Nonlinear and pulsed optomechanical measurement in sliced photonic crystal nanobeams

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In optomechanical systems, co-localizing light and mechanical oscillations at the nanoscale can lead to strong interaction between photons and phonons. Such optomechanical coupling enables extremely sensitive detection of nanoscale motion, that allow exploring the fundamentals of quantum measurement as well as novel sensing technologies. Linear continuous measurements of mechanical resonator position are famously limited by Heisenberg's uncertainty principle, in the form of the Standard Quantum Limit (SQL). We study optomechanical systems in which photons and phonons are coupled with extreme strength, to demonstrate new applications of nonlinear and non-continuous measurement of nanomechanical motion.

We study 'sliced' photonic crystal nanobeams (Fig. 1), which host optical cavity modes that are confined to a 40 nm gap, thereby establishing record photon-phonon coupling rate of 25 MHz to the flexural mechanical modes of the nanobeam. Over a wide range of temperatures, the natural thermomechanically-induced cavity frequency fluctuations dominate the apparent optical linewidth (Fig. 2). The system thereby operates in a new nonlinear regime, which pronouncedly impacts optical response, displacement measurement, and radiation pressure effects [1]. We demonstrate that the strong nonlinearity can be used to perform sensitive quadratic position measurement – a promising route towards the creation of phonon number states of the mechanical resonator [2]. Moreover, we show that the instantaneous resonator position can be resolved with single nanosecond pulses, approaching the regime where they could surpass the standard quantum limit of continuous measurement [3].

References

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Figures

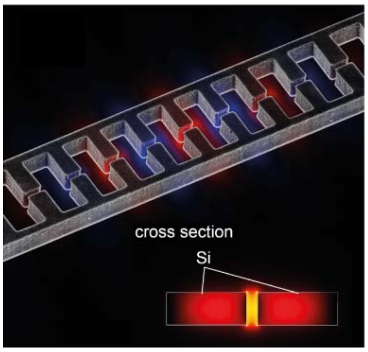

Figure 1: Sliced photonic crystal nanobeam

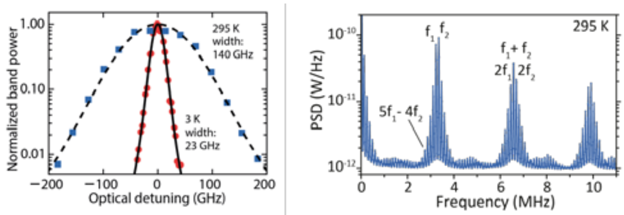

Figure 2: Nonlinear optomechanics with thermal fluctuations: (left) Effective optical linewidth dominated by thermomechanical fluctuations. (right) Nonlinear measurement of mechanical motion.