

Highlights

RESEARCH AREA 3 - Quantum Science and technologies - 2024

Supercurrent rectification with time-reversal symmetry broken multiband superconductors

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This work investigates nonreciprocal supercurrent effects in Josephson junctions incorporating multiband superconductors that intrinsically break time-reversal symmetry. Using the Usadel formalism in the dirty limit, we demonstrate that supercurrent rectification—the superconducting diode effect—can be achieved without external magnetic fields through the synergy of interband phase mismatch, impurity scattering, and phase frustration. In two-band systems, interband impurity scattering is shown to be a critical control parameter, where its interplay with the interband phase relation determines both the amplitude and sign of the rectification. For three-band superconductors, multiband phase frustration generates complex, nonsinusoidal current-phase relations. A central finding, illustrated in Figure 1, is that the rectification amplitude in the interband phase space is defined by a unique hexagonal pattern of nodal lines where the diode effect vanishes. We show that this nodal structure and the surrounding threefold regions of alternating rectification sign are highly sensitive to the relative tunneling amplitudes of each band. These results provide distinct hallmarks for identifying spin-singlet multiband superconductivity with spontaneous time-reversal symmetry breaking.

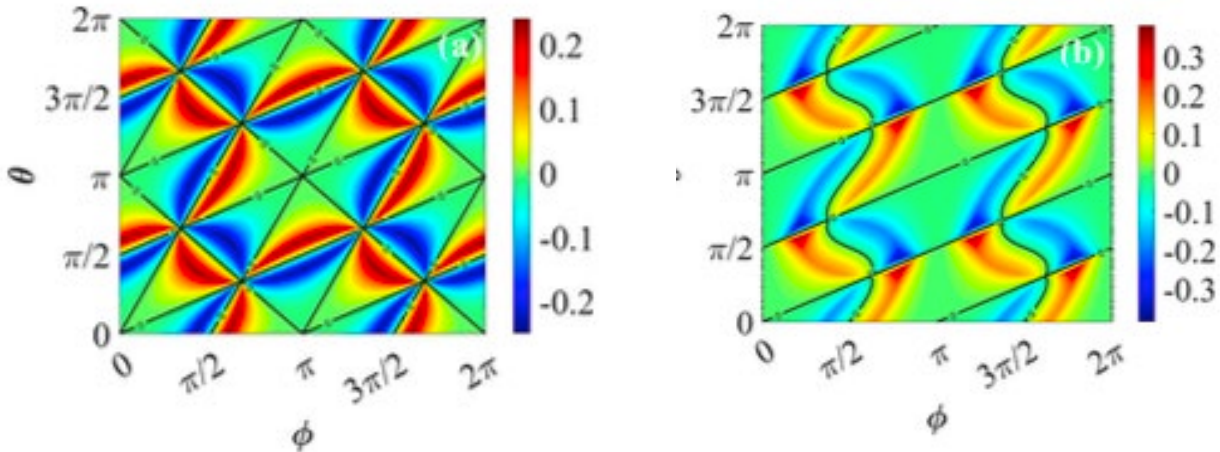


Fig. 1: Diode rectification amplitude of the Josephson junction between a single-band and a three-band superconductor as a function of phase differences in a three-band superconductor for different (a) $R_{N1} = R_{N2} = R_{N3}$, (b) $R_{N1}/R_{N2} = 1$, $R_{N1}/R_{N3} = 2$, at zero temperature. R_{Ni} are contributions to the junction's resistance for each band channel.