Master 2 theoretical internship proposal

Subject: Theory of Josephson junction lasers in superconducting circuit QED

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Superconducting circuits are a promising platform for quantum engineering. They have many applications ranging from amplifiers and detectors to quantum computers and quantum metrological standards. Superconducting circuits are also used in fundamental science, as they can simulate paradigmatic models of quantum many-body physics and quantum electrodynamics.

One example of fundamental effects is **lasing** that has been observed for a small nonlinear driven quantum system (a voltage-biased Josephson junction) coupled to a microwave photonic bath (a multi-mode superconducting resonator) [1]. Recently, an experiment at Néel Institute showed that a similar system could also end up in a thermal rather than coherent state [2].

The task now is to develop a theory which could describe the transition between coherent and thermal states of the resonator. On the semiclassical level, we have to describe a transition between regular and chaotic motion of a complex dynamical system. On the quantum level, we face the problem of thermalization or its absence in a driven-dissipative quantum many-body system.

The first step, which is **the subject of this internship**, will be to take the coherent lasing solution, found in the theoretical work [3] for a $\lambda/2$ resonator used in the experiment [1], and check if an analogous solution can be constructed for a $\lambda/4$ resonator used at Néel Institute. This work will necessarily involve both analytical and numerical calculations.

This internship work can be continued as Ph.D.

Necessary background: quantum mechanics, classical dynamical systems

Bibliography: [1] M. C. Cassidy et al., "*Demonstration of an ac Josephson junction laser*", Science **355**, 939 (2017).
[2] S. Cailleaux et al., to be published.
[3] S. H. Simon and N. R. Cooper, "*Theory of the Josephson Junction Laser*", Phys. Rev. Lett. **121**, 027004 (2018).