Q 48: Optomechanics I

Time: Thursday 11:00–13:00 Location: P/H1

Q 48.1 Thu 11:00 P/H1

Optomechanical limit cycles in the quantum regime — •Niels Lörch and Klemens Hammerer — Institut für Theoretische Physik, Leibniz Universität Hannover and Max-Planck-Institut für Gravitationsphysik (Albert-Einstein-Institut), Callinstr. 38, 30167 Hannover, Germany

Optomechanical systems can exhibit self-sustained oscillations where the quantum state of the mechanical resonator possesses nonclassical characteristics such as sub-Poissonian phonon statistics and negative Wigner function density. Using laser theory we derive conditions on the system parameters to prepare such nonclassical states for different experimental setups in steady state.

Q 48.2 Thu 11:15 P/H1

Stochastic dynamics of optomechanical oscillator arrays — •Roland Lauter[1,2], Steven Habraken[1], Aditi Mitra[3], and Florian Marquardt[1,2] — [1]Institut für Theoretische Physik II, Friedrich-Alexander Universität Erlangen-Nürnberg, Staudtstraße 7, 91058 Erlangen — [2]Max Planck Institute for the Science of Light, Günther-Scharowsky-Str. 1/Bau 24, 91058 Erlangen — [3]Department of Physics, New York University, 4 Washington Place, New York, NY 10003

We consider arrays of coupled optomechanical cells, each of which consists of a laser-driven optical mode interacting with a mechanical (vibrational) mode. The mechanical modes can settle into stable finite-amplitude oscillations. We study the collective classical nonlinear dynamics of the phases of these oscillators, which is described by a certain extension of the well-known Kuramoto model. When including noise in our model, we find connections to the physics of surface growth. Besides, in two-dimensional arrays, we find that spiral structures and their dynamics play an important role.

Q 48.3 Thu 11:30 P/H1

Quantum synchronization of optomechanical systems — •Talitha Weiss[1], Andreas Kronwald[1], and Florian Marquardt[1,2] — [1]Institut für Theoretische Physik II, Friedrich-Alexander Universität Erlangen-Nürnberg, Staudtstraße 7, 91058 Erlangen — [2]Max Planck Institute for the Science of Light, Günther-Scharowsky-Straße 1/Bau 24, 91058 Erlangen

Optomechanical arrays have been suggested as a novel system for studying many-body physics of interacting photons and phonons, and are experimentally realizable e.g. in optomechanical crystal structures. Driving all optomechanical systems into self-sustained oscillations can lead to synchronization.

We investigate how this synchronization is modified in the quantum regime by numerically simulating the full quantum behavior of two coupled optomechanical systems. In addition to the classically known synchronization regimes, we find parameter regions where quantum fluctuations drive transitions between different synchronization phases. We investigate the quantum to classical transition and how ideal synchronization is altered in presence of quantum fluctuations.

Q 48.4 Thu 11:45 P/H1

Topological Phases in Optomechanical Arrays — •Christian Brendel[1], Vittorio Peano[1], Michael Schmidt[1], and Florian Marquardt[1,2] — [1]Institute for Theoretical Physics, Friedrich-Alexander-Universität Erlangen-Nürnberg — [2]Max Planck Institute for the Science of Light

Topological states of matter are particularly robust, since they exploit global features insensitive to local perturbations. In this talk, we describe how to create a Chern insulator of phonons in the solid state. The proposed implementation is based on a simple setting, a dielectric slab with a suitable pattern of holes. Its topological properties can be wholly tuned in-situ by adjusting the amplitude and frequency of a driving laser that controls the optomechanical interaction between light and sound. The resulting chiral, topologically protected phonon transport along the edges can be probed completely optically. Moreover, we identify a regime of strong mixing between photon and phonon excitations, which gives rise to a large set of different topological phases. This would be an example of a Chern insulator produced from the interaction between two physically very different particle species, photons and phonons.

Q 48.5 Thu 12:00 P/H1

Quantum transport in optomechanical arrays with disorder — •Thales Figueiredo Roque[1,2] and Florian Marquardt[1,3] — [1]University of Erlangen-Nürnberg, Erlangen, Germany — [2]University of Campinas, Campinas, Brazil — [3]Max Planck Institute for the Science of Light, Erlangen, Germany

Optomechanical arrays consist of lattices of optical and vibrational modes coupled together by radiation forces. Their effective band structure for photons and phonons can be tuned via a laser drive, creating a versatile and novel model system for many condensed-matter phenomena. In this work, we study the effects of disorder on quantum transport in 2D optomechanical arrays. This will be essential for upcoming first experimental realizations of optomechanical arrays in the near future.

Q 48.6 Thu 12:15 P/H1

Microwave Quantum Illumination — •Shabir Barzanjeh[1], Jeffrey Shapiro[2], and Stefano Pirandola[3] — [1]Institute for Quantum Information, RWTH Aachen University, 52056 Aachen, Germany — [2]Research Laboratory of Electronics, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139, USA — [3]Department of Computer Science, University of York, York YO10 5GH, United Kingdom

Quantum illumination is a quantum-optical sensing technique in which an entangled source is exploited to improve the detection of a low-reflectivity object that is immersed in a bright thermal background. Here we describe and analyze a system for applying this technique at microwave frequencies, a more appropriate spectral region for target detection than the optical, due to the naturally-occurring bright thermal background in the microwave regime. We use an electro-optomechanical converter to entangle microwave signal and optical idler fields, with the former being sent to probe the target region and the latter being retained at the source. The microwave radiation collected from the target region is then phase conjugated and upconverted into an optical field that is combined with the retained idler in a joint-detection quantum measurement. The error probability of this microwave quantum-illumination system, or 'quantum radar', is shown to be superior to that of any classical microwave radar of equal transmitted energy.

Q 48.7 Thu 12:30 P/H1

Entangling distant superconducting qubits using nanomechanical transducers — •Ondrej Cernotik, Denis Vasilyev, and Klemens Hammerer — Institute for Theoretical Physics, Institute for Gravitational Physics (Albert Einstein Institute), Leibniz University Hannover, Germany

Optical fields are ideal for transmission of quantum information due to low losses and high repetition rates. Microwave fields, on the other hand, can be used to manipulate superconducting systems that belong among the most promising candidates for quantum computing architecture. A device enabling conversion between electromagnetic fields of such distinct frequencies would thus represent a basic building block of future quantum computer networks. Nanomechanical oscillators represent an extremely suitable platform for this task as they can couple to both optical and microwave fields. The electromechanical interaction is achieved through capacitance of an LC circuit, where the change of voltage couples to the position of a mechanical membrane forming one plate of the capacitor, while coupling to the visible light is due to radiation pressure from light reflected off the membrane.

Here we study how such nanomechanical transducers can be employed to generate entanglement between two superconducting qubits placed on two separate chips. Our protocol is based on continuous Bell measurement of the outgoing light fields and applying feedback on the qubits. With such a setup, it is, in principle, possible to generate entanglement between qubits deterministically in the steady state.

Q 48.8 Thu 12:45 P/H1

The optomechanical damping basis — •Juan Mauricio Torres[1], Ralf Betzholz[2], and Marc Bienert[2] — [1]Institut für Angewandte Physik, Technische Universität Darmstadt, D-64289 Germany — [2]Theoretische Physik, Universität des Saarlandes, D-66123 Saarbrücken, Germany

We present the solution to the eigenvalue problem of the Lindblad master equation describing an optomechanical setup. The set of eigenvectors of the corresponding Liouville operator is called the damping basis [1]. The system consists of an optical mode representing the electromagnetic field inside a cavity with a moving mirror which stands for the mechanical mode. The effects of loses are taken into account by assuming a contact to two separate baths of zero and non-zero temperature for the optical and mechanical mode respectively. As an application, we present analytical calculations of the output spectrum of the cavity and time dependent correlation functions of the system operators.

[1] H.J. Briegel and B.G. Englert, Phys. Rev. A 47, 3311 (1993)