SYNM 1: Frontiers of Nanomechanics

Time: Wednesday 15:00–17:30 Location: H 0105

Invited Talk SYNM 1.1 Wed 15:00 H 0105

Mechanical resonators in the quantum regime — •Andrew N. Cleland — Department of Physics, University of California, Santa Barbara CA 93106 USA

I will describe our recent experiments, representing about ten years' development of nanomechanical and quantum circuit technology, which culminated in our formulating and creating a quantum mechanical resonator that could *easily* be prepared in quantum (non-classical) states of mechanical vibration. Key requirements included a mechanical design that supported a microwave-frequency mechanical resonance; using a piezoelectric material in order to achieve very strong electromechanical coupling; and employing a Josephson junction, implemented as a phase quantum bit (qubit), to measure and interact with the mechanical resonator. Operating at 25 mK on the mixing chamber of a dilution refrigerator, this integrated electromechanical system can be cooled to its quantum ground state without additional intervention. Then, employing the extraordinary nonlinearity provided by the Josephson qubit, and the coherent interactions of this qubit and the mechanical resonator, we were able to prepare and measure non-classical mechanical states of motion in the resonator.

Invited Talk SYNM 1.2 Wed 15:30 H 0105

Quantum optomechanics: exploring the interface between quantum physics and gravity — •Markus Aspelmeyer — Vienna Center for Quantum Science and Technology (VCQ), Faculty of Physics, University of Vienna, Austria

Quantum optics provides a high-precision toolbox to enter and to control the quantum regime of the motion of massive mechanical objects. This opens the door to a hitherto untested parameter regime of macroscopic quantum physics. Due to the large available mass range – from picograms in nanomechanical waveguides to kilograms in mirrors for gravitational wave detection – it becomes possible to explore the fascinating interface between quantum physics and (quantum) gravity in table-top quantum optics experiments. I will discuss a few examples.

Invited Talk SYNM 1.3 Wed 16:00 H 0105

Integrated transduction and coherent control of high Q nanomechanical systems using dielectric gradient forces — •Eva M. Weig — LMU München

Nanomechanical resonators, freely suspended bridges with nanoscale cross-sections, are receiving an increasing amount of attention both in fundamental experiments and sensing applications. In particular, prestressed silicon nitride is explored as a high Q material for nanomechanical systems (NEMS): As a consequence of the intrinsic tensile stress of the nitride film, room temperature quality factors of several 100,000 are observed in the 10 MHz eigenfrequency range. To take advantage of the large quality factor, non-dissipative transduction and manipulation schemes have to be developed which do not introduce extra damping.

We employ optically or electrically induced gradient forces to implement dielectric transduction as an efficient way to actuate and probe high Q nanomechanical resonators and to control the resonator eigenfrequency. The displacement sensitivity can be enhanced considerably by taking advantage of near-field coupling to a cavity, which, at the same time allows to benefit from back-action induced dynamics, enabling to cool the Brownian motion or to initiate cavity-pumped self-oscillation. A realization based on a room temperature microwave cavity offers a plug and play solution for all-integrated transduction, and can be employed to probe the dynamics of two strongly coupled resonator modes.

Invited Talk SYNM 1.4 Wed 16:30 H 0105

Cavity optomechanics with microwave photons — •John Teufel — NIST, Boulder, USA

Accessing the full quantum nature of a macroscopic mechanical oscillator first requires elimination of its classical, thermal motion. The flourishing field of cavity optomechanics provides a nearly ideal architecture for both preparation and detection of mechanical motion at the quantum level. We realize a microwave cavity optomechanical system by coupling the motion of an aluminum membrane to the resonance frequency of a superconducting circuit [1]. By exciting the microwave circuit below its resonance frequency, we damp and cool the membrane motion with radiation pressure forces, analogous to laser cooling of the motion of trapped ions. The microwave excitation serves not only to cool, but also to monitor the displacement of the membrane. A nearly shot-noise limited, Josephson parametric amplifier is used to detect the mechanical sidebands of this microwave excitation and quantify the thermal motion as it is cooled with radiation pressure forces to its quantum ground state [2].

[1] Teufel, J. D. et al., Nature 471, 204-208 (2011).
[2] Teufel, J. D. et al., Nature 475, 359-363 (2011).

Invited Talk SYNM 1.5 Wed 17:00 H 0105

Optomechanical crystals — •Oskar Painter — Thomas J. Watson, Sr., Laboratory of Applied Physics, California Institute of Technology, Pasadena CA 91125 USA

In the last several years, rapid advances have been made in the field of cavity optomechanics, in which the usually feeble radiation pressure force of light is used to manipulate (and precisely monitor) mechanical motion. These advances have moved the field from the multi-km interferometer of a gravitational wave observatory, to the optical table top, and now all the way down to a silicon microchip. In this talk I will describe these advances, and discuss our own work to realize radiation pressure within nanoscale structures in the form of coupled photonic and phononic crystals (dubbed optomechanical crystals). Applications of these new nano-opto-mechanical systems include: all-optically tunable photonics, optically powered RF and microwave oscillators, and precision force/acceleration and mass sensing. Additionally there is the potential for these systems to be used in hybrid quantum networks, enabling storage or transfer of quantum information between disparate quantum systems. I will introduce several conceptual ideas regarding phonon-photon translation and slow light effects which may be used in such quantum settings, and discuss recent experiments to realize them in practice.