TT 46: Transport: Nanomechanics (jointly with MM)

Time: Tuesday 14:00–15:45 Location: A 053

TT 46.1 Tue 14:00 A 053

Inductively coupled cavity optomechanics — •P. Schmidt[1,2], M. Pernpeintner[1,2,3], K.F. Wulschner[1,2], S.T.B. Goennenwein[1,3], A. Marx[1], R. Gross[1,2,3], and H. Huebl[1,3] — [1]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, Garching, Germany — [2]Physik-Department, Technische Universität München, Garching, Germany — [3]Nanosystems Initiative Munich, München, Germany

Cavity optomechanics allows to study the light-matter interaction with micro-, meso-, and macroscopic objects offering the possibility to access the quantum mechanical regime in the literal sense [1]. Transferring this approach to the microwave (MW) domain gives rise to the field of cavity electromechanics. Typical electromechanical systems consist of a micro- or nanomechanical resonator coupled capacitively to a superconducting MW resonator.

Here, we present the approach of an inductively coupled electromechanical system. To this end, we implement a dc-SQUID with a vibrational element at the current antinode of a $\lambda/4$ MW resonator. Hereby, the eigenfrequency of the MW resonator becomes tunable. As the vibration of the nano-string changes the SQUID loop area, we expect that the electromechanical coupling becomes flux-tunable.

We present first experimental results obtained from MW transmission spectroscopy in a dilution refrigerator and compare it with our theoretical model. These results indicate an expected tunability of the electromechanical coupling from 0 to 1 kHz.

[1] M. Aspelmeyer *et al.*, Physics Today **65**, 29 (2012).

TT 46.2 Tue 14:15 A 053

Circuit Electromechanics with a Non-Metallized Nanobeam — •Matthias Pernpeintner[1,2,3], T. Faust[4], F. Hocke[1,2,3], J. P. Kotthaus[4], E. M. Weig[4,5], R. Gross[1,2,3], and H. Huebl[1,2] — [1]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, Garching, Germany — [2]Nanosystems Initiative Munich, München, Germany — [3]Physik-Department, Technische Universität München, Garching, Germany — [4]Center for NanoScience (CeNS) and Fakultät für Physik, Ludwig-Maximilians-Universität, München, Germany — [5]Department of Physics, University of Konstanz, Konstanz, Germany

In the field of cavity optomechanics, a motional degree of freedom is coupled to an optical cavity. This approach can be transferred to the solid state environment e. g. by combining a superconducting microwave cavity with a nanomechanical resonator.

Whereas typically metallized mechanical resonators are used, we present an alternative approach which is based on the dielectric coupling between a superconducting coplanar waveguide microwave resonator and a non-metallized tensile-stressed silicon nitride nanobeam.

We use the Duffing nonlinearity of the strongly driven beam to calibrate the amplitude spectrum of the mechanical motion and determine the electromechanical vacuum coupling. We find a quality factor of 480,000 at a resonance frequency of 14 MHz and 0.5 K. We deduce a vacuum coupling of 11.5 mHz, which is in quantitative agreement with finite element based model calculations.

This type of hybrid platform will allow further studies on the properties of non-metallized beams and more complex mechanical hybrids.

TT 46.3 Tue 14:30 A 053

Coupling Graphene Mechanical Resonators to Superconducting Microwave Cavities — •Peter Weber, Johannes Güttinger, Ioannis Tsioutsios, Darrick E. Chang, and Adrian Bachtold — ICFO-Institut de Ciencies Fotoniques, 08660 Castelldefels (Barcelona), Spain

Graphene is an attractive material for nanomechanical devices because it allows for exceptional properties, such as high frequencies, quality factors, and low mass. An outstanding challenge, however, has been to obtain large coupling between the motion and external systems for efficient readout and manipulation. Here, we report on a novel approach, in which we capacitively couple a high-Q graphene mechanical resonator (Q = 100.000) to a superconducting microwave cavity. The initial devices exhibit a large single-photon coupling of ~10 Hz. Remarkably, we can electrostatically change the graphene equilibrium position and thereby tune the single photon coupling and the mechanical resonance frequency by a large amount. The strong tunability opens up new possibilities, such as the tuning of the optomechanical coupling strength on a time scale faster than the inverse of the cavity line width. With realistic improvements, it should be possible to enter the regime of quantum optomechanics.

TT 46.4 Tue 14:45 A 053

Spin-vibration interaction in a nanomechanical spin-valve — •Pascal Stadler[1], Wolfgang Belzig[1], and Gianluca Rastelli[1,2] — [1]Fachbereich Physik, Universität Konstanz, 78457 Konstanz, Germany — [2]Zukunftskolleg, Fachbereich Physik, Universität Konstanz, 78457, Konstanz, Germany

We study spin-dependent transport in a suspended carbon nanotube quantum dot in contact with two ferromagnetic leads and with the dot's spin interacting with the flexural modes [1,2]. The spin-vibration interaction arises from the spin-orbit coupling or a magnetic field gradient. We use a nonequilibrium Green's functions technique to evaluate the phonon occupation and the transport properties. The interaction between the spin and the vibration leads to a mechanical damping and, for an applied bias-voltage, to a steady nonequilibrium occupation of the harmonic oscillator. Depending on the magnetic configuration and the bias voltage polarity, a single vibrational mode can be strongly cooled, heated or can approach a regime of a mechanical instability. Owing to the sensitivity of the electron transport to the spin orientation, we find signatures of the nanomechanical motion in the current-voltage characteristic.

[1] P. Stadler, W. Belzig, and G. Rastelli,
Phys. Rev. Lett. **113**, 047201 (2014).
[2] P. Stadler, W. Belzig, and G. Rastelli, arXiv:1408:6357.

TT 46.5 Tue 15:00 A 053

Large current noise in nanoelectromechanical systems close to continuous mechanical instabilities — Jochen Brüggemann[1], •Guillaume Weick[2], Fabio Pistolesi[3], and Felix von Oppen[4] — [1]I. Institut für Theoretische Physik, Universität Hamburg, D-20355 Hamburg, Germany — [2]Institut de Physique et Chimie des Materiaux de Strasbourg, Université de Strasbourg, CNRS UMR 7504, F-67034 Strasbourg, France — [3]Laboratoire Ondes et Matiere dÂquitaine, Université de Bordeaux, CNRS UMR 5798, F-33400 Talence, France — [4]Dahlem Center for Complex Quantum Systems & Fachbereich Physik, Freie Universität Berlin, D-14195 Berlin, Germany

We investigate the current noise of nanoelectromechanical systems close to a continuous mechanical instability. In the vicinity of the latter, the vibrational frequency of the nanomechanical system vanishes, rendering the system very sensitive to charge fluctuations and, hence, resulting in very large (super-Poissonian) current noise. Specifically, we consider a suspended single-electron transistor close to the Euler buckling instability [1,2,3]. We show that such a system exhibits an exponential enhancement of the current noise when approaching the Euler instability which we explain in terms of telegraph noise [4].

[1] G. Weick et al., PRB 81, 121409(R) (2010)
[2] G. Weick et al., PRB 83, 035420 (2011)
[3] G. Weick et al., PRB 84, 125454 (2011)
[4] J. Brüggemann et al., PRB 85, 125441 (2012)

TT 46.6 Tue 15:15 A 053

Mechanically induced iSWAP gate and maximally entangled states in a carbon nanotube — •Heng Wang and Guido Burkard — Department of Physics, University of Konstanz, D-78457 Konstanz, Germany

We study a nanomechanical system where two separated single-electron spins in two quantum dots in a suspended carbon nanotube (CNT) are driven by an ac electric field in a parallel magnetic field. An indirect coupling between two single-electron spins is induced based on the simultaneous interaction of the two spins with the mechanical mode of the CNT. We show how a two-qubit iSWAP gate and arbitrary single-qubit gate can be obtained by analyzing the effective Hamiltonian from the time dependent Schrieffer-Wolff transformation and the time evolution operator. Combining the iSWAP gate and single-qubit gates, maximally entangled states of two spins can be generated with a single step by varying the frequency and the strength of the external electric driving field. The iSWAP gate and single-qubit gates can be turned off when suppressing the spin-phonon coupling by electrostatically shifting the electron wave function on the nanotube.

TT 46.7 Tue 15:30 A 053

Nonlinear phononics using atomically thin membranes — Daniel Midtvedt and •Alexander Croy — Max-Planck-Institute for the Physics of Complex Systems, Dresden, Germany

In recent years, there has been considerable interest in tailoring material and wave-propagation properties using structured materials, prominent examples being phononic and photonic crystals. Here, we propose a design that allows for engineering flexural-phonon propagation by facilitating atomically thin membranes [1]. The strong geometric nonlinearity present in such systems leads to phonon-phonon interactions, which allow the study of many-body effects. Using a continuum mechanics description of a periodically pinned graphene membrane, we investigate the properties of the resulting phononic crystal and demonstrate that defects in the pinning lattice support localized modes. Two such modes in close proximity interact via the elastic energy, and constitute a simple model of a phononic dimer. We show that the defect Hamiltonian in the rotating-wave approximation is equivalent to a classical Bose-Hubbard model. By tuning the properties of the pinning lattice and the amplitudes of the flexural vibrations, we observe a bifurcation corresponding to the transition from “Rabi” to “Josephson” dynamics. Further, we demonstrate a wide tunability of the dimer frequencies by local back-gates, which allows for studies of the (non-linear) Landau-Zener transition.

[1] D. Midtvedt, A. Isacsson and A. Croy, Nat. Commun. **5**, 4838 (2014).