Half-integer Shapiro Steps in Highly Transmissive InSb Nanoflag Josephson Junctions

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High-quality III–V narrow bandgap semiconductor materials with strong spin–orbit coupling and large Landé g-factor provide a promising platform for next-generation applications in the field of high-speed electronics, spintronics, and quantum computing. InSb stands out due to its narrow bandgap, high carrier mobility, and small effective mass, making it very appealing in this context. In fact, this material has attracted tremendous attention in recent years for the implementation of topological superconducting states. An attractive pathway to obtain two-dimensional (2D) InSb layers is the growth of freestanding single–crystalline InSb nanoflags [1].

We demonstrated fabrication of ballistic Josephson-junction devices based on these InSb nanoflags with Ti/Nb contacts that show gate-tunable proximity-induced supercurrent and sizable excess current [2]. The devices show clear signatures of subharmonic gap structures, indicating phase-coherent transport in the junction and a high transparency of the interfaces.

The high quality of the devices enabled the observation of the Josephson diode effect in these Josephson junctions [3]. When subjected to an in-plane magnetic field, these devices enter a non-reciprocal transport regime, manifesting an asymmetry between positive and negative critical currents, as illustrated in Fig. 1(a). The degree of asymmetry varies with the angle between the in-plane field and the current direction, exhibiting a pronounced temperature dependence. Our data demonstrate that these devices can work as Josephson diodes, with dissipation–less current flowing in only one direction. Under microwave irradiation, we observe half-integer Shapiro steps (see Fig. 1(b)) that are robust to temperature, suggesting their possible nonequilibrium origin [4]. Our results demonstrate the potential of ballistic InSb nanoflag Josephson junctions as a valuable platform for understanding the physics of hybrid devices and investigating their nonequilibrium dynamics.

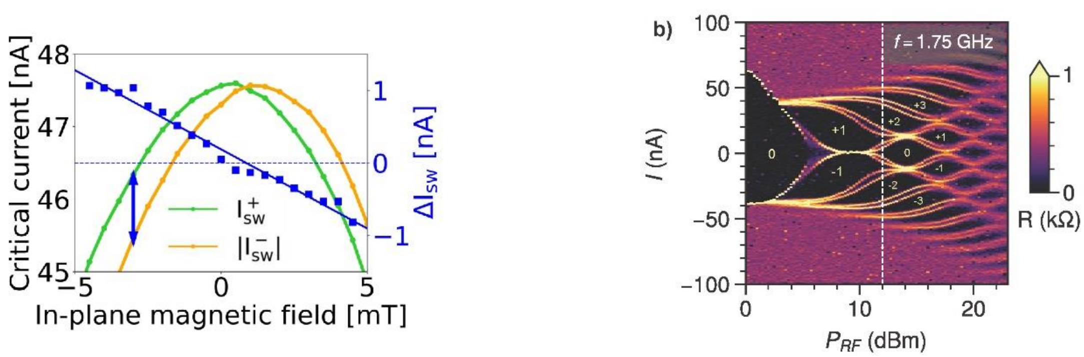

Fig.1. (a) Switching current dependence on in-plane magnetic field. The switching current demonstrates a clear asymmetry between the positive and negative branch, shown in green and orange, respectively. The negative branch is higher for positive values of the magnetic field, and the relation is reversed for negative field. The panel also shows that $\Delta I_{sw} = I_{sw}^{+} - |I_{sw}^{-}|$ changes linearly with in-plane magnetic field around $B_{ip} = 0$. The blue arrow visualizes ΔI_{sw}. (b) Evolution of the differential resistance R as a function of current bias I and microwave power P_{RF} at f = 1.75 GHz. Pairs of bright peaks indicate the presence of half-integer steps. Label numbers refer to the corresponding step index n.)

References

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