TT 42: Nano- and Optomechanics

Time: Wednesday 10:45–12:30 Location: H7

TT 42.1 Wed 10:45 H7

Optomechanics of a suspended carbon nanotube quantum dot coupled to a coplanar microwave resonator, part 1: theory — Stefan Blien, Patrick Steger, Niklas Hüttner, Richard Graaf, and •Andreas K. Hüttel — Institute for Experimental and Applied Physics, Universität Regensburg, Regensburg, Germany

A clean, suspended single wall carbon nanotube is the ultimate limit of a nanomechanical beam resonator, where the fundamental transversal vibration mode reaches resonance frequencies on the order of 100MHz – 1 GHz and mechanical quality factors up to 10^6. Placing a nanotube next to a coplanar resonator at cryogenic temperatures results in a microwave optomechanical system with dispersive coupling. This system, however, has a fundamentally new property: the nanotube is also a quantum dot, and the interaction of motion and single electron tunneling dominates its behaviour.

We demonstrate how Coulomb blockade leads to an enhanced optomechanical coupling g that is also tuneable by the gate potential. The inherent electronic nonlinearity acts as amplifier, leading to values up to $g \simeq 10\,\mathrm{kHz}$ already at moderate cavity occupation. With the combined optomechanical system in the far resolved sideband limit, many interesting experiments become feasible.

TT 42.2 Wed 11:00 H7

Optomechanics of a suspended carbon nanotube quantum dot coupled to a coplanar microwave resonator, part 2: experiment — •Stefan Blien, Patrick Steger, Niklas Hüttner, Richard Graaf, and Andreas K. Hüttel — Institute for Experimental and Applied Physics, Universität Regensburg, Regensburg, Germany

A clean, suspended single wall carbon nanotube is the ultimate limit of a nanomechanical beam resonator. We have implemented a transfer technique to integrate such a nanotube into a superconducting circuit, and present measurements on a combined device coupling a suspended carbon nanotube quantum dot to a coplanar microwave resonator mode at millikelvin temperatures.

Nanotube vibration and microwave cavity form a dispersively coupled optomechanical system, which we characterize via two-tone spectroscopy (red side band photon upconversion) as well as optomechanically induced transparency (OMIT). The interaction of charge transport and vibration, via Coulomb blockade and single electron tunneling, leads to a strongly enhanced, tunable optomechanical coupling.

TT 42.3 Wed 11:15 H7

In situ tunable string resonators in a network — •Daniel Schwienbacher[1,2,3], Thomas Luschmann[1,2], Rudolf Gross[1,2,3], and Hans Huebl[1,2,3] — [1]Walther-Meissner-Institut, Bayerische Akademie der Wissenschaften, Garching, Germany — [2]Physik-Department, Technische Universität München, Garching, Germany — [3]Nanosystems Initiative Munich (NIM), München, Germany

Mechanical resonator networks are currently discussed in the context of model systems giving insight to condensed matter problems including topology[1]. Here, we discuss networks based on three high-Q nanomechanical string resonators (nanostrings) made from highly tensile stressed Si_3N_4. The strings are strongly coupled via shared support structures and thus can form a fully mechanical, classical multi-level system. Moreover, the individual strings are tunable in frequency [2], which allows to investigate their coupling dynamics using continuous wave and time domain techniques. In particular, such systems allow the experimental explorations of quantum classical analogies such as Landau-Zener dynamics[3,4]. We extend the previous work performed on two coupled strings to three resonators and discuss the additional features of the inter string dynamics, such as the classical analog of Landau-Zener dynamics in a three mode system and the observation of dark states.

[1] Brendel et al., Phys. Rev. B **97** 020102(R) (2018)
[2] Pernpeintner et al., Phys. Rev. App. **10** 034007 (2018)
[3] Faust et al., Nat. Phys. **9**, 485-488 (2013)
[4] Seitner et al., Phys. Rev. B **84**, 245406 (2016)

TT 42.4 Wed 11:30 H7

Nano-strings in circuit QED — •Philip Schmidt[1,2,3], Daniel Schwienbacher[1,2,3], Natalie Segercrantz[1], Mohammad T. Amawi[1,2], Christoph Utschick[1,2], Matthias Pernpeintner[1,2,3], Rudolf Gross[1,2,3], and Hans Huebl[1,2,3] — [1]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, Garching, Germany — [2]Physik-Departement, Technische Universität München, Garching, Germany — [3]Nanosystems Initiative Munich, München, Germany

In nano-electromechanics, quantum mechanical phenomena can be studied in the literal sense. For example, the coupling of a nanomechanical element to a superconducting resonator allows to cool the mechanical mode to its ground state and to squeeze its motion. Replacing the linear microwave resonator with a nonlinear one enables the preparation of more complex non-classical mechanical states.

Here, we discuss such a realization, based on Josephson junctions in superconducting circuit environments. In particular, we envisage the scenario of a mechanically compliant tensile-strained nanostring embedded into a microwave resonator combined with Josephson junctions circuits. We present experimental data of such ciruits and critically highlight limitations imposed by the embeded Jospheson junctions regarding the device performance.

Such hybrid systems open new perspectives in the field of optomechanics ranging from sensing applications to the use of quantum states.

TT 42.5 Wed 11:45 H7

Circuit electromechanical hybrid system featuring three-body interactions — •Natalie Segercrantz[1], Daniel Schwienbacher[1,2,3], Philip Schmidt[1,2,3], Rudolf Gross[1,2,3], and Hans Huebl[1,2,3] — [1]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, Germany — [2]Physik-Departement, Technische Universität München, Garching, Germany — [3]Nanosystems Initiative Munich, München, Germany

Nanomechanical resonators coupled to a microwave cavity are promising candidates for both sensing applications and quantum experiments including the preparation and transfer of non-classical states. The control and manipulation of these quantum circuits can be extended by adding a non-linear element, such as a transmon qubit, to the system. Recently, an architecture involving embedding a nanobeam into the shunt capacitance of a transmon was proposed [1]. This hybrid system with the nanomechanical transmon coupled capacitively to the microwave resonator includes three-body interactions between the mechanical and the electrodynamical degrees of freedom. Ground-state cooling and the preparation of mechanical Fock- and cat-states was theoretically predicted for the system.

We present a design on the three-body hybrid system consisting of a superconducting coplanar waveguide resonator, a transmon and a nanomechanical resonator. Using finite element simulations, the device parameters are optimized with respect to the coupling strengths and resonance frequencies.

[1] M. Abdi *et al*, Phys. Rev. Lett. 114, 173602 (2015)

TT 42.6 Wed 12:00 H7

SiN nanomechanical resonators for cavity-optomechanics — •Felix Rochau, Irene Sánchez Arribas, Alexandre Brieussel, and Eva Weig — Universität Konstanz, Konstanz, Germany

We study a high-finesse fiber-based micro-cavity with small mode volume. Similar to the membrane-in-the-middle approach to cavity-optomechanics, silicon nitride (SiN) stripes are used as 1D mechanical resonators, or to introduce nano-objects inside the cavity. To understand the system, the interaction between the cavity mode and the transverse flexural modes of the SiN stripe resonators are studied. Optomechanical coupling strength and mechanism can be tuned by changing the resonator position with respect to the cavity mode. First attemps to observe dynamical backaction are presented.

TT 42.7 Wed 12:15 H7

Modelling of coupled molecular rotors — Huang-Hsiang Lin[1,2], Alexander Croy[1], •Rafael Gutiérrez[1], and Gianaurelio Cuniberti[1,3] — [1]Institute for Materials Science and Max Bergmann Center of Biomaterials, TU Dresden, 01069 Dresden, Germany — [2]Max Planck Institute for the Physics of Complex Systems, 01187 Dresden, Germany — [3]Dresden Center for Computational Materials Science, TU Dresden, 01062 Dresden, Germany

The possibility of creating molecular gears able to transfer motion has opened novel routes to implement true molecule-based mechanical analogs of computational machine. Here, we use a classical description of rigid molecules to investigate the dynamics of coupled gears for different arrangement and in presence of disorder. To be specific, we consider two gears and many gears problem; Then we demonstrate the solution analytically and numerically. In particular, we focus on the question of transfer of angular momentum acting on assembly of gears, which is relevant in light of recent experiments.