Institut Néel

Quantum internship – Academic year 2025-2026

Coherent Nanomechanics at Ultra-low Temperatures

Level : M1

General Scope :

Resonators with mechanical coherence times of order 10 milliseconds at 10 mK have been demonstrated.[1] Such highly coherent mechanical systems could be used as quantum memories in hybrid systems for quantum communication and computation. They could also be used for testing fundamental aspects of quantum mechanics, including gravitational effects. At the same time, we have cooled nanomechanical resonators to microkelvin temperatures, yielding passive ground state cooling of ~10 MHz mechanical modes.[2] We are now using our unique refrigerator to cool ultra-high Q mechanical resonators. Since the mechanical decoherence rate $\Gamma_m \bar{n}_{\mathrm{th}}$ depends on the damping rate Γ_m and the equilibrium phonon occupation $\bar{n}_{\mathrm{th}}$, a good understanding of the temperature dependence of both of these quantities is required.

Research topic and facilities available :

We are using optomechanical devices fabricated by the Kippenberg group at EPFL for the project.[1] These drum devices have exceptionally low mechanical dissipation and relatively strong optomechanical coupling. Using the microkelvin microwave optomechanics cryostats of the Néel Ultra-Low Temperatures group,[3] which are unique in the world, we cool the devices below 1 mK to measure the temperature dependence of the mechanical properties. Initial work has revealed a surprising variability in the thermalization of similar devices on a single chip. The PhD student will extend these measurements to additional samples of the same type as well as other devices expected to have even lower dissipation. This will allow us to test our preliminary finding that the thermal coupling of nanomechanical resonators to the cryostat is correlated with the resonator's damping.

1. A. Youssefi *et al. Nature Physics* (2023) doi: 10.1038/s41567-023-02135-y

2. D. Cattiaux *et al. Nature Communications* (2021) doi: 10.1038/s41467-021-26457-8

3. M. Raba *et al*. *Phys. Rev. Applied* (2024) doi: 10.1103/PhysRevApplied.22.024027

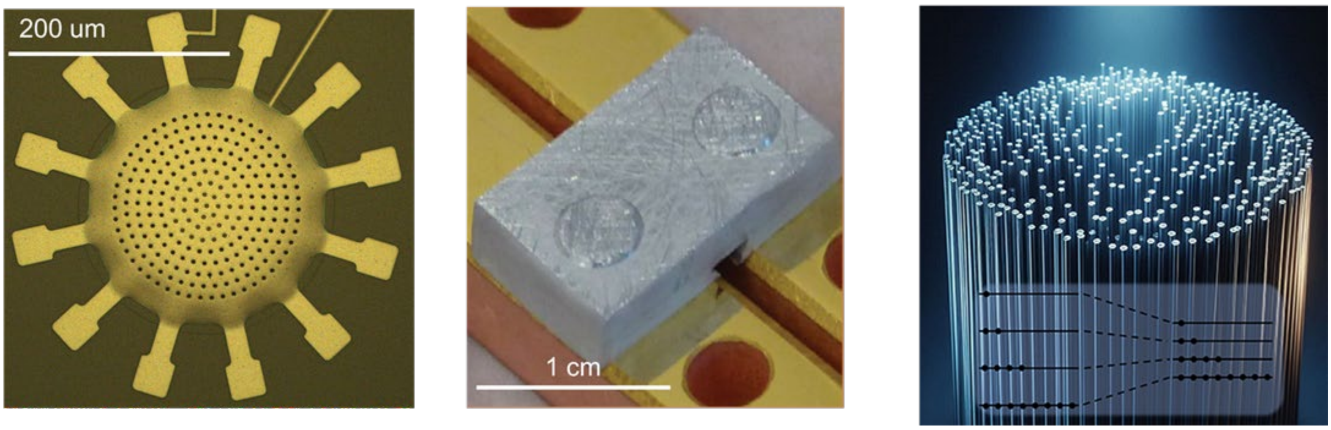

Figure: (left) One of the coherent drum devices, (center) the ultra-low resistance superconducting heat switch for nuclear demagnetization refrigeration, (right) artist's impression of the aluminum wire bundle nuclear refrigerant with inset depicting the population of the Zeeman levels at two magnetic fields.

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Required skills :

- Enthusiasm for challenging experiments at ultra-low temperatures
- Solid foundation in quantum mechanics and condensed matter

Starting date and duration : Flexible

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