Freie Universität Berlin

Physikalisches Kolloquium des Fachbereich Physik
Arnimallee 14, D-14195 Berlin
Freitag, 12. Juni 2015, 15 h c.t., Hörsaal A (R. 1.3.14)

Cavity Quantum Optomechanics with high Q Optical Microresonator

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The mutual coupling of optical and mechanical degrees of freedom via radiation pressure has been a subject of interest in the context of quantum limited displacements measurements for Gravity Wave detection for many decades(*1*). Braginsky's predicted that radiation pressure can give rise to *dynamical backaction*, which allows cooling and amplification mechanical modes of a mirror. While this effect has only recently been observed in LIGO, experimentally these phenomena remained inaccessible many decades due to the faint nature of the radiation pressure force. With the discovery of optomechanical interactions in high Q optical microresonators(*2*) in 2005, and a host of new systems that have emerged since then, it has become possible to study radiation pressure interaction in micro- and nanoscale resonators which has led to the field of *cavity quantum optomechanics(3, 4)*. The high Q of the microresonators, not only enhances nonlinear phenomena – enabling for instance optical frequency comb generation(*5*) on a chip– but also enhances the radiation pressure interaction and is an underlying principle cavity quantum optomechanics. Over the past decade, cavity optomechanics has allowed to extend the quantum control from ions, molecules and atoms, to mechanical oscillators, that can be engineered and coupled to other systems.
In this talk, I will describe a range of optomechanical phenomena that have been observed in our laboratory at EPFL, using high Q optical microresonators. Radiation pressure back-action of photons is shown to lead to effective cooling(*1, 6-8*) of the mechanical oscillator mode using dynamical backaction. When combined with cryogenic buffer gas precooling using He-3 gas, sideband resolved cooling allows to cool the oscillator, such that it resides in the quantum ground state more than 1/3 of its time(*9*). Increasing the mutual coupling further, it is possible to observe quantum coherent coupling(*9*) in which the mechanical and optical mode hybridize. In addition, it is possible to observe the effect of optomechanically induced transparency(*10*), which can be used in a wide range of optomechanical protocols – both in the classical and quantum domain - , ranging from state transfer from light to mechanics(*11*), or coherent wavelength conversion between vastly different frequencies(*12*), to preparing squeezed laser beams for LIGO(*13*). New frontiers of quantum optomechanics that are now possible, include the generation of non-classical states of motion via post-selection(*14*) as well as the use of ground state cooled oscillators to create quantum limited amplifiers that use the damped mechanical oscillator as a engineered reservoir(*15*). In addition, optomechanical systems have recently enabled real time quantum feedback of nanomechanical oscillators(*16*), which enable to track the oscillators state faster that the influence of environmentally induced thermal decoherence. The optomechanical toolbox developed over the past decade has enabled to extend quantum control to mechanical oscillators.

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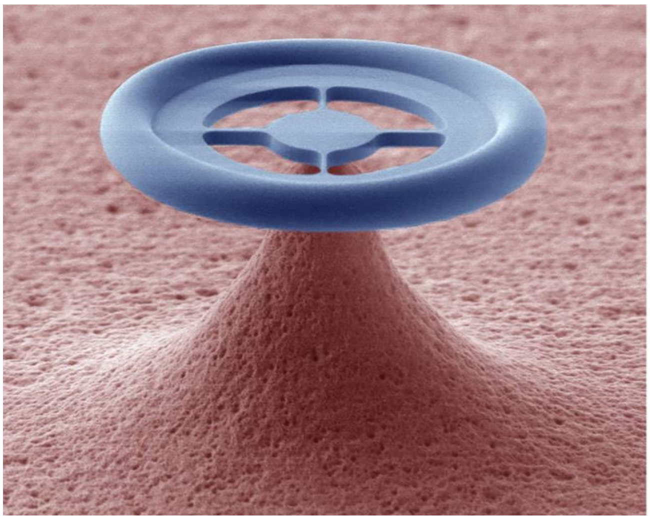

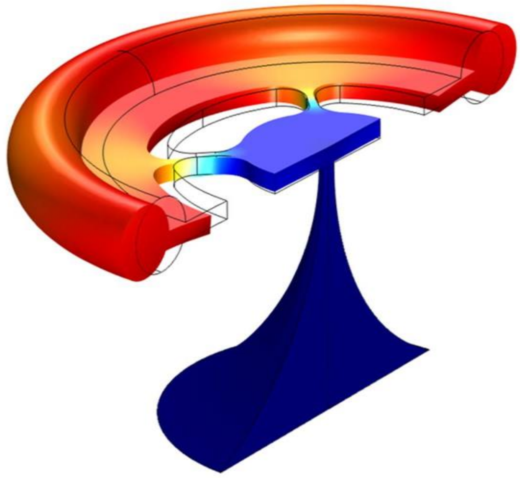

Figure: SEM image of a toroid resonator and the optomechanical coupling between the optical and mechanical degree of freedom mediated by radiation pressure.

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