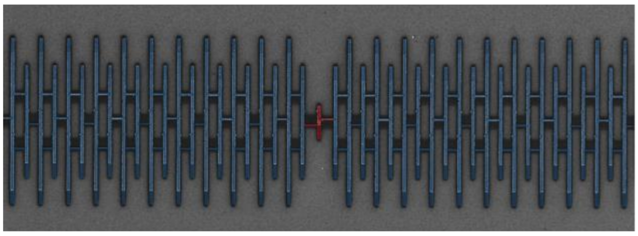
NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2022-2023

Probing a quantum phase transition using superconducting qubits

General Scope: One of the present leading technologies for the realization of a universal quantum computer is based on *superconducting quantum circuits*. It exploits superconducting circuits based on Josephson junctions, which are characterized by quantized energy levels and for this reason can be adopted as quantum bits (qubits), the basic units of quantum information. While high quantum coherence has been demonstrated for systems containing a few number of qubits, a full-fledge quantum computer will require the interconnection and manipulation of hundreds of highly coherent qubits. This obviously imposes very challenging engineering issues.



Quantum simulator we recently developed [1,2]. A quantum bit (in red) couples to a superconducting metamaterial (in blue). This metamaterial hosts as many as 100 propagating electromagnetic modes, which are all strongly coupled to the qubit. This forms a complex many-body system, that could display a localized-delocalized quantum phase transition.

Our team focuses on the fabrication and characterization of machines called quantum simulators [1,2], which are dedicated to a given class of physical problems (e.g. quantum impurities, Hubbard models...). The required building blocks (quantum bits) as well as the control electronics are similar to the one of the universal quantum computer but since universality is not required, the overhead developments are less stringent. As such, these simulators allow us to address complex many-body problems with an experimental platform much simpler than a universal quantum computer. More specifically a localized/delocalized quantum phase transition has been strongly debated since the seminal work of Schmid in 1983 [3]. This Master project aims at setting-up a superconducting qubit experiment to shed new light on this phenomenon.

[1] Observation of quantum many-body effects due to zero point fluctuations in superconducting circuits, S. Léger et al. *Nature Communications* **10**, 5259 (2019). [2] Measuring the finite-frequency response of a bosonic quantum impurity, S. Léger et al. arXiv:2208.03053 [3] Diffusion and Localization in a Dissipative Quantum System, A. Schmid, *Physical Review Letters* **51**, 1506–1509 (1983).

Research topic and facilities available: The quanteca team specializes in the coherent control and manipulation of superconducting quantum circuits. The student will use state-of-the-art setups combining very low temperatures (around 10 mK), fast electronics and quantum-limited microwave detection chains. The devices are fabricated in the clean room of the Neel Institute (Nanofab).

Possible collaboration and networking: Our team is part of several national and international networks. For this specific project we are collaborating closely with Serge Florens at the Néel Institute, Denis Basko at LPMMC and with Izak Snyman at the University of Witwatersrand in Johannesburg, South Africa.

Possible extension as a PhD : Yes. This project is funded by the European Union.

Required skills: Master 2 or Engineering degree. We are seeking motivated students who want to take part to a state-of-the-art experiment and put some efforts in the theoretical understanding of many-body physics using superconducting quantum circuit.

Starting date : Spring 2023

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