Towards Andreev molecules in semiconducting nanowires

[1]Vittorio Buccheri
[1]Ivo Cools, [2]Thomas Kanne, [2]Jesper Nygård, [1]Simone Gasparinetti, [1]Attila Geresdi.

[1]Department of Microtechnology and Nanoscience. Chalmers University of Technology, SE, 41296, Göteborg, Sweden.

[2]Center for Quantum Devices, Niels Bohr Institute, University of Copenhagen, DK-2100 Copenhagen, Denmark.

buccheri@chalmers.se

Semiconducting Josephson junctions have recently attracted attention due to the interesting physics they present as a combination of superconducting and semiconducting properties [1] and, particularly, for their suitability in Quantum Information [2, 3, 4]. The main role in this kind of devices is played by the Andreev bound states, which are fermionic modes created in the weak link as a consequence of electron-hole Andreev reflections at the semiconductor-superconductor interfaces. It has been experimentally proven that Andreev bound states in a single semiconductor Josephson junction can be coherently addressed and used to realize a quantum bit [5, 6, 7]. Such a result pushes towards the investigation of devices with two or more weak links hosting coupled Andreev bound states, the so-called Andreev molecules [8, 9].
In this talk, I present characterization measurements on a device in which a semiconducting nanowire hosting two junctions is coupled to a superconducting resonator in a rf-SQUID configuration.
We control the chemical potential in the weak link and the superconducting phase across the nanowire via electrostatic gates and external magnetic field, respectively.
We demonstrate strong coupling between the resonator and an Andreev bound state by single-tone and two-tone spectroscopy measurements. I conclude by presenting preliminary results towards independent control of individual Andreev bound states in a 2-junction device.

References

[1] E. Prada, P. San-Jose, M.W.A. de Moor et al. From Andreev to Majorana bound states in hybrid superconductor–semiconductor nanowires. Nat Rev Phys 2, 575–594 (2020).
[2] M.A. Desposito and A. Levy Yeyati, Controlled dephasing of Andreev states in superconducting quantum point contact. Phys. Rev. B, 64, 140511(R) (2001).
[3] G. Wendin and V.S. Shumeiko, Quantum bits with Josephson junctions (Review Article). Low Temp. Phys. 33(9), 724-744 (2007).
[4] C. Padurariu and Yu. V. Nazarov. Theoretical proposal for superconducting spin qubits. Phys. Rev. B 81, 144519 (2010).
[5] C. Metzger, S. Park, L. Tosi, et al., Circuit-QED with phase-biased Josephson weak links. Phys Rev. Res. 3, 013036 (2021).
[6] M. Hays, V. Fatemi, D. Bouman, et al. Coherent manipulation of an Andreev spin qubit. Science, 373, 430 (2021).
[7] M Hays, G. de Lange, K. Serniak et al., Direct Microwave Measurement of Andreev-Bound-State Dynamics in a Semiconductor-Nanowire Josephson Junction. Phys. Rev. Lett. 121, 047001 (2018).
[8] O. Kürtössy, Z. Scherübl, G. Fülöp et al., Andreev Molecule in Parallel InAs Nanowires. Nano Lett., 21, 7929-7937 (2021).
[9] D.Z. Haxell, M.Coraiola, M. Hinderling et al., Demonstration of the Nonlocal Josephson Effect in Andreev Molecules. Nano Lett., 23, 7532-7538 (2023).