Q 8: Micromechanic oscillators II

Time: Monday 14:00–15:30 Location: F 142

Q 8.1 Mon 14:00 F 142

Dissipative opto-mechanics in a membrane interferometer
— •Henning Kaufer, Andreas Sawadsky, Ramon Moghadas Nia, Sergey Tarabrin, Klemens Hammerer, and Roman Schnabel — Institut für Gravitationsphysik, Leibniz Universität Hannover and Max-Planck-Institut für Gravitationsphysik (Albert-Einstein-Institut), Callinstr. 38, 30167 Hannover, Germany

Opto-mechanical coupling can either be dispersive or dissipative. In the latter case, the movement of a mechanical oscillator rather changes the cavity linewidth than the cavity length. It was found that a signal-recycled Michelson-Sagnac interferometer with translucent, high-Q micromechanical oscillator is a topology that allows for the dissipative coupling mechanism to dominate over the dispersive coupling. The dissipative coupling features cooling in the unresolved sideband regime and some anomalous optical instability for a red and blue detuned cavity. In my talk, I will present the experimental setup and recent results.

Q 8.2 Mon 14:15 F 142

Cavity-Enhanced Long-Distance Coupling of an Atomic Ensemble to a Micromechanical Membrane
— •Andreas Jöckel[1], Maria Korppi[1], Aline Faber[1], Matthew T. Rakher[1], Berit Vogell[2], Kai Stannigel[2], Peter Zoller[2], Klemens Hammerer[3], and Philipp Treutlein[1] — [1]Departement Physik, Universität Basel, Schweiz — [2]Universität Innsbruck, Österreich — [3]Universität Hannover, Deutschland

We present first experimental results on creating a hybrid quantum system where a dielectric membrane inside an optical cavity is coupled via a light field to a distant ultracold atomic ensemble trapped in free space. The coupling is mediated by a laser beam that couples to the cavity and creates an optical lattice for the atoms, thus coupling to the atomic center of mass motion. This coupling is enhanced by the cavity finesse as well as the square root of the number of atoms.

The system can be operated in two modes, where one can either observe coherent dynamics between the systems, or switch on a strong dissipation by cooling the atoms, thereby sympathetically cooling the membrane. The cooling scheme does not require resolved sidebands for the cavity, which relaxes a constraint present in standard optomechanical cavity cooling.

In a previous experiment [PRL 107, 223001(2011)] without a cavity we could demonstrate the bi-directional coupling of rubidium atoms to a SiN mechanical membrane oscillator. With the new system a substantial increase of the interaction is expected and even ground state cooling of a cryogenically pre-cooled membrane should be possible.

Q 8.3 Mon 14:30 F 142

Strong-coupling effects in dissipatively coupled optomechanical systems
— •Talitha Weiss, Christoph Bruder, and Andreas Nunnenkamp — Department of Physics, University of Basel, Klingelbergstrasse 82, CH-4056 Basel, Switzerland

We study cavity optomechanical systems in which the position of a mechanical oscillator modulates both the resonance frequency (dispersive coupling) and the linewidth (dissipative coupling) of a cavity mode. Using a quantum noise approach we calculate the optical damping and the optically-induced frequency shift. We find that dissipatively coupled systems feature two parameter regions providing amplification and two parameter regions providing cooling. To investigate the strong-coupling regime, we solve the linearized equations of motion exactly and calculate the mechanical and optical spectra. In addition to signatures of normal-mode splitting that are similar to the case of purely dispersive coupling, the spectra contain a striking feature that we trace back to the Fano line shape of the force spectrum. Finally, we show that purely dissipative coupling can lead to optomechanically-induced transparency which will provide an experimentally convenient way to observe normal-mode splitting.

Q 8.4 Mon 14:45 F 142

Cavity Optomechanics with levitating Nanospheres
— •Nikolai Kiesel, Florian Blaser, Uros Delic, David Grass, Rainer Kaltenbaek, and Markus Aspelmeyer — Vienna Center for Quantum Science and Technology (VCQ), Faculty of Physics, University of Vienna, A-1090 Vienna, Austria

Optically trapped nanospheres have been proposed as mechanical resonators for cavity optomechanics with great potential [1]: This approach promises, amongst others, optomechanical quantum information protocols at room temperature and fundamental quantum experiments with objects of up to 10^{10} amu [2]. These ideas require cavity optomechanical cooling and control of the nanospheres centre-of-mass motion. However, cavity cooling of such optically trapped and internally hot objects without internal level structure has not been experimentally achieved so far.

We present the experimental demonstration of a levitated nanosphere coupled to a high-finesse cavity and optomechanical readout and cooling of its center-of-mass motion.

Next steps towards operation in UHV and implementation of levitated ultra-high quality mechanical resonators in optical cavities will be dicussed.

[1] Romero-Isart O. et al., NJP 12, 33015 (2010), Chang D. et al. PNAS 107, 0912969107, (2009), Barker P, et al., PRA 81, 023826 (2010). [2] Romero-Isart, O et al., PRL, 107, 020405 (2011), Romero-Isart, O., PRA 84, 5 (2011), Kaltenbaek, R. et al., MAQRO, Exp. Astro., 1-42 (2012)

Q 8.5 Mon 15:00 F 142

Optomechanics beyond linearization: Two-phonon induced transparency
— Kjetil Børkje[1], •Andreas Nunnenkamp[2], John D. Teufel[3], and Steven M. Girvin[4] — [1]Niels Bohr Institute, University of Copenhagen, Blegdamsvej 17, DK-2100 Copenhagen, Denmark — [2]Department of Physics, University of Basel, Klingelbergstrasse 82, CH-4056 Basel, Switzerland — [3]National Institute of Standards and Technology, Boulder, Colorado 80305, USA — [4]Departments of Physics and Applied Physics, Yale University, New Haven, Connecticut 06520, USA

We identify a novel signature of the intrinsic nonlinear interaction between light and mechanical motion in cavity optomechanical systems. This signature is observable in the resolved-sideband limit even if the cavity linewidth exceeds the optomechanical coupling rate. A strong laser drive red-detuned by twice the mechanical frequency from the cavity resonance frequency makes two-phonon processes resonant, which leads to a nonlinear version of optomechanically-induced transparency. This effect provides a new method of measuring the mean phonon number of the mechanical oscillator that is not susceptible to technical laser noise and should be observable with optomechanical coupling strengths that have already been realized in experiments.

Q 8.6 Mon 15:15 F 142

Continuous-time quantum state engineering in optomechanics
— •Sebastian Hofer[1], Markus Aspelmeyer[1], and Klemens Hammerer[2] — [1]Vienna Center for Quantum Science and Technology, Faculty of Physics, University of Vienna, 1090 Vienna, Austria — [2]Institute for Theoretical Physics, Institute for Gravitational Physics, Leibniz University Hannover, 30167 Hannover, Germany

Control and state preparation of mechanical oscillators on the quantum level is one of the main goals of quantum optomechanics and has seen plenty of theoretical and experimental interest lately. Preparing a mechanical system in the ground state by side-band cooling has already been achieved. Recently cooling of mechanical motion has as well been demonstrated in a pulsed scheme, which also has the potential to prepare a mechanical squeezed states.

Building on our previous work which discussed optomechanical teleportation in the pulsed regime we here explore continuous-time mechanical state engineering. More specifically, we analyze a *continuous* quantum teleportation protocol which allows for teleportation of squeezed light states onto a mechanical oscillator by applying stochastic-master-equation methods developed in the context of continuous measurement and quantum control and estimation theory. We also show that with a similar scheme it is possible to generate continuous entanglement swapping between two oscillators. Furthermore we consider optomechanical feedback cooling in different parameter regimes and discuss its limitations.