# Q 23: Optomechanics I & Optovibronics

Time: Wednesday 11:00–12:45 Location: A320

Q 23.1 Wed 11:00 A320

**Quantum optomechanics with a levitated nanoparticle and an on-chip photonic crystal cavity** — •Seyed Khalil Alavi[1,2], Jin Chang[3], Danial Davoudi[1], Marion Hagel[4], Simon Gröblacher[3], and Sungkun Hong[1,2] — [1]Institute for Functional Matter and Quantum Technologies, Universität Stuttgart, Stuttgart, DE — [2]Center for Integrated Quantum Science and Technology, Universität Stuttgart, Stuttgart, DE — [3]Kavli Institute of Nanoscience, Department of Quantum Nanoscience, Delft University of Technology, Delft, The Netherlands — [4]Max Planck Institute for Solid State Research, Stuttgart, DE

A levitated dielectric nanoparticle coupled to an optical cavity is a promising platform for quantum optomechanics. Recent progress includes cooling the particle's motion to the ground state achieved with a conventional optical cavity. A photonic crystal nanocavity (PCN) is an attractive alternative offering enhanced optomechanical coupling. The optomechanical coupling up to 10 kHz has been previously demonstrated with a stand-alone PCN. However, the system's fragility to optical absorption and mechanical perturbation prevented further advancement toward the quantum regime. In this talk, we present a new platform based on an on-chip PCN that can achieve the goal. The new PCN architecture ensures significantly improved mechanical and thermo-optic stability, allowing experiments at a high vacuum and with a large number of intracavity photons. We discuss our recent progress toward obtaining the quantum cooperativity above one.

Q 23.2 Wed 11:15 A320

**Optoacoustic active phonon cooling in waveguides** — •Laura Blázquez Martínez[1], Philipp Wiedemann[1], Andreas Geilen[1], Changlong Zhu[1], and Birgit Stiller[1,2] — [1]Max Planck Institute for the Science of Light, Staudtstrasse 2, 91058, Erlangen, Germany — [2]Physics department office, FAU Erlangen-Nürnberg, Staudtstr. 7 / B2, 91058, Erlangen, Germany

Optomechanical cooling is usually observed in resonator-based setups. In waveguides, active cooling via optomechanical or optoacoustic interactions is still largely unexplored. Here, we demonstrate experimentally active optoacoustic phonon cooling using the nonlinear effect of Brillouin-Mandelstam scattering in a chalcogenide glass photonic crystal fibre (PCF). The regime of height saturation for the anti-Stokes peak is demonstrated experimentally. Based on the Brillouin resonance behaviour, we show cooling by a temperature difference of $\Delta T \approx 190$ K from room temperature at 7.53 GHz, exceeding 3 times previously reported values.

Q 23.3 Wed 11:30 A320

**Coherent control of Brillouin optomechanics in waveguides** — •Changlong Zhu[1], Junyin Zhang[1], Christian Wolff[2], and Lijun Qiu[1] — [1]Max Planck Institute for the Science of Light, Staudtstr. 2, 91058 Erlangen, Germany — [2]Centre for Nano Optics, University of Southern Denmark, Campusvej 55, DK-5230, Odense M, Denmark

Brillouin optomechanics in waveguides allows a triply-resonant interaction between an optical, scattered light, and an acoustic wave. Here, we present a formalism to describe backward Brillouin optomechanics in waveguides in the dynamic regime with a pulsed pump. This formalism reveals the connection between waveguide Brillouin optomechanics and cavity optomechanics. By utilizing this theoretical framework, we show a closed solution for the coupled-mode equation of Brillouin optomechanics under the undepleted assumption, which can be used to investigate the coherent control of waveguide optomechanics in the quantum regime, such as coherent photon-phonon transfer, phonon cooling, and photon-phonon entanglement. In addition, we propose a dynamic Brillouin cooling scheme in Brillouin-active integrated waveguides, where the optical dissipation exceeds the mechanical dissipation which is the common case in optical waveguides. By modulating the coupling intensity of the backward Brillouin anti-Stokes interaction via a pulsed pump, a phonon cooling factor with several orders of magnitude can be achieved.

Q 23.4 Wed 11:45 A320

**Quantum optics approach to non-adiabatic phenomena in molecules** — •Michael Reitz[1], Jacopo Fregoni[2], Raphael Holzinger[3], Agnes Vibok[4], and Claudiu Genes[1,5] — [1]Max Planck Institute for the Science of Light, Erlangen, Germany — [2]Departamento de Física Teórica de la Materia Condensada and Condensed Matter Physics Center (IFIMAC), Universidad Autónoma de Madrid, Madrid, Spain — [3]Institut für Theoretische Physik, University of Innsbruck, Innsbruck, Austria — [4]Department of Theoretical Physics, University of Debrecen, Debrecen, Hungary — [5]Physics Department, Friedrich-Alexander Universität Erlangen-Nürnberg, Erlangen, Germany

We propose an open quantum system approach to non-adiabatic phenomena in molecules, especially relevant during or after photoexcitation. In particular, we provide analytical approaches that qualitatively describe processes such as nonradiative transitions, internal conversion and intersystem crossing. The main overarching aspect of this theory is the derived unidirectionality of transfer between higher energy electronic states to lower energy states mediated by nonadiabatic couplings followed by quick vibrational relaxation, i.e., the often invoked Kasha's rule.

Q 23.5 Wed 12:00 A320

**Nonlinear opto-vibronics in molecular systems** — Quansheng Zhang[1], •Micheal Reitz[1], and Claudiu Genes[1,2] — [1]Max Planck Institute for the Science of Light, Erlangen, Germany — [2]Department of Physics, University of Erlangen-Nuremberg, Erlangen, Germany

Opto-vibrational interactions in molecular systems occur in a hybrid fashion as light couples to electronic transitions, which in turn are modified by the vibrations of the nuclei. In standard approaches, under the Born-Oppenheimer approximation, the vibronic coupling is a spin-boson interaction modeled by a Holstein Hamiltonian, i.e., an electronic transition between two copies of the same harmonic potential landscape is slightly shifted. However, the potential landscapes for the excited and ground electric states may be different, with two different frequencies for the two harmonic curves. In such a case, the polaron transformation is modified by an operation involving a conditional squeezing operator.

We present here an analytical treatment based on a set of quantum Langevin equations for elective spin operators dressed by oscillations. These equations can be solved under some approximations to obtain information on emission and absorption spectra. Moreover, we propose to exploit the intrinsic nonlinear vibronic interaction to map light states to nuclear vibrations and viceversa. Our results are also applicable to quadratic optomechanics, such as in the membrane-in-the-middle scenario.

Q 23.6 Wed 12:15 A320

**Interaction-Induced Directional Transport on Driven Coupled Chains** — •Helena Drüeke and Dieter Bauer — Universität Rostock

We examine whether interaction between particles may introduce (topologically protected) directional transport in a driven two-particle quantum system. As a simple example, we consider two one-dimensional chains of equal length, each with one particle. The two particles interact but stay on their respective chain. The particles move alternatingly and without a preferred direction.

Without interaction between the particles, they each diffuse along their chains. Interaction between them suppresses this diffusion. With the proper timing of their alternating movement, the particles form a bound doublon state. Depending on their starting positions, this doublon either remains stationary or moves along the chain. The motion of the doublon consists of alternating, leapfrogging motion of the two particles.

Q 23.7 Wed 12:30 A320

**Teaching Quantum Optics and Quantum Cryptography with Augmented Reality Enhanced Experiments** — •Adrian Abazi[1], Paul Schlummer[2], Jonas Lauströer[3], Jochen Stuhrmann[3], Rasmus Borkamp[3], Wolfram Pernice[1], Reinhard Schulz-Schaeffer[3], Stefan Heusler[2], Daniel Laumann[2], and Carsten Schuck[1] — [1]Center for Nanotechnology, WWU Münster — [2]Institut für Didaktik der Physik, WWU Münster — [3]Department Design, HAW Hamburg

Recently, the Nobel Prize in physics was awarded for experiments with entangled photons, pioneering quantum technologies. To meet the growing demand of this field by furthering scientific comprehension of quantum physics and quenching misconception, especially about entanglement, new teaching approaches are required. Addressing this, we present a mixed reality quantum learning environment, by integrating commercially available AR-Headsets with a quantum optics setup for photon-pair generation and bell measurements. Students measure Bells inequality and conduct a version of the Ekert 91 quantum key distribution protocol. Simultaneously, visualizations of the underlying models and measurement results are rendered as holograms on appropriate locations of the optics setup. Dedicated actions, such as choosing a measurement basis, are reflected in the visualizations in real time. The learning environment has been implemented and is tested in undergraduate lab-courses. The components and software of the environment have been chosen to ease modifications and transfer.