Thermoelectric effects in double-nanowire superconducting islands.

Pablo Burset Atienza (pablo.burset@uam.es)
Alfredo Levy Yeyati (a.l.yeyati@uam.es)
Departamento de Física Teórica de la Materia Condensada.

The performance of electronic circuits can be improved transforming the unavoidable waste heat they generate into useful electricity, or work. In non-quantum devices, such thermoelectric energy harvesting is usually hindered by a very inefficient heat-to-work conversion. As electronic components are miniaturized to the nano scale, quantum coherence can help overcome this limitation and provide highly efficient heat engines.

Superconducting hybrid junctions are very good platforms to implement quantum-coherent thermoelectric devices since the energy-dependent density of states in a superconductor facilitates strong thermoelectric effects. Then, breaking the electron-hole symmetry by some mechanism can generate charge currents from temperature gradients or heat flows from electric potentials [1,2].

In this project, we will explore double-nanowire superconducting islands with multiple terminals, see figure. The strong spin-orbit interaction in each nanowire and the coupling between parallel ones become the key ingredients that break electron-hole symmetry. Moreover, the double-nanowire island is gate tunable and accessible by multiple terminals. Consequently, this platform offers very versatile spin-filtering effects, where an external magnetic field can switch between different spin filter directions in a controlled fashion [3]. Double nanowire superconducting islands have recently been experimentally implemented, see figure, and are the focus of an intense research activity for their potential applications as qubit devices or platforms for topological superconductivity.

The goals of this project are <u>(i) to theoretically describe charge and energy transport in a double-nanowire superconducting island and (ii) to explore the influence of quantum effects on the efficiency of the resulting thermal engines</u>. During your research, you will apply scattering theory to study quantum transport in the presence of superconducting correlations in a system that couples the electron spin, charge, and energy (or heat) degrees of freedom. You will also familiarize yourself with the concepts of quantum entanglement, phase-coherent transport, and topology in condensed matter systems.

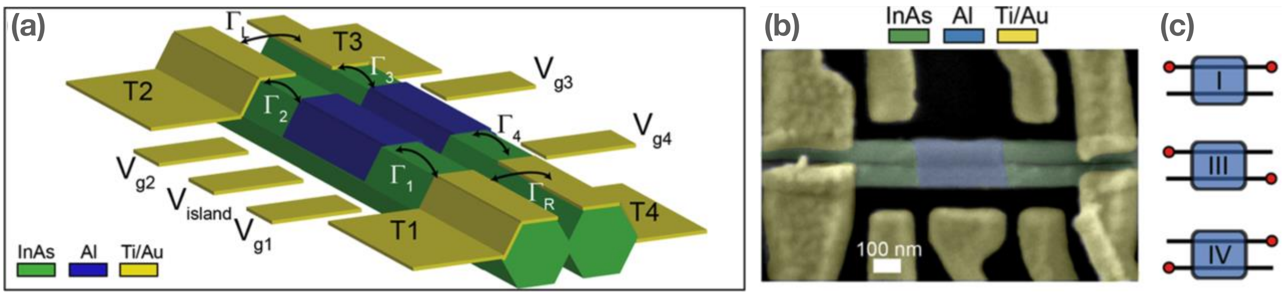

Figure. (a) Sketch of a multi-terminal double-nanowire superconducting island device. (b) Scanning electron microscope image of a functional device. (c) Schematic illustrating different configurations.

[1] R. Sánchez, P. Burset, A. Levy Yeyati. *Cooling by Cooper pair splitting*. Phys. Rev. B **98**, 241414(R) (2018).

[2] F. Keidel, S-Y. Hwang, B. Trauzettel, B. Sothmann, P. Burset. *On-demand thermoelectric generation of equal-spin Cooper pairs*. Phys. Rev. Research **2**, 022019(R) (2020).

[3] A. Vekris, J. C. Estrada-Saldaña, T. Kanne, T. Hvid-Olsen, M. Marnauza, D. Olsteins, M. M. Wauters, M. Burrello, J. Nygård, K. Grove-Rasmussen, *Electronic Transport in Double-Nanowire Superconducting Islands with Multiple Terminals*, Nano Letters **22**, 5765 (2022).