TT 15: Nano- and Optomechanics

Time: Tuesday 11:15–12:45 Location: H23

TT 15.1 Tue 11:15 H23

Mechanical frequency control in inductively coupled electromechanical systems — •Thomas Luschmann[1,2,3], Philip Schmidt[1,2], Frank Deppe[1,2,3], Achim Marx[1], Alvaro Sanchez[4], 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]Munich Center for Quantum Science and Technology, Munich, Germany — [4]Department of Physics, Universitat Autonoma de Barcelona, Bellaterra, Spain

Nano-electromechanical systems couple mechanical motion to superconducting quantum circuits at microwave frequencies. While traditional, capacitive coupling strategies operate in the weak coupling regime, inductive coupling schemes based on partially suspended superconducting interference devices (SQUID) have demonstrated significantly improved coupling rates. Such systems are expected to allow for the exploration of phenomena beyond the linearized opto-mechanical interaction. Here, we present an investigation into the tuning of the mechanical resonance frequency in an inductively coupled system. The experimental data quantitatively corroborates theoretical predictions for SQUID-based electromechanical systems. In addition, we observe a magnetic field dependent tuning of the mechanical resonance frequency, which we attribute to an effective interaction of the atomic lattice and the superconducting vortex lattice.

TT 15.2 Tue 11:30 H23

Current-induced forces in nano-electromechanical systems: A hierarchical equations of motion approach — •Samuel Rudge and Michael Thoss — Physikalisches Institut, Albert-Ludwigs Universität Freiburg

Current-induced forces in nanostructures provide valuable insight into the mechanisms of nonequilibrium charge transport through nanoelectromechanical systems [1]. In this contribution, we investigate specifically the electronic friction in molecular junctions using the hierarchical equations of motion approach [2-3]. Since this method is, in principle, numerically exact, it allows us to extend previous studies [4] beyond the Born-Markov approximation and incorporate strong intrasystem interactions. To demonstrate the approach, we consider a resonant level model coupled to a low-frequency vibrational mode, which is treated semi-classically, and reproduce the exact electronic friction known from nonequilibrium Green's function theory [4]. We then also incorporate a high-frequency vibrational mode, which is strongly coupled to the electronic degrees of freedom and is treated fully quantum mechanically.

[1] J. T. Lü *et al.*, Phys. Rev. B **85**, 245444 (2012)
[2] Y. Tanimura, J. Chem. Phys. **153**, 020901 (2020)
[3] J. Bätge *et al.*, Phys. Rev. B **103**, 235413 (2021)
[4] W. Dou *et al.*, J. Chem. Phys. **143** 054103 (2015)

TT 15.3 Tue 11:45 H23

Generation of coherent acoustic phonons at the atomic scale with femtosecond Coulomb forces — •Shaoxiang Sheng[1], Anne-Catherine Oeter[1], Mohamad Abdo[1], Kurt Lichtenberg[1], Mario Hentschel[3], and Sebastian Loth[1,2] — [1]University of Stuttgart, Institute for Functional Matter and Quantum Technologies, Stuttgart, Germany — [2]Max Planck Institute for Solid State Research, Stuttgart, Germany — [3]University of Stuttgart, 4th Physics Institute, Stuttgart, Germany

Coherent acoustic phonons enable ultrafast control of solids and have been exploited for applications in various acoustic devices. We find that localized coherent acoustic phonon wavepackets can be launched by THz-induced ultrafast Coulomb forces in a scanning tunneling microscope (STM) junction. The wavepackets induce an ultrafast displacement of the surface with several picometers amplitude and propagate into the sample with low losses. The surface displacement can be precisely controlled by varying the tip-sample distance. This nonthermal femtosecond force excitation enables localized measurements of phonon propagation with nanometer spatial resolution, can be used for diagnostics below surfaces and opens new perspectives in exploiting coherent phonons at the atomic scale.

TT 15.4 Tue 12:00 H23

Josephson optomechanics — •Surangana Sen Gupta[1], Bjoern Kubala[1,2], Ciprian Padurariu[1], and Joachim Ankerhold[1] — [1]ICQ and IQST, Ulm University, Germany — [2]Institute of Quantum Technologies, German Aerospace Center (DLR), Ulm, Germany

Optomechanical phenomena can be investigated in the microwave regime using a circuit-QED setup combining superconducting microwave cavities and a mechanical degree of freedom. In conventional optomechanics the cavity is usually driven to a coherent state by a laser. In contrast, in circuit optomechanics, the cavity can be driven by inelastic tunneling in a Josephson junction, which provides a large inherent non-linearity and leads to complex quantum states of light [1]. Here, we theoretically investigate a superconducting cavity with a single mode ω_0 coupled to a mechanical resonator. The cavity is driven by a dc-biased Josephson junction at $2eV_{dc} = p\hbar\omega_0$ where each Cooper pair excites $p = 1, 2, 3$ photons.
(i) We characterise signatures of the mechanics in the emission spectrum for squeezed light ($p = 2$) and for the $p = 3$ case, which is challenging for optical cavities, but easily realised in our microwave cavities. The inherent nonlinearity not only allows efficient driving at $p \geq 2$, but can also drastically change the spectrum at $p = 1$, where for stronger driving Mollow-like features arise. (ii) We calculate heating and cooling rates for the mechanical degree of freedom and find in the non-linear regime enhanced and non-monotonous rates.

[1] G. C. Ménard *et al.*, Phys. Rev. X **12**, 021006 (2022).

TT 15.5 Tue 12:15 H23

Magnomechanics in suspended magnetic beams — Kalle S. U. Kansanen[1], •Camillo Tassi[2], Harshad Mishra[3], Mika A. Sillanpää[3], and Tero T. Heikkilä[1] — [1]Department of Physics and Nanoscience Center, University of Jyväkylä, P.O. Box 35 (YFL), FI-40014 Jyväskylä, Finland — [2]Donostia International Physics Center, 20018 Donostia-San Sebastian, Spain — [3]Department of Applied Physics, Aalto University, P.O. Box 15100, FI-00076 Aalto, Finland

Cavity optomechanical systems have become a popular playground for studies of controllable nonlinear interactions between light and motion. An alternative scheme with much smaller footprint is provided by magnomechanics, where phonons interact with magnons, instead of photons. Here, we consider the magnomechanical interaction occurring in a suspended magnetic beam, a scheme in which both magnetic and mechanical modes physically overlap and can be detected and also driven individually. We show that a sizable interaction - originated from both magnetoelastic and demagnetizing coupling - can be produced if the beam has some initial static deformation.

TT 15.6 Tue 12:30 H23

Improving device parameters in nanotube microwave optomechanics — Nicole Kellner, •Fabian Stadler, Niklas Hüttner, and Andreas K. Hüttel — Institute for Experimental and Applied Physics, Universität Regensburg, Regensburg, Germany

In recent work [1,2], we have demonstrated optomechanical coupling between a carbon nanotube with an embedded quantum dot and a coplanar microwave resonator. The experiment displayed enhancement of the coupling by several orders of magnitude via the nonlinearity of Coulomb blockade. The resulting novel optomechanical system can have figures of merit close to several interesting parameter regimes, as, e.g., strong optomechanical coupling (with hybridization of vibrons and photons) and the quantum coherent limit (where manipulation is faster than thermal decoherence). With this in mind, here we discuss our ongoing work to improve the components of this system, the optomechanical coupling, and its adressing and readout. — [1] S. Blien *et al.*, Nat. Comm. **11**, 1636 (2020); [2] N. Hüttner *et al.*, in preparation.