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Current phase relation in WTe2-based Josephson junctions

WTe2, a transition metal dichalcogenide with large spin-orbit interactions, is predicted to have striking topological properties that combine type II Weyl semimetal character with second-order 3D topological insulator (SOTI) character. SOTIs are characterized by topologically protected (insensitive to disorder) helical 1D states at their hinges. 1D states located at certain edges of multilayer WTe2 have indeed been demonstrated in Josephson interferometry experiments. However, their ballistic nature was not tested.
We have designed WTe2-based Superconducting Quantum Interference Devices (SQUIDs) in which the supercurrent through the junction close to one edge of the crystal interferes with the supercurrent far from the edge.. Depending on the geometry of the junction along the edge, the SQUID oscillations are dominated by the contributions of either the bulk states or the edge states. In the case where a large number of bulk states are contacted by superconducting electrodes in both junctions, we observe sinusoidal SQUID-like oscillations whose amplitude is modulated by orbital interferences between diffusive trajectories delocalised in the whole bulk of the junctions. This interference pattern has been investigated in the three magnetic field directions. On the special case where only few edge states are contacted in the junction along the edge, the strongly asymmetric SQUID pattern is dominated by the contribution of the current-phase relation of those edge states and exhibits a sawtooth shape. This shape is a tell-tale sign that the supercurrent through the edge flows ballistically over 600 nm (which is ten times the estimated normal state mean free path) and is due to the SOTI character of WTe2.

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