Local parity flipping Andreev transitions

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The application of cQED techniques is a convenient approach to probe hybrid superconductor-semiconductor devices: it allows non-invasive manipulation of their quantum states and enables sensing features complementary to those provided by transport measurements.

For instance, microwave spectroscopy has been recently used to map the phase diagram of a quantum dot Josephson junction, where the competition between the induced superconducting correlations and the Coulomb repulsion determines the boundaries between a singlet and a doublet ground state [1]. Here, we analyse microwave measurements of an InAs hybrid nanowire Josephson junction close to the pinch-off (depletion of electrons). As in the case of the quantum dot, the frequency shift of a resonator coupled to the system [2,3] indicates singlet/doublet alternation over certain gate voltage range. Surprisingly, the corresponding microwave induced transitions display sharp dips reaching zero energy close to the phase boundaries, suggesting these transitions connect the singlet (even parity) and the doublet (odd parity): while parity flipping transitions are typical in transport experiments (*e.g.* [4]), they are forbidden when induced by microwave radiation, which can only excite a quasiparticle or break a Cooper pair to create two of them.

We show that these transitions can be theoretically understood by means of an additional localized state isolated in the junction [5], which acts as a reservoir for an electron, thus allowing a local parity flip in the main subsystem.

References

[1] A. Bargerbos, M. Pita-Vidal *et al.*, PRX Quantum **3** 030311 (2022).
[2] C. Metzger, Sunghun Park, L. Tosi *et al.*, Phys. Rev. Research **3**, 013036 (2021)
[3] Sunghun Park, C. Metzger, L. Tosi *et al.*, Phys. Rev. Lett. **125**, 077701 (2020)
[4] J. D. Pillet *et al.*, Nat. Phys. **6**, 965–969 (2010)
[5] Similar model proposed in H. Barakov and Y. Nazarov, arXiv:2201.07848; based on data from V. Levajac, J. Y.Wang, L.P. Kouwenhoven *et al.*

Figures

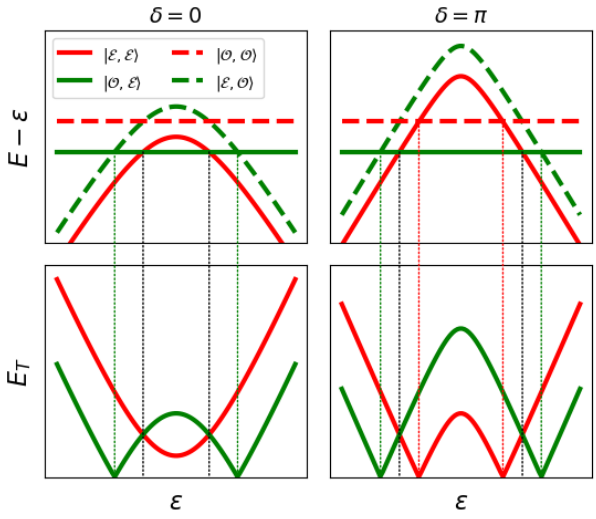

Figure 1: Model of the junction and the ancillary level, at a fixed phase difference δ. Top: energies of the many-body states with even/odd parity in each subsystem. Bottom: corresponding allowed transitions.

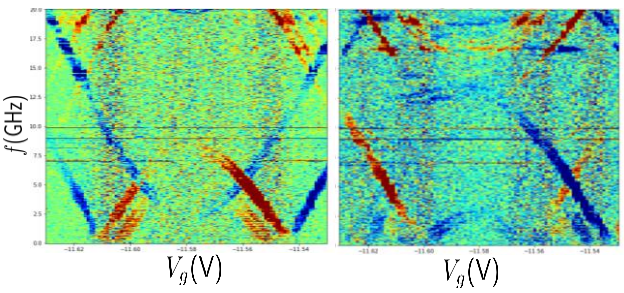

Figure 2: Two-tone spectroscopy over gate.