

APCTP LECTURE

DATE : May 11 (Mon) | PLACE : Webinar by ZOOM & Youtube
TIME : 10:00~11:20 / 13:00~14:20 / 15:00~16:20

TITLE **Emergent electromagnetism
and nonlinear/nonreciprocal
responses of quantum materials**

SPEAKER **Prof. Naoto Nagaosa**
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ABSTRACT Quantum materials have a large potential to develop novel functionalities due to the geometric nature of the electronic states in solids. Berry phase is a typical concept representing the quantum geometry of electrons, which is described as Emergent Electromagnetic Field (EEMF) [1]. This EEMF is also related to the nonlinear responses as well as the linear responses such as anomalous Hall effect and spin Hall effect. I will talk about the recent developments in this field.

When the system lacks both parity and mirror symmetries, it is called “chiral” and can be classified into right-handed and left-handed. Chirality is one of the most fundamental issue in many branches of sciences [2]. In biology, the chirality of DNA is the same for all the living creatures on earth. In chemistry, to synthesize the molecules of one chirality selectively is an important issue. In physics, the parity violation is a striking feature of weak interaction. On the other hand, responses of the quantum systems away from the thermal equilibrium are the subject of intensive recent interest. Kubo formula provides a unified framework to describe the linear responses for weak external stimuli. On the other hand, the non-equilibrium phenomena have been studied mostly in terms of the classical dynamics by nonlinear differential equations with stochastic forces. Chaos and dissipative structure are the two representative examples of this direction. However, the quantum aspects of the nonlinear dynamics is not yet explored so much.

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In this lecture, I will focus on the functionalities due to EEMF, and also the nonlinear and nonreciprocal responses of solids [3]. When the system is chiral, the nonlinear responses can be asymmetric with respect to the direction, where the most fundamental principles in physics manifest themselves, i.e., the symmetries, dissipation, quantum-classical crossover/transition, quantal Berry phase and topology, and many-body correlation effects. The concrete examples to discuss include magnetochiral anisotropy of semiconductors [4], Weyl semimetals [5], and superconductors [6], nonlinear spin current generation in Rashba-Dresselhaus systems, and shift currents under photo-excitations [7].

The collaborators of these works are T. Morimoto, K.W. Kim, R. Wakatsuki, K. Hamamoto, M. Ezawa, H. Ishizuka, S. Hoshino, S.Koshikawa, S.Shimizu, Y.Kaneko Y. Saito, T. Ideue, Y. Iwasa, M. Kawasaki and Y. Tokura.

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[2] M. Gardner, The Ambidextrous Universe. Left, Right and the Fall of Parity,
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[4] T. Ideue et al., Nature Physics **13**, 578-583 (2017).

[5] T. Morimoto and N. Nagaosa, Phys. Rev. Lett. **117**, 146603 (2016).

[6] R. Wakatsuki et al., Science Advances **3**, e1602390 (2017).

[7] T. Morimoto and N. Nagaosa, Science Advances **2**, e1501524 (2016).