Towards quantum control of an ultracoherent mechanical resonator with a fluxonium qubit

Himanshu Patange
L. Najera, R. Rousseau, K. Gerashchenko, T. Jacqmin, S. Deléglise

Laboratoire Kastler Brossel, CNRS, Collège de France, Sorbonne University
4 Place Jussieu, 75005 Paris, France

himanshu.patange@lkb.upmc.fr

Superconducting quantum circuits are one of the most promising platforms for the realization of a scalable quantum computer. On the other hand, owing to recent advances in phononic engineering, chip-scale mechanical resonators with lifetimes in excess of 100 s have been recently demonstrated [1]. These macroscopic mechanical systems, typically vibrating at MHz frequencies have a coherence time in the second range in a thermal environment at 10 mK. Interfacing an ultra-coherent macroscopic mechanical resonator with a superconducting qubit would be a remarkable breakthrough: from the point-of-view of quantum computing, such a hybrid platform would enable a 3-orders of magnitude boost in coherence time. Furthermore, mechanical resonators could play an important role as quantum transducers, connecting superconducting circuits and optical photons [2]. On a more fundamental perspective, such a hybrid platform would be ideal to test gravitational collapse models in an unprecedented regime [3]. One of the biggest challenges consists in bridging the frequency gap between these resonators that typically oscillate below 10 MHz, and superconducting qubits in the GHz domain. Our approach is to overcome the frequency gap between this mechanical object and superconducting quantum circuits by coupling the former to a cutting-edge superconducting circuit: the fluxonium qubit [4]. This highly non-linear circuit is composed of a Josephson junction shunted by a large inductance in the high-impedance regime and has recently outperformed the transmon architecture, which constitutes the current quantum computing standard. Opportunely, the frequency of the qubit manifold in the heavy fluxonium regime naturally matches the mechanical resonance frequency of the ultracoherent mechanical membranes envisioned in this project. Furthermore, the large capacitive shunt of the heavy fluxonium is also ideally suited for a capacitive coupling scheme to the mechanical system.

In this talk, I will present results obtained on phononic crystal membrane resonators and the fluxonium qubit, and the flip chip assembly which is required to couple the two systems.

Figures

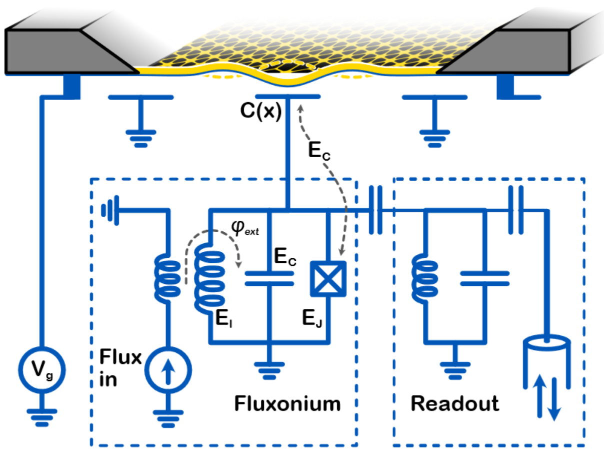

Figure 1: Flip chip assembly with the aim to capacitively couple the mechanical membrane with the fluxonium qubit.

References

[1] Y. Tsaturyan, et al. Nat. Nanotech. 12, 776 (2017)
[2] R. W. Andrews, et al. Nat. Phys. 10, 321 (2014)
[3] R. Penrose. Gen. Rel. and Grav. 28, 581 (1996)
[4] V. E. Manucharyan, et al. Science 326, 113 (2009)