Master 2: *International Centre for Fundamental Physics*

INTERNSHIP PROPOSAL

Keywords: experimental physics, quantum computing, superconducting circuits

Laboratory name: LPENS
CNRS identification code: UMR 8023
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Internship location: ENS 24 rue Lhomond 75005
Thesis possibility after internship: YES
Funding: YES (Alice&Bob)

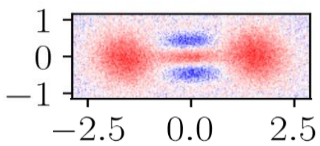
Quantum computing with driven-dissipative superconducting circuits

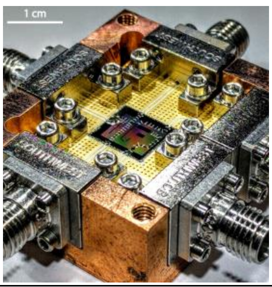
Quantum systems can occupy peculiar states, such as superposition or entangled states. These states are intrinsically fragile and eventually get wiped out by inevitable interactions with the environment. Protecting quantum states against decoherence is a formidable and fundamental problem in physics, which is pivotal for the future of quantum computing.

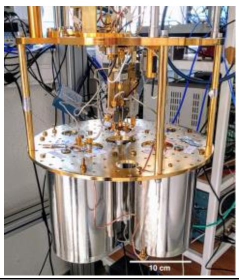
In recent years, and in collaboration with the startup Alice&Bob, we have developed a new type of quantum bit (qubit), coined the cat-qubit. The cat-qubit is encoded in a superconducting circuit that is rf-powered, continuously exchanging pairs of photons with a reservoir [1]. We have demonstrated that this mechanism endows the cat-qubit with exponential protection against bit-flip errors [2], reaching up to ten seconds of bit-flip time [3]. However, qubits are only useful if they can interact with eachother.

The goal of this internship, that is a first step towards a PhD in collaboration with Alice&Bob, is to **implement a two-cat-qubit gate**. The outstanding challenge is that this gate must not break bit-flip protection. If this challenge is met, we will have demonstrated all the building blocks to implement a fully protected logical qubit. The candidate will work on qubit design, mounting chips in a cryogenic setup, and data acquisition and analysis.

1. Z. Leghtas *et al.* Confining the state of light to a quantum manifold by engineered two-photon loss. **Science** 347, 853-857 (2015).
2. R. Lescanne *et al.* Exponential suppression of bit-flips in a qubit encoded in an oscillator. **Nature Physics** volume 16, pages 509–513 (2020).
3. U. Réglade & A. Bocquet *et al.* Quantum control of a cat-qubit with bit-flip times exceeding ten seconds. In review in Nature (2023). Preprint arXiv:2304.01425.







Condensed Matter Physics: **YES** Macroscopic Physics and complexity: NO
Quantum Physics: **YES** Theoretical Physics: NO