Master /PhD thesis Project

Hybrid superconductor-semiconductor for parity protected qubit

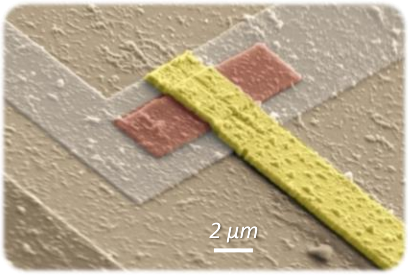

Fig. 1: Colorized SEM micrograph of a S-Sm nanostructure. Light gray shows superconducting Al, yellow normal metal Ti/Au gates and red semiconducting Ge.

Hybrid Superconductor – Semiconductor (S-Sm) nanostructures are nano-circuits which combine superconducting and semiconducting materials. Such devices take advantage, first from the superconductivity that is a macroscopic quantum effect and can be viewed here as a quantum coherence provider –needed ingredient to create a quantum bit or qubit. Second, from the semiconducting properties that allow changing the amount of carriers using an electrostatic gate – like in a field effect transistor (FET).

Our research focuses on hybrids made from aluminum-germanium nanostructure that we fabricate in our academic cleanroom, see Fig. 1. In a nutshell, our samples consist of a loop interupted by two hybrids nanostructures. By studying the multi-harmonicity of their current response to an applied magnetic field, we observed that only the transport of an even number of Cooper pair is allowed [1,2]. Such property is the building block to a type of protected qubit, the parity protected qubit [3].

The aim of this project is to incorporate our hybrid nanostructure in a circuit Quantum ElectroDynamics (cQED) architecture, a well-known and heavily used architecture in superconducting quantum information, to explore its properties as a qubit. For this integration, we leverage our long-term collaboration with the CEA - LETI and use advanced flip-chip integration, where two quantum chips of different nature are coupled together, see Fig. 2.

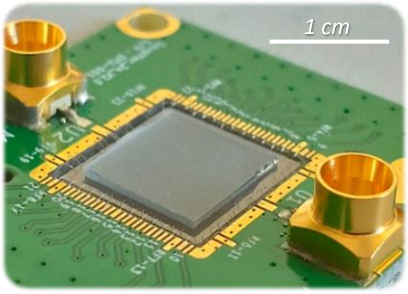

Fig. 2: Home-made PCB with a flip-chip sample micro-bonded in its center for microwave and DC measurement at cryogenic temperature.

The final sample will be probed at cryogenics temperature in state-of-the-art DC and microwave measurement setup.

During the master project, you will collaborate on a daily basis with our entire team (www.lateqs.fr) with 30 people including 15 Ph.D. You will participate to the development of new samples that includes design, theory and nano-fabrication performed in our cleanroom facility. You will also learn to cool down samples to reach cryogenic temperatures and you will perform measurements using state-of-the-art DC and RF techniques.

This master project may continue as a PhD thesis.

[1] Phys. Rev. Research 6, 033281, **2024**
[2] arXiv:2405.14695, **2024**
[3] npj Quantum Information, 6, **2020**

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