# Towards quantum effects with a $\mu$g-scale mechanical oscillator

L. Neuhaus, Rémi Metzdorff, Salim Zerkani, Sheon Chua, Thibaut Jacqmin, Samuel Deléglise, Tristan Briant, Pierre-François Cohadon, Antoine Heidmann

Laboratoire Kastler Brossel, UPMC, ENS, Collège de France, CNRS UMR 8552, Paris, France

Recent advances in cavity quantum optomechanics have enabled breakthroughs such as ground state cooling of mechanical motion, observation of quantum backaction and the standard quantum limit of position measurement and entanglement between optical and mechanical degrees of freedom. Simultaneously, the upgraded version of current gravitational-wave interferometers is expected to suffer from optomechanical effects such as parametric instabilities and quantum backaction, while the sensitivity of such interferometers has already been quantum-enhanced. Despite sharing the same fundamental optomechanical coupling mechanism, the typical mass of the mechanical degree of freedom in these two research fields differs by twelve orders of magnitude.

Our optomechanical system bridges this gap with an effective mass around 40 $\mu$g and its design gives insight to typical effects appearing in this intermediate regime. The mechanical oscillator is a 1-mm thick quartz micropillar with a compression-dilatation mode oscillating at 3.6 MHz. A mirror on top of the pillar allows to construct a Fabry-Perot cavity to optically detect and control the oscillator motion. In recent experiments, we have reached mechanical quality factors as high as $25 \times 10^6$ and an optical finesse near $10^5$ at temperatures below 10 K.

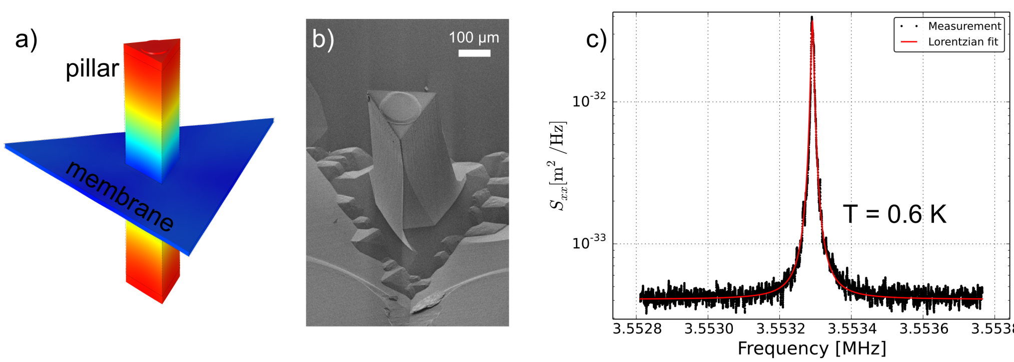


Fig. 1 – a) Mode shape of the fundamental compression mode of the mechanical resonator. b) Scanning electron microscope image of the fabricated structure with a circular mirror coating on the top surface of the pillar. c) Optically measured thermal displacement noise spectrum of the fundamental resonator mode in a cryogenic environment, yielding an estimative effective mode temperature of 600 mK for an incident power of 2 $\mu$W.

While our optomechanical device now fulfills the requirements for ground state cooling in a cryogenic environment, this experiment is prevented by about 10 dB excess cavity phase noise. We are currently designing mirror substrates structured with a phononic crystal in order to decrease this excess noise and enable cooling of our system to the mechanical quantum ground state. In this regime, we plan to inject squeezed light into our optomechanical cavity to test schemes for measuring mechanical displacement with sensitivities below the standard quantum limit.