Half-integer Shapiro steps in highly transmissive InSb nanoflag Josephson junctions

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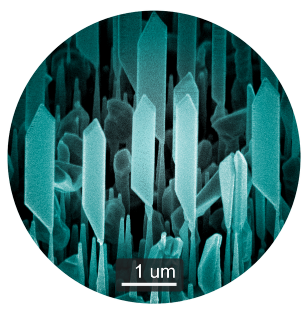
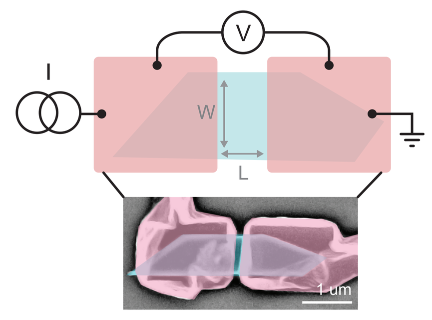
MATERIALS & PLATFORM

We study a hybrid semiconducting - superconducting Josephson junction composed of an InSb nanoflag with Nb contacts. Free-standing InSb nanoflags appear to be a highly flexible platform since they can be grown without defects on lattice-mismatched substrates, while still offering a narrow bandgap, strong Rashba spin-orbit coupling, and a large g-factor of InSb.[1]

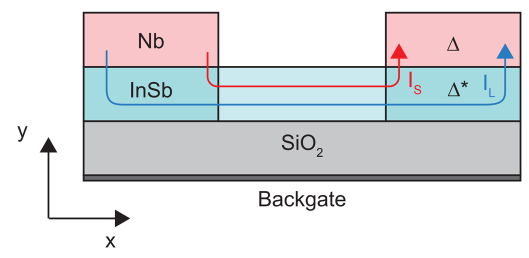


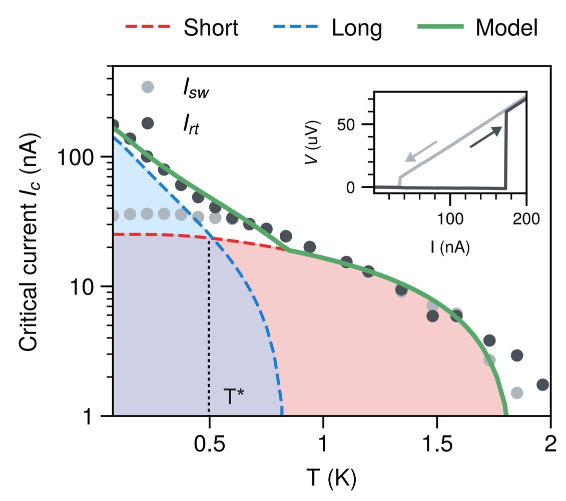


Left: SEM image of free standing InSb nanoflags.
Right: a simplified schematic of the device
(L ~ 80 nm, W ~ 650 nm)

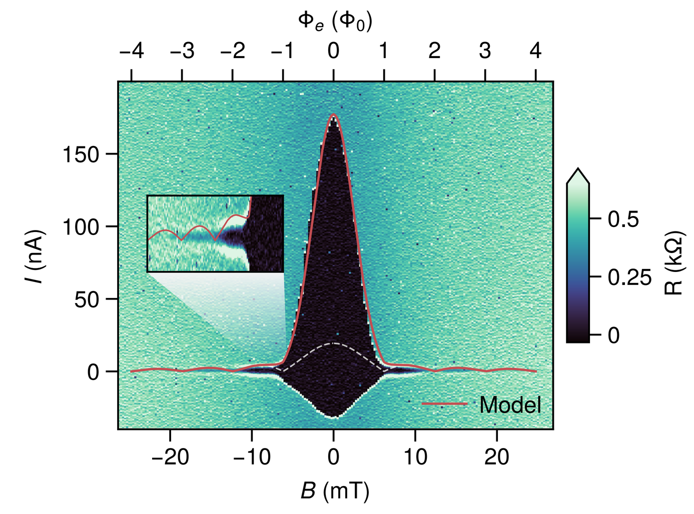
TRANSPORT

Our device features two dominant channel contributions: short and long, as schematized on the right side. Their presence is indicated by the temperature dependence of the supercurrent and the magnetic interference maps.





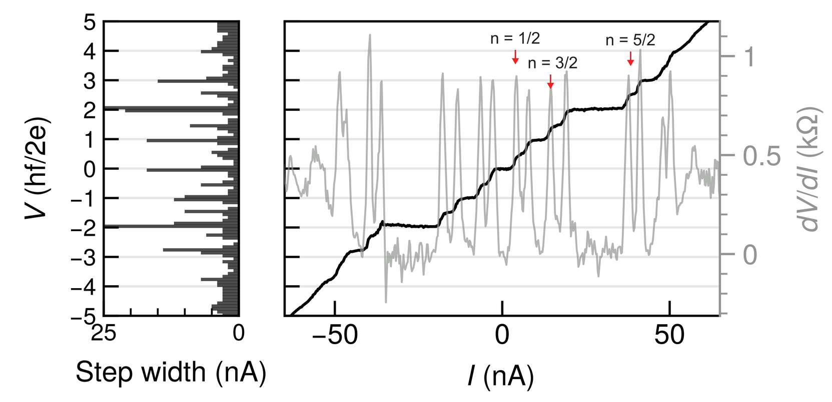
Temperature dependence of the switching current (black dots) and the retrapping current (grey dots). The green line represents the sum of the channels contributions.



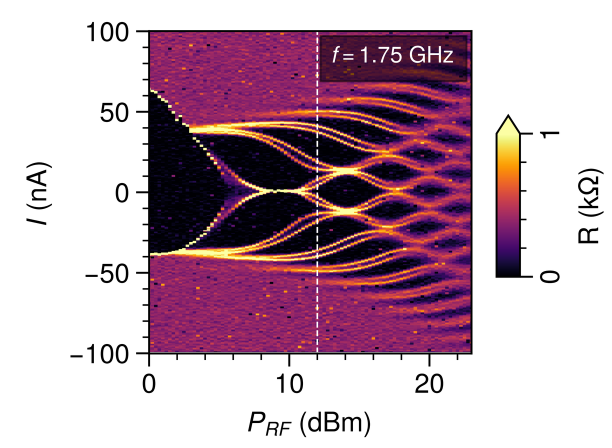
Magnetic interference map. The red curve takes into account both the long and short contributions. The grey line shows the pattern resulting from the short channel only.

HALF-INTEGER SHAPIRO STEPS

In the presence of microwave irradiation, Shapiro steps appear in the *V(I)* characteristic due to the phase locking of the junction to the external drive frequency. They have a quantized amplitude of $V = nhf/2e$ with n an integer in a Josephson junction with a sinusoidal current-phase relationship (CPR). In our system, strong half-integer steps are visible and cannot be explained solely by the additional harmonics of the skewed CPR that we expect.

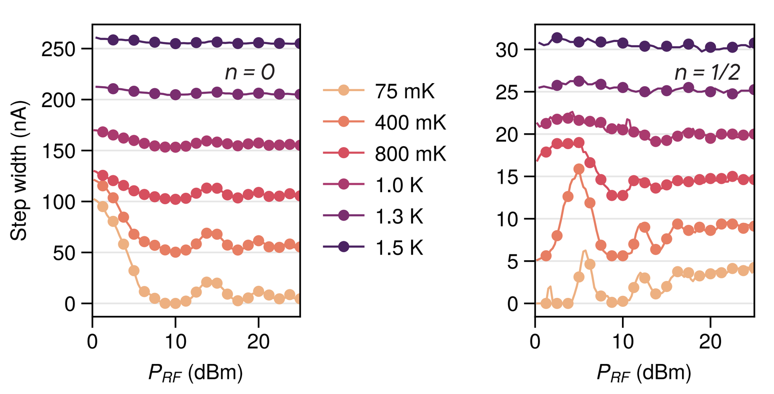


The black line (V) and the grey trace (dV/dI) feature both integer (n = 1, 2, 3, ..) and half-integer (n = 1/2, 3/2, 5/2, ...) steps. The histogram on the left provides an immediate visualization of the step width.

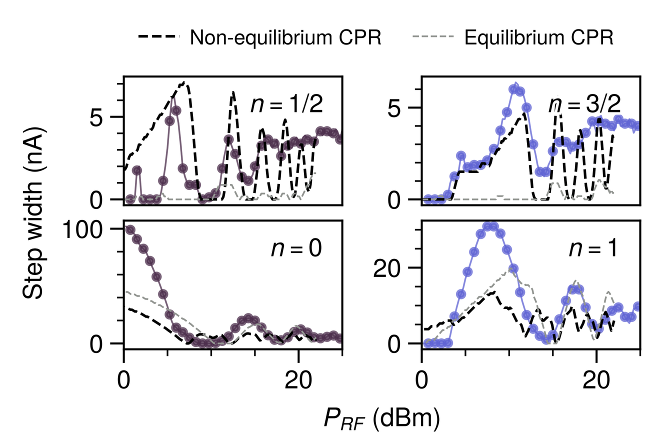


The full color plot shows bright peak pairs, stark evidence of fractional steps occurring over a wide range of powers up to the step *n = 7*.

NON-EQUILIBRIUM SUPERCURRENTS



Temperature evolution of the step width for the step n=0 and n=1/2, with exponential suppression of the former and non-monotonic decay of the latter.



Amplitudes of integer and half-integer step widths are compared to simulations with non-equilibrium and equilibrium CPRs. Only the formers capture the presence of half-integer steps.

The observed half-integer Shapiro steps indicate a CPR with a second harmonic stronger than the first one. In SNS junctions, this CPR can be realized when a non-equilibrium population of Andreev states is excited.[2] The non-monotonic temperature dependence of the half-integer steps further suggests non-equilibrium supercurrents.[3] However, when compared to existing theories, the observed phenomenology is only partially captured across the full range of microwave powers and temperatures that we investigated.

CONCLUSIONS

Our findings highlight the importance of non-equilibrium effects in hybrid Josephson junctions and underscore the potential of InSb nanoflags as a hybrid platform for coherent microwave manipulation of Andreev states. Nevertheless, further research is needed to better understand the origin of the strong half-integer steps observed.

Bibliography
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