and other brain regions such as the cerebral cortex and thalamus. Here, we present a multiscale model of BG circuitry integrating neuronal dynamics and network-level phenomena. The model describes the distinct roles of neurons in the external globus pallidus (GPe), which acts as a hub of the circuitry. Biophysically plausible spiking neuron models are built based on extensive electrophysiological recordings of GPe neurons (7,000 recordings over 12 subregions of GPe). The neuronal dynamics are characterized via nonlinear dynamics and chaos theory, and their coding properties are tested on memory and learning tasks. Finally, electronic circuit simulations based on the simulation program with integrated circuit emphasis (SPICE) are performed to provide a useful tool for designing BG-inspired neuromorphic systems.

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Keywords:

Basal ganglia, External globus pallidus, Computational modeling, Neuronal dynamics, Network property

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P1-bp.209

Machine-learning-based identification for diffusion states of the CRISPR-Cas9 complex

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Abstract:

The CRISPR-Cas9 system serves as an adaptive immune system in prokaryotic organisms, responsible for recognizing and cleaving foreign genetic elements through RNA guide sequences. This unique mechanism has propelled the CRISPR-Cas9 system into a powerful gene editing tool. Despite its widespread application, the precise targeting process of this system remains elusive. In this study, based on single-particle tracking experiments focused on the diffusion of the CRISPR-Cas9 complex along a long double-stranded DNA, we develop an innovative machine learning tool designed to identify distinct diffusion states exhibited by the CRISPR-Cas9 complex. Our approach involves trajectory segmentation using a sliding window technique, quantification of relevant physical parameters, and application of Gaussian mixture models for fitting. Through this methodology, we successfully uncover multiple distinct diffusion states and find that the CRISPR-Cas9 complexes explore the target sequences using these distinct states.

Keywords:

Machine Learning, CRISPR-CAS9, Diffusion

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P1-bp.210

Dynamic co-generation of interacting beta and gamma oscillations and their implication in neural communication

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Abstract:

Oscillations in different frequency bands have been associated to the simultaneous routing of information streams in different directions, notably in cortico-cortical or cortico-subcortical communication. However, oscillations in vivo are far from being regular metronomes and are rather bursty, especially in the beta (15-30 Hz) and gamma (40-120 Hz) bands. Can multiplexed information routing emerge robustly in multi-regional circuits despite such stochastic-like burstiness?
To elucidate how the interaction of bursts with different frequency bands facilitate the information transfer, we constructed a computational spiking network model showing emergent collective dynamics in two different frequency bands, thanks to the introduction of two different inhibitory synapse subtypes. We tuned the network parameters so that the two subpopulations with different resonant frequencies have comparable excitability levels (i.e., iso-firing-rate), and then we study how network dynamics change across a smooth transition from less to more synchronized states as an effect of increasing recurrent inhibition strength (at equivalent firing levels).
Exploring systematically the parameter space of such regional model, we identify a variety of different multi-frequency regimes, with frequencies that can also deviate from the ones hardwired in term of interneuronal properties, but emerge rather from inter-population interactions. We then use information-theoretical metrics to quantify in these different multi-frequency oscillatory regimes directed inter-population functional connectivity in different frequency bands. The plan is to establish a dictionary of correspondence between oscillatory modes and functional multi-layer graphlets of functional connectivity, to show that multiplexed information transfer is constrained but not completely shaped by circuit structure, but rather emergent from collective dynamics.

Keywords:

neural oscillations, beta oscillation, gamma oscillation, transient oscillatory activity (bursts), spiking neural network model

Terahertz spectroscopic measurements of Molybdenum-Rhenium alloy superconductors

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Abstract:

Molybdenum-Rhenium (Mo-Re) alloys are type-II superconductors with T_c=12 K. These superconductors exhibit higher critical temperature T_c than those of constituent elements, so they have a great potential to be applied to aerospace industry. It has been demonstrated that the critical temperature T_c increases with the Re content, as evidenced by transport measurements [1]. However, optical measurements of the superconducting gap have not yet been reported. Here we provide temperature-dependent optical data acquired from Mo-Re thin films (Mo:Re = 1:1, T_c= 9 K) by terahertz time-domain spectroscopy. Our data show a superconducting gap of 2Δ=22 cm^{-1} (2.73 meV). Mo-Re could be useful for a comparative study of binary alloy superconductors addition to existing BCS-type ones.

[1] Shyam Sundar et al 2015 New J. Phys. 17 053003

Keywords:

superconductors, alloy superconductors, Mo-Re

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P1-co.102

Optical properties of $CrPS_4$.

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Abstract:

$CrPS_4$, an insulator with a gap of ~1.9 eV , exhibits an A-type antiferromagnetic ground state formed by in-plane ferromagnetic monolayers with interlayer antiferromagnetic coupling along the c axis below the Neel temperature of 38 K [1]. We report on the temperature dependence of the fundamental optical properties of $CrPS_4$, using optical spectroscopic measurements in the UV-V-NIR regions. We identified a d-d transition of the chromium ion and the absorption edge [2]. The absorption edge blueshifted with decreasing temperature reaching ~2.1 eV at 4 K. The d-d transition was found to be rather insensitive to the magnetic ordering.

[1] Peng, Y., Ding, S., Cheng, M., Hu, Q., Yang, J., Wang, F., Xue, M., Liu, Z., Lin, Z., Avdeev, M., Hou, Y., Yang, W., Zheng, Y., Yang, J., Magnetic Structure and Metamagnetic Transitions in the van der Waals Antiferromagnet $CrPS_4$. *Adv. Mater.* 2020, 32, 2001200.
[2] *ACS Nano 2017, 11, 10935-10944*

Keywords:

CrPS4.

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P1-co.103

Ce 도핑에 따른 고 엔트로피 합금(Ta–Nb–Hf–Zr–Ti) 초전도 특성 변화 연구

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Abstract:

고엔트로피 합금(high-entropy alloy)은 5가지 이상의 주요 금속 원소로 이루어져 있음에도 불구하고, 단순 격자 구조를 형성하여 높은 강도와 경도를 갖는 새로운 형태의 신개념 합금이다. 최근, 고 엔트로피 합금 물질에서 초전도 현상이 발견되어 소재로의 활용뿐만 아니라 새로운 물리현상을 연구할 수 있는 후보 물질로 제안되고 있다 [1,2]. 대표적으로 체심 입방 구조(body-centered cubic structure)를 갖는 Ta-Nb-Hf-Zr-Ti 고엔트로피 합금 초전도체는 약 8 K에서 초전도 상전이가 발생하고 성장 조건에 따라 초전도 상부 임계자기장(H_{c2})이 최대 12 T, 임계전류밀도(J_C)는 약 1 MA cm^{-2}로 큰 값을 가지며, 이온 조사에 저항성이 강한 특성을 보인다 [3]. 본 연구에서는 Ta-Nb-Hf-Zr-Ti 고엔트로피 합금 초전도체에 f-전자를 가진 Ce 원소를 0.1 wt%, 0.5 wt%, 1 wt%, 2 wt%, 4 wt%, 8 wt% 도핑하여 f-전자와 초전도 전자쌍 사이의 상호작용에 따른 초전도 특성 변화를 관찰하였다. 아크 용해(arc melting) 방법으로 성장시킨 시료들의 구조와 균질성을 X선 회절(XRD) 및 에너지 분산형 X-선 분광(EDS) 분석을 통해 확인하였고, 온도와 자기장의 변화에 대한 각 시료의 전기적 및 자기적 특성을 측정하였다. 본 발표에서는, f-전자를 가진 Ce 원소 도핑에 따른 Ta-Nb-Hf-Zr-Ti 고엔트로피 합금 초전도체의 임계특성(임계온도, 상부임계자기장, 그리고 임계전류밀도)의 변화를 논의하고자 한다.

[1] P. Koželj *et al.*, “Discovery of a Superconducting High-Entropy Alloy” *Physical Review Letters* **113**, 107001 (2014).
[2] Liling Sun and R. J. Cava, “High-entropy alloy superconductors: Status, opportunities, and challenges” *Physical Review Materials* **3**, 090301 (2019).
[3] Soon-Gil Jung et al., “High critical current density and high-tolerance superconductivity in high-entropy alloy thin films” *Nature Communications* **13**, 3373 (2022).

Keywords:

고 엔트로피 합금 초전도체, Ta-Nb-Hf-Zr-Ti, Ce 도핑

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P1-co.104

Exploring Superconductivity in $Pb_{10-x}Cu_x(PO_4)_6O$: Comprehensive Investigations without Cu_2S Impurity

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Abstract:

Regarding room-temperature and ambient-pressure superconductor, $Pb_{10-x}Cu_x(PO_4)_6O$(0.9<x<1.1), a comprehensive exploration has been undertaken - not only the methods documented in published paper but also various experimental approaches. Furthermore, to eliminate the Cu_2S impurity which has been frequently addressed in many papers, powder and single-phase $Pb_9Cu(PO_4)_6O$ are fabricated using a sulfur-free recipe. Temperature, reaction time, and the ratio of copper doping have been manipulated and the fabricated samples have been subjected to various observations including resistivity, critical temperature (T_c), magnetic property, X-ray diffraction (XRD), and Raman spectroscopy. These investigations collectively contribute to a comprehensive understanding of the material's properties and its potential as a superconductor.

Keywords:

: room-temperature and ambient-pressure superconductor, single crystal, superconductivity

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P1-co.105

A Detailed Numerical Analysis of Optical Conductivity in High-temperature Superconductors Using the Slave-Boson Approach to the t-J Hamiltonian

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Abstract:

We apply the slave-boson approach to the *t-J* Hamiltonian in order to study the optical conductivity in two-dimensional high-temperature superconductors with variation of hole doping and temperature [1]. We discuss the interaction between the spin and charge degrees of freedom to identify the origin of the peak-dip-hump structure in the optical conductivity of high temperature superconductors. We also investigate the role of the antiferromagnetic spin fluctuations and the order parameter phase fluctuations on the optical conductivity of high temperature superconductors.

References

[1] J-H. Eom, S-S. Lee, K-S. Kim, and S-H. S. Salk, *Phys. Rev. B* **70**, 024522 (2004).

Keywords:

slave-boson approach, t-J Hamiltonian, optical conductivity, two-dimensional high-temperature superconductors

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P1-co.106

High Entropy Alloy (HEA) superconductor : optical characteristics and the effects of ion irradiation

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Abstract:

HEAs have attracted a lot of interest, due to its distinctive combination of qualities, including extremely high strength, exceptional corrosion resistance, and most importantly potential for superconductivity. Our work focuses on how ion-irradiation, especially Kr ions affects the optical properties of the Ta1/6Nb2/6Hf1/6Zr1/6Ti1/6 . Ion irradiation has shown to be an effective method for changing the characteristics of materials, resulting in modifications to the microstructure, flaws, and electronic structure. The optical properties of the HEA samples are extensively studied and connected with the induced structural and compositional change by Kr ion irradiation at various fluencies at 120 keV. Additionally, to clarify the underlying mechanisms causing changes in the optical characteristics, microstructural and compositional changes are examined. This study advances our understanding of the relationship between ion irradiation, microstructure, and optical characteristics in complex alloy systems, opening the door to the development of customized materials and their optimization for particular uses.

Keywords:

High Entropy Alloys, Kr Ion irradiation, Optical properties, Superconductor

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P1-co.107

Synthesis and physical properties of $Pb_{10-x}Cu_x(PO_4)_6O$

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Abstract:

Striking claim of the superconductivity above room temperature in the newly discovered material, called LK-99 ($Pb_{10-x}Cu_x(PO_4)_6O$, 0.9 < x < 1.1), has excited the scientific community because of its potential opportunity to revolutionize the energy, transportation, and even computing fields [1-2]. A number of following studies have been reported in the past month right after the LK-99 was reported [3-10]. The superconductivity in this compound, however, is still under puzzle as it is not observed in the majority of the follow-up researches [4-10]. Among them, Zhu *et al*. pointed out that the origin of the superconducting-like drop in the resistivity of LK-99 may come from the structural transition of an impurity phase, copper (Ⅱ) sulfide (Cu_2S), at around 385K [8]. In order to clarify the superconducting-like properties of LK-99, we have synthesized this compound via solid state reaction with Cu_3P and $Pb_2(SO_4)O$ precursor, as described in the original paper by Lee *et al.* The reaction was performed at high temperature in evacuated quartz tubes with or without alumina crucible. The final materials in both batches came out inhomogeneous and contained copper grains that are not reacted. The x-ray powder pattern of the samples from the reaction without crucible shows similar peaks with LK-99 with additional Cu and Cu_2S minor peaks. Its resistivity, on the other hand, yields insulating temperature dependence with an abrupt transition at around 326-341K with a hysteresis behavior, which is different from the superconducting behavior in ref. [1-2]. In this presentation, synthesis method with various growing conditions and corresponding physical properties of LK-99 will be discussed.

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[10] H. Singh, A. Gautam, M. Singh, P. Saha, P. Kumar, P. Das, M. Lamba, K. Yadav, P. K. Mishra, S. Patnaik, and A. Ganguli, arXiv:2308.06589 (2023)

Keywords:

LK-99, Synthesis, Cu2S, Cu3P, Room-temperature superconductor(RTSC)

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P1-co.108

LK-99, The Attempt of Synthesis & Measuring Physical Properties

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Abstract:

We systematically explored LK-99, a potential room-temperature superconductor proposed by Sukbae Lee et al [1]. Synthesis attempts, including the procedure from the original paper, yielded LK-99 at 925℃. X-ray diffraction revealed coexisting monoclinic and hexagonal apatite phases, with their proportions influenced by cooling methods. Interestingly, resistivity measurements (4K to 400K) unveiled metallic behavior, not superconductivity below 400K.

[1] S. Lee, J. Kim, and Y.W. Kwon, arXiv: 2307.12008 (2023).

Keywords:

Oxide , Superconductivity, Reproducibility

Single crystal growth of topological superconductor candidate Ti_3Sb

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Abstract:

The A15 phase refers to a group of alloys with the chemical formula A_3B. Resent research shows that the A15 superconductors have nontrivial topological electronic band structure. In this work, single crystals of Ti_3Sb, superconducting material which has A15 phase, are successfully synthesized with a tetra-arc Czochralski method. The crystals are characterized by x-ray diffraction, scanning electron microscopy with energy-dispersive spectroscopy and superconducting quantum interference device measurement. We investigated the isotropic upper critical field by electrical resistivity measurement under the high magnetic field.

Keywords:

Topological superconductor candidate, A15 compound, Single crystal, superconductivity

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P1-co.110

Fabrication of high quality $YBa_2Cu_3O_7$ thin film for Josephson Junction

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Abstract:

Josephson junction is widely used for various purposes such as SQUID and Qubit. Among many combinations of insulator and superconductor, we have studied Josephson junction composed of $YBa_2Cu_3O_7$, high temperature superconductor. As a first step of fabricating the Josephson junction, it is necessary to find deposition conditions of $YBa_2Cu_3O_7$ thin film showing high critical temperature. We grow $YBa_2Cu_3O_7$ thin film on $SrTiO_3$(001) using Pulsed Laser Deposition(PLD) technique and investigate the conditions of several critical variables such as oxygen partial pressure and laser influence until find a condition showing critical temperature above 90 K. Then, we analyze the behavior of critical temperature regarding different variables.

Keywords:

Josephson junction, Pulsed Laser Deposition, YBa2Cu3O7

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P1-co.111

Thermal transport experiment on quasi-one-dimensional spin chain $NiTe_2O_5$

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Abstract:

Lately, thermal transport has been in the spotlight because thermal transport has been used to probe charge-neutral Majorana fermion in the Kitaev quantum spin liquid candidate material[1]. Thermal conductivity measurement via thermal transport is used to probe itinerant particles and quasiparticles including charge-neutral particles as well as charged particles. In solid-state, electrons and phonons play a predominant role to carry the thermal energy but the quasiparticles also can contribute to carrying thermal energy. Consequently, in the electron correlated systems, thermal conductivity is sensitively affected by exotic and quantum-mechanical magnetic excitations. Recently, we found a new quasi-one-dimensional spin chain system $NiTe_2O_5$[2]. In terms of entropy gains, a one-dimensional spin chain does not have long-range ordering. Instead, it can have some interesting excitations like spinon. $NiTe_2O_5$ undergoes an archetypal antiferromagnetic phase transition across 30.5 K with an unconventional critical exponent of the antiferromagnetic order parameter. Beyond the ordering temperature and up to room temperature, it was found that short-range spin correlation surprisingly survives [3]. In addition, it was reported that the p-d hybridization induced magnetoelastic coupling and yields a high-order magneto-dielectric effect[4]. Hence, $NiTe_2O_5$ exhibits an intriguing correlation concerning its spin degree of freedom. In order to investigate obscure magnetic excitation within $NiTe_2O_5$, we have developed a thermal transport experiment setup for relatively smaller specimens and studied thermal properties in $NiTe_2O_5$, In this presentation, we will introduce our experiment setup and discuss the preliminary experimental results.

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[2] J. H. Lee *et al.*, *Physical Review B* **100**, 144441 (2019).
[3] S-H Baek *et al.*, *Physical Review B* **104**, 214431 (2021).
[4] A. Tiwari *et al.*, *Physical Review Materials* **6**, 044409 (2022).

Keywords:

One-dimensional magnet, spin chain, NiTe2O5, Thermal transport, Thermal conductivity

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P1-co.112

Thermoelectric Properties of the Mn_3Sn-based Heterostructures

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Abstract:

The anomalous Nernst effect (ANE) is a phenomenon that occurs with a temperature gradient in a ferromagnetic conductor generating a transverse voltage perpendicular to both magnetization and heat current. This effect can be observed in non-ferromagnetic materials including antiferromagnetic materials such as Mn_3Sn as well as ferromagnets, it has been suggested that a large ANE can originate from Berry curvature associated with Weyl points near the fermi energy indicating a significant enhancement in the material's energy conversion efficiency. Therefore, the Mn_3Sn is a promising material for thermoelectric applications. Though there have been excellent reports about the characteristics of epitaxially grown Mn_3Sn thin films, the thermoelectric properties of various Mn_3Sn-based structures are still under question. In this presentation, we will discuss the ANE in epitaxially grown Mn_3Sn with various material contacts.

Keywords:

Anomalous Nernst Effect (ANE), Temperature gradient, Heat current, Berry curvature, Weyl points

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저온에서 증착된 준강자성 (001) $NiCo_2O_4$ 박막의 자기적 및 전기적 특성

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Abstract:

저온에서 증착된 준강자성 (001) $NiCo_2O_4$ 박막의 자기적 및 전기적 특성

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이전 보고에서 준강자성 (001) $NiCo_2O_4$ 박막은 (001) $MgAl_2O_4$ 기판 위에 약 250 ℃ ~ 350 ℃에서 제작되어 왔다. 우리는 펄스 레이저 증착법을 이용하여 다른 증착 변수를 고정하고 증착 온도를 320 ℃에서 25 ℃까지 낮추면서 (001) $MgAl_2O_4$기판 위에 $NiCo_2O_4$ 박막을 증착하였다. θ - 2θ 스캔 X선 회절 실험(XRD) 결과, 증착 온도가 320 ℃에서 150 ℃로 낮아질수록 $NiCo_2O_4$ (004) 피크가 높은 각도 쪽으로 조금씩 이동하여 수직 방향의 격자 상수가 감소하는 것을 확인하였으며, 125 ℃ 이하에서는 $NiCo_2O_4$(004) 피크가 발견되지 않아 다결정성 또는 비정질 박막이 만들어짐을 확인하였다. 또한 ω – scan XRD 패턴에서 $NiCo_2O_4$(004) 피크의 반치전폭 (Full width half maximum : FWHM)은 320 ℃에서 약 0.03 °였고 150 ℃에서는 0.05 °로 약간 증가하였다. $NiCo_2O_4$ 박막의 원자 힘 현미경(Atomic force microscopy : AFM) 이미지에서 제곱평균제곱근(RMS) 표면 거칠기 값은 150 ℃이상에서 1.4 nm ~ 2.5 nm 였고 125 ℃ 이하에서는 1 nm 이하로 상대적으로 작았다. 자기 광 커 효과 (Mageto-optic Kerr effect : MOKE) 자기 이력 곡선 측정에 따른 박막의 보자력은 320 ℃에서 600 Oe로 최대였으며 이후 점차 감소하여 150 ℃에서 약 130 Oe였고 125 ℃ 이하의 온도에서는 수직 자기 이방성이 측정되지 않았다.

Keywords:

스피넬 산화물, 준강자성, 수직자기이방성

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P1-co.114

Enhancing Spin Lifetime of Fe Atoms on Ag(111) through an Aromatic Molecule

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Abstract:

In this work, we present significantly enhanced spin lifetime of Fe atoms on Ag(111) via anchoring them with a planar aromatic molecule (perylenetetracarboxylic-dianhydride, PTCDA). Using a scanning tunneling microscope (STM), we assemble two Fe atoms with PTCDA and lift it into an upright configuration atop a pedestal of Fe atoms. In this configuration, we found that the Fe atoms show spin lifetime of several milliseconds, stabilized by the surrounding ligand fields. Our work shows precise manipulation and characterization of spin states in an artificially built spin structure, yielding an unprecedented enhancement in the spin lifetime of atomic spins positioned on a metallic surface.

Keywords:

Scanning tunneling microscope (STM), Perylenetetracarboxylic-dianhydride (PTCDA)

2023 KPS Fall Meeting
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P1-co.115

Electric and magnetic properties of $Fe_{1.1-x}Mn_xSb_{0.9}$

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Abstract:

This research presents a comprehensive study of the physical properties of solid solution $Fe_{1.1-x}Mn_xSb_{0.9}$ ($0 \le x \le 1.1$) formed by mixing ferromagnetic and antiferromagnetic . By systematically varying the ratio of Fe and Mn while keeping the Sb composition constant, the intriguing interplay between magnetic behavior and electronic property(resistivity) was explored. Especially, for similar Fe and Mn content ($x \approx 0.5$), we observed an interesting metal-insulator transition which occurs at the Néel temperature, suggesting a strong correlation between electric and magnetic properties. This kind of phase transition is quite extraordinary, since antiferromagnetic phase is usually an insulating phase in the common case of Mott-Hubbard-type metal-insulator transition. We also observed an intriguing magnetoresistance behavior in this solid solution, which exhibit a maximum value at the same Néel temperature. We will discuss the possible mechanism of this exceptional metal-insulator transition and related phenomena.

Keywords:

metal-insulator transition, magnetoresistance, ferromagnetism, antiferromagnetism

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P1-co.116

Generation of ferromagnetism in $CaRuO_3/Sr_2RuO_4$ superlattices

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Abstract:

For Ruthenate thin films, tunning of microstructure using strain and defect has been considered as a key ingredient for modifying magnetic properties. Among ruthenates, $SrRuO_3$ (SRO) is well known ferromagnetic metal, whereas Sr_2RuO_4 (SRO214), the first Ruddlesden-Popper phase of SRO, does have non-ferromagnetic properties. Also, $CaRuO_3$ (CRO), despite having an iso structure of SRO, is paramagnetic metal due to larger RuO_6 octahedral distortion compared to SRO. In a thin film system, the combination of artificially controlled ruthenates is attractive for understanding the correlation between microstructure and magnetic properties.

In this study, we prepared superlattice structures (SLs) with paramagnetic CRO and SRO214. $(CRO)_n/(SRO214)_2$ SLs were stacked in 10 periods with varying the number n of CRO unit cells (*u.c.*) to generate ferromagnetism. The structure of the SLs was characterized by high-resolution X-Ray diffraction. The crystal structures of individual layers in SLs did not change, significantly. However, the octahedral configuration of the CRO layer was changed over 3 *u.c.*, and the RuO_6 rotation angle increased in proportion to n. We confirmed that these microstructural changes lead to an increase in the Ru-O bonding length and a decrease in bonding angle, results in the strengthening of p-d hybridization. Moreover, we observed that the magnetic states of SLs were changed from paramagnetic to ferromagnetic if n is greater than 4. The saturated magnetization value is linearly increased with increasing the number of *u.c.* for the CRO layer, while the ferromagnetic transition temperatures of SLs are determined to be ~50K, which is comparable to the theoretical value of ferromagnetic CRO. Our finding provides that the magnetic basis of CRO is strongly correlated with the charge transfer interactions between Ru 4d – O 2p orbitals in the RuO_6 octahedral networks and ferromagnetism can be artificially induced by tuning these properties.

Keywords:

CaRuO3, Sr2RuO4, superlattice, octahedral rotation, magnetic phase transition

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P1-co.117

ARPES study on the ferromagnetic transition in 2H-$Mn_{1/3}TaS_2$

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Abstract:

Intercalation of the magnetic transition metal between layered transition metal dichalcogenides (TMDs) induces various magnetic phenomena such as chiral helimagnetism, giant valley Zeeman coupling, and noncollinear antiferromagnetic Weyl semimetal phases.
Here, we study on the ferromagnetic (FM) transition in 2H-$Mn_{1/3}TaS_2$ by angle-resolved photoemission spectroscopy (ARPES). We observed folded band structures by the formation of Mn superstructure and significant change by FM transition. Our results provide a novel insight for the role of the intercalated magnetic atoms in 2H-TMDs and understanding FM in band structure.

Keywords:

Ferromagnetism, Transition-metal dichalcogenides, Angle-resolved photoemission spectroscopy (ARPES), 2H-TaS2, Manganese

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P1-co.118

Magnetic Anisotropy of the perpendicular spin states in $Fe_{1-x}Co_xSn$

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Abstract:

Kagome materials provide a fascinating platform for exploring various physical properties stemming from the geometrical aspect of the kagome lattice. We present an investigation into the magnetic anisotropy and the corresponding electrical transport measurements of the $Fe_{1-x}Co_xSn$ single crystals. The robustness of emergent axial spins and original planar spins is influenced by the strength and direction of the magnetic field. Axial spins undergo spin flop-like transitions only at the high temperatures close to T_N, whereas planar spins experience reorientation only within the basal planes. Tilted spins are sensitive to magnetic fields since it exists as an intermediate state between two perpendicular spin orientations. We introduce a scenario in which dopants, acting as lattice obstacles, play a crucial role in inducing the axial ordering. This is supported by the observation of similar magnetic behaviors in $Fe_{0.94}Ni_{0.06}Sn$.

Keywords:

antiferromagnetism, kagome lattice, spin ordering

P1-co.119

Strong Charge-to-Spin Conversion at a Van der Waals Interface of Topological Insulator and Ferromagnet

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Abstract:

Topological surface states (TSS) with spin-momentum locking in topological insulator (TI) generate current-induced spin polarization and produce strong spin-orbit torque (SOT) on proximitized ferromagnets. Their relatively low conductance, however, introduces current leakage problem through the bulk states of the TI or the adjacent ferromagnetic metal layers, reducing the interfacial charge-to-spin conversion efficiency. Here we used a van der Waals (vdW) heterostructures of a bulk-insulating topological insulator Sn-doped $Bi_{1.1}Sb_{0.9}Te_2S_1$ and an atomically-thin ferromagnetic metal Fe_3GeTe_2 and Fe_3GaTe_2 to enhance the relative current ratio on the TSS up to 20%. The resulting two dimensional charge-to-spin conversion efficiency reaches ~ 1 nm^{-1} at 200 K, much larger than those of TI-based and heavy-metal-based SOT devices. These findings demonstrate that all-vdW heterostructure offers a promising platform for exploiting strong interfacial charge-to-spin conversion of vdW TIs for efficient current-controlled magnetization.

Keywords:

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P1-co.120

Orbital-driven double nodal-line states in a room-temperature van der Waals ferromagnet Fe_3GaTe_2

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Abstract:

The band topology in van der Waals (vdW) magnets provides a promising route to enhance and control magnetoelectronic responses, thereby enabling the identification of novel spintronic functionalities. However, such functionalities have been demonstrated below room temperature due to a lack of suitable materials possessing both topological band structure and high-T_c magnetism. Here we show that a room temperature vdW ferromagnet Fe_3GaTe_2 hosts double topological nodal-line states with large and tunable Berry curvature. The two orbital-driven nodal-line states with opposite spin-polarization, one flat and the other dispersive in energy, are located near the Fermi level and contribute additively to Berry curvature. The dominant contribution of the flat nodal-line state to the Berry curvature is modulated by spin orientation due to spin-orbit coupling, leading to unconventional angle-dependent anomalous Hall effect. Our results demonstrate that Fe_3GaTe_2 is a promising spintronic material for exploiting unique band topology and two-dimensional magnetism at room temperature.

Keywords:

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P1-co.121

Ultra-thin 2D Fe_3GaTe_2 rare-earth free permanent magnet at finite temperatures

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Abstract:

Permanent magnets (PM) are one of the most important components in contemporary technology, and they are widely employed in a variety of equipment such as electric motors, generators, and magnetic resonance imaging (MRI) machines. [1, 2]. Despite substantial research into permanent magnets in bulk-type materials, the prospect of permanent magnets in two-dimensional materials has received less attention. In this work, we investigate temperature dependent magnetic properties of atomically thin (2~3 nm thickness) two-dimensional (2D) Fe_3GaTe_2. We obtain that both trilayer and four-layer thicknesses structures have T_C of 340 K ~352 K. Both systems have perpendicular magnetic anisotropy, and the uniaxial anisotropy constant is monotonically decreased with increasing temperature. At 300 K, the 2D Fe_3GaTe_2 has a coercive field of 0.34 T at 2 nm thickness, and it becomes 0.44 T at 3 nm thickness. We also obtain a maximum energy product $(BH)_{max}$ of 24 kJ/m^3 at 2 nm thickness, and it is further increased to 26 kJ/m^3 at 3 nm thickness at 300 K. Nonetheless, these $(BH)_{max}$ are decreased by more than 2 times with including the demagnetization factor. Overall, we obtain that 2D Fe_3GaTe_2 at 2~3 nm thickness possesses the same scale of coercive field and maximum energy product of well-known bulk ferrite PM. Our findings suggest that the atomically thin 2D system might be a promising rare-earth-free PM for small-scale device applications.

Keywords:

permanent magnet, two dimensional

P1-co.122

High-crystalline Van der Waals ferromagnet Fe_3GeTe_2 grown by flux-assisted growth method

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Abstract:

Fe_3GeTe_2 (FGT) is a well-known van der Waals ferromagnetic material that exhibits exotic magnetic properties such as strong perpendicular magnetic anisotropy energy and magnetic skyrmion and is considered a strong candidate material for future spintronic device. However, most studies rely on the mechanical exfoliation method to fabricate the FGT devices due to the difficulties in synthesizing the high quality FGT thin film with conventional fabrication methods. These limitations result in difficulties in controlling the shape of the crystalline flakes and the thickness of the exfoliated film. In this report, we have successfully fabricated the highly crystalline FGT grains with various thicknesses by adapting the flux-assisted growth method. Furthermore, we report the magnetic properties of the grown FGT by using the magneto-optical Kerr effect (MOKE).

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Keywords:

2D van der Waals ferromagnetic materials, Chemical Vapor Deposition (CVD), Flux-Assisted Growth (FAG)

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P1-co.123

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:

CrPS4, graphene, Anomalous Hall effect, Ferromagnetism, Heterostructure

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P1-co.124

위상 준금속 $NdSb_{0.5}Te_{1.5}$의 온도와 자기장에 따른 전기저항 특성 연구

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Abstract:

LnSbTe(Ln=란타넘족 희토류) 화합물 중 하나인 NdSbTe는 위상 준금속 후보 물질로 약 2.7 K에서 반강자성 자기 상전이를 갖고 f-전자와 자유전자 사이의 강한 상호작용이 나타나 자성, 위상 상태, 그리고 강상관전자(strongly correlated electron) 사이의 관련성을 연구할 수 있는 물질로 여겨지고 있다 [1]. 이전에 보고된 $NdSb_{1-x}Te_{1+x}$의 연구 결과에서 x값의 변화에 따라 자기 상태와 위상학적 상태가 크게 바뀔 수 있음이 관찰되었다 [1,2]. 본 연구에서는 $NdSb_{0.5}Te_{1.5}$의 전기저항 특성을 온도와 자기장에 대해 관찰하였다. 전기저항은 고온에서 저온 영역까지 준금속에 해당하는 의존성을 나타내었고 반강자성 상전이 온도에서 언덕 모양의 특징을 보였다. 반강자성 상전이 온도 아래에서 자기장에 따른 전기저항은 임계 자기장(H_c ~ 0.5 T)에서 급격하게 감소하였으며 자기장의 경로에 따라 이력현상이 발견되었다. 이전에 보고된 $NdSb_{1-x}Te_{1+x}$의 자기장에 대한 전기적 특성 결과를 비교하여 NdSbTe물질의 위상학적 상태와 자기 특성 사이의 강한 상호작용에 대해서 논의하고자 한다.

[1] K.Pandey *et al.*, “Electronic and magnetic properties of the topological semimetal candidate NdSbTe” *Phys. Rev. B* **101**, 235161 (2020).
[2] Tyger H. Salters *et al.*, “Charge density wave-templated spin cycloid in topological semimetal $NdSb_xTe_{2-x-\delta}$” *Phys. Rev. Materials* **7**, 044203 (2023).

Keywords:

Topological semimetal, NdSbTe, Antiferromagnetism

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P1-co.125

High-frequency ESR study of anisotropic triangular antiferromagnet $Cu_2(OH)_3NO_3$

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Abstract:

In the pursuit of a quantum spin liquid, anisotropic triangular Heisenberg antiferromagnets (THAFs) have been hailed as a promising experimental platform. A recent addition to this landscape is $Cu_2(OH)_3NO_3$ (monoclinic $P2_1$ structure), which features a spatially anisotropic triangular lattice of Cu^{2+} ions. An unusual magnetic ground state, along with an intriguing *H-T* phase diagram, is envisioned to be a coexistence of dominant resonating valence bond correlations and antiferromagnetic long-range order (ALRO). In this presentation, we report the successful growth of mm-size single crystals of $Cu_2(OH)_3NO_3$ and their low-energy excitations using a high-frequency ESR technique.

Our magnetic susceptibility $\chi(T)$ for *H//ab* and *H^ab* shows a broad maximum at $T_\chi^{max} \simeq 12$ K, indicative of short-range magnetic correlations. Below T_χ^{max}, $\chi(T)$s exhibit a slope change at ~7.2 K followed by a small kink at ~4.6 K, confirming the occurrence of magnetic ALRO. The T=2 K magnetization shows a field-induced slope change at ~1.3 T and 1.8 T, indicating the existence of two successive spin-flop transitions. Our preliminary out-of-plane high-frequency ESR reveals two distinct signals in the ALRO phase and the emergence of antiferromagnetic-like resonance in the putative stripe phase. Our ESR results indicate that two different magnetic correlations are present in the studied compound.

Keywords:

Frustrated magnet, Quantum spin liquid, Triangular lattice, Antiferromagnetic Resonance

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P1-co.126

Spin-Lattice Excitations in the Layered Antiferromagnets $MPSe_3$ (M=Fe, Mn)

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Abstract:

Magnetism in van der Waals (vdW) materials has recently garnered significant attention due to their potential for advanced applications. In this study, we investigate the magnetic transition in layered $MPSe_3$ (M=Fe, Mn) flakes utilizing temperature-dependent Raman spectroscopy. Our findings reveal unique features in the Raman spectrum that are strongly correlated with the antiferromagnetic ordering in $MPSe_3$. We analyze the spin-dependent phonon modes in $MPSe_3$ by applying the Suzuki - Kamimura formalism. Consequently, our comparative analyses of the spin correlation function and the reduced magnetization provide compelling evidence of the 2D Ising characteristic especially in $FePSe_3$. Our results clearly show the potential of $MPSe_3$ as a prominent platform for exploring fundamental aspects of low-dimensional magnetism.

Keywords:

MPSe3 (M=Fe, Mn), Raman spectroscopy, antiferromagnetic ordering, spin-dependent phonon modes, low-dimensional magnetism

2023 KPS Fall Meeting
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P1-co.127

Enhancing Sensitivity of wide-field quantum diamond microscope using nanopillar arrays

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Abstract:

The Nitrogen Vacancy (NV) center in diamond possesses intrinsic characteristics that make it suitable for magnetometric applications. However, sensitivity remains a prevailing challenge mainly due to the high refractive index of diamond. Recent studies have shown that the most common strategies to enhance the optical and spin properties of NV diamond involve surface micro- and nano-patterning.

In this study, we systematically conducted measurements of photoluminescence (PL) and optically detected magnetic resonance (ODMR) using nanopillar arrays on NV diamonds with various diameters and spacings. The diameter was varied from 200nm to 600nm, while the spacing between the pillars was adjusted to sub-micrometer ranges. Nanopatterning the NV center diamond led to a significant enhancement in both PL intensity and ODMR contrast. Notably, the ODMR contrast increased proportionally to the spacing of the pillars, showing an enhancement of up to 50%. When the spacing was minimized, the PL demonstrated a maximum 3-fold increase. As a result of these enhancements, the widefield sensitivity was moderately improved, reaching a maximum improvement of up to 2 times compared to the unpatterned flat surface. The sensitivity could be further enhanced with optimized design of nanopillar arrays.

Keywords:

nanofabrication, Single crystal Diamond, Color center, Nitrogen Vacancy Diamond

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P1-co.128

Investigating Electron Properties of Dysprosium, Fe-Porphyrin Metal-Organic Coordination Networks on Au(111) and Ag(100) Surfaces

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Abstract:

We used scanning tunneling microscopy/spectroscopy (STM/STS) and density functional theory (DFT) to investigate the structural and magnetic properties of a lanthanides-based metal organic coordination network. These techniques enabled us to achieve high-resolution imaging and a thorough characterization of an atomically precise surface supported magnetic molecular architecture. We focus on exploring the electronic characteristics of metal-organic networks constructed using Iron-Tetrakis-(4-Cyanophenyl) Porphyrin (Fe-TCPP) and Dysprosium (Dy). Fe-TCPP and Dysprosium were sequentially sublimated onto metal surfaces, specifically Au(111) and Ag(100).

This study provides electronic and magnetic characterization of the molecular Fe-TCPP self assembled architecture and Dy-based Fe-TCPP coordination network supported on Au(111) and Ag(100). By depositing and arranging a stochiometric amount of Fe-TCPP and Dy, distinct 2D structures could be fabricated, each with tailored magnetic properties. This fabrication protocol paves the way toward the realization of magnetic and possibly multiqubit 2D architectures on surfaces that can store and manipulate quantum information, thereby pushing forward the frontiers of quantum computing and information processing.

Keywords:

metal-organic network, Lanthanide, STM/STS

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P1-co.129

Co 입자 형상과 물성과의 상관관계 연구

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Abstract:

본 연구에서는 flash 증착 방법으로Al_2O_3 (0001) 기판위에 증착한 Co 박막을 다양한 온도 (800 ~ 1000 ^oC)에서 열처리를 통해 다양한 형상을 제작하고, 형상 변화에 따른 구조적, 자기적 특성을 고찰하였다. 그 결과, 제작된 Co 입자들은 너비가 높이보다 4배이상 큰 타원체 형상을 뒤었다. Co 입자들은 fcc 구조 Co (111) 방향으로 성장하였음을 X-선 회절 측정을 통해 확인하였다. 자성 특성 분석 결과, Co입자의 포화 자화값은 입자의 크기에 비례하고 보자력은 입자 크기에 반비례하는 것을 확인하였지만, 결정성 변화와의 상관관계는 없었다. 또한, 열처리 온도가 높아짐에 따라 Co입자의 자화율이 작아지는 특성을 나타내었고, 이는 결정 자기 이방성의 영향을 받은 것으로 추정된다.

Keywords:

코발트 나노구조, Dewetting, 입자 크기 및 형상, 자기이방성

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P1-co.201

Characterization on Lead-Free Hybrid Perovskite $[NH_3(CH_2)_5NH_3]CuCl_4$: Thermodynamic Properties and Molecular Dynamics

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Abstract:

It is essential to develop novel zero-and two-dimensional hybrid perovskites to facilitate the development of eco-friendly solar cells. In this study, we investigated the structure and dynamics of [NH3(CH2)5NH3]CuCl4 via various characterization techniques. Nuclear magnetic resonance (NMR) results indicated that the crystallographic environments of 1H in NH3 and 13C on C3, located close to NH3 at both ends of the cation, were changed, indicating a large structural change of CuCl6 connected to N-H···Cl. The thermal properties and structural dynamics of the [NH3(CH2)*n*NH3] cation in [NH3(CH2)*n*NH3]CuCl4 (*n* = 2, 3, 4, and 5) crystals were compared using thermogravimetric analysis (TGA) and NMR results for the methylene chain. The 1H and 13C spin- lattice relaxation times (T1ρ) exhibited similar trends upon the variation of the methylene chain length, with *n* = 2 exhibiting shorter T1ρ values than *n* = 3, 4, and 5. The difference in T1ρ values was related to the length of the cation, and the shorter chain length (*n* = 2) exhibited a shorter T1ρ owing to the one closest to the paramagnetic Cu2+ ions.

Keywords:

perovskite, ferroelasticity, nuclear magnetic resonance, thermodynamic properties, organic-inorganic hybrid

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P1-co.202

Effect of Cation Incorporation on the Structural Distortions and Phase Transitions in $MA_xFA_{1-x}PbCl_3$ Perovskite Single Crystals

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Abstract:

In recent years there has been considerable interest in hybrid organic-inorganic compounds (HOIPs) due to their adaptable and tunable properties. This study investigates the structural, vibrational and mechanical properties of mixed halide perovskite single crystals by incorporating another cation at the A-site of the perovskite crystal structure using advanced spectroscopic techniques. Powder X-ray diffraction (XRD) analysis confirmed cubic crystal symmetry similar to $MAPbCl_3$ and $FAPbCl_3$, with minimal secondary phases, indicating a successful synthesis of the synthesized $MA_xFA_{1-x}PbCl_3$ (x = 0.6 & 0.7) mixed halide single crystal. NMR spectroscopy was used to identify the exact composition of the synthesized mixed crystals. Raman spectroscopy revealed significant changes, i.e. broadening of vibrational modes with increasing temperature, suggesting suppression of structural phase transitions. Brillouin spectroscopy further supported these findings, showing continuous changes in acoustic properties without abrupt anomalies. The results suggest that the incorporation of the FA cation induces structural perturbations, in particular tilting of the $PbCl_6$ octahedra, which reduces the dynamic disorder within the crystal. The observed suppression of phase transitions suggests the potential for tailored control of properties in mixed lead chloride perovskite systems. The crystal exhibited softness to shear stress and the presence of polar Nano regions, similar to the properties of ferroelectric relaxors. Further investigation of mixed lead chloride single crystals, such as $MA_xFA_{1-x}PbCl_3$, is crucial to understanding their behavior and exploring their applications in optoelectronics and perovskite-based technologies. This study contributes to the fundamental understanding of mixed lead chloride perovskite materials and paves the way for future investigations to exploit the unique properties of mixed halide perovskites for advanced optoelectronic applications.

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Keywords:

Lead halide perovskites; MA1-xFAxPbCl3; Raman spectroscopy; Brillouin spectroscopy

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P1-co.203

Crystal structure, phase transition, thermodynamics, and molecular dynamics of organic–inorganic hybrid crystal $[NH(CH_3)_3]_2ZnCl_4$

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Abstract:

Understanding the physical properties of the organic–inorganic hybrid $[NH(CH_3)_3]_2ZnCl_4$ is necessary for its application. Considering its importance, the crystal structure was found to be orthorhombic, and the phase transition temperatures for the five phases V, IV, III, II, and I were determined to be 257, 286, 326, and 348 K, respectively. Based on the chemical shifts caused by the local field around ^1H, the ^1H environments for CH_3 did not change with temperature, whereas those for NH varied owing to the variation in the hydrogen bond N−H···Cl, which is related to the change in the Cl environment around Zn in the anion. The coordination geometries of ^{14}N and ^1H around ^{13}C became highly symmetrical as temperature increased. Finally, the spin-lattice relaxation time $T_{1\rho}$ values, corresponding to the energy transfer for the ^1H and ^{13}C atoms of the cation, changed significantly with temperature. The activation energies obtained from the $T_{1\rho}$ results were three–four times larger for phase I than for phases V and IV. This study provides an understanding of the fundamental properties of organic–inorganic hybrid materials.

Keywords:

crystal structure, phase transition, organic–inorganic compound, nuclear magnetic resonance, perovskite

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P1-co.204

Multifunctionality of Bismuth Ferrite and Barium Titanate Solid Solution by Samarium Oxide Doping Effects

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Abstract:

The bismuth ferrite ($BiFeO_3$) and barium titanate ($BaTiO_3$) solid solution system has evolved for ferroelectric and piezoelectric-based electronic applications. This system shows the multi-functional properties. For example, the high performance of the piezoelectric property shown at the morphotropic phase boundary with $0.67BiFeO_3$-$0.33BaTiO_3$. Also, high mechanical quality observed at $0.80BiFeO_3$-$0.20BaTiO_3$. In this study, the multiferroic property of samarium-doped $BiFeO_3$-$BaTiO_3$ solid solution with increasing Sm doping contents at Bi site. The composition is $0.80Bi_{1-x}Sm_xFeO_3$-$0.20BaTiO_3$ (x = 0, 0.01, 0.03, 0.05, 0.08, and 0.10). The best piezoelectric property is observed at $0.80Bi_{0.97}Sm_{0.03}FeO_3$-$0.20BaTiO_3$ with 97 pC/N. Also, the crystal structure, ferroelectric, and ferromagnetic properties are measured at room temperature.

Keywords:

Bismuth ferrite, Barium titanate, ferroelectric, piezoelectric, ferromagnetic

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P1-co.205

Exploration of VO_2 thin films with oxygen deficiency

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Abstract:

VO_2 has captured the attention of researchers due to its thermochromic properties and rapid semiconductor-to-metal transition. The semiconductor-to-metal shift occurs around 343K, coupled with a transformation from monoclinic to rutile crystal structure. The transparency of the monoclinic phase to near-infrared (NIR) radiation stands in contrast to the NIR opaqueness of the rutile phase. Maintaining precise stoichiometry in VO_2 is crucial, as even slight adjustments in oxygen levels can lead to the stabilization of different VO_2 polymorphs. Additionally, fine-tuning the stoichiometry offers a means of controlling the characteristics of VO_2. With this motivation, we have prepared stoichiometric and oxygen deficient VO_2 thin films on differently oriented sapphire substrates by radio frequency (RF) sputtering technique. The stoichiometric VO_2 thin films depicted characteristic semiconductor to metal transition around 343K. We noticed a complete suppression of semiconductor to metal transition in oxygen deficient VO_2 thin films and a metallic behavior was seen throughout the studied temperature range i.e. 273K to 373K. Oxygen deficiency led to significant modifications in the structural, electronic and optical properties of VO_2 thin films.

Keywords:

Thermochromic, VO2

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P1-co.206

Origin of morphotropic phase boundary in thin-film $Hf_{0.5}Zr_{0.5}O_2$ on the TiN electrode

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Abstract:

Our study aims to clarify the morphotropic phase boundary observed in Zr-doped hafnia systems. We utilize density-functional-theory calculations to examine various structural phases of $(Hf,Zr)O_2$ thin films on TiN electrodes. We account for Zr composition, film thickness, and temperature to model the free energy of $(Hf,Zr)O_2$ on TiN electrodes. Our assessment of the thermodynamic stability of each structural phase in terms of surface and interface energies under the substrate strain allows us to determine that the substrate strain and temperature significantly reduce the energy differences between different phases. Our findings lead to the energy reversal between tetragonal and orthorhombic phases when the film thickness increases. Based on our results, we propose that the formation of a high-temperature tetragonal phase, arising from the rapid thermal or annealing processes, is crucial to the appearance of the morphotropic phase boundary in $Hf_{0.5}Zr_{0.5}O_2$. Understanding the origin of the morphotropic phase boundary can have significant implications for device applications.

Keywords:

dielectric, morphotropic phase boundary, ferroelectric, dft, interface/surface energy

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P1-co.207

Optical properties of film $LaFeO_3$ on $SrTiO_3$

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Abstract:

We investigated the temperature-dependent optical properties of thin-film $LaFeO_3$ (LFO) samples deposited on $SrTiO_3$ (STO) substrates at different oxygen partial pressures $P(O_2)$ and different film thicknesses by pulsed laser deposition (PLD) technology. The reflectance spectra of samples were measured using a Bruker company's Vertex 80v Fourier transform infrared (FTIR)-type spectrometer. Taking advantage of the high reflectance of $SrTiO_3$ in the far-infrared region, we obtained the absorption coefficient from the measured reflectance using Beer-Lambert's law. Independently, the absorption coefficient was also obtained using the transfer matrix method, which includes the multiple internal reflections in the film and substrate. The dielectric constant was obtained from the fitting parameters. The phonons are blue-shifted and narrowed, lowering the temperature. We will discuss the relationships between the static dielectric constant and the thickness, as well as the relationship between the dielectric constant and the $P(O_2)$.

Keywords:

FTIR, LaFeO3, Transfer matrix, Dielectric constant

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P1-co.208

Optimization of Substrate Treatment for (001)-oriented Nb-doped $SrTiO_3$ Substrate

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Abstract:

Advancements in the growth of epitaxial oxide thin film have opened a new avenue for the potential applications of nanotechnologies as well as fundamental research regarding quantum properties. Nonetheless, a key challenge arises from the fact that the perovskite crystal substrates employed in most of the oxide thin film fabrication are cleaved along a specific crystallographic orientation. This process unavoidably poses difficulties in consistently depositing thin films of high quality on top of the substrate. M. Kawasaki *et al.*, have developed a methodology to refine the processing of widely used $SrTiO_3$ (STO) substrate for the epitaxial oxide thin film growth.
Our study focused on Nb-doped $SrTiO_3$ (Nb:STO) substrates, which possess almost the same lattice parameters as those of STO, while they exhibit distinct characteristics. First, we have optimized the surface treatment condition to give the Nb:STO substrates atomically-flat surfaces of a single termination. Therein, by manipulating the treatment conditions, e.g., chemical etching, annealing temperature, and annealing time, we governed the termination of the substrate. Furthermore, atomic force microscopy (AFM), Angle-Resolved X-ray Photoelectron Spectrometer (ARXPS), and Reflection high-energy electron diffraction (RHEED) were used to investigate the chemical structure of the substrate surface. Our study not only enhances the application of Nb:STO but also adds to the comprehension of the mechanism behind etching treatment for the substrate.

Keywords:

Substrate treatment, Reflection high-energy electron diffraction, Atomic force microscopy, Angle-Resolved X-ray Photoelectron Spectrometer, Nb:SrTiO3

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P1-co.209

Self-assembled vertically aligned nanocomposites of strontium cobalt oxide

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Abstract:

During the epitaxial growth of a thin film, the strain effect resulting from the lattice mismatch between the thin film and substrate gives rise to peculiar changes in crystal and electronic structure. While the thin film on the planar substrate experiences an effect of biaxial strain, the incorporation of a nanocomposite structure offers an avenue to induce the additional *c*-axial strain. Vertically aligned nanocomposites (VANs), consisting of nanopillars and a matrix of distinct materials, effectively sustain *c*-axial strain even in thicker films. In essence, VANs introduce a new dimension in strain engineering for the fundamental properties of thin film.

Here we demonstrate the self-assembled growth of $SrCoO_{2.5}$:CoO_x VAN thin films. Through meticulous control of the conditions of pulsed laser epitaxy, we successfully fabricated the $SrCoO_{2.5}$:CoO_x VANs of varying quantities of CoO_x nanopillars. Significantly, our investigation highlights the direct correlation between the amount of CoO_x nanopillars and the physical properties of the $SrCoO_{2.5}$, including strain and magnetic properties. This work holds paramount importance due to its potential to manipulate thin film properties by modulating nanopillar arrangements.

Keywords:

vertically aligned nanocomposite, transition metal oxide, thin film, strain engineering, pulsed laser epitaxy

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P1-co.210

Improvement in Conductance Characteristics of Ferroelectric Synaptic Transistor by Logarithmic Incremental Pulse Scheme

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Abstract:

Neuromorphic computing is one of the next generation computing proposed to solve problems such as bottleneck in traditional von-Neumann architecture, enabling parallel data processing and adaptive learning processes. However, the non-linear and asymmetric analog synaptic plasticity of ferroelectric-based neuromorphic computing deteriorate the learning accuracy. In this study, we demonstrate the improvement in analog conductance characteristic of ferroelectric thin film transistor by varying the pulse scheme for synaptic plasticity. Hafnium zirconium oxide with a thickness of 9.4 nm was deposited as a ferroelectric material by atomic layer deposition, and indium tin zinc oxide was deposited as a channel layer. The three pulse schemes for comparing conductance characteristic are identical, incremental voltage, and logarithmic incremental voltage. In simulation, we used NeuroSim with the Modified National Institute of Standard and Technology handwritten dataset to obtain accuracy based on the conductance characteristics for the three pulse schemes. These results suggest that the analog conductance characteristic of ferroelectrics, which need to be improved for neuromorphic computing, can be improved through pulse modulation.

Keywords:

Neuromorphic computing, Ferroelectric, Hafnium zirconium oxide, Thin film transistor, Synaptic device

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P1-co.211

Hard piezoelectric properties of lead-free $BiFeO_3$-$BaTiO_3$ ceramics

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Abstract:

Hard piezoelectric properties are investigated in lead-free $BiFeO_3$-$BaTiO_3$ (BF-BT) ceramics. Rhombohedral (R) phase ceramics of (1-*x*)BF-*x*BT (*x* = 0.20-0.30) were prepared using a conventional solid-state reaction and water-quenching process. The R structure is observed in *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 ceramic shows the best hard piezoelectric properties: the highest Q_m = 403, and the highest T_C = 607 °C. In contrast, *x* = 0.30 ceramic shows 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:

Piezoelectric, BiFeO3-BaTiO3, Mechanical quality factor, Curie temperature, Lead-free

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P1-co.212

High Piezoelectric Performance of Bi and Fe-Compensated $0.67BiFeO_3$-$0.33BaTiO_3$ Piezoelectric Ceramics

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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 with morphotropic phase boundary at $0.67BiFeO_3$-$0.33BaTiO_3$. However, poor ferroelectric and piezoelectric properties with high leakage currents are often shown. Because of non-stoichiometric compounds as Bi-rich ($Bi_{20}FeO_{40}$) and Fe-rich phases ($Bi_2Fe_4O_9$) 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. And the process for controlling the rich phase of Fe and Bi were investigated. This resulted in improvement in d_{33}, d_{33}^* and dielectric properties. The experimental process with 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.213

X-ray micro-diffraction study of structural change in (1-x)$BaTiO_3$-x$CaZrO_3$

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Abstract:

The morphotropic phase boundaries (MPBs) of (1-*x*)$BaTiO_3$-*x*$CaZrO_3$ (BTCZ) is located at the room temperature, leading to readily produce high piezoelectricity and permittivity, so that BTCZ is one of the promising candidates of lead-free piezoelectric materials. By changing the $CaZrO_3$(CZ) contents, the structure can be changed between tetragonal and rhombohedral. Recently, we demonstrated the tunability of the photoluminescence of Eu3+ doped (1-*x*)$BaTiO_3$-*x*$CaZrO_3$ (BTCZ:Eu) by changing structural phases.
In this study, we performed a grain by grain local structural analysis of BTCZ:Eu with varying x =(0.00 ~ 0.15) which indicates Ca^{2+}/Zr^{4+} ion substitution within the MPB region. Herein, we used X-ray Micro Diffraction(XMD) equipment in the 4B beamline of the Pohang Accelerator Laboratory. XMD analysis uses CCD to captures the Laue images which has diffraction peaks from samples within a focused small x-ray beam. Therefore, this method is specialized in analyzing crystal structures of grains on and near the surface of the sample. By processing Laue images within the scanned area, we analyzed the 2D distribution and trends of lattice parameters and strain distributions for each sample.
The processed map showed the average strain of samples increased from 417 MPa to 607 MPa with increasing $CaZrO_3$ contents. Additionally, it was clear that the higher strain was concentrated near the grain boundaries, rather than evenly distributed. These strains may have accumulated at the boundaries during the grain growth. Also, the distortion angles had higher values for x=0.10 and 0.15, which is consistent with the Rietveld refinement results that showed higher rhombohedral structure components. Also, the histogram and the 2D map of the distortion angles suggested that there were two types of grains, one with smaller distortion angles, i.e. tetragonal-like grain, and the other with higher distortion angles, i.e. rhombohedral-like grain, especially for x=0.10 and 0.15. The c/a ratios of the sample decreased as increasing x, but remained in rather small deviations ($<10^{-2}$) from 1. The results showed the structural change of BTCZ:Eu in MPB region well which is closely related to Ca^{2+}/Zr^{4+} ion substitution.

Keywords:

BTCZ, BTCZ:Eu, Perovskites, X-ray micro-diffraction

P1-co.214

Pulsed laser epitaxy of Mo(d^2)-doped SrRu(d^4)O_3 thin films

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Abstract:

4*d* transition metal oxides (TMOs) have been intensively explored with respect to their various intriguing physical phenomena resulting from the strong interplay among charge, spin, lattice, and orbital degrees of freedom. In addition to on-site Coulomb interaction (U) and Hund's coupling (J_H), 4*d* transition metal ions exhibit finite spin-orbit coupling (SOC), determining the electronic structure. There have been several theoretical and experimental studies on correlated electronic phase diagrams by varying those interaction parameters. Among 4*d* TMOs, $SrRuO_3$ (SRO) with $4d^4$ configuration is of particular interest for its rich electronic states including non-Fermi liquid and Weyl semimetal states. SRO is an itinerant ferromagnet with a Curie temperature (T_C) of 160 K. The intrinsic SOC modifies the spin alignment via the Dzyaloshinskii – Moriya interaction, which might lead to the formation of skyrmions and the resultant topological Hall effect [1, 2]. On the other hand, $SrMoO_3$ (SMO) with $4d^2$ configuration is another metallic 4*d* TMO. Compared to SRO, it is still largely underexplored in terms of its electronic transport mechanism, despite its extremely small room-*T* resistivity with Fermi-liquid behavior [3]. In contrast to SRO, SMO exhibits Pauli paramagnetic behavior with *T*-independent magnetic susceptibility.
Previously, there have been several attempts to dope SRO thin film with 3*d* TM ions through Ru-site chemical substitution resulting in the suppression of the ferromagnetic T_C and metal-insulator transition in the electronic transport. In this study, we assess whether Mo-doping on SRO thin films provides emergent phenomena and functionalities by manipulating the degree of electronic and magnetic correlations through chemical substitution. We studied the optical and electronic transport properties of the epitaxially stabilized $SrRu_{1-x}Mo_xO_3$ (SRMO, x = 0 – 0.5) thin films grown using pulsed laser epitaxy by alternately ablating two targets, SRO and SMO, with adjusted laser pulse numbers according to the deposition rate on (001) $SrTiO_3$ substrates. Structural characterization done by using x-ray diffraction confirms the growth of high-quality SRMO thin films with a systematic lattice compression following the increase in the Mo concentration. The resulting change from the $4d^2$-doping into the complex electronic structure of the $4d^4$ system such as SRO is corroborated by the slight distortions of the metal-oxygen octahedra leading to a profound impact on the spin coupling and modification of their electronic transport and magnetic properties. Our study provides deeper insights into understanding the systematic changes in the magneto-transport properties of epitaxial SRMO thin films useful for spintronic device applications.

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[3] Prasetiyawati, R. D. *et al.*, Curr. Appl. Phys. 2023, 53, 110.

Keywords:

strontium molybdate, strontium ruthenate, perovskite oxide, transition metal oxides

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P1-co.215

Collective Control of Potential-constrained Oxygen Vacancies in $LaAlO_3/SrTiO_3$ Heterostructures for Analog Resistive Switching Applications

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Abstract:

Filamentary resistive switching is one of the most important ways for developing next generation nonvolatile memory devices using oxide materials. However, despite many advantages, their practical applications in neuromorphic technologies are limited because of the non-uniform and indeterministic switching behavior. Considering the inherent stochasticity of the migration of point defects, the pursuit of reliable resistive switching demands a completely new approach. In this study, we demonstrate a collective control of oxygen vacancies in LaAlO3/SrTiO3 (LAO/ STO) heterostructures to achieve reliable and gradual resistive switching. Using an electrostatic potential constraint in ultrathin LAO/STO heterostructures, the formation of conducting filaments is suppressed, but precisely control the concentration of oxygen vacancies. Since the conductance of the LAO/STO device is governed not by their individual probabilistic migrations but by the ensemble concentration of oxygen vacancies, the resistive switching is more uniform and deterministic compared to conventional filamentary devices. We provide direct evidence for the collective control of oxygen vacancies by spectral noise analysis and modeling by Monte-Carlo simulation. As a proof of concept, we show the improved analog switching performance of the filament-free LAO/STO devices, revealing potential for neuromorphic applications. Our results establish an approach to store information by point defect concentration, just like biological ionic channels, for enhancing switching characteristics of oxide materials.

Keywords:

collective control, filament-free, oxide heterostructures, oxygen vacncies, resistive switching

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P1-co.216

The temperature dependent electronic structures of CeB_4 : DMFT(Dynamical Mean Field Theory) study

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Abstract:

Negative thermal expansion (NTE), which is also known as "contraction upon heating", is one of the unusual physical properties but quite ubiquitous in materials. Not only the weakly correlated *s,p*-electron solids, Si, Ge, Te, ZrW2O8 but also many *d,f*-electon solids show NTE, too : $Fe_{0.65}Ni_{0.35}$ alloy famous for INVAR, SmB_6, SmS, YbB_{12}, $YbCu_2Si_2$, δ-Pu, CeB_6, $CeAl_3$, CeB_4 and so on. In general, the NTE in weakly-correlated electronic systems has the phonon-origin via a specific transverse-phonon mode or rigid-unit mode under pressure. In contrast, the NTE in strongly-correlated electron system has the electron-origin via pressure-induced electronic energy difference between relevant states. And another mechanism that leads NTE is "valence transition" to mixed valence. CeB_4 is recently reported to have the NTE below T = 50K [1]. In this research, we focused on the T-evolution of the electronic structure of CeB_4 to capture the development of any valence transition of Ce *4f* electron by employing DMFT [2,3]. Unlike our expectation, we have observed no evidence on the valence transition of Ce *4f* electron with respect to the temperature change. We discuss the possible reasons of NTE observed in CeB_4.

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Keywords:

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P1-co.217

P-31 NMR study in a $NiPS_3$ single crystal.

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Abstract:

We report a P-31 nuclear magnetic resonance (NMR) study in a high quality single crystal of the van der Waals material, $NiPS_3$. The P-31 NMR spectrum shows very complex temperature and angle dependences in both the normal and antiferromagnetically ordered states. In the normal state, our data reveal that there are strikingly unusual strong spin correlations which persist up to high temperatures. In the ordered state, the P-31 spectrum turns out to be very complicated, implying that the spin structure is much more complicated than known so far.

Keywords:

van der Waals antiferromagnet, nuclear magnetic resonance (NMR), NiPS3

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P1-co.218

Direct Investigation of Valence State in Kondo lattice $YbCuAs_2$ Using Resonant X-ray Emission Spectroscopy

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Abstract:

Rare-earth intermetallic compounds possess exotic physical phenomena due to different microscopic interactions. Especially, in Yb-based Kondo system, local and almost full 4f shell shows strong hybridization with conduction electrons denoted as Kondo interaction. This hybridization can lead to the instability of the 4f shell and nonintegral 4f occupancies, and one can enter the intermediate valence regime where a strong quantum mechanical mixing of different valence state. In this study, we have investigated the valence state in Kondo lattice $YbCuAs_2$ by employing resonant X-ray emission spectroscopy experiment. We have observed the temperature dependence of Yb valence state and clarified that $YbCuAs_2$ is a newly-discovered intermediate valence material. We also have tracked the contribution of lattice distortion on this valence fluctuation using additional X-ray diffraction study.

Keywords:

Mixed Valence, Resonant X-ray Emission Spectroscopy, Kondo Lattice

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P1-co.219

Optical study of a new kagome metal $Ni_3M_2S_2$ (M = In, Tl)

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Abstract:

Kagome materials, which can host flat bands, van Hove singularities, and Dirac cones, have attracted much attention due to their exotic topological states. Among the kagome lattice compounds, the ferromagnetic shandite kagome metal, $Co_3Sn_2S_2$, has been reported as a magnetic Weyl semimetal. The nickel-based kagome metal $Ni_3M_2S_2$ (M = In, Tl), a non-magnetic isostructural counterpart of $Co_3Sn_2S_2$, has been synthesized recently, but its electronic response has been rarely studied. In this work, we investigated the optical response of $Ni_3M_2S_2$ using infrared spectroscopy. We found that the low-energy optical conductivity of the two compounds exhibited a linear frequency dependence, which is a characteristic signature of Dirac/Weyl semimetals. Interestingly, a gap-like feature was observed only in $Ni_3Tl_2S_2$. We will discuss a possibility that $Ni_3M_2S_2$ can be a new candidate topological material hosting Dirac nodes.

Keywords:

Kagome metal, Optical spectroscopy, Topological material

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P1-co.220

Melting unidirectional charge density waves across twin domain boundaries

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Abstract:

Solids undergoing a transition from order to disorder experience the proliferation of topological defects. The melting process allows access to the transient quantum states unachievable in equilibrium. However, the highly dynamic nature of these states with femtosecond lifetime hinders a detailed exploration of their properties with atomic precision. Here, we use a scanning tunneling microscope to visualize the unidirectional charge density wave (CDW) and its static spatial progression across a twin domain boundary (TDB) in the rare earth tritelluride $GdTe_3$. Combining STM with a spatial lock-in technique, we reveal that the order parameter's amplitude attenuates with the formation of dislocations and thus two different unidirectional CDWs coexist near the TDB, reducing the CDW anisotropy. Notably, we discover a competition between this anisotropy and the CDW gap. Our study provides valuable insight into the behavior of topological defects and transient quantum states in non-equilibrium conditions.

Keywords:

GdTe3, Scanning tunneling microscopy, Rare earth tellurides, Topological defects, Charge density waves

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P1-co.221

Investigation of Charge Density Wave (CDW) Order parameters in kagome metal (K, Rb)V3Sb5 using X-ray scattering

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Abstract:

The vanadium-based kagome metal, AV_3Sb_5 (A = K, Rb, Cs) has significant interest due to its display of intriguing many-body physics phenomena, such as superconductivity (SC) and charge density wave (CDW), which are coupled to the non-trivial energy band structures originating from the kagome lattice geometry.
By employing X-ray scattering techniques, we explore the temperature-dependent behavior of 2X2X2 and 2X2X1 CDW orders in (K, Rb)V_3Sb_5. Intriguingly, we find a coexisting 2X2X2 and 2X2X1 CDW order in KV_3Sb_5, unlike in RbV_3Sb_5 where only the 2X2X2 CDW order is observed. This coexistence in KV_3Sb_5 is reminiscent of the behavior seen in CsV_3Sb_5, which also manifests nematicity and chiral charge order. Our findings may offer key insights into the underlying free energy landscape, potentially paving the way for understanding unconventional superconductivity and other complex many-body physics phenomena in AV_3Sb_5 materials.

Keywords:

CDW, Kagome metal, X-ray scattering

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P1-co.222

Optical study of kagome metal $Cs(Ti_{1-x}V_x)_3Sb_5$

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Abstract:

A vanadium-based kagome metal CsV_3Sb_5 has drawn much attention since they exhibit a wide variety of intriguing topological states and electronic instabilities. A prominent example includes an unconventional charge-density-wave (CDW) which is associated with the saddle points. Hole doping of the system via substitution of Ti for V is expected to lift the saddle points below the Fermi level, providing an effective way to tune the Fermi surface instabilities in CsV_3Sb_5. Here, we investigate the optical response of $Cs(Ti_{1-x}V_x)_3Sb_5$ (x = 0, 0.01, 0.02, and 0.06) single crystals from 10 K to 300 K. The optical spectra of $Cs(Ti_{1-x}V_x)_3Sb_5$ show clear doping dependences on the Drude peaks and the optical excitation at about 0.2 eV below the critical temperature T_{CDW}, suggesting a fluctuation in the CDW phase. We will discuss the origin of the changes in the optical spectra upon Ti doping.

Keywords:

CsV3Sb5, Charge-density-wave, Ti-doping

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P1-co.223

Band insulator to Mott insulator transition in ML 1T-$TaSe_2$

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Abstract:

Two-dimensional (2D) transition metal dichalcogenides (TMDs) are an atomically thin material that reduces screening effects and increases Coulomb interaction with an environment without interlayer coupling. Especially, 1*T*-TaX_2 (X = S, Se) have been well known to have Mott-type states by the formation of the charge density wave (CDW). Here we report the temperature-dependent band structures of monolayer 1*T*-$TaSe_2$ via angle-resolved photoemission (ARPES). Our results reveal that CDW-induced 2D Mott state persists above 300 K while CDW band evolves with increasing temperatures. Our findings shed light on new possibilities for controlling of novel electronic phases in 2D TMDs.

Keywords:

Transition metal dichalcogenides (TMDs), 1T-TaSe2, Mott insulator, Angle-resolved photoemission (ARPES), Molecular beam epitaxy (MBE)

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P1-co.224

Controlling Pulse Laser Annealing to observe Resistance Switching Behavior in $LaAlO_3/SrTiO_3$ Heterostructure Memristors

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Abstract:

Memristors based on resistive switching have risen as one of the next-generation promising technologies in fields like non-volatile memory technology and applications such as AI, including deep learning. Memristors based on certain metal/oxide/metal material systems have exhibited resistive switching behavior due to the presence of oxygen vacancies. Hence, it is essential to conduct an in-depth investigation into the conduction mechanism of oxide memristors, while manipulating different factors like the density of oxygen vacancies and charge carriers. Research has also been conducted on the resistive switching behavior of perovskite oxides, in the form of thin films and as bulk materials containing 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 fabricated a Memristor device on a $LaAlO_3/SrTiO_3$ heterostructure through the utilization of Photo lithography and Pulse Laser Deposition techniques to deposit square-shaped Pt electrodes. We observed variations in resistive switching by controlling various conditions of pulse laser annealing at $LaAlO_3$.

Keywords:

Memristor, resistive switching

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P1-co.225

Compositional Gradient in Tungsten-Doped Vanadium Dioxide Thin Films for Exploring Doping Effects on Metal-Insulator Transition Characteristics

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Abstract:

Vanadium dioxide (VO_2) has been researched extensively, mainly due to its metal-Insulator transition (MIT) phenomena which occur at the transition temperature of T_{MIT}, ~340 K. Since the T_{MIT} is higher than the room temperature, various approaches to lower T_{MIT} have been considered for achieving real-world device applications. Among those, cation substitution doping of V^{4+} with W^{6+} is considered to be an efficient method to lower T_{MIT} of VO_2 in details stably. Therefore, understanding W-doping effects on MIT characteristics of VO_2, is crucially important.
In this work, a set of VO_2 films doped with W gradually were constructed in the different ranges of W composition and their finely tunable MIT characteristics driven by W-doping effects have been investigated. This combinatorial approach would be of relevance to understanding doping effects in correlated oxides efficiently and more deeply as well as enhancing applicability of MIT devices.

Keywords:

vanadium dioxide (VO2), insulator-metal transition (MIT), substitutional doping

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P1-co.226

Fabrication of antiperovskite Sr_3SnO thin films using sputtering technique

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Abstract:

Symmetry and topology are fundamental principles that underlie our understanding of matters, and topological materials are derived from the interplay between symmetry and topology. Antiperovskite compounds A_3BO (A = Ca, Sr, Ba; B = Sn, Pb) have attracted interest as candidates for three-dimensional Dirac systems [1]. Antiperovskite Sr_3SnO has been suggested as a topological crystalline insulator, and highly Sr-deficient $Sr_{3-\delta}SnO$ has been reported to be superconducting [2], leading to it as a possible intrinsic topological superconductor [3]. Despite their immense potential, the high instability of antiperovskite oxides is troublesome in fabricating and securing the samples, which presumably results in less extensive research on these materials. In this study, we investigated the physical properties of Sr_xSn_yO compositional spread thin films prepared by co-sputtering of Sr, Sn, and SnO_2 targets. The Sr and Sn ratios across the spread film were examined using wavelength dispersive spectroscopy. The Sr_3SnO phase was confirmed by *ex-situ* X-ray diffraction measurements with various passivation methods. We discuss the change in the crystalline phases and electrical properties depending on the composition. This work would encourage the research on antiperovskite oxides as a platform for studying tunable topological systems *via* structure, defect, and composition engineering.

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Keywords:

Antiperovskite, Topological material, Compositional spread, Thin film, Passivation

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P1-co.227

Transition of temperature-dependent resistivity behavior in superlattices: Influence of $SrIrO_3$ film thickness and presence of $SrTiO_3$ 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. Based on this, in this study, $SrIrO_3$ was deposited under different conditions of "insulator-like" and "metal-like" deposition, with varying presence of a $SrTiO_3$ capping layer. 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. Results showed that under "insulator-like" conditions and in the presence of a $SrTiO_3$ capping layer, $SrIrO_3$ exhibited temperature-dependent resistance behavior similar to an insulator for from 9 to 20 unit cells, intermediate for from 7 to 8 unit cells, and metal-like for from 1 to 6 unit cells. Under the "metal-like" condition, the $SrIrO_3$ thin film did not show any anomalies. Through these experimental results, we aim to elucidate the role of the capping layer.

Keywords:

SrIrO3, resistivity behavior, perovskite oxide structure

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P1-co.228

Influence of ion-implantation on the metal insulator transition of VO_2

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Abstract:

VO_2 is a typical metal-to-insulator transition (MIT) material with the critical temperature (T_c) of ~70 ^oC accompanied by a first-order structural phase transition (SPT). For practical applications of VO_2, accurately controlling Tc is required using artificial parameters. We examined the electrical and local structural properties of hydrogen (H) and nitrogen (N) ion implanted VO_2 (H-VO_2 and N-VO_2) films using temperature-dependent resistance and X-ray absorption fine structure (XAFS) measurements at the V K edge. H and N ions with the flux of 10^{13}-10^{15} ions/cm^2 and the energy of 100 – 300 keV were vertically implanted to the films. The I-V and in-situ XAFS were simultaneously measured on H-VO_2 and N-VO_2 films and directly compared. XAFS measurements revealed that the structural disorder as well as bond lengths of V-O and V-V pairs on VO_2 were significantly changed when ions were implanted. The T_c of VO_2 was lowered by 10 ^oC for both heating and cooling, compared to that of untouched VO_2. The transition region of VO_2 was expanded by ion implanted. The electrical property changes of ion-implanted VO_2 was mainly caused by structural property changes because no changing effects were observed. The T_c values of the H-VO_2 and N-VO_2 films considerably depend on the flux and the energy of H and N ions. This study showed that the T_c of VO_2 can be controlled by proper ion implantation.

Keywords:

VO2, metal insulator transition, structural phase transition, XAFS, Ion implantation

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P1-co.229

Reduction of nickelate by pulsed laser annealing

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Abstract:

In 2019, superconductivity was discovered in infinite-layer structure nickelate with a 3d-orbital like cuprate. This structure is made by depositing a thin film of perovskite nickelate, followed by topotatic reduction with CaH_2. However, CaH_2 is very toxic and this method makes all parts of the thin film react. In order to solve this problem and make the reaction more effective, reduction was attempted using a pulsed laser. After depositing a nickelate thin film, pulsed laser was irradiated on it. It was observed that the resistance increased up to 100,000 times according to the pulsed laser irradiation time. Then, by measuring XRD and XPS, it was found that oxygen vacancy occurred instead of topotatic reduction. In addition, the application possibility of pulsed laser annealing was examined by using a mask to cause a reaction only in a local area.

Keywords:

reduction, oxygen vacancy, nickelate, infinite-layer, pulsed laser deposition

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P1-co.301

Nanoscale three-dimensional network structure of a mesoporous particle unveiled via adaptive multi-distance coherent X-ray tomography

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Abstract:

Mesoporous nanoparticles provide rich platforms to devise functional materials by customizing the three-dimensional (3D) structures of nano-pores. With the pore network as a key tuning parameter, the noninvasive and quantitative characterization of these 3D structures is crucial for the rational design of such functional materials. This has prompted researchers to develop versatile nanoprobes with a high penetration power to inspect various specimens sized a few micrometers at nanoscale 3D resolutions. Here, with adaptive phase retrievals on independent data sets with different sampling frequencies, we introduce multi-distance coherent X-ray tomography as noninvasive and quantitative nanoprobe to realize high-resolution 3D imaging of micron sized specimens. The 3D density distribution of an entire mesoporous silica nanoparticle was obtained at a 13 nm 3D resolution for quantitative physical and morphological analyses of its 3D pore structure. The topological features of the whole 3D pore network and pore connectivity were examined to gain insights into the potential functions of the particle (e.g., catalytic agent and energy storage material). The proposed multi-distance tomographic imaging scheme with quantitative structural analyses is readily available for *in operando* nanoscale characterization of functional materials under various operational conditions, thus advancing studies on energy materials by facilitating the structure-based rational design of functional nanoparticles.

Keywords:

mesoporous functional nanomaterials, nanoscale pore network, coherent diffraction imaging, coherent X-ray tomography, noninvasive and quantitative 3D nano-imaging

Observation of self-induced strain and suppression of Metal-Insulator Transition in V_2O_3 thin film using In-situ X-ray Diffraction

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Abstract:

Vanadium sesquioxide (V_2O_3) is a transition metal oxide which exhibits a Metal-Insulator Transition (MIT) at temperature of ~150K, accompanied by coupled Structural Phase Transition (SPT) and Magnetic Phase Transition (MPT). The mechanism of MIT has been a source of debate for few decades, as some of the complex phenomena near phase transition still remains unexplained. In this study, using in-situ synchrotron in-plane X-ray diffraction, we have observed the SPT and strain generation inside epitaxial V_2O_3 thin film near transition. We suspect the self-induced strain from partial structural phase transition is the source for wide phase coexistence temperature range of V_2O_3. Details results of experiment will be presented.

Keywords:

V2O3, X-ray Diffraction, Metal-Insulator Transition, Structural Phase Transition, Self-induced Strain

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P1-co.303

Development of a multiplex imaging chamber to investigate ultrafast phenomena at PAL-XFEL

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Abstract:

Variety X-ray techniques are utilized to investigate the specimens in various fields. In general, scattering and absorption processes arise from the X-ray interaction with matter. Output signals from these processes contain structural information and electronic structure of specimens. Investigation using complementary X-ray techniques improve the understanding of the complex system in a holistic way. Here, we will introduce a multiplexing X-ray chamber, which can collect small- and wide-angle X-ray diffractions and X-ray emission spectrum simultaneously to examine morphological information with nanoscale resolution, crystal arrangement at the atomic scale and electronic structure of the specimens.
PAL-XFEL (Pohang Accelerator Laboratory X-ray Free Electron Laser) shows sub 20 fs timing jitter performance. It provides unique opportunities to study photon-induced ultrafast dynamics using a femtosecond infrared laser with high stability. Newly developed multiplexing chamber is applied in studying ultrafast phenomena. In this presentation, we'll also show pump-probe experiment result.

Keywords:

XFEL, Coherent diffraction imaging, Multiplexing experiment, X-ray diffraction, X-ray emission spectroscopy

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P1-co.304

Operando Lattice Distortion in Photoexcited Perovskite-oxides during Photocatalytic Conditions by Coherent Diffraction Imaging

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Abstract:

Solar energy's decentralized and clean nature offers an endless resource. Photocatalytic water splitting converts this energy into hydrogen, a promising fossil fuel alternative. ABO3 perovskite-oxides, like SrTiO3, are compelling due to cost-effective synthesis, catalytic resilience, and strong photocatalytic activity.
SrTiO3 showcases intricate interplay between A-site orientation, lattice vibration, and electron/hole localization in the crystal lattice, yielding polaron formation and distortions. Understanding these mechanisms is vital for fundamental insights and industrial use, as SrTiO3 serves various photocatalytic applications, including H2 production and CO2 reduction.
The interaction between photogenerated carriers and the host catalytic components creates polaron-induced lattice distortions, impacting photocatalytic efficiency. Unraveling the lattice-carrier coupling at ultrafast timescales holds significance. This poster presents dynamic findings of SrTiO3 behavior under distinct environmental conditions, revealing time-dependent strain increase due to polaron generation, offering insights into enhanced photocatalysis.

Keywords:

Perovskite-oxides, SrTiO3, BCDI, Photocatalytic, Strain

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P1-co.305

Direct investigation of ultrafast melting process of Au with time resolved coherent X-ray diffraction imaging

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Abstract:

The interest in ultrafast light-matter interaction has increasing significantly with the availability of femtosecond laser pulses to enable mode-selective perturbation by exclusively exciting valence electrons. This has enabled researchers to track intermediate states during cascading reactions of energy transfer processes from optical excitation to eventual phase change of materials. We are revisiting the solid-liquid phase transition, with direct visualization, to gain an understanding of a fundamental physical phenomenon. Using single-shot XFEL time-resolved coherent diffraction imaging, we observed the direct density change on the femtosecond laser driven nonequilibrium dynamics of gold nanoparticles. By imaging laser fluence and polarization dependent atomic density distributions combined with all-atom simulations of two-temperature molecular dynamics, we uncovered that ultrafast melting of Au is controlled by photoexcited electron-originated transient ionic pressure. By filling the gap in understanding the dynamic interaction between electron and ion, this work provides a leverage to control ultrafast ionic dynamics with the femtosecond laser field.

Keywords:

Ultrafast phase transition, XFEL, Coherent Diffraction Imaging

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P1-co.306

Scanning microscopy for single diamond nitrogen vacancy centers

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Abstract:

The quantum state of diamond nitrogen vacancy (DNV) has a long decoherence time at room temperature, which is advantage for sensitive magnetic field measurements. Due to feature, DNV is currently used in various fields such as quantum computing and quantum communication as well as in various quantum sensing-based microscopy fields.

in this paper we introduce the development of measurements devices for optically detected magnetic resonance (ODMR) by using a single DNV.

The experimental setup is a confocal microscope with main space scanning that is measuring the amount of red fluorescence produced by excited a single diamond sample absorbing a 532nm green laser
The magnetic resonance is scanned by applying the microwave frequency consistent with the DNV's Zeeman separation frequency to a single DNV sample and comparing the photon coefficient ratio of fluorescence.

Keywords:

DNV

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P1-co.307

Photoinduced ultrafast melting of metallic glass nanoparticles directly observed by XFEL single-pulse imaging

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Abstract:

The exploration of ultrafast light-matter interactions has invigorated research on light-induced quantum control of material properties by opening new avenues for producing new phases of matter in nonequilibrium states. In this study, we investigate ultrafast melting of metallic glass materials using time-resolved single pulse imaging. The metallic glass exhibits an amorphous structure without long range atomic orders. The absence of crystalline order gives rise to distinctive melting reactions. Its melting process expects to be different from the crystalline metal without phonons. However, the fundamental mechanisms underlying the rearrangement of the metallic glass structure remain elusive. From the single-pulse time-resolved imaging experiments performed at PAL-XFEL, we obtained direct nanoscale images of single metallic glass nanoparticles (MG-NP) undergoing nonequilibrium melting excited by femtosecond IR laser (800 nm). Upon laser illumination, anisotropic shape deformation of the MG-NP occurred promptly (within 1 ps). The NP deforms, accompanying inhomogeneous distribution of the mass density, more severely as the melting proceeds. Inhomogeneity in the density distribution become more apparent. It displays highly inhomogeneous distribution with low-density regions localized to form bands, which prevents further development of the shape deformation. We present the nanoscale imaging results that visualize ultrafast melting in metallic glasses, which promote in-depth understanding on structural deformation accompanied during the melting (glass) transition

Keywords:

X-ray free electron laser, Single-particle imaging, Coherent diffraction imaging, Metallic glass nanoparticle

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P1-nu.001

Discussion on the instanton effects in the QCD sum rule for the scalar meson $a_0(980)$ as a tetraquark state

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Abstract:

We discuss the instanton effects in the QCD sum rule for the scalar meson $a_0(980)$ as the tetraquark state where the two tetraquark states, one state consists of the spin-0 diquark and anti-diquark and the other state of the spin-1 diquark and anti-diquark, are mixed. We show that including contributions from the instaton in the QCD sum rule constructed the operators up to dimension 10 of $O(\alpha_s)$, although its contribution is much smaller than contribution from OPE(Operator Product Expansion) to QCD sum rule, the mass of $a_0(980)$ fitted from the QCD sum rule becomes more stable and has the value closer to experimental value.

Keywords:

Scalar meson, QCD sum rule, Instanton, Operator product expansion

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P1-nu.002

π→ππ transition GPDs and the non-diagonal DVCS

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Abstract:

The generalized parton distributions (GPDs) provide various information on the hadron structure such as angular momentum and spatial distribution of active parton inside the hadron and can be accessed through the hard exclusive reactions such as the deeply virtual Compton scattering (DVCS) and deeply virtual meson production. In particular, in the presence of the resonance state of the target nucleon, one can access the transition GPDs which may give us information on the dynamics of hadron excitations. In this work, we study the non-diagonal DVCS process of $\gamma^* \pi \to \gamma \pi \pi$, which is a subprocess of the Sullivan-type reaction of $eN \to eN' \gamma \pi \pi$, involving the $\pi \to \pi\pi$ transition GPDs as a spinless hadron example of developing the framework of the transition GPDs. The parameterizations of $\pi \to \pi\pi$ transition GPDs up to the leading twist accuracy are introduced and their symmetric properties are investigated. We used the soft-pion theorem to show that they are normalized in terms of the usual pion GPDs under the condition that one of the two final state pions is taken to be soft. Also, we considered the $\pi \to \rho$ transition as it contributes to the reaction by subsequent decay of ρ meson into two pions.

Keywords:

non-diagonal DVCS, transition GPD

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P1-nu.003

The Evaluating Inevstigation on Using Helium and Oxygen Ion Beam for Radiation Therapy

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Abstract:

The carbon ion therapy is already used as the external radiation therapy benefit from the dose distribution of the Bragg peak. Considering the biological effect, the heavier ion beams should be more efficient on killing the target cells. Therefore, in this study, the helium and oxygen ion beams are evaluated as the candidates of radiation therapy beam based on the Monte Carlo method. In the study, the selected stable and radioactive helium and oxygen ion beams are irradiated in water phantom. For the calculation results, the distribution graphs for tracks and doses, the depth dose distributions and the lateral dose distributions are obtained. Based on the calculation result, it can be found that the helium ion beams show a short tail effect and the oxygen ion beams show a better lateral dose profile comparing with carbon ion beam. In addition, in-beam PET might be achieved for radioactive oxygen ion beam. In conclusion, the helium and oxygen ion beams have special clinical value comparing with carbon ion beam in some specified cases.

Keywords:

Radiation Therapy, Monte Carlo Method, Heavy Ion Beam

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P1-nu.004

Exactly Separable X(5) Potential in $^{152\text{-}164}$Dy

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Abstract:

Iachello proposed two new symmetries called E(5) and X(5). In these symmetries, the properties of the nucleus at the critical point of phase transition are described as Bohr Hamiltonian's special solution. In this study, the energy spectra of the ground state, β, and γ bands in axially deformed nuclei have been studied by using the exactly separable X(5) potential of the form $U(\beta) + V(\gamma)/\beta^2$ in the Bohr Hamiltonian. An infinite square well potential and a harmonic oscillator potential were used as U(β) and V (γ), respectively. The relative positions of all bandheads and the internal structures of all bands were determined by using the theory with only one parameter. The results of numerical application to the ground state, β, and γ bands in $^{152\text{-}164}$Dy are in a good agreement with the experimental data.

Keywords:

phase transition, critical point, X(5) potential, 152-164Dy

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P1-nu.005

Report of the improvement of the beam tracking algorithm of the prototype Beam Drift Chamber (pBDC) for the LAMPS experiment

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Abstract:

The Beam Drift Chamber (BDC) is designed for the reconstruction of the track irradiated to the Large Acceptance Multi-Purpose Spectrometer (LAMPS) with the rare isotope beam produced by the Rare isotope Accelerator complex for ON-line experiments (RAON).
The prototype BDC (pBDC) has developed with long intensive tests, and the recent version of pBDC is tested with the cosmic muon and beam irradiated from HIMAC, Japan.
In this poster, we present the improvement of the tracking algorithm and the update of the performance of the pBDC.

Keywords:

BDC, Beam Drift Cahmber, Drift chamber, LAMPS, RAON

Characterization of $CeBr_3$:^{228}Ra scintillation crystal

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Abstract:

It is important to understand and model backgrounds to improve the sensitivity of underground experiments searching for rare events. ^{228}Ac and its daughter nuclei are one of the main backgrounds in underground experiments because of γ-rays, α and β particles in the decay process of ^{228}Ra. We have developed a $CeBr_3$ scintillation crystals doped with ^{228}Ra in order to study the background produced by ^{228}Ra. The $CeBr_3$ scintillator is suitable for measuring this radioactive decay because of its high light yield, good energy resolution, and short decay time. In this study, we compare the scintillation properties such as light yield, energy resolution, and decay time of the $CeBr_3$ scintillation crystal w/o ^{228}Ra doping. The activity of ^{228}Ra in the $CeBr_3$:^{228}Ra crystal is estimated based on background distributions of $CeBr_3$:^{228}Ra.

Keywords:

CeBr3, 228Ra, light yield, scintillator

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P1-nu.007

Characteristics of radiography system based on CMOS camera

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Abstract:

Recently, radiography has received considerable attention for its novel applications in homeland security, science, industry, and related fields. This report outlines the characteristics of a radiographic system developed from a digital camera. The system was built using the Raspberry Pi HQ camera and optical elements, while thin films were prepared as scintillation screens and then tested with ambient light/ X-ray beam. Using the Slanted-Edge methodology, the Edge/Line Spread Functions were deduced, which enabled extracting the Modulation Transfer Function (MTF). In addition, Noise Power Spectrum (NPS) was extracted and then allowed to estimate the Detective Quantum Efficiency (DQE). The results of MTF and DQE show that the developed system is a promising option for radiography applications.

Keywords:

Radiography, camera, scintillation, MTF, DQE

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P1-nu.008

Growing low-background NaI(Tl) using VGF method for dark matter search

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Abstract:

Many research groups are investigating the detection of dark matter through weakly interacting massive particles using sodium iodide nuclei as a detection medium. An essential requirement for these NaI-crystal-based experiments is the achievement of minimal internal background, primarily attributed to radioactive potassium, critical for annual modulation analysis. The production of large size crystals poses an additional challenge. This situation has resulted in numerous efforts to create NaI(Tl) crystals with minimal radioactivity. Diverse methodologies have been used to grow NaI(Tl) crystals. The VGF technique is useful for fulfilling the requirements of dark matter search projects, including significant crystal quantities and diameters ranging from 3-5 inches. VGF furnaces possess advantages such as low cost (compared to Czochralski or Kyropolus devices), simplicity, compactness, defined temperature profiles, and low defect density. Several VGF furnaces can be constructed quickly to meet project requirements. This study outlines the procedures for designing, assembling, and growing large NaI(Tl) crystals using the VGF method. Additionally, an analysis of the luminescence characteristics of the crystals was included as evidence of the method's feasibility.

Keywords:

Dark matter search, NaI:Tl, VGF method, crystal growth

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P1-nu.009

Cooling Performance Evaluation of Atmospheric Neutron Target Mockup with Tantalum

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Abstract:

The 100 MeV proton accelerator can produce neutrons with a high-energy spectrum generated from collisions between protons and target materials. These days, KOMAC is making many efforts to increase capabilities of the proton accelerator for advanced technology and science, especially with the growing demand from the industry field. As part of this, a mock-up of an atmospheric neutron target using Tantalum was fabricated to provide an environment for investigating semiconductors under atmospheric radiation impacts. The target system has a structure in which neutrons are generated by a nuclear reaction between a proton having an energy of 100 MeV and a tantalum (Ta) target. The Ta is in the form of a thin cylinder with a diameter of 10 cm and a thickness of 1.2 cm, and is composed of a frame and a flange surrounding it. It is possible to establish experimental conditions that meet the stable operating conditions of a thermal load test facility through simulation analysis based on a commercial program that secures reliability. In this experiment, the temperature distribution for each area of the test mock-up according to the heat load application condition was preliminarily analyzed using ANSYS CFX. The cooling performance of the mock-up was tested under the heat flux change condition in the range of 0.2 MW/m^2 to 0.5 MW/m^2, and the temperature data measured by the infrared camera were compared and analyzed with the results of preliminary simulation.

Keywords:

Accelerator, Atmospheric Neutron, Target

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P1-nu.010

Simulation study on charged-particle production as a function of transverse activity classifier in proton-proton collisions

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Abstract:

In the past decade, small collision systems, such as proton-proton and proton-ion collisions, have attracted significant attention in the field of high-energy nuclear physics. This stems from the similarity of observed phenomena including strangeness enhancement and collective flow in such systems to those in heavy ion collisions. Moreover, a particular interest has emerged to investigate particle production with respect to the Underlying Event (UE) activity, aiming to uncover the primary causes of observables traditionally associated with heavy-ion collisions.
In this study, we categorize events into three azimuthal regions - "toward," "transverse," and "away"- based on the highest transverse momentum (p_T) particle in each event. The size of the UE is estimated by using the relative transverse activity classifier, $R_T = N_T/\langle N_T \rangle$, where N_T corresponds to the number of charged particles in each azimuthal region. In the previous measurements by ALICE, higher p_T particle production relative to the R_T-integrated distribution decreases with increasing R_T in the "toward" and "away" regions. These results and theoretical models indicate a strong correlation between the number of multiple-parton interactions and the measured R_T. For this poster, we test the sensitivity of R_T with respect to different model-dependent quantities in both PYTHIA-8 and EPOS-3 event generators. In particular, the sensitivity of R_T is used to compare the relative fraction of core/corona in EPOS-3 to test the phenomenological dependency of R_T as a descriptor of the UE.

Keywords:

PYTHIA-8, EPOS-3, Underlying Event, RT

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P1-nu.011

Feasibility study of K_1 measurement in pp collisions with ALICE

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Abstract:

Measuring chiral partners, such as K_1 and K^* mesons whose vacuum width is less than 100 MeV, is suitable for investigating chiral symmetry restoration in heavy-ion collisions. According to a recent theoretical calculation, the K_1/K^* ratio within heavy-ion collisions is anticipated to be substantially larger than the predictions of the statistical hadronisation model. By exploring the K_1/K^* ratio as a function of multiplicity across diverse collision systems ranging from pp to central heavy-ion collisions, valuable insights into the effects of chiral symmetry restoration can be obtained. The ALICE detector has remarkable particle identification capabilities, thereby enabling the measurement of the K_1 meson through its hadronic decay pathways like $K_1^- \rightarrow \rho^0 K^-$ and $K_1^- \rightarrow \pi^- K^{*0}$. In this poster, the feasibility study of the K_1 measurement in pp collisions with ALICE is presented.

Keywords:

Chiral partner, Heavy-ion collision, ALICE

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P1-nu.012

Investigating new methods for high-purity phi-meson identification in hadron-hadron collisions

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Abstract:

The measurement of the phi-meson is of great importance in the field of high-energy nuclear physics, as it provides insights into the phenomenon of strangeness enhancement (SE) across various collision systems. While this enhancement has historically been recognized as a distinctive characteristic of the Quark-Gluon Plasma (QGP), it is intriguingly observed even in proton-proton collisions where QGP is believed to be absent. The phi-meson can serve as a unique probe into the underlying features of SE, since its description of hadronization imposes significant constraints on different phenomenological approaches. In experiments, the phi-meson yield is estimated through the reconstruction of the invariant mass of its constituent decay particles, which involves the challenging task of identifying K+K- pairs. This is further complicated due to the extremely short lifetime (mean of 1.55±0.01 × 10^−22 seconds) of the phi-meson, resulting in decaying kaons that are indistinguishable from primary kaons through traditional particle identification techniques. To overcome such complications, we aim to develop new methods of estimating the combinatorial background of the invariant mass distribution of K+K- pairs (branching ratio = 49.2±0.5%). We use the PYTHIA-8 event generator to simulate the production of the phi-meson in proton-proton collisions, and demonstrate higher purity by implementing various kinematic selection criteria for the phi-meson.

Keywords:

Quark gluon plasma, phi-meson identification, Invariant mass

P1-nu.013

Searching for a hint of jet modification in small systems with AMPT model

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Abstract:

A collective behavior of produced particles and jet modification in heavy-ion collisions are evidence of the formation of Quark-Gluon Plasma (QGP). Interestingly, a similar collective behavior has been observed in small collision systems, such as pp and pA collisions, but there is no sign of jet modification yet. The system size of pp and pAu collisions may not be large enough for the jet modification that can be measured experimentally. Using the two-particle correlation method, we perform a model study with AMPT, which can reproduce the collective behavior in small systems, to search for a hint of jet modification in pA collisions. In this poster, we will present the status of the model study and the prospect of real data analysis.

Keywords:

AMPT, Two particle correlation, Jet modification

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P1-nu.014

Jet flavor tagging in pp collisions using neural network for the ALICE experiment

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Abstract:

Jet is a bunch of particles with high momenta that emerge from the initial hard scatterings in high-energy particle collider experiments. Typically, jets result from the parton shower, hadronization, and decay processes of energetic partons. Jet flavor tagging identifies which flavor of quark or gluon is responsible for jet production. Charm and bottom quarks require more energy for their production due to their larger masses compared to light quarks. Consequently, the production of heavy quarks can be precisely calculated using perturbative QCD, underscoring the significance of heavy flavor jet measurements in advancing the understanding of QCD. The heavy-flavor jets can be identified based on their properties of more jet constituents and longer lifetime of charm and bottom hadrons. This study introduces a neural network approach to improve flavor tagging performance using Monte-Carlo simulation data for the ALICE experiment. In this research, jet flavor tagging is performed, including a secondary vertex finding process by Set2Graph neural network. Due to the exceptional vertex finding performance of the Set2Graph neural network, an increase in the accuracy and purity of jet flavor tagging is anticipated.

Keywords:

ALICE, Jet flavor tagging, Neural network

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P1-nu.015

Investigation of bias on the centrality-dependent nuclear modification factor in p+A collisions with Monte-Carlo event generators

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Abstract:

The nuclear modification factor is one of the main observables to quantify the properties of medium effects of Quark-Gluon Plasma (QGP) produced in heavy-ion collisions at the LHC at CERN and RHIC at BNL. Recently, extensive studies have been performed to search for medium effects in high multiplicity p+p and p+A collisions. There are several experimental results of collective flow, but no clear evidence of jet modification is observed. One difficulty in the quantitative study of medium effects with nuclear modification factor is a bias to determine the number of binary collisions ($\langle N_{coll} \rangle$) in various multiplicity ranges. This bias is due to the different kinematics of hard and soft scatterings, and the bias effect is larger in p+A collisions where the overall multiplicity is small. There are different approaches to handle this bias. Recent PHENIX results show suppression of high p_T π^0 in high multiplicity d+Au collisions at 200 GeV with a newly calculated $\langle N_{coll} \rangle$ based on the nuclear modification factor of direct γ, expected to have no medium effect. We investigate this bias effect in small systems for different physics processes with the Monte-Carlo event generator (PYTHIA). This study helps further understand experimental data, particularly centrality-dependent nuclear modification factors.

Keywords:

Centrality bias, Nuclear modification factor, Small collision system

2023 KPS Fall Meeting
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P1-pa.001

Performance Tests of Pure LaCl3 Scintillation Crystal

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Abstract:

The development of 35Cl-contained crystals for the fast neutron detection has been proposed because of significant cross-sections for 35Cl(n,p)35S and 35Cl(n,alpha)32P reactions. Cs2LiYCl6 scintillation crystal has been considered for the fast neutron spectroscopy due to its dual mode gamma/neutron capability with good energy resolution, but it has issues of radiation tolerance and inability to separate alpha and proton particles using the pulse shape discrimination(PSD). Pure LaCl3 crystals have been grown using Bridgman technique, and three different sizes of the crystals have been prepared for tests of their performance. In this paper, we present motivation of studying the pure LaCl3 crystal and its PSD capability for direct neutron spectroscopy. The radiation hard characteristics of the pure LaCl3 crystals using 100 MeV proton beam at KoreaMulti-purpose Accelerator Complex are also presented.

Keywords:

LaCl3, radiation damage, pulse shape discrimination, Bridgman

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P1-pa.002

Design and optimization of KAPAE phase II detector and trigger

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Abstract:

The KNU Advanced Positronium Annihilation Experiment (KAPAE) can contribute to the field of particle physics by investigating rare decays in 3-gamma annihilation of positronium, such as those involving milli-charged particles, the mirror world, new light X-bosons, and extra dimensions. The ground state of positronium (Ps) exhibits two distinct configurations based on the relative spin orientations: the triplet state ($^3S_1$), known as ortho-positronium (o-Ps), and the singlet state ($^1S_0$), referred to as para-positronium (p-Ps). Given the conservation of C-parity, the decays of p-Ps and o-Ps lead to even and odd numbers of gamma particles, respectively. This study involves designing and optimizing KAPAE phase II detector and a phoswich trigger utilizing PEN film and BGO scintillation crystals. Investigating the performance of diffused BGO scintillation crystals, we observed energy resolutions of 12% and 11.2% for the single-side PMT configuration and the coincidence of both-side PMT configurations, respectively. I'll present the study of the minimization of dead areas, enhanced trigger efficiency, and optimization of the detector design for KAPAE phase II experiment.

Keywords:

KAPAE, positronium, phoswich, BGO

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P1-pa.003

Measurements of concentration of Gd in Gd-loaded LAB-based Liquid Scintillators

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Abstract:

Neutrinos can be detected using inverse beta decay (IBD) in a detecter filled with a liquid scint-illator. Commonly, because neutrino experiments take a long time, the gadlinium concentration of a gadolinium (Gd)-loaded linear alkyl benzene (LAB)-based liquid scintillator must be stable.Therefore, the gadolinium concentration and the water content of the liquid scintillator should be optimized for the experiment. In this study, the gadolinium concentration was measured by using EDTA (ethylene diamine tetraacetic acid) titration, we described methods for measuring in various Gd concentrations.

Keywords:

EDTA titration, Gd-loaded LAB-based Liquid Scintillators, neutrino experiments

2023 KPS Fall Meeting
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P1-pa.004

Vertex Reconstruction with Deep Learning based on GNN in KNO Detector

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Abstract:

The Korean Neutrino Observatory (KNO) is a project proposed as a next generation neutrino experiment with a large scale water Cherekov detector. Precise determination of the event vertex location is important in many aspects of the neutrino physics analyses. In this presenation, we present an event vertex reconstruction method using a deep learning algorithm based on Graph Neural Network (GNN).

Keywords:

deep learning, korean neutrino observatory, neutrino

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P1-pa.006

Axion dark matter search around 23.5 μeV using a multi-cell microwave cavity and a flux-driven Josephson parametric amplifier

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Abstract:

The axion is a hypothetical particle that was first proposed as a potential solution to the strong CP problem in particle physics. It is also one of the most promising candidates for explaining dark matter. In a global effort to prove the existence of axions, many institutes rely on axion haloscopes that make use of the axion-to-photon conversion to prove the existence of dark matter axions. IBS-CAPP set up an experiment to search for axions in the mass range of 23.33 μeV to 23.74 μeV, with sensitivity to a benchmark set by the KSVZ model, using a novel multiple cell (8-cells) cavity and a state-of-the-art flux-driven Josephson parametric amplifier. In this poster, we present the status of the experiment and discuss its prospects.

Keywords:

axion, dark matter, strong CP, josephson parametric amplifier

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P1-pa.007

Data classification for KAEM using Quantum Machine Learning

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Abstract:

KoreA Experiment on Magnetic Monopole (KAEM) is designed to search for elementary magnetic monopoles in the region of mass and charge below the electron mass and charge. Using the GEANT4 simulation package, we configured the electromagnetic calorimeters and the trigger-veto detector and generated Monte Carlo events. In this study, quantum machine learning is used to classify these events into two categories such as signal and background. For this classification, a hybrid classical-quantum model is established by combining a quantum convolution (quanvolution) filter and the classical CNN model. The performance of quantum machine learning is compared with that of classical machine learning in image classification. This poster will present this comparison results.

Keywords:

Quantumm machine learning, Quanvolutional Neural Networks(QNNs), Hybrid classical-quantum, image classification

2023 KPS Fall Meeting
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P1-pa.008

Development of 16-channel switching system for testing of Hyper-Kamiokande readout electronics

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Abstract:

For Hyper-Kamiokande water Cherenkov detector, there will be 20,000 photomultiplier tubes (PMTs) of 20-inch diameter and about 7200 PMTs of 3-inch diameter will be deployed. There will be the readout electronics associated with these PMTs installed in the detector as well to measure the intensity (photon counting) and arrival time of Cherenkov light. Testing of these 27,200 electronics channels will be time-consuming and error-prone if it would be done single channel by single channel. To facilitate the testing of these electronics channels, we have developed a switching system that distributes an input signal sequentially to 16 channels of the readout electronics. The switching system consists of a switch board equipped with relay chips and a control board equipped with a field-programmable gate array (FPGA) chip. In this presentation, the design, fabrication, and performance of the switching system including insertion loss and isolation (cross-talk) will be reported.

Keywords:

Hyper-Kamiokande, Switching system

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P1-pa.009

Estimation of the background and sensitivity for AMoRE-II

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Abstract:

The AMoRE-II project represents the subsequent phase of the Advanced Mo-based Rare process Experiment (
AMoRE), dedicated to the search for the neutrinoless double beta decay within the ^{100}Mo isotopes. The initial phase of AMoRE-II is being prepared at the Yemi Underground Laboratory (Yemilab), situated within the Handuk mine on Yemi Mountain.

To achieve the maximal sensitivity, the AMoRE needs to operate the detector with an exceedingly low background rate of 10^{-4} background events/keV/kg/year. Predominant contributors to the background include radioactive impurities embedded within construction materials, especially the long-lived uranium and thorium isotopes. Additionally, background arises from the influx of environmental neutrons, muons, and gamma rays at the experimental site. To quantitatively assess the background conditions ingerent in the AMoRE-II setup, comprehensive simulations were conducted employing the GEANT4 Toolkit. These simulations examined the contributions to background levels originating from both proximate and distal components.

In this presentation, we will explain the diverse background simulations, encompassing assessments of external shield materials, detector modules, and intricate components near the detectors. Finally, the estimated background levels within the region of interest will be presented.

Keywords:

Backgrounds for the underground experiments, Geant4 simulation, AMoRE, neutrinoless double beta decay

2023 KPS Fall Meeting
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P1-pa.010

Feasible study of ratio LAB and DIN-based LS using SiO2 core-shell perovskite QDs perovskite

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Abstract:

The spectroscopic characteristics of the SiO2 core-shell perovskite QDs used as solvents are examined in this work, along with how the DIN/LAB mixing ratio affects the photomultiplier signal response. The scattering of MIE was estimated for the size of quantum dot nanoparticles in comparison to their emission wavelength.

Keywords:

LS, SiO2 core-shell perovskite QD, DIN, LAB, PMT

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P1-pa.011

Fast Neutron Monitoring System for the COSINE-100 Experiment

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Abstract:

The COSINE-100 experiment, a dark matter weakly interacting massive particles (WIMPs) search experiment, runs at the Yangyang Underground Laboratory, about 700m below the earth's surface with a low cosmic-ray muon background environment.

In this experiment, it is important to distinguish neutron event rate, because nuclear recoils by neutron events can mimic the WIMP-nucleon interactions. To monitor the neutron event rates, we have installed a liquid scintillator detector to detect fast neutrons.

Neutron events were selected based on the boosted decision tree (BDT) method and we were able to achieve a figure of merits discriminating gamma with a value of 6.4 sigma. The time coincidence condition was employed for the identification of alpha events, which ultimately allowed us to determine the neutron flux.

In this poster, the discrimination of alpha and gamma will be presented in detail.

Keywords:

Neutron, COSINE-100, WIMP, DarkMatter, BDT

2023 KPS Fall Meeting
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P1-pa.012

Event selection status in the NEON experiment for coherent elastic neutrino-nucleus scattering signal detection

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Abstract:

The Neutrino Elastic Scattering Observation with NaI (NEON) experiment is being conducted at the Yeonggwang Hanbit Nuclear Power Plant in South Korea. The main goal of the NEON experiment is to detect coherent scattering of electron neutrinos using a 16.7kg NaI(Tl) crystal detector. Since the energy threshold for signal detection is very low, around 0.3 keV, it is crucial to minimize background noise components, including electronic noise generated mainly by PMTs. We are currently observing a background level of 6 counts/day/kg/keV at a threshold of 0.6 keV. In this poster, we introduce the characteristics of noise components and explain the results of waveform simulations in the vicinity of the 1 keV range using a data-driven machine learning approach to distinguish between scintillation signals and PMT noise.

Keywords:

neutrino, NEON, cenns, cevns, event selection

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P1-pa.013

RENE Prototype Design

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Abstract:

The primary objective of the Reactor Experiment for Neutrinos and Exotics (RENE) is to investigate oscillations of sterile neutrinos within the Δm_41^2 range of approximately 2 eV^2. The detector will be located at the tendon gallery of a reactor in Hanbit Nuclear Power Plant at Younggwang.
In this study, we present the precise 3D design and modeling of the RENE detector. This design was implemented using the SolidWorks software, taking into account the structure, material of the detector and manufacturability in reality.
We performed Solidworks simulation of structural safety with Gd-LS and LS filled in the target and gamma catcher region.

Keywords:

RENE

P1-pa.014

A study to improve performance for AMoRE-II Detectors

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Abstract:

The AMoRE collaboration is conducting experiments to detect neutrinoless double beta decay of 100Mo. The experiments use large molybdenum-based scintillating crystals with cryogenic sensors. The forthcoming AMoRE-II will involve using large cylindrical Li2MoO4 (LMO) crystals 6 cm (H) x 6 cm (D), with diffusive surfaces to reduce preparation time and minimize damage by humidity. Even with the increased mass of these crystals, they perform similarly to the previous 5 cm (H) x 5 cm (D) LMO crystals. The diffusive surfaces of the LMO crystals have improved the discrimination between alpha and beta/gamma particles through pulse shape discrimination (PSD) analysis, despite the slower signal compared to polished crystals. We have also investigated muon events, which showed two bands in the PSD parameter (like the signal's rise time) of the LMO crystal with polished surfaces. Developing detectors with LMO crystals requires optimization of the crystal and environmental setup conditions and utilizing pulse shape analysis due to the lower scintillation light yield than CaMoO4 crystals used in the previous phases. We will present detailed information on the preparation and expected results of the AMoRE-II R&D experiment

Keywords:

AMoRE, Li2MoO4, LTD

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P1-pa.016

The performance test of 20 inch PMT for RENE experiment

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Abstract:

RENE (Reactor Experiment for Neutrinos and Exotics) is the experiment to search for sterile neutrino at $\Delta m_{41}^2 \simeq 2eV^2$. The detector will be located at the tendon gallery of a reactor in Hanbit Nuclear Power Plant at Yonggwang. Two 20 inch PMTs, R12860 made by Hamamatsu will be installed for RENE prototype detector. Several tests were performed to investigate the characteristics about charge and time response of PMT. In this presentation, position and wavelength dependency of PMT will be reported in details.

Keywords:

RENE, 20 inch PMT, neutrino, wavelength, position

2023 KPS Fall Meeting
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P1-pa.017

Simulation of neutron on A WIMP Detector using GEANT4

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Abstract:

Using the Geant4 simulation, we have tested a Xenon detector's efficiency in detecting WIMPs. This detector is ideal due to their ability to differentiate between the relevant and background signals. Our study revealed that neutrons deposit energy in the Xenon detector, irrespective of their incoming energy. This result is important because it needs to discriminate between signals from WIMPs and neutrons. Given that the neutrons contribute significantly to disfferenciate to background interference in WIMP detectors, this capability enhances the detector's sensitivity and increase our chances of detecting WIMPs from background signals.

Keywords:

GEANT4, WIMP

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P1-pa.018

Investigating the Potential of Perovskite Nanocrystal-Doped Liquid Scintillator: A Feasibility Study

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Abstract:

Liquid scintillators are extensively employed as targets in neutrino experiments and in medical radiography. Perovskite nanocrystals are recognized for their tunable emission spectra and high photoluminescence quantum yields. In this study, we investigated the feasibility of using perovskites as an alternative to fluor, a substance that shifts the wavelengths. The liquid scintillator candidates were synthesized by doping 450, 480 and 510-nm perovskite nanocrystals into fluor PPO with varying nanocrystal concentrations in a toluene solvent. The several properties of the perovskite nanocrystal-doped liquid scintillator were measured and compared with those of a secondary wavelength shifter, bis-MSB. The emission spectra of the perovskite nanocrystal-doped liquid scintillator exhibited a distinct monochromatic wavelength, indicating energy transfer from PPO to the perovskite nanocrystals. The light yield, pulse shape, and wavelength shift of the scintillation events were measured based on the Compton scattering of a 60Co radioactive source, triggered by a coincidence of photomultiplier tube (PMT). The light yields were evaluated from observed Compton edges from the γ - ray source. A decrease (or increase) in area-normalized PMT pulse height was observed at higher perovskite nanocrystal (or PPO) concentrations. The results demonstrated the sufficient potential of perovskite nanocrystals as an alternative to traditional wavelength shifters in liquid scintillator.

Keywords:

Perovskite Nanocrystal, Liquid Scintillator, PMT, Neutrino detector

P1-se.101

Hexagonal Ge-AlN core-shell microneedles: Growth method and mechanism

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Abstract:

반도체 분야에서 core-shell 결합 기술은 나노 복합 반도체를 형성함으로써 반도체의 특성 변화를 유도할 수 있기에 중요한 소자 응용 기술이다. 본 연구에서는 Mixed-source HVPE 성장 방법을 통해 형성된 AlN nanowire로부터 hexagonal Ge-AlN core-shell microneedles을 성장하였다. 성장은 소스 영역과 성장 영역이 구분되지 않고, 성장 중 소스를 공급하지 않는 Mixed-source HVPE 성장 방법을 사용하여 수행하였다. 일반적인 core-shell 성장 방법과 달리 AlN nanowire의 초기 형성으로 인해 AlN shell이 먼저 형성된다. 이후 Ge 원소를 흡수하여 세로 방향으로 성장하고, 측면 확장되어 Ge core이 형성되는 새로운 성장 mechanism을 파악하였다. 형성된 hexagonal Ge-AlN core-shell microneedles의 표면과 단면은 FE-SEM 및 TEM 결과를 통해 조사하였다. 단면 EDS 맵핑 분석은 microneedles의 shell 및 core가 각각 95.62 at.% Al 및 98.15 at.% Ge로 구성되었음을 보여주었다. 라만 스펙트럼 결과로부터 입방체 Ge에 비해 6.3cm^{-1} 낮은 E_{2g} 모드 값을 관찰하였다. 이러한 결과들은 Mixed-source HVPE를 사용하여 안정적인 hexagonal Ge-AlN core-shell microneedles을 성장하였음을 나타낸다.

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Keywords:

Mixed-source HVPE, Core-shell, hexagonal, Microneedle, Nanowire

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P1-se.102

Characterization of hexagonal Si epilayers grown on 4H-SiC substrates

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Abstract:

SiC는 Si보다 에너지 효율이 높기 때문에 고효율 전력소자용 소재로 현재 많은 연구가 진행되고 있다. 그러나 SiC는 SiC/SiO2 게이트 구조에서 Si/SiO2 게이트 구조보다 높은 계면 트랩 밀도(Dit)를 가지고 있다. 이에 SiC/SiO2 게이트 구조의 Dit를 줄이는 가장 효과적인 방법으로 4H-SiC 기판 위에 고품질의 결정질 Si 에피층을 성장시키는 방법이 많은 관심을 받고 있다. 본 연구에서는 혼합소스 HVPE 방법을 이용하여 SiC 기판 위에 미완성 상태의 Al 기반 나노 구조체를 형성한 후 Al 기반 나노 구조체가 주변 Si 원자를 흡수하여 성장된 육각형 Si 에피층의 성장을 보고한다. 이러한 4H-SiC 기판 위에 Si 에피층의 성장 메커니즘은 총 5단계에 걸쳐 진행되며 이를 FE-SEM을 통해 확인하였다. 또한 EDS의 결과로부터 4H-SiC 기판 위에 성장된 에피층이 Si 에피층임을 확인하였다. 추가적으로 Raman 측정을 진행하였으며 성장된 Si 에피층은 P63/mmc(D46h) 공간군에 속하는 육각형 2H-Si 구조로 추정되며 이는 일반적인 입방정계 Si 구조와는 다른 특성을 나타내는 것을 확인하였다. 따라서 본 연구는 SiC/SiO2 게이트 구조의 Dit를 줄이는 방법으로 혼합소스 HVPE 방법을 이용한 Si 에피층의 성장을 제안하며, 이러한 결과는 Si on SiC 구조가 잠재적인 차세대 고효율 전력소자 응용에 기여 될 것으로 기대된다.

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Keywords:

4H-SiC, HVPE, hexagonal Si, Si epilayer, Si 에피층 성장 메커니즘

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P1-se.103

Effects of RF power on oxygen content and surface morphology of $ZnSnN_2$ grown by reactive RF magnetron sputtering

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Abstract:

Ternary II-VI-N_2 is a promising material system which can substitute III-nitrides due to its intrinsic merits such as earth-abundant, non-toxic, and inexpensive elements. Among various II-VI-N_2 ,$ZnSnN_2$ has various expected superior characteristics such as direct bandgap in visible range, high absorption coefficient and high carrier mobility. However, $ZnSnN_2$ has a serious issue for device application; intrinsic degenerate high n-type doping. The extreme n-type polarity is responsible for the presence of oxygen-associated donor-like defects. In this report, we have grown several $ZnSnN_2$ samples on a (0001) sapphire substrate using reactive RF magnetron sputter by varying RF power to reduce the n-type doping concentration. We also probed the samples with various techniques to see the changes in morphological and structural properties upon changing RF power.

The authors would like to acknowledge support from the National Research Foundation of Korea (NRF) grant funded by the Korean government (MSIT) (NRF-2022R1F1A1064130).

Keywords:

ZnSnN2, reactive RF magnetron sputtering, RF power, oxygen content, surface morphology

다목적 응용을 위한 희토류 도핑된 $NaKLaNbO_5$ 형광체의 합성 및 발광 특성

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Abstract:

최근 몇 년 동안 광학 온도계의 비접촉식 온도측정은 농업, 건강 관리, 산업 생산, 과학 연구 등과 같은 다양한 분야에서의 광범위한 응용으로 인해 점점 더 많은 관심을 받고 있다. 본 발표에서는 온도 센서 응용을 위한 고체상 반응법을 통해 Sm^{3+} 및 Tb^{3+} 이온 단일/공동 도핑된 $NaKLaNO_5$ 형광체를 제작하였고, 그 발광특성을 조사하였다. 또한, X-선 회절 분석은 도펀트 이온이 결정 구조에 약간의 영향을 미친다는 것을 보여주고, 광발광 및 광발광 여기 스펙트럼은 주로 electric dipole-dipole 상호 작용에 의존하는 농도 quenching의 영향을 보여준다. 공동 도핑된 샘플의 방출 강도에 따른 온도는 303 K에서 483 K의 온도에서 연구되었다. 그 후, 최적화된 $NaKLaNbO_5:Sm^{3+}/Tb^{3+}$ 형광체를 준비하고 이를 기반으로 한 다채널 수명 온도계측 특성을 조사하였다. 이러한 결과는 합성된 Sm^{3+} 및 Tb^{3+} 도핑된 $NaKLaNbO_5$ 재료가 광학 수명 온도 계측 및 보안 필름의 다목적을 위한 잠재적 형광체가 될 것으로 기대됨을 시사한다.

Keywords:

형광체, 희토류, NaKLaNbO5, 발광특성, 온도계측

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P1-se.105

Al_2O_3-passivation layer as a route to prevent oxidation of HfS_2 in ambient condition

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Abstract:

Unexpected oxidation of two-dimensional transition metal dichalcogenides (TMDs) in ambient condition is a critical issue which can possibly degrade their physical properties as well as device performance. Hafnium disulfide (HfS_2) as one of the IVB-TMDs has expected superior electrical and physical properties as compared with its siblings such as MoS_2. However, device applications of HfS_2 have been restricted due to its rapid oxidation in ambient condition. In this report, we investigated the effect of surface passivation of HfS_2. For the investigation, HfS_2 is grown using chemical vapor deposition (CVD), and its surface is passivated using Al_2O_3 formed by atomic layer deposition (ALD). The HfS_2 passivated by Al_2O_3 is less affected by oxidation as compared with the bare HfS_2.

Keywords:

HfS2, CVD, TMDs, oxidation

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P1-se.106

Structural and electrical characteristics of Pt thin films fabricated by oblique-angle deposition

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Abstract:

Oblique-angle deposition(OAD) 기술을 적용해 증착한 박막은 낮은 굴절률, 자기 및 광학 이방성 등 다양한 특성을 손쉽게 제어할 수 있어 나노 구조를 필요로 하는 다양한 응용 분야에서 연구되어 왔다. OAD 박막의 근본적인 특성으로는 다공성(porosity)이 있는데, OAD 박막의 다양한 물성이 다공성의 정도에 따라 변하게 된다. 이 다공성은 증착 장비, 증착 물질의 종류, 그리고 무엇보다 증착 물질의 입사각에 따라 크게 영향을 받기 때문에 다공성을 정밀하게 제어하는 기술과 그 원리의 이해는 OAD 증착 박막의 응용을 위해 매우 중요하다.

본 연구는 스퍼터를 이용하여 Pt 금속 박막을 OAD 기술로 증착 후, 다양한 입사각에 따른 다공성의 변화와 그에 따른 박막의 구조적, 전기적인 특성을 분석하였다. 첫째로, Si 기판 위에 다양한 입사각에 따라 증착된 Pt 박막의 나노 구조를 주사전자현미경(SEM)을 통해 관찰하여, 실제 나노 기둥의 각도를 tangent rule에 의한 이론상의 각도와 비교하여 분석하였다. 또한, 그림자 효과에 기반한 구조 모델을 적용해 박막의 다공성 정도를 계산하여, 이를 증착 물질의 입사각, 나노 기둥의 각도 등과 비교하여 그 관계를 분석하였다. 둘째로, 4-point-probe 장비를 이용한 면저항 측정을 통해 OAD 박막의 전기적인 특성을 조사하였다. OAD Pt 박막의 면저항은 입사각이 증가함에 따라 지수적으로 증가하는 경향을 보여 박막의 다공성 정도와 밀접한 관계가 있음을 확인하였다. 박막을 표면에서 회전시키며 면저항을 측정하였을 때, 방사형 방향에 따라 달라지는 면저항의 이방성을 발견하였다. 이와 같은 현상은 한쪽 방향으로 배열된 나노 기둥이 면저항 측정에서 방사형 방향에 따라 다공성의 차이가 발생하기 때문인 것으로 보인다.

본 연구는 OAD 기술을 적용해 다양한 입사각에 따라 증착한 Pt 박막의 구조적 특성과 그에 따른 전기적 특성을 보여준다. Pt 금속 박막의 다공성을 계산하기 위해 그림자 효과에 기반한 구조 모델을 적용하였고, 다공성과 면저항의 관계를 심층적으로 분석하였다.

Keywords:

OAD, 박막, 입사각, 다공성, 나노 기둥, 면저항, 이방성

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P1-se.107

Thickness-dependent Reflectance and RGB color on Optical image of Perovsktie microplate

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Abstract:

$CsPbBr_3$ has recently gained significant attention in semiconductor devices owing to its ability to form high-quality materials via low-temperature solution processes. We employed the antisolvent-vapor diffusion method to generate $CsPbBr_3$ perovskite micro-crystals with various shapes and sizes. In this study, we investigated a method to estimate the thickness of perovskite microplates from optical micrograph. Using a transfer Matrix Method (TMM), we calculated the reflectance of $CsPbBr_3$ microcrystals grown on a SiO_2/Si substrate depending on the thickness. Converting from the calculated reflectance to CIE XYZ and RGB values, we demonstrated a thickness-dependent RGB color chart of $CsPbBr_3$ microplates. These results can provide a simple approach to estimate the thickness of microcrystals with the various shapes.

Keywords:

CsPbBr3 perovskite microplate, Optical image, RGB color index

Measurement of the Carrier Lifetime in the Mid-wavelength Photodiode using InAs/GaSb Type II Superlattice

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Abstract:

Increasing the carrier lifetime is crucial for improving the performance of the device in the type II strained layer superlattice (SLS). A longer carrier lifetime allows more time for carriers to contribute to the device's electrical signal, leading to better sensitivity and performance. We used the technique of the reflectance measurement by a microwave , the change in microwave reflectance was then measured, and the carrier lifetime could be deduced from the response. We will present the measured carrier lifetime about the InAs/GaSb type II SLS.

Keywords:

Photodiode, Type II SLS, Superlattice

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P1-se.109

Estimation of effective refractive index of colloidal quantum dot thin film using optical contrast spectroscopy

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Abstract:

Colloidal quantum dots consist of an inorganic semiconductor core and organic ligands, so they can be produced in a dispersed form in an organic polymer solution. These properties facilitate the fabrication of simple devices utilizing spin coating technology. The effective refractive index of colloidal quantum dot films can vary depending on factors such as ligand type and core size. This study incorporates analytical computational techniques based on reflectance and optical contrast measurements, which were acquired using the transfer matrix method and micro-reflectance spectroscopy. Based on these analysis, we introduce an approach to infer the effective refractive index of entire quantum dot thin films.

Keywords:

Colloidal Quantum Dot, Optical Contrast, Effective Refractive Index

P1-se.110

Enhanced stability of perovskite nanocrystals by the microwave-assisted method

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Abstract:

Perovskite nanocrystals (PNCs) demonstrate remarkable optical and optoelectronic characteristics. Their exceptional photoluminescence quantum yield (PLQY), narrow full width at half maximum (FWHM), and adjustable bandgap have prompted extensive exploration in diverse fields including solar cells, light-emitting devices, and X-ray scintillators. However, the synthesis of $CsPbI_3$ PNCs has remained a challenge, primarily due to instability issues. A promising approach involves microwave-assisted synthesis, which offers a more straightforward and scalable means of producing high-quality perovskite nanocrystals.

In this study, we delved into the microwave-assisted synthesis of $CsPbI_3$ PNCs. Through careful manipulation of precursor ratios and reaction durations, we successfully optimized the composition of $CsPbI_3$ nanocrystals. The outcome yielded $CsPbI_3$ nanocrystals with an impressive high PLQY of around 90% and enhanced stability. This microwave-assisted method not only ensures quality but also holds the potential for large-scale production of these nanocrystals.

Keywords:

Perovskite, stability

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P1-se.111

Au Buffer Layer Effects on Fabrications of $LiNbO_3$ on ZnO:Al Double Layers by Using the RF Magnetron Sputter Depositions

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Abstract:

We investigated the effects of Au buffer layer for fabrications of lithium niobate ($LiNbO_3$, LN) on aluminum-doped zinc oxide (ZnO:Al) double layers by using the RF magnetron sputter deposition method. The Au buffer layers were deposited by using the DC magnetron sputter deposition method on the substrate and/or the ZnO:Al thin films; Rapid thermal annealing (RTA) processes in a low vacuum pressure of 10.0 Pa were applied to the Au buffer layers on the substrate and/or on the ZnO:Al thin films with or without Au buffer layer in the temperature range between 700°C and 1000°C. As the deposition time was decreased for the Au buffer on the substrate, the intensity of the Au (111) X-ray diffraction (XRD) peak was decreased but the four-point probing (FPP) surface resistance was increased. As the substrate temperature was decreased from 600°C to RT during the depositions of the ZnO:Al thin film, the intensity ratio of $I_{(101)}$ / $I_{(002)}$ was decreased to zero in the XRD patterns of ZnO:Al thin films without buffer layer. The ZnO:Al (101) XRD peak was not observed in the XRD patterns of the ZnO:Al thin films with Au buffer layer. As the RTA process temperature for the ZnO:Al thin film was increased from 700°C to 1000°C, the intensity of Zn (002) XRD peak increased while the FPP surface resistance was decreased. LN/ZnO:Al double layer was fabricated by coating the LN thin films on the RTA processed ZnO:Al thin film with or without Au buffer. The LN (0006) + Li_3NbO_4 XRD peaks were observed in the RTA processed LN thin films. As the RTA process temperature was increased from 700°C to 1000°C in the LN/ZnO:Al double layer, the XRD peak revealed that the LN layer on ZnO:Al layer without Au buffer layer was decomposed into polycrystalline Li_3NbO_4 + LN + $LiNb_3O_8$ phases. Although only the Li_3NbO_4 and ZnO (0002) XRD peaks were observed in the XRD pattern of the as deposited LN/ZnO:Al double layers, we observed that the intensities of the LN (006) and $LiNb_3O_8$ XRD peaks were increased in the XRD pattern of the RTA processed LN/ZnO:Al double layers. We are further studying on the Au buffer layer effects on the physical properties of the LN/ZnO:Al double layer to fabricate a staggered bottom-gate thin film transistor configurations where there is ferroelectric insulating LN layer on the transparent conductive ZnO:Al layer with or without Au buffer layer on the substrate.

Keywords:

Au buffer layer, RF magnetron Sputtering, LiNbO3 thin film

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P1-se.112

Theoretical study of electronic structure and thermal properties of phase change materials: $Cr_2Ge_2Te_6$ and $Ge_2Sb_2Te_5$

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Abstract:

$Cr_2Ge_2Te_6$(CGT), known as a material of phase transition, has unique properties and characteristics that are in contrast to the well-known $Ge_2Sb_2Te_5$(GST) material. For example, CGT exhibits high electrical resistance, and GST exhibits low resistance when in a crystalline state. However, when in an amorphous state, CGT exhibits low resistance, while GST has high resistance. It is also known that low resistance occurs within amorphous structures due to Cr-Cr clustering. In this study, we investigate the electronic structures of CGT and GST using density functional theory (DFT) calculations. Using the density-derived electrostatic and chemical (DDEC6) analysis method, we calculate the sum of bond order and introduce the concept of metavalent bonding to elucidate the electrical properties of phase change materials. Further, we study the atomic-scale evolution of CGT and GST depending on temperature using molecular dynamics (MD) and neural network potentials (NNPs). Thus, we investigate its thermal behavior and characteristics during the melting and crystallization process.

Keywords:

neural network potentials (NNPs), crystallization process

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P1-se.113

Study on effect of antimony composition on InAsSb/GaSb optical and structural properties

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Abstract:

InAsSb is known to be the best candidate for infrared detectors in the range of 3-5 μm. In this experimental work, we have studied the optical and structural properties of InAsSb/GaSb structures grown by Molecular Beam Epitaxy (MBE-RIBER-32P). The structural properties are studied by High Resolution X-Ray Diffraction (HRXRD) and optical properties by photoluminescence and photo reflectance measurements. To obtain high device characteristics, achieving lattice-matched structures is favourable. To do so, we examine the different structures with various Sb compositions and consequently different lattice constants. Finally, we want to make a comparison between structural and optical results and make a correlation between them to achieve high-performance structures for IR detector applications.

Keywords:

Photoluminescence, Photoreflectance, lattice matched, HRXRD, MBE

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P1-se.114

Contactless electro-reflectance study of optical properties for InGaAs/InAlAs digital alloy

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Abstract:

To form the InGaAlAs quaternary alloy we adopted InGaAs/InAlAs digital alloy growth process and rapid thermal annealing (RTA). The InGaAs/InAlAs digital alloys are grown by using molecular beam epitaxy(MBE). And the RTA temperature was changed form 700 ℃ to 850 ℃. The optical and properties affected by RTA process was investigated through the Contactless electro-reflectance (CER). The CER results showed compositional changes in the dominant InAlAs barrier and cladding layers due to RTA.

Keywords:

CER, digital alloy, InGaAs/InAlAs, RTA

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P1-se.115

New mobility measurement Method with transmission line method For 2D Material with High Contact Resistance

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Abstract:

To measure mobility, generally linear mobility measurement is chosen. However, in 2D material with high contact resistance(RC), the well-known method to obtain linear mobility shows a lower level value compared to the actual 2D channel mobility. Therefore, a measurement method was developed to remove the influence of RC using the 4-point probe measurement method and obtain the mobility of the channel only. However, when using the 4-point probe, the voltage drop along the channel was not linear, and the phenomenon that the result value could be distorted. Here, we suggest a new measurement method with the transmission line method(TLM).

In previous studies aimed at improving the RC of MoS_2 devices using LiF, it was confirmed that the gap between the mobility obtained by linear mobility measurement and 4-probe point measurement was reduced in the device with improved RC compared to the existing devices. As a result of obtaining the mobility using the new measurement method using the TLM data measured in the above study, it was confirmed that the distance with the mobility obtained from the linear mobility measurement decreased similarly to the mobility obtained from the 4-probe point measurement. .

Keywords:

MoS2, 4-point probe, transmission line method, 2D channel mobility, contact resistance

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P1-se.116

Modification of localized surface plasmon resonance in liquid via conductive atomic force microscopy

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Abstract:

Localized surface plasmon resonance (LSPR) effect is used as a valuable tool for controlling light-matter interaction applications in catalysis, photovoltaics, and waveguides. Moreover, the LSPR effect induces strongly enhanced optical fields near plasmonic structures, which significantly increases the excitation rate of emitters. The properties of the LSPR effect are sensitive to the plasmonic structure, i.e., size, shape, and materials; however, it is difficult to enhance the intensity of the LSPR effects without modifying the plasmonic structure. Tip-enhanced nano-spectroscopy has been developed, which utilizes the LSPR effect to highly enhance the optical signal of materials at the single-molecule level and enable measurements with spatial resolutions below ~10 nm. To further improve the sensitivity of tip-enhanced nano-spectroscopy while maintaining a consistent tip-substrate structure, we present conductive atomic force microscopy in a liquid to induce a capacitor effect between the Au tip and Au substrate. By applying a bias voltage to the Au tip and substrate in a liquid, we can strongly concentrate or disperse the charge density at the tip, enabling us to modify the LSPR effect. Furthermore, we demonstrate that modulation of the photoluminescence of WSe_2 can be achieved by controlling the excitation rate of the emitter through the LSPR effect.

Keywords:

Plasmonics, TMD, LSPR

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P1-se.117

Photocurrent and Responsivity of InGaAsP Semiconductor-based Metal-Semiconductor-Metal Near-Infrared Photodetector

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Abstract:

To satisfy the demands of complex functionalities such as Internet of Things and autonomous driving, a variety of sensors are required. Among these, photodetectors find applications in fields like vehicle distance sensing and detection of manufacturing process errors. Photodetector is a device that detects current signals generated by carriers as a result of light absorption. Developing components with rapid photoresponse and high sensitivity is crucial for such devices.
The most commonly used photodetector structure is the positive-intrinsic-negative (PIN) configuration, consisting of a wide intrinsic semiconductor layer between p-type and n-type semiconductors. Recently, the Metal-Semiconductor-Metal (MSM) structure consisting of a periodic arrangement of metal grids and semiconductor material gain a lot of interest in this field. While the PIN structure controls carrier mobility by degree of dopant concentration, the MSM structure can function as a photodetector by creating a grid structure on the semiconductor without the need for semiconductor doping. Consequently, the MSM structure reduces the fabrication process compared to the PIN structure, enabling the production of highly sensitive devices by improving light absorption by the surface plasmon effects. Moreover, MSM structures can be fabricated on various semiconductor materials, so there is flexibility in material selection and structural adjustments to fabricate MSM photodetector.
In this experiment, I fabricate a 400 nm period of MSM structure on a 400 nm intrinsic InGaAsP layer, which is grown on an intrinsic InP substrate. I measure photocurrent and responsivity of the device using lasers with wavelengths ranging from 900 nm to 1400 nm at 50 nm intervals. The results indicate high photocurrent and responsivity in the near-infrared region. These findings will contribute to understanding the impact of the metal grating structure on photodetection. Consequently, this research can propose more enhanced MSM photodetector structure based on the insights gained from these results.

Keywords:

Photocurrent, Responsivity, InGaAsP, MSM photodetector, Nano grating

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P1-se.118

Optical and electrical properties in 2-D semiconductors with varying layer numbers

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Abstract:

In various domains, 2-Dimensional materials are being extensively investigated as the forefront candidates for next-generation semiconductor materials. Notably, the diverse physical properties of these materials, which change according to the number of layers, open up possibilities for their application in semiconductor devices like transistors. In this study, single-layer to multi-layer 2-D materials exfoliated using Scotch tape were transferred onto p-type doped Si/SiO2 substrates. The optical properties of the materials are measured using Raman spectroscopy, Photoluminescence (PL), and Atomic Force Microscopy (AFM). Furthermore, the electrical characteristics of the devices are also measured. Moreover, through the deposition of metal onto the semiconductor material and the fabrication of a transistor structure, the electrical properties of the device are evaluated by applying bias voltage. The phenomenon of Raman spectrum and PL shifting with respect to the number of layers was observed in most materials, accompanied by variations in drain current.

Keywords:

2-d material, transistor, multi-layer, single-layer, semiconductor

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P1-se.119

Study on the Aging Effect of Quantum Dot-Based Light-Emitting Diodes (QLEDs): Impact of Encapsulation and Role of PFI Insertion Layer

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Abstract:

Quantum dot-based light-emitting diodes (QLEDs) have emerged as a promising technology for next-generation displays due to their remarkable color performance and energy efficiency. However, ensuring the long-term stability and durability of QLED devices remains a critical challenge. The aging characteristics, such as the evolution of efficiency and luminance of quantum-dot light-emitting diodes (QLEDs), are greatly affected by encapsulation. When encapsulated with ultraviolet curable resin, the efficiency increases over time, a known phenomenon termed as positive aging, which remains one of the unsolved mysteries. This research report investigates the relationship between encapsulation using UV-curable resin and the performance of QLED devices, with a specific focus on the role of Perfluorinated resin solution containing Nafion (PFI) as an interlayer. By analyzing phenomena occurring at the QD/ZMO interface and ZMO/Al interface, the changes in the performance of QLED devices over aging time are examined, and PFI is employed as a barrier layer to mitigate the influence of UV-curable resin. Through a systematic study of the resin's effects during various aging periods from 0 to 120 hours, valuable insights are provided for optimizing QLED encapsulation techniques for enhanced efficiency and reliability.

Keywords:

QLED, Positive Aging, Quantum Efficiency, UV Curing Resin, Encapsulation

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P1-se.120

질화 붕소 중간 계면층 사용으로 암전류를 감소시켜 성능이 향상된 그래핀/실리콘

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Abstract:

실리콘 양자점 (Si quantum dots, SiQDs)이 내장된 SiO_2(SiQDs:SiO_2)는 벌크 실리콘에 비해 가시 광 영역에서의 우수한 광반응도와 빠른 응답속도로 광전자 소자 응용 분야에서 많은 연구가 진행되고 있다. 최근 우리는 그래핀 투명 전도성 전극 기반 SiQDs:SiO_2를 보고하였다. 결과적으로 가시 광 영역에서 우수한 성능과 빠른 응답속도를 보였으나, 높은 암전류 (Dark current, DC)로 인하여 광검출기의 중요한 성능지표 중 하나인 검출능과 선형 동적 범위에서는 높은 성능을 달성하지는 못하였다. 본 연구에서 우리는 (trifluoromethanesulfonyl)-amide(TFSA) 도핑된 그래핀(TFSA-그래핀)/SiQDs: SiO_2/n-Si 이종접합 광 검출기에 육각형 질화붕소 (hexagonal boron nitride, h-BN) 중간층을 사용하여 TFSA-그래핀/h-BN/SiQDs:SiO_2 이종접합 광 검출기 소자를 제작하였다. 본 소자는 0 V에서도 광반응을 보이는 "자가 발전" 특성을 보였으며, 최대 10^6의 광전류/암전류 비율을 나타내었다. 또한, 소자의 광 검출능은 h-BN를 사용하지 않은 경우보다 약 4배 이상 증가하였다. 본 발표에서는 위의 실험 결과들을 토대로 TFSA-그래핀/h-BN/SiQDs:SiO_2 소자의 DC 감소에 의한 소자의 성능향상에 대한 메커니즘에 대해서 논의하고자 한다.

Keywords:

그래핀, 실리콘 양자점, 질화붕소, 이종접합, 광 검출기

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$LaVO_3$/다공성 실리콘 광대역 자가발전 광 검출기 소자

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Abstract:

고성능 광대역 광 검출기 제작에 있어 자외선부터 가시광선 영역의 높은 흡수율을 보이는 $LaVO_3$와 다공성 실리콘 (porous Si, PSi) 재료의 접합은 이상적이다. 본 발표에서는, 화학적 에칭을 통해 제작된 PSi 위에 스퍼터링 시스템을 이용하여 LaVO3 박막을 증착 하였다. 결과적으로, 본 소자는 0 V에서 10^4의 가장 높은 광전류/암전류 비율을 나타내며, 이는 자체 전원 공급을 의미한다. 소자는 300-1000nm까지 영역에서 광 반응도를 보였으며, 특히 830 nm에서 최대 0.4 AW^{-1}의 광 반응성과 1.6 x 10^{12} cm $Hz^{1/2}$ W^{-1}의 검출능 보였다. 또한, $LaVO_3$/PSi 소자는 68 dB의 선형 동적 범위, 그리고 48/53μs 상승/하강 응답 특성을 보였다. 이러한 광 검출기 성능지표는 이전 보고된 $LaVO_3$/Si과 $LaVO_3$ 기반 소자 보다 우수한 특성을 보였다. 본 발표에서는 실험 결과들을 바탕으로 $LaVO_3$/PSi 이종 접합 구조의 물리적인 메커니즘에 대해서 논의하고자 한다.

Keywords:

페로브스카이트 산화물, 다공성 실리콘, 이종접합, 자가발전, 광 검출기

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P1-se.122

Graphene Oxide forming directly on MLG via UV-O_3 treatment for resistive switching memory

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Abstract:

Resistive Random Access Memory (RRAM) is one of the promising memory device for implementing future electronics for its competitive advantages such as high integration, fast switching speed and so on. We fabricated all 2D-material RRAM which both the electrode and the active layer are 2D materials with MLG (Multi-layer Graphene) as the electrode and graphene oxide (GO) formed on MLG by UV-O_3 treatment. We investigated the resistive switching in GO by the dependency of UV-O_3 treatment time which analyzed by a repeating DC voltage sweep, Raman spectrum and AFM measurement. In addition, the bipolar resistive switching mechanism was confirmed through the algebraic relation between the current and voltage. We hope that this research will help develop electronic devices based on 2D materials.

Keywords:

RRAM, Graphene, Graphene Oxide, UV-O3 treatment

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P1-se.123

MoO_x-incorporated PEDOT:PSS hole transport layer for organic solar cells

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Abstract:

In this study, we introduce a novel hole extraction system that utilizes MoOx with PEDOT:PSS based on the charge recombination and generation characteristic. By mixing MoOx with PEDOT:PSS, we were able to improve the conductivity of the film by 10 times compared to that of pristine PEDOT:PSS. This improvement is attributed to the efficient charge recombination and generation characteristic between MoOx and PEDOT:PSS. Additionally, no additional absorption peak was observed in the hole transport layer, indicating that the system does not follow the P-type doping technique. When applied as the hole extraction layer (HEL) for PTB7-Th and PC[70]BM-based organic solar cells, the MoOx-mixed PEDOT:PSS thin film increased the short circuit current density and fill factor of the device, resulting in an increase in power conversion efficiency from 6.7% to 8.1% when the MoOx mixing ratio was 3%.

Keywords:

organic solar cell, PEDOT:PSS, MoO3, Hple transport layer

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P1-se.124

Design and fabrication of quantum dot-based short-wave infrared photodiode devices

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Abstract:

Infrared lights are invisible and are known to have low energy and relatively stable properties. The demand for infrared sensors, which are used to detect infrared light, is increasing significantly. Light detection and ranging (LiDAR), one of the infrared sensor technologies, mainly utilizes wavelengths around 900nm, which are in the near-infrared (NIR) range. There is an advantage in using silicon (Si) as an opto-electronic device due to its low fabrication cost. However, due to the ability of near-infrared wavelengths to penetrate deeply into the eyeball and potentially cause severe damage to the cornea, lens, and retina, there are significant limitations in its range of application. In addition, light with near-infrared wavelengths loses its detection performance in infrared sensors due to scattering and absorption in the atmosphere. To solve this problem, we intend to utilize the short-wave infrared (SWIR) region of 1400nm or greater. Materials used to detect light in the short-wave infrared include InGaAs grown through the epitaxial growth process and colloidal quantum dots produced using the solution manufacturing process. InGaAs shows good performance in detecting the 1500 ~ 2500nm range, but there is a disadvantage of the production cost is very high. A way to overcome the limitations of near-infrared and reduce costs is to utilize colloidal quantum dots, which are materials that can absorb infrared light. These quantum can be synthesized using a solution-based method. Because of size-tunable of crystals, quantum dots can control a wide range of band gap energies. Various device structures are possible for utilizing quantum dots with controlled physical properties through quantum dot surface treatment. Furthermore, now that it is being produced for using solution in the thin film manufacturing process, it is possible to fabricate devices at a low cost. Here, we study the design and fabrication of suitable short-wave infrared 1500nm wavelengths and photodiode devices structure to be used in infrared sensors. We achieve this by using lead chalcogenides colloidal quantum dots (PbS , PbSe, etc.).

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Keywords:

short-wave infrared, quantum dot, photodiode, lead chalcogenide

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P1-se.125

Technical Research for Ensuring the Stability of Indium Phosphide

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Abstract:

Colloidal quantum dots consist of an inorganic semiconductor core and an organic ligand. Due to the quantum confinement effect, the bandgap changes depending on the size of the core, leading to a variety of light colors. Colloidal II-VI semiconductor quantum dots have stability exceeding 60-80% and high quantum efficiency, attracting much attention and research. However, recent interest has shifted towards the development of III-V semiconductor quantum dots that lack toxic materials. Yet, compared to II-VI quantum dots, the III-V ones show reduced stability, posing challenges for device fabrication. To address this, there's been a focus on enhancing the stability of InP quantum dots by exchanging their Oleic acid Ligand with ZnCl2. By increasing the concentration of ZnCl2 and extending the reaction time accordingly, the stability of InP quantum dots was secured. This discussion aims to delve into the experimental results stemming from these adjustments.

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Keywords:

Indium Phosphide, Colloidal quantum dots, nontoxicity

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P1-se.201

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:

Schottky, Photoluminescence, Quantum yield, MoS2

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P1-se.202

Effect of precursor ratio on carrier dynamics in colloidal CdSe quantum dots

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Abstract:

Quantum dots (QDs) are semiconductor nanoparticles whose band gap can be easily tuned by size effect and are widely studied in various industrial applications such as display and solar cell. It is necessary to control the surface properties of QDs that enhance the luminescence properties and quantum yield. The surface characterization of QDs can be easily controlled by adjusting the ligand to precursor ratio, which in turn controls the cation to anion ratio. In general, the valence band of CdSe QDs is composed of the p-orbital of the chalcogenide (Se2-), but it is known that the conduction band level is composed of s-metal orbitals (Cd2+). By tuning the precursor ratio of the CdSe QDs, the band gap energy and the carrier trapping rate on the surface of the QDs can be controlled. In this work, CdSe QDs were synthesized by the hot injection method depending on the precursor ratio, and the optical properties and carrier dynamics were analyzed.

Keywords:

Quantum dot, CdSe, Precursor ratio, Carrier dynamics, Hot injection

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P1-se.203

과포화 재결정법을 이용한 페로브스카이트 나노 결정의 상온 합성과 광학적 특성 연구

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Abstract:

$CsPbX_3$ 무기 할라이드 페로브스카이트는 특유의 높은 발광양자수율과 더불어 좁은 반치폭, 할라이드 음이온의 치환을 이용해 밴드갭을 조절할 수 있는 점, 그리고 상온에서의 쉬운 합성으로 인해 차세대 발광 물질로서 주목을 받고 있다. 일반적으로 페로브스카이트 나노 결정을 성장시키는데 주로 사용되는 고온 주입법은 상대적으로 높은 진공도와 온도에서 합성하기 때문에 상온 합성법에 비해 어려움이 있다. 하지만 상온 합성법은 상온과 상압에서 높은 발광양자수율을 가지는 페로브스카이트 나노 결정을 제작할 수 있다는 점에서 많은 연구가 되고 있다. 상온 합성법 중에서도 과포화 재결정(Supersaturated recrystallization) 합성법은 높은 용해도를 가진 용매에 전구체와 리간드를 녹인 후 낮은 용해도를 가진 용매에 주입할 시 생기는 용해도의 차이로 인해 $CsPbX_3$ 나노 결정을 침전시키는 방법이다. 이때 리간드는 침전되는 $CsPbX_3$ 나노 결정의 표면을 부동태화 시키며 나노 결정을 분산시키는 역할을 한다. 본 연구에서는 과포화 재결정 합성법으로 올레인산과 올레일아민을 리간드로 이용한 $CsPbBr_3$ 페로브스카이트 나노 결정을 제작하고 흡수도, 발광, 발광양자수율 측정과 같은 광학적 특성과 시분해 발광을 기반으로 운반자 동역학을 분석하였다.

Keywords:

페로브스카이트, CsPbBr3, 과포화 재결정, 광학적 특성, 운반자 동역학

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P1-se.204

Optical characterization of cubic and pyramidal $MAPbBr_3$ film formed by perovskite nano-seed

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Abstract:

Since the optical and electrical properties of halide perovskites depend on their crystal orientation, a detailed analysis of the crystal orientation is required for higher performance in applied devices. In this study, we analyzed cubic and pyramidal MAPbBr3 films with (100) and (111) planes synthesized by using quantum dots as nano-seeds. The (100) cubic and (111) pyramidal structures were confirmed by XRD and SEM, and we found that the (111) pyramidal film has a narrower optical bandgap compared to the (100) cubic film. In addition, optical and electrical properties were investigated using measurements such as KPFM, TRPL, and power-dependent PL, suggesting potential applications for both structures.

Keywords:

Perovskite, MAPbBr3

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P1-se.205

Unveiling Trap Charges Crucial for the Operation of MoS_2-based Field-Effect Transistor

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Abstract:

Nowadays, transition metal dichalcogenide (TMD) stands out because of its semiconducting characteristics. And it has several advantages for easy fabrication, bandgap modulation by layers, and electrical property modulation. Furthermore, TMD is applicable for state-of-the-art devices such as nonvolatile memory, neuromorphic, and effective doping devices. One of the most interesting properties in TMD-based field-effect-transistor (FET) is the trapping effect, significantly affecting the electrical properties of TMD-based FET. Thus, We investigate the trap charges of two-dimensional material, molybdenum disulfide (MoS_2), using the transient current method and Arrhenius plot of the transfer curves. In drain transient analysis, pulsed gate bias induces the trapping and de-trapping process between the MoS_2 channel and gate dielectric. Thus, the trap levels and densities are estimated by the conventional double-exponential fitting. Furthermore, Arrhenius plotting indicates that the hysteresis of the transfer curves originates from the interface trap, which allows us to calculate fixed and mobile trap charges information.

Keywords:

molybdenum disulfide, trap charges, transient current, Arrhenius plot

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P1-se.206

Manipulation of optical properties of 0D/2D heterostructures

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Abstract:

양자점과 단일 층 전이금속 칼코겐 화합물로 이루어진 0D/2D 헤테로구조에서 전하 이동에 따른 광학 특성 변화를 규명하기 위해서 광발광 연구를 수행하였다. 기계적 박리 방법을 통해서 얻은 단일 층 WS_2에서의 광발광 스펙트럼으로부터 엑시톤과 트라이온 반응을 확인할 수 있었다. 이 위에 CdSe 양자점이 도포된 0D/2D 헤테로구조에서 CdSe 양자점에 의해서 단일 층 WS_2의 광발광 특성이 변함을 알 수 있었다. 특히 양자점이 없는 WS_2와 비교했을 때 0D/2D 헤테로구조에서의 엑시톤 대비 트라이온의 세기 비율이 변하였는데 이는 양자점과 WS_2 사이에 전하 이동이 일어났음을 나타내는 것이다. 또한 양자점의 크기 변화에 따라서 전하 이동 현상에 차이가 있음을 알 수 있었다. [이 연구는 정부(과학기술정보통신부)의 재원으로 한국연구재단의 지원을 받아 수행되었음 (과제번호: 2019R1A2C1003366, 2022R1A4A1033358)]

Keywords:

Quantum dot, Tungsten disulfide, Photoluminescence, Charge transfer, Exciton, Trion

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2023-10-24 - 2023-10-27

P1-se.207

Oxidation of freestanding monolayer Transition metal dichalcogenides on Zinc Oxide nanorods

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Abstract:

Transition metal dichalcogenides (TMDCs), which consist of layered structures formed by combining transition metals and chalcogenides, have attracted attention due to their unique properties. The bandgap transition from being direct (in monolayers) to becoming indirect (in bulk layers), along with the predominance of excitonic emission in photoluminescence (PL), are advantages of TMDCs. Furthermore, due to their sub-nanometer scale, the miniaturization and integration of TMDC devices are enabled, making them promising candidates for the fields of photonics and optoelectronics. However, the low quantum yield (QY) due to nonradiative channels presents a significant challenge to the practical applications for TMDCs.
To address this issue, many studies have reported the utilization of O_3 treatment for PL modulation. These studies were usually conducted on SiO_2 substrate, where substrates hinder analysis of the intrinsic properties of TMDCs and limit the enhancement QY of TMDCs. In this study, we prepared ZnO nanorod substrates with freestanding TMDCs and confirmed the inherent oxidation behavior via Raman scattering and PL signals. Unlike SiO_2 substrates, the oxidation is more prevalent in TMDCs exposed to air on both side, top and bottom, which significantly affects the optical properties. This work shows the most natural oxidation behavior of intrinsic TMDCs without strain and offers new strategies for enhancing the QY of TMDCs.

Keywords:

Freestanding effect, ZnO NRs, TMDCs, PL modulation, UV-O3 Treatment

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P1-se.208

Tip-enhanced Förster resonance energy transfer spectroscopy in monolayer $MoSe_2$

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Abstract:

Monolayer transition metal dichalcogenides (TMDs) have garnered significant attention as a class of modern materials, due to their optical, electronic, and mechanical properties that deviate from bulk counterparts. The grain boundaries, chemical bonding, and the presence of nanodefects in TMDs strongly affect their characteristics. Therefore, investigating these properties with nanoscale spatial resolution presents a formidable challenge. Tip-enhanced photoluminescence (TEPL) facilitates high-resolution and high-sensitivity local spectroscopic investigations and imaging while in a non-destructive way. However, the efficiency of TEPL encounters limitations due to the spectral mismatch between the plasmonic resonance of Au tips and the excitonic emission of $MoSe_2$ and WSe_2, which exhibit longer wavelengths. In this study, we actively controlled enhancement of TEPL performance in monolayer $MoSe_2$ via Förster resonance energy transfer from CdSe quantum dots (QDs) to $MoSe_2$ and controlled by manipulating distance between Au tip and QDs. Our work presents a strategy for expanding the scope of Au-tip based TEPL spectroscopy. This approach enables the investigation and characterization of two-dimensional materials across the spectrum, ranging from the visible to the near-infrared region.

Keywords:

Tip-enhanced photoluminescence, Transition metal dichalcogenides, MoSe2, Förster resonance energy transfer, Near-infrared

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P1-se.209

Direct observation of the evolution of Mexican-hat band structure in quasicrystalline Bi(111) thin films

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Abstract:

Higgs and Goldstone's modes are collective excitations of the amplitude and phase of an order parameter associated with spontaneous symmetry breaking and characterized by the Mexican-hat-shaped potential. In addition to the superconductors, these collective excitations have been observed in superfluid helium, solid-state systems, and ultracold quantum gases [1,2].
The materials with Mexican hat bandstructure have recently garnered significant interest due to their ability to induce various intriguing phases and structural phase transition [3]. In this work, we directly observe that the isotropic 12-fold Mexcian hat band structure formed in a quasicrystalline Bi(111) bilayer. Then, thermal annealing resulted in a trivial band structure of the Bi(111) phase with a 6-fold Mexcian hat band structure through a non-isotropic 12-fold one. Our results resolve why the bulk Bi(111) with strong spin-orbit coupling is trivial semimetallic in the problem of topological identification.

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Keywords:

Order parameter, Spontaneous symmetry breaking, Mexican hat potential, Topological classification, Quasicrystalline Bismuth films

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P1-se.210

Modulation of electrical properties in 2D tellurium via ozone treatment

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Abstract:

Two-dimensional (2D) semiconductors have been intensively studied due to excellent optical and electrical properties with high flexibility. In the electronics, both p- and n-type semiconductor are essential components to fabricate various logit circuits. However, a few p-type semiconductors have been applied although numerous n-type semiconductors have been studied. Black phosphorous, representative p-type semiconductor have attracted the interest of scientists, however its instability under ambient conditions is the main drawback in the fields of fundamental study and practical application. To solve this problem, 2D tellurium with high stability and field effect mobility is recently reported. However, high off current of BP and Te originating from the narrow band gap energy (~0.4 eV) is still challenging issue in p-type semiconductor. In this study, we prepared 2D TeO_2, p-type semiconductor with a wide bandgap (3.28 eV) using the oxidation of hydrothermally synthesized 2D Te to solve the narrow bandgap problem. The β-TeO_2 phase was successfully formed by two different oxidation process using UV-O_3 and thermal treatment. This work can be contributed to the exploit of electronics with 2D semiconductors by addressing the p-type semiconductor issues.

Keywords:

2D semiconductor, Intrinsic p-type, hydrothermal synthesis, wide bandgap semiconductor, 2D tellurium

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P1-se.211

Investigating the photoconductivity modulation of a WSe2 monolayer using polyvinylpyrrolidone for in-plane p-n homojunction.

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Abstract:

Transition metal dichalcogenides (TMDCs) have unique features as a result of the quantum confinement effects, which depend on the number of layers. As the thickness of the material decreases to a monolayer, it exhibits properties of a direct bandgap, which indicates strong light-matter interactions and remarkable exciton binding energies. Tungsten diselenide (WSe_2), a representative material of the TMDCs, has a direct bandgap of approximately 1.65 eV in its monolayer (1L). Among the various two-dimensional materials, 1L-WSe_2 demonstrates remarkable light absorption capabilities and photodetectivity. However, the commercial application of optoelectronics based on TMDCs has faced ongoing challenges, such as low optical quantum yields resulting from atomic-scale thicknesses and the complex processes required for the formation of the various heterojunctions. In this study, a straightforward organic coating method was utilized to convert the electrical and optical characteristics of 1L-WSe_2 synthesized through chemical vapor deposition. For this particular objective, polyvinylpyrrolidone (PVP) was employed as an n-type dopant. Typically, WSe_2 exhibits p-type or ambipolar properties, and the doping process allows for carrier-type switching between n-type and p-type. Electrical and optical measurements confirmed the transition from conventional p-type properties to n-type properties. Interestingly, in addition to the change in the majority of carrier properties, the photoconductivity exhibited a distinct behavior. To conduct a comprehensive analysis of the behavior of the photogenerated carriers, we performed I-V measurements using an excitation source, followed by subsequent analysis at both low and high temperatures. Based on the aforementioned properties, we have successfully implemented the PN homojunction of 1L-WSe_2. By investigating the photoconductivity of two-dimensional semiconductors utilizing atmospherically stable organic films, we propose a methodology for the development of in-plane p-n homojunction. Our research is expected to make a significant contribution to the advancement of future studies on two-dimensional solar cells and their applications in optoelectronics.

Keywords:

TMDCs, WSe2, PVP, n-doping, photoconductivity, p-n homojunction

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P1-se.212

Interfacial charge trapping of monolayer MoS_2 for optoelectronic nonvolatile memory

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Abstract:

Optoelectronic memory is essential in the semiconductor industry due to the advancements in optoelectronic materials and manufacturing techniques. In contrast to traditional investigations on photodetectors, the field of optical memory based on two-dimensional semiconductors has recently garnered significant attention. Two-dimensional (2D) optoelectronic memories have exhibited significant on/off ratios, the capability to store multi-bit data, and ultra-fast switching speeds. In general, Si or III-V compound-based transistors for photodetectors have been reported to cause unacceptably large threshold-voltage variations by thickness fluctuation on the rough interface. In contrast to the bulk transistors, the 2D semiconductors can be realized with optoelectronic memory characteristics based on high current switching ratio and long retention time. It is related to the defect sites at the interface of two-dimensional materials, specifically the phenomenon of interfacial charge trapping due to the presence of chalcogen vacancies in 2D transition metal dichalcogenides (TMDCs). It has been experimentally demonstrated that this particular property exhibits nonvolatile memory characteristics, thereby facilitating photodetection and functioning as a storage medium for photoexcited carriers. In this study, we fabricated thin-film transistors by employing n-type monolayer molybdenum disulfide (MoS_2) grown by chemical vapor deposition, with the aim of achieving 2D optoelectronic memory. Program-readout-erase cycle measurement and retention time analysis were conducted on MoS_2 to demonstrate its nonvolatile properties. The results indicated the feasibility of gate-controlled nonvolatile memory. Additionally, polyvinylpyrrolidone (PVP) was employed as a coating material on the surface of MoS_2 in order to improve stability at elevated temperatures, which can be attributed to the passivation effect. The performance exhibited by MoS_2 optoelectronic memories in this study represents a significant breakthrough for the advancement of integrated photonics in the future.

Keywords:

2D semiconductor, MoS2, Optoelectronic memory, Nonvolatile, Charge trapping

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P1-se.213

Transition metal dichalcogenides/Gold nanoparticle plasmonic structure through reversible phase transition

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Abstract:

Two-dimensional (2D) Transition metal dichalcogenides (TMDCs) have been studied extensively due to unique physical properties. In their application, the localized surface plasmon resonance (LSPR) of metal has been applied for the enhancement of performance for optoelectronics of TMDCs. In this study, homogeneous gold nanoparticles (Au NPs) are synthesized at the van der Waals space of TMDCs through the reversible phase transition depending on electron density. According to LSPR of Au NPs, photoluminescence of bulk TMDCs is improved than pristine, and the result can be expanded to the facile fabrication of plasmonic structure for cutting edge optoelectronics of TMDCs.

Keywords:

Transition metal dichalcogenides (TMDCs), van der Waals (vdW) gap, phase transition, Gold nanoparticle, localized surface plasmon resonance (LSPR)

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P1-se.214

Measurement of $MoSe_2$ carrier dynamics using pump-probe microscopy

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Abstract:

Measuring the diffusion of carriers within materials holds potential applications in the design of nanoelectronic and optical devices. Particularly, by leveraging information about carrier diffusion paths and velocities to optimize charge transport pathways within devices, it becomes possible to achieve more efficient device performance. Therefore, the measurement of carrier diffusion in materials is of paramount significance.
TMDc (Transition Metal Dichalcogenides) materials have drawn considerable interest due to their unique electrical properties and promising prospective applications. The photoluminescence (PL) of MoS_2 and $MoSe_2$ is attenuated by vacancies of chalcogen elements (S, Se), and it has been observed that laser irradiation or heating on a hot plate leads to enhancement through substitution of these vacancies with oxygen (O). However, the exact processes behind the observed enhancement in PL intensity remain inadequately explained.
In this study, we employed a mode-locked Ti: Sapphire laser to implement a Pump-Probe scan system for measuring carrier diffusion and carrier lifetimes in TMDc materials at room temperature under atmospheric conditions. By utilizing a Pump-Probe microscope, we conducted measurements on the carrier lifetime of $MoSe_2$ at selenium vacancies through O-substitution, aiming to decipher the mechanism behind the increase in PL intensity. The PL enhancement mechanism through measurements on O-substituted $MoSe_2$ carrier lifetimes at selenium vacancies contributes to a deeper understanding of these materials' behaviors.

Keywords:

MoSe2, carrier dynamics, Pump-Probe scan system, photoluminescence

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P1-se.215

The Effects of Thermal Annealing on the Electrical and Optical Properties of Lignin

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Abstract:

Lignin, derived from trees and abundant in nature, is emerging as a prominent biopolymer. Cost-effective and accessible through the pulp industry, lignin avoids complex synthesis, simplifying manufacturing. With a substantial carbon content, electrical properties of lignin can be modulated by thermal annealing, making it suitable for bioelectric devices.

In this study, thermal annealing of lignin was performed for the application of bioelectric devices. Spin-coated lignin films were thermally annealed in a glove box with a N_2 environment and under ambient conditions. Compared to air-dried films, annealed lignin films exhibited increased carbon and oxygen content. Optical properties showed increased absorbance near the UV region and a broadened absorption spectrum in annealed lignin. In addition, red-shifted peaks were observed in the photoluminescence spectrum. This is attributed to the narrowing of the band gap. The potential to tune the bandgap and optical properties of lignin by thermal annealing suggests applications not only in bioelectric devices but also in lignin-based optoelectronics.

Keywords:

Lignin, Biopolymer, Bioelectric device, Thermal annealing

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P1-se.216

Correlation Between Raman and Photoluminescence Spectra in Single- and Few-Layer MoS_2/AuNPs Hybrid Structures Under Resonant Excitation

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Abstract:

Transition metal dichalcogenides (TMDs) are promising candidates for ultra-thin functional semiconductor devices. In particular, incorporating plasmonic nanoparticles into TMD-based devices enhances the light-matter interaction for increased absorption efficiency and enables control of device performance such as electronic, electrical and optical properties. Raman scattering and photoluminescence (PL) are commonly employed techniques for monitoring device performance, as they offer insights into structural, electronic, and optical properties. However, despite the interrelation of these properties, there is still a lack of correlation studies between Raman scattering and PL. Especially, conducting such analyses in multi-layers poses challenges due to their structural complexity. Here, we obtained Raman scattering and PL signals from mono-, bi-, and tri- layer MoS_2 on gold nano particle (AuNPs) hetero-hybrid structures under resonant optical excitation and conducted correlation studies. The Raman shift of E_{2g}^1 (E') mode mainly due to the biaxial strain induced by AuNPs and is accompanied by PL spectral shift. The magnitude of strain decreases as the number of layers increases, and the change in exciton energy decreases accordingly. The Raman shift of the A_{1g} (A_1') mode is influenced by both electrical and optical doping in the MoS_2/AuNPs heterostructure, leading to changes in the spectral width of the PL. In all number of layers, the formation of biexcitons is increased by the field enhancement from AuNPs, and PL emission in the lower energy band increases. However, as the number of layers decreases, the electron doping effect and trions formation becomes more prominent, so the relatively smaller change in spectral width is observed.

Keywords:

transition metal dichalcogenides , plasmonic nanoparticles, Raman spectroscopy, Photoluminescence spectroscopy, resonant excitation

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P1-se.217

Optical properties of monolayer WSe_2 on honeycomb patterned gold template

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Abstract:

Monolayer transition metal dichalcogenides (1L TMDs) are attractive direct bandgap semiconductor materials for optoelectronic applications. Because the optical and electrical properties of TMDs can be tuned and exploited, various experiments have been conducted using TMDs. Among them, strain engineering is an effective method for modifying and tuning the optical and electrical properties of 1L TMDs. However, previous strain studies have not analyzed tensile and compressive strains simultaneously within a single flake. To accurately observe the effects of tensile and compressive strains, it is important to apply them simultaneously within a single flake.

In this study, we fabricated a periodic honeycomb template that allows us to simultaneously observe tensile and compressive strain within a single flake. In addition, we covered the honeycomb template with gold to increase the intensity of optical measurements due to surface enhanced Raman scattering (SERS). Thus, we developed an Au honeycomb template that allows us to simultaneously analyze strain due to SERS effects. The Au honeycomb template was fabricated using conventional photolithography and radio frequency (RF) sputtering. 1L WSe_2 was transferred to the Au honeycomb template using a wet transfer method. Atomic force microscopy (AFM) and scanning electron microscopy (SEM) were used to verify the surface morphology of 1L WSe_2 on the Au honeycomb template. Photoluminescence (PL) measurements were conducted to investigate the effect of strain on the 1L WSe_2. Three-dimensional finite difference time-domain (3D-FDTD) simulations were implemented to investigate the SERS effect due to surface plasmon coupling between the 1L WSe_2 and the Au honeycomb template. Raman scattering measurements were also performed to verify the agreement between the 3D-FDTD simulations and experimental results. The results of this study demonstrate that the strain and SERS effect on the 1L TMD can be measured simultaneously using a periodic Au honeycomb template. This provides a new platform for studying the enhanced optical properties of 1L TMDs.

Keywords:

Monolayer WSe2 , Strain, surface-enhanced Raman scattering, surface plasmon coupling, TMD

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P1-se.218

Controllable Synthesis of Topological Quantum Materials Based on Platinum and Tellurium Using Laser Irradiation

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Abstract:

A topological quantum material has unique physical properties due to the non-trivial topology of their band structure, and these properties are actively studied in the fields of spintronics, catalysis, and superconductivity.

Synthetic materials based on Pt-telluride, such as $PtTe_2$, Pt_3Te_4, Pt_2Te_3, and PtTe, are representative examples of topological quantum materials. $PtTe_2$, which is the broadband photo-response of the Type-II Dirac semimetal can be applied in photodetectors. The properties of the topological metal, Pt_3Te_4, make it a promising catalyst for the Hydrogen Evolution Reaction (HER). Additionally, the topological semimetal characteristics of PtTe exhibit Type-II superconductivity, maintaining its superconducting properties even in the presence of an external magnetic field. However, these materials require high temperatures and long time for synthesis.

In this study, different topological quantum materials consisting of platinum and tellurium were synthesized using a laser at room temperature. The Pt-telluride systems were characterized using the Raman scattering method, and it was confirmed that the nature of the system can be controlled by the laser intensity. The electrical conductivity was also measured and compared. This approach can be used as one of several methods to synthesize materials simply at ambient conditions.

Keywords:

Topological Material, Laser Synthesis, Platinum Telluride, Raman Spectroscopy

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P1-se.219

Valley and spin filtering with magnetic proximity effects on a bowtie-shaped monolayer WS_2

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Abstract:

Dealing with valley degree of freedom is of great interest in two-dimensional materials. The energy band structures and electronic transport properties of a quantum system implanted with a monolayer transition metal dichalcogenides (TMDCs) are investigated using the two-band k·p Hamiltonian with parameters from the density functional theory (DFT) calculation. The quantum system based on a ballistic point contact with zigzag edges has a bow tie-shaped scattering region with a tunable gate on a ferromagnetic substrate. The magnetic proximity effect from an Eu-terminated ferromagnetic substrate (EuS) generates a large effective magnetic field that shows significant valley splitting in the monolayer WS_2. Because of the bowtie-shaped scattering region, a quantized number of channels for electrons are available. In the narrowest region, we set a local gate to manipulate the polarization of the current. The results give more control over the valley degree of freedom in addition to the control of the charge and spin degree of freedom of carriers for next-generation devices. Experimental realization of the present quantum system would provide such control in future valleytronic devices.

Keywords:

TMDC, valley, spintronics, magentic proximity effect, k·p Hamiltonian

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P1-se.220

Nonlinear Hall Effect in 2D Tellurene under Time-Reversal-Symmetric Conditions

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Abstract:

Nonlinear Hall effect presents a transverse current in second-order response to an external electric field. While Onsager's reciprocal theorem dictates the absence of linear response under the time-reversal-symmetric conditions, a second-order nonlinear response may persist in non-centrosymmetric materials. This is attributed to intrinsic effects from the Berry curvature dipole and extrinsic effects stemming from skew scattering and side jump [1, 2]. Nonlinear Hall effect was demonstrated in bilayer WTe_2 [3], few-layer WTe_2 [4], corrugated bilayer graphene [5], strained WSe_2 [6], surface states of the topological insulator Bi_2Se_3 [7], and the Weyl semimetal $TaIrTe_4$ [8].

2D Tellurene (2-dimensional trigonal tellurium) is composed of 1D helical atomic chains, which are held by van der Waals interaction. It possesses no inversion symmetry with strong spin-orbit interactions and has narrow bandgap ~0.3 eV with a Weyl node at the conduction band edge, thus called as a Weyl semiconductor [9-11]. In this study, we report the nonlinear Hall effect in 2D tellurene. With electric current flowing along the c-axis, a nonlinear Hall voltage was detected when Fermi energy was near the conduction band edge. Intriguingly, symmetry constraints do not allow the generation of a non-linear Hall voltage resulting from Berry curvature dipole. The discrepancy between theoretical and experimental results leads us to investigate further potential origins that may come from surface effects, additional symmetry breaking induced by external bias, and the contribution from a Weyl node.

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£ These authors contributed equally to this work.

Keywords:

Nonlinear Hall Effect, Tellurene, Berry curvature dipole

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P1-se.221

Electrical and Thermoelectric Transport Properties of Tellurene

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Abstract:

We examined the electrical conductance and thermoelectric power (TEP) of 2D trigonal tellurium (Te) synthesized via the hydrothermal method. 2D Te is a narrow-gap semiconductor with a bandgap of 0.34 eV. At room temperature, it shows p-type behavior attributed to from Te vacancies. At low temperatures, ambipolar transport was observed in both TEP and electrical conductance, under the modulation by the back-gate bias. For instance, the sign of TEP signal shifted from negative to positive values, indicating a transition in the majority carrier type from electrons to holes. The ambipolar property also accompanies the metal-to-insulator transition. Our coherent measurements of electric and thermoelectric properties of 2D Te are expected to elucidate the correlation between these two physical phenomena.

Keywords:

Ambipolar, Tellurene, Thermoelectric, metal-to-insulator transition

P1-se.222

Determining the twist angle of the moiré superlattice in 2D materials using polarized Raman spectroscopy

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Abstract:

Moiré superlattices, observed in 2D material sheets stacked at small twist angles, have a strong influence on various electronic properties. Extensive research has been conducted to investigate various properties such as superconductivity and topological insulation in this structure. An important parameter that determines the properties of moiré superlattices is the twist angle. There are different methods for determining the twist angle, such as using optical microscopy (OM) or second harmonic generation (SHG). The OM method is applicable to all materials, but accuracy can be an issue when it comes to measuring the exact twist angle. The method using SHG is a reliable technique because it utilizes the inherent properties of the material to determine the exact angle, but this method is not easily accessible. Addressing these issues is necessary to facilitate advances in the field of moiré superlattices.
In this work, we propose a practical approach to establish the crystallographic axis using polarized Raman spectroscopy and use it to measure the twist angle. The strain-dependent behavior of the E mode in MoS_2 was used to establish the crystallographic axis of MoS_2, which can be used to determine the twist angle of MoS_2 moiré superlattice. These results can also be utilized to determine the moiré twist angle of other TMD materials. Additionally, this study is expected to establish a foundation for future investigations on moiré superlattice and make a substantial impact on the field of moiré research.

Keywords:

Polarized Raman, Transition Metal Dichalcogenides, Moiré, Crystallographic axis, Strain

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P1-se.223

Quantative model of raman peak shift in a monolayer MoS_2 under bending strain and temperature change.

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Abstract:

Transition Metal Dichalcogenides (TMDs) have attracted significant attention due to their bandgap corresponding to visible spectrum. (Especially in a monolayer, they have direct bandgap) Raman scattering shifts sensitively with the number of layers so it enables non-destructive analysis of physical or chemical properties instantly which is utilized broadly by many researchers. Therefore, if the Raman scattering is analyzed with a theoretical model, essential behaviors of quantum particles in a material can be described in detail.
Here, a theoretical model of how the Raman modes of MoS_2 change with strain or temperature is analyzed and validated by experiment. This confirms the feasibility of quantitative optical analysis methods to handle applied variables on MoS_2.
From this result, theoretical description of Raman peak shifts under strain and temperature change is verified. This can lead to profound understanding of quantum particles in TMDs or other kinds of 2-dimensional material in the future.

Keywords:

MoS2, Raman scattering, strain, temperature

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P2-ap.101

Overcoming the thermal quenching effect in Emission of Eu^{3+} doped HfW_2O_8 via Negative Thermal Expansion

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Abstract:

The development of efficient luminescent materials has paved the way for advancements in various fields including solid-state lighting, displays, sensors, and optical communication. However, thermal quenching effect is an ongoing challenge to overcome. Thermal quenching effect in luminescence refers to the decreases in luminescence intensity with increasing temperature, caused by the thermal energy promoting non-radiative processes. Here, we suggest a novel strategy to overcome thermal quenching effect using negative thermal expansion (NTE) in host materials. In this study, $Hf_{1-x}Eu_xW_2O_8$ (x = 0, 0.01, 0.03, 0.05, 0.07, 0.09, 0.12, and 0.15) was synthesized by a fast solid state reaction method with water quenching. Temperature dependent X-ray diffraction patterns on our samples exhibited the phase transition from α-phase ($P2_13$, cubic) to β-phase (Pa-3, cubic) as the temperature increased from room temperature to 200 °C. Additionally, we found highly linear contraction of lattice constants, i.e., negative thermal expansion (NTE). The thermal expansion coefficient and the volume thermal expansion coefficient were determined as approximately -1.1×10^{-5} and -3.4×10^{-5}, respectively. Interestingly, the emission from f - f transition of Eu^{3+} showed negligible thermal quenching with increasing temperature. We suggest that this intriguing behaviour originates from the increase in the intensity of crystal field to Eu^{3+} due to lattice contraction by NTE of HfW_2O_8.

Keywords:

Negative thermal expansion, Rare earth ions, Functional oxide, Photoluminescence

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P2-ap.102

The enhancement of tunneling electroresistance effect of ferroelectric tunnel junction by using conductive filament formation

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Abstract:

Since ferroelectricity of Si-doped hafnium dioxide (HfO_2) was discovered in 2011 by Böscke et al. [1], HfO_2 is receiving a great of attention due to their applications for nonvolatile memory devices. As the thickness of the ferroelectric layer is reduced to a few nanometers, quantum-mechanical tunneling across the ferroelectric layer is possible and such tunneling conductance is dependent on the polarization direction (the so-called tunneling electroresistance effect (TER)). Ferroelectric tunnel junctions (FTJs) use this TER effect and they have garnered significant interest for their possible utilization in future-generation memory solutions. This is due to their appealing benefits, such as high data storage density, non-destructive data reading, rapid write and read access, and efficient energy utilization. In this study, we systematically investigated TER effect and its modulation by changing the tunneling barrier layer. We first fabricated Mo/Ta_2O_5/TiN capacitors and observed the conductive filament (CF)formation on the Ta_2O_5 layer. Then, Mo/ hafnium zirconium oxide (HZO)/TiN capacitors were fabricated and the low resistance state and high resistance state were observed according to the polarization direction of the ferroelectric layer. Finally, we fabricated a Ta_2O_5/HZO heterostructure and maximized the on/off ratio of FTJs through a extra band structure modification by CF formation due to a valence change mechanism in the Ta_2O_5 layer.

[1] TS Böscke et al, "Ferroelectricity in hafnium oxide thin films," Applied Physics Letters 99 (10), 2011

Keywords:

Ferroelectric tunnel junction, tunneling electroresistance, conductive filament, memristor, ferroelectric

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P2-ap.103

Fabrication of self-rolled-up SiO/SiO_2 microtube

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Abstract:

Inspired by origami and kirigami, the planer nanomembranes are made of different materials that can be transformed into complex 3D microstructures by introducing the internal strain gradient, such as helices and tubes. The microtubes made through the rolling-up technique have gained research attention due to the technology's high flexibility, integrability, and versatility. The versatility of rolled-up microtubes can be seen in the flexible design of rolled-up microtubes and various applications, including micromotors, resonators, and sensors that can be achieved on rolled-up microtubes. In general, microtubes consist of prestrained nanomembranes deposited on the sacrificial layers. However, this fabrication requires a selective under-etching procedure using solvent, which not only removes the sacrificial layer to make a microtube but also dissolves the strained nanomembranes. In order to avoid the limitation of material choice because of a selective-under etching procedure, a polymer material of photoresist is selected as the sacrificial layer in this work. During the rolling process, the direction of the rolled-up microtube can be varied, which can be controlled by geometry design. We apply a corner attachment to achieve the desired rolling direction of the rolled-up microtubes. In this work, the rolled-up microtube has been fabricated by releasing SiO/SiO_2 nanomembranes from the photoresist sacrificial layer using acetone, and the rolling direction control by defining the corner attachment of nanomembranes.

Keywords:

Rolled-up, SiO/SiO2 microtube, Corner attachment

Metal-Insulator Phase Transition Characteristics of Vanadium Dioxide Thin Films Tailorable by Substitutional Doping Gradation

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Abstract:

Metal-insulator transition (MIT) phenomena have been considered to be attractive for fundamental physics interests as well as for various applications. Vanadium dioxide (VO_2) undergoes a phase transition at the MIT temperature (T_{MIT}) of ~67 ℃ abruptly. To broaden the scope of VO_2 applications, somehow limited to switching devices, the substitutional doping to replace V^{4+} with dopant cations including W^{6+} is known to be an efficient and reliable method via reducing T_{MIT} and modifying MIT characteristics.
In this work, we synthesized VO_2 thin films with W doping gradation perpendicular or parallel to the film surface by co-sputtering followed by heat treatment. In the case of these graded W-doped VO_2 thin films, the temperature coefficients of resistances (TCRs) were shown to be greater than those of pure VO_2 and uniform W-doped VO_2 thin films in a broad temperature region. These results would be available to advancing temperature sensors and heat detectors to next-generation as well as exploring 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.105

Femtosecond Laser-induced Phase Transformation of WO_3 Nanorods synthesized on Laser-induced Graphene for Flexible Solar Water Splitting Cell

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Abstract:

"The era of global warming has ended; the era of global boiling has arrived." The UN strongly warned about the climate crisis facing humanity. For swift action to prevent the increase of global temperature until irreversible level, most researchers have investigated renewable energy sources to replace fossil fuels. Among them, photoelectrochemical water splitting cell (PEC cell), one of the hydrogen energy harvesters, is an attractive solution due to its several benefits. The solar ray incident to semiconductor photoelectrode makes photoexcited charge carriers, which generate water redox reactions, decomposing the H_2O molecules to H_2 and O_2 gases. With this mechanism, the PEC cell uses renewable solar energy to get clean H_2 gases without CO_2 emission.
To develop the PEC cell to the commercial level, there are lots of successful attempts such as heterojunction, layering catalysts, and defect engineering. However, these are only focused on the enhancement of the water splitting performance. Mechanical flexibility also can be a solution to expand the application of the PEC cell like other devices, such as flexible thin film solar cells and flexible supercapacitors. Nevertheless, only few papers about flexible PEC cells have been reported. It seems to be because it is difficult to fabricate a photoelectrochemically stable and flexible current collector, and the conventional high-temperature process necessary for the fabrication of the semiconductor photoelectrode is not suitable for flexible substrates.
Herein, we demonstrate the fabrication of a flexible photoanode based on monoclinic WO_3 (m-WO_3) nanorods for solar water splitting by two laser techniques, which are the solution to overcome the aforementioned challenges for flexible PEC cell. The photoelectrochemically stable current collector was manufactured by direct laser writing carbonization (DLWC) technique on polyimide film. The Laser-induced graphene (LIG), a carbon electrode made using DLWC, has excellent mechanical/chemical robustness and electrical conductivity enough to use as a flexible current collector for photoanode. The WO_3 nanorods were hydrothermally synthesized on the surface of LIG without additional seed layering. Then, the high-temperature annealing process was replaced with laser-induced phase transformation using femtosecond laser (fs-LIPT). The orthorhombic $WO_3 \cdot 0.33H_2O$ (o-WO_3) nanorods, a crystalline structure after hydrothermal synthesis, could be transformed to m-WO_3 which is a suitable structure for PEC cell by irradiation of the femtosecond laser. The focused laser beam with longer wavelength (780 nm) than the bandgap of o-WO_3 (~3.5 eV) could be absorbed *via* two-photon absorption. Finally, the electrodeposition of NiFe layered double hydroxide catalyst was conducted to improve the photoelectrochemical stability. The fabricated flexible photoanode shows good mechanical and electrochemical stability with 1.46 mA/cm^2 photocurrent density

Keywords:

Photoelectrochemical Water Splitting, Femtosecond Laser, Laser Processing, Laser-induced Phase Transformation, Two Photon Absorption

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P2-ap.106

Electrocaloric cooling with triboelectric nanogenerator

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Abstract:

Recently, due to global warming, attention has been focused on the development of more efficient cooling methods. The vapor compress method, which is the existing cooling method, has an environmental problem in which refrigerants cause greenhouse effects, so an alternative is needed. Cooling methods using the electric calorific effect have attracted attention because it does not use refrigerants.

We are developing a self-powered cooling system that combine electrocaloric effect and triboelectric nanogenerator. We noted P(VDF-TrFE-CFE) as an electrocaloric material. The triboelectric nanogenerator charged the P(VDF-TrFE-CFE) to about 1200V. Upon discharging, the P(VDF-TrFE-CFE) exhibited a cooling effect of approximately 1 K.

Keywords:

Triboelectric nanogenerator, Electrocaloric effect

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P2-ap.107

Er이온을 첨가한 $K_5Y(P_2O_7)_2$의 구조 및 광학 특성 연구

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Abstract:

본 연구에서는 Er^{3+}이온이 첨가된 $K_5Y(P_2O_7)_2$ (KYP:Er) 시료의 구조와 자외선 발광 및 상향 변환 발광(upconversion luminescence, UC)에 대해 조사하였다. KYP:Er 시료는 고상반응법(Solid-state reaction method)을 통해 합성했다. Er^{3+}이온의 UC 발광 특성을 높이기 위해 감응제로서 Yb^{3+}이온을 첨가했다. X-ray diffraction 구조 분석을 통해 KYP:Er 시료가 이차상이 없는 삼사정계(Triclinic, $P\bar{1}$) 구조임을 확인하였다. KYP:Er 시료가 자외선으로 여기할 때 광발광(Photoluminescence)을 측정한 결과 Er^{3+}이온의 525/547 nm(녹색)와 660 nm(적색) 발광 신호를 얻었다. 980 nm의 적외선 레이저로 여기하여 측정한 UC 발광에서도 자외선 여기와 마찬가지로 Er^{3+}이온이 525/547 nm(녹색), 660 nm (적색)에서 UC 발광하는 것을 확인했다. 이때 525/547 nm(녹색)와 660 nm(적색) 신호의 세기 비율이 여기 방식에 따라 다르게 관측되는 특성을 보여주었다. 이러한 연구 결과를 통해 KYP:Er 시료가 우수한 자외선 발광 및 상향 변환 발광 특성을 가짐을 확인하였다.

Keywords:

K5Y(P2O7)2, Er3+, Yb3+, upconversion luminescence

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P2-ap.108

Photomodulation of Two-dimensional Electron Gases at $LaAlO_3/SrTiO_3$ Heterointerfaces enabled by Surface Deprotonation

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Abstract:

Persistent Photoconductivity (PPC) of the two-dimensional electron gases (2DEGs) in $LaAlO_3/SrTiO_3$ (LAO/STO) heterostructures make them suitable for optoelectronic memory applications. The optoelectronic memory applications require the capability of instantly suppressing the PPC for reversible switching operations. However, it is still elusive to reproducibly suppress the PPC, limiting the practical applications of LAO/STO heterostructures. In this study, we demonstrate a reversible photomodulation of the 2DEG in LAO/STO heterostructures. By ultraviolet (UV) light pulses, we show that the 2DEG at the interface of LAO/STO undergoes a gradual transition into the PPC states with different conductivities. Significantly, complete removal of PPC is achieved through a water treatment. In addition, we verify that the PPC switching can be highly reproducible when the following conditions are met: (1) moderate oxygen deficiency in STO and (2) the minimized band edge fluctuations at the interface. By utilizing X-ray photoelectron spectroscopy and analyzing electrical noise, we show that the surface-induced electron relaxation in STO is directly correlated with the PPC characteristics of the 2DEG interface. Our results will provide a solid foundation for the development of photoresponsive memristors or optoelectronic devicese based on oxide 2DEG systems.

Keywords:

Photomodulation, Persistent photoconductivity, Two-dimensional electron gases, Oxygen vacancies, Low-frequency noise

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P2-ap.109

Structural transformation and Photoluminescence properties of HfO_2 by doping Pr^{3+} and Eu^{3+}

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Abstract:

It has been suggested that by incorporating a small amount of rare earth ions, the functionality of electronic materials can be enhanced by introducing luminescent properties. HfO_2 based materials have attracted significant attention because of the high dielectric permittivity (k) and excellent thermodynamic stability. In this work, we fabricate luminescence high-k materials by co-doping Pr^{3+} and Eu^{3+} ions to HfO_2 ($Hf_{1-x}Pr_xO_2$:Eu, x = 0.00, 0.01, 0.03, 0.05, 0.07 and 0.09) in the solid state reaction method. The doping concentration of Eu^{3+} was 0.4 mol%. The Rietveld refinement based on X-ray diffraction revealed that the structural transformation from monoclinic ($P2_1/c$) to cubic (Fm-3m) of HfO_2 occurred with increasing x mainly due to the doping of Pr^{3+}. Photoluminescence (PL) spectra of $Hf_{1-x}Pr_xO_2$:Eu were measured under 396 nm excitation. The PL spectra showed typical orange-red emissions of Eu^{3+} ions. As x increased, the PL intensity decreased due to increase of local symmetry of $Hf_{1-x}Pr_xO_2$. Since HfO_2 has higher dielectric constant at Fm-3m than $P2_1/c$, the doping of Pr^{3+} increase the dielectric constants of HfO_2, which was not affected significantly by the co-doping of Eu^{3+}. Our experiment suggest that $Hf_{1-x}Pr_xO_2$:Eu has a potential to be a multi-functional luminescence high-k materials.

Keywords:

Photoluminescent, Dielectricity, high-k materials, HfO2, Rare earth

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P2-ap.110

Investigation of surface chemical state of $SrFeO_{2.5}$ films during topotactic transition by ambient pressure X-ray photoelectron spectroscopy

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Abstract:

Topotactic transition between a metallic perovskite $SrFeO_3$ and an insulating brownmillerite $SrFeO_{2.5}$ has been extensively studied due to its potential applications such as synaptic components for neuromorphic computing and memory devices. The transition is one in which only ordered oxygen vacancies (OVCs) are formed and removed while the crystallographic framework is maintained. These OVCs are known to be strongly influenced by the strain that can affect the capability to dissociate gas molecules of a material. However, there are still few studies on the effect of the strain on the surface chemistry and the topotactic transition.

In this study, we investigated the correlation between the surface chemistry and the transition of $SrFeO_{2.5}$ films with different strain state. $SrFeO_{2.5}$ films were grown on $SrTiO_3$(001) and $(LaAlO_3)_{0.3}(Sr_2AlTaO_6)_{0.7}$(001) (LSAT), substrates using the pulsed laser deposition. Structural analysis based on X-ray diffraction confirmed that both films have highly crystallinity and the $SrFeO_{2.5}$ film grown on STO(001) showed weaker in-plane compressive strain than the film grown on LSAT(001) due to the small lattice mismatch between the film and STO substrate. Ambient-pressure X-ray photoelectron spectroscopy (AP-XPS) was used to investigate the change in the surface chemical state and the corresponding electrical resistance of the films during the topotactic transition. We observed a larger amount of surface SrO state in $SrFeO_{2.5}$ film grown on STO(001) substrate, where the phase transition occurs more slowly, than the film grown on LSAT(001) substrate. We discuss the correlation between strain state, surface SrO and resistance on the topotactic transition

Keywords:

Topotactic transition, brownmillerite, perovskite, AP-XPS

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P2-ap.111

Synthesis and characterization of SnO_2 thin films based ultraviolet photodetectors

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Abstract:

We report on the performance of ultraviolet (UV) photodetectors composed of SnO_2 thin films having thickness thinner than 15 nm. The SnO_2 thin films were deposited on sapphire (0001) substrates using powder sputtering method. To reduce the native oxygen vacancies, the samples were grown in a pure O_2 gas atmosphere with a working pressure of 5 x 10-3 torr. Based on the characterization results through synchrotron X-ray diffraction (XRD) and atomic force microscopy (AFM), We determined the structural properties of SnO_2 thin films as a function of film thickness. At 2.5 nm thick sample, the surface of the thin film is relatively smooth. As for Θ-rocking curve, it was observed that as thickness of SnO_2 thin film increased, the background also increased. This is because of the surface state effect. Surface state effect are responsible for the relatively slow response speed. Metal-SnO_2 thin film-metal type photodetectors were fabricated, and their photoresponsivity to UV light in the range from 200 to 400 nm was investigated. The device of 4.4 nm thickness exhibited a photo-to-dark current ratio ~7.3 $\times 10^4$ at an applied bias of 10 V and 254 nm UV exposure. A maximum responsivity was estimated at a wavelength of 260 nm, and the cutoff edge wavelength appeared around 350 nm. On these results, We have successfully demonstrated that SnO_2 thin film of 2.5 nm was candidate for UV photodetectors.

Keywords:

SnO2 thin film, ultraviolet photodetector, Powder sputtering, Oxygen vacancies, Photoresponsivity

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P2-ap.112

Investigation of Ferroelectricity and Switching Dynamics of $Hf_{0.5}Zr_{0.5}O_2$ Thin Films Depending on Annealing Temperatures

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Abstract:

Hafnium oxide-based materials have attained great attention since 2011, the year of the discovery of ferroelectricity in this material. This discovery has given us many opportunities to overcome various problems, such as the scaling problem in conventional ferroelectrics and the poor complementary metal oxide semiconductor process. For these reasons, ultra-thin doped-HfO_2 are considered as a strong candidate for nonvolatile memories and neuromorphic devices. Generally, post-annealing process is necessary in fabrication process of doped-HfO_2 thin film for crystallization of ferroelectric orthorhombic phase ($Pca2_1$). In the post-annealing process, annealing temperature is an important factor to determine the grain size. Also, the grain size significantly affects the formation of ferroelectric phase. Therefore, it is highly required to investigate the effect of annealing temperature on ferroelectricity of doped-HfO_2 thin films. In this study, we studied the ferroelectric properties, especially polarization switching dynamics, of $Hf_{0.5}Zr_{0.5}O_2$ (HZO) films annealed at different temperatures (550 – 700 °C). We fabricated Mo/HZO/TiN capacitors by using radio frequency sputtering method. We measured the structural and electrical properties of the capacitors using grazing incident x-ray diffraction, transmission electron microscopy, and a ferroelectric tester. We also detected the grain sizes of the HZO thin films and found that it becomes larger with increasing the annealing temperature. To investigate the polarization switching dynamics, we measured transient switching current and time-dependent piezoresponse force microscopy images. Interestingly, we observed that the switching speed of the film annealed at 600 °C is faster than that of the film annealed at 550 °C. This indicates that the polarization switching speed is not simply elucidated by the grain size. We discuss the relationship between the annealing temperature and defect concentration and explain its effect on the dynamics of polarization switching. Consequently, this work stresses the impact of annealing temperatures on HZO thin films and the possibility of controlling switching behaviors due to defects induced by annealing process.

Keywords:

Hf0.5Zr0.5O2(HZO), Ferroelectricity, Grain size, Annealing temperature, Piezoresponse Force Microsocpy (PFM)

Investigation on photoluminescence and photochromism in Eu^{3+} doped $(Ba_{1-x}Ca_x)TiO_3$

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Abstract:

Currently, ferroelectric ceramics with excellent photochromic (PC) behavior have been studied intensively. Among them, the physical properties of $(Ba_{1-x}Ca_x)TiO_3$ ceramics have been extensively studied, but the PC characteristics of $(Ba_{1-x}Ca_x)TiO_3$ ceramics by rare earth doping have rarely been reported. In this work, photoluminescence and photochromic properties of $(Ba_{1-x}Ca_x)TiO_3$ doped with Eu^{3+} were reported. The ceramic samples used in the experiments were prepared using traditional solid-state techniques. After ultraviolet (UV) irradiation (λ = 385 nm), the reflectance of the samples decreased in the visible light region and also the PL intensity decreased. Changes in reflectance and PL emission due to photochromism could revert to their original values via heating samples at 200 °C for 5 min. The effect of Eu^{3+} doping on the ferroelectric properties of $(Ba_{1-x}Ca_x)TiO_3$ ceramics was confirmed by measuring the P-E loop. After Eu^{3+} doping, P_s significantly decreases from 9.62 μC/cm^2 to 4.28 μC/cm^2, which shows that Eu^{3+} doping greatly affects the ferroelectric properties of $(Ba_{1-x}Ca_x)TiO_3$ ceramics. We also discussed the effect of the Eu^{3+} doping on the photochromic behavior and ferroelectric properties in $(Ba_{1-x}Ca_x)TiO_3$.

Keywords:

photochromic, ferroelectric, (Ba1-xCax)TiO3 , photoluminescence

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P2-ap.114

Mechanically stable and highly crystalline $LaNiO_3$ flexible thin film electrode

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Abstract:

LaNiO3(LNO) is a typical oxide electrode that has mainly been used to deposit a functional oxide thin film on a polycrystalline substrate such as silicon. Although LNO is an oxide, it is used in various industrial fields as an electrode that can increase the crystallinity of thin films due to its very low resistance and perovskite crystal structure. In the era of the 4th industrial revolution, interest and need for flexible electronic materials such as wearable computers and flexible solar cells are increasing. Since the physical properties of the electronic material used are greatly affected by the crystallinity of the material, it is essential to optimize the LNO deposition conditions in order to synthesize a thin film of flexible electronic material with high crystallinity.

Here, we report the conditions that were explored to maximize crystallinity and electrical conductivity through the sol-gel deposition of LNO thin films of varying thicknesses and temperatures on flexible F-mica. F-mica substrate, which is resistant to high temperatures, was exfoliated to a thickness of 20 um. Through XRD and R-T data, high crystallinity and low resistance thin film was deposited under conditions of about 800 degrees and about 100 nm or more. These films exhibited stable resistance even during high bending cycles. In addition, we deposit PZT thin film on the formed electrode by spin coating. We confirm high crystallinity and dielectric constant data measuring the XRD and P-E loop after bending, and through this, high adhesion and crystallinity as an electrode were confirmed.

Keywords:

LaNiO3, Flexible film, Mechanically stable, Oxide electrode

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P2-ap.115

Phase separation of Indium gallim oxide thin films grown by powder sputtering method in a reducing atmosphere

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Abstract:

We report the phase separation of indium gallium oxide thin films grown on sapphire (0001) substrates using powder sputtering method in a reducing atmosphere. The resultant thin films were highly non-stoichiometric state of $(In_xGa_{1-x})_2O_{3-y}$ thin films determined by oxygen vacancies. 2 or 5 wt% of In atoms were added to Ga_2O_3 powder to prepare the powder sputter target. Two sereies of samples were peparaed with vaying the film thicknesses to investigate the structural evolution and phase separation as a function of film thickness. Characterization results through synchrotron X-ray diffraction and scanning electron micrscopy (SEM) indicates that the phase separation occurs by forming monoclinic β-Ga_2O_3, hexagonal-$InGaO_3$, and cubic-In_2O_3 phases. Furthermore, segregation of In atoms were observed, which is very clear on the EDX chemical analysis during SEM measurements. We will present the details of results to confirm the spontaneous phase separation in non-stoichiometric $(In_xGa_{1-x})_2O_{3-y}$ thin films.

Keywords:

Phase separation, Indium gallium oxide thin films, Powder sputtering, In metal segregation

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P2-ap.201

Superlattice design of quantum-cascade lasers using artificial neural networks and genetic algorithms

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Abstract:

Quantum cascade lasers (QCLs) are widely used as high-power mid-infrared (mid-IR) light sources. To design quantum cascade lasers with specific emission wavelength and high output power, optimizing the superlattice structures is necessary since it directly affects sub-band formation, emission wavelength, and optical gain properties. In such multi-objective optimization tasks, employing classical optimization algorithm such as genetic algorithms (GA) has proven effective. However, due to the stochastic nature of classical algorithms, evaluating the output characteristics of numerous potential candidates iteratively is required to find the optimal solution. When output characteristics of potential candidates are evaluated based on classical numerical simulators, optimizing the superlattice structures of the QCL based on the GA can be very time-consuming. In this study, we propose to optimize a superlattice structure of the active region of mid-IR QCLs based on the GA by replacing time-consuming numerical evaluation processes of QCL candidates with faster artificial neural networks (ANNs). As a result, ANNs enabled the successful optimization of a QCL device having an optical gain of 37 cm^{-1} at 8.35 μm in a time approximately 500 times shorter than conventional methods.

This research was supported by National Research Foundation of Korea (2021R1F1A1062591, 2020M3H4A3081665).

Keywords:

quantum cascade laser, multi-objective optimization, genetic algorithm, artificial neural network

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P2-ap.202

Anomalous Raman spectrum of 1L-$NiPS_3$ in 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. HS combining magnetic materials have not yet been studied intensively. In this work, 1L-$NiPS_3$/nL-$FePS_3$ 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 reveals many properties of the crystal structure and electro-magnetic properties in materials. $NiPS_3$ 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 splitting of P_{N2} in HS in $NiPS_3$ is observed, which is absent in bare 1L-$NiPS_3$. This suggests that there is a magnetic interlayer interaction caused by nL-$FePS_3$ that activated the magnetic Raman signal in 1L-$NiPS_3$. In addition, the one-magnon mode P_{F1} in $FePS_3$ shows different polarization dependence between $FePS_3$ and HS, which is a result of an interlayer interaction between two materials. The temperature-dependent Raman spectra of P_{F1} and P_{N2} show different Néel temperatures, which suggests the origins of the transition temperature may not be the same.

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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:

Raman spectrum, antiferromagnetic, NiPS3, FePS3, Temperature dependence

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P2-ap.203

Raman Study of low frequency magnons in $NiPS_3$

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Abstract:

$NiPS_3$ is one of the layered van der Waals magnetic materials that has been studied, showing XXZ-type antiferromagnetic ordering below the Néel temperature (T_N) of 155 K [1]. The antiferromagnetic ordering is suppressed in the monolayer [2]. Recently, several groups reported low-energy excitations in bulk $NiPS_3$, measured using different experimental tools such as THz spectroscopy, the pump-probe method, and electron-spin resonance (ESR) [3-5] and the signals have been identified as low-energy magnons gapped from the ground state.
We conducted ultralow-frequency polarized Raman scattering measurements and observed three low-frequency peaks in bulk $NiPS_3$ (~170 nm) at 3.5 K. These peaks are labelled M_1, M_2, and M_3, with frequencies of 11, 32, and 41 cm^{-1}, respectively. The three peaks have different dependences on polarization and temperature. M_1 is relatively stronger, and its dependence on the thickness is studied: for thinner samples, M_1 appears at lower frequency, reaching 6 cm^{-1} for a 2-layer sample at 3.5 K, whereas this signal is not observed for the monolayer. These results are compared with the analysis of the latest neutron scattering data to confirm the origin of this signal as being due to the magnon excitation.

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Keywords:

NiPS3, magnon, van der Waals magnetic material, ulatrlow-frequency Raman, antiferromagnet

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P2-ap.204

Inverse Spin Hall Effects in Noncollinear Magnetic System $IrMn_3$/Co

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Abstract:

We investigated inverse spin Hall effects induced by the broken magnetic symmetry in the antiferromagnet $IrMn_3$. The magnetic mirror symmetry is broken laterally in $L1_2$-$IrMn_3$ thin films. We observed a large out-of-plane anisotropy below room temperature for 1.5 nm thick $IrMn_3$ with the Néel temperature of 140 K. About 0.5 % of AMR was measured at low temperature (1.5 K) in a magnetic field of 0.3 T. In this work, Co was used for spin current detection. Both Co and $IrMn_3$ films were prepared at room temperature using the UHV-Molecular Beam Epitaxy (MBE) film deposition technique beyond the wafer-scale CVD-grown graphene layer. Its magnetic and transport properties were characterized by SQUID magnetometer and 4-probe method, respectively. Surface analysis was carried out by Raman spectroscopy and atomic force microscopy as well. Based on these results, we identify the mechanism to induce the inverse spin Hall effect through a noncollinear magnetic structure that breaks the spin rotation symmetry.

Keywords:

Antiferromagnet, Inverse spin Hall effect

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P2-ap.205

Study on magnetodynamics of different CoGd structures using ferromagnetic resonance (FMR)

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Abstract:

We investigate the magnetodynamics of ferrimagnetic GdCo alloy and its multilayer structures at room-temperature utilizing ferromagnetic resonance (FMR) based on a coplanar waveguide (CPW). According to a recent study, the compensation of magnetization and angular momentum of ferrimagnetic thin films can be tuned by modulating compositions of Gd and Co [1]. Our study was motivated by these observations, and then we prepared four different samples, $Gd_{25.0}Co_{75.0}$, [Gd (0.1 nm)/Co (0.3 nm)]×6, [Gd (0.2 nm)/Co (0.6 nm)]×9, and [Gd (0.3 nm)/Co (0.9 nm)]×18, to understand the compenstion mechanism between Gd and Co. While the overall amounts of Co and Gd were kept in the entire sample series, and these were deposited by using DC/RF UHV sputter system. In this presentation, we discuss how magnetic damping (α) and effective magnetization (Meff) will be varied from FMR measurements.

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Keywords:

Ferromagnetic Resornance(강자성공명), Ferrimagnet (준강자성)

2023 KPS Fall Meeting
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P2-ap.206

Tetragonal distortion inducing magneto-crystalline anisotropy in bcc-Fe and fcc-Ni

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Abstract:

Magneto-crystalline anisotropy (MCA) refers to a tendency to favor a specific magnetization direction [1]. In cubic structures, bcc-Fe and fcc-Ni, the magneto-crystalline anisotropy energy (E_{MCA}) vanishes due to symmetry [2]. In this study, we investigate E_{MCA} of Fe and Ni through tetragonal distortion using a first-principles study. Strong dependence of E_{MCA} on c/a is evident [3]. For Fe case, E_{MCA} is -34 and +56 μeV/atom for c/a = 0.95 and 1.05, respectively. For Ni case, E_{MCA} is +25 μeV/atom for c/a = 0.95 but -65 μeV/atom for c/a = 1.05. From band analysis, band shifts by tetragonalization influence E_{MCA}, both sign and magnitude.

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Keywords:

Magneto-crystalline anisotropy, Symmetry breaking, First-principle study

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P2-ap.207

Magneto-crystalline anisotropy of cubic Fe_4N via tetragonalization

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Abstract:

Fe_4N has drawn attention as potential applications for magnetic recording materials with thermal and chemical stability, and high Curie temperature (767 K) [1,2]. In Fe_4N with anti-perovskite structure, Fe is distinguished by two types, Fe-1 and Fe-2, whose magnetic moments are 2.95 and 2.33 μ_B , respectively. Herein, we investigate magneto-crystalline anisotropy (MCA) [3] via tetragonalization (0.95≤ c/a≤ 1.05) using first-principles calculations. When c/a<1, E_{MCA} = 0.34 meV/f.u. for c/a = 0.95. On the other hand, when c/a>1, E_{MCA} = -0.18meV/f.u. for c/a = 1.03. For understanding such sign change of E_{MCA}, band structure is analyzed in the framework of perturbation.

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Keywords:

Magneto-crystalline anisotropy, tetragonalization, first-principles calculations

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P2-ap.208

Deep-Learning-Based Optical Design Optimization of Multilayer Thin Films

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Abstract:

When light passes through multiple thin film layers, reflection/transmission spectrum greatly depends on the refractive index and thickness of each thin layer due to optical interference effect. This is an essential consideration when manufacturing thin-film-based optical devices or displays. Hence, a careful optical modeling and design of multiple thin films is required based on the transfer matrix method. Recently, deep learning algorithms such as deep neural networks (DNNs) have been applied to perform optical design optimization of multilayer thin films. In the case of inverse design applications, a tandem neural network has been used to alleviate a so-called one-to-many-mapping problem, which take places when different multilayer structures have nearly the same reflection/transmission spectrum.

In this study, we investigate a deep-learning-based optical design optimization of multilayer thin films, focusing on a tandem neural network to improve the performance of inverse design. In particular, we apply convolutional neural networks (CNNs) to implement an inverse design. We demonstrate that a CNN-CNN-based tandem neural network shows the improved accuracy than a conventional DNN-DNN-based one in the inverse design of multilayer thin films.

This research was supported by National Research Foundation of Korea (2021R1F1A1062591).

Keywords:

Thin Film, Optical Design Optimization, Deep Learning, Inverse Design

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P2-ap.209

Spin-orbit torque switching of $L1_0$ FePt granular film

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Abstract:

Effective electrical control of magnetic devices is a significant challenge in the development of MRAM with high energy efficiency and ultra-high density. In particular, spin-orbit torque (SOT) is essential for enhancing MRAM performance because SOT enables ultra-fast magnetization control under 1 ns and guarantees read-write selectivity. SOT generally occurs in a bilayer structure which consists of non-magnetic (NM) and ferromagnetic (FM) materials.

As a FM layer, $L1_0$ FePt – x granular films (X = Al_2O_3, C, TiO_2, Ta_2O_5) has a large perpendicular magnetic anisotropy energy ($K_u \approx 7\times10^7$ erg/cc) that ensures stability against thermal fluctuations in a very small volume.[1] Therefore, it has been used for high-density magnetic recording media and MRAM applications. In this study, We discuss about the SOT-induced switching behavior of the $L1_0$ FePt Granular film where the grain sizes and shapes are randomized in an insulating media.

Keywords:

Spin-orbit torqe, FePt

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P2-ap.210

Efficient Workflow of First-principles Calculations via Machine Learning

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Abstract:

Density functional theory (DFT) calculations based on the Kohn-Sham equation are powerful for determining material's scientific properties in modern solid-state physics. However, the computational cost and resource requirements increase significantly with the number of elements in the unit cell. In recent years, machine learning has made notable progress and has been actively applied in physics to comprehend complex problems easily. We propose an efficient workflow to accelerate first-principles calculations using graph neural networks. After understanding the performance of the suggested workflow, we show their usage in the related fields.

Keywords:

DFT, First-principles Calculations, Machine Learning

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P2-ap.211

$Mn_{3+x}Sn_{1-x}$ 박막에서 조성에 따른 자성특성의 결정학적 연구

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Abstract:

Mn_3X 화합물 (X=Ga, Ge, Sn)은 비 공선형 반 강자성체로서, 이 화합물들이 가지는 독특한 전자기적 특성으로 물질 연구자들의 주목을 받고 있다. 이 화합물들은 Kagome 격자라고 불리는 독특한 결정 구조를 가지고 있으며, 이 격자는 스핀들이 120˚ 간격으로 배열되는 형태를 띠고 있다. 특히, Mn_3Sn 화합물은 (0001) c-평면을 따라 Mn 원자 당 약 $0.002\mu_B$의 아주 작은 순 자화를 가짐에도, 큰 Berry phase의 형성으로 상온에서 일반 강자성체에 준하는 비 정상 홀 효과를 발생하는 것이 관찰되었다[1]. 이러한 Berry curvature은 운동량 공간에서 유효 자기장의 역할을 하는데[2], 이로 인해 Mn_3Sn은 바일 반금속 특성을 갖는 등, 응집물질물리 분야에서 흥미로운 시스템으로 여겨지고 있다[1].

이번 연구에서는 다양한 조성을 갖는 $Mn_{3+x}Sn_{1-x}$ 박막의 자기적 특성에 대해 연구하였다. $Mn_{3+x}Sn_{1-x}$ 박막은 UHV 마그네트론 스퍼터링 시스템을 사용하여 MgO(110) 기판에 증착하였다. XRD 구조분석에서 Mn_3Sn peak 뿐만 아니라 Mn_3Sn_2와 $Mn_{1.75}Sn$ peak을 관측하였다. 이러한 Mn_3Sn외에 관측된 이차상이 박막의 스핀-궤도 토크(spin-orbit torque, SOT) 유도 스위칭 특성을 억제시키는 것으로 예상된다. 발표에서는 $Mn_{3+x}Sn_{1-x}$ 박막에서 조성에 따른 비 정상 홀 전도도와 SOT 스위칭 특성에 대하여 상세하게 설명할 것이다.

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Keywords:

Mn3Sn, Noncollinear-Antiferromagnet, Kagome structure, Spin-orbit torque switching

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P2-ap.212

K-point convergence of total energy in density functional theory calculation

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Abstract:

The recent development of density functional theory (DFT) calculation methods has led to automatic high-throughput calculations. Several big computational databases such as the Materials Project, NOMAD, and OQMD were constructed for screening purposes, and machine learning models were also generated using the calculation results. DFT calculation of a crystalline material requires a k-point convergence test to obtain converged physical quantities. In the construction of the computational databases, a lot of materials with different atomic structures are of interest, and thus in principle convergence tests should be performed for each material. To provide a useful guideline to foster high-throughput calculations, we performed the k-point convergence tests for 101 materials of 9 structures. The general trends will be discussed in the presentation.

Keywords:

density functional theory, high-throughput, k-point sampling, machine learning

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P2-ap.213

Development of near-edge X-ray absorption fine structure spectroscopy data processing

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Abstract:

X선 흡수 미세구조 분광법(near-edge X-ray absorption fine structure spectroscopy)은 방사광 시설에서 화학적 결합 상태를 식별하는 강력한 도구이다. 신소재의 발전으로 인해 학계와 업계의 연구자들은 싱크로트론 빔라인에서 수십에서 수백 개의 샘플을 측정해야 한다. 이때문에 분석 소프트웨어와 자동화된 측정 방법이 빔라인에서 개발되었다. 기존의 분석 소프트웨어는 실험 데이터를 분석하기 위한 다양한 기능을 지원하지만 분석 방법이 복잡하고 학습하는 데 많은 시간이 걸릴 수 있다. 대용량의 스펙트럼 데이터를 처리하기 위해서는 사용이 간편하고 단시간에 결과를 제공할 수 있는 새로운 분석 소프트웨어가 필요하다. 우리는 빔라인에서 하나의 샘플을 측정하는 데 필요한 것과 비슷한 짧은 시간에 결과를 보고할 수 있는 NEXAFS 분광학 데이터로부터 분자 방향을 계산하는 소프트웨어인 Beagle을 개발했다. 이는 "버튼 클릭"만으로 데이터 로딩부터 결과 인쇄까지 단일 순서로 진행되도록 설계되었다. 소프트웨어의 기능에는 데이터 세트 인식, 배경 수정, 플롯 정규화, 전자 수율 계산 및 분자 방향 결정이 포함된다. 분석 결과는 txt 파일(스펙트럼 데이터), pdf 파일(그래픽 이미지), Origin 파일(스펙트럼 데이터 및 그래픽 이미지)로 저장할 수 있다.

Keywords:

X선 흡수미세구조 분광법, 데이터 처리, 분자 방향 결정

2023 KPS Fall Meeting
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P2-ap.214

Prediction of Ferromagnetic Phase of Fe_xO_y using Generative Adversarial Network

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Abstract:

With the exponential advancement in computing capabilities over recent years, we now have the tools to compute and predict a vast spectrum of solid-state physical properties of materials. Among various computational methods, the density functional theory (DFT) calculation method stands out as a powerful approach to glean insights into materials' atomic and electronic properties. Popular computational packages like Vienna Ab initio Simulation Package (VASP) and Quantum Espresso have enabled researchers to make groundbreaking discoveries in this field. Concurrently, the rise of machine learning techniques has carved new paths in numerous research areas. Its application is not limited to just data analysis; it has now become instrumental in predicting and discovering new material structures. In this study, we will find the phase of Fe_xO_y with ferromagnetic properties using deep learning by confirming that the magnetic properties of Fe_xO_y vary with phase. To identify and possibly predict Fe_xO_y phases with ferromagnetic properties, we employ a deep learning methodology, specifically leveraging the capabilities of the generative adversarial network (GAN). This research not only emphasizes the dynamic relationship between phase and magnetic properties but also showcases the transformative potential of machine learning in material science research.

Keywords:

machine learning, ferromagnetic, deep learning

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P2-ap.301

Enhancing Device Performance through Vertical Organic Diodes and Organic Permeable Base Transistors (OPBTs)

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Abstract:

In this paper, we present research findings focused on addressing the challenges posed by the channel length limitations in horizontal structure devices, particularly in achieving high current density. We propose a solution through the advancement of vertical structure devices. Vertical devices leverage the equivalence of semiconductor film thickness and channel length, enabling the creation of nanometer-scale channels and thereby facilitating the attainment of high current density. Our study involves the utilization of P-type organic semiconductor materials to fabricate vertical diodes and modified diode structures, leading to the development of Organic Permeable Base Transistors (OPBTs). The fabricated vertical organic diodes exhibit varying current characteristics based on the scale of the active area and reveal regions resembling Space-Charge-Limited Current (SCLC) in their voltage-current (J-V) curves. These observations prompt us to propose the possibility of assessing key properties of organic semiconductors, such as carrier mobility and trap levels, through mathematical modeling. Furthermore, the OPBTs display the formation of pinholes within the base electrode due to the generation of native oxide. These pinholes play a crucial role in determining the device's behavior. Through experimental investigations, we establish correlations between the thickness of the deposited Al (base electrode) and the operational behavior of the OPBTs. We also explore how variations in the base thickness and the formation of native oxide impact the transistor characteristics. Finally, OPBTs fabricated under optimized processing conditions exhibit promising attributes as next-generation organic field-effect transistors (FETs). These devices showcase notably low operation voltages, high On/Off ratios, and elevated current density. These advancements will significantly contribute to the progression of the future semiconductor industry.

Keywords:

Organic field-effect transistors, organic semiconductors, Organic Diode

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The Post-annealing Induced Enhancement of Vacuum Deposited Green Perovskite Light-emitting Diode

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Abstract:

Due to its advantages in terms of large-area deposition feasibility, ease of thickness and composition control, the vacuum deposition of lead halide perovskite is a promising fabrication technique for the commercialization of perovskite light-emitting diodes (PeLEDs). However, vacuum-deposited PeLEDs exhibit a limitation in terms of low external quantum efficiency (EQE) compared to solution-processed PeLEDs. Meanwhile, the post-treatment techniques such as annealing under vacuum or inert gas, and solvent-assisted annealing showed improved device performance. Nevertheless, there is a deficiency in research regarding how these post-treatments enhance the performance of PeLED devices.
Here, we investigated the mechanism by which thermal annealing under inert gas enhances PeLED device performance. The mixed-phase perovskite film was fabricated through the co-evaporation of cesium bromide (CsBr), methylammonium bromide (MABr), and lead bromide ($PbBr_2$). After the vacuum deposition, the film was transferred to a nitrogen-filled glove box and thermally annealed, and a two-fold increment of EQE was observed. The alteration of characteristics of perovskite films was analyzed in terms of morphology, crystallinity, electronic structure, phase distribution, and optical properties.

Keywords:

Halide perovskite, perovskite light-emitting diodes, halide perovskite vacuum deposition, post-annealing, CsPbBr3/Cs4PbBr6

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Nanostructure engineering in organic semiconductor devices toward interface matching

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Abstract:

Development of nanomaterials have attracted much attention due to their physical, chemical, optical, mechanical, and thermal properties on the scale that are different from those of bulk materials. In particular, nanostructured arrays are known to be effective structures that increase energy transfer due to a gradual change in impedance at an interface between individual media.
It is known that the nanosurface of the moth eye, which is the key to optical impedance matching, directs the light to the pattern when light is incident, improving the transmittance of light. These nanopatterns have been widely used to reduce light loss. The nanostructure has been reported as an electrical impedance matching layer by concentrating the current flowing on the patterned interface. Therefore, we applied it to an organic semiconductor device with high contact resistance due to the heterojunction between the semiconductor and the electrode. Lowering it plays an important role in improving device performance. To solve this problem, nanopatterned electrodes that gradually change the impedance at the interface between metal and organic semiconductor in organic devices were fabricated in periodic patterns using nanoimprint lithography (NIL) technology. The enhanced current mechanism was analyzed through numerical simulation, and it was confirmed that it is effective for charge injection and transport.

Keywords:

Nanostructure, Interface engineering, Organic electronics

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Changing raman signal of Fine matter by local thermal effect of gold nanoparticles

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Abstract:

Local heat transfer technology is used in medical, biological, and optical communications. In this study, we propose a method to apply this local heat transfer technique.
This study presents a method for thermal effect by gold nanoparticle. An alternative sample for fine matter is Polystyrene Latex Bead (PS Bead) The gold thin film was produced using the self-asssemble technique of the gold nanoparticles. When the gold thin film was placed on the fine particles, The incident light causes the plasmon effect of the gold nanoparticles to generate heat. These particles were measured using Raman spectroscopy and scanning electron microscope (SEM).
As a result of preparing the sample, It has been shown that the photothermal effect of gold nanoparticles can be used to selectively transfer heat to a sample.

Keywords:

Fine matter, Thermal Effect, Gold nanoparticle

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TiO_2를 활용한 폴리우레탄 폼의 내황변성 개선 연구

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Abstract:

폴리우레탄은 높은 강도, 내화학성, 우수한 가공성 및 우수한 기계적 특성으로 인해 다양한 상업 및 기술 응용 분야에 사용되고 있다. 하지만 폴리우레탄은 UV에 노출될 경우 노란색으로 변하는 황변 현상이 발생하는 단점이 있다. 또한 폴리우레탄은 UV에 노출되면 구조적 변화를 일으켜 물리적, 기계적 특성이 저하되는 것으로 알려져 있다. 변색 및 파괴로 이어질 수 있는 황변은 폴리우레탄이 실외 응용분야에 적용되는 것에 제한이 되고 있다. 이러한 황변 현상을 해결하기 위하여 UV흡수제, 카본 블랙, HALS 등을 사용하여 다양한 연구가 진행되고 있다.

UV 흡수제는 폴리우레탄의 UV 저항성을 개선하는 효과적인 방법 중 하나이다. 무기 UV 흡수제 중 하나인 이산화티타늄(TiO_2)는 우수한 화학적 안전성, 광학적 특성, 저비용 및 환경 친화적인 특성을 가진 UV 흡수제로 UV 차폐 분야에 사용되고 있다. TiO_2는 rutile형과 anatase형이 널리 사용되고 있으며, Rutile은 결정 밀도와 UV-가시광선 흡수능력은 anatase보다 크지만 anatase는 UV-가시광선에 비해 상대적으로 높은 반사율을 가지고 있다. 이러한 다른 특성을 가진 anatase와 rutile을 폴리우레탄에 합성한 결과물은 물리적, 기계적 특성 및 UV흡수 특성이 다를 것이라고 판단된다. 이에 본 연구에서는 TiO_2 anatase와 rutile을 폴리우레탄과 혼합하여 폴리우레탄의 물리적, 기계적 특성 변화를 비교하고 내황변성 개선 연구를 진행하였다.

Keywords:

TiO2, 폴리우레탄, 황변

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Mid Infrared molecular sensing using 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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Enhancing Performance and Stability of Inverted Perovskite Solar Cells through Fluorine-Based Lewis Acid Doping in the Hole Transport Layer

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Abstract:

Perovskite solar cells (PSCs) have exhibited a remarkable surge in power conversion efficiency (PCE), which escalates from a modest 3.8% to an astonishingly competitive range surpassing 26%, thereby establishing a formidable challenge to the dominance of silicon-based solar cells. In the domain of inverted planar PSCs, those incorporating a hole transport layer (HTL) constructed from poly[bis(4-phenyl)(2,4,6-trimethylphenyl)amine] (PTAA) have impressively showcased elevated PCE. However, PTAA's inherent carrier concentration typically remains at a low level, prompting the adoption of dopants to amplify its conductivity. Conventional dopants such as 2,3,5,6-tetrafluoro-7,7,8,8-tetracyanoquinodimethane (F4-TCNQ) and bis(trifluoromethane)sulfonimide lithium salt/4-tert-butylpyridine (Li-TFSI/t-BP) play a role in boosting PTAA's conductivity and facilitating charge transport. While enhancing charge transport, these dopants have downsides. F4-TCNQ is costly and poorly soluble. Li-TFSI's solubility is good but its high hygroscopicity degrades materials and leads to hysteresis. Also, t-BP's low boiling point causes quick evaporation in PSCs, harming stability. In this study, we introduced the novel fluorine-based Lewis acid dopant to enhance PTAA conductivity and improve PSC stability. By boosting PTAA conductivity and perovskite grain size, the doped PTAA-based device achieved a PCE of 20.69%, surpassing the undoped PTAA-based device's 18.50% PCE. Furthermore, the long-term stability of the doped PTAA-based PSC was demonstrated without encapsulation. After 500 hours, the doped device retained 62% of its initial efficiency, whereas the undoped device dropped to 38%. This study aids the design of stable, high-performing inverted PSCs through straightforward HTL doping.

Keywords:

Perovskite solar cell, PTAA, Hole transport layer, Doping

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NIR 대역 PPG, BFI 신호 기반 비침습적 혈중 글루코스 농도 예측 모델 개발

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Abstract:

2012~2018년 국민건강영양조사에서 국내 30세 이상 성인 인구의 7명 중 1명(13.8%)이 당뇨병을 겪고 있다. 현재 당뇨환자 들은 매 측정마다 채혈이 요구되는 Self-Monitoring of Blood Glucose(SMBG) 방식을 주로 사용한다. 이 불편함을 해소하기 위해 최소 침습 방식의 혈당 측정기술이 개발되었지만 센서 삽입에 따른 감염우려와 부족한 정확도로 인해 아직까지 SMBG 방식을 대체하지 못하고 있다. 이에 따라 감염우려가 없는 비침습적 혈당 측정 기술 개발을 위한 연구가 활발히 이루어지고 있다. 특히 근적외선(NIR)을 이용한 혈당 측정 기술은, NIRS와 PPG 신호를 활용하는 방향으로 이루어지고 있다.

본 연구에서는 기존에 사용한 NIRS 방식 및 PPG 정보와 더불어 BFI 정보를 가지고 인공지능을 활용하여 혈중 당 농도에 대한 신뢰할 만한 값을 얻어내는 것을 목표로 한다. 인체 내부에서 빛을 많이 흡수하는 물, 헤모글로빈, 그리고 산화 헤모글로빈의 영향을 고려해 서로 다른 파장을 가지는 4개의 레이저 (660, 785, 808, 830nm)를 사용했다. 또한 각 파장에 대응하는 필터를 사용해서 4 개의 CCD에 분리하여 측정했다. Diffuse Speckle Contrast Analysis(DSCA) 방식으로 Speckle 패턴과 세기를 분석하여 각각 PPG와 BFI를 측정했다. 자체 제작한 MATLAB 코드로 데이터를 처리했으며, 인공지능을 활용해 분석했다.
경구 포도당 부하 검사(OGTT) 방식에 따라, 금식 후 포도당 용액 일정량을 섭취해 혈당 농도의 급격한 변화를 유발했으며, 혈당 수치가 증가함에 따라 혈당 예측값 역시 같이 증가함을 확인했다.

Keywords:

Blood glucose, Non-invasive, PPG, BFI, NIR

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Dopant-free poly[bis(4-phenyl)(2,4,6-trimethylphenyl)amine] hole transport layer for perovskite solar cells: Simple heterocyclic compound as precursor solvent

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Abstract:

Triple cation perovskite solar cells have emerged as the preferred option for achieving remarkable power conversion efficiency in contemporary research endeavors. Based on this perovskite material, Poly[bis(4-phenyl)(2,4,6-trimethylphenyl)amine] (PTAA) is a wildly used hole transport material to fabricate inverted structure perovskite solar cells. Because of hydrophobic of PTAA film, it is hard to make high quality perovskite film on top of PTAA layer. Researchers used Phenethylammonium iodide (PEAI), MoO3 etc. as dopant to change the hydrophobic surface of PTAA. Here, we have introduced a heterocyclic compound as a dopant-free hole transport layer (HTL) solvent, effectively addressing this issue. By using this solvent to dissolve PTAA, the morphology of hole transport layer was enhanced and the contact between HTL and perovskite layer was optimized. After optimization, the efficiency of perovskite solar cell was raised from 17.44% to 19.06%, and the fill factor was enhanced significantly from 0.66 to 0.79. The mitigation of defects at the interface between the hole transport layer (HTL) and the perovskite film was evidenced through the attainment of a smoother PTAA film, improved perovskite film coverage, and a reduced occurrence of pinholes on the perovskite layer.

Keywords:

perovskite solar cells, hole transport layer, PTAA

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A photoemission study on the electronic properties of two-dimensional metal organic chalcogenolates

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Abstract:

Two dimensional metal organic chalcogenolates (2D MOCs) are assessed to hold tremendous potential in applications due to their interesting physical properties originating from their organic-inorganic hybrid quantum well (HQW) structure. In the HQW system, charge carriers are allowed to traverse along metal chalcogenide inorganic layer which is sandwiched by two organic layers composed of bulky organic groups. Consequently, carriers are confined within inorganic layers, resulting in tightly bound anisotropic excitons stable at room temperature. Moreover, it has been reported that certain sorts of 2D MOCs possess a direct band gap in the blue-range region in their bulk state. It points a significant distinction from the other 2D metal chalcogenides, which usually exhibit a wide direct band gap only in monolayer state. However, such intriguing electronic properties, have yet been sufficiently confirmed with experimental techniques that directly reveal the electronic structure. In this study, we synthesized films of silver phenylselenolate $[AgSePh]_{\infty}$, a typical 2D MOC, via solution-processed conversion method. We monitored the precise valence and conduction band electronic structure along with precisely ascertained band gap, ionization energy, and electron affinity employing photoemission spectroscopy and inverse photoemission spectroscopy. The resulting electronic structure was carefully characterized with a supporting of first-principles calculation. Furthermore, we also suggest exciton binding energy of the 2D MOC by comparing with the result obtained from optical spectroscopies. We expect our research can offer a novel perspective to reach deeper understandings of 2D MOC, thereby, pave the way for their practical applications.

Keywords:

Photoemission spectroscopy, Inverse Photoemission Spectroscopy, 2D Metal Organic Chacogenolate, Silver phenylselenolate, DFT calculation

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Variational Quantum Eigensolver Implementation with a SKKU Superconducting Qubit Device

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Abstract:

VQE(Variational Quantum Eigensolver) 알고리즘은 NISQ 시대의 양자 컴퓨터에서 실용성을 가져올 것으로 기대되는 가장 주목받는 알고리즘 중 하나이다. 현재 본 연구팀에서는 자체적으로 제작한 초전도 큐비트 소자를 이용하여 소규모 회로기반 범용 양자컴퓨터를 구현하고 있다. 사용되는 큐비트 소자에서 단일 큐비트 게이트 충실도는 99% 이상, QST(Quantum State Tomography)를 이용한 벨 상태 충실도는 약 95% 이상을 보여주고 있다. 이 발표에서는 자체적인 하드웨어를 이용하여 VQE 알고리즘을 시연하고, 이를 통해 수소분자의 바닥 상태 에너지를 시뮬레이션하는 결과를 소개한다. 특히 이번 발표에서는 VQE를 이용한 수소분자 시뮬레이션의 결과와 함께, 시스템 하드웨어를 직접 제어할 수 있는 장점을 활용하여 에러의 완화 및 에러 분석과 향후 진행할 시뮬레이션 규모의 확장성 등에 대하여 논의한다.

Keywords:

Superconducting Qubit, Transmon, Variational Quantum Eigensolver, Cross-Resonance Gate, Quantum Computing

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Predicting Qubit Parameters from Room-temperature Characterization

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Abstract:

초전도 큐비트 기반 양자컴퓨터에는 트랜스몬(Transmon)회로가 가장 널리 사용되고 있다. 공정을 통해 제작된 초전도 큐비트 소자는 10mK 정도에서 활용하기 때문에 소자의 특성을 평가(characterization)하는 과정에서도 10mK 수준의 냉각이 필요하다. 하지만 희석냉동기의 cool-down 및 warm-up 시간을 고려하면 극저온 특성평가는 많은 시간이 소요되며, 이러한 큐비트 특성평가가 연구개발의 시간적 병목이 되고 있다. 본 발표에서는 초전도 큐비트의 대규모 회로를 구성하기 위해서 극저온 측정 이전에 상온에서 미리 특성을 가늠하는 방법에 대하여 살펴본다. 먼저 초전도 큐비트는 조셉슨 접합(Josephson junction)과 수동소자의 전자회로이기 때문에 전자기적 유한요소 시뮬레이션을 통해 소자의 회로 특성을 예측할 수 있다. 또한 큐비트의 주파수는 조셉슨 접합의 임계전류에 의해 결정되는데, 이는 Ambegaokar-Baratoff 공식을 통해 상온의 저항 특성을 통해 예측할 수 있다. 이 발표에서는 본 연구팀의 안정된 소자공정 데이터를 기반으로 상온에서의 저항 측정을 통해 큐비트의 주파수를 얼마나 잘 예측할 수 있는지에 대하여 실험결과를 발표한다. 소자의 저항과 이론적인 비선형성 값 등을 이용한 시뮬레이션 결과와 실제 측정값을 비교하고, 소자의 특성을 확인한다. 특히 다중 큐비트 양자프로세서의 경우 큐비트의 주파수 산포(distribution)가 중요한데, 본 연구의 결과는 상온에서의 측정 데이터를 통해 다중 큐비트 소자에서 산포를 어느정도 잘 예측할 수 있음을 보여준다.

Keywords:

Superconducting Qubit, Transmon, Qubit Characterization

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P2-ap.314

Cat state generation with desired fidelity and time by optimizing parameter configuration using a lookup graph

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Abstract:

Compared to the conventional quantum error correction codes which encode a logical qubit into multiple physical qubits, cat codes encode quantum information in an infinite dimensional Hilbert space of a single oscillator. This gives an advantage of reducing hardware overhead. Moreover, since a cat qubit consists of a superposition of far distant coherent states in the phase space, the probability of coherent state wave function overlapping each other decays exponentially with the cat size. This suppresses bit flip errors and provide noise bias.
Cat states can be generated by letting the Kerr-cat qubit evolve under the two-photon driven Hamiltonian. This Hamiltonian includes three important parameters which need to be optimally combined for high fidelity generation: **maximum drive amplitude($\epsilon 0p$)**, **ramping time(τ)** and **Kerr strength(K)**. In this presentation, we introduce a parameter graph to show which parameter combination satisfy fidelity and generation time constraints. This reduce time for finding optimal parameter combination.

Keywords:

cat state, generation, parameter graph, fidelity, hamiltonian

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P2-ap.315

Ion-gel gate induced molecular level modulation in mixed molecular vertical junctions

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Abstract:

Molecular electronic has been widely studied as the next step in miniaturizing electronic devices. Molecular devices can function as diodes, transistors and photo-switches. Various fabrication methods of molecular devices are being used today. Of these, ReSEM (repeated surface exchange of molecules) method allows two molecular kinds to be self-assembled in a molecular junction, in which one kind of molecules acts as a main molecule of the device while the other molecular kind acts as a supporting molecule.
The aim of this study is to show that molecular junctions made with ReSEM can be gated to allow molecular orbital modulation. 16-mercaptohexadecanoic acid (16-MHDA) and dodecane-thiol (C12) molecules were used as main molecule and supporting molecule, respectively, in this study. Template-stripped gold was used as the bottom electrode in the molecular junction, while monolayer graphene was used as the top electrode. And ion-gel was deposited on top the graphene electrode and was used as a gate electrode to modulate the molecular level of the 16-MHDA molecule. An advantage of the ReSEM method is to allow high voltage bias to gold bottom electrode. We observed asymmetric rectifying behavior in the ReSEM molecular junctions, which can be explained by frontier molecular orbitals. In particular, at negative gate voltage, the molecular junction displayed an increase in the rectification ratio. This study can demonstrate gate controllability of rectifying behavior in ReSEM molecular junction.

Keywords:

molecular electronics, self assembled monolayer, ion gel gating, 16-mercaptohexadecanoic acid

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P2-ap.316

Photoelastic coefficient of Au thin films measured by a modified spectroscopic rotating polarizer ellipsometer

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Abstract:

In general, the photoelastic coefficients of optically transparent crystalline solids can be measured by using birefringence under the application of stress. The polarization of light passing through a ~mm thickness of a crystal undergoes a change of polarization, which is easily detectable. However, in the case of metals, which have a penetration depth of only 10 ~ 20 nm, a change in polarization is hardly measurable, making it an extremely challenging task with conventional methods. Although the photoelastic coefficients of metals are essential parameters for correctly analyzing the reflectivity response on both static and ultrafast timescales whenever temperature variation is involved. So far, only three metallic elements (Ni, Cr, Au) at specified wavelengths have been measured using ultrafast Sagnac interferometry [1] and nonlinear Korteveg-de Vries analysis [2]. However, these methods are very sensitive to many ultrafast responses of materials parameters, which cannot be accurately measured.
In this work, by developing a modified rotating polarizer ellipsometry, we successfully obtained photoelastic coefficients of an Au thin film fabricated on a piezoelectric substrate (PMN-PT). The electric field pulse modulation and balanced detection techniques employed in this new technique yield high reliability and reproducibility, hence making it suitable for a wide range of metals.

Keywords:

Photoelastic cofficient, rotating polarizer ellipsometry, piezoelectric material

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P2-ap.317

Luminescent behavior of Mn^{4+} doped Mg_2TiO_4 deep-red emitting phosphors for LED and latent fingerprint visualization application

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Abstract:

The non-rare-earth Mn^{4+}-activated phosphors have recently received vast amounts of attention for broadband excitation and deep-red narrow-band emission because the $^4A_{2g}\rightarrow^4T_{1g}$ and $^4A_{2g}\rightarrow^4T_{2g}$ transitions in Mn^{4+} in the octahedral coordination environment exhibit near-UV and visible-light absorptions, respectively. As we know, the Mn^{4+} emission is almost independent from the crystal field splitting but significantly affected by different host lattices. Mn^{4+}-activated oxides have high chemical stability and an environment-friendly preparation process. Specially, Titanate compounds are well known for their spinel crystals with excellent chemical stability and cubic structure, so the Mn^{4+} site is represented by a trigonal or octahedral symmetry. It is more reliable for making crystal field analysis and contrast with the Tanabe-Sugano diagram without considering the low-symmetry crystal field effects.
Here, we demonstrated that Mg_2TiO_4:Mn^{4+} can be used for LEDs and latent fingerprint visualization applications. The deep-red Mg_2TiO_4:Mn^{4+} phosphors were prepared using sol-gel process, and their crystallinity and luminescence characteristics are analyzed and discussed in details. Furthermore, the use of Mg_2TiO_4:Mn^{4+} for LEDs and latent fingerprint visualization is evaluated.

Keywords:

Red-emitting, Mn4+, photoluminescence, LEDs, fingerprints

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P2-ap.318

Thermal stability improvement in rare-earths-doped sodium gadolinium orthovanadate with post-transition metal doping

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Abstract:

Rare-earths-doped (Eu^{3+}, Dy^{3+}, and Sm^{3+}) orthovanadates were synthesized employing the sol-gel method. Similarly, the Sn doped and Sn co-doped orthovanadates were prepared with stoichiometric amounts of dopants. The XRD patterns show strong diffraction peaks, maintaining consistent 2θ values, and were devoid of any impurity phases. Also, SEM images show minimal/no alterations in morphology for Sn doped and Sn co-doped orthovanadates and the elements presence was confirmed with the EDX spectra. The incorporation of Sn into the V-site led to enhanced host emission, attributed to change in V-O bond lengths (lattice distortion), and the charge imbalance (oxygen vacancies) between Sn^{4+} and V^{5+}. On the other hand, the emission of rare-earths doped also showed enhanced optical characteristics. The thermal stability of single doped and co-doped samples shows enhanced characteristics with increased activation energy values which is essential for better color stability and service life. This set the stage to synthesize more materials with Sn as potential dopant to improve the optical and thermal properties of the material. Enhancement of luminescence intensities and creation of vacancies make these materials as promising candidates for photochemical and optical applications.

Keywords:

orthovanadates, thermal stability, tin, vacancies, energy transfer

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P2-ap.319

Flexible metamaterial based on graphene-conductive inks for broadband perfect absorption

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Abstract:

In this work, we introduce a flexible broadband metamaterial perfect absorber (FBMPA) which utilizes a conductive-graphene ink on a polyimide substrate. The flat FBMPA demonstrated an absorption rate over 90% across a wide frequency range (7.88 to 18.01 GHz), which was also polarization-insensitive and stable up to an oblique incidence of 30 degrees of the incident electromagnetic wave. The high absorption rate was maintained even when the FBMPA was wrapped around the cylindrical surfaces, with varying radii from 4 to 50 cm. The absorption mechanism was explained by the perfect impedance matching and the dielectric loss of absorber. Our proposed flexible metamaterial could be appropriate for the commercial applications of next generation of flexible, ultra-broadband, polarization/oblique-incidence insensitive, low-cost, ultrathin and wearable absorbers, in the near future.

Keywords:

metamaterial; flexible; broadband absorption; graphene inks

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P2-ap.320

Growth and characterization of ultrathin single-crystalline two-dimensional Ruddlesden-Popper phase halide perovskite

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Abstract:

In the recent decade, two-dimensional Ruddlesden-Popper phase (2D RP) lead halide perovskites have received more attention as a group of promising material for optoelectronic devices due to high light-absorption coefficient, long carrier diffusion length, and improved stability compared to their three-dimensional counterparts. A majority of 2D RP perovskites previously studied were in film form which is considered advantageous to be applied in devices thanks to its facile fabrication and ease of thickness control. However, polycrystalline structure of the film makes them inappropriate for understanding the fundamental nature of 2D RP perovskites. On the other hand, the single crystals exhibit much suitable properties for such studies for example, absence of grain boundary, better carrier mobility, and higher ion migration activation energy. Nevertheless, it remains a challenge to stably grow high-quality ultra-thin 2D RP perovskite single crystals. A sub-micrometer thickness is especially required if one attempts to monitor substrate-dependent behaviors or conduct surface-sensitive techniques. In this work, we suggest the growth method for ultra-thin single crystal of phenylethylamine lead iodide $(C_6H_5C_2H_4NH_3)_2PbI_4$ using induced peripheral crystallization method which is inspired by the earlier study of Liu *et al*. We harvested millimeter-scaled crystals with thickness less than a few micrometers by gradually lowering the temperature of the solution on ITO substrates. We also observed how the crystals' growth behavior and morphology change as the synthetic parameters being controlled. Moreover, the electronic and structural characteristics of the crystals are experimentally confirmed by photoelectron spectroscopy and X-ray diffraction, respectively. We anticipate our findings in 2D RP perovskite single crystals can offer fruitful information both in fundamentals and applications.

Keywords:

2D RP perovskite, single crystal, crystal growth, ultra-thin, photoelectron spectroscopy

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Hyper Raman scattering in two-dimensional halide perovskite $(C_6H_5C_2H_4NH_3)_2PbI_4$ 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=2.0×10^5cm/MW) due to the so-called giant oscillator strength. The internal energy of the biexciton is precisely determined to be 4660.8 meV by fitting the one-photon photoluminescence signal using the biexciton emission equation. Upon increasing the biexciton density, a sharp peak emerges near the ground state of the biexciton, which turns out to shift by $\Delta 2\omega$ when the excitation photon energy is varied by $\Delta\omega$. 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] T. Ishihara, et al, J. Phys. Soc. Jpn. 53 2407-2410 (1984)

Keywords:

2D halide perovskites, Biexciton, Hyper Raman scattering, Giant two-photon absorption

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P2-ap.322

Measurement of OLED AC impedance and modeling of equivalent circuits

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Abstract:

We report on the alternating-current(ac) driven Organic light-emitting diodes (OLEDs). Despite the various roles of OLEDs, there is a lack of analysis of alternating-current responses. OLEDs serve as a light source in biochemical sensors, Photomedicine systems, or in vivo optogenetic stimulators. These platforms can be powered by energy harvesters, the output of which is an ac signal. Another emerging application of OLED is optical communication. OLEDs can replace traditional (inorganic) near-infrared LEDs or even the concept of visible-light communication was put forward. These systems adopt ac signals as their integral part. Therefore, there is a timely need to investigate fundamental frequency responses of advanced OLEDs. OLEDs are prepared by employing a well-established and stable host:dopant materials system. In addition to OLED with general structure, we analyze OLED with two OLEDs stacked in parallel. A parallel structure OLED is implemented by stacking two OLEDs and physically connecting anode electrodes at both ends. The cathodes between the two OLEDs are used as common electrodes. This allows multiple OLEDs to be connected in parallel and provides high radiant exitance. Impedance spectroscopy is conducted on these OLEDs under a wide range of electrical driving conditions. Measure the impedance of the OLED under alternating-current and represent it in Nyquist Plots. Nyquist plots recorded over a wide range of conditions are fitted to an equivalent circuit model, extracting the interface and bulk parameters. The interface parameter can be used to analyze the electrode and the semiconductor interface. Bulk parameters can be used to analyze what happens in bulk layer. The interface parameter is relatively independent of the bias, and the bulk parameter is dependent on the bias.

Keywords:

OLED, impedance spectroscopy

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P2-ap.323

Investigating the role of organic spacers on energy level alignment at interfaces in two-dimensional organic-inorganic hybrid Ruddlesden-Popper perovskites

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Abstract:

Recently, two-dimensional organic-inorganic hybrid Ruddlesden-Popper (2D RP) D RP perovskites have garnered attention as the next-generation optoelectronic materials due to their excellent optical properties and great environmental stability. 2D RP perovskites have been employed into the most part of perovskite optoelectronics in forms of quasi-2D and 2D/3D structures which enhance the efficiencies, or as passivation layers, boosting up the lifetimes. Such accomplishments of 2D RP perovskites are based on the unique two-dimensional crystal structure provided by constituent organic spacers that separates metal halide layer from each other or surrounding environments. However, contemporary studies on the 2D RP perovskites are majorly focused on their role in device operations while the impact of organic spacers in energy level alignments are still well not understood despite its importance. The peculiar properties of organic spacers such as less conductivity, low dielectric constant, and dipole moment inevitably differentiates the energy level alignment characteristics from other three-dimensional (3D) semiconductors including 3D perovskites or inorganic 2D semiconductors.
In this study, 2D RP perovskites with typical alkyl-group organic spacer were prepared to examine its impact in energy level alignment. We investigate the interface between 2D RP perovskite films and substrates with different work functions through X-ray and ultraviolet photoelectron spectroscopy. The substrates were chosen to cover wide-ranged work functions which are spanning from PEDOT:PSS (c.a. 5.1 eV) to PEIE/ITO (c.a. 3.4 eV). The monitored energy level shift at the interfaces shows different aspect of that found in 3D perovskites like $MAPbI_3$ even though both systems have same metal (Pb) and halide (I) combination. We expect our result can provide an efficient and optimized approach for the further improvement of high-performance 2D RP perovskite optoelectronic devices.

Keywords:

2D RP perovskites,XPS,UPS

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Integration of In-situ Core/Shell Perovskite for Improved Photodetection Performance of MoS2 photodetector

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Abstract:

Two-dimensional (2D) transition metal dichalcogenides (TMDCs) are promising materials that can be used in various fields such as low-power devices and optoelectronic devices due to their atomically thin nature, tunable band gap, high on/off ratio, and excellent electrical properties [1]. From a material perspective, the photodetectors based on 2D TMDCs have the potential to create flexible devices with high integration density. However, their atomic-level thinness results in low light absorption, which hinders sensitive photodetection [2].

In this study, we address the shortcoming of low light absorption by depositing in-situ core/shell perovskite onto the MoS_2 channel, which significantly improves charge transfer and light absorption efficiency [3]. By providing alternating dark and illuminated conditions to the devices and measuring the on and off currents, it was found that the on/off ratio of the in-situ core/shell perovskite-MoS_2 heterostructure devices was increased by 50 times and the responsivity by nine times compared to other MoS_2-based photodetectors. Our research improves the performance of the 2D MoS_2 photodetector through a simple process, which provides a promising approach for a low-cost, highly integrated, and stretchable photodetector based on 2D materials.

References
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3. J. S. Kim et al., *Nature*, 611, 688 **(2022)**

Keywords:

Hybrid photodetector, MoS2, Perovskite

P2-ap.325

산소분위기 하에서 홀센서 맥박계와 광혈류측정기를 이용하여 측정한 말초혈류속도와 산소포화도의 특성 연구

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Abstract:

오늘날 인류의 3대 사망 원인 중 하나인 뇌혈관질환은 산소농도가 부족하거나 혈관이 막혀 혈류가 원활하지 않을 때 발생하는 뇌질환이다. 이를 해결하기 위한 방법은 심혈관계를 담당하는 심장에서 나오는 생체맥파 신호를 측정 및 진단하고 고압산소를 치료하는 것이다. 광용적맥파측정기인 PPG(photoplethysmography)와 영구자석을 장착한 홀센서 집게형 맥진기를 이용하여 10분간 동시에 측정한 두 파형으로부터 산소포화도(SpO_2)와 말초혈류속도(PBFV)의 특성을 조사하였다. 뇌질환 환자의 고압산소치료 중 홀소자. PBFV는 요골동맥 중앙에서 클립형 비중계로, 손목 등쪽에서 PPG로 각각 측정한 첫 번째 맥파 피크와 두 번째 맥파 피크 사이의 시간차를 의미한다. 정상인에 비해 상대적으로 낮은 혈압과 빠른 요골동맥 맥박수를 보인 40대 뇌경색 질환 남성 대상자를 대상으로 10분간 고압산소 요법의 효능에 따른 SpO_2와 PBFV 값의 경향은 다음과 같다. SpO_2의 경우 98에서 100으로 증가하고 PBFV의 경우 0.38 m/s에서 0.25 m/s로 감소했다. 이러한 결과는 피험자가 착용한 산소호흡기, 대기압 1.1기압, 산소농도 26%의 산소호흡기에 10 L/min의 순산소를 흘린 조건에서 고압산소 치료 전후 요골동맥의 맥박파형을 비교한 결과이다. 약실에서 -27%. 수축기 피크에 도달하는 S.time인 S.time(수축기 시간)은 치료 전 127 ms에서 치료 후 112 ms로 15 ms 만큼 감소한 것을 확인하였다. 4차 산업혁명 시대의 디지털 헬스케어 분야에 적합한 뇌질환 환자의 고압산소 치료 효능 축적 데이터를 기반으로 개인 건강관리에 적용할 말초혈관질환 진단 및 예측 인공지능(AI) 알고리즘 개발 가능할 것이다.

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Keywords:

말초혈류속도, 산소포화도, 뇌혈관질환, 홀센서 집게형 맥진기

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Simulation and Experiment of Organic Anti-Ambipolar Transistor

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Abstract:

The Anti-Ambipolar Transistor(AAT) device has received a lot of attention as a functional building block. The potential of rectifiers, photodetectors, artificial synapses, and frequency doublers are being proven, but there are many physical mechanisms that have not yet been revealed. In this paper, we present an understanding of the AAT device structure with p-type and n-type junctions and a physical mechanism of the AAT structure. First, the experimentally obtained current-voltage data were reproduced for the first time through two-dimensional finite element simulations, to prepare a strong theoretical framework for AAT structural analysis. We found that in the AAT structure, a larger voltage drop occurs at the contact part and the PN junction, and more drain voltage is consumed at the PN junction, resulting in a strong electric field. This interesting phenomenon was fully verified by performing a series of simulations and structural analyses on internal charges and potential distributions. An experiment was conducted to confirm this phenomenon, and the AAT structure was implemented using DNTT and PTCDI-C8 materials. The current-voltage characteristics confirm that the AAT effect can be actually implemented. Therefore, our results are expected to further improve our understanding of the physical mechanism for utilizing the AAT structure.

Keywords:

Anti-Ambipolar Transistor(AAT), PN junction, Voltage drop

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P2-ap.327

Advancing OFETs on SiO_2 Substrates through Inkjet Printing

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Abstract:

Organic Field-Effect Transistors (OFETs) are attracting increasing attention due to their low cost manufacturing processes and adaptable characteristics. This study is conducted to create OFETs with inkjet-printed electrodes on a familiar SiO_2 platform. On SiO_2 surfaces, inkjet-printed Ag is deposited in dot form. To mitigate this, we introduced a PMMA layer as a bank layer.
Furthermore, attempts were made to enhance the electrical characteristics of OFETs by increasing the work function of Ag electrodes through Self-Assembled Monolayer (SAM) processes. However, an issue arose post-SAM treatment during spin coating of the channel layer, where the SAM-treated Ag electrodes beneath were detaching. To address this, XL-100 was introduced at a 10% concentration to the PMMA layer to enhance crosslinking effects. Additionally, adjustments to the annealing conditions of the Ag electrodes were made. These efforts led to the successful fabrication of OFET devices where electrode detachment was prevented even after SAM processes.
In this study, device characteristics were analyzed using optical microscopy and electrical performance evaluation. The findings highlight the practical potential of stable inkjet printing on SiO_2 substrates for diverse device applications.

Keywords:

Organic field-effect transistors, Organic semiconductors, Inkjet printing, Self-Assembled Monolayer

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P2-as.001

Antarctic ice simulation studies of ice properties using IceCube Upgrade camera system

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Abstract:

The IceCube Neutrino Observatory, located at the geographic South Pole with a volume of cubic-kilometers, detects neutrinos using Cherenkov light emissions from charged particles produced in neutrino interactions. The optical properties of the ice in the detector are one of the major systematic uncertainties for analyses using IceCube data. One of the major goals of IceCube Upgrade, where 7 new strings with novel optical modules and calibration devices are added to the center of the IceCube volume, is to improve the knowledge of these optical properties. A novel camera-based calibration system will be installed into the photodetection modules to be used in the calibration of the IceCube Upgrade detector. There is an ongoing effort to simulate images that are expected from the camera system in the Antarctic ice to develop a method to analyze the image data. This simulation study will allow us to estimate the performance of the camera-based calibration process of the IceCube Upgrade such as the measurement of the optical properties of the Antarctic ice. Given that Antarctic ice serves as the medium for the IceCube detector, it becomes imperative to measure the optical properties of this ice. This study focuses on two optical properties; effective scattering length, and effective absorption length. We will present the outlined sensitivities to the effective scattering lengths of Antarctic ice, along with the preliminary results from the simulation study.

Keywords:

IceCube, IceCube Upgrade, Simulation

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P2-as.002

Production and Test Results of the IceCube Upgrade Camera System

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Abstract:

The IceCube Neutrino Observatory, located in Antarctica, is the largest neutrino observatory in existence. An upgrade consisting of seven densely instrumented strings in the center of the volume with newly designed digital optical modules (DOMs) is being built to delve into lower energy ranges and gain a deeper understanding of the detector medium. Understanding of the detector medium is crucial for minimizing systematic errors and for more precise calibration of the IceCube Upgrade, a novel camera system with the LED illumination system was developed and produced by Sungkyunkwan university, which will be installed in every newly designed DOM.

This presentation introduces the production process of these cameras and the test results obtained during the production. Since 2012, every single camera system produced has undergone a camera acceptance test (CAT) to verify and calibrate their performance during production stages. After the CAT, cameras are being integrated into the DOMs, and additional tests are conducted as a part of DOM final acceptance test (FAT). These tests ensure that individual cameras meet conditions suitable for scientific purposes while measuring their characteristics and storing them. In this presentation, the specific measurements conducted by these tests will be outlined with detailed steps and setups, and the test results for all produced cameras will also be included.

Keywords:

IceCube, IceCube Upgrade, IceCube Upgrade Camera System, Calibration, Camera Production

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P2-as.003

Deployment Hole Ice Study with the IceCube Upgrade Camera System

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Abstract:

The IceCube Neutrino Observatory, located at the geographic South Pole, detects neutrinos by observing Cherenkov light emissions caused by relativistic charged particles from the interaction between neutrinos and the Antarctic ice. For the measurement of the properties of the detector medium, the IceCube Upgrade with seven new strings inside the current array, will include a camera system which was developed and built by Sungkyunkwan University (SKKU). It is anticipated that trapped gas bubbles will form a central bubble column within the hole ice, which refers to the refrozen ice in the drill hole after the deployment of strings. This study evaluates the accuracy with which properties of the bubble column (position, scattering length and size) can be determined through simulations using the camera system. The simulations use a geometry with a camera pointing downward and a LED pointing upward. As a result of the simulations, two light points were visible in the images: one directly emitted from the LED and the other from the scattered light inside the bubble column. The simulated images undergo an image analysis process using a maximum likelihood method.

Keywords:

IceCube, IceCube Upgarde, IceCube Upgrade Camera System, Camera Simulation, Bubble Column

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P2-as.004

Geometry Measurement using camera system for the IceCube Upgrade

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Abstract:

The IceCube Neutrino Observatory, located in Antarctica, is the world's currently largest neutrino observatory. It uses the ice to detect neutrinos through Cherenkov radiation. IceCube has 5160 optical modules attached to vertical strings at depths between 1.5 and 2.5km in the ice. The IceCube Upgrade project aims to enhance performance by adding seven strings with new optical modules (mDOM and D-Egg) and calibration devices. These modules include photomultiplier tubes for neutrino observation and calibration tools to improve detection accuracy by understanding ice properties. The IceCube Upgrade Camera System, consisting of an LED and a camera, will play a crucial role in calibration by capturing images of the newly frozen hole ice and the existing bulk ice, aiding our understanding of ice characteristics. The project is planned for installation into the ice between 2024 and 2025. Ongoing simulations involve using the SKKU upgrade camera system, with more than 2,300 cameras/LED pairs, to accurately determine the position and orientation of the IceCube Upgrade digital optical modules (DOMs). A triangulation method is used to determine the LED positions located on the optical modules based on the observing camera positions and directions. Iterations of the DOM positions are used to optimize the geometry. The status of an automated geometry optimization procedure and the expected geometry accuracy is discussed.

Keywords:

IceCube, IceCube Upgrade, Geometry Measurement, Camera System, Simulation

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P2-as.005

Long Exposure Time Verification for the IceCube Upgrade Camera System

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Abstract:

The IceCube Neutrino Observatory, currently the largest neutrino telescope, lies deep within the South Pole ice. It consists of 5,160 digital optical modules (DOMs) with photomultiplier tubes (PMT) on each of them, which are arranged along 86 strings throughout a cubic-kilometer volume. The IceCube Upgrade will add seven new strings with denser spacing and newly designed DOMs, enhancing the capability to detect lower energy ranges. The SKKU made IceCube Upgrade Camera System, with more than 2000 camera systems, is being integrated into these new DOMs. Utilizing cameras and LEDs will provide a deeper understanding of the detector medium properties, leading to reduced systematic errors in future analyses. Camera response measurements including noise and linearity have been conducted to precisely characterize cameras during future operations in the ice. This study focuses on exposure time optimizations, with a particular focus on operating cameras for long exposure times, which are beyond the normal operations mode of the camera. In circumstances where there is insufficient light or when more precise measurements are necessary, understanding the camera's performance under long exposure settings becomes crucial. Long exposure times, up to 30 s, might be beneficial when observing light propagating from adjacent string light sources, which are more than 30m away. Standard camera operations and mass testing used exposure times of up to 3700 ms, with the option to stack images for longer total exposure. Verification of long exposure times as discussed here might have operational benefits.

Keywords:

IceCube, IceCube Upgrade, Camera System

2023 KPS Fall Meeting
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P2-as.006

Visualization of trajectories in gravitational fields as geodesic: Focused on Kepler problems

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Abstract:

The three-body problem concerns the motion of three objects affected by gravity. Since the three-body problem does not admit a closed-form solution in general, the studies on the three-body problem have been focused mainly on finding its periodic solutions using numerical methods. To obtain a numerical solution to the three-body problem, we can use Newtonian mechanics or Lagrangian mechanics. The latter is due to Euler-Lagrange equation, which is equivalent to the geodesic equation on the Lagrangian system. We compare accuracies between numerical solutions of Newtonian mechanics and the geodesic equation for the on the Lagrangian system. We observe that the latter solution is more accurate on Kepler problem with Runge-Kutta method. We show that the geodesic equation gives more accurate estimation of the periodic solutions of the three-body problem with a long cycle than Newtonian mechanics.

Keywords:

Geodesic, Kepler problem, Lagrangian system, Runge-Kutta method, Three-body problem

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P2-at.001

Electromagnetically induced absorption and transparency of a degenerate two-level system in Rb atoms with circularly polarized laser beams: Effects of neighboring transitions

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Abstract:

Electromagnetically induced absorption (EIA) and electromagnetically induced transparency (EIT) of a degenerate two-level system (DTLS) in Rb atoms with respect to the parallel and orthogonal circular polarization configurations of coupling and probe lasers have been investigated for the effects of neighboring transitions through Doppler broadening. Coherent absorption profiles with and without neighboring effects are calculated to illustrate neighboring effects between DTLS and neighboring states. For the same circular polarization configuration, spectra for the open transitions exhibit EIA or EIT due to neighboring effects depending on hyperfine energy splitting. For the orthogonal polarization configuration, the dominance of closed D2 transition results in the observation of asymmetric and split EIA at all of transitions regardless of the openness or closing of the transitions. The spectra of ^{85}Rb and ^{87}Rb are analyzed by investigating the variation of the spectra of ^{85}Rb with an artificial increase of the hyperfine splitting and accordingly with the decreasing of the neighboring effects.

Keywords:

EIT, EIA, noncycling

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P2-at.002

Effects of neighboring transitions on electromagnetically induced absorption and transparency of a degenerate two-level system in ^{87}Rb atoms with respect to varying hyperfine spacings

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Abstract:

We investigate the effects of neighboring transitions through Doppler broadening on Electromagnetically induced absorption (EIA) and electromagnetically induced transparency (EIT) of a degenerate two-level system (DTLS) in ^{87}Rb atoms with respect to varying hyperfine spacings. The coupling and probe beams are resonant at $F_g = 2 \rightarrow F_e = 1$, 2, and 3 transitions with linear parallel and linear orthogonal polarizations. We demonstrate how neighboring transitions can alter EIA and EIT by varying hyperfine spacings artificially in the $5P_{3/2}$ state. For the first time, EIT has been detected instead of EIA in closed systems like $F_g = 2 \rightarrow F_e = 3$ of ^{87}Rb for linear parallel case, where measured spectra match theoretically calculated ones. EIAs are detected for the open $F_g = 2 \rightarrow F_e = 1$ and 2 transitions at the linear perpendicular polarization due to neighboring effects.

Keywords:

EIA, EIT, Hyperfine

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P2-at.003

Modulation Transfer Spectroscopy for D1 transition of Rb atoms

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Abstract:

Modulation transfer spectroscopy for D1 transition of Rb with only noncycling transition have been investigated experimentally and theoretically by solving optical Bloch equation with respect to four different linear orthogonal, linear parallel configurations, circular orthogonal, and circular parallel configurations.

MTS signal of the F″=2 ->1 of ^{87}Rb atom and F″=3 ->2 of transitions of ^{85}Rb atom among D1 transition lines are giving the strong MTS signals compared to the other transitions. The observed line shapes agree with the theoretical one obtained from solving optical Bloch equation.

Keywords:

D1 transition, MTS, noncycling

Towards Laser Cooling of MgF Molecules: Building a Hermetic 2nd Repump Laser

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Abstract:

Laser cooling is an effective method of bringing atoms down to ultracold temperature. To implement this technique in molecules, we must use multiple lasers to address the complex energy structure of molecules, especially the vibronic modes. Due to a highly-diagonal Frank-Condon Factor (FCF) of the MgF molecule, we believe that up to ~2×10^4 photon scattering is possible by utilizing three laser systems: the main, the first repump, and the second repump lasers.
In this project, we developed and built an External Cavity Diode Laser (ECDL) for the 2nd repump laser system using a laser diode (LD) with a center wavelength of 370 nm. To pull the center wavelength of the LD towards a shorter wavelength, we need to operate the LD at temperatures below zero-degree Celsius and hence a hermetic housing and a nitrogen purging system were employed. Also, we utilized the mod-hop free pivot configuration for a stabler wavelength tuning option of the ECDL.
This presentation will summarize the design, building process, and performance of the hermetic ECDL. With this laser, we plan to perform spectroscopy of the 2nd repump transition of MgF, and eventually trap the molecules in a Magneto-optical trap (MOT).

Keywords:

Laser cooling, Molecule, ECDL, Repump laser, MgF

2023 KPS Fall Meeting
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P2-at.005

Laser frequency stabilization in the 10^{-14} Level by optimizing Modulation Transfer Spectroscopy on the ^{87}Rb D_2 Line

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Abstract:

Implementing a highly frequency-stabilized laser using the D_2 transition line of alkali metal atoms is an essential process for high-precision measurement systems such as atomic interferometers and atomic clocks. We achieved a stabilized optical frequency at the level of tens of Hz by adjusting parameters such as the diameter and power of the probe and pump beams which are used in the modulation transfer spectroscopy for the ^{87}Rb. These parameters influence the linewidth of the atomic transitions and the interaction cross-section between atoms and photons. They also affect the white noise level of the photodiode, and are adjusted to achieve an optimized signal-to-noise ratio. The frequency stability is represented by the Allan deviation of the beat signal between two highly stabilized lasers of different frequencies and it reached a short-term stability level of $4.5\times10^{-14}/\sqrt{\tau}$. And the long-term stability did not exceed 2×10^{-12} over 1×10^{5} seconds. Additionally, we evaluated the factors affecting frequency stabilization, such as electrical noise, laser intensity stability, residual amplitude modulation (RAM), temperature fluctuations, and DC offset fluctuations of the RF components and frequency locking system .

Keywords:

spectroscopy, Atom gravimeter, MTS

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P2-at.006

Numerical study of a hybrid superradiant optical clock with zero frequency pulling coefficient

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Abstract:

Active optical clocks using superradiance in the bad cavity limit have a potential of eliminating the frequency pulling effect that limits the precision of active optical clocks. However, their lasing frequency as well as the linewidth are determined by those of the pump laser used to prepare the atomic superposition states. To overcome this problem, we propose to employ two phase-locked pump lasers with opposite pump-atom detunings. Each intensity is set for a pulse area less than π so that both the conventional lasing due to population inversion and the superradiance lasing due to atomic coherence can occur simultaneously and affect each other. We performed numerical simulations for rare-earth atoms such as Ba, Sr and Ca, varying the pump linewidth, the pump-atom detuning, the pump pulse area, and the average number of atoms in the cavity, in order to find the conditions under which the output laser frequency remains constant even when the cavity-atom detuning changes. As a result, we found that the output frequency is fixed at the atomic resonance, i.e., zero frequency pulling over a cavity-atom detuning range of ± 10MHz when the pump-atom detunings were set at ±2MHz. As the mean number of atoms in the cavity increased to several thousands, the output linewidth decreased to far less than 1/1000 of the pump laser linewidth of 10kHz due to gain narrowing.

Keywords:

active optical clock, superradiance, frequency pulling, bad cavity limit, rare-earth atoms

2023 KPS Fall Meeting
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P2-at.007

Photon-counting heterodyne spectroscopy of a superradiant laser

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Abstract:

It is known that superradiant lasing via quantum coherence of atoms can have a narrow linewidth compared to that of the conventional lasing. When atoms with controlled phase via a nano-hole array traverse a high-Q cavity, the strong interaction between the atoms and the cavity field results in superradiant lasing. We measured the spectrum of such superradiant lasing by using the heterodyne-style photon-counting second-order correlation spectroscopy (PCSOCS). Specifically, the second-order correlation function of the heterodyne signal formed by the lasing output and a local oscillator was measured in order to obtain the autocorrelation function, and the spectrum was then obtained by performing a Fourier transform of it. We confirmed that the output frequency of the superradiant laser follows the frequency of the pump laser instead of the atomic or cavity resonance frequency. According to our theory, the linewidth of the superradiant laser is determined by the pump laser linewidth when the pump linewidth is narrower than that of the cavity. But as the pump linewidth becomes larger than that, it is expected that the superradiant lasing loses quantum coherence of atoms and thus its linewidth converges to a specific value. By varying the average number of atoms in the cavity as well as the linewidth of the pump laser, we have investigated how the linewidth of the superradiant lasing changes. The results will be discussed in this presentation.

Keywords:

superradiance, phase-controlled atom, optical heterodyne spectroscopy, second order correlation , nano-hole array

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P2-at.008

Study of anharmonic and resonance effects in IR spectra of atmospheric gas complexes

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Abstract:

Characterization of primary atmospheric gases CO_2, CH_4, N_2O, and industry originated fluorinated gases like hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and their complexes rely heavily on theoretically predicted infrared (IR) spectra. In this work we examined the infrared spectra (IR) of main greenhouse gases based on their global warming potentials (GWPs) [1]. In light of literatures, geometries and vibrational frequencies from well-known quantum chemical models, the second-order Møller-Plesset (MP2) and DFTs including B3LYP, ωB97XD, B3PW91 are carefully examined. For dispersion effects in DFTs, Grimme's D3 dispersion corrections [2] are employed and compared with CCSD calculations [3,4].
Proper treatments of anharmonic effects and resonances in higher level of theories via second-order vibrational perturbation theory (GVPT2) [5], vibrational self-consistent theory (VSCF) [6], and their variations i.e. PT2-VSCF, VCI-VSCF provided improvement in the spectral profile of the molecules. On the basis of computed vibrational frequencies and spectra for CO_2, H_2O the anharmonic VCI-VSCF calculations were closer to the experimental results. Numerical assessments with available experimental results [7] offers the best combinations of optimal *ab initio* theories with anharmonic corrections. Therefore, the same computational schemes have been next applied to IR spectra of various fluorinated gas complexes like CF_4, CHF_3, CH_2F_2, and CH_3F. This work also highlights the vital role of resonance effects in the IR spectra of complex molecules such as HFCs and CFCs.

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Keywords:

Atmospheric gas, Vibrational frequencies, IR Spectra, anharmonic corrections

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P2-at.009

Manifestation of Laser Resonance Chromatography on Lu+ ions

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Abstract:

Optical spectroscopy of superheavy elements is experimentally challenging as their production yields are low, half-lives are very short, and their atomic structure is barely known. Conventional spectroscopy techniques such as fluorescence spectroscopy are no longer suitable since they lack the sensitivity required in the superheavy element research.

A new technique called Laser Resonance Chromatography (LRC) could provide sufficient sensitivity to study superheavy ions and overcome difficulties associated with other methods. In this contribution, I will introduce the LRC technique and report the progress and the results from inauguration experiments conducted on Lu+, the lighter chemical homologue of Lr+.

This work is supported by the European Research Council (ERC) (Grant Agreement No. 819957).

Keywords:

Laser Resonance Chromatography, Super heavy ion, Ion mobility separator, Heavy ion accelerator

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P2-at.010

Mode-hop assisted single beam all-optical atomic magnetometer

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Abstract:

We demonstrate a mode-hop assisted single beam all-optical atomic magnetometer. Our magnetometer operates alternating pumping and probing modes. Single elliptically pollarized laser is used as pumping and probing beam.
In the pumping period, the laser input current is modulated at Larmor frequency of 87Rb. We modulated laser current in a wide range so that the laser output frequency often goes across the resonant and off-resonant frequency. This mode-hop assisted pumping is crucial for enhancing the optical pumping process.
In the measuring period, the laser input current is fixed to a set point and we measure the free induction decay signal. The amplitude of decay signal depends both on the optical pumping rate and the polarization of laser. In the fast rotating regime, when pumping rate is small enough, the pumping rate can be obtained from the polarization orientation angle ₩{theta} and retardation ₩{phi} of the probing beam. We confirmed this behavior and utilized it to optimize our single-beam magnetometer sensitivity.

Keywords:

Atomic Magnetometer, Mode-hop, Single Beam

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P2-at.011

Optimization of Saddle Coil for Uniform Magnetic Field in Atomic Magnetometer Experiment

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Abstract:

The operation of atomic magnetometer is as follows. The resonant pump beam optically pumps atomic vapor cell consisting of alkali-metal atoms and buffer gases in circularly polarized state. Subsequently, local magnetic field strength can be detected by measuring optical rotation signals, with Lamor frequency, of linearly polarized probe beam that enters perpendicular to pump beam.
The cell and saddle coil, producing uniform B field in the same direction as pump beam, exist inside the magnetic shielding box. And the Helmholtz coilpair generate oscillating B field, which induces spin precession of atoms, in a direction perpendicular to the uniform B field.
At this point, in order to miniaturize magnetometer, saddle coil is used instead of solenoid which requires more than certain length to generate uniform magnetic field. Therefore, our goal is calculating uniform magnetic field inside the saddle coil and optimizing design of saddle coil from theoretical and numerical perspective.

Keywords:

Atomic Magnetometer, Uniform B Field, Saddle Coil

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P2-at.012

Vapor cell oven design and simulation for spin-exchange relaxation-free magnetometer

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Abstract:

The spin-exchange relaxation-free (SERF) magnetometer enables highly precise measurement of magnetic fields. For precise magnetic field measurements, a high temperature and a non-magnetic environment are necessary. In this study, we designed an Rb vapor cell oven to create such environments with simulations, and we analyzed the spatial distribution of the temperature and magnetic field. The heating film was constructed using constantan material, and a multi-layer structure was designed to enable self-suppression of the magnetic field generated by the current. Additionally, a structure made of Hexagonal Boron Nitride material was inserted to hold the positioning of the cell and heating film. Simulation results show that, when a current of 0.33A flows, the average temperature of the cell is 148.9 degrees and the average magnetic field strength is 5.65 nT. This result satisfies both conditions for SERF.

Keywords:

SERF magnetometer, Non-magnetic heating film, Vapor cell oven

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P2-at.013

Long-term polarization stabilization of a polarization maintaining fiber by dynamic temperature control

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Abstract:

We report a long-term polarization stabilization of the output beam in a polarization-maintaining (PM) fiber by applying a heat to the fiber. When the polarization of the input beam is not aligned with the optical axis of the PM fiber, it can result in instability in the optical polarization of the system utilizing PM fiber. Therefore we constructed a feedback loop with thermal contact to stabilize the polarization of the output beam. As a result, we achieved a long-term polarization stability caused by thermal fluctuations.

Keywords:

polarization-maintaining (PM) fiber, polarization stabilization

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P2-at.014

Polarization-selective four-wave mixing signals in degenerate multi-level system of ^{85}Rb cooling transition line

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Abstract:

We reported the realization of a polarization-selective four-wave mixing signals in ^{85}Rb atoms using coupling-probe spectroscopy such as saturated absorption spectroscopy. In a degenerate multi-level atomic system, the four-wave mixing signal is generated by a counter-propagating laser which is linearly polarized. Our experiments were conducted on the $F_g = 3 \rightarrow F_e = \{2, 3, 4\}$ transitions of the ^{85}Rb D2 transition line. We detect the orthogonal polarization component to the polarization of the probe beam to distinguish the co-propagating four-wave mixing signals. The polarization component, orthogonal to the polarization of the transmitted probe beam, corresponded to the linear polarization angles of the coupling and probe beams and showed good agreement with theoretical results.

Keywords:

Polarization-selective four-wave mixing signal, 85Rb D2 cooling transition line, Coupling-probe spectroscopy

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P2-at.015

Trap parameters measurement of ^{133}Cs cold atoms

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Abstract:

We present an in-depth study of forced, damped harmonic oscillations in a 133Cs atomic cloud within a MOT setup. The study demonstrates the relationship between parameters such as magnetic field gradient, saturation parameter, and modulation amplitude by examining resonance curves under various experimental conditions. We consider all potential transition lines caused by repumping and trapping lasers. As compared to previous models, the resulting trap parameters—trap frequency, damping coefficient, and driving force—are more accurately measured and have more consistency with experimental consideration. Furthermore, the study theoretically inquiries into the influence of repumping lasers on trap parameters, indicating how changes in repumping intensity and detuning can have a significant impact on these parameters.

Keywords:

Magneto-optical Trap, Cesium Trap Parameters, Non-linear dynomics

2023 KPS Fall Meeting
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P2-at.016

Low-frequency electric field measurement using Rydberg Stark spectroscopy

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Abstract:

We introduce the development of a spectroscopic measurement applied for low-frequency electric field measurement, utilizing Rydberg atom-based spectroscopy. Rydberg atoms, with their electric polarizability directly proportional to the 7th power of the principal quantum number, offer a highly sensitive quantum state for electric field sensing. Using Electromagnetically Induced Transparency (EIT) technology, which enables precise atomic spectroscopy through quantum interference, we measured Stark-shifted energy levels in Rydberg rubidium vapor cells subjected to external electric fields. The sensitivity of the measured electric field was found to be 70mV/cm. This research not only advances our understanding of Rydberg atom behavior in the presence of electric fields but also opens promising avenues for low-frequency electric field measurement.

Keywords:

Rydberg atom, Stark effect, Electromagnetically Induced Transparency

2023 KPS Fall Meeting
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P2-at.017

광펌핑 원자 자력계 Free Induction Decay 신호의 고속 주파수 계수법 개발

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Abstract:

원자 자력계는 측정하고자 하는 자기장을 원자의 분광 정보를 이용하여 계측하는 장치이다. 핵종에 따른 원자 자기모멘트의 세차 주파수는 외부 자기장의 크기에 비례하므로, 측정 자기장의 정확도는 free induction decay (FID) 신호의 주파수 측정 정확도에 의존한다. 주파수를 정확하게 측정하기 위해서는 긴 측정 시간이 필요하지만, FID 신호는 여러 가지 이완 기전의 영향으로 짧은 시간 동안 빠르게 감쇠한다. 우리는 짧은 측정 시간 신호에서의 주파수 추정 정확도를 높이기 위해 원자 자력계가 측정한 FID 신호를 일정한 주파수 템플릿과 비교하는 방법을 구성하였다. 가우시안 잡음을 포함하는 가상의 FID 신호에 대하여, 개발된 방법으로 신호의 주파수를 추정하고, 오차 분석을 수행하여 개발한 방법의 feasibility와 한계를 조사한다. 개발된 방법으로 FID 신호가 사라지기 전에 고속으로 정밀하게 자기장의 주파수를 측정할 수 있으며, 자기 차폐되지 않은 환경에서 작동하는 원자 자력계의 측정 대역폭을 높이는데 활용될 것이다.

Keywords:

optical pumped magnetometer, rubidium vapor, Free Induction Decay signal

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P2-at.018

Towards quantum-enhanced sensing: generation of two-mode squeezed light from four-wave mixing in hot ^{85}Rb vapor

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Abstract:

Photon pairs generated from four-wave mixing process are one of the promising quantum light sources that enable ultra-precision measurements beyond the standard quantum limit. We generate two-mode squeezed state of light and measured over -3.5 dB of intensity difference squeezing between probe and conjugate beams, using four-wave mixing in hot Rb vapor. This research will lead to the development of quantum-enhanced sensors and other promising applications such as quantum computing.

Keywords:

quantum technology, quantum sensing, quantum metrology, squeezed state, quantum computing

2023 KPS Fall Meeting
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P2-co.101

Polarization-optimized tip-enhanced strong coupling of single quantum dots

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Abstract:

Optimizing the near-field strong coupling of a single quantum emitter is crucial for the control of quantum systems, yet the orientation matching between the emitter exciton and the cavity plasmon remains a challenge. In this study, we propose a method to control the orientation matching, thereby enhancing the coupling strength. To verify the changes in the distribution of localized surface plasmons formed between a plasmonic Au tip and a quantum dot (QD), we alter the incident excitation polarizations and observe the corresponding modifications in the photoluminescence spectra of the strongly coupled system. Furthermore, for randomly aligned QD dipoles, we demonstrated the optimization of the cavity plasmon orientation, leading to the maximization of coupling strength. This work paves the way for advancing applications in quantum information science.

Keywords:

Single quantum emitter, Strong coupling, Tip-enhanced spectroscopy

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P2-co.102

Nb Josephson junctions fabricated using helium ion beam

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Abstract:

We present the fabrication and characterization of niobium (Nb) Josephson junctions on Nb wires using a focused helium ion beam. Initially, Nb wires of 300 nm width were fabricated via e-beam lithography and reactive ion etching (RIE). Subsequently, employing a Zeiss Orion Nanofab helium ion microscope, Josephson junctions were patterned at the center of the superconducting wire utilizing a 30 keV helium ion beam at normal incidence, with an ion beam current of 1.5 pA. The beam dwell time and step size were 0.2 ms and 0.2 nm, respectively. By varying the helium ion dose and the width of ion beam expose on the Nb wires, we investigated their impacts. The Josephson junctions were eventually characterized at temperatures as low as 4.2 K within a liquid helium cryostat. Notably, the device with a helium expose width of 30 nm and a helium ion dose of 2×10^5 ions/nm² exhibited a characteristic voltage of 1.2 mV, indicative of well-defined Josephson junction behavior.

This work is supported by the National Research Foundation of Korea (NRF) Grant funded by the Korean Government (NRF-2023R1A2C1004832, 2021R1A2C1011046, and 2022M3E4A1069445) and DGIST R&D Program of the Ministry of Science, ICT, Future Planning (23-CoE-NT-02, 23-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:

Nb, Josephson junction, Helium ion beam

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P2-co.103

Gate-dependent transport properties near the electrical phase transitions in $Mo_{0.67}W_{0.33}Se_2$ devices with dual gates

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Abstract:

We have studied tunable electrical phase transitions in $Mo_{0.67}W_{0.33}Se_2$ (MoWSe) dual-gate FET devices. One of the gates has a back-gated structure in field-effect transistors fabricated on SiO_2/Si substrates, the other gate has a top-gated structure fabricated on a few layers of insulating boron nitride. One gate was used to scan a gate bias voltage, while the other gate electrode was used to modulate the electronic band. By varying the gate bias voltages of the dual gates, the electronic band profile of MoWSe can be modulated over a wide range to higher and lower energy levels, resulting in the ability to broadly control the electrical phases of MoWSe. Gate-voltage induced reversible electrical phase transitions were observed in both gate response curves. The electrical current changes abruptly at 100 K < T < 150 K with decreasing T and a modulation gate bias voltage from positive to negative. The thermal activation energies and channel current of the high and low temperature branches differ by orders of magnitude at the same band modulation voltage, indicating that the electrical band at the Fermi level has been significantly modified. Gate response measurements for dual gate voltages were carried out on a few layer devices, confirming the clear gate voltage dependent electrical phase transition behaviors. The possible origins of the gate voltage dependent conducting and non-conducting phases in MoWSe are discussed.

Keywords:

TMDC, Field Effect Transistor,Dula gates, Phase Transition

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P2-co.104

Gate-tunable supercurrent in Ti nanowire

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Abstract:

Recently, a notable advancement involves the achievement of gate-tunable supercurrent in superconducting nanowires (NWs) through the utilization of side-gate electrodes. In this experimental work, we focused on fabricating and characterizing a superconducting Ti NW with top gate electrodes. By employing the electron-beam lithography technique, we successfully fabricated the NWs, after which a 10-nm-thick Al_2O_x layer was deposited onto its surface to form the top gate electrodes. The dimensions of the Ti NW were as follows: thickness = 29 nm, width = 230 nm, and length = 10 μm. Operating at an ultra-low base temperature of T = 7 mK, the critical current (I_c) of the Ti NW was found to be I_c = 700 nA. Interestingly, when subjecting the NW to a top gate voltage (V_g), we observed a complete suppression of I_c at approximately $|V_g|$ = 8.7 V. This notable reduction in I_c was consistently observed in various Ti NWs featuring distinct widths. To comprehensively elucidate the behavior of the Ti NW, we analyzed the variations in dynamic conductance as a function of temperatures, magnetic fields, and top-gate voltages. Our innovative device architecture holds significant promise for the advancement of gate-tunable, fully-metallic superconducting quantum devices and circuits. The successful manipulation of supercurrent through top gate electrodes opens new avenues for the development of versatile and controllable superconducting quantum systems.

Keywords:

Superconducting nanowire, top gate, titanium

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P2-co.105

Fabrication technique for twisted double-bilayer graphene device without deformation of the superlattice pattern

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Abstract:

Twisted graphene system is an attractive platform that provides us with easy accessibility to abundant physics, depending on the twist angle. For example, in the magic angle regime, it's possible to readily achieve superconductivity, ferromagnetism, and Mott insulator phases [1, 2], while at marginal angles, one can obtain edge states resulting from superlattice formation [3, 4]. However, the most significant challenge for making twisted graphene devices is the spatially inhomogeneous twist angle within the device. Not only during the stacking process but also in every step of the standard device fabrication, lattice relaxation can occur, leading to a relatively low yield of devices with the desired twist angle.

To investigate how the twist angle changes during device fabrication, we fabricated marginally twisted double-bilayer graphene (mTDBG) stacks with superlattice formation at 300-500 nm and imaged the size of the superlattice directly using infrared nearfield scanning optical microscopy (IR-NSOM) at every fabrication step until the mTDBG device was complete. In this meeting, we will present our developed method for mTDBG device fabrication that perfectly preserves the superlattice pattern without inducing any deformations.

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Keywords:

Twistronics, Twisted bilayer graphene

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P2-co.106

Waveguide in Strained Zigzag Graphene Nanoribbon

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Abstract:

Graphene, an atomically thin layer of carbon atoms arranged in honeycomb lattice, has outstanding mechanical properties, like very large Young's modulus ~ 1000 GPa[1,2] and elastic strain regime up to 20%[3]. It is known that graphene is a good material for investigating effects of strain which causes its electronic properties. There have been numbers of studies on strained graphene, reporting strain-engineered energy gap[4], valley transport phenomena[4,5], Dirac fermion confinements[6], etc. In particular, characteristic pseudo-magnetic fields due to elastic strain in graphene enable a way of controlling its transport properties, by confining or guiding Dirac fermion transport.
In this study, we investigate that strain effects of a nanowrinkle in graphene allow for guiding Dirac fermion along the nanowrinkle. Solving Dirac equation in the low-energy limit, we show that there can emerge an effective potential well in the strained region. The strain-induced waveguide along the nanowrinke is analyzed by comprehensive studies of strain effects on the bound states in the potential well. In addition, we consider the valley degree of freedom of the guided states and examine a possibility of valley transport through the waveguide.

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Keywords:

graphene, strain engineering, waveguide

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P2-co.107

Degenerated energy states induced by geomatical symmetry in a rectangular quantum dot

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Abstract:

The confinement energies of a rectangular quantum dot have been studied experimentally. Quantum states inside a square quantum dot are degenerated due to geometric symmetry. Modifying the aspect ratio of horizontal and vertical length in square quantum dot can break the degeneracies of square quantum dots. The devices are fabricated on a GaAs/AlGaAs heterostructure based two-dimensional electron gas (2DEG) wafer. Quantum point contact (QPC) is electrostatically coupled with the rectangular quantum dot to measure confinement energies in rectangular quantum dots. This experimental setup allows to detect an energy state inside closed quantum dots. The aspect ratio of the rectangular quantum dot was controlled by the gate voltage. Finally, we measured the confinement energies and degenerate states inside a rectangular quantum dot as a function of the aspect ratio of the rectangular quantum dot. We also measured confinement energy changes as a function of magnetic field.

Keywords:

2DEG, Quantum dot, Mesoscopic, GaAs/AlGaAs

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P2-co.108

The modulation of the electronic band profile of the two dimensional layered materials in the Fermi level pinned and depinned contacted devices

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Abstract:

We have studied the modulation of the electronic bands of two-dimensional layered materials such as WSe_2, $MoTe_2$ and MoS_2 over a wide range by using them as two-dimensional conducting channels in a dual-gate mode. One of the gates has a back-gated structure in field effect transistors fabricated on SiO_2/Si substrates, the other gate has a top-gated structure fabricated on a few layers of insulating boron nitride. Gate response curves obtained from the metal-contacted devices prepared by different preparation methods, such as thermal evaporation, sputter deposition, mechanical pressing, showed the different behaviour in shape and type, which was shown to be due to the difference in the pinned positions of their Fermi levels in the bandgap of the two-dimensional layered materials. In particular, Fermi level depinning was observed in the mechanically van der Waals contacted devices. By varying the control gate bias voltages of the dual gates, we demonstrated that the electronic band profile of the two-dimensional conducting channel can be modulated over a wide range to higher and lower energy levels, resulting in the ability to realize *p*-metal, *p*-semiconductor, ambipolar, *n*-semiconductor and *n*-metal electronic states.

Keywords:

Fermi-Pinning, WSe2 Dual Gate Field Effect Transitor, thermal evaporation, sputter deposition, mechanical pressing

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P2-co.109

박막에서 쌍결정 경계 (twin boundary)의 조절 연구

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Abstract:

박막의 성장에서 낟알 경계 (Grain Boundary: GB)와 쌍결정 경계 (Twin Boundary: TB)는 대표적이 결함이지만 서로 다른 구조적 물리적 특성을 가진다. BG의 경우 기판과 증착되는 물질 사이의 응력이 잘 제어되고 성장조건을 잘 조절되는 경우 제거하는 것이 불가능하지는 않으나 TB는 GB와 달리 제거하는 것이 매우 어렵다. 박막 성장 시 많은 수의 핵이 생성되고 이 핵을 중심으로 박막의 성장이 진행된다. 이 때, 결정학적으로는 동일하지만 층 쌓기 순서 (stacking order)가 다른 경우의 경계가 TB가 되고 이는 피할 수 없는 결함이다. TB가 물성에 미치는 영향을 연구하기 위해서 GB가 제거된 Cu 박막과 Ag 박막을 원자층 에피탁시 (atomic sputtering epitaxy: ASE)방법을 이용하여 제작하였다. 박막의 초기 성장 시에 나타나는 TB의 변화를 Ag 박막의 두께를 5 ~ 40 nm 까지 조절하며 조사하였다. TB와 GB는 전자 후방 산란 회절 (Electron Backscatter Diffraction: EBSD)을 통하여 관찰하였다. 박막의 두께가 증가하면서 TB의 양이 줄어드는 것을 볼 수 있었으며 이는 박막이 두꺼워지면서 쌍결정이 합쳐지면서 나타나는 현상으로 보여진다. 50 nm 두께의 박막에서 열처리에 따른 TB의 변화를 Cu 단결정 박막을 이용하여 진행하였다. 열처리 조건에 따라 TB의 개수가 초기상태의 38%까지 줄어드는 것을 확인하였다. TB는 박막성장에서 제거할 수 없는 결함이다. 본 연구에서는 박막이 성장되는 초기상태에서 TB의 변화를 조사하였으며 열처리를 통해서 개수를 줄일 수 있음을 확인하였다. TB의 변화에 따른 물성의 변화에 대한 연구가 추후 진행될 예정이다.
이 논문은 삼성전자 미래기술육성센터의 지원 (SRFC- MA2202-02)과 2022년도 정부(교육부)의 재원으로 한국연구재단의 지원(NRF-2022R1I1A1A01071367)을 받아 수행된 연구임.

Keywords:

Twin boundary, Grain boundary, 낟알경계, 쌍결정 경계, 단결정 박막

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P2-co.110

Orientation-dependent structural properties of CoO films studied using polarized XAFS

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Abstract:

We examined the orientation-dependent local structural properties of ultrathin CoO films using orientation-dependent XAFS measurements at the Co K edge. Oriented CoO (111) and (100) films were fabricated on α-Al2O3 (111) and () substrates, respectively, using radio-frequency sputtering deposition at 700 oC. The crystallinity of the films was characterized using X-ray diffraction (XRD) measurements. Polarized XAFS analyses revealed that CoO initially forms small islands on the substrate, and subsequently, becomes a film. During island growth, the coordination numbers of Co and O atoms are much smaller than those of a perfect CoO and both directions (in-plane and out-of-plane) of the films have a substantial amount of structural disorder and distortion existing in the crystals. Once CoO forms a film, the structural defects are mostly disappeared. This indicates that there are structural amounts of defects existing near the interfaces of CoO/ Al2O3. The defects will affect the physical and chemical properties of CoO films. The growth mechanism and the interfacial structural properties are essentially important to understand the physical and chemical properties of CoO. CoO-based materials have been widely studied for applications to various fields, including catalysts, rechargeable batteries, and memory devices.

Keywords:

CoO, epitaxial growth, film, local structure, XAFS

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P2-co.111

Collapse of 2 x 1 insulating dimer state in monolayer 1T-$IrTe_2$ by Rb dosing

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Abstract:

1*T*-$IrTe_2$ is distinguished from the conventional TMDs by the polymeric Te-Te interlayer coupling associated with valence states of $(Te_2)^{3-}$ and Ir^{3+}, and various structural transitions with decreasing temperatures. However, recent study revealed that monolayer (ML) $IrTe_2$, which is totally absence of Te-Te interlayer coupling, only shows a 2 x 1 dimerized structure with band gaps larger than 1 eV, in stark contrast to metallic bilayer (BL) $IrTe_2$. This metal-to-insulator transition is suggested as Fermi surface nesting-assisted local bond formation due to the absence of Te-Te interlayer coupling.

Here, we study on Rb-dosed ML $IrTe_2$ via angle-resolved photoemission spectroscopy (ARPES). Our ARPES results reveal that the band structure of insulating ML $IrTe_2$ transforms to metallic state with dosing Rb, indicating collapse of the 2 x 1 dimer state in ML $IrTe_2$. We will discuss the effect of Rb-dosing on ML $IrTe_2$ and compare with metallic BL $IrTe_2$ to understand the nature of insulating 2 x 1 dimerized structure.

Keywords:

IrTe2, Angle-resolved photoemission spectroscopy, Transition metal dichalcogenides, Monolayer

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P2-co.112

Effects of post annealing on phase of $PbTiO_3$ nanotubes

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Abstract:

Nanostructures show physical differences such as very small size and large surface area compared to bulk materials, and new physical phenomena can be expected as a result.
In this study, porous anodic alumina (PAA) was used as a mold and $PbTiO_3$ nanotubes (PTO-NTS) were fabricated by sol-gel spin coating method. PAA was fabricated through two-step anodization and has well-aligned pores with a diameter of ~50 nm and a length of ~20 μm. 0.3 M PTO solution was deposited on the prepared PAA by a spin-coating method. Next, polycrystalline PTO nanotubes were fabricated through drying at 200 °C for 2 minutes, pyrolysis at 400 °C for 5 minutes, and crystallization at 650 °C (O_2 atmosphere) for 30 minutes. Finally, the PAA was removed through chemical etching (using 10 wt% NaOH). After that, changes in structure and morphology due to the post annealing effect were investigated. The Raman analysis results show the change from tetragonal PTO structure to anatase TiO_2 structure through post annealing at 750 °C for 9 hours.
These structural changes are expected to be due to the high volatility of Pb and the large surface area of the nanotubes.

Keywords:

Post anneling , Ferroelectric PbTiO3 nanotubes, Anatase TiO2 nanotubes

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P2-co.113

Surface and Interface Characterization of Thin Films by Neutron Reflectivity

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Abstract:

Surface and interface structures are critical for the electric and magnetic properties in thin film devices. Neutron reflectivity is a powerful nondestructive characterization technique for these nanoscale structures and dynamics in polymers, metals, oxides, and their heterostructures. Due to the large difference in neutron scattering length density of atoms and few milli-electron volt energy of neutron beam, the structure and density of thin films can be analyzed in nanoscale without degradation during the measurement. In HANARO neutron facility, a cold neutron reflectometer REF-V was constructed for neutron reflectivity research and has been supporting scientific and industrial communities for more than 10 years. This vertical-type reflectometer can measure Q up to 0.3 A^{-1} with the minimum reflectivity of Rmin = 10^{-6}. Recent research includes the interface structure and its effect on electrical transport in organic semiconductor blends, the vertical structure of Fe-based permanent magnet thin films, and more. In this presentation, the reflectivity research and beam time application guide for REF-V reflectometer will be given.

Keywords:

neutron reflectivity, neutron scattering, interface anaylsis, organic semiconductor, thin film

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P2-co.114

Surface photovoltaic effect on pristine and K adsorbed MoS2 surface

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Abstract:

By using synchrotron lights, we investigated changes in the photoelectron spectroscopic (PES) information on pristine and K-deposited MoS2 surfaces. Deposition of K on the surface at both room temperature (RT) and low temperature (LT) resulted in shifts of the PES peaks towards higher binding energies, indicating *n*-type (electron) doping. Additionally, photoelectron intensities were observed at energies above the valence band across the gap. These intensities originate from the conduction band (CB) moving below the Fermi level of the sample. The Fermi level, determined by the intensity cut-off, was found to be at a lower binding energy than that of the reference Au sample. This indicates the development of surface photovoltage (SPV) on the MoS2 sample during PES measurement. For the pristine surface, the Fermi edge in the PES is not visible, making it difficult to determine the SPV. However, the deposition of a small amount of K inducing CB electron emission enabled us to deduce the SPV of the pristine surface, which is about 0.8 eV at LT. As the amount of deposited K increases, the SPV diminishes, however, the SPV of the K-deposited surface increases over time. The mechanism behind the SPV changes with the K deposition and time evolution will be discussed.

Keywords:

Molybdenum disulfide

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P2-co.116

Two-Dimensional Networks of Biphenyl with OH Ligands on Au(111) Studied by Scanning Tunneling Microscopy

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Abstract:

Hydrogen bonds are ubiquitous playing an important role in the formation of functional molecular structures. On metal surfaces, they link molecules together to form overlayer network structures with possible applications in electronic devices. Here, we present our experimental results on two-dimensional networks of biphenyl with OH ligands studied using scanning tunneling microscopy on Au(111). We observed several types of ordered networks including zigzag, triangular and pinwheel structures. These structures were explained by molecular models that incorporated hydrogen bonds between molecules. The structures observed in this study could be used to create new types of hydrogen-bonded materials.

Keywords:

scanning tunneling microscope, two-dimensional network, hydrogne bond

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P2-co.117

Dirac cone in 1T-VS_2 single crystals

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Abstract:

Transition-metal dichalcogenides (TMDCs) are known for exhibiting a wide range of properties, including superconductivity, charge-density wave (CDW), ferromagnetism, and Dirac states. Specifically, within the TMDCs family, VX_2 (X = Te, Se, S) compounds exhibit CDW transitions. There are also interesting discussion about their magnetic properties and the origins. Recent studies surprisingly reported the presence of Dirac cones at the M-points in both VTe_2 and VSe_2 single crystals. Similar Dirac band structures may be anticipated either in bulk VS_2 or their thin film forms. Here, we studied the electronic structures of both bulks and thin films by using angleresolved photoemission spectroscopy (ARPES). We analyzed the characteristics of Dirac cone for different compounds. Given the reported correlation between the Dirac band structure and lattice distortion in VTe_2, we discussed the Dirac band of VS_2 at 15 K and 323 K across the CDW transition. In addition, we compared the ARPES data on the monolayer films of different compounds VX_2. Finally, we discuss the theoretical origin of the Dirac cone and the potential applications of such Dirac cone materials. (NRF-2020R1A2C200373211, RS-2023-00220471, [Innovative Talent Education Program for Smart City] by MOLIT.)

Keywords:

2D material, Dirac cone, VS2, Single crystal, ARPES

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P2-co.201

Investigations of thermoelectric properties of different gallium nitride polytypes through first-principles approach

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Abstract:

In recent years, exploring new polytypes of III-V semiconductors has been widely practiced for the development of thermoelectric devices of high efficiency. In this work, the thermoelectric properties of new polytypes, namely the wurtzite(wz), Berrylium oxide (β-BeO), Nickel arsenide (NiAs), Silicon carbide (*SiC*), and Titanium arsenide *(TiAs*) phases of GaN have been investigated using the first-principles approaches. It is found that the p-type of doping induces enhancement of the power factors (PFs) and figure-of-merits (*zT*) of the GaN polytypes. The optimal *p*-type doping for PFs has been recognized as - 1.67 eV for wz-GaN, - 1.78 eV for β-BeO-GaN, - 1.33 eV for NiAs-GaN, - 1.58 eV for SiC-GaN, and - 1.48 eV for TiAs-GaN. These optimal p-type doping has induced the room-temperature PFs as high as 13.75×10^{10} W/mK^{2}s recorded for wz-GaN, 13.61×10^{10} W/mK^{2}s for β-BeO-GaN, 41.14×10^{10} W/mK^{2}s for NiAs-GaN, 14.06×10^{10} W/mK^{2}s for SiC-GaN, and 49.21×10^{10} W/mK^{2}s for TiAs-GaN. Furthermore, the PFs of the GaN polytypes are enhanced by increasing the temperature. Due to such significant PFs, the zT values corresponding to p-type doping have been recorded as 1.013 for *wz*-GaN, 0.998 for β-BeO-GaN, 1.00 for NiAs-GaN, 1.015 for SiC-GaN, and 0.999 for TiAs-GaN. Moreover, we comprehensively discussed the electrical and thermal conductivities and Seebeck coefficients (S) for the predicted GaN polytypes. The results of the thermoelectric properties presented in this study reveal the predicted GaN polytypes may find interesting applications in thermoelectric devices for clean energy harvesting.

Keywords:

First-principles calculations, GaN, New polytypes, Thermoelectric properties

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P2-co.202

Magnetic Order Classification of Pyrochlore Iridates by Machine Learning

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Abstract:

In this work, we employ a machine learning methods to identify magnetic structures of pyrochlore iridates from electronic features. We generate the dataset by using a multi-orbital Hubbard model considering strong spin-orbit coupling with Hartree-Fock approximation. When Coulomb interaction U is increased in the metallic state, an all-in/all-out configuration emerges, while in the topological insulator state, an antiferromagnetic configuration is favored. The phase diagram is constructed by varying the Ir-Ir hopping mediated by oxygen, direct Ir-Ir hopping, and U. The dataset is processed into momentum-resolved density of states with several broadening factors. We use decision tree ensemble algorithms to classify magnetic orders and investigate which electronic properties plays important role.

Keywords:

Pyrochlore iridates, magnetic structure, machine learning, Hubbard model, Hartree-Fock approximation

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P2-co.203

Prediction of Lattice thermal conductivity of material applied at power semiconductor with Machine learning force field and ab-initio molecular dynamics

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Abstract:

Especially in the industrial field, such as the semiconductor, thermoelectric and device application, there exists a crucial need to investigate the thermal conductivity of materials. Also, thermal conductivity prediction is one of the very challenging topics in theory point of view since the tremendous computational time is required. Recently, machine-learning regression algorithms show great promises for building high-accuracy interatomic potential fields for atomistic modeling. Here, we develop machine learning based interatomic potential using the first-principles molecular dynamic simulations, and calculate these materials and doped system based on Green-Kubo formula from 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 expect that this machine-learning force field method can be a promising tool for predicting thermal conductivity of complex compounds including anti-symmetric doped systems composed of hundreds of atoms with very high accuracy.

Keywords:

Equilibrium Molecular Dynamics, Green-Kubo Method, Machine Learning Force Field, Lattice Thermal Conductivity

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P2-co.204

Electronic structures of graphene/MoSSe/hBN heterostructure using First-Principle Calculation

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Abstract:

Since the discovery of graphene, research into the unique properties of two-dimensional (2D) materials has surged. These atomically thin materials have demonstrated a plethora of novel electronic, optical, and mechanical behaviors, redefining our understanding of condensed matter physics. One of the standout characteristics of 2D materials is their ability to form heterostructures. 2D materials allow for the direct stacking of different layers, leading to custom-engineered properties. These van der Waals heterostructures, as they are commonly known, are formed by combining different 2D crystals, thus enabling researchers to manipulate electronic states, enhance light-matter interactions, and explore a new frontier of materials science. In this study, we make a heterostructure consisting of graphene and Janus MoSSe monolayers with hBN stacked on top, and calculate its electrical properties, electron density, and band structure using density functional theory (DFT). We compare two ways of placing hBN on the graphene/MoSSe heterostructure: on top of graphene/MoSSe or between graphene and MoSSe. In addition, we compare two types of contact interfaces between graphene and MoSSe: graphene/SMoSe and graphene/SeMoS. It is confirmed that the addition of hBN eliminates the n-type doping of graphene. These results provide insight into the basic characteristics of the graphene/MoSSe/hBN heterostructure.

Keywords:

Density functional theory (DFT), Van der Waals heterostructures, Janus MoSSe, hBN, graphene

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P2-co.205

Electronic structure and Landau level spectrum of lattice-relaxed twisted triple-bilayer graphene

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Abstract:

We study the electronic structure and landau level spectrum of twisted triple bilayer graphene (t3BG) based on atomistic calculations for three possible configurations AB/AB/AB, AB/BA/AB and AB/AB/BA denoting the specific stacking of each bilayer where the top and bottom bilayers are rotated with respect to the middle bilayer. By simulating the atomic relaxation process and using an accurate real-space TB model, we aim to gain insights into the unique electronic characteristics of this system. We further predict which structures are likely to be energetically stable.

Keywords:

Graphene, Electronic structure , Landau levels

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P2-co.206

Commensuration torques and lubricity in double moire twisted trilayer hexagonal boron nitride and graphene heterostructures

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Abstract:

We obtain the double moire commensuration torques and predict high lubricity in double moire twisted trilayer hexagonal boron nitride and graphene heterostructures by relaxing the atomic positions with interatomic forces modeled through pairwise classical force fields using the LAMMPS molecular dynamics code. Firstly, for t3BN, in absence of lattice mismatch between the 3 layers, our lattice relaxation calculations show that when the twist angle of one interface is fixed, these t3BN systems display local energy minima when the two moire patterns are commensurate, *i.e.* when their angles are aligned and they have the same period. The global energy minimum happens when one of the twist angles drops to zero recovering perfect alignment reminiscent of t2BN behavior. We also calculate the sliding energy landscapes for the commensurate moire pattern geometries to predict the most probable local stacking atomic structure in experimental devices. When twisting the layers away from commensuration, the relative sliding does not matter hinting towards enhanced superlubricity. Secondly, for combinations of hBN and G, inducing a lattice mismatch between layers, we draw a similar commensuration-*vs*-incommensuration energetical conclusion with the additional observation that unlike for t3BN, the global minimum does not anymore always match the case of 0°—alignment between the rotating and the middle layer, thus transforming the local minimum from the doubly commensurate phase into a global minimum, making these configurations particularly enticing to energetically engineer the twist angle between layers.

This work was supported by the Korean NRF through the Grants No. 2020R1A2C3009142 (Y.P., and N.L.), and Samsung Science and Technology Foundation Grant No. SSTF-BA1802-06 (P.J., M.S. and J.J.).

Keywords:

Double moire commensuration, twisted trilayer heterostructures

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P2-co.207

Layer Antiferromagnetic State in Extended Hubbard Corrected Tight-binding Model of Rhombohedral Stacked Few-layer Graphene

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Abstract:

Rhombohedral stacked graphene with three or more layers exhibiting a chiral stacking structure possesses a low-energy state, and the density of states in this low-energy state demonstrates a divergence referred to as the Van Hove singularity near the Fermi level. The Van Hove singularity enhances many-body interactions, leading to intriguing phenomena. This amplified interaction results in the collapse of spin/valley degeneracy and the creation of an excitonic band gap, even in a neutral state without electric or magnetic fields. On the other hand, the reported computational results have accurately predicted outcomes for trilayer ABC graphene. However, they have failed to explain the experimental observation of a near 10meV band gap in four layers of rhombohedral graphene. In this study, we report an extended Hubbard-corrected tight-binding model that incorporates realistic estimates of the on-site Hubbard U and inter-site Hubbard V1 and V2 parameters for the π bands of rhombohedral stacked few-layer graphene. These estimates are based on the Agapito-Curtarolo-Buongiorno-Nardelli pseudo-hybrid functional method. Furthermore, we demonstrate that this model accurately predicts the antiferromagnetic energy gap observed in four or more layers of rhombohedral stacked graphene.

Keywords:

Flat band, Graphene

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P2-co.208

Simulation of Transverse Field Ising Chain Model: A Comparative Study Using DMRG and Exact Solution

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Abstract:

The Density Matrix Renormalization Group (DMRG), implemented through the Tensor Network Method, is a powerful technique for finding good solutions for one-dimensional problem . We compare the solution of the exact Bogoliubov-like Hamiltonian via the Jordan-Wigner transformation and numerical DMRG solution, and further discuss potential realization of the solution in modern quantum annealing hardwares.

Keywords:

Tensor Network, DMRG, Transverse Ising Chain

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P2-co.209

Thermoelectric properties of a novel half-Heusler compounds NbRuX (X = Sb and Bi)

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Abstract:

Heusler compounds have received a lot of attention as potential candidates for thermoelectric (TE) materials due to having narrow band gap, high Seebeck coefficients, and large number of valence electrons. Particularly, non-magnetic half-Heusler (HH) compounds with a valence electron count of 18 are not only semiconducting, but also suitable to TE applications. Therefore, searching for emerging HH compounds with outstanding performance is a crucial challenge. In this work, we examine the transport and thermoelectric properties of novel HH NbRuX (X = Sb and Bi) using the first-principles calculations and Boltzmann transport methods. Consequently, both materials are shown to be semiconducting characters with indirect band gaps. In addition, we reveal that both materials are also shown to be dynamically stable using the phonon calculations. A more detailed discussion of thermoelectric properties of NbRuX (X = Sb and Bi) will be given.

Keywords:

Thermoelectric property, First-principles calculations, NbRuSb, NbRuBi, Half-Heusler compounds

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P2-co.210

Revisiting $LaMnO_3$: density functional theory study

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Abstract:

$LaMnO_3$ is one of the representative transition metal oxides. While the electronic structures and magnetic properties of $LaMnO_3$ are well-studied, the density functional theory approach of the system is known to be very tricky. The electronic structures and magnetic properties of the ground state are very sensitive to the employed Hubbard U and Hund's coupling J_H parameters, and the different usage of the DFT+U dramatically changes the physics of the system.

Here, we thoroughly study $LaMnO_3$ with various options which depend on DFT and systematically investigate their impacts on the ground state of the $LaMnO_3$.

Keywords:

DFT + U (LDA + U), Transition metal oxide

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P2-co.211

Crystal structures of bismuth oxides in varying oxidation states: a first-principles study

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Abstract:

Spin-charge conversion phenomena have attracted considerable attention due to their potential applications in spintronics and quantum computing. Recent experimental findings have revealed a remarkable transition in the spin-charge conversion behavior of bismuth oxides at a certain oxygen concentration. For a thorough investigation of the spin-charge conversion phenomenon, a meticulous understanding of various bismuth oxides is required. We present the crystal structure of bismuth oxides in their various oxidation states using first-principle calculations based on density functional theory (DFT). For each oxidation state, we generated several structures and selected the most energetically stable one. We systematically analyzed the change in the crystal structure at different oxidation states, aiming to identify the critical structural modifications that trigger the observed difference in the sign of spin-charge conversion. The insights gained from this study could pave the way for tailoring spin-charge conversion effects in oxide materials for future spintronic applications.

Keywords:

spin-charge conversion, bismuth oxides, crystal structure, oxidation states, first-principle calculations, spintronic applications

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P2-co.212

Systematic first-principles study of magnetism in 2D monolayer transition metal dichalcogenides family

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Abstract:

Two-dimensional transition metal dichalcogenides (TMDCs) have garnered significant attention in recent times due to their nanoscale applications and unique electric and magnetic properties. Their magnetic properties are governed by their symmetries of crystal and chemical environments. Particularly, Janus-type structural manipulation can break the inherent inversion symmetry, leading to fascinating magnetic behaviors. However, their theoretical understanding of electronic and magnetic properties is less studied. In this research, a systematic investigation of monolayer TMDCs including Janus structures was conducted using density functional theory (DFT). Furthermore, their magnetic states and interactions are investigated by magnetic force response theory (MFT). We expect that these results can pave the way for exploring intriguing magnetic phenomena.

Keywords:

2D magnetism, First-principles calculations, Janus structure, Transition metal dichacogenide

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P2-co.213

Ab initio study on the electronic structures of multi-layered graphene with various stacking sequences

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Abstract:

Graphene has attracted attention due to its unique electrical properties, in particular the occurrence of a flat band phenomenon under certain conditions. The most prominent approach so far to induce this result is to stack two layers of graphene at a specific angle known as the "magic angle". However, due to its sensitivity, it is difficult to fabricate devices with the required accuracy. Recently, an alternative approach using unstable rhombohedral graphite encapsulated with hexagonal boron nitride (hBN) has been experimentally implemented. In this approach, a wider flat band can be achieved by changing the layers of graphene without any instability in the rhombohedral graphene structure. This technique gives similar but simpler results compared to twisted bilayer graphene. Our goal is to find out the broadest flat band by changing the stacking sequence of the graphene layers, and to propose the correct stacking sequence that is experimentally valuable. Using the density functional theory, we first evaluated the stability of each stacking sequence of the graphene and selected the physically possible states. Then, we calculated the electronic band structure of each case of a few layers of graphene and compared the extent of the flat band to find out the optimum stacking sequence that has the widest flat band in the electronic band structure.

Keywords:

DFT, Graphene, Multilayer, flat band

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P2-co.214

Supervised machine learning approach for the detection of multiple nanobubbles in graphene

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Abstract:

Nanobubbles in graphene, causing local strain, impact electronic properties. Recognizing them is crucial, and a machine learning (ML) approach based on density of states (DOS) showed promise for single bubbles in earlier work. We propose a supervised ML method for detecting multiple nanobubbles by analyzing electronic traits. We train a one-dimensional convolutional neural network with DOS for multiple bubbles. We use the DOS as input and the heights, widths, and the number of nanobubbles as output. This, along with a deep learning model, demonstrates accurate predictions for bubble properties, even with varied noise levels. This ML-aided electrical technique holds potential for graphene nanobubble detection.

Keywords:

machine learning, graphene

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P2-co.215

Bath parameter fitting of hybridization function: database construction for machine learning

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Abstract:

We construct a machine learning model for the bath fitting procedure in Dynamical Mean-Field Theory (DMFT), a well-known method for addressing systems with strong electron correlations. DMFT simplifies the intricate many-body problem by approximating it with an impurity that exhibits local interaction and an effective bath hybridized with the impurity. Due to the limitations of Hamiltonian-based impurity solvers, which can handle only a finite number of bath orbitals, we determine optimal bath parameters to represent the originally continuous hybridization function by minimizing a distance function. This optimization involves a multidimensional function, which often fails if the initial bath parameters are situated around local minima of the distance function. Consequently, an appropriate machine learning model allows us to enhance the performance of DMFT calculations.
For supervised learning, we explore several features to represent the hybridization function, including the hybridization function at specific frequencies and coefficients from the expansion of Legendre polynomials. To generate labels for supervised learning, we optimize bath parameters for a lattice Hamiltonian designed with various combinations of hopping parameters. We test both gradient descent and derivative-free algorithms for efficiency and accuracy.

Keywords:

Bath fittig, Machine learning, Hybridization function

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P2-co.216

Machine-learning models for band gap of kesterite materials based on hybrid density functional theory

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Abstract:

Accurate computational databases are important to improve the prediction performance of machine-learning (ML) models. Herein, using hybrid DFT calculation data, we develop ML models to predict the band gap (E_g) of kesterite materials with the random forest, gradient boosting, support vector machine, linear regression algorithms and suggest the functional form for E_g with the root-mean-square-error of 0.137 eV and R^2 of 0.921. We found that the distance between group-IV and group-VI elements is important to estimate E_g. Furthermore, we generated test kesterite materials and searched materials whose predicted E_g within the optimum range of 1.0-1.5 eV by using the developed ML models. Their ML predicted E_g were also compared with hybrid DFT calculations. We suggest 9 materials whose ML predictions and DFT calculations of E_g in the proper range for photovoltaic applications.

Keywords:

Machine Learning, Kesterite, Density Functional Theory

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P2-op.001

커 렌징 효과를 이용한 Yb:CALGO 펄스 레이저 제작 및 특성 분석

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Abstract:

레이저는 수많은 응용분야에서 필수적인 도구로 사용되고 있으며, 점점 안정적이고 효율적인 레이저를 요구하고 있다. 본 연구에서 사용된 Yb:CALGO (Yb:CaGdAlO$_4$) 펄스 레이저는 우수한 효율성과 안정성을 가지고 있으며, 다양한 용도에서 사용될 수 있다. 본 연구는 Yb:CALGO 펄스 레이저를 설계,제작 및 특성에 대한 분석을 중심으로 진행하였다.
Gain medium으로 선택한 Yb:CALGO crystal은 3%로 도핑 되어있고, 길이는 7mm로 제작되었다. 펌프 소스로는 gain medium의 피크 흡수파장과 일치하는 980nm의 레이저 다이오드를 사용했다. 이 레이저를 parabolic mirror를 통해 수직으로 반사 시켜gain medium 을 통과하게 한다. gain medium을 통과한 펌프 빔은 parabolic mirror와 gain medium을 잇는 선과 같은 선상에 있는 Mirror 1(R=300mm)를 지나서 반사도 99.8%를 가진 high reflector로 진행한다. High reflector에서 반사된 빛은 다시 원래 경로대로 돌아가 마찬가지로 parabolic mirror와 gain medium을 잇는 선과 같은 선상에 있고, M1과 반대 방향에 존재하는 Mirror 2(R=500mm)에 반사된다. M2에서 반사된 빛은 GTI 거울사이를 왕복하고, 최종적으로 out coupler를 통해 출력된다. 이 과정에서 H.R과 O.C를 gain medium에서 유도 방출된 빛이 왕복하며 증폭돼서 레이저가 출력되도록 제작했다.
펄스 레이저 제작을 위한 핵심 과정으로, 모드 락킹은 CW 레이저의 cavity의 안정적으로 작동하는 지점의 경계에서 시작했다. 이 과정에서 펄스 모드의 커 렌징 효과를 사용하여 CW 모드를 효과적으로 제한할 수 있었다.

Keywords:

Yb:CALGO, Solid-State Lasers, Pulse Laser, Kerr lens mode locking

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P2-op.002

Design of fs Ti:sapphire laser oscillator with LD pumping

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Abstract:

The development of Ti:sapphire laser oscillators using laser diodes (LD) has been studied due to their advantages of being low-cost, compact, and easy to use. However, the poor pump beam quality of laser diodes, which consist of semiconductors, requires beam shaping for improved efficiency. A combination of lenses can manipulate the properties of the beam propagating into a Ti:sapphire gain medium. It is necessary to adjust the focal length of the lenses depending on the beam properties, which are influenced by the type of LD used.

Blue and green LDs were used in the experiment. The beams generated from each LD were attempted to be controlled using 4 lenses and The beam shape into the gain medium depended on the LD. In this presentation, we will discuss the characteristics of the Ti:sapphire laser oscillators with the LDs.

Keywords:

Blue and Green LD Pumping, low-cost, pump beam quality, beam shaping

P2-op.003

이중 파장대역을 이용한 초분광 단층 영상

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Abstract:

기하 위상 렌즈가 가지는 색분산 효과는 현미경의 깊이 방향 스캐닝을 통해 영상을 획득하는 효과를 기계적인 움직임이 없이도 구현할 수 있게 하였다[1]. 이러한 장점을 이용함으로써 평면에서의 단차와 같은 형상 정보를 획득하는데 응용이 가능하게 되었으며 연구 논문을 통해서 발표된 바가 있었다. 이러한 기하 위상 렌즈는 일반적인 렌즈와는 달리 구동하는 파장대역이 매우 넓은 장점을 가지고 있다. 이러한 특징은 일반적인 렌즈보다 큰 색분산 효과를 가지기 때문이며 이러한 특징을 적극적으로 이용함으로써 광계측에서 새로운 방법을 제안할 수 있게 되었다.
기하 위상 렌즈를 분산 효과가 큰 렌즈로 고려하게 되면 반사되는 파장에 따른 렌즈의 심도가 다른 기능을 이용할 수 있게 된다. 이러한 특징을 이용하여 투명한 샘플에 대해 두께를 측정한 결과가 보고 되었다[2]. 본 연구실에서는 이 연구를 기반으로 단층영상을 구현함으써 투명한 샘플에 대한 단층영상을 비간섭계 기법으로 구현이 가능함을 확인하였다. 이러한 기능은 파장의 대역폭이 넓을수록 측정 가능한 깊이 심도의 향상으로 연결될 수 있다. 이러한 장점을 이용하기 위해서는 다양한 중심 파장을 가지는 광원을 여러개 이용하거나 광대역 광원을 이용함으로써 실험적으로 구현이 가능할 것으로 예상된다.
본 논문에서는 중심 파장이 다른 두 광원을 이용하여 초분광 단층영상을 구현한 결과에 대해서 제시하고자 한다. 중심 파장이 각각 0.6 ㎛와 0.8 ㎛인 두 광원을 이용해 단일 기하 광학 렌즈에 입사하고 이를 통해 확보된 향상된 영상 구현 깊이를 이용하여 투명한 샘플에 대한 단층영상을 구현하고자 하였다.
This research was supported by Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education(No.2022R1I1A3066087).

Keywords:

초분광, 단층영상, 이중 파장대역

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P2-op.004

바이오 리액터 모니터링 시스템을 위한 소구경 현미경 광학계 개발

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Abstract:

본 연구에서는 바이오 리액터 내부에서 실시간으로 세포 이미징이 가능한 현미경 광학계를 개발했다. 바이오 리액터는 백신·의약품 개발을 위해 세포를 배양하여 대량 생산하는 장치로, 의약품, 백신 개발에 광범위하게 활용되는데, 내부의 세포 배양 정도와 오염 유무를 확인하기 위하여 모니터링 시스템이 필요하다. 기존의 바이오 리액터 모니터링 시스템은 세포가 검출기를 통과할 때의 투과도 변화를 통해 간접적으로 세포 밀도를 측정하는 방법과 바이오 리액터 내부의 시료를 추출하여 외부에서 이미지를 관찰하는 방법을 주로 사용한다. 그러나 위의 두 가지 방법은 세포의 밀도를 정확히 계측할 수 없거나, 측정 과정에서 오염이 발생할 위험이 크다. 따라서 바이오 리액터 내부를 현미경 광학계를 활용하여 직접 관찰하는 이미징 시스템을 통해 세포의 숫자를 직접 관찰하거나, 더 나아가 세포 및 배양액의 화학적 특성을 분광학적으로 분석하는 시스템 개발의 필요성이 대두되고 있다. 그러나 일반적으로 활용되는 바이오 리액터용 프로브는 15 mm 내외의 작은 구경을 가지고 있어, 일반적인 현미경 광학계를 적용할 수 없는 문제가 있다. 이러한 문제를 해결하기 위해 본 연구에서는 소구경의 Aspheric Lens를 채용, 구경이 15 mm 내외인 현미경 광학계의 개발 및 성능 평가 결과를 보여준다. 이러한 방법으로 개발한 광학계는 바이오 물질 생산 분야뿐 아니라 수질오염 물질 모니터링 등 여러 분야에 광범위하게 적용될 수 있을 것으로 기대한다.

Keywords:

바이오 리액터 모니터링, 세포 이미징, 소구경 현미경 광학계

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P2-op.005

Thickness Characterization of SiO2/Si Wafers Using a Rotating Compensator-Type Spectroscopic Ellipsometer

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Abstract:

Ellipsometry is a measurement technique that analyzes the polarization state change induced by the sample, enabling determination of optical constants and film layer thickness. This method finds widespread application across various fields due to its remarkable sensitivity, accuracy, and non-contact, non-destructive nature.
Using the constructed ellipsometer, we conduct measurements on SiO2/Si wafers with different thicknesses of SiO2 layers.
The devised ellipsometer employs a rotating compensator-type configuration, which is further enhanced by the incorporation of an objective lens pair to reduce the beam profile. This enhancement facilitates measurements in confined sample areas, thus enabling the analysis of samples with finer dimensions.

Keywords:

ellipsometry, spectroscopy, film thickness

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P2-op.006

Phase shifting lateral scanning white light interferometry

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Abstract:

Since artificial intelligence and big data had been advanced, the amount of data to be stored within a limited size has increased. The devices have become more complicated and smaller because of integration and miniaturization. Therefore, detection and restoration of the defect such as dust on mask, non-uniform thickness or nanometer alignment mismatch have attracted many semiconductor industries. However, because of the small field of view of commercial non-destructive methods such as confocal microscopy and interferometry for identifying device surfaces, image stitching is required to measure large areas. But, if there is no specific structure for a field of view, it is difficult to use feature-based image stitching.
Here, we developed phase shifting lateral scanning white light interferometry for inspection large area wafer topography. Scanning stage used in traditional lateral scanning interferometry had moved at the speed of one pixel of the camera speed and taken signals from every pixel, so the amount of data was large and the speed was slow. Modulation of the fringe spacing that vertically produced to the scanning direction enables increasing the speed of stage and adapting phase shift technique. Sub centimeter topography imaging without image stitching can be obtained with nanometer vertical resolution by using Michelson type interferometric objective lens.

Keywords:

Lateral scanning microscopy, White light interferometry, wafer insepction, phase shifting lateral scanning white light interferometry, phase shifting white light interferometry

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P2-op.007

PEDOT:PSS Film with Brij C10-additive Characterized by THz-TDS

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Abstract:

Poly(3,4-ethylenedioxythiophene)-poly(styrene sulfonate) (PEDOT:PSS) is a well-known conductive polymer widely applicable in transparent electrodes or substrates. However, its sheet resistance (R_{sheet}) still needs to be substantially reduced for practical uses. In a recent study, addition of polyethylene glycol hexadecyl ether (Brij C10) into the PEDOT:PSS solution was reported to result in a reduction in R_{sheet} from $2.6\times10^{6}\Omega\ sq^{-1}$ to $1.5\times10^{3}\Omega\ sq^{-1}$. We intend to analyze the change in terms of optical conductivities obtained with terahertz time domain spectroscopy (THz-TDS). For the film thickness of 50~100 nm, normalized transmitted amplitude for a bare PEDOT:PSS is close to 1.0, which decreases to 0.8 upon addition of Brij C10, implying that the film with added Brij C10 exhibits higher conductivity.

Keywords:

sheet resistance, PEDOT:PSS, Brij C10, THz-TDS

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P2-op.008

mutilcycle 15 THz generation from lithium-niobate wafers using 150TW laser

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Abstract:

There's a lot of challenge to generate high-energy THz waves, which is essential to explore the nonlinear phenomena of THz radiation-matter interactions as well as their underlying physics. One of the most widely used mechanisms for generating high power THz waves with laser-based source is optical rectifications. For the efficient THz generation, the phase-matching condition is one of the crucial factors. For thin lithium-niobate (LN) wafers, it was expected that generation of approximately 15 THz waves would occur via optical rectification due to the relatively low absorption at that frequency and the phase-matching condition of group refractive index of LN and refractive index of the THz wave, $n_g=n_{THz}$.

In this study, we conducted measurements of the energy, as well as spatial and spectral characterizations, of multicycle 15 THz waves generated from large-aperture LN wafers using a 150 TW laser. The energy of the generated 15 THz waves was measured using a pyroelectric detector for various thicknesses of LN, both with and without MgO doping. The LN samples had thicknesses of 25 ㎛, 50 ㎛, and 100 ㎛, all with a diameter of 75 mm. The spatial characterization of the THz waves was obtained by capturing THz images with a microbolometer camera. To characterize the temporal and spectral profiles of the generated THz waves, a single-shot interferometer was employed. This interferometer facilitated the acquisition of temporal and spectral information regarding the THz waves generated from LN. This comprehensive approach provided valuable insights into the generation, propagation, and properties of the 15 THz waves produced from the large-aperture LN wafers.

Keywords:

THz, Lithium Niobate, 15 THz, High power THz generation

P2-op.009

테라헤르츠 분광법을 이용한 니켈크롬박막의 전기적 특성 연구

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Abstract:

테라헤르츠 시간-영역 분광법 (THz-time domain spectroscopy: THz-TDS)을 통해 니켈-크롬 (Ni/Cr) 필름의 두께와 전기적 성질을 정밀하게 측정하였다. 우리는 Tinkham식을 활용하여 Ni/Cr 필름의 복소 광학 상수를 성공적으로 추출하였으며, 실험 결과로부터 얻은 값은 드루드 모델과의 비교를 통해 Ni/Cr 필름의 전기 및 광학 상수의 높은 신뢰성을 확인하였다. 또한, 전기전도도 값을 기반으로 Ni/Cr 필름의 두께를 정확하게 추정할 수 있었다. 전통적인 헤이즈 미터와 투과 밀도계 측정법과 비교했을 때, THz-TDS로 얻은 측정값이 잘 일치함을 확인하였다. 이러한 결과는 THz-TDS가 금속 나노 필름 분석에 있어 효율적인 비파괴검사 (NDT) 방법으로 적합하며, 산업 분야의 품질 관리에도 큰 도움이 될 것임을 시사한다.

Keywords:

Terahertz, Spectroscopy, Thin flim, thickness

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P2-op.010

Terahertz microcavities for studies on interaction between excitons and phonon-polaritons

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Abstract:

Microcavities can amplify electromagnetic waves at specific frequencies via high quality factor resonances. Conventional wafers separated by few tens to hundreds of microns can support such resonances at terahertz frequencies, enabling studies on phonon-polaritons in various materials, including organic-inorganic hybrid perovskites. We aim to explore various combinations of wafers and separations for inducing ultrastrong photon-phonon coupling and simultaneously enable optical measurements at visible frequencies, e.g. photoluminescence, such that we can unveil possible interactions between excitons and phonon-polaritons.

Keywords:

resonance, phonon-polariton, Microcavity, Terahertz

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P2-op.011

Terahertz metamaterial lens by 3D printing

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Abstract:

The terahertz (THz) electromagnetic waves have a variety of imaging applications in fields such as medical diagnosis, non-destructive tests, and security based on their sensitivity to molecular vibration, low photon energy, and transparency to dielectrics. For the application, further development of optical elements is required, because of the lack of suitable material. Metamaterial-based optics is a good candidate for this situation due to their controllability of optical response beyond fundamental material properties. However, the common process of metamaterial fabrication requires excessively elaborate and time consumptive methods such as lithography and computer numerical control machining. Thus, a more simple and fast fabrication method is essential for proliferation and practical applications. Here, we demonstrate 3D printing of THz optics based on all-dielectric metamaterial. Considering the pixel shape of the 3D printer, we designed a square-pillar structured unit cell, which has full-wave phase controllability and constant transmittance using FDTD simulation with material properties measured by THz time-domain spectroscopy. By parabolic phase arrangement of unit cells, various types of focusing lenses are designed. considering sufficient printing resolution, a low-cost LCD-typed 3D printer with photopolymer resin was adopted for lens printing. The focusing performance of this lens was appraised using both simulations and experiments with a THz camera. The 3D printed metalens showed good focusing performance with polarization insensitivity.

Acknowledgments: This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korean government (MSIT) (No. 2022R1F1A1074851).

Keywords:

terahertz, metamaterial, metalens, 3d printing, imaging

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P2-op.012

Nanostructuring PEDOT using maskless photolithography

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Abstract:

In this work, we fabricated nanoantenna arrays based on highly conductive Poly(3,4-ethylenedioxythiophene):Sulf-N-Methyl-2-pyrrolidone (PEDOT:Sulf-NMP) using maskless photolithography. Optimal conditions such as exposure intensity and time were obtained for the subwavelength nanopattern fabrication. We observed geometry-dependent extinction peak position, indicating that localized surface plasmon resonances were successfully excited by the resulting nanoantenna arrays. The experimental results were also supported by finite-difference time-domain (FDTD) optical simulations.

Keywords:

Nanoantennas, Maskless photolithography, Localized surface plasmon resonances, Conducting polymers

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P2-op.013

Ultrastrong Phonon-Photon Coupling in Terahertz Nano-Slots with Dual Resonances

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Abstract:

Organic-inorganic hybrid perovskites have attracted significant attention due to its exceptional optical efficiency and finds applications in various areas such as solar cells and light-emitting devices. They also possess very strong optical phonon modes at low terahertz frequencies, which may be utilized in realizing phonon-polaritons via ultrastrong light-matter coupling. Of particular interest is the lead-based inorganic-organic hybrid perovskite, MAPbI3, which exhibits two phonon modes at approximately 1 THz and 1.75 THz.
In the present study, we attempt to realize ultrastrong phonon-photon coupling in the two phonon modes simultaneously, by utilizing terahertz nano-slots with two different slot lengths, which will possess dual resonances.
Our objective is to observe the unique characteristics and interactions of the different phonon-polaritons in the context of phonon-phonon and photon-photon interactions.

Keywords:

Ultrastrong coupling, Perovskites, Terahertz, Phonon-polariton, Nano-slots

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P2-op.014

Surface Lattice Resonance using Organic Excitonic Nanoantennas

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Abstract:

When nanoparticles are arranged in an ordered array, they can scatter light and generate diffracted waves. When one of the diffracted waves propagates in the plane of the array, it can cause an interesting phenomenon that couples localized resonances excited by individual nanoparticles to each other, resulting in a sharp narrowing of the spectral width of the resonance. This phenomenon, also called surface lattice resonance (SLR), has become a very active and interesting area of fundamental research due to the very high-quality factors and related effects compared to typical single-particle resonances. Until recently, plasmonic SLRs have been actively investigated by coupling diffracted waves with localized surface plasmon resonance (LSPR). However, recent studies have shown that nanostructured organic excitonic materials can support localized surface exciton resonance (LSER), similar to LSPR in metal nanostructures, as well as Mie resonances. In this work, the SLR of organic excitonic nanostructures was studied. Simulated and measured spectra from the fabricated nanostructures show a dramatic improvement in spectral widths and quality factors compared to those from single nanostructures. Furthermore, we show that the SLR can be further enhanced by controlling the material surrounding the nanostructures. These findings provide new options for SLR engineering to control the resonances.

Keywords:

Surface lattice resonance, Organic excitonic materials, Localized surface exciton resonances, Nanoantennas

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P2-op.015

실리콘 광집적회로에 구현된 pin diode의 자발적 방출에 기반한 quantum random number generator

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Abstract:

오늘날 암호화, 보안 등의 측면에서 난수의 필요성이 대두되고 있다. 난수란 무작위로 추출된 수이며, 무작위이기에 예측할 수 없다. 컴퓨터 상에서 다양한 방법으로 난수를 만들 수 있으나, 대부분의 난수는 시드(seed)와 알고리즘에 의존하여 생성된다. 때문에 시드와 알고리즘을 알아낸다면 결과값으로 나오는 난수 또한 예측할 수 있다. 반면 양자물리학의 불확정성에 의존하여 만들어내는 난수는 강력한 무작위성을 제공한다. 시드와 알고리즘으로 생성된 예측 가능한 난수를 의사 난수(pseudo random number)이라 하며 물리적 현상을 통해 생성된 예측 불가능한 난수를 순수 난수(true random number)라고 한다. 이번 연구에서는 실리콘 광집적회로에 구현된 pin diode의 자발적 방출(spontaneous emission)을 통한 광자의 무작위한 생성 시간의 측정으로 순수 난수성을 분석한다. 위 방법을 통해 생성된 난수가 얼마나 예측 불가능한지 판단하기 위해 NIST statistical test (NIST SP 800-22)를 통해 무작위성을 검증한다.

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Keywords:

Quantum random number generator, 양자난수발생기, 실리콘 광집적회로, 자발방출, pin diode

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P2-op.016

Brillouin scattering by surface phonon vibration via High-Q On-Chip Microresonator

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Abstract:

We suggest an approach to create surface phonon vibrations utilizing a chalcogenide glass microresonator integrated onto a chip, featuring a notably high Q-factor. Through simulations, we determined the optimal resonator parameters to achieve efficient generation of surface phonon oscillations. This investigation opens the door to designing optical structures capable of manipulating surface phonon properties, potentially enabling their utilization as on-chip sensors.
The interaction of light and phonon is one of the main research topics in nonlinear optics. By analyzing the nature of the phonon oscillations that occur during the interaction, mechanical properties of materials can be measured and controlled. In particular, the vibrations of surface phonons can be utilized for sensing due to their strong sensitivity to surface materials, unlike the well-known vibrations of bulk phonons. We have implemented a simulation that can obtain the conditions to generate surface phonon vibration in on-chip resonator and designed the optimized resonator.
In this study, we adapted an open-source numerical Brillouin analysis tool to find conditions to generate surface Brillouin scattering in resonator. The first condition is that both the pump light and the Stokes light generated through Brillouin scattering must be in the resonant mode of the optical resonator. To satisfy this condition, the Brillouin scattering frequency must match the free spectral range of the resonator. The second condition is that the Brillouin gain must be greater than the loss of light in the optical resonator. To satisfy this condition, the intensity of light injected into the resonator must be greater than the threshold power Pth, which is given as
$P_{th} = \pi^2 n_{eff}^2 L_{trip} (1+K)^3 / \lambda_p^2 K Q_{int}^2 G_B$.
In this equation, n_{eff}, L_{trip} and K are effective refractive index, round-trip length of resonator and coupling strength, respectively. Also, λ_P, Q_{int} and G_B are pump wavelength, intrinsic quality factor and Brillouin gain coefficient, respectively. Since the smaller the threshold power, the more efficient the resonator can generate surface phonon vibration, this study focus on finding resonator with high G_B and Q_{int}, which are the parameters to easily lower the threshold power.
Considering these variables, we set up a resonator design which has the cross-section shape is trapezoidal and the core material is chalcogenide. We simulated the optimal design by varying the thickness of the core material. The simulation results show that the eigen frequency of the phonon can be varied by simply adjusting the thickness of the core material, which can be utilized in the design of micro-oscillator with appropriate frequencies for applications in the GHz bandwidth, such as wireless communications.

Keywords:

Brillouin scattering, surface phonon vibration, High Q On-Chip Microresonator, Brillouin gain, Threshold power

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P2-op.017

Optical spin Hall effect in out-of-plane refraction

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Abstract:

The classical concept of refraction's law characterizes the incident plane as the plane encompassing both the wavevector of the incident beam and the surface normal vector at the boundary of two distinct optical mediums. The optical spin Hall effect generally alludes to the spin-related lateral displacement of the refracted beam in a direction perpendicular to the incident plane. In this study, we demonstrate that deviating refraction from the incident plane becomes feasible by introducing an additional two-dimensional phase gradient at the interface. The resulting spin-dependent spatial segregation of photons is governed by manipulating the 2D supplementary momentum originating from the metasurface, as described by the generalized Snell's law of refraction.

Keywords:

Out-of-plane refraction, Optical spin Hall effect

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P2-op.018

Anomalus double peaks in non-coupled organic films with Fabry-Perot cavity

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Abstract:

Strong light-matter coupling forms polariton states with properties of both light and matter when the rate of energy exchange in between is faster than the average dissipation rate. We combined a TDBC (5,6-dichloro-2-[[5,6-dichloro-1-ethyl-3-(4-sulfobutyl)benzimidazol-2-ylidene]propenyl]-1-ethyl-3-(4-sulfobutyl)benzimidazolium hydroxide, inner salt, sodium salt) layer with a Fabry-Perot cavity to systematically study the condition to achieve strong coupling. For thin TDBC layers, we could successfully reproduce commonly reported Rabi splitting between polariton states formed by strong coupling. However, for thicker TDBC layers, we also observed anomalous double extinction peaks even when the TDBC layers were located at the node of the cavity resonance, which cannot be explained by strong coupling. We demonstrate that the TDBC layers with a sufficient thickness can effectively reduce or expand the cavity lengths and thus affect the cavity resonances due to the highly wavelength-dependent permittivity of TDBC. All the results were successfully reproduced by the finite-difference time-domain (FDTD) simulations.

Keywords:

Strong light-matter coupling, exciton-polariton, TDBC, Fabry-Perot cavity, FDTD simulation

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P2-op.019

Strong plasmon-exciton coupling using Ag nanodisk array and TDBC

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Abstract:

Polaritons, which are hybrid quasiparticles with properties of both light and matter formed by strong light-matter coupling, are attracting attention for advanced materials such as polariton lasers and polariton switches. In this work, we present the strong plasmon-exciton coupling phenomena using plasmonic Ag nanodisk arrays and excitonic J-aggregated cyanine dye TDBC (5,6-dichloro-2-[[5,6-dichloro-1-ethyl-3-(4-sulfobutyl)benzimidazol-2-ylidene]propenyl]-1-ethyl-3-(4-sulfobutyl)benzimidazolium hydroxide, inner salt, sodium salt). We systematically studied the effect of the periodicity, diameter, and thickness of the Ag nanodisk arrays and the thickness of the TDBC on strong coupling using the finite-difference time-domain (FDTD) simulation. Further, we experimentally realized the optimized strongly coupled systems using electron beam lithography and studied their nanooptical properties.

Keywords:

Strong Light-Matter Coupling, Exciton-Polariton, Nanodisk, J-aggregate, FDTD simulation

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P2-op.020

자율주행 자동차용 LiDAR기기 개발에 응용을 위한 광위상배열 소자 연구

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Abstract:

본 연구는 3차원 공간에서 움직이는 물체의 거리와 속도를 탐지할 수 있는 광센서 중 라이다기기 개발을 위해서 연구 중인 optical scanner 이며, 광위상배열(Optical Phased Aarray :OPA) 구조를 갖는 소자 설계와 제작 후 광특성 분석을 수행하였다. 먼저, OPA 광소자는 크게 외부 입력광을 소자에 입사시키는 목적으로 Fiber to Chip Coupler와 입력된 빔을 여러 경로로 분리하는 다중모드 간섭 분배기, 열 광학 효과를 이용하는 위상변조기, 방출부 등의 4가지로 구성되었다. 각 구성요소의 최적화된 설계는 3차원 FDTD 전산모사를 통해 구조를 설계하였다.
실리콘 기판위에 2㎛ 두께의 Bottom Oxide layer가 있고 실리콘 나이트라이드 기능성 레이와 SiO2 상부 클래딩이 있는 구조에 도파로를 제작하였다. 제작된 OPA는 실리콘 나이트라이드를 기능성 레이어로 한 채널의 입력광이 16채널로 분배되어 약 5%의 방출효율로 입력된 빔을 2차원 공간상에서 가로방향으로 15° 정도로 조향됨을 확인하였다. 이러한 실험 결과를 바탕으로 OPA를 이용한 이차원 빔 조향은 자율주행 차량을 위한 전자식 스캐너를 탑재한 LiDAR 기기에 이용 가능성을 시사한다.

Keywords:

LiDAR, Optical Phased Array, Photonics Integrated Circuit

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P2-op.021

1차원 센서를 사용하는 D-ToF 방식 Mechanical type LiDAR 수신부 광학계의 Ghost 분석

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Abstract:

LiDAR(Light Detection and Ranging) 기술은 주변 조명 조건에 상관없이 거리를 측정하고 물체를 감지할 수 있기 때문에 첨단 운전자 보조 시스템(Advanced Driver Assistance System, ADAS) 및 완전자율주행을 위한 고해상도 3차원 지도 구현의 핵심 기술로서 그 중요성이 증가되고 있다. D-ToF(Direct Time-of-Flight)방식은 가장 간단하고 널리 사용되는 LiDAR의 물체 위치 측정법 중 하나로 특정 방향으로 송신부에서 레이저 펄스를 보내고 물체에서 반사된 빛을 수신부 (센서)가 기록하여 송수신 시간 간격을 계산하여 물체의 거리를 측정하는 방식이다.

LGIT LiDAR의 수신부 광학계는 입사창, 상,시야(FOV) 내에서 물체에 반사된 빛을 집속시키기 위한 렌즈, 특정 파장 대역의 신호만을 통과시켜 불필요한 노이즈를 줄이는 대역 투과 필터(Band-pass filter), 센서를 보호하기 위한 센서창으로 구성되어 있다.

위와 같이 광학계에 투과성 광학 부품이 포함되는 경우 고 반사율 물체 또는 가까운 거리에서의 강한 빛에 노출된 상황에서 고스트 현상을 유발할 가능성이 있으며 이는 부정확한 측정 결과로 인해 사용자의 안전에 위협을 초래하므로 그 효과를 검토할 필요가 있다.

고스트 현상은 일반적으로 실제 존재하지 않는 허상이 촬영되는 것을 말하며, 광학계의 성능을 저하시키는 주된 요인 중 하나이다. 따라서 고스트 현상의 영향을 예측하는 것은 광학계 성능 결정에서 중요한 부분을 차지한다. 고스트 현상의 원인은 광학계 투과성 광학 부품의 표면에서 빛이 완전히 투과되지 못하고 부분 반사되는 것이다. 광학부품 각각이 고스트 현상 유발에 기여하는 정도와 경로를 분석하면 고스트 효과를 억제할 수 있는 방법을 도출할 수 있다.

따라서 이번 연구에서는 LGIT LiDAR의 수신부 광학계 구조를 소개하고 해당 광학계에서 발생할 수 있는 고스트의 종류와 강도를 예측한다. 그 후에 광학 부품의 기울임(tilting) 방법을 사용하여 고스트 영상의 성분을 서로 다른 지점으로 분리, 1차원 어레이 센서에서 고스트 현상을 억제할 수 있는 방법에 대해 소개한다.

Keywords:

LiDAR, Optics, Optic system, Laser, Ghost

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P2-op.023

Single Photon Emitters of Chemical Treated WSe_2

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Abstract:

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We investigated the single photon emissions (SPE) of WSe_2 after chemical treatment. The localized SPE from defect states of WSe_2 can be found with a very low probability, which is hindered by other emissions from the localized states.[1] We prepared mono- and few-layer WSe_2 on the SiO_2/Si substrate and the thickness of the flakes was identified using optical contrast, photoluminescence (PL), and Raman spectroscopy. Some of the sharp peaks that were observed only at low temperatures (~4 K), can be identified as SPE using the Hanbury-Brown-Twiss interferometer. The samples were treated with the organic superacid Bis(trifluoromethane)sulfonimide (TFSI), known to activate chalcogen vacancies and enhance the PL quantum yield in WS_2 and MoS_2. However, in the case of WSe_2 and $MoSe_2$, it has been reported that the PL intensity decreased at room temperature.[2] To understand the role of chemical treatment on the various types of defects, we systematically studied the effect of chemical treatment on SPE in WSe_2.

Keywords:

single photon emissions (SPE), chemical treatment, WSe2

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P2-pa.001

Development of Jet-based MET correction at Level-1 trigger for the CMS Phase-II upgrade

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Abstract:

The High Luminosity Large Hadron Collider (HL-LHC) is planned to make proton-proton collision at 14TeV with very high instantaneous luminosity in order to perform precision tests of the Standard Model (SM) and search for new physics beyond the SM. Due to the substantial increase of the instantaneous luminosity, the CMS Level-1 (L1) trigger upgrade will be essential for its operation at HL-LHC. The Correlator Trigger (CT) is one of the major parts of the L1 trigger upgrade, responsible for aggregating inputs from all upstream systems and combining the information for L1 physics objects. The CT will be capable of providing essential physics objects such as Missing Transverse Momentum (MET), Jets and their tagging information based on the PF (Particle Flow) or PUPPI (Pileup Per Particle Identification) candidates, thus enabling best possible trigger performance. In this presentation, we discuss the development of jet-based MET correction using PF information in the CT. In addition, update on the latest results for the implementation of the L1 trigger algorithm using APx trigger board firmware, are reported.

Keywords:

CMS, Phase-2, Trigger, MET

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P2-pa.003

Study of characteristics of Low Gain Avalanche Detector (LGAD) sensors

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Abstract:

The CMS collaboration is preparing the CMS Phase-2 Upgrade for the challenging conditions at the High-Luminosity LHC (HL-LHC). The MIP Timing Detector (MTD) is designed to enable the presicion timing at a level of 30-40 ps in order to mitigate pileup effect. The ETL (Eadcap Timing Layer), which will be installed in the endcap region of the MTD, will be instrumented with a hermetic double layer of LGAD (Low Gain Avalanche Detector) sensors covering the high radiation pseudo-rapidity region between $|\eta|=1.6$ and 3.0. We report the current status of the characteristic study of LGAD sensors produced by Fondazione Bruno Kessler (FBK) in Italy.

Keywords:

CMS, MTD, ETL, LGAD, HL-LHC

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P2-pa.004

KDAR neutrino search in JSNS^2

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Abstract:

The J-PARC Sterile Neutrino Search, JSNS^2 is located at the J-PARC's Material and Life Science Facility (MLF) where the world's most intense source of KDAR (Kaon Decay-At-Rest) neutrino created by a 3 GeV proton beam incident on a liquid mercury target. JSNS2 observed the clear KDAR spectrum of monoenergetic neutrinos at 236 MeV from the J-PARC Spallation Neutron Source. In this presentation, we report the observed KDAR spectrum and the Monte-Calro study for cross section calculation.

Keywords:

KDAR, monoenergetic neutrinos, J-PARC

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P2-pa.005

A performance study of small scale computing clusters using a new benchmark scheme dedicated to particle experiments

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Abstract:

The tremendous size of data samples generated by particle experiments requires a proper accounting scheme, which is essential in planning the amount of computing resources used to process and analyze those samples. Until recently, major particle physics collaborations used HS06 to measure the performance of CPU's built in their computing clusters and create resource usage reports. Though HS06 is a popular benchmark package, it was not optimized for the needs of particle physics collaborations. HEPScore23 is a new benchmark scheme created by WLCG HEP-SCORE Deployment Task Force, built on the reference executables submitted by particle physics collaborations to address their specific needs. The authors deployed HEPScore23 in two small-scale computing clusters constructed in their institutes and checked its responses. The size of the clusters is typical for educational institutes. The deployment process and the output of HEPScore23 will be discussed in this poster.

Keywords:

computing, cluster, benchmark, performance, HEPScore23

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P2-pa.006

Non thermal leptogenesis in PQ Higgs pole inflation

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Abstract:

We propose the PQ Higgs pole inflation model based on the conformal coupling between the Standard Model (SM) Higgs and gravity. The model can explain the origin of the axion by the angular part of a complex scalar, and it provides a possibility to explain the CMB experiments such as WMAP and Planck. In the reheating epoch, the inflaton can decay into other particles in the SM. We show that the right-handed neutrinos (RHNs) can be produced dominantly by the inflaton decays, setting the initial condition for the RHN abundance during reheating. In the PQ Higgs pole inflation, we show the interplay between baryogenesis via leptogenesis, the successful inflation and the correct dark matter density from the axion.

Keywords:

Leptogenesis, PQ, Inflation

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P2-pa.007

Event generation for millicharged particle search at Fermilab

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Abstract:

NuMI and LBNF beams at Fermilab can provide a suitable environment to search for millicharged particles produced from the decay of neutral mesons. In order to estimate the sensitivity of an experimental proposal, appropriate signal events need to be generated. The setup and result of the simulation studies performed by using Pythia and Madgraph are presented in this poster.

Keywords:

Fermilab, NuMI, LBNF, millicharge

2023 KPS Fall Meeting
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P2-pa.008

Development of MC generation on HPC for LHC

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Abstract:

Massive Monte-Carlo event generation is necessary to study physics at the Large Hadron Collider (LHC). The number of event has to be increased in precision measurement, search for new physics phenomena and complicated final states usually come with large backgrounds. Securing huge amount of CPU, memory and disk spaces has been a serious issue in sustainable LHC grid computing. On the other hand, various R&D studies has to be performed for more efficient use of resources such as adopting hardware accelerators or commercial Cloud computing resources. We developed an interface to utilize many-CPU or multi-node environment in event generation, which is common in the High-Performance Computing (HPC).

Keywords:

MC generator, LHC, HPC

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P2-pa.009

Analysis of lithium pollution reduction of lithium charge stripper by using skimmer

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Abstract:

Proposed was the method to lessen beamline pollution caused by the lithium gas generated from the operation of lithium charge stripper for a heavy ion accelerator. In order to liquefy and solidify the lithium vapor generated when forming the lithium film, a skimmer capable of contacting the lithium vapor is placed on the beamline. Three skimmers were installed in consideration of the length of the beamline to increase the contact area and conceived in a curved type. The analysis on the arrangement of three skimmers showed that the lithium film formed lithium gas with the mass flow rate of 0.5 g/s per second. When the flow of the generated gas is forced to change direction through the vacuum pump, the degree of vacuum of the beam line is 3.88 x 10-7 mbar, which was 1/100 of the degree of vacuum of the charge stripper. The vacuum pressure by using a curved type skimmer was about 30 % lower than that by using a straight-type skimmer, where the flow velocity was 3 x 10-11 m/s, indicating it would take 1260 years for the lithium vapor to reach the beamline. Conclusively, it was predicted that the beamline would operate optimally without any lithium contamination by using a curved skimmer.

Keywords:

accelerator, charge stripper

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P2-pa.010

Pomeron-CQM Model of J/psi photoproduction including the final-state interaction

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Abstract:

The constituent quark model has been a valuable framework for understanding the internal structure of hadrons, particularly in the context of photoproduction reactions involving heavy mesons like the J/y. In this study, the CQM model have been used to extend the Pomeron Exchange model by Donnachie and Lanshoff with removing the VDM assumption. This work also has evaluated the final state interaction of J/yphotoproduction. The resulting Pomeron-CQM model can then explain the data of JLab at energies very near J/y production threshold.

Keywords:

J/Psi Photoproduction, CQM Model

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P2-pa.011

Pre-Kicker study in JSNS2 experiment

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Abstract:

JSNS2 (J-PARC Sterile Neutrino Search at the J-PARC Spallation Neutron Source) is an electron antineutrino appearance experiment to research the sterile neutrino around Δm^2~$1eV^2$ as a direct test of LSND anomaly. Electron antineutrino is searched by IBD (Inverse Beta Decay) process in the liquid scintillator. One of the main background for the IBD is Michel electron from the cosmic muon. Normally, we can identify Michel electrons using pairing between cosmic muon and electron. But we are missing a few of Michel electrons when cosmic muon is coming before the beam timing. To reject such kinds of events, we are considering the installation of Pre-Kicker. Pre-Kicker is a kind of cosmic muon decay time flag constructed by NIM modules. And we had a short test on the beam-off time in 2023, April. In this presentation, Pre-Kicker rate and performance analysis results are shown using beam-off data.

Keywords:

JSNS2, Sterile Neutrino, Trigger

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P2-pa.013

Muon g-2 and supersymmetry in light of gauge coupling unification and proton decay

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Abstract:

In the Minimal Supersymmetric extension of the Standard Model, we limit the parameter space to that which is compatible with the LHC and the muon g-2 experiment. Moreover, we examine the impact of the resulting mini-split SUSY spectrum on gauge coupling unification and proton decay.

Keywords:

g-2, SUSY, unification, proton decay

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P2-pa.014

PQ inflation and axion quality problem

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Abstract:

Axion had been introduced to solve the strong CP problem, and it also can be a nice candidate for dark matter. From the PQ field, we identify the radial component as the inflaton and the axial component as the QCD axion. In this case, we consider a slow-roll inflation in the presence of a PQ breaking higher order potential. During the slow-roll inflation, we show that the PQ breaking term induces a nonzero velocity for the axion, thus causing the kinetic misalignment for the axion. We discuss the implications of the successful inflation and the axion quality for determining the axion relic density.

Keywords:

axion, inflation, inflaton, strong cp problem

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P2-pa.015

MC study of D^0→V gamma decays at Belle II experiment

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Abstract:

We are studying the radiative decays of D^0 meson, $D^0 \to V\gamma$ at Belle II experiment. Threre are 4 channels, $V = \phi, \rho^0, \bar{K}^{*0}$ and ω . The target measurements are branching fraction and A_{CP}. The first motivation of our study is to observe $D^0 \to \omega\gamma$ and improve precision of previous measurements in other modes($V = \phi, \rho^0, \bar{K}^{*0}$). We would like to present current status of MC study.

Keywords:

Belle II, D meson, Radiative, Charm

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P2-pa.016

Feasibility study for tthh production in CMS Run3 data using Deep Neural Network.

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Abstract:

Since the discovery of Higgs particles in 2012, identifying their properties has been an important task in particle physics. Among the di-higgs processes which enable us to study higgs properties, tthh channel is predicted to be one of the most dominant channels with higher center of mass energy and larger luminosity circumstance of further LHC experiments. However the tthh process is expected to be really hard to find, not only beacause of its extremely small cross-section (~O(-3)pb at *s = 13.6TeV*), but also the enermous backgrounds that significantly mimic the signal. In this study, the event samples are produced with Monte Carlo event generators targeting the Run3 experiments with *Lexp= 300fb-1*. The significance of the tthh beyond the backgrounds is calculated after traditional cut-flow method and the event classification approach using DNN classifier.

Keywords:

tthh, Run3, lhc

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P2-pa.017

Study of 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 new physics 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 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

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P2-pa.018

Identification of ttH(bb) from ttbb events using Spiking Neural Network on Loihi neuromorphic chip

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Abstract:

After the Higgs boson discovery in 2012, we are struggling to find a new particle that should exist to explain dark matter, asymmetry of matter-antimatter or unification of forces, etc. To address these, we harness billion-events per second from the proton-proton collisions. In the High-Luminosity LHC, more data will be collected with more information. To surmount this challenge, we propose a Spiking Neural Network (SNN) to select interesting events. In this study, we try to identify ttH(bb) events from ttbb events using SNN on Loihi neuromorphic chip and compare its performance with the traditional Deep Neural Network. With the results of this study, we will discuss the feasibility of using SNNs for future collisions.

Keywords:

Spiking Neural Network, Deep Neural Network, CMS, Top

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P2-pl.101

Effect of microwave power on the formation of the crystalline diamond by CVD deposition method

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Abstract:

We studied the effects of microwave power on diamond synthesis in microwave plasma chemical vapor deposition (MP-CVD). Thin layers of diamond were grown on high-pressure and high-temperature (HPHT) diamond plates at various microwave power, ranging from 2700 to 4300 W. Optical microscopy images (OMI), Raman spectroscopy, and atomic force microscopy (AFM) scans were employed to characterize the morphology and crystalline quality of the diamond samples. The results demonstrate that microwave power plays an essential role in controlling the surface roughness and crystalline quality of the diamonds during deposition.

Keywords:

Microwave plasma power, MP-CVD diamond deposition, single crystalline diamond.

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P2-pl.102

레이저 흡수 분광법을 이용한 헬륨 유도 결합 플라즈마내 준안정 준위 밀도 측정

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Abstract:

헬륨 플라즈마에서 준안정 준위는 긴 수명시간을 가지며 큰 여기 에너지를 가지고 있기 때문에 플라즈마 이온화와 상태 유지에 중요한 역할을 한다. 헬륨 유도 결합 플라즈마 내에서 헬륨 준안정 준위의 역할을 이해하기 위하여, 레이저 흡수 분광법이 결합된 헬륨 유도 결합 플라즈마 발생장치를 구성하였다. 396.5 nm(2^1S – 4^1P)와 1083 nm(2^3S – 2^3P)의 발진 파장을 가지는 2대의 고분해능 레이저를 이용하여 헬륨 유도 결합 플라즈마의 레이저 흡수 분광신호를 측정하였고, 헬륨 2^1S와 2^3S 준안정 준위의 밀도를 결정하였다. RF 전원과 헬륨 기체의 압력 변화에 따른 헬륨 준안정 준위들의 밀도 변화를 측정하였으며, 헬륨 방출 분광신호의 변화 특성화 비교 분석하였다. RF 안테나로부터의 거리 변화에 따른 헬륨 준안정 준위의 밀도와 기체 온도와의 상관관계를 분석했다.

Keywords:

레이저 흡수 분광법, 유도 결합 플라즈마, 준안정 준위

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P2-pl.103

Investigating AC loss in low current ramp rates of KSTAR superconducting PF magnets

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Abstract:

For nuclear fusion reactions,, continuous confinement of high-current and long-pulse plasma is necessary. In order to maintain a steady state of plasma current, the superconducting magnets of the tokamak should also be operated stably, with heat controlled to a minimum. However, a slight increase in the outlet temperature of the KSTAR PF (poloidal field) magnet and current ripple were observed, particularly when the current ramp rate is 0.5 kA/s or less. In this range, the evaluated AC loss showed a different trend compared to the range where the current ramp rate was higher than 0.5 kA/s. The total heat load was observed to be significantly higher than the theoretical value, which means that losses must be added. This could be a hindering factor in the operation of long pulse plasmas. To ensure stable plasma control, the current operation of the superconducting magnet coils should be optimized and the AC losses should be applied accurately in the full range of ramp rate. In this study, the parametric study of AC losses based on the results of the PF coil in the low current ramp rate were analyzed to stably operate the superconducting magnet.

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This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MSIT). (PG2219-2)

Keywords:

PF coil, AC loss, hysteresis loss, Superconducting magnet

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P2-pl.104

충돌-방사 모델을 이용한 아르곤 유도 결합 플라즈마의 물성 진단

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Abstract:

플라즈마 방출광의 선세기비와 충돌-방사 모델이 결합된 플라즈마 광진단법은 플라즈마에 영향을 주지 않으면서, 플라즈마의 물성을 진단할 수 있는 방법이다. 아르곤 유도 결합 플라즈마의 전자온도와 전자밀도를 진단하기 위하여, 플라즈마 내 에너지 준위의 밀도를 계산할 수 있는 아르곤 충돌-방사 모델을 개발하였다. RF 파워와 아르곤 기체 압력의 변화에 따른 플라즈마의 방출광 스펙트럼과 선세기비를 측정하였다. 측정된 선세기비와 충돌-방사 모델을 이용하여, 아르곤 유도 결합 플라즈마의 동작 조건 변화에 따른 유도 결합 플라즈마의 전자온도와 전자밀도 변화를 진단하였다.

Keywords:

아르곤 플라즈마, 유도 결합 플라즈마, 충돌-방사 모델

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P2-pl.105

Particle Image Velocimetry and Lissajous Curve for a Plasma Actuator Based on Series 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, a plasma actuator with three electrodes connected in series is analyzed for velocity profile and fluid behavior through particle image velocimetry (PIV) data for three cases. The first case examines the effect of varying voltage within the same structure, the second case investigates the impact of altering the structure under constant voltage conditions, and the third case explores the influence of adjusting the gap distance between the front and back electrodes while keeping the voltage and structure constant. In addition, Lissajous curves were created for the three cases to calculate the capacitance and power consumption for the structure, voltage, and gap distance, respectively. We analyzed the tendency of velocity profile and capacitance according to power.

Keywords:

Plasma actuator, Surface Dielectric Barrier Discharge, Particle Image Velocimetry, Lissajous curve

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P2-pl.106

Calculation of the radial electric field profile using the Motional Stark effect diagnostic system

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Abstract:

The intrinsic radial electric field (Er) is crucial in the performance of tokamak plasmas. In particular, It is widely accepted that the shear (radial variation) of the electric field suppresses turbulent transport in the edge region of plasma, resulting in improved confinement performance. It is envisioned to measure the radial electric field at KSTAR using the line-splitting base Motional Stark effect (MSE) approach. However, there is no reference data that can be compared with the measured radial electric field since related research has never been performed before at KSTAR. Therefore, the radial electric field in various operation scenario of KSTAR to be used as reference data was calculated.

By measuring the polarization angle of the Stark-split emission and calculating through the momentum or force balance equation, the electric field profile is determined. The radial electric field was calculated for each operating mode of KSTAR through an appropriate calculation formula. As a result of the calculation, the sensitivity of the polarization angle measured by MSE diagnostics according to the correction of radial electric field was estimated.

Keywords:

Radial electric field, KSTAR, Motional Stark effect, polarization angle

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P2-pl.107

Particle-in-Cell 플라즈마 시뮬레이션에서 Super particle 비율이 미치는 영향

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Abstract:

반도체 공정에서 필수적인 플라즈마 공정의 효율적인 제어를 위해선 플라즈마의 물리적인 특성을 이해해야 한다. 하지만 플라즈마의 복잡한 상호작용을 실험적으로 직접 이해하기 어려우므로 물리현상을 해석하기 위해 particle-in-cell(PIC) 시뮬레이션이 활용되고 있다. 플라즈마 내의 실제 입자 수는 매우 많기 때문에 이를 모두 계산하는 것은 컴퓨터 하드웨어의 한계로 인해 불가능하다. 따라서 PIC 시뮬레이션에서는 하나의 입자가 실제 입자들을 대표하는 super particle 개념을 통해 계산하면서 통계적으로 동일한 현상이 유지되는 것을 가정한다. 플라즈마 시뮬레이션에서 입자 하나 당 실제 입자 수를 의미하는 NP2C (The number of physical particles to computational particles)는 플라즈마 내 입자 충돌 및 상호작용 확률에 관여한다. 본 연구에서는 GPU로 병렬화된 2차원 PIC 시뮬레이션을 사용하여 NP2C의 변화가 플라즈마 밀도 및 방전 현상에 어떠한 영향을 미치는지 분석한다.

Keywords:

PIC 시뮬레이션, super particle

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이중 주파수 구동 축전 결합 플라즈마 장비에서 이온 에너지 분포함수에 미치는 blocking capacitor의 영향

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Abstract:

이온 에너지 분포 함수(IEDF)를 제어하는 것은 반도체 식각 공정에서 필수적이다. 이중 주파수 축전 결합 플라즈마(DF-CCP)는 각각 고주파(HF)와 저주파(LF) 전력의 변화를 통해 이온 플러스와 이온 에너지를 별도로 제어할 수 있다는 장점을 가진다. Blocking capacitor는 RF 전원과 전극 사이에 연결되어 IEDF에 영향을 주는 DC self-bias를 생성하는 역할을 한다. 단일 주파수[1]에서 DC self-bias가 정상 상태에서 일정하다는 것은 잘 알려져 있지만, 여러 개의 전극이 주어진 경우 다중 주파수에 의한 self-bias 모델은 아직 잘 연구되지 않았다. 본 연구에서는 여러 개의 전극이 포함됨 CCP에 대한 외부회로 모델을 개발하였고, GPU로 병렬화된 2차원 입자-셀 시뮬레이션[2,3]을 이용하여 DF-CCP에서 blocking capacitor에 의한 IEDF를 분석하였다.

Keywords:

축전 결합 플라즈마(CCP), 입자-셀 시뮬레이션, Blocking capacitor

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P2-pl.109

Simulation studies on effect of target configuration on laser-ablated plasma scale length

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Abstract:

The plasma generated from laser-induced ablation process of solid target can be an effective source for overdense plasma. The overdense plasma with ramped-density can compress negatively-chirped laser pulse due to difference of critical densities. However, laser-ablated plasma generally has very short plasma scale length. To achieve high compression ratio in the pulse compression scheme using plasma, the plasma scale length must be extended to mm-scale ultimately. For the extension of the plasma scale length to such length scale, various target configuration was attempted. The foam target was designed to extend plasma scale length by adjusting initial mass density and electron density of the target. Moreover, the cone target was designed to further extension of plasma scale length by forming converging plasma at the center axis of cone target. This presentation will show results of simulations with these various target design.

Keywords:

chirped-pulse amplification, Laser, Plasma, Laser-ablated plasma, Solid target

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P2-pl.110

Effect of fluctuation of plasma density at laser pulse compression by a density gradient plasma

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Abstract:

Negatively chirped laser pulse를 pulse 전체가 반사될 정도로 충분히 높은 밀도까지 증가하는 plasma gradient에 조사할 경우, 펄스의 앞 단에 있는 높은 진동수를 가지는 광자가 낮은 진동수를 가지는 광자에 비해 플라즈마의 더 깊은 곳까지 도달하여, 반사된 pulse는 조사되었을 때에 비해 짧은 bandwidth를 가지게 된다. 이 현상을 이용하여 조사한 pulse의 chirping에 알맞은 density profile을 가지는 plasma gradient를 compressor로서 chirped-pulse amplification(CPA)에 활용할 수 있다. 플라즈마는 CPA에 일반적으로 활용되는 solid-state gating과 달리 high intensity로 인해 파괴되지 않기 때문에 향후에 exawatt 이상의 peak power를 가지는 pulse를 만들어 낼 가능성이 있다. 하지만 실제 실험 환경에서 plasma gradient를 만든다고 할 때 의도하지 않은 fluctuation이 존재할 수 있다. 이러한 fluctuation은 광자가 예상보다 더 일찍 또는 늦게 반사되게 하여 pulse compression에 악영향을 줄 수 있다. 이번 연구에서는 몇 가지 fluctuation을 가정하고, particle-in-cell 시뮬레이션과 계산을 통하여 해당 fluctuation이 plasma에 조사된 pulse에 미치는 영향을 확인하는 것을 목적으로 한다.

Keywords:

chirped-pulse amplification(CPA), plasma gradient, fluctuation

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P2-pl.111

Plasma generation from Processed Low Reflectance Aluminum Using Femtosecond Laser pulses

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Abstract:

Femtosecond laser surface processing, a technique commonly employed in metals and silicon, enables modification of reflectivity without the necessity for coatings [1]. This presentation will introduce a method of femtosecond laser processing to create low-reflectivity aluminum alloy and the property of the processed aluminum as a laser-plasma source. The resulting aluminum was subjected to a 1 TW laser system, servers as a high-density laser-plasma source. The laser-induced plasma shapes were measured and compared with those of un-processed aluminum by a 266 nm ultra-short pulse interferometer. These results can suggest the potential of optically modified solid targets for plasma mirrors and grating for pulse cleaning and laser compression applications in the field.

Keywords:

Plasma based laser pulse compression, Overdense Plasma

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P2-pl.112

Al Plasma Diagnostics with a Nomarski Interferometer Using a Frequency-tripled Ti:sapphire Laser

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Abstract:

The peak power output of femtosecond lasers is almost saturated these days due to the size and damage threshold of the grating in the chirped pulse amplification compressor. In order to circumvent these restrictions, some researches have been undertaken to identify materials with greater damage tolerance. One promising idea is using the dispersive property of plasma for laser pulse compression. Since the compression efficiency of the laser pulse is strongly related with the plasma density distribution, it is imperative to understand the temporal expansion dynamics of the plasma. Thus, we conducted a time-resolved Nomarski interferometer to measure side-view density profiles of the laser-produced aluminum plasma. Our experimental setup utilized frequency-tripled Ti:sapphire laser, producing a probe pulse with a central wavelength of 266 nm. This measurement system will be employed for studying laser-aluminum target interactions in experiments exploring plasma-based laser pulse compression.

Keywords:

frequency-tripling, Nomarski interferometer

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P2-pl.113

다중 펌프레이저를 이용한 라만 산란 증폭 빔 결합기

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Abstract:

강한 레이저는 오늘날 여러 물리학 연구 혹은 산업에 사용되고 필요로 되고 있습니다. 강한 레이저를 만드는 방식 중 하나로 라만 산란을 이용하는 방식이 있다. 이는 플라즈마에 플라즈마 진동수만큼의 차이가 있는 두개의 레이저를 서로 반대방향으로 충돌시켜 펌프 레이저의 에너지를 다른 시드 레이저에게 옮기며 증폭시키는 방식이다. 기존 라만 산란 증폭방식은 하나의 긴 펌프의 에너지를 다른 짧은 레이저에게 이동시키지만 우리는 여러 개의 펌프를 사용하여 기존 보다 더 짧은 증폭 길이에서 같거나 기존이상의 증폭률을 가질 수 있다. 이는 전산 모사를 통하여 여러 펌프를 사용했을 때 200 um의 플라즈마를 2개의 펌프를 이용하였을 때에 비하여 더 증폭이 일어난 것을 확인할 수 있었다. 우리는 이러한 다중펌프를 이용한 라만 산란 빔 결합기에서 펌프의 성질에 따른 증폭차이를 확인할 것이다. 이러한 방식은 플라즈마를 매개체로 약한 여러 레이저를 하나로 합치는 방식으로 앞으로 더욱 강한 레이저가 필요한 경우 새로운 해결책이 될 것이다.

Keywords:

beam combiner, laser plasma, Raman scattering, pulse amplification

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P2-pl.114

High-Density-Gradient laser-produced plasma diagnostics using a double-grating differential interferometer

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Abstract:

We employed A high-power Ti:Sapphire laser system with a peak power of 1 TW to tightly focus the laser beam onto a gas jet featuring a nozzle orifice size of 100 μm. As a consequence, laser-produced plasma was generated within the target medium. To evaluate the plasma density, we employed the differential interferometry and compared the obtained measurements with those obtained from standard interferometry. For the application of the differential interferometry, we developed a novel interferometer configuration utilizing a pair of gratings. The direct assessment of phase shift gradients using the differential interferometry effectively mitigates the detrimental impact of all kinds of noises arising from phase measurement, recovery, unwrapping, and Abel inversion processes. Consequently, this technique exhibits enhanced precision and reliability compared to the standard interferometry. In this presentation, we will elaborate on the comprehensive results achieved through this experimental setup.

Keywords:

interferometer

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P2-pl.115

플라즈마 확산 메커니즘을 통한 고밀도 플라즈마 생성에 대한 연구

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Abstract:

고밀도 플라즈마 생성은 플라즈마 과학 및 응용 분야에서 중요한 과제로 간주되고 있습니다. 이를 위해 플라즈마 확산 메커니즘을 정확히 이해하는 것이 필수적입니다. 본 연구에서는 플라즈마 확산 메커니즘의 특성을 이론과 PIC 시뮬레이션을 통해 탐구하였습니다. 우리는 실험 결과를 통해 시간에 따라 이온과 전자의 밀도가 어떻게 변화하는지를 분석하였습니다. 이를 통해 이온과 전자의 밀도 간의 관계와 모션의 비교, 확산 현상, 그리고 전자 온도 변화를 확인하였습니다. 특히, 타겟에서의 밀도가 임계 밀도보다 높을 경우, 임계 밀도에서 얻을 수 있는 반사율을 더욱 높일 수 있음을 관찰하였습니다. 또한, 우리는 이 시스템이 펄스 및 밀도의 변화에 매우 영향이 크다는 것을 확인하였습니다.

Keywords:

Laser ablation, Critical density, Plasma diffusion, PIC code, Electron density

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P2-pl.116

Single-shot chirped-pulse interferometry to measure the transient optical properties of Warm Dense Matter

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Abstract:

Fourier Domain Interferometry(FDI) is a well-used experimental method for observing transitions of properties in Warm Dense Matter(WDM) produced by an ultrafast high-power laser.
In order to observe periods with time intervals of approximately a few femtoseconds to picoseconds, the multi-shot FDI experiment was essential. With the aim of improving this time-consuming experiment, a Chirped Pulse Interferometry(CPI) technique was developed. The CPI experiment is to extend the original pulse to the desired length of pulse duration by various method, and then use it to produce interference to measure changes in properties.
In our setup, the pulse width was adjusted using gold-coated N-BK7 material, which can reciprocate the distance up to 2m. Before entering the target, the first interferometry divided the reference pulse and probe pulse. After passing the target, the second interferometry combines the reference pulse and the following probe pulse, which contains the information that interacts with the laser and target material, to create an interference fringe pattern.
We plan to analyze these patterns and phase differences to find out the movement speed of the electrons and optical properties for example reflectivity of warm dense matter.

Keywords:

FDI, CPI, WDM, High-power femtosecond laser

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P2-pl.117

Particle-in-cell simulation for transition radiation from hot electrons produced in relativistic laser-solid interactions

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Abstract:

Optical transition radiation (OTR), which is emitted when charged particles pass through an inhomogeneous media, can be used as a diagnostic for producing hot electrons, dephasing of electron bunches, and intense laser-solid interactions. In this study, we present 2D particle-in-cell (PIC) simulations for OTR generated in relativistic laser-solid interactions. The OTR by electron bunches from Ti thin foils irradiated at relativistic laser intensities is simulated by tracking the motion of hot electrons penetrating the foils. Furthermore, the modulations of the electron bunch structure and the OTR spectra according to laser intensity are also calculated. These results will help the analytical understanding of ultrafast surface dynamics and relativistic Doppler effects in robust laser-solid interactions.

Keywords:

Laser-plasma interaction, Particle-in-cell (PIC), Optical transition radiation (OTR), Hot electron generation

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P2-pl.118

플라즈마 cut-off frequency 이용한 Thz 생성 및 증폭

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Abstract:

본 연구는 컷 오프 주파수에 해당하는 플라즈마 공간에서 전류를 유도시켜 생성되는 전자기파를 탐구했다. 전도성을 가지는 금속 도파관, 플라즈마와 같은 물질은 전자기파를 반사, 흡수하는 성질을 가진다. 이때, 플라즈마의 특성에 의해, 특정 밀도를 가지는 플라즈마 주파수에 해당하는 전자기파는 외부로부터 플라즈마로 전파하지 못하고 반사된다. 그러나 플라즈마 주파수에 해당하는 전자기파를 플라즈마 내부에서 발생시킬 때, 전자기파가 생성되어 전파됨은 이론적으로 확인할 수 있다. 전자기파를 생성시키는 전류를 플라즈마 내부에 배치시켰을 때, 전자기파는 전류원으로부터 확산의 형태로 나가는 것을 확인했다. 이때, 전류원을 생성시키기 위해, 많이 알려진 Two-color laser Thz generation 방법을 통해 플라즈마 주파수를 포함하는 Thz범위에 해당하는 전류를 발생시켜 전자기파를 생성시켰으며, 푸리에 분석을 통해 플라즈마 주파수에 일치하는 Thz의 시그널이 증폭됨을 확인하였으며, 짧은 시그널을 가지는 일반적인 Two-color Thz pulse 와는 다르게, 플라즈마 주파수에 해당하는 오래 지속되는 Thz의 시그널 또한 확인했다.

Keywords:

laser plasma, cutoff-frequency enhanced emssion, Thz generation

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P2-pl.119

High energy resolution off-resonant spectroscopy to probe electronic structures using self-seeded XFEL beams

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Abstract:

High energy resolution off-resonant spectroscopy (HEROS) has been employed at synchrotron facilities to investigate the electronic structures of matters in fields such as chemistry and atomic physics. The advent of X-ray free electron lasers (XFELs) has led to intense femtosecond X-ray pulses, enabling the application of HEROS to matters under extreme conditions such as high energy-density or warm dense systems. Here we show that HEROS, using a self-seeded XFEL pulse and a high-resolution spectrometer at the PAL-XFEL, can be a remarkable technique for providing complete information on valence electronic structures of matters, even warm dense matters. The HEROS measurements extracted the K-edge energy and X-ray absorption spectra of Cu with only one XFEL energy, providing more detailed information than conventional X-ray absorption spectroscopy. Furthermore, the variations in the valence states of warm dense Cu were sensitively captured in the HEROS calculations based on density functional theory (DFT). These results suggest the capability of HEROS for conducting time-resolved studies of electronic dynamics in transient systems.
This work is supported by the National Research Foundation of Korea (NRF-2019R1A6B2A02100883, NRF-2019R1A2C2002864, and NRF-2020K1A3A7A09080402).

Keywords:

High energy resolution off-resonant spectroscopy (HEROS), Resonant inelastic X-ray scattering (RIXS), X-ray free electron laser (XFEL), X-ray absorption spectroscopy, Electronic structure

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P2-pl.201

Generation of Soft X-Ray Attosecond Free Electron Laser using Non-Resonant Laser Modulator

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Abstract:

X-ray free-electron laser technology with attosecond pulse duration relies on laser modulator technology using a laser and a wiggler. The resonant frequency of the laser for the modulator appears as a function of the wiggler period, the strength of the wiggler magnetic field, and the electron beam energy passing through the wiggler. Here, the laser has different wavelength and energy range characteristics depending on the type of the gain medium. Therefore, it is necessary to find the laser specifications which are close to the optimal conditions in the availability. In particular, this study investigates the qualitative and quantitative characteristics of the electron beam which interacts with the non-resonant frequency laser while they pass through the wiggler, and of the generation condition of the resulting free electron laser.

Keywords:

soft x-ray, attosecond fel, laser modulator

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P2-pl.202

Commissioning of 6.5MeV electron Beam of Microtron for Thz FEL system

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Abstract:

A microtron-based THz FEL system has been installed and is under commissioning for the beam extraction out of the microtron and the beam alignment to the beamline with a 6.5 MeV electron beam. The extracted current is increased and stabilized by adjusting the modulator voltage and the emission current of cathode. After aligning the beam extractor, the emittance measurement and the beam alignment through 90° beamline to the undulator will be done. The emittance measurement system is designed and installed in the straight section. In this paper, the results of commissioning including the emittance measurement will be presented.

Keywords:

electron beam, Microtron, Emittance

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P2-pl.203

Development of a capillary gas-cell with plasma density gradient for LWFA experiment.

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Abstract:

The laser wakefield accelerators (LWFA) are workhorse for future compact accelerator in few centimeter scale. The one of the promising application from LWFA is x-ray free electron lasers (FELs). However, to meet requirements for FELs, the generated electron beam should have lower energy jitter and energy spread. In order to control the beam energy and jitter, there are many approaches for injection methods such as colliding laser, ionization, and density gradient. The density gradient have produced a good quality electron beam using the gas jet with a shock wave from the knife edge. However, the gas-jet with shock wave has a pressure jitter due to high backing pressure. Compared to the gas-jet, the capillary gas-cell has stable gas flow and low jitter of pressure. Thus, we developed the capillary gas-cell with density gradient structure by adding modulated gas-cell. In this presentation, I will talk about characteristics of newly developed capillary gas-cell and PIC simulation results for LWFA with a gradient density.

Keywords:

capillary, LWFA, plasma density gradient

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P2-pl.204

A non-destructive energy spread detection for electron beam of XFEL with stripline-based monitor

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Abstract:

A stripline-based monitor has been proposed for use in a non-destructive monitoring system aimed at measuring the correlated energy spread of the electron beam in an X-ray free electron laser (XFEL). The energy spread within the beam leads to elongation of the transverse distribution as it passes through the dispersive section, composed of dipole magnets such as the magnetic chicane bunch compressor of the XFEL linear accelerator. This elongation of the transverse distribution is evaluated by the quadrupole moment, which is defined as the difference between the squared horizontal and vertical beam sizes.

The electron beam induces an image current on the vacuum chamber, with its density dependent on both the beam position and the transverse distribution (i.e., the quadrupole moment) at the chamber surface. Therefore, it is possible to non-destructively monitor the energy spread of the electron beam by measuring the quadrupole moment at the dispersive section using the stripline monitor.

The stripline monitor has been fabricated and implemented at the electron linear accelerator for basic science (eLABs) at PAL. It's been tested with 70 MeV electron beam to assess its feasibility for application as an energy spread monitor in the bunch compressors of PAL-XFEL, where three bunch compressors are used to generate the FEL pulse. Experimental results indicate that the stripline-based energy spread monitor is indeed applicable for the electron beam at PAL-XFEL.

Keywords:

beam position monitor, electron beam energy spread , PAL eLABs

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P2-pl.205

알라닌과 Gafchromic 필름을 이용한 가속기 시설 내 선량 평가 방법

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Abstract:

한국원자력연구원 양성자과학연구단 가속기개발연구부에서 운영 중인 100 MeV 선형가속기와 빔라인 시설 등의 운영과 관련하여 가속기 터널과 빔라인 격실 내에서 양성자빔 수송 과정에서 발생하는 방사선에 의한 누적선량 평가를 위해 알라닌을 이용한 선량평가방법의 적용 가능성에 대해 검토한 바 있다. 초기 실험 결과에서 일부 구간 방사선량의 증가가 알라닌을 이용한 ESR 선량측정법에 의해 확인됨에 따라 선형가속기 탱크와 덤프 표면, 빔라인 장치 표면. 가속기 터널 내벽과 빔라인 격실 내벽에 2종류의 알라닌과 Gafchromic film (MD-V3) 이 부착된 측정 유닛을 부착하였다. 기존의 알라닌 이외 필름을 부착한 이유는 알라닌은 누적선량값의 변화를 육안으로 관찰하기 어려운 점이 있기 때문에 색상 등의 변화로 손쉽게 관찰이 가능한 필름을 이들 유닛들은 지난 6월 2일에 부착하였으며 8월 21일에 일차적으로 수거하여 중간 결과를 점검하였다. 이번 발표에서는 현재까지의 중간 측정결과를 중심으로 발표하고 가속기 운전 중 발생한 특이사항과 선량 평가 결과와의 상관관계 파악 가능성을 검토해보고자 한다. 일부 지점에서 부착된 필름의 측정 범위를 초과한 선량값이 측정됨에 따라 더 높은 구간의 선량 측정이 가능한 필름의 추가적인 부착과 필름 종류의 선택에 대해서도 검토해보고자 한다. 또한 동일 부착 위치 내 알라닌 측정값들 사이에 유의미한 차이가 관찰됨에 따라 가속기의 운전 및 빔 수송과 관련된 원인 규명과 더불어 좀 더 세밀한 측정이 가능한 방법에 대한 검토 결과도 함께 제시하고자 한다.

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Keywords:

알라닌, 누적 방사선량, Gafchromic 필름, 가속기, 빔라인

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P2-pl.206

Round beam generation and Emittance exchange studies using difference resonance coupling with Korea-4GSR lattice

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Abstract:

In the 4th generation storage ring (4GSR), intentional coupling between horizontal and vertical motions can be employed to create a round beam. This round beam effectively mitigates the intra-beam scattering effects and enables a larger beam current compared to the flat beam case. Furthermore, the round beam offers advantages for certain X-ray beamline configurations.
On the other hand, the dynamic aperture in the 4GSR is significantly more constrained than that of the 3GSR due to stronger nonlinear effects. To address this issue, a proposed solution within the community involves an emittance exchange injection technique based on resonance coupling within the booster ring. This approach facilitates a reduction in the horizontal beam size during injection by effectively interchanging the horizontal and vertical emittances of the beam. Consequently, this process serves to enhance the injection efficiency.
We will investigate these beam manipulation schemes based on the different resonance coupling for the Korea-4GSR lattice using Accelerator Toolbox simulations.

Keywords:

4GSR, Round beam, Emittance exchange injection, difference resonance coupling

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P2-pl.207

Capacitive pick-up monitor optimization for the RAON low-energy experimental systems

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Abstract:

The Rare Isotope Accelerator Complex for ON-line Experiments (RAON) transfers both stable ion (SI) and rare isotope (RI) beams with a wide range of energy for nuclear physics research and other applications. Ion beams with energies up to a few tens of MeV/nucleon will be provided to the low-energy experimental systems: the Korea Broad Acceptance Recoil Spectrometer and Apparatus (KoBRA) and the Nuclear Data Production System (NDPS). Due to the extended beam transport line from the end of the Superconducting Linac3 (SCL3) to the KoBRA production target, longitudinal focusing is inevitable for the TOF experiments at KoBRA. Therefore, a re-bunching system was installed in the middle of the SCL3-KoBRA beam transport line. Similarly, a Half Wave Resonator, located in the middle of the SCL3-NDPS beam transport line, should be used as a re-buncher to deliver a longitudinally bunched ion beam in the NDPS target room.

To validate the operation of the re-bunchers, the bunch length should be monitored both with and without the re-bunchers at the target positions. Therefore, we developed a capacitive pick-up monitor to measure the beam shape and arrival time at the target position without disrupting the beam. After finalizing the optimized design, we proceeded with the manufacturing and testing of the capacitive pick-up monitors. The beam test and installation are scheduled to be completed by the end of 2023.

Keywords:

Capacitive pick-up monitor, RAON, Bunch length, KoBRA, NDPS

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P2-pl.208

Research for orbit correction at RAON SCL2

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Abstract:

The RAON accelerator generates various types of beams by ion sources and accelerates these beams by using superconducting RF cavities. For scientific experiments in various fields, the construction of low-energy superconducting accelerator (SCL3) section has been completed and the beam commissioning is in progress. In addition, the beam accelerated by the SCL3 section can be re-accelerated by the high-energy superconducting accelerator (SCL2) section. During the beam operation at these accelerator sections, sudden beam loss can lead to serious damage to the accelerator devices, and thus various beam physics studies have been conducted to prevent this effect. Among them, the distortion of the beam orbit due to errors of accelerator devices occurring in the SCL2 section can be a significant cause of beam loss, so research on orbit correction has been conducted. Here, we report the research results.

Keywords:

RAON accelerator, orbit correction, SCL2

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P2-pl.209

Improvement 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, we 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. However, since it takes an extremely long calculation time [1], K-Means (K-Means clustering algorithm) 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.

Keywords:

texture, image segmentation, Canny edge, K-Means clustering algorithm, K-Nearest Neighbors algorithm

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P2-pl.210

Leveraging Game Engines for Interactive Digital Twin Simulations: A Case Study with Unreal Engine and NuBDeC

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Abstract:

Digital twin technologies are increasingly essential for simulating complex systems, such as fusion devices. While game engines like Unity [1] and Unreal Engine can offer platforms for real-time interaction, integrating specialized simulation codes such as NuBDeC [2, 3] can be challenging. In this study, we incorporate NuBDeC—a C++ code for modeling fast ion motion induced by Neutral Beam Injection (NBI)—into Unreal Engine. Specifically, we adapt NuBDeC's collision detection routine for the engine and develop an interactive visualization tool to detect and analyze fast ion prompt losses that could lead to heat flux on the corresponding collision point. By utilizing Unreal Engine's C++ class structure, we implement both broad and narrow phases of collision algorithms [4]. This approach enables real-time simulation against the actual geometry of the KSTAR fusion device's wall. Our future work will focus on creating a library that can manage device-dependent and device-independent data separately, expanding the practical utility and applicability of digital twins across various fusion devices.

Acknowledgements
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Keywords:

Digital twin, Collision detection, Neutral beam injection, Fast ion, KSTAR

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P2-pl.211

아르곤 제어개스 주입에 의한 KSTAR H-mode 플라즈마에서의 열속 감소 효과의 SOLPS-ITER 전산모사

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Abstract:

국제열핵융합실험로(ITER) 및 핵융합실증로(DEMO) 등의 미래 토카막 장치에서 노심플라즈마에서 디버터 타겟으로 유입되는 막대한 입자속 및 열속을 감소시키는 것은 안정적인 운전 달성에 매우 중요한 과제이다. 이를 위해 질소나 네온 등 불순물 제어개스 주입법이 매우 효과적인 방법으로 전세계적으로 활발히 연구되고 있다. 본 연구에서는 아르곤 제어개스를 주입하여 디버터로 향하는 열속과 입자속을 대폭 감소시키고 디버터-플라즈마 분리를 획득한 최근의 KSTAR 실험결과를 SOLPS-ITER 코드를 이용한 전산모사를 통해 비교 분석하였다. 전산모사를 통해, 주입되는 중수소 연료 개스 및 아르곤 제어개스의 주입량이 각각 일 때 외측 디버터로 향하는 열속이 0.02 MW/m^2의 매우 낮은 수준으로 감소하는 결과를 얻었으며, 이 결과는 외측 타겟에서 볼로미터 진단결과와 일치함을 확인하였다. 입자속은 아르곤을 주입하지 않은 계산과 비교하여 약 1/2 수준으로 감소하였으며, 이는 실험의 랑뮤어 탐침 진단 결과에서 아르곤 주입을 통해 나타나는 입자속 감소율과 유사하다. 또한, 아르곤의 선방출광이 에너지 손실의 상당부분을 차지하는 것을 확인하였다. 아르곤이 주입되지 않은 플라즈마의 전산모사 결과와의 비교를 통해 디버터 타겟 근처에서의 이온-전자 재결합 빈도의 증가 및 전자 온도의 상당한 감소를 확인하는 등 실험 결과와 정성적으로 일치하는 결과를 얻었다.

Keywords:

SOLPS-ITER, Divertor, Argon, Detachment

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P2-pl.212

텅스텐 디버터 식각률 측정을 위한 다중 선스펙트럼 기반 S/XB 진단법 개발

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Abstract:

텅스텐은 디버터 대면재로서 여러 토카막 장치들에서 사용되고 있다. 플라즈마에 의해 식각된 텅스텐 입자가 역으로 토카막 플라즈마에 유입되면 강한 방사손실을 일으키므로, 텅스텐의 식각률 측정은 코어 플라즈마의 성능 저하 예측에 있어 중요하다. 다양한 텅스텐 진단법 중에서 분광진단 기반의 S/XB 방법은 실시간으로 텅스텐 유입량 측정이 가능하다는 장점이 있다. S, X, B는 각각 이온화 계수와 Excitation 계수, Branching ratio를 나타낸다. 코로나 평형 모델을 통해 이론적으로 구한 S/XB 값에 특정 선스펙트럼의 세기를 곱하면 식각된 텅스텐의 유입량을 계산할 수 있다. 여기서 S/XB 값은 중성 텅스텐 입자의 준안정 상태 밀도가 볼츠만 분포를 따른다고 가정하는데, 자유 매개변수로 텅스텐 원자의 온도가 도입되어 이로 인해 모호성이 존재한다. 이를 해결하기 위해 본 연구에서는 6개의 선스펙트럼을 이용하여 텅스텐 원자의 온도에 의한 모호성을 해소하는 S/XB 진단방법을 제시하였다. 이 방법은 코로나 평형 모델을 기반으로 다중 선스펙트럼의 세기를 조합하여 준안정 상태의 밀도를 계산하는 방식으로 텅스텐의 식각률을 구한다. 이 방법의 유효성을 검증하기 위해 KAERI 플라즈마 빔 조사장치를 이용하여 텅스텐 샘플에 아르곤 이온빔을 조사하였으며, 본 연구에서 제시한 분광진단을 통해 얻은 텅스텐 식각률과 아르곤 이온 Flux 및 Sputtering yield를 사용하여 얻은 결과를 비교하였다. 연구의 결과, 방전전류 150 A, 아르곤 이온 입사에너지 80 eV에서 5.54×10^{20} $m^{-2}s^{-1}$의 텅스텐 식각률을 얻었으며, 20% 이내의 오차로 측정되었다. 또한, 준안정 상태의 밀도를 직접 계산하여 기존의 S/XB 방법에서 이론적 가정에 의한 모호성 문제를 해결하였다.

Keywords:

S/XB method, Tungsten Divertor, Sputtering Rate, Spectroscopic Diagnostics, Corona Model

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P2-pl.213

Optimization of a Slotted Waveguide Antenna to Launch Lower Hybrid Fast Wave in KSTAR Plasmas

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Abstract:

A waveguide antenna with $n_{\parallel}$0~2.8 at 2.45 GHz has been designed for the lower hybrid fast wave (LHFW) experiments in KSTAR plasmas. The designed antenna consists of corrugated walls inside a rectangular waveguide to reduce guided wavelength and an open waveguide upper wall that radiates the Ey field into plasmas. However, the large opening area of the antenna excites considerable slow waves due to Ez field formed between the corrugated walls. The upper wall with the large opening area is modified with a small slot array to suppress the radiation of the Ez field. A slot length is selected for resonant radiation in an air medium. Slot spacing is determined to launch the fast waves with a π/2 phase difference. The length of each slot is adjusted for a uniform radiation power profile to maintain the $n_{\parallel}$ spectrum from the first slot to the last slot. S-parameters and spatial field profiles of the designed slotted waveguide antenna are measured using a network analyzer. After comparing the simulation results with the experimental results, 10 kW power injection test is planned.

Keywords:

Lower Hybrid Fast Wave (LHFW), Slotted Waveguide Antenna, KSTAR

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P2-pl.214

크립톤 개스 주입에 의한 KSTAR 플라즈마 열속 감소의 SOLPS-ITER 전산모사

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Abstract:

KSTAR를 포함한 여러 토카막 장치에서는 질소, 네온 등 제어개스를 주입하여 디버터 영역에 방사 파워를 증가시켜 디버터 타겟으로 전달되는 열속과 입자속 감소를 달성하고 이를 분석하는 연구가 활발히 연구되고 있다. 최근 KSTAR에서는 제어개스로 크립톤을 주입하여 디버터 열속을 감소시킨 중요한 실험결과를 획득하였다. 본 연구에서는 경계 플라즈마 수송 코드인 SOLPS-ITER를 이용하여 크립톤 주입 실험결과와 전산모사 결과간의 비교 분석을 수행함으로써 열속 감소에 기여하는 기작에 대한 분석을 진행하고 있다. 전산모사 조건은 실제 KSTAR 실험과 동일하게 설정하였고, 크립톤 주입량에 따른 입자속, 열속 등의 물리량을 실험결과와 비교하였다. 그 결과, SOL 영역에서의 전자 밀도, 온도 및 디버터 타겟의 입자속, 열속 등 주요 플라즈마 변수들이 정량적으로 일치하는 것을 확인하였다. 또한, 실험 내 전자 밀도 및 온도 재현 과정에서 SOL 영역의 전자의 확산계수 및 열전도율 분포를 확보하였다. 이미징 볼로미터 진단계로 획득한 방사파워를 전산모사와 비교한 결과, 열속 감소에 따른 방사파워 변화에 대해 정성적 일치를 확인하였다. 실험과 전산모사 간의 정량적 차이를 해결하기 위해 불순물의 영향으로 SOL 영역에 인가되는 가열 파워의 값이 불순물이 존재하지 않는 실험과 차이가 존재할 수 있어 이에 대한 분석이 진행 중이다.

Keywords:

SOLPS-ITER, Krypton, heat flux reduction, particle flux reduction

SOLPS-ITER 전산모사를 활용한 KSTAR 플라즈마내 중수소 개스 주입 및 플라즈마 드리프트 영향 분석

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Abstract:

미래 핵융합 장치에서 디버터 타겟으로 입사하는 입자속 및 열속이 크게 감소된 상태를 일컫는 디버터-플라즈마 분리 운전은 플라즈마 대면재 보호를 위해 필수적인 것으로 인식되고 있다. 이러한 디버터 운전을 예측하고 이해하기 위해 SOLPS-ITER와 같은 경계 플라즈마 수송 코드를 사용한 전산모사 연구가 전세계적으로 활발히 수행되고 있다. 전산모사 결과의 신뢰도 확보를 위해서는 이러한 코드에 사용되는 물리적 모델을 검증하는 것이 필수적이며, 이를 위한 방법 중 하나가 현존하는 토카막 장치에서 얻은 실험 데이터와 전산모사 결과를 비교하는 것이다. 본 연구에서는 SOLPS-ITER 전산모사를 통해 중수소 연료개스를 주입한 KSTAR 실험 데이터와 비교한 결과를 제시한다. 자기장 수직방향의 수송계수를 실험의 전자 온도 및 밀도 분포를 바탕으로 조정하였을 때, 디버터 분리가 일어나기 전인 attached regime의 디버터 타겟 입자속 및 열속에 대하여 정량적 수준의 일치를 얻었다. KSTAR L-mode 플라즈마에서 관찰된 것과 동일하게, KSTAR의 독특한 내/외측 디버터 분리 비대칭성 또한 전산모사를 통해 성공적으로 재현하였다. 방사파워 분포 등 실험과 전산모사 간 정량적 차이를 해결하기 위해 입력변수를 바꾸어가며 전산모사가 진행 중이다. 이와 더불어, 플라즈마 드리프트를 포함한 전산모사를 수행하여 드리프트가 경계 플라즈마 및 전산모사를 통한 실험 재현에 미치는 영향에 대해 분석하였다. 드리프트가 포함된 경우, 포함되지 않은 경우와 비교하여 디버터 영역의 전자 온도 및 밀도 분포가 변화하였으나, 내/외측 디버터 분리 비대칭성에는 변화가 없는 것으로 나타났다.

Keywords:

SOLPS-ITER, KSTAR, D2 gas injection, Plasma drifts, Divertor detachment

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Gaussian process tomography 방법을 이용한 토카막 내 불순물 수송계수 획득 알고리즘 개발 및 GUI 적용

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Abstract:

토카막 노심 플라즈마 내로 침투한 불순물이 특정 영역에 과도하게 축적될 경우 방사광 방출에 의해 플라즈마 감금성능 저하 및 심할 경우 플라즈마 붕괴 등 여러 부정적 현상이 일어날 수 있기 때문에 불순물의 수송현상을 분석하는 것은 토카막 장치의 안정적 운전을 위해 매우 중요한 문제이다. 본 연구팀에서는 플라즈마 내 불순물 수송 연구를 위해 불순물 수송해석 시뮬레이션 코드(KIM)를 개발해왔으며 최근 이를 GUI화 하였다. 플라즈마 진단 결과를 바탕으로 불순물 수송계수를 찾아내는 기존의 알고리즘은 계산시간이 오래 걸리는 단점이 있다. 이를 극복하기 위해 본 연구에서는 Gaussian process tomography (GPT) 방법을 사용하여 불순물 수송계수 분포를 찾아내는 알고리즘을 개발하였으며, 팬텀 테스트를 통해 정확도를 검증하고 계산시간을 비교하였다. 개발된 알고리즘은 불순물 밀도의 연속방정식을 유한차분법을 사용하여 불순물 수송계수에 대한 식으로 변화시켜, 측정된 불순물의 밀도 분포 변화와 방정식으로 계산된 밀도 분포 변화의 차이를 최소화하는 수송계수의 1차원 분포를 GPT 방법을 사용하여 획득한다. KSTAR 및 JET 장치에서 얻어진 수송계수 분포를 이용하여 팬텀 테스트를 진행한 결과, 개발된 알고리즘은 4개의 테스트에 대해 1% 미만의 root-mean-square error를 가지는 것을 확인하여 알고리즘의 정확도를 검증하였다. 또한 이 알고리즘을 이용한 계산시간은 100 ms 이내로 빠른 불순물 수송해석에 사용될 수 있음을 확인하였다. 개발된 알고리즘은 KIM 코드에 결합되어 GUI화 하였으며, KSTAR 내의 불순물을 해석하는데 큰 도움이 될 것으로 기대된다.

Keywords:

Gaussian process, 불순물 수송계수, GUI

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Bayesian Neural Network for predicting disruption using 0D parameters and 1D profiles in KSTAR

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Abstract:

Disruption phenomenon, which is induced by various instabilities, is one of the important issues in tokamak plasmas since it causes harmful damage to tokamak devices. Thus, predicting disruption in advance to maintain stability is of the highest priority for future fusion reactors. There are several ways to predict disruptions including DECAF, which is a physics-based disruption predictor. In addition, data-driven approach has been suggested and showed outstanding results for predicting disruptions using multiple modalities of data. However, general neural networks based on a frequentist framework show lack of the ability to estimate the uncertainty associated with its output, leading to overconfidence of their prediction. Therefore, Bayesian framework is needed for the treatment of uncertainties. In this research, we make use of Bayesian Neural Networks for covering the uncertainty and attempt to reduce the false alarms for disruption prediction. We utilize several diagnostic data and 1D profiles data to enhance the model capabilities and analyze it by using explainable AI techniques. Furthermore, to cover the imbalanced data distribution induced by small time scale of disruptions compared to the operation time, we apply modified loss functions including Focal Loss and LDAM Loss during the training process. Consequently, we demonstrate the effectiveness of our approach for predicting disruptions based on KSTAR experiment data.

Keywords:

Disruption, Bayesian neural network, Explainable AI

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Formation of amorphous Ga_2O_3 thin films on metal substrates by MOCVD and characteristics of diodes

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Abstract:

Ga_2O_3는 4.7~4.9 eV의 넓은 밴드갭과 8.0MV/cm의 높은 항복 전압을 가지며, Baliga's figure of merit(BFOM)는 3571로 GaN나 SiC보다 훨씬 높아 차세대 초고전압 전력반도체에 사용될 것으로 기대된다. 현재 Ga_2O_3 결정의 호모 에피택시(homoepitaxy)로 소자를 제작할 수 있지만 기판에 존재하는 높은 결함과 낮은 열전도율로 인해 소자 성능 향상에 한계가 있다[1-2]. 따라서 다양한 종류의 기판을 이용한 이종접합(heterojunction) 박막을 사용하여 단점을 극복하고 고성능 소자를 제작하기 위한 많은 연구가 진행되고 있다. 그러나 다양한 기판 중에서 금속 기판에 대한 연구 결과는 거의 없다. 금속 기판을 사용하면 열전도성 문제를 해결할 수 있을 뿐만 아니라 다양한 유형의 장치 응용 프로그램을 제공할 수 있다. 따라서 금속 기판을 이용한 Ga_2O_3 이종접합 박막의 성장에 관한 연구는 매우 중요하다.
Ga_2O_3 박막은 금속 유기 화학기상증착법(MOCVD)을 사용하여 Ti과 Ni 기판 위에 성장하였다. TMGa(trimethylgallium)와 H2O는 Ga 및 O 공급원으로 사용되었고, 초고순도 질소(6N) 가스는 H_2O 버블링 시스템 및 TMGa의 캐리어 가스로 사용되었다. 성장온도는 고온에서 금속 기판이 거칠어지는 것이 확인되어 450~650℃ 범위에서 50℃씩 온도를 변화해 주며 증착하였다. 성장 후 성장온도별로 Ga_2O_3의 성장을 확인하기 위해 X-선 회절분석(X-ray diffraction, XRD)을 통해 분석한 결과 성장온도가 550℃ 이하에서는 비정질로 형태로 관찰되었고, 600℃ 이상에서는 ε과 β의 혼합상이 관찰되었다. 주사전자현미경(FE-SEM)을 사용하여 표면 형상을 관찰한 결과 500℃에서 성장한 샘플이 가장 평탄한 표면이 확인되었고, 500℃보다 성장온도가 증가할수록 표면이 거칠어졌다. 표면 분석 후 전기적 특성을 확인하기 위해 e-beam evaporator를 사용하여 Ga_2O_3 박막에 위에 금속 전극을 형성하여 수직 쇼트키 다이오드를 제작하였으며, 제작된 다이오드의 전류-전압(I-V) 및 커패시턴스-전압(C-V) 특성을 평가하였다. I-V 측정 결과, 대부분의 다이오드 소자에서 매우 높은 동작 전압을 나타냈으며, 비교적 균일한 표면을 갖는 500℃에서 성장한 샘플은 가장 낮은 동작 전압을 가짐을 확인할 수 있었다.

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Keywords:

MOCVD, Ga2O3, Amorphous, Metal Substrate

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온도에 따른 ITO 박막의 물성변화 연구

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Abstract:

주석이 첨가된 인듐 산화물(Indium tin oxide; ITO)은 인듐, 주석 그리고 산소의 다양한 비율의 삼원 조성물로써, 높은 가시광 영역대 투과율(>80 %)과 낮은 비저항(~10^{-4} Ω·cm)을 갖는 *n*-형 산화 반도체이다. 위와 같은 특성으로 유기 발광 다이오드(OLED) 및 태양전지, 박막 트랜지스터, 터치패널 스크린, 스마트 창호 등과 같은 다양한 광전자 산업 분야에서 많이 활용된다. 또한, 최근에는 극한 환경에서의 필요한 전극의 활용가능성 및 응용도 중요시되고 있다 [1].
본 연구에서는 비정질 ITO 박막의 온도변화에 따른 전기 및 구조, 광학, 화학적 특징의 변화를 조사하였다. 진공상태에서 온도가 올라감에 따라, 비정질 ITO는 전기적 저항이 급격히 증가하고, 온도가 더 증가하면서 저항이 다시 감소하는 것을 확인하였다. In-situ X-선 회절 분석 결과, 저항 피크는 비정질 ITO 박막의 다결정화 과정과 연관이 있는 것을 확인하였다. 또한, 광학적 분광 분석으로 통해서 다결정화 되는 온도에서 광학적 밴드갭이 급격히 늘어나는 것을 관찰하였고, 이는 전자 농도의 증가와 관련 있는 것을 알 수 있었다. X-선 광전자 분광 분석을 통해 비정질 ITO 박막의 전자농도 증가가 산소결함이 아닌, Sn^{2+}와 Sn^{4+}의 상대적 조성비 변화와 관련 있는 것을 확인하였다.
[1] Kim et al., Sci. Rep, **10**, 12486 (2020)

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후속 열처리 공정에 의한 상 변이 메커니즘을 이용한 고품질 Ga_2O_3 박막의 형성 및 전기적 전도성 제어

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Abstract:

β-Ga_2O_3는 4.9 eV에 달하는 넓은 밴드갭을 가지고 있으며, n-type doping을 통한 전기적 전도성 제어가 가능하고, 열적, 화학적으로도 매우 안정하여 다양한 활용이 기대되는 물질이다. 또한, 현재 전력반도체로 주목받고 있는 GaN와 SiC보다 높은 항복 전압 특성을 가지고 있어 차세대 초고전력반도체 재료로 응용될 것으로 기대된다. Ga_2O_3 결정은 벌크 기판이 존재하여 호모 에피탁시 결정 성장이 가능하지만, 다양한 종류의 소자 제작을 위해서는 헤테로 에피탁시에 의한 결정 성장에 대한 기반 기술 축적이 중요하다고 할 수 있다. 그렇지만 β-Ga_2O_3는 헤테로 성장에 의한 박막 형성 시 기판들과의 정합성이 좋지 않고, 결함이 많아 고품질(특히 표면이 매우 평평한)의 박막 성장이 쉽지 않다는 단점을 가지고 있다. 반면, 비정질 Ga_2O_3 박막은 기판의 영향을 크게 받지 않아서 평탄도가 우수한 박막을 얻을 수가 있고, 열처리 후에도 박막의 평탄성을 그대로 유지할 수 있는 특징을 가진다. 본 연구에서는 비정질 Ga_2O_3 박막의 우수한 평탄도를 유지하는 동시에, 열처리에 의해 ε-Ga_2O_3 및 β-Ga_2O_3 박막상으로 변환시킨 Ga_2O_3 박막의 구조적 및 전기적 특성 변화에 대해 조사하였다. 비정질의 Ga_2O_3 박막들은 유기금속 화학기상 증착법(metal organic chemical vapor deposition, MOCVD)를 이용하여 n-Si 기판 위에 Ga_2O_3를 저온(500°C)에서 30분간 증착하였다. 저온 증착이 완성된 비정질의 Ga_2O_3 박막들은 후속 열처리 과정을 통하여 박막들의 결정상을 변화시켰다. 열처리는 650°C와 800°C에서 30분 수행하였으며, 열처리 분위기 가스로는 N_2와 O_2를 각각 사용하였다. 열처리 과정이 완성된 시료의 n-Si 기판 면은 Al(100nm)을 증착하고, 박막 표면에는 Ti/Au(50nm/50nm)을 증착한 후 열처리(500°C, 5min)를 통하여 금속 전극 구조를 형성하였다. 열처리 후의 박막 결정상들의 구조적 특징은 FE-SEM 및 XRD 분석을 통하여 평가되었다. 열처리 조건에 따라서 결정 구조가 비정질에서 ε-Ga_2O_3 결정상을 거쳐 β-Ga_2O_3 결정상으로 변화하는 것을 확인할 수 있었다. 결정상들의 변화에도 불구하고 박막들의 표면 거칠기에는 거의 변화가 없었다. 열처리 온도가 증가하면서 박막들의 전기적 전도성은 감소하는 것을 확인하였으며, 그에 따라서 박막들의 커패시턴스 특성도 변화하는 것을 관찰할 수 있었다. Ga_2O_3 박막들의 열처리에 의한 기판과 박막 간의 계면 결함 혹은 박막 내의 캐리어 밀도 변화 등에 대한 평가 등에 대해서는 추후 논의할 예정이다. 지금까지의 결과들을 통해서 비정질 박막을 열처리에 의해 결정상을 변화시키는 공정은 다양한 종류의 소자 제작에 있어서 매우 효과적인 방법이라고 판단된다.

이 연구는 2023년도 정부(산업통상자원부)의 재원으로 한국산업기술진흥원의 지원을 받아 수행된 연구입니다.(RS-2022-00154720, 2023년 Si-on-SiC 구조 기반 차세대 전력반도체 개발 기술 혁신 프로그램).

Keywords:

MOCVD, Ga2O3, n-Si, CTLM

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P2-se.004

산소분압의 변화에 따른 스퍼터 증착법으로 제작된 Ga_2O_3 박막의 특성 변화

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Abstract:

사파이어 기판에 RF 마그네트론 스퍼터 증착법으로 도핑되지 않은 Ga_2O_3 타켓을 사용하여 아르곤에 대한 산소 유량의 비율 변화에 따른 Ga_2O_3 박막의 물성 변화를 조사하였다. 제작된 박막의 결정성은 XRD 패턴으로 변화를 조사하였고, 박막의 광학적 밴드갭은 흡광도를 통하여 계산하였다. 상온에서 제작된 Ga_2O_3박막들은 XRD 분석에서 비정질 박막 특성을 보였고, 1000 ℃ 열처리한 후에는 산소분압에 따라 전반적으로 β-Ga_2O_3 다결정 박막이 되었다. Ga_2O_3박막의 증착률은 산소분압의 증가에 따라 감소하였고, Ga_2O_3의 광학적 밴드갭은 산소분압 변화에 따라 4.78 eV에서 4.97 eV까지 변화를 보였다. 표면거칠기의 제곱평균제곱근은 1.33 nm에서5.74 nm까지 측정되었다.

Keywords:

Ga2O3, RF sputter, O2 partial pressure

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P2-se.005

Tailored Core-Shell Synthesis and Slurry Formulation for Enhanced Scratch-Free Copper CMP

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Abstract:

In the context of Cu chemical-mechanical-planarization(CMP), as device scaling-down accelerates, the demand for scratch-free CMP processes has grown. To address this, there is a heightened requirement for reducing the size of colloidal silica abrasives in Cu-CMP slurries. However, diminishing the size of colloidal silica abrasives often leads to a rapid decrease in polishing rate, presenting a challenge. To overcome this issue, the development of a novel abrasive-based slurry utilizing a hybrid organic core and inorganic shell (silica) abrasive is essential.
Upon introducing NH4OH to the negatively charged polystyrene core, leading to a shift to a positively charged surface, followed by the addition of negatively charged tetraethyl orthosilicate (TEOS) for silica growth, the formation of a raspberry-shaped shell was observed. This calls for the active utilization of various techniques including reactor agitation control, uniform pH maintenance, temperature distribution management, and inert atmosphere control to optimize the sequence and elucidate the mechanism. Moreover, the mass ratio of silica shell synthesis is employed to achieve fine-tuned control over the shell thickness within the range of 10 to 80 nm. Following the optimized synthesis sequence, the synthesis of 300-nm polystyrene core / silica shell abrasives was executed. Subsequently, the slurry design involved the introduction of an accelerator agent chemical for ferric catalyst binding and a Cu / SiO_2 selectivity chemical using Zwitterion. Dispersion stability assessment revealed a negative charge with a zeta-potential exceeding -60 mV and a secondary abrasive size ranging from 500 to 600 nm. Evaluation of the slurry on a 12-inch wafer exhibited a remarkable selectivity ratio of 53:1 between Cu-film and SiO_2-film, and even at a pressure of 3.5 psi, it demonstrated minimal scratching, with fewer than 10 scratches.

Acknowledgement
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Keywords:

Chemical-Mechanical-Planarization, Cu-film CMP, Hybrid organic core / inorganic shell abrasive, Silica shell synthesis

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P2-se.006

Reversible multi-mode switching behavior for VO2 mott memristor

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Abstract:

To realize the potential of memory-centric parallel com┐puting architectures and neuromorphic electronics, it's essential to have numerous building components with a range of switching capabilities. To mitigate the device complexity, the implementation of multiple switching modes that rely on a single active material in a straight forward device form is necessary. We've successfully demonstrated this approach through a Mott memristor with multi-switching modes, which features a vanadium dioxide switching layer. The nature of the multi-switching modes- volatile and nonvolatile - is contingent on the voltage polarity applied to the electrode. The operation of the device is governed by the Mott transition within the switching layer and modulated by oxygen vacancy.

Keywords:

mott transition, insulator-to-metal transition, memristor, neuromorphic computing

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P2-se.007

Lowering dielectric constant of ferroelectric HZO film with ultra-thin Al_2O_3 intermediate layer

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Abstract:

HfO_2-based ferroelectric thin films have been one of the most active research topics in the semiconductor device field recently. However, the metal-ferroelectric-insulator-semiconductor (MFIS) structure used as a gate stack has an inevitable limitation of significant voltage drop across the insulator layer. It comes from the fairly large difference in dielectric constant between ferroelectric and insulator layers. In this study, we suggest that the dielectric constant of $Hf_{0.5}Zr_{0.5}O_2$ (HZO) ferroelectric film can be reduced sufficiently while maintaining its ferroelectricity. An ultra-thin Al_2O_3 layer is inserted inside the HZO film to make HZO/Al_2O_3/HZO trilayer structure during atomic layer deposition process. In conjunction with TiN electrodes deposited in the Ar-rich environment during the reactive magnetron sputtering process, the trilayer structure is found to have an effective dielectric constant of ~18 without deteriorating its ferroelectricity. This effective dielectric constant is ~37% smaller than the dielectric constant of normal ferroelectric HZO layer and is even smaller than the value calculated theoretically by considering the series connection of the trilayer. Our work can provide a practical guide for reducing the switching voltage and increasing the stability of ferroelectric polarization in the devices adopting the MFIS structure.

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Keywords:

Hafnium Zirconium Oxide, Ferroelectric thin film, MFIS stack, Effective dielectric constant

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Investigating the Effect of Metal Ion Doping on the Performance of ZnO-based RRAM Memory Devices

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Abstract:

In the advancement of the semiconductor device technology, ZnO could be a prospective alternative than the other metal oxides for its versatility and huge applications in different aspects. Resistive random access memory (RRAM) has a simple metal/insulator/metal structure and operates more than 100 times faster than flash memory, making it the next-generation memory, but it is difficult to secure stable memory characteristics, so many researchers are working on improving reliability. For RRAM devices that are switched between low and high resistance states, research is being conducted in the direction of inducing conductive filaments to form at the same location during switching, such as ZnO layer with different structures, switching path formation, and switching area limitation methods.

In this study, a metal ion beam irradiation facility at Korea multi-purpose accelerator complex (KOMAC) was used to fabricate a ZnO-based RRAM devices with stable characteristics by inducing the generation of conductive filaments in ZnO thin films. The Ni^+ and Co^+ ions with difference energies was irradiated to ZnO thin films, respectively. The energies of 20 keV and 40 keV can be injected into the surface and center of the ZnO thin film, respectively, according to the SRIM simulation results. The irradiation dose was the same as 1×10^{14} #/cm^2. The memory characteristics of the fabricated RRAM devices were compared and the physical properties of the active layer were analyzed by XPS, SEM, PL, etc. In this presentation, the details experimental results on the metal ion beam irradiation effect of ZnO-based RRAM devices will be presented.

Keywords:

ZnO RRAM, Conductive filament formation, next-generation memory devices, Metal Ion Beam Irradiation

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P2-se.009

Enhancing surface plasmons at visible to near-infrared wavelengths by ITO nanoparticles in light pressure for piezoelectric energy harvesting

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Abstract:

We utilized the localized surface plasmon resonance (LSPR) phenomenon that occurred on the metal surface to fabricate energy harvesting devices using light pressure. The design of the device is motivated by the need to drastically increase the power output of existing piezoelectric devices based on surface plasmon (SP) resonance. In the near-infrared (NIR) and visible light regions, the SP excited from the ITO/Ag bilayer structure can generate electrical energy by enhancing the solar radiation pressure. The light pressure electric generator (LPEG) with the ITO layer generates an open-circuit voltage of 295 mV, a short-circuit current of 3.78 μA, and a power of 532.3 $\mu W/cm^2$ under a solar simulator. The effect of the ITO layer on LPEG's electrical output was analyzed by measuring its outputs to visible and NIR light using an optical filter. FDTD simulations also confirmed the ITO/Ag bilayer's role in enhancing incident light pressure.

Keywords:

Light pressure, Surface plasmon, ITO, Piezoelectric device, FDTD simulation

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P2-se.010

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.

Keywords:

1D/2D heterostructure, molecular configuration engineering , molecule/2D hetero selector , hetero band engineering

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P2-se.011

높은 광반응 및 넓은 광대역의 그래핀/WS_2/다공성 실리콘 이종접합 광검출소자

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Abstract:

다공성 실리콘은 벌크 실리콘에 비해 광흡수와 광반응도가 우수하여 높은 투과도와 전기전도도를 가진 그래핀과 이종접합을 통하여 광전자 소자 분야에 많이 응용되고 있다. 하지만 그래핀과 다공성 실리콘 계면의 밴드 엇갈림으로 인하여 광전자 소자의 성능에 한계가 있다. 본 연구에서는 그래핀과 다공성 실리콘 사이에 중간층으로 2차원 물질인 WS_2를 삽입하여 그래핀/WS_2/다공성 실리콘 이종접합 광검출소자를 제작하였다. WS_2는 큰 에너지 갭을 가지고 있어 그래핀과 다공성 실리콘 계면의 밴드 엇갈림을 완화시키고 전자와 정공을 잘 분리시키게 한다. 이러한 메커니즘을 통하여 광검출소자의 성능 지수인 광반응도, 양자효율, 검출능, 및 시간분해 광전류의 상승/감쇠 시간이 각각 최대 0.46 AW^{-1}, 88 %, 6.9 x 10^9cm $Hz^{1/2}W^{-1}$, 및 2.46/1.16 μs로 나타내었다. 또한, 벌크 실리콘을 사용한 광검출 소자에 비해 가시광선 영역에서 광반응이 더 빠르고 광대역은 더 넓은 특성을 보였다. 600 nm 파장에서 2000 시간 동안 측정하였을 때, 초기 광반응도 대비 약 80 % 이상의 성능이 유지되어 소자의 장기안정성이 우수함을 보였다. 본 발표에서는 위의 실험 결과들을 토대로 그래핀/WS_2/다공성 실리콘 이종접합 광검출소자의 성능 향상에 대한 메커니즘에 대해서 논의하고자 한다.

Keywords:

그래핀, WS2, 다공성 실리콘, 이종접합, 광검출소자

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P2-se.012

Above-Room Temperature 2D Ferromagnet Fe3GaTe2

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Abstract:

Recently, novel phenomena observed on the 2D van der Waals (vdW) magnets draw significant attention of various studies for their physical properties and nanometer-scale devices. 2D vdW magnets showed the breakdown of the Wagner-Mermin theorem, which enabled the layer-by-layer magnetic manipulation and heterostructures with atomically clear interfaces, arousing the expectation to the promising platform of next generation devices. However, relatively low critical temperature of several novel 2D magnets such as Fe_3GeTe_2 and CrI_3 has been an obstacle for their practical applications. Even though Fe_xGeTe_2 (x=4,5) with excess Fe atoms and $CrTe_2$ exhibits above-room temperature magnetic ordering, those novel materials have limitation of low anisotropy or incompatibility with ambient condition.

In this work, we report the successful synthesis of stable, high-quality ferromagnet Fe_3GaTe_2 single crystal. Our SQUID-VSM measurements confirmed the above room-temperature Curie temperature (~370 K) with high perpendicular magnetic anisotropy, which shows the promising future for the spin polarizing layer for further device applications. With those highly promising intrinsic properties, our study paves the way to the actual application of vdW magnets to highly energy efficient spintronic devices.

Keywords:

Low-dimensional materials, Ferromagnetism, Anomalous Hall Effect

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P2-se.013

A Modified Wet Transfer Method for Eliminating Interfacial Impurities in Graphene

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Abstract:

Graphene, renowned for its remarkable electrical properties, holds immense potential for electronic applications. However, conventional wet transfer methods utilizing FeCl3 as a copper etchant often introduce impurities, thereby diminishing graphene's electrical performance.
In response, we present a modified wet transfer method that employs a UV-treated SiO2 substrate for pre-absorbing impurities from graphene before the final transfer. Utilizing optical microscopy and Raman mapping, we confirm the effective removal of impurities, resulting in a pristine graphene-substrate interface.
Electrical characterization, employing the transmission line model (TLM) and Hall effect measurements (HEMs), demonstrates that our modified wet transfer method outperforms conventional approaches. Specifically, it significantly reduces electron-hole asymmetry and sheet resistance when compared to traditional techniques. Our method represents a promising advancement for achieving high-quality graphene suitable for electronic applications, offering an improvement over conventional wet transfer processes.

Keywords:

graphene transfer, FeCl3, interfacial impurity, clean interface, janus interface

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P2-se.014

Considerable Contact Resistance Effects on Vertical Carrier Density Profile within WSe_2 Multilayers

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Abstract:

Conducting channel migration depending on the thickness of 2D multilayers has been demonstrated theoretically and experimentally by ascribing it to the high interlayer barrier and the thickness-dependent carrier mobility via electrostatic gate and drain bias. However, when a high contact resistance exhibits at the metal-to-2D semiconducting multilayers with the inherent tunneling barrier between the vertically neighboring layers, the distinctive charge carrier transport feature is significantly suppressed. Herein, we report strong channel access contact resistance effects on the vertical carrier density profile along the thickness in WSe_2 multilayer transistors. For the constructed top electrodes demonstrating a pseudo ohmic behavior, we observed clear double humps in the second derivative of transconductance (dg_m) curves, implying conducting channel migration along the *c*-axis of WSe_2 multilayers indifferent to drain bias (V_D) conditions. Meanwhile, at the bottom electrodes demonstrating a relatively high contact resistance effect, the second hump of dg_m exclusively appears at high V_D regimes ($3.0 \text{ V} \leq V_D$), signaling the restricted channel migration caused by poor contact quality, even in the identical WSe_2 multilayers. We additionally confirmed this distinct feature in dg_m curves by connecting the bottom- and top-electrodes together to support our observation. Furthermore, low-frequency noise measurements were employed to determine the surface trap density of supporting dielectrics and the relevant carrier scattering mechanism. Our study provides valuable insights into the effects of contact resistance on carrier transport in WSe_2 multilayer transistors, showing the way on the optimization of device performance and contact quality.

Keywords:

multilayers, contact resistance, vertical carrier density profile, carrier transport, low-frequency noise analysis

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Synthesis of Au nanoparticles supported ITO and its application to electrochemical sensor

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Abstract:

수질 환경 모니터링에 다양한 센서가 필요하다. 특히 수중 유해위험물질 검출을 위한 센서의 감도를 향상시키기 위한 연구의 필요성이 증가하고 있다. 나노입자-나노입자 흡착은 나노입자를 이용한 다양한 분야에서 응용될 수 있는 중요한 기술이다.
본 연구에서는 용액을 이용하여 Au 나노입자를 합성하고, 이를 Indium Tin Oxide (ITO) 나노입자에 부착시키는 방법으로 Au-ITO 나노입자를 합성하고, 이를 이용하여 필름을 제작하였다. 센서 제작은 Au-ITO film 양단에는 Ag 전극을 인쇄하여 제작하고, 제작한 센서에 35μl의 분석물 (DI water 중 10~400 ppm 정도로 희석된 유해위험물질)을 떨어뜨려 센서의 동작을 확인하였다. ITO film과 다양한 조건에서 합성한 Au-ITO film를 이용한 센서의 응답의 크기, 민감도, 응답시간을 비교하였다.

본 연구는 2023년도 해양수산부 재원으로 해양수산과학기술진흥원의 지원을 받아 수행된 연구이다 (20210660, 해양 위험유해물질(HNS) 배출 등 관리기술 개발사업, 해양산업시설 배출 위험유해물질 영향평가 및 관리기술 개발).

Keywords:

나노입자, ITO film, Au-ITO film

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A Study on the Fabrication of Capacitive Sensor Using Indium-Tin-Oxide (ITO) film for the Detection of Hazardous and Noxious Substances

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Abstract:

수질 환경 모니터링에 사용하기 위한 수중 유해위험물질 검출을 위한 센서의 필요성이 증가하고 있다. 현재 광학식, 전기화학식, 저항형 등의 센서들이 존재하지만, 기존 센서의 한계점을 보완할 수 있는 새로운 센서의 개발이 필요하다.

본 연구에서는 ITO 투명전도막을 이용한 정전용량형 수중 유해위험물질 검출센서를 제안하였다. 정전용량 센서는 의료, 로봇공학, 전자기기 등 다양한 분야에서 응용되고 있는 중요한 기술이다. 수중에서 안정적인 금속산화물 투명전도막을 이용한 정전용량 센서는 고감도, 고해상도, 비용 효율성 등 다양한 방면에서 장점이 있을 것으로 기대된다.

상용 Indium-Tin-Oxide 투명전도막 (2.5cm×7.5cm) 한 쌍을 이용하고, 스페이서로 Teflon Tape을 사용한 정전용량 센서를 제작하였다. 센서의 동작 측정은 LCR Meter를 사용하였다.

정전용량 센서의 구조변화에 따른 기본적 용량변화를 확인하고, 100ul의 분석물 (HNS+DI Water)을 투입하여 분석물의 용량 변화에 따른 농도변화를 확인하였다. 또한 사용한 분석물의 전도도에 따라 두 전극간의 전도도의 변화를 측정하여 필요에 따라 전도성 센서로도 작동함을 확인하였다.

본 연구는 2023년도 해양수산부 재원으로 해양수산과학기술진흥원의 지원을 받아 수행된 연구이다 (20210660, 해양 위험유해물질(HNS) 배출 등 관리기술 개발사업, 해양산업시설 배출 위험유해물질 영향평가 및 관리기술 개발).

Keywords:

ITO(indium-tin-oxide), 위험유해물질 (HNS: Hazardous and Noxious Substances), 정전용량 센서, 전도성 센서

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Improvement of selectivity of detection of Hazardous and Noxious Substances(HNS) in the sea using Indium Tin Oxide(ITO) film

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Abstract:

수중에 유출된 화학물질, 폐기물 및 생물학적 물질을 포함하여 Hazardous and Noxious Substances (HNS)라고 한다. 이는 인체 건강과 관련된 문제와 해양생태계 손상 등의 환경문제를 발생시키기 때문에 지속적 모니터링이 필요하다. 선행 연구에서 금속산화물을 이용한 수중 유해물질 검출용 센서가 개발되어 있다. 하지만 여러 물질이 혼재되어 있는 경우에는 활용하기에 어려움이 있다. 그러므로 여러 가지 HNS 물질에 대한 특성을 분석하고, 각 센서별 동작특성을 분석하여, 여러 가지 HNS가 혼재되어 있는 경우에 적용할 수 있는 검출 방법의 제안을 목적으로 연구를 수행하였다.
센서의 제작은 Indium Tin Oxide(ITO) 인쇄필름을 활용하였다. 50×20 크기의 ITO 필름의 양단에 Ag 전극을 형성하였다. 제작된 센서의 동작을 확인하기 위해서 센서에 35μl의 분석물(DI water 중 20~160 ppm의 농도로 희석된 HNS)을 투입하였다. 이때 전기 저항의 변화를 측정하여 센서 특성을 분석하였다.
사용한 유해물질로는 법정 HNS 19종과 현장 조사에서 발견되는 주요 오염물질 11종을 선택하고 이들의 수중 거동부터 쌍극자모멘트 등 기본적 물질 특성을 분석하였다. 또한 각 HNS별 분석물 접촉시 발생하는 저항변화로 농도를 예측하고, 측정한 HNS 분석물별 pH의 변화를 동시에 측정하여 두 가지 결과를 비교 분석하였다.
분석 결과 쌍극자모멘트와 농도별 pH로 HNS를 극성분자와 비극성분자 및 유기용매로 분류가 가능함을 확인하여 HNS 혼재시 그룹별로 분류할 수 있다는 점을 알 수 있었다.

본 연구는 2023년도 해양수산부 재원으로 해양수산과학기술진흥원의 지원을 받아 수행된 연구이다 (20210660, 해양 위험유해물질(HNS) 배출 등 관리기술 개발사업, 해양산업시설 배출 위험유해물질 영향 평가 및 관리기술 개발).

Keywords:

Hazardous and Noxious Substances (HNS), Indium Tin Oxide(ITO)

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A Study on the Influence of Surface Residual Binder of Indium Tin Oxide Film in the Utilization of Underwater Hazardous Substance Detection Sensor

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Abstract:

수중에 유출된 화학물질, 폐기물 및 생물학적 물질 등의 유해위험물질(Hazardous and Noxious Substances :HNS)은 건강과 생태계 손상 등의 환경문제를 발생시키기 때문에 지속적 모니터링이 필요하다. 선행 연구에서 금속산화물을 이용한 수중 유해물질 검출용 센서를 연구하였다. 금속산화물 필름을 제작하기 위해서는 나노입자의 결속과 부착을 위해 유기바인더를 사용한다. 하지만 이 유기바인더는 필름의 전도특성을 제한하고 표면에 잔류하면 센서동작의 감도를 감소시킨다. 때문에 이를 제거하기 위한 디바인딩 공정을 진행하지만 잔류바인더를 완전히 배제하는 것은 곤란하였다. 이러한 점은 특히 고감도 센서 연구에 있어서 큰 영향을 줄 것으로 판단된다.
본 연구에서는 표면의 잔류 바인더를 제거하기 위한 세척 공정을 도입하여 표면 세척에 의한 필름의 물성변화와 센서의 특성변화를 조사하였다.
필름의 제작은 Indium Tin Oxide(ITO) 금속산화물 나노입자를 활용하였다. 제작된 필름의 표면 세척은 바인더가 수용성이 있는 것을 이용하여 DI water를 이용한 초음파 세척 방법으로 진행하였다. 세척 전후 ITO 필름의 표면형상과 표면에너지, 전기적 특성과 센서 동작 특성의 변화를 현미경, 전자현미경, 접촉각측정기, 전기저항 등을 측정하여 비교하고 고찰하였다.
연구 결과를 정리하면 바인더의 표면 잔류 정도는 시료마다 편차가 있었으나, 표면세척 공정이 센서특성을 개선시키는 것을 확인하였다.

본 연구는 2023년도 해양수산부 재원으로 해양수산과학기술진흥원의 지원을 받아 수행된 연구이다 (20210660, 해양 위험유해물질(HNS) 배출 등 관리기술 개발사업, 해양산업시설 배출 위험유해물질 영향평가 및 관리기술 개발).

Keywords:

유기바인더, 표면세척, 물성변화

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A study on the application of underwater metal ion detection sensor using ITO nanoparticle printed thin film

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Abstract:

중금속은 인체와 생태계에 위험한 영향을 미치며, 특히나 수중에 존재하는 중금속은 그 피해 확산 속도나 피해 규모가 광범위하기 때문에 이에 대해서 수중에서의 중금속 이온의 검출을 위한 센서의 개발이 필요하다. 특히 산업시설 배출수에 존재할 가능성이 있는 중금속을 실시간으로 검출하는 센서는 존재하지 않다. 다양한 중금속 이온 검출방법에 대한 연구들이 있지만 한계점들이 존재한다.
본 연구에서는 ITO(Indium Tin Oxide) 나노입자를 이용하여 수중에서 금속이온을 검출할 수 있는 센서를 연구하였다. ITO nano powder와 유기바인더(α-terpineol+ethyl cellulose)를 혼합하여 paste를 제작하여 PET 기판위에 Printing 하는 방식으로 제작하였다. 제작한 ITO film을 전자현미경을 이용하여 인쇄 정밀도 및 Tape Test를 통해 기계적 특성을 확인하였으며, I-V sourcemeter를 이용하여 film의 전기적 특성을 측정하여 센서의 전기적 특성을 확인하였다. 센서의 전기적 특성은 ITO film에 DI water중 금속이온(Ba, Mn, Se, Zn, Sn)이 50~200μg/L이 희석되어 있는 분석물(metal ion+DI water) 35μl를 떨어트려 금속이온의 농도 변화에 따른 센서의 동작을 확인하였으며 실험을 통해 금속이온 농도에 따른 응답 변화를 관찰하였고, 농도 증가에 따른 응답 증가 및 금속이온 검출 가능성을 확인하였다. 연구를 통해 수중에 존재하는 금속이온 검출 센서로 활용할 수 있을 것으로 기대된다.

본 연구는 2023년도 해양수산부 재원으로 해양수산과학기술진흥원의 지원을 받아 수행된 연구이다 (20210660, 해양 위험유해물질(HNS) 배출 등 관리기술 개발사업, 해양산업시설 배출 위험유해물질 영향 평가 및 관리기술 개발).

Keywords:

Heavy metal detection, Metal ion sensor

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P2-st.001

Nonlocality in vapor deposition polymerization

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Abstract:

The growth mechanism of polymer films is investigated using dynamic scaling analysis of atomic force microscopy images of Parylene-AF4 films grown by vapor deposition polymerization at room temperature. In the steady growth regime above film thickness d~300 nm, both the average local slope and global slope remain constant, suggesting a self-similar mound surface, i.e. $k_{loc} \approx k_G \approx 0$. During the vapor deposition polymerization of Parylene-AF4, where film growth is driven by chemical reaction-limited aggregation, the anomalous intrinsic local fluctuations seen in the other Parylene film variants, Parylene-C and Parylene-N, completely disappear. The nonlocality of the surface growth of parylene-AF4 is blurred with an extremely small sticking coefficient, while mound formation with a constant slope remains intact.

Keywords:

Parylene, Kinetic roughening, Polymer film growth, Reaction limited aggregation, Vapor deposition polymerization

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Thermodynamic bounds in deterministic chemical reaction systems far from equilibrium

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Abstract:

Thermodynamic uncertainty relation (TUR) provides a universal lower bound on the product of entropy production and fluctuations of the output of a non-equilibrium process. Non-equilibrium physico-chemical systems exhibit dissipative structures by exchanging energy and matter with their surroundings. We investigated the TUR bound in some deterministic models of chemical and biochemical systems that exhibit oscillatory and chaotic dynamics. The deterministic models considered include Brusselators, the Sel'kov model of glycolytic oscillations, the interlinked cascade of Rab GTPase proteins, the Oregonator and the Willamowski-Rössler model. We found that for all the models, the TUR holds obeying a universal lower bound on the uncertainty product, $Q \geq 2$. While previous studies found Q belongs to the range of 30-400 for mesoscopic biochemical oscillators, we found that the minimum of the TUR uncertainty product, Q_{min} is in the range of 10-100 for the deterministic biochemical oscillators considered in the present study. We also found that the Oregonator chemical oscillator model with experiment-based Field Försterling parameters underperforms the TUR's lower bound of 2. The present study contributes towards a deeper understanding of TUR on macroscopic chemical reaction systems.

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Keywords:

Thermodynamic uncertainty relation, non-linear, non-equilibrium, chemical reaction networks, entropy production

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The speed-accuracy trade-off under viscoelastic feedback using one-dimensional biased random walks

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Abstract:

In this study, we investigate the speed-accuracy trade-off mediated by viscoelastic feedback in the context of one-dimensional directed motion of motor proteins. Our approach employs biased random walks to characterize the motor protein's directed motion, while accounting for viscoelastic influences. To capture the essence of viscoelastic effects, we introduce a probability that represents negative feedback against the direction of motion. This probability serves as the key mediator in establishing a trade-off relationship between two critical factors: speed, defined by mean displacements divided by time, and accuracy, quantified by the Fano factor. As a result, stronger viscoelastic feedback results in slower speeds while improving accuracy. We also confirm that the trade-off relationship remains valid within the bounds proposed by the thermodynamic uncertainty relation. While our model represents a simplified portrayal of the intricate dynamics of motor proteins, we believe that our model offers some insights into the role of viscoelastic feedback in the one-dimensional motion of motor protein such as kinesin or dynein.

Keywords:

Non-equilibrium steady state, Active transport, Motor protein, Thermodynamic uncertainty relation, Viscoelasticity

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P2-st.004

이황화레늄(ReS_2)과의 상호작용에 의한 네마틱 액정의 배향 특성 연구

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Abstract:

이황화레늄(ReS_2)은 7족 전이금속 칼코겐화합물(TMDC) 그룹에 속하는 물질로, 구성 원자들이 층내에서는 다이아몬드 모양의 Re-Re 사슬을 형성하고 층과 층 사이에서는 Van der Waals 결합을 하는 2차원물질이다. 이황화레늄은 일반적인 2차원물질과는 달리, 여러 물리적 비등방성을 보이며 다른 2차원물질에서는 흔히 발견되지 않는 고유한 물성으로 인해 상당한 관심을 끌고 있다.
네마틱 액정은 액체상의 유동성과 결정상의 방향성을 동시에 갖는 물질이다. 이때, 액정분자들이 이루는 국소적인 평균 방향을 방향자(director)라고 한다. 네마틱 액정은 비등방성과 동시에 작은 외부 자극으로도 제어 가능한 탄성을 갖고 있다.
본 연구에서는 액정 방향자와 이황화레늄의 상호작용을 이해하고, 그 이해를 기반으로 이황화레늄의 구조를 광학적 분석을 통해 파악한다. 투과율 및 반사율, 위상차와 같은 정보에 더하여, 이황화레늄과 액정의 비등방성이 구분되는 라만 산란 등뿐 아니라, 이황화레늄 플레이크의 모양까지 고려하여 분석한다.

Keywords:

네마틱 액정, 2차원물질, 이황화레늄(ReS2), TMDC, 비등방성

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P2-st.005

Critical Binder Ratio of Long-range Antiferromagnetic Quantum Ising Chain

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Abstract:

We investigate the universality of the Binder ratio at the critical point of the antiferromagnetic quantum Ising chain with algebraically decaying long-range (LR) interactions. We employ the variational Monte Carlo (VMC) method with the restricted Boltzmann machine (RBM) for a trial wave function ansatz to find a critical ground state. We find that the critical Binder ratio deviates from the value of the short-range (SR) limit for the LR decay exponent $₩alpha < 2$. We also find that the critical value of the Binder ratio that we measured in our VMC+RBM calculations in the SR limit is in excellent agreement with the universal ratio of the classical 2D Ising model under the mixed boundary conditions where the system is periodic in one direction while it is open in the other direction.

Keywords:

Long-range Quantum Ising Chain, Quantum Criticality

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P2-st.006

Direct measurement of correlation length in pair contact process with diffusion

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Abstract:

We investigate the pair contact process with diffusion in one dimension by using a correlation length-like quantity K, defined as $K(L,t) = L\sigma^2 / \langle \rho \rangle^2$, where L, ρ, σ^2, and $\langle \cdots \rangle$ are the system size, the particle density, the variance of ρ, and the ensemble average, respectively.
At the critical point p_c, K increases as times increases, following a power law of $K(t) \sim t^{1/z}$, where z is the dynamic exponent.
If the annihilation rate p is less than p_c, K stops increasing and becomes a constant K_stat, which is expected to $K_\mathrm{stat}(p) \sim (p_c - p)^{-\nu_\perp}$, where $\nu_\perp$ is the spatial correlation-length exponent.
Measuring K, we obtain $z = 1.755(15)$ and $\nu_\perp = 1.0785(83)$.

Keywords:

Absorbing phase transition, Pair contact process with diffusion, Correlation length

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P2-st.007

Optimal combinations of simple discrimination strategies in direct and indirect reciprocity

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Abstract:

Cooperation in social settings is a puzzling phenomenon in evolutionary studies. Most past research has viewed direct and indirect reciprocity as separate ways to boost cooperation. In our study, we looked at how strategies evolve in the repeated Prisoner's Dilemma game in a closed society. Here, players often interact with the same person multiple times and are aware of each other's reputations. By considering both the history of direct interactions between players and public information about their actions, we aimed to find the best strategy to encourage cooperative behavior. Our results suggest that smartly blending both forms of reciprocity leads to more sustainable group cooperation than traditional methods. Moreover, this combined strategy outperforms the classic tit-for-tat strategy, especially in situations where mistakes can happen, presenting a fresh approach to maintaining cooperation.

Keywords:

game theory, prisoner's dilemma, reciprocity

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P2-st.008

Prediction of public official elections based on regional voter turnout

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Abstract:

We are analyzing the link between regional voting patterns and election outcomes for public officials in South Korea. Though the nation has a multi-party framework, in practice, it largely functions as a two-party system between the primary conservative and liberal parties. Our study focuses on two primary triggers for these party power shifts: 1) notable changes in party support among the electorate, and 2) notable changes in voter turnout among specific party supporters. If the second factor plays a significant role in these transitions or closely relates to the first, then voter turnout patterns can be used to predict election results. Building on this, we have derived indicators from the turnout data in politically inclined regions and demonstrate their accuracy in predicting elected officials.

Keywords:

Public official election, Political tendency, Regional voting patterns

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P2-st.009

Investors as information creators: the role of the writer for social media in financial markets.

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Abstract:

We exploit the overlapping writer activity structure of the social media contents to understand co-movements of firm returns and characterize its evolution over time. Using this approach from the social media activity of writers, we find the non-trivial structure in creating information from heterogeneous firms: a distribution function of contents for writers follows a power-law with different exponents and changes over time. Employing statistical and dynamical properties of writers in social media, we show that the number of contents in a specific firm has a significant prediction power for focal firm returns. We also find that the investment strategies based on the writer's characteristics yield monthly additional profits.

Keywords:

complex systems, social media

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P2-st.010

Modeling epidemic processes in mobility-based networks of Republic of Korea

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Abstract:

A microscopic picture of COVID-19 spreading in Republic of Korea (hereafter Korea) has not been fully explored, despite a recent empirical study on mesoscopic transmission networks [Kwon and Jo, Chaos **33,** 013107 (2023)]. We first generate surrogate networks of individuals based on the origin-destination mobility dataset of Korea. Then we perform numerical simulations of epidemic processes like the SIR model on those networks to obtain individual transmission networks and their mesoscopic versions, which are finally compared to empirical mesoscopic networks. Such a comparison might help to get some insights into the microscopic mechanism of COVID-19 spreading in Korea.

Keywords:

epidemic process, SIR model, human mobility, COVID-19

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P2-st.011

비엔나와 대구 도시철도의 네크워크 중심성 비교

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Abstract:

지하철(subway)로 대표되는 도시철도의 역과 선로는 네트워크 이론의 노드(node)와 에지(edge)로 위상학(topology)적으로 표현된다. 그래프 이론의 중심성(centrality)에 의거하여 오스트리아 비엔나(109개 역)와 대구(91개 역) 도시철도 전체역의 특성을 비교 분석하였다. 이 두 도시는 역의 개수는 비슷하지만 도시철도 네트워크의 형태는 상이하다. 대구는 단순한 X 자 형태로 뻗어나가나, 비엔나는 격자 모양의 다소 복잡한 형태이다. 그래프 이론에서 제시한 중심성 중에서 근접 중심성(closeness centrality) 값을 비교해 두 도시의 도시철도 네트워크의 위상학적인 유형을 파악해 보고자 한다. 두 도시의 네트워크 형태에 따라 역들의 중심성 값 군집도가 다르게 나타난다. 근접 중심성의 분포도를 보면, 대구는 계단식으로 우하향하는 경향을 보이는 반면 비엔나는 상승하다가 다시 내려가면서 고른 분포 양상을 나타낸다. 지형적인 요소들을 반영할 순 없지만, 중심성 값의 분포도를 보게 되면 네트워크의 유형 분석을 통하여 거꾸로 위상학적인 네트워크 유형 특성을 유추 할 수 있다. 이에 도시철도 네트워크의 유형 분류를 위해서는 추가적으로 몬테카를로 시뮬레이션이나 프랙탈 차원 등의 분석이 필요하며, 이를 위상학적인 그래프 이론 분석과 결합하면 좀 더 실제적인 분석이 가능하게 된다.

Keywords:

그래프 이론, 도시철도, 네트워크 형태, 근접중심성, 비엔나

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P2-st.012

Roughening transition of information landscape on complex networks

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Abstract:

본 연구에서는 Halvorsen-Pedersen-Sneppen이 제안한 모델을 활용하여 complex network 위에서 정보의 경쟁이 다양성에 미치는 영향을 조사하였다[1]. 우리는 정보의 다양성을 측정하기 위해 정보값$\{\tau_i\}$ 을 표면의 높이$\{h_i\}$ 에 mapping하였다. 정보의 다양성은 width, $W(N,t) \equiv \sqrt{\frac{1}{N}\sum_{i=1}^{N}(\bar{\tau} - \tau_i)}$,로 표현할 수 있다. 우리는 수치 시뮬레이션을 통하여 $W(N,t)$ 가 네트워크의 구조에 따라 달라짐을 발견하였다. 특히 무작위 네트워크에서는 information landscape가 control parameter와 무관하게 항상 smooth상임을 발견하였다. 그러나 scale-free 네트워크에서는 degree exponent γ 가 작은 곳에서는 rough상이며, γ 가 큰 곳에서는 smooth 상이 되는 roughening transition이 있음을 발견하였다. 추가로 우리는 $W(N,t)$로 표현되는 정보의 다양성이 낮은 차원에서와 달리 특이 현상을 보여줌을 발견하였다[2]. 이런 특이한 현상의 몇 가지 가능한 이유에 대해 논의한다.

References:

[1] G. S. Halvorsen, B. N. Pedersen, and K. Sneppen, Phys. Rev. E **103**, 022303 (2021)
[2] K. Kim and S.-H. Yook, Phys. Rev. E **107**, 034307 (2023)

Keywords:

Complex networks, Interface roughening

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P2-st.013

Hierarchy and inequality of faculty hiring in South Korea

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Abstract:

A faculty hiring network has its importance in forming academia, and non-meritocratic perceptions on academic workforce regarding institutions' prestige, racial composition of scholars, and preferred educational trajectories. These non-meritocratic elements can form an imbalanced representative composition of the academic workforce and reinforce the inequality. A study investigated the impact of institutional prestige in the North American high education system, and its results displayed a significant inequality of PhD granting institutions' faculty production.
However, it is obscure to what extent that institution's prestige meddles in the faculty hiring in South Korea's high education [1]. To analyze S. Korea's faculty production among institutions, we collected educational trajectories of Computer Science, Physics, and Biology faculty in S.Korea's PhD granting institutions. With the collected data, we examined hierarchies in South Korea's faculty hiring network by ranking institutions with SpringRank method [2].
The results showed that institutions abroad, especially in the United States, placed at the top of the rankings in S. Korea's higher education system. In other words, it reveals that S. Korea's faculty hiring network highly relied on faculty who studied abroad. In addition to that, when we consider S. Korea's faculty hiring network as a closed system by considering domestic scholars only, its inequality is steeper than that of the US' system, which signifies it is more unequal. The results shed light on the mechanism of establishment of S. Korea's pivotal academic workforce and provide an insight into a diversity of faculty compositions in S. Korea.

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[2] Caterina De Bacco et al., A physical model for efficient ranking in networks. Sci. Adv. 4, eaar8260 (2018). DOI:10.1126/sciadv.aar8260

Keywords:

faculty hiring, complex system, inequality, network, hierarchy

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P2-st.014

Wealth dynamics on the networked Talent versus Luck model

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Abstract:

A. Pluchino, et al. suggested “Talent versus Luck (TvL)” model, an agent-based model that individual’s wealth change is determined by its talent and luck of every moment. In this model, the distribution of agents’ capital follows the power-law.

We showed that the TvL model described by specific capital change rules corresponds to the non-interactive Bouchaud-Mezard (BM) model.

After that, we introduce sharing & pooling interaction to the TvL model and investigate how the talent configurations in the network affect its capital dynamics.

We defined ‘talent assortativity’ and focus on it to analyze the results.

Keywords:

wealth dynamics, complex networks, agent based model, stochastic process, econophysics

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P2-st.015

Unveiling Characteristic Substructures in Anomalous Diffusion through Deep Learning

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Abstract:

Diffusion phenomena caused by random interactions between particles and surroundings manifest in the movement of various objects such as chemicals, particulates, cells, and air masses. Anomalous diffusion, a deviation from Brownian diffusion, can often be observed in these phenomena when particle interactions violate the general central limit theorem, leading to nonlinearity in mean square displacement over time.
Previous study have introduced mathematical models to explicate anomalous diffusion phenomena. Categorizing these phenomena within appropriate mathematical models is pivotal for unraveling their underlying physical mechanisms. Recent advancements in leveraging deep learning methods have shown promise in accurately classifying anomalous diffusion trajectory; however, the Black-Box nature of deep learning models poses constraints on further analysis and result interpretation.
In this study, we present a novel methodology that facilitates further analysis from deep learning results by pinpointing distinctive substructures within anomalous trajectories that significantly influence classification outcomes.
Our approach use a ResNet-based neural network architecture, incorporated trajectory dimensionality into the network design. With this architecture, we can use the gradient-weighted class activation map (Grad-CAM) technique. The Grad-CAM method identifies the input regions with that significantly impact classification progress. By harnessing the inherent features of ResNet and the results from Grad-CAM, we can discern characteristic substructural patterns embedded within anomalous diffusion trajectories.
This combined framework not only show the high accuracy on anomalous diffusion classification but also provides interpretable insights into the pivotal substructure driving classification decisions. Our methodology bridges the gap between accurate classification and insightful analysis, paving the way for a deeper understanding of complex diffusion processes in diverse applications.

Keywords:

Anomalous diffusion, Diffusion Phenomena, Deep Leaning, Machine Learning, Interpretable AI

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P2-st.016

Boosting Generalization in Neural Networks with Stochastic Restarting

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Abstract:

In this study, we present the Stochastic Restarting at checkpoint (Sto-Re) algorithm, a novel approach aimed at augmenting the generalization capabilities of neural networks by strategically resetting all parameters from a designated checkpoint. By establishing a connection between the dynamics of stochastic gradient descent (SGD) and Langevin dynamics, we leverage the stochastic restarting strategy, a well-explored concept in the field of statistical physics renowned for its role in expediting target search processes. Our theoretical analysis demonstrates that incorporating the Sto-Re algorithm into SGD can efficiently optimize model parameters compared with ordinary SGD in a simple case. We also illustrate that the Sto-Re algorithm is advantageous when the stochasticity of SGD increases. Furthermore, our empirical results provide evidence of its capacity to robustly improve performance across a range of network architectures, datasets, and optimizers. An important aspect of the Sto-Re algorithm is its ease of implementation, rendering it accessible for practical use and allowing it to be employed alongside other training strategies. Ultimately, our findings suggest that the Sto-Re algorithm holds significant potential for enhancing the training and optimization processes of neural networks.

Keywords:

neural network, optimization, SGD, stochastic resetting, generalization

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P2-st.017

A Comprehensive Evaluation of Information Entropy-based Network Directionality Estimation Method using world trade web and brain networks

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Abstract:

In network systems, directional information is essential; however, building directional networks can be challenging. A recent method using information entropy has been proposed to extract directionality from undirected networks [1]. Nevertheless, a thorough evaluation on the effectiveness of this approach is yet to be conducted. In this study, we examine the validity of this method with the World Trade Web network which is originally tested by the previous paper [1], by varying Rényi entropy parameters and employing three types of edge removal approaches. These removals are based on ascending, descending, and random sorting of edge weights [2]. Althouth we confirmed that the proposed method showed high correlations between ground truth and estimated weights of directional edges, our findings also reveal that the initially reported high accuracy and precision in the WTW evaluation are associated with a significant number of reciprocal edges. Specifically, the performance scores decrease upon edge removal. In particular, edge removals with random edge weights inducing low reciprocal ratio showed lower performance than the other removals. Indeed, the entropy-based directionality extraction method yielded a low precision in Drosophila larva brain networks, which contain a limited number of reciprocal edges. This work implies the importance of caution and systematic performance evaluation when utilizing the entropy-based directionality extraction method.

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[2] Kim, D., Lee, E., Kang J.: A Comprehensive Evaluation of Entropy-based Directionality Estimation Method, *J. Kor. Phys. Soc.*, in press.

Keywords:

Effective out-degree, Network science, Confusion matrix, Information theory, Brain network

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P2-st.018

Quantifying concurrency of edges in temporal networks

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Abstract:

Concurrency is a concept from mathematical epidemiology and refers to the extent to which a person has multiple partners at the same time. However, there are few valid quantitative metrics to measure it. In this study, we quantify concurrency by introducing a metric referred to as "Edge Event Correlation (EEC)", which evaluates the correlation between two edges each containing a set of time-stamped events. We analyzed the EEC for eight undirected and three directed empirical temporal networks. We compared the EEC values between edge pairs that shared a node (i.e., adjacent edge pairs) and edge pairs that did not. In undirected networks, adjacent edge pairs showed significantly higher EEC values than non-adjacent edge pairs. In directed networks, we further categorized adjacent edge pairs into expanding, concentrating, and passing types depending on the direction of edges. Among them, only the expanding edge pairs, which share a node as the source, showed higher EEC values than those of non-adjacent edge pairs. Consequently, the EEC seems to be a promising metric for quantifying and understanding concurrency in temporal network data.

Keywords:

temporal network, time-stamped events, correlation

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P2-st.019

Functional connectivity and network analysis in the mouse brainstem after concussion

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Abstract:

Mild traumatic brain injury (mTBI) frequently occurs in everyday life. It is diagnosed based on cognitive or neurological symptoms without fully understanding the neuropathological basis for the outlook behaviors. Recent neuroimaging studies in humans and animals using functional MRI support neuropathological evidence of mTBI in brain structure or functional abnormalities. However, little is known about the ability of the brainstem to change its function after a concussion. Therefore, according to the concussion days, we investigated functional connectivity and functional network properties in the mouse brainstem. Functional connectivity and global and local network properties were significantly lower than sham on post-concussion day 7 and returned to normal on post-concussion day 14. We also found that the brainstem network's local efficiency and clustering coefficient were highly correlated with anxiety-like behaviors on post-concussion days 7 and 14. Our findings indicate that functional connectivity in the mouse brainstem is essential for concussion recovery through functional reorganization.

Keywords:

Functional connectivity, Functional MRI, Concussion

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P2-st.020

Characterization of spiking neuron-based reservoir computers

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Abstract:

Reservoir computing (RC) is a relatively new machine-learning framework that uses an abstract neural network model, called reservoir. Here, we characterize the neural dynamics and network properties of spiking neuron-based reservoir computers. The computational performance of RC largely depends on intrinsic neuronal spiking dynamics, avalanches, and edge-of-chaos behaviors. The reservoir networks undergo dynamic transitions among relatively large clusters of neurons, small clusters, and unclustered neurons—the formation of large clusters and collective oscillation of cluster size are the most distinctive characteristics of the reservoir dynamics during the Modified National Institute of Standards and Technology (MNIST) database classification task. This study provides new insight into our understanding of the computational principles of RC concerning the spiking dynamics of the individual neurons and the system-level collective behavior.

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Keywords:

Reservoir computing, Spiking neural network, Neuronal avalanche, Self-organized criticality

On the interpretability of reservoir computers: Hamiltonian flow and criticality

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Abstract:

Interpretability is a fundamental concept of modern artificial intelligence (AI) models, yet the recent surge in interpretable/explainable AI research has led to confusion on definitions, methods, and applications of this concept—this is partly due to the negligence of physics underlying AI models. This study uses analytical approaches and numerical simulations to unveil the link between the physics of the reservoir network and its interpretability. The dynamics of the reservoirs are described in various ways including Hamiltonian mechanics, network-theoretic aspects, and neuronal avalanches. The obtained primary dynamical properties are related to the prediction accuracies of some machine learning tasks, then the results are compared with the layer-wise relevance propagation methods. This study provides new insight into the computational principles and interpretability of reservoir computing systems.

Funding information:
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Keywords:

reservoir computer, self-organized criticality, interpretable artificial intelligence

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P2-st.022

Multiscale description of cardiac dynamics

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Abstract:

This study explores the critical behavior of the cardiac system using multiscale approaches. The primary focus is to explicate the logical path of how complex phenomena emerges from smaller-scale dynamics. The emergence of criticality in the cardiac dynamics is interpreted as a collective behavior of cardiac cells such as cardiomyocyte and Purkinje fiber. The action potential dynamics of individual cardiac cells are reconstructed via Hodgkin-Huxley type models, then a cardiac model connecting dynamics of different scales from cellular to physiological level is constructed. Finally, the critical behavior of the cardiac system is explained by the nonlinear and chaotic properties of the generated model system.

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Keywords:

Cardiac dynamics, Criticality, Complex phenomena

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P2-st.023

Interplay between spiking dynamics, network morphology, momory processes in a dopamine-reward Pavlovian conditioning system

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Abstract:

Spiking Neural Networks (SNNs) are biologically relevant neural networks that rely on spiking dynamics and synaptic connections to learn. Understanding the spiking dynamics and network morphology in SNNs is crucial for understanding the learning process. In this study, we analyze the spiking time series and the indegree-outdegree relationship of nodes in a dopamine-reward Pavlovian learning system, which is an Izhikevich network with a three-factor Spike-Timing Dependent Plasticity (STDP) learning rule. We find that as learning progresses, the network structure changes from a fully recurrent random connection to a feed-forward network morphology with an indegree-outdegree (or W_{in}^{sum} - W_{out}^{sum}) correlation of approximately -1. Additionally, we observe the formation of multiple subpopulations with distinct characteristics in terms of spiking dynamics and graph theory perspectives, which underlie diverse spatio-temporal burst patterns when the trained system is purely driven by noise. We also find that the overall dopamine level significantly affects burst profiles and neuronal subpopulation composition, with a critical value leading to a discontinuous first-order transition in Pavlovian learning effectiveness. Our results emphasize the importance of analyzing spiking dynamics and network morphology together in SNN learning, and further investigation is needed to understand the computational significance of the distinct subpopulations.

Keywords:

Spiking Neural Network, Pavlovian Learning, Spiking Dynamics, Spike Timing Dependent Plasticity

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P2-st.024

The Role of Rigid Random Connectivity in Temporal Pavlovian Conditioning of a Model Spiking Neural Network

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Abstract:

Recently we have demonstrated that a model spiking neural network can be Pavlovian-conditioned so as to discern small sequences of temporal events occurring within the fast timescale of milliseconds. Two essential components of this conditioning process are 1) plastic synaptic connections that are subject to the well-established spike timing dependent plasticity (STDP) and 2) dopamine rewards which modulate the activation level of STDP. Here we hypothesize that some node connections are rigid (that is, the weights assigned to some edges are not a variable but a constant, even during the conditioning process. Then, we investigate the role of this non-plastic synapse population, alongside the plastic ones, as related to the discernibility of different, three element, temporal events. For an obvious reason, if the size of the rigid subpopulation gets too large, the conditioning itself is not working. Surprisingly, however, having some (< 30%) subpopulation of synapses can significantly extend the discernable dynamic ranges of both two time intervals associated with three-element temporal events. This interesting result may be a good explanation as to why often the neural architecture of brain connectivity shows a mixture of plastic and rigid components.

Keywords:

Spiking Neural Network, Pavlovian Conditioning, Spike Timing Dependent Plasticity, Izhikevich model

P2-te.002

고등학교 양자물리학 수업에서 물리 교사의 논증구조 분석

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Abstract:

양자 기술의 발전과 함께 최근 양자물리 교육에 대한 관심이 높아지고, 2022 개정 교육과정에서 양자물리 내용이 증가하였다. 이에 현재 이루어지고 있는 양자물리 수업 현장을 분석하여 양자물리 수업 방안에 관한 시사점을 도출하고자 하였다. 교실에서의 수업은 교사의 설계와 수행에 크게 좌우되므로 연구의 초점으로 물리 교사가 양자물리 내용을 다룰 때 어떤 논증 구조로 다루는지 탐색하였다. 이를 위해 4명의 물리 교사의 물리학1, 물리학2, 고급물리학 수업 중 양자물리 내용을 다루는 수업을 녹화하여 분석하였다. 양자물리학 교육의 실태에 관한 분석 결과를 통해 요구되는 양자물리 수업에 관한 제언뿐 아니라, 양자물리학 지도를 위한 교원연수 및 예비교사 교육에 관한 제언을 제공하고자 한다.

Keywords:

양자물리학 교육, 논증, 수업 분석

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P2-te.003

온라인 시험 및 평가 플랫폼을 활용한 물리 교육에 대한 학생들의 인식 변화

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Abstract:

한 국립대학에서 자체 개발한 변수-랜덤화 온라인 시험 및 평가 플랫폼을 이공계 학생들이 대규모로 수강하는 일반물리학Ⅰ, Ⅱ 교과목에 지난 2년 동안 활용하였다. 매 학기마다 전체 물리 교과목들의 중간 및 기말시험을 이 온라인 플랫폼으로 일괄적으로 실시하였고, 수강생들에게 이 플랫폼을 활용한 온라인 평가 방법의 선호도와 만족도, 교육 효과성을 연차적으로 설문하고 분석하였다.

그 결과 1차년도 조사에서는 온라인과 지면 시험의 선호 비율이 비슷했는데, 2차년도에는 70 % 이상의 학생들이 온라인 시험을 더 선호한다고 응답하였다. 그 이유로는 시험 결과의 즉각적 확인과 시험 응시방법의 편의성, 시험지 제출이 편리하고 신속하기 때문이라고 답하였다. 반면 초기 조사에서 지면 시험을 선호하는 이유로 가장 큰 비율을 차지하던 지면 시험의 익숙함은 최근 조사에서 크게 감소하였다. 만족도 측면에서는 화면 디자인과 그림, 글자 등 문제의 명확성 측면에서 대부분의 수강생들이 만족하는 것으로 나타났다. 또한 온라인 플랫폼을 사용한 성적 평가에 대해서도 긍정적으로 나타났는데, 1차년도보다 2차년도의 만족도가 증가하였다. 그리고 교육 효과성 측면에서, 온라인 평가 플랫폼을 이용한 수시평가나 과제물 부여가 학습 동기 유발과 성적 향상에 도움이 되었다고 응답하였다. 매우 도움이 되었다는 응답도 1차년도보다 2차년도에서 증가하였다.

이러한 조사 결과는 지난 2년간 꾸준하게 시행되고 향상된 온라인 시험 및 평가 플랫폼을 활용한 물리 교육 시스템에 대한 학생들의 인식이 긍정적이고 만족스러운 방향으로 변화되고 있음을 의미한다. 초연결 기술의 발전과 학생들의 온라인 기기에 대한 사용 편의성과 친숙도가 증대되고 있기에 물리 교육에서 온라인 평가 플랫폼은 교수자의 수시평가 및 학습 역량 진단의 편의성뿐만 아니라, 학생들의 학습 만족도와 역량을 향상시킬 수 있는 효과적인 교육 수단으로 확산될 수 있을 것으로 기대된다.

Keywords:

물리교육, 일반물리학Ⅰ, 일반물리학Ⅱ, 온라인 시험, 온라인 평가 플랫폼

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P2-te.004

초등학교 교사의 과학전람회 물리분야 지도 경험에 대한 질적 탐구

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Abstract:

이 연구는 초등학교 교사들의 과학전람회 물리분야 지도 경험을 질적으로 분석하여 개인변인에 따른 과학전람회 지도 경험의 공통점과 차이점을 밝히고, 그 경험이 교사의 성장에 미친 영향을 탐색하는 것을 목적으로 한다. 이를 위해 물리분야의 과학전람회 지도 경험이 있으며 탐구 수행과 지도 경력이 상이한 초등교사 3명을 연구 참여자로 설정하였다. 교사의 과학전람회 지도 경험과 함께 과학 교수지향 등 개인변인에 대한 심층 면담을 수행하여, 연구 참여자들이 과학전람회를 지도하는 과정에서 겪었던 다양한 경험의 의미를 탐색하고 과학 교수지향, 전람회 참여 목적 등의 개인적 변인과의 관계를 분석하였다. 이 연구를 통해 과학 탐구 지도와 관련된 교육적인 시사점과 함께 교사 개인의 성장에 대한 함의를 제공하고자 한다.

Keywords:

과학전람회, 탐구 지도

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P2-te.005

양자 상태 단층 촬영을 통한 두-입자 계의 분석

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Abstract:

본 연구에서는 CHSH (Clauser-Horne-Shimony-Holt) 부등식의 위배를 실험적으로 입증하고, 이를 확장하여 양자 상태 단층 촬영 (QST, Quantum State Tomography)을 통해 두-입자 계의 상태를 확인하고자 양자 광학 실험을 진행했다. 빛알의 이산성을 나타내는 변수인 이차 자체상관함수의 $g^{(2)}(0)$ 값을 측정한 결과 0.026 ± 0.011로 명백히 1보다 작은 값이 나와 단일 빛알의 존재를 확인할 수 있었다. CHSH 부등식의 위배와 양자 상태 단층 촬영은 양자역학이 예측하는 범위 내에서 이론과 일치하는 수치를 얻었다. 본 연구는 학부생 수준에서 2개 이상 큐비트의 상태를 나타내는 밀도행렬을 이론적으로 계산할 뿐 아니라 실험적으로도 확인함으로써 양자역학의 교육에서 의미 있는 기여가 된다.

Keywords:

CHSH inequality, QST, autocorrelation function, quantum physics education

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P2-te.006

양자구속 효과의 실험적 경험을 위한 교육용 키트 제작

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Abstract:

교육학적 측면에 있어, 실험 수업은 사고력 증진, 동기부여, 경험부족 예방과 진로결정을 위해 중요성이 매우 높다. 그러나, 연구중심대학 및 선진국의 대학교와는 달리, 개발도산국 및 국내의 일반적인 대학들의 경우 실험에 필요한 장비가 없거나 노후화되어 최신 기술을 접목하거나 경험할 수 있는 실험 수업을 용이하게 진행하기 어려운 측면이 있다. 그에 따라, 이러한 교육적 사회 불평등을 해소하고 학부수준에서 경험가능한 실험을 다양화하기 위해 실험 환경의 제약 요소가 낮고, 비용의 제약을 크게 받지 않는 학부친화적 실험의 개발이 시급한 실정이다. 본 연구에서는 아두이노를 기반으로 양자점을 합성하는 교육용 키트를 제작할 수 있도록 도모하였다. 아두이노를 통한 전자회로의 구성과 프로그래밍, 화학적 정제 기법, 양자점의 양자구속효과에 따른 발광 특성 변이를 배울 수 있으며, 화학-전기전자-물리학의 포괄적인 융복합적 교육이 가능하도록 하였다.

Keywords:

양자점, 교육기자재, 아두이노