Q 56: Optomechanics II

Time: Thursday 14:30–15:45 Location: f342

Q 56.1 Thu 14:30 f342

Photon-Phonon Interactions in Nano-Photonic Waveguides

— •Hashem Zoubi and Klemens Hammerer — Institute for Theoretical Physics, Leibniz University Hanover

Stimulated Brillouin Scattering (SBS), i.e. the scattering of photons from acoustic phonons in dielectric materials, is induced mainly by electrostriction phenomena in bulk media. It was shown recently that SBS can be enhanced by orders of magnitudes when approaching the nanoscale regime due to radiation pressure. We develop a microscopic quantum theory that includes electrostriction and radiation pressure on the same footing. We derive the photon-phonon coupling parameter, which combines SBS and quantum optomechanical processes. We present the results by giving detailed calculations for the case of a nanoscale waveguide of circular cross section. We extract an effective photon-photon interaction which is a step toward many-body physics of photons.

Q 56.2 Thu 14:45 f342

Measurement-induced long-distance entanglement of superconducting qubits with optomechanical transducers

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While superconducting systems provide a promising platform for quantum computing, their networking poses a considerable challenge as they cannot be interfaced directly to light—the natural carrier for transmission of quantum signals through channels at room temperature. Here, we show that remote superconducting qubits can be prepared in entangled states by coupling them to mechanical oscillators whose positions are monitored with optical fields. Continuous homodyne detection of light provides information on the total spin of the two qubits such that entangled qubit states can be post-selected. Entanglement generation is possible without ground state cooling of the mechanical oscillators for systems with an optomechanical cooperativity moderately larger than unity; in addition, our setup tolerates a substantial loss of photons in transmission. The approach is scalable to generation of multipartite entanglement and represents a crucial step towards quantum networks with nodes using superconducting circuits.

Q 56.3 Thu 15:00 f342

Optomechanical multistability in the quantum regime

— •Andreas Alvermann, Christian Schulz, and Holger Fehske — Institut für Physik, Universität Greifswald

Classical optomechanical systems feature self-sustained oscillations, where multiple stable periodic orbits at different amplitudes coexist. While these orbits persist in the quantum dynamics sufficiently close to the classical limit, a new dynamical pattern emerges as one moves deeper into the quantum regime: Transitions between different orbits are induced by the spreading of the quantum state in phase space, and the stability of orbits changes in a predictable way.

We explain the resulting dynamical patterns from the point of view of phase space dynamics, and derive a Langevin equation with a specific quantum noise term that comes into play only through the deviation of quantum states from classical states. We also discuss to which extent the transition to chaos observed in the classical dynamics survives in this context, and point out in which way the Langevin description is of general relevance for dissipative quantum systems in the vicinity of—but not arbitrarily close to—the classical limit.

Q 56.4 Thu 15:15 f342

An optomechanical interface bridging x-ray and optical photons

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Future photonic quantum networks will require interfaces between different photon frequency regimes. So far, conversion experiments bridged the visible with telecommunication bands in infrared [1,2]. Going towards shorter wavelengths bears however certain advantages: x-rays are better focusable, are more robust and penetrate deeper through materials than visible or IR photons. They also carry much larger momenta, potentially facilitating the entanglement of light and matter at a single-photon level.

Here we envisage for the first time an optomechanical system that bridges optical photons and x-rays. The x-ray-optical interface system comprises of an optomechanical cavity and a movable microlever interacting with both an optical laser and with x-rays via resonant nuclear scattering. We develop a theoretical model for this system and show that x-ray absorption spectra of nuclei can be tuned optomechanically [3]. In particular, our theoretical simulations predict optomechanically induced transparency of x-rays, which can be used for metrology-relevant applications.

[1] M. T. Rakher *et al.*, Nature Photon. **4**, 786 (2010)
[2] A. G. Radnaev *et al.*, Nature Phys. **6**, 894 (2010)
[3] W.-T. Liao and A. Pálffy, arXiv:1508.06769

Q 56.5 Thu 15:30 f342

Optomechanics in the time domain

— •Ralf Riedinger[1], Sungkun Hong[1], Alex Krause[2,3], Tim Blasius[2,3], Oskar Painter[2,3], Simon Gröblacher[4], and Markus Aspelmeyer[1] — [1]Universität Wien, Vienna, Austria — [2]Kavli Nanoscience Institute and Thomas J. Watson, Sr., Laboratory of Applied Physics, California Institue of Technology, Pasadena CA, USA — [3]Institute for Quantum Information and Matter, California Institute of Technology, Pasadena CA, USA — [4]Kavli Institute of Nanoscience, Delft University of Technology, Delft, Netherlands

Optomechanical systems suffer from noise associated with continuous optical drives, e.g. absorption heating or parametric instabilities. Recently, it was proposed to use short optical pulses to circumvent these problems. Optical time domain probes can be used e.g. to realize quantum non-demolition measurements of mechanical positions. We report recent progress on time domain measurements on photonic crystal based mechanical resonators.