**Boundary supercurrent and continuous non-integer Shapiro steps in NiTe2-based Josephson junctions**
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Topological materials with boundary (surface/edge/hinge) states have attracted tremendous research interest. Additionally, unconventional (obstructed atomic) materials have recently drawn lots of attention owing to their obstructed boundary states. Experimentally, Josephson junctions (JJs) constructed on materials with boundary states produce the peculiar boundary supercurrent, which was utilized as a powerful diagnostic approach. Here, we report the observations of boundary supercurrent in NiTe2-based JJs [1]. Particularly, applying an in-plane magnetic field along the Josephson current can rapidly suppress the bulk supercurrent and retain the nearly pure boundary supercurrent, namely the magnetic field filtering of supercurrent. Further systematic comparative analysis and theoretical calculations demonstrate the existence of unconventional nature and obstructed hinge states in NiTe2, which could produce hinge supercurrent that accounts for the observation.

Moreover, we report the observation of continuous non-integer Shapiro steps in NiTe2-based JJs. The inverse AC Josephson effect produces quantized voltage Shapiro steps in microwave-driven JJs, foundational to modern quantum metrology and topological superconductivity research. While three established step types are recognized—integer (σ=1, 2...), even-integer (σ=2, 4...), and fractional (σ=1/2, 1/3...)—we report a fourth category of continuously tunable non-integer steps (σ∈ℝ) in NiTe2-based superconductor-normal-superconductor (SNS) JJs. Through microwave power-dependent measurements, we demonstrate three characteristic regimes: (i) First, a downward shift of all Shapiro steps by integer steps at low power. (ii) Subsequently, emergence of a new step from zero voltage followed by continuous upward evolution of all steps with increasing power, revealing continuously tunable steps (σ). (iii) Finally, complete restoration of canonical integer steps at high power. The dependence on frequency and temperature is further systematically examined. We propose that these observations could be attributed to the nonequilibrium charge imbalance effect at the S/N interface, with simulations providing qualitatively consistent results.

[1] T. Le et al., Nature Commun. 15, 2785 (2024).