

Linear Higgs Mode Excitation enabled by Lifshitz invariants in Time-Reversal Symmetry Broken Superconductors

Chihiro Mamiya¹, Raigo Nagashima², and Naoto Tsuji^{1,3,4}

¹*Department of Physics, The University of Tokyo*

²*Institute for Theory of Condensed Matter, Karlsruhe Institute of Technology*

³*RIKEN Center for Emergent Matter Science (CEMS)*

⁴*Trans-Scale Quantum Science Institute, The University of Tokyo*

Time-reversal-symmetry-breaking (TRSB) superconductivity has attracted considerable attention, particularly in recently discovered multiband Kagome superconductors [1], whose origin of the TRSB is proposed to be orbital loop-current order state (Fig.1).

The Higgs mode, amplitude oscillations of the superconducting order parameter, is a valuable probe of superconductivity. In conventional settings, however, it does not couple linearly to light, and its observation is restricted to nonlinear response. Here, we propose a mechanism that makes the Higgs mode active in the linear-response regime.

Within Ginzburg-Landau theory, we introduce particle-hole even “type I” and odd “type II” Lifshitz invariants, taking form of $\psi_i^* \mathbf{D} \psi_j$ [2]. While the former enables linear excitation of the Leggett (relative phase) mode [3], the latter requiring TRSB induces a direct linear coupling between the Higgs mode and an external electromagnetic field.

We performed a group-theoretical classification that identifies all pairs of irreducible corepresentations of magnetic point group permitting the invariant. We further verify these predictions through microscopic calculations of the optical conductivity for several loop-current models, including a Kagome model.

Our results establish a general class of TRSB multiband superconductors with possibility of hosting an optically active Higgs mode in linear response and provide a framework for identifying symmetry-allowed Lifshitz invariants for other systems.

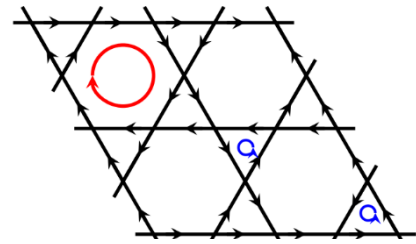


Fig.1: The isotropic Kagome model with loop current

[1] C. Mielke *et al.*, *Time-reversal symmetry-breaking charge order in a kagome superconductor*, Nature **602**, 245–250 (2022).

[2] RM, CM and NT, *Type II Lifshitz invariant and optically active Higgs mode in time-reversal symmetry broken superconductors*, arXiv:2604.15054 (2026).

[3] T. Kamatani *et al.*, *Optical response of the Leggett mode in multiband superconductors in the linear response regime*, PRB **105**, 094520 (2022).