INSTITUT NÉEL Grenoble

Topic for Master 1 internship – Academic year 2024-2025

Probing gravitational decoherence with a nanomechanical wire coupled to a fluxonium qubit

General Scope: Understanding the interplay between quantum mechanics and general relativity is one of the greatest challenge in today's research in physics. Various models have been proposed to unify gravitation and quantum theories, and it is now crucial to find experimental ways to test these models. Among the prospects, it has been proposed to look for decoherence induced by gravitational effects if a massive object can be prepared in a quantum (non-classical) state of position [1]. The ambition to prepare a macroscopic object in a quantum state could appear unrealistic, but it has recently become possible thanks to the recent breakthroughs in superconducting quantum circuits and nanomechanical systems.

The idea is to use a superconducting qubit to gain quantum control over a massive mechanical oscillator [2]. One of the challenges in such experiments is that the low frequency of the oscillator, typically in the Megahertz range, prevents efficient control using conventional qubits that operate in the Gigahertz range. Fluxonium qubits working at such low frequencies have been recently developed, and record coherence times have been demonstrated [3]. Such fluxonium qubits are therefore ideal candidates to control massive mechanical oscillators. The general aim of this project is to couple a low frequency fluxonium qubit with a nanomechanical superconducting wire, in order to prepare highly non-classical states of position and start testing gravitational effects.

Research topic and facilities available: We aim to realize a fluxonium qubit with state-of-the-art coherence times in small but significant in-plane magnetic fields (mT), along with high-Q nanomechanical wires. The student will learn how to design, fabricate and operate a sub-GHz fluxonium qubit at cryogenic temperatures (tens of mK). We will characterize how the coherence properties of this qubit depend on the magnetic field amplitude and orientation, and on the qubit design. If time permits, we will start investigating the behavior of nanomechanical superconducting wires.

The fabrication will take place in the clean room of the Néel institute using state-of-the-art techniques such as electron beam lithography. The cryogenic microwave measurements will be performed in a dilution refrigerator equipped with ultrafast electronic control systems.

References

[1] M. F. Gely and G. A. Steele, AVS Quantum Science (2021)
[2] X. Ma., J. J. Viennot et al., Nature Physics (2021)
[3] A. Somorrof, Q. Ficheux et al., Phys. Rev. Lett (2023)

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