SFB 910

SFB 910 Symposium

“Going beyond weak coupling: nonlinear magneto-mechanics”

Friday, 26th November 2021, 15:00 s.t.
via Zoom
For information on how to access the event, please contact:
henning.reinken@itp.tu-berlin.de

Technische Universität Berlin
Straße des 17. Juni 135, 10623 Berlin

15:00 **Nonlinear magneto-mechanics**

Prof. Dr. Gerhard Kirchmair *(Universität Innsbruck)*

15:50 **Break**

16:00 **Improving cooling performance in an optomechanical system using a nonlinear cavity**

Nicolas Diaz *(Freie Universität Berlin)*

16:30 **Inductively coupled electromechanics based on a mechanically compliant SQUID**

Thomas Luschmann *(Walther-Meissner-Institut, Bayerische Akademie der Wissenschaften)*

Guests are welcome!

Sabine Klapp Andreas Knorr Anja Metelmann

http://www.itp.tu-berlin.de/sfb910/

Abstracts

Nonlinear magneto-mechanics

Prof. Dr. Gerhard Kirchmair *(Universität Innsbruck)*

The possibility to operate massive mechanical oscillators in the quantum regime has become central in fundamental sciences. Optomechanics, where photons are coupled to mechanical motion, provides the tools to control mechanical motion near the fundamental quantum limits. Our setup consists of a magnetic field sensitive cavity coupled to a magnetic cantilever, a beam equipped with a magnet on its tip, leading to a position dependent magnetic field. A SQUID embedded in our superconducting cavity provides the sensitivity to magnetic fields. As the inductance of the SQUID changes with magnetic field, the frequency of the cavity is coupled to the position of the cantilever. In this magneto-mechanical system, we achieve single photon coupling strength, which are among the highest in the field and more than a factor of ten larger compared to other electro-mechanical systems.

Despite working at cryogenic temperatures, macroscopic mechanical objects (i.e. the cantilever) are in highly excited thermal states and need to be cooled close to the ground state in order to investigate quantum phenomena. One of the most common approaches is to utilize the cavity for sideband cooling. To be able to cool the ground state, usually the lifetime of the cavity has to exceed the mechanical frequency, which gets increasingly challenging when working with more massive systems. We demonstrate a novel cooling scheme by using the intrinsic nonlinearity of the cavity induced by the SQUID. We show, that the non-linearity has to be included in describing the back action and demonstrate a one order of magnitude improvement in the cooling compared to a linear system with comparable parameters. With our system it seems to be possible to overcome the back-action limit, which limits the cooling performance in linear cavities. It could even be a way reach the ground state with a system in the bad cavity limit.

Improving cooling performance in an optomechanical system using a nonlinear cavity

Nicolas Diaz *(Freie Universität Berlin)*

Ground state cooling of a mechanical resonator is the prerequisite to utilize them for quantum information processing, and for ultrasensitive precision measurements at the quantum limit. In the field of cavity optomechanics dynamical backaction cooling and feedback protocols have been successfully used to bring macroscopic mechanical elements into or near the quantum ground state. Cooling in the linear regime of optomechanics has been extensively studied in the literature. However, here we show the emergence of new effects once a nonlinear environment for the mechanics is considered. We study the cooling properties of a mechanical resonator coupled to a nonlinear cavity, acting as a high-Q Duffing oscillator. We demonstrate that the presence of the Duffing-nonlinearity improves the cooling efficiency significantly. Moreover, we show that the cooling still improves even when driving the oscillator beyond bistability. These advantages of the nonlinear environment are not limited to the resolved sideband regime, and extend the realm of optomechanical architectures in the quantum regime. into patterns of patched synchrony.

Inductively coupled electromechanics based on a mechanically compliant SQUID

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], Hans HUEBL[1,2,3]

[1] *Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, Walther-Meißner-Str.8, 85748 Garching, Germany*
[2] *Physik-Department, Technische Universität München, James-Franck-Str.1, 85748 Garching, Germany*
[3] *Munich Center for Quantum Science and Technology, Schellingstr.4, 80799 München, Germany*
[4] *Department of Physics, Universitat Autonoma de Barcelona, 08193 Bellaterra, Catalonia, Spain*

Nano-electromechanical systems introduce optomechanics, the coupling of mechanical displacement to the photon field of an optical resonator, to the field of superconducting quantum circuits in a highly successful manner. While impressive achievements have been demonstrated so far, those rely on coupling rates operating in the weak vacuum coupling regime and therefore do not have access to the full wealth of the optomechanical interaction Hamiltonian. The majority of devices in the field realize the optomechanical interaction via a capacitive coupling scheme, where the displacement of the mechanical element is transduced into a variation of the microwave resonator capacitance and hence its resonance frequency. Recently, inductive coupling schemes based on partially suspended superconducting interference devices (SQUID) were introduced, where mechanical displacement is transduced into a change of the resonator's inductance. Such systems are expected to exhibit significantly higher vacuum coupling rates and allow for the exploration of phenomena beyond the linearized optomechanical interaction. In this presentation, we focus on the advantages of inductively coupled electromechanics and present experimental results regarding demonstrated and achievable coupling rates, the possibilities of tuning the coupling rates and resonance frequencies, as well as solid-state sensing applications.