Q 6: Mikromechanische Systeme

Time: Monday 10:30–12:15 Location: V7.02

Q 6.1 Mon 10:30 V7.02

Pulsed Laser Cooling for Cavity-Optomechanical Resonators — Javier Cerrillo[1], •Shai Machnes[1], Markus Aspelmeyer[2], Witlef Wieczorek[2], Martin Plenio[1,3], and Alex Retzker[1] — [1]Institut fur Theoretische Physik, Universitat Ulm, D-89069 Ulm, Germany — [2]Vienna Center for Quantum Science and Technology, Faculty of Physics, University of Vienna, Boltzmanngasse 5, A-1090 Vienna, Austria — [3]QOLS, The Blackett Laboratory, Imperial College London, Prince Consort Rd., SW7 2BW, UK

A pulsed cooling scheme for optomechanical systems is presented that is capable of cooling at much faster rates, shorter overall cooling times, and for a wider set of experimental scenarios than is possible by conventional methods. The proposed scheme can be implemented for both strongly and weakly coupled optomechanical systems in both weakly and highly dissipative cavities (where sideband cooling fails due to its inherent rate limitation). We study analytically its underlying working mechanism, which is based on interferometric control of optomechanical interactions, and we demonstrate its efficiency with pulse sequences obtained using methods from optimal control. The short time in which our scheme approaches the optomechanical ground state allows a significant relaxation of current experimental constraints. Finally, the presented framework can be used to create a rich variety of optomechanical interactions and hence offers a novel, readily available toolbox for fast optomechanical quantum control.

Q 6.2 Mon 10:45 V7.02

Hybrid quantum system: CNT coupled to BEC — •Polina Mironova and Reinhold Walser — TU Darmstadt, Darmstadt, Germany

Hybrid quantum systems, i.e., coupling objects of quantum optics and solid state physics, have gained great attention during the last decade. This interest is due to the variety of possible applications, e.g. high-precision force and mass measurements or quantum computation. A particularly promising candidate for hybrid quantum system is the free standing carbon nanotube (CNT) on an atom-chip interacting with the bath of ultra cold atoms / BEC as realised by the experiments of the group of J. Fortagh [1]. We describe the oscillations of the CNT within a two mode model. Perturbation theory is used to solve the Heisenberg equations of motion while neglecting the backaction of the CNT on the BEC. The mean value of displacement around the equilibrium position of the CNT and corresponding standard deviation are calculated.

References:

[1] M.Gierling et al. "Cold-atom scanning probe microscopy", *Nature Nanotechnology*, **6**, 446-451 (2011)

Q 6.3 Mon 11:00 V7.02

Quantum dynamics of nonlinear nanomechanical resonators in an optoelectromechanical setup — •Simon Rips[1], Martin Kiffner[2], Ignacio Wilson-Rae[1], and Michael Hartmann[1] — [1]TU München, James-Franck-Strasse, 85748 Garching — [2]University of Oxford, Parks Road, Oxford, OX1 3PU

We investigate the quantum regime of nonlinear nanomechanical resonators within an optoelectromechanical setup. While resolved sideband cooling provides access to the groundstate of mechanical motion, we show a way to generate manifestly non-classical dynamics for such nanomechanical resonators. To achieve this, we enhance the intrinsic geometric nonlinearity per phonon of the mechanial mode with inhomogeniuos electrostatic fields. This causes the motional sidebands to split into separate spectral lines for each phonon number and transitions between individual phonon Fock states can be selectively addressed by external (optical, radiofrequecy or electrostatic) fields. The capabilities of this approach are demonstrated via a scheme to prepare stationary phonon Fock states[1] and by exploring functional quantum operations for nanomechanical oscillators.

[1] arXiv:1104.5665

Q 6.4 Mon 11:15 V7.02

Spectroscopy of mechanical dissipation in micro-mechanical membranes — •Andreas Jöckel[1], Maria Korppi[1], Matthew T. Rakher[1], Matthias Mader[2], David Hunger[2], Stephan Camerer[2], and Philipp Treutlein[1] — [1]Departement Physik, Universität Basel, Schweiz — [2]Institut für Physik, LMU München, Deutschland

We report on the characterization and tuning of the mechanical modes of high-Q SiN-membrane oscillators [1]. Such membranes are used in many optomechanical experiments and have Q-factors up to 10^7 with frequencies in the hundreds of kHz regime and masses of a few ng, resulting in large ground state and thermal amplitudes. We show that the membrane eigenfrequencies can be tuned by locally heating the membranes with laser light, resulting in a release of tensile stress. We observe that the Q-factor changes in a reproducible way by more than two orders of magnitude as a function of membrane frequency and reveals distinct resonances. We show that these resonances can be explained by coupling to localized frame modes. Away from the resonances, the Q-factor is independent of frequency. Higher order modes show the same maximum Q, but different coupling strengths to the frame.

[1] Appl. Phys. Lett. 99, 143109 (2011)

Q 6.5 Mon 11:30 V7.02

A versatile scheme for read-out and actuation of nanomechanical motion using silica microspheres — •Leonhard Neuhaus[1], Emmanuel van Brackel[1], Emanuel Gavartin[1], Pierre Verlot[1], and Tobias Kippenberg[1,2] — [1]Ecole Polythechnique Federale Lausanne, CH-1015 Lausanne, Schweiz — [2]Max-Planck-Institut für Quantenoptik, Hans Kopfermann Strasse 1, 85748 Garching, Deutschland

Opto-nanomechanical systems serve as exceptional force transducers due to an ultra-low mass and high mechanical quality factors combined with enhanced readout via a high-finesse-optical microcavity. We report readout and actuaction of nanomechanical Si_3N_4-oscillators using evanescent coupling to ultrahigh optical-*Q* silica microspheres. Compared to earlier work, we have significantly enhanced optomechanical coupling rates and the intracavity power due to the use of a superior microcavity. This enables the observation of dynamical backaction cooling rates up to 8 kHz. We were also able to use this setup to probe different types of oscillators, such as niobium-coated strings or few-layer graphene sheets. We counteract a limitation of optomechanical coupling rates resulting from the parametric instabiliy by an external feedback loop with radiation-pressure actuation. Our setup could prove useful to a number of experiments requiring the ultra-sensitive detection of nanomechanical motion, while the higher accessible powers due to feedback-stabilization will likely permit the observation of fundamental effects of quantum backaction in the future.

Q 6.6 Mon 11:45 V7.02

Entangling coupled nanomechanical oscillators at moderate temperatures — •Alessandro Ridolfo and Michael Hartmann — TU München, James-Franck-Strasse, 85748 Garching

We analyse the generation of entanglement, arising from two mode sqeezing, in an open quantum system consisting of two parametrically driven coupled harmonic oscillators. We found that it is possible to bring entanglement in the regime of tenths of Kelvin for frequencies in the regime of tens of MHz, provided that the coupling between the two oscillators is periodically modulated in time. The used physical parameters in our work are very close to those accessible in the most recent nanomechanical systems [1], enabling to exploit these nanotechnologies for a real step forward in creation of entanglement avoiding the use of delicate precooling setups.

[1] Q. P. Unterreithmeier et al., Nature, 458, 1001, (2009)

Q 6.7 Mon 12:00 V7.02

Quantum-coherent coupling of a mechanical oscillator to an optical cavity mode — Ewold Verhagen[1], Samuel Deléglise[1], •Stefan Weis[1,2], Albert Schliesser[1,2], and Tobias J. Kippenberg[1,2] — [1]Ecole Polytechnique Fédérale de Lausanne, 1015 Lausanne, Switzerland — [2]Max-Planck-Institut für Quantenoptik, 85748 Garching, Germany

Optical laser fields have been widely used to achieve quantum control over the motional and internal degrees of freedom of atoms and ions, molecules and atomic gases. A route to controlling the quantum states of macroscopic mechanical oscillators in a similar way is to exploit the parametric coupling between optical and mechanical degrees of freedom through radiation pressure in suitably engineered optical cavities. If the optomechanical coupling is 'quantum coherent', i.e., if the coherent coupling rate exceeds both the optical and the mechanical decoherence rate, quantum states can be transferred from the optical field to the mechanical oscillator and vice versa, thus allowing control of the mechanical oscillator state using the wide range of available quantum optical techniques. In this work we achieve for the first time quantum-coherent coupling between optical photons and a micromechanical oscillator. Simultaneously, coupling to the cold photon bath cools the mechanical oscillator to an average occupancy of n=1.7 motional quanta. Excitation with weak classical pulses reveals the exchange of energy between the optical light field and the micromechanical oscillator in the time domain at the level of less than one quantum on average.