Cavity Optomechanics: Backaction Cooling of Mechanical Oscillators

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The possibility to observe quantum phenomena of macroscopic objects has been a long-standing challenge in Quantum Physics and has recently received significant attention as researchers from diverse communities seek to demonstrate quantum phenomena of nano- and micro-scale mechanical oscillators coupled to optical laser fields. A major challenge, in this new field of *Cavity Optomechanics*[1] are the extremely low temperatures required to cool mechanical systems down to their ground state as well to perform quantum limited measurements of the mechanical amplitudes in the regime of low occupancy. In this talk I will describe the advances the Max Planck Institute of Quantum Optics has made in this field. Using on chip micro-cavities that combine both optical and mechanical degrees of freedom in one and the same device, we have been able to shown that the radiation pressure back-action of photons can be used to passively cool the mechanical oscillator[2], akin to Doppler Cooling of Atoms. Furthermore, we have been able to demonstrate for the first time resolved sideband cooling[3] [4], by using optical microresonators whose mechanical oscillator frequency exceeds the cavity decay rate. This technique is well known in Atomic Physics to provide ground state cooling. Moreover the ability to monitor the motion of the oscillator with a quantum limited sensitivity of $10^{-18} m/\sqrt{Hz}$ will be discussed and a description of our quest to ever lower phonon occupancies using cryogenic exchange gas cooling to 1.6 K described.

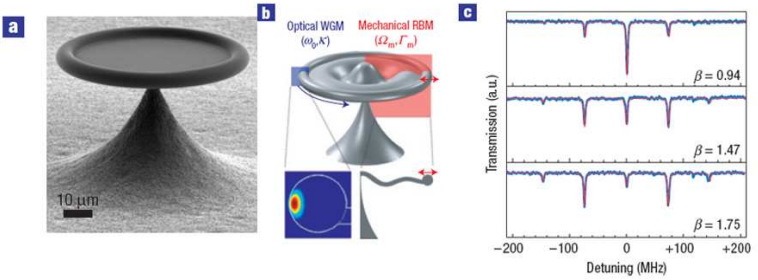

Figure 1: *Radiation pressure cooling of toroidal microcavities in the resolved sideband regime*[2,4].

[1] T. J. Kippenberg, K.J. Vahala, *Optics Express* 15, 17172-17205 (2007)

[2] A. Schliesser, P. Del'Haye, N. Nooshi, K. J. Vahala, T. J. Kippenberg,"Radiation pressure cooling of a micromechanical oscillator using dynamical ", *Physical Review Letters* 97, 243905 (Dec 15, 2006).

[3] I. Wilson-Rae, N. Nooshi, W. Zwerger, T. J. Kippenberg,"Theory of Ground State Cooling of a Mechanical Oscillator Using Dynamical Backaction", *Physical Review Letters* 99, 093902 (2007)

[4] A. Schliesser, R. Riviere, G. Anetsberger, O. Arcizet, T. J. Kippenberg, "Demonstration of Resolved Sideband Cooling of a Mechanical Oscillator.",*Nature Physics* 2008 (2008).