凝縮系物理学ゼミナール

Condensed Matter Seminar

Location: Room 413, School of Science Bldg. 5 (理学 5 号館 413 号室)
Time and date: 13:30 – 15:00, Wednesday, 21 May 2014

Theory of Charge and Heat Polarizations with the Keldysh Formalism

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Abstract:

The charge polarization (CP) is one of the most important quantities in the condensed matter physics. In the classical electromagnetism in matters, it is defined by the volume integral of the product of the charge density and the position. However, the position operator is ill-defined in crystals, and the CP cannot be defined naively. Instead, an ingenious definition was established to calculate the temporal integral of the charge current induced by an adiabatic change in the Hamiltonian [1]. The CP is associated with the Berry connection in the Bloch basis, and is interpreted as the expectation value of the position operator in the Wannier basis.

The heat polarization (HP) is a heat analog of the CP, and is a textbook concept to define the heat current [2]. However, even its definition has not been established yet, and it remains unknown whether the spontaneous HP appears in inversion-broken insulators or not. In addition, it was recently proposed that the HP can be induced by an angular velocity of rotation in (3+1)-D topological superconductors (TSCs) [3]. The proper definition of the HP is the important first step towards a microscopic understanding of the heat cross correlation.

Here we provide a general formalism for polarization based on the gauge-covariant Keldysh formalism [4]. The HP consists of the heat-transfer and heat-generation contributions, which are equivalent to the Kubo-formula contribution to the Nernst conductivity and the orbital magnetization, respectively. As a result, in contrast to the charge-heat analogy naively expected, the HP vanishes near zero temperature owing to the Mott rule. Nonetheless, in (3+1)-D TSCs, the HP can be induced not by rotation but by a torsional magnetic field, which is described by the Lorentz-temporal part of the Nieh-Yan action.

References:

[1] R. D. King-Smith and D. Vanderbilt, Phys. Rev. B **47**, 1651 (1993).
[2] G. D. Mahan, *Many Particle Physics* (Kluwer Academic/Plenum Publishers, 2000).
[3] K. Nomura *et al*., Phys. Rev. Lett. **108**, 026802 (2012).
[4] A. Shitade, J. Phys. Soc. Jpn. **83**, 033708 (2014).