凝縮系物理学ゼミナール Condensed Matter Theory Seminar Date: 13:30-15:00, Wednesday, 4 June 2025

Title: Linear and Nonlinear Optical Responses in Topological Superconductors: Quantum Geometry and Collective Mode Speaker: Mr. Hiroto Tanaka Language: English

Abstract:

Optical measurements have revealed remarkable properties of superconductors. Recent progress in experimental techniques enables us to access nonlinear optical phenomena in superconductors. Nonlinear optics can detect the Higgs mode [1]. Another intriguing aspect of nonlinear optics is its close relation to quantum geometry in topological materials. The quantum geometric quantities, such as the Berry curvature and the quantum metric, give characteristic contributions to the superconducting nonlinear conductivities [2, 3].

Although the relationship between optical phenomena and the quantum-geometric properties has been focused on, the many-body effect on the quantum-geometric contribution to optical responses remains uncovered. In this study, we investigate the effects of collective modes on the linear and nonlinear optical responses in the promising platforms of topological superconductivity [4]. We also explore the possibility of nonlinear responses to detect topological superconductivity. This study focuses on photocurrent conductivity. Our numerical results demonstrate the sign reversal of the photocurrent conductivity at the topological transition.

To obtain the above results, we have developed a theoretical formulation of linear and nonlinear optical responses based on the Kadanoff-Baym method. Our formula leads to physically reasonable results of optical responses in a broad range of multiband superconductors. Optical responses would pave the way for investigating the interplay of quantum geometry and collective modes in superconductors.

References:

- R. Matsunaga *et al.*, Science **345**, 1145 (2014); R. Shimano and N. Tsuji, Annual Review of Condensed Matter Physics **11**, 103 (2020).
- [2] H. Watanabe et al., Phys. Rev. B 105, 024308 (2022).
- [3] H. Tanaka et al., Phys. Rev. B 110, 014520 (2024).
- [4] H. Tanaka and Y. Yanase, arXiv:2502.15373.