凝縮系物理学ゼミナール
Condensed Matter Seminar
Date: 13:30-15:00, Wednesday, 25 December 2024

Title: Anomalous thermal and spin transport in spin-triplet superconductors
Speaker: Dr. Taiki Matsushita (Condensed Matter Theory Group)

Abstract:

Spin-triplet superconductors are characterized by the spin 1 of Cooper pairs [1], offering platforms for novel superconducting spintronics phenomena [2]. At the same time, the spin-triplet superconducting order is a source of topological superconductivity [3], and its importance has grown significantly with the emergence of topological electronic materials. Spin-triplet superconducting orders have primarily been discussed in heavy fermion materials, but the shapes of the order parameters remain under debate. In this talk, we discuss responses to temperature gradients as potential probes of spin-triplet superconducting orders.

In the first half of this talk, we focus on chiral superconducting order, which is a key ingredient of time-reversal-symmetry-broken (TRSB) topological superconductors (TSCs), and discuss the anomalous thermal Hall effect (ATHE) as a unique property of these systems [3]. The ATHE has two distinct mechanisms: intrinsic (topological) and extrinsic (impurity-scattering) mechanisms [4,5]. The intrinsic mechanism of the ATHE relies on gapless Majorana boundary modes, ensuring the T-linear behavior of the zero-field thermal Hall conductivity at low temperatures. Remarkably, the intrinsic contribution to the thermal Hall conductivity is quantized in TRSB TSCs at low temperatures, providing a definitive probe of Majorana boundary modes [5]. To identify TRSB TSCs through thermal Hall measurements, the intrinsic ATHE should dominate over the extrinsic ATHE at low temperatures. However, whether the extrinsic contribution to the ATHE results in a T-linear contribution at low temperatures—and if so, how large it is—depends on the details of the disorder. We analyzed the ATHE to identify the dominant mechanism and found that the extrinsic ATHE dominates the thermal Hall response even at low temperatures if impurity bands lie near the Fermi energy and contribute to thermal transport [6], while the intrinsic mechanism governs the low-temperature behavior of the thermal Hall response in clean systems.

In the second half of this talk, we consider spin current responses in helical superconductors and nonunitary (spin-polarized spin-triplet) superconductors. Helical superconducting states represent two time-reversal copies of chiral superconducting states and thus realize time-reversal-invariant TSCs [3]. Here, we show that the helical (spin-dependent chiral) nature of the order parameters influences scattering events of quasiparticles at impurity sites via vertex corrections to the thermal current [7]. This introduces spin-dependent asymmetries in the scattering direction, inducing the spin Nernst effect, which is a spin current generation perpendicular to temperature gradients. In nonunitary superconducting states, the spin polarization of the condensate induces a spin current along temperature gradients [8]. Remarkably, the thermoelectric spin current survives in the Meissner state while the Meissner effect sharply suppresses the

thermoelectric charge current. We dub this the superconducting spin Seebeck effect. Our proposals of these spin current responses establish spin caloritronics as sensitive probes of the spin structure of spin-triplet superconducting order parameters.

References :

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