Q 57: Micromechanical Oscillators II

Time: Friday 10:30–12:30 Location: A 320

Q 57.1 Fr 10:30 A 320

Exploring Optomechanics with optically levitating dielectric objects — •Anika C. Pflanzer, Oriol Romero-Isart, and J. Ignacio Cirac — Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, D-85748 Garching, Germany

Optomechanical systems hold the promise to facilitate the preparation of superposition states of macroscopic objects. While the main drawback in ground state cooling of the center-of-mass motion in most systems, such as membranes or cantilevers in optical cavities, is their large heating rate, optically levitating sub-wavelength dielectric objects in high-finesse cavities realize a setup with negligible mechanical damping. They do not couple to a thermal reservoir and consequently the main source of heating can be circumvented. The transition to larger objects comes with a coupling of the center-of-mass motion to other modes of the mechanical oscillator, which we take into account by an additional heating rate. Furthermore, the cavity's finesse decreases with the size of the trapped objects. These effects, limiting the maximal size of objects that can be cooled in this cavity system by state-of-the-art quantum optomechanical techniques, are investigated in detail and possible alternatives are discussed.

Q 57.2 Fr 10:45 A 320

Interfacing Opto-mechanics with Atoms — •Klemens Hammerer — University of Innsbruck, Austria

We propose and analyze setups interfacing opto-mechanical systems with single atoms or atomic ensembles. In particular we show that strong, coherent coupling between a single trapped atom and a mechanical oscillator can be mediated via a laser-driven high-finesse cavity. In free space it is still possible to achieve a coherent coupling between a micromirror and an ensemble of atoms trapped in a standing wave field reflected thereof. Finally, in a travelling wave, pulsed scheme allows for a quantum non-demolition measurement of hybrid atomic-micromechanical Einstein-Podolsky-Rosen variables. The wave function of the massive mechanical oscillator and the collective atomic spin is thereby collapsed into an entangled EPR state. These setups provide the basic toolbox for coherent manipulation, preparation and measurement of micro- and nanomechanical oscillators via the tools of atomic physics. Beyond interfaces of optomechanics to AMO systems, I will discuss general perspectives of strong and super-strong optomechanical coupling.

Q 57.3 Fr 11:00 A 320

Cavity-Optomechanics with Silica Microresonators at Helium-3 Temperatures — •Stefan Weis[1], Rémi Rivière[1], Olivier Arcizet[1,2], Albert Schliesser[1], Samuel Deléglise[1], Emanuel Gavartin[3], and Tobias J. Kippenberg[1,3] — [1]MPI für Quantenoptik, 85748 Garching, Germany — [2]Institut Néel, CNRS, 38042 Grenoble, France — [3]Ecole Polytechnique Fédérale de Lausanne, 1015 Lausanne, Switzerland

We present the optical and mechanical properties of toroidal resonators thermalized to Helium-3 (600 mK) temperatures, which exhibit ultra-high optical Q (up to 10^8) whispering gallery mode resonances coupled via radiation pressure to mechanical radial breathing modes.

Recent experiments performed in a Helium-4 cryostat aiming at ground state cooling the mechanical degree of freedom have combined cryogenic precooling with laser cooling. Final phonon occupation numbers of about 60 quanta [1] could be attained, which were however limited by the mechanical losses due to two-level systems at temperatures above 1.6 K. Here, we demonstrate that the mechanical Q dramatically improves at temperatures below 1 K, enabling mechanical Q factor in excess of 10,000.

The large achievable mechanical Q factors, combined with low initial occupancies of < 200 for 75 MHz oscillators, render this system a promising candidate for ground state cooling and a range of experiments pertaining to quantum measurement theory of mechanical oscillators.

[1] A. Schliesser et al., Nature Physics 5, 509 (2009)

Q 57.4 Fr 11:15 A 320

Single-Photon Optomechanics in the Strong Coupling Regime — •Uzma Akram[1], Nikolai Kiesel[2], Markus Aspelmeyer[2], and Gerard Milburn[1] — [1]Department of Physics, School of Mathematics and Physics, The University of Queensland, St. Lucia, QLD 4072, Australia — [2]Faculty of Physics, Quantum Optics, Quantum Nanophysics and Quantum Information, University of Vienna, Austria

We give a theoretical description of a coherently driven opto-mechanical system with a single added photon. The photon source is modeled as a cavity which initially contains one photon and which is irreversibly coupled to the opto-mechanical system. We show that the probability for the additional photon to be emitted by the opto-mechanical cavity will exhibit oscillations under a Lorentzian envelope, when the interaction with the mechanical resonator is strong enough. Our scheme provides a feasible route towards quantum state transfer between optical photons and micromechanical resonators.

Q 57.5 Fr 11:30 A 320

Quantum optomechanics beyond rotating-wave-approximation: Towards optomechanical entanglement — Simon Gröblacher[1,3], •Sebastian Hofer[1], Michael Vanner[1], Klemens Hammerer[2,4], and Markus Aspelmeyer[1] — [1]Fakultät für Physik, Universität Wien, 1090 Wien, Österreich — [2]Institut für Theoretische Physik, Universität Innsbruck, 6020 Innsbruck, Österreich — [3]Institute for Quantum Optics and Quantum Information (IQOQI), Austrian Academy of Sciences, 1090 Wien, Österreich — [4]Institute for Quantum Optics and Quantum Information (IQOQI), Austrian Academy of Sciences, 6020 Innsbruck, Österreich

We investigate the dynamics of a mechanical oscillator coupled to an optical cavity by radiation pressure. Going into the strong coupling regime enables us to access dynamics beyond the rotating-wave-approximation. This sets the way for the creation of nonclassical quantum states and optomechanical entanglement.

Q 57.6 Fr 11:45 A 320

Optomechanische Verschränkung im instabilen Regime — Christian Höhne und •Carsten Henkel — Universität Potsdam

Das Kühlen von beweglichen Spiegeln durch rotverstimmtes Laserlicht ist eine erfolgversprechender Weg, um makroskopische Objekte in ihrer Bewegung an die Quantengrenze zu bringen. Wir untersuchen hier den Fall von blauer Verstimmung, wo eine parametrische Resonanz zur Instabilität von Spiegel und Lichtfeld führt ("Heizen"). Es wird eine Beschreibung entwickelt, die dieses Verhalten in Analogie zur Schwelle eines Lasers beschreibt: der Spiegel ist die "Lasermode", das getriebene Lichtfeld im Resonator das "gepumpte Medium". Das System stabilisiert sich nichtlinear durch die Rückwirkung der Spiegelbewegung auf die Resonatorkennlinie. Wir zeigen, dass für geeignet große Kopplung die beiden Oszillatoren sich spontan verschränken, und charakterisieren diese "Verschränkungs-Schwelle" mit Hilfe von Darstellungen der symplektischen Gruppe auf dem Raum der Kovarianzmatrizen.

Q 57.7 Fr 12:00 A 320

Observation of strong coupling between a micromechanical resonator and an optical cavity field — •Simon Gröblacher[1,2], Klemens Hammerer[2,3], Michael Vanner[1,2], and Markus Aspelmeyer[1,2] — [1]Fakultät für Physik, Universität Wien, A-1090 Wien, Österreich — [2]Institut für Quantenoptik und Quanteninformation, Österreichische Akademie der Wissenschaften, A-1090 Wien und A-6020 Innsbruck, Österreich — [3]Institut für theoretische Physik, Universität Innsbruck, A-6020 Innsbruck, Österreich

We report the observation of strong coupling between a macroscopic mechanical resonator and an optical field, which is an essential requirement for the preparation of mechanical quantum states.

Q 57.8 Fr 12:15 A 320

Squeezing optomechanical systems — •Andrea Mari[1] and Jens Eisert[1,2] — [1]Institute of Physics and Astronomy, University of Potsdam, D-14476 Potsdam, Germany — [2]Institute for Advanced Study Berlin, D-14193 Berlin, Germany

We introduce a framework of optomechanical systems that are driven with a mildly amplitude-modulated light field, but that are not subject to classical feedback or squeezed input light. We find that in such a system one can achieve large degrees of squeezing of a mechanical micromirror - signifying quantum properties of optomechanical systems - without the need of any feedback and control, and within parameters reasonable in experimental settings. Entanglement dynamics is shown of states following classical quasiperiodic orbits in their first moments. We discuss the complex time dependence of the modes of a cavity-light field and a mechanical mode in phase space. Such settings give rise to certifiable quantum properties within experimental conditions feasible with present technology.

[1] A. Mari and J. Eisert, Phys. Rev. Lett. 103, 213603 (2009).