Q 71: Cavity QED and QED II

Time: Friday 11:00–13:00 Location: P 4

Q 71.1 Fri 11:00 P 4

Hyperbolic Phonon Polaritons and Color Centers in hBN: a new platform for quantum optics — •Jiecheng Feng[1,2,3], Johannes Eberle[1], Sambuddha Chattopadhyay[1,4], Johannes Knörzer[1], Eugene Demler[1], and Atac Imamoglu[1] — [1]ETH Zurich, Zurich, Switzerland — [2]Max Planck Institute for the Structure and Dynamics of Matter, Hamburg, Germany — [3]RWTH Aachen University, Aachen, Germany — [4]Harvard University, Massachusetts, USA

Hyperbolic phonon polaritons (HPPs) in hexagonal boron nitride (hBN) confine mid-IR light to deeply subwavelength scales but are typically generated and probed with classical near-field tips, limiting quantum control. We link this platform with the rapidly developing field of hBN color centers, bright, photostable, atomically localized emitters, by developing a cavity-QED framework in which a single color center serves as a quantum source of HPPs. We quantify emitter-HPP coupling and analyze two routes: spontaneous phonon-sideband emission, which yields single-HPP events and becomes single-mode in ultrathin slabs; and stimulated Raman driving, which provides frequency selectivity, tunable conversion, and narrowband excitation that launches directional, ray-like HPPs over micrometers. We also propose a two-emitter correlation test applicable to both schemes. Together, these results point to a new direction for mid-IR light-matter experiments that unite strong coupling, spectral selectivity, and spatial reach within a single material system.

Q 71.2 Fri 11:15 P 4

Cavity-assisted defect removal in a small-scale toric code — •Junyi Zhang and Francesco Petiziol — Technische Universität Berlin

We design and investigate a dissipative defect-removal mechanism in a small scale toric code coupled to a leaky cavity. The model considered includes coherent perturbations that delocalize either electric or magnetic anyon pairs, producing superpositions of error configurations with respect to information encoded in the ground state. By combining analytical and numerical tools, we study how coherent anyon delocalization competes with cavity-assisted dissipation engineering in determining cooling efficiency and steady state behavior, for different coupling schemes. This analysis provides insights into the potential and fundamental limitations of cavity-assisted cooling as a passive error suppression pathway in a topologically ordered system.

Q 71.3 Fri 11:30 P 4

Towards x-ray quantum optics using periodically structured cavities — •Robert Horn and Jörg Evers — Max-Planck-Institut für Kernphysik, Heidelberg, Germany

Due to their narrow linewidth, Mössbauer nuclei, such as ^{57}Fe, have become an important platform for studying the nature of photons in the hard x-ray regime. These nuclei not only serve as potential nuclear clocks but also emerge as promising candidates for x-ray quantum dynamics. A typical environment for studying quantum optical effects in the linear x-ray regime is that of a thin-film cavity with embedded Mössbauer nuclei probed at grazing incidence. A recently developed ab initio approach using the electromagnetic Green's tensor provides a robust theoretical and numerically efficient framework for describing this setup.

In this project, we propose a modified setup that breaks the system's translational symmetry along the wave-propagation direction by introducing a periodic spacing of the nuclei. Our aim is to investigate the emergence of additional scattering channels and the correlations between them, as well as to compute the corresponding reflection and transmission spectra.

Q 71.4 Fri 11:45 P 4

Comparison and interference of Photoelectron Circular Dichroism of a chiral molecule induced directly or by Interatomic Coulombic Decay of an antenna atom — •Lara Marie Tomasch, Omar Jesus Franca Santiago, and Stefan Yoshi Buhmann — Institut für Physik, Universität Kassel, Heinrich-Plett-Straße 40, 34132 Kassel, Germany

We aim to examine the photoelectron circular dichroism of a chiral molecule via two different channels: First, the direct ionization of the molecule with circularly polarised light. This is a well-known effect [1]. Alternatively, a non-chiral atom can serve as an antenna atom. This donor atom is first excited by circularly polarised light, the energy is then transfered via resonant Interatomic Coulombic Decay to the chiral acceptor molecule. There is a noticeable change in the resulting signal, depending on which channel is responsible for the ionisation [2].

In an experiment with intermediate distances between atoms and molecules both of these ionization channels can contribute simultaneously. We hence want to focus on possible interference effects and compare this simultaneous coherent process to the two individual processes.

[1]: Ritchie, B., Theory of the angular distribution of photoelectrons ejected from optically active molecules and molecular negative ions. Phys. Rev. A 13, 1411 (1976)

[2]: Buhmann, S. Y. et al, Photoelectron Circular Dichroism of a Chiral Molecule Induced by Resonant Interatomic Coulombic Decay from an Antenna Atom. Phys. Rev. Letters 134, 253001 (2025)

Q 71.5 Fri 12:00 P 4

Control of photon number wave packets in a microcavity — •Luca Nimmesgern[1], Moritz Cygorek[2], Doris E. Reiter[2], and Vollrath Martin Axt[1] — [1]Universität Bayreuth, Germany — [2]CMT, TU Dortmund, Germany

In order to implement quantum information algorithms, it is necessary to be able to directly control the quantum state of the underlying physical platform. Light is promising candidate, offering fast transmission and low decoherence. However, its infinite degrees of freedom make it challenging to define an optimal method for encoding information in its quantum state.

While most research is concerned with low photon numbers, our efforts are focused on states including higher, but not macroscopically large photon numbers. In this regime, structures, called photon number wave packets, which are characterised by an oscillating mean and finite width, have been recently investigated [1]. In this contribution, we show how the dynamics of these structures can be understood. Further, we demonstrate how additional packets can be dynamically created [2]. The conceptual simplicity of this manipulation might indicate the packet structure to be a suitable base for novel ways of information encoding.

[1] L. Nimmesgern *et al.*, Phys. Rev. B **109**, 155436 (2024).

[2] L. Nimmesgern *et al.* (submitted), arXiv:2509.03083.

Q 71.6 Fri 12:15 P 4

Master Equation for a quantum gas of polarizable particles in Cavities — •Tom Schmit[1], Catalin-Mihai Halati[2], Tobias Donner[3], Giovanna Morigi[1], and Simon B. Jäger[4] — [1]Theoretische Physik, Universität des Saarlandes, 66123 Saarbrücken, Germany — [2]Max Planck Institute for the Physics of Complex Systems, Nöthnitzer Str. 38, 01187 Dresden, Germany — [3]Institute for Quantum Electronics, Eidgenössische Technische Hochschule Zürich, Otto-Stern-Weg 1, 8093 Zurich, Switzerland — [4]Physikalisches Institut, University of Bonn, Nußallee 12, 53115 Bonn, Germany

Quantum gases of atoms and molecules in optical cavities offer a formidable laboratory for studying the out-of-equilibrium dynamics of long-range interacting systems. The interaction is mediated by multiple scattering of cavity photons and can induce emerging patterns and self-organized structures determined by the interplay of photon-mediated forces, dissipation, and quantum and thermal fluctuations. Theoretical descriptions of these phenomena often rely on mean-field or weak-coupling approximations, though their validity in this context can be limited or even questionable. In this work, we present the derivation of a Lindblad master equation for the dynamics of the sole motional variables of polarizable particles, such as atoms or molecules, that dispersively couple to cavity fields. We validate the theoretical description by showing that it captures the dynamics from weak to strong cavity-mediated interactions. Our theory provides a powerful framework for the description of out-of-equilibrium dynamics of quantum gases in cavities and their relaxation towards their steady state.

Q 71.7 Fri 12:30 P 4

Enhancing atom-photon interaction with integrated nanophotonic structures — •Xiaoyu Cheng[1], Benyamin Shnirman[1,4], Alexandra Koepf[1,4], Hadiseh Alaeian[2], Xueyi Wang[3], Sunny Yang[3], Tilman Pfau[1], and Robert Loew[1] — [1]5. Physikalisches Institut, Universitaet Stuttgart — [2]School of Electrical and Computer Engineering, Purdue University, Indiana, USA — [3]Department of Electrical Engineering, Yale University, Connecticut, USA — [4]Institut für Mikroelektronik Stuttgart (IMS-Chips), Stuttgart, Germany

Hybrid devices consisting of thermal atomic vapor and nanophotonic structures are interesting platforms for manipulating the interaction between atoms and photons. For example, we exploit cooperative effects on such hybrid platforms to study the coherent atom-photon coupling in the strong coupling regime. This requires high quality factor micro-ring cavities with small mode volume. We demonstrate that micro-rings with 700K quality factor strongly couple with multiple Rubidium atoms with collective coupling strength of several GHz, which is above the atomic decaying rate and cavity loss, results in the cooperativity C larger than 1. Moreover, we are interested in the thermal and temporal dynamics of Rb atoms experiencing strongly pulsed lasers, known as Light Induced Atomic Desorption (LIAD). With carefully designed nano-photonic structures, one can in principle probe the angular and temporal distribution of LIAD atom clouds.

Q 71.8 Fri 12:45 P 4

Design of 1D Photonic Crystal Nanobeam Cavities for Quantum Dot Integration — •Oscar Camacho Ibarra, Sandesh Kallappa Mahajan, Jan Gabriel Hartel, Atzin Ruiz Perez, Sonja Barkhofen, and Klaus Jöns — hqpd lab, PhoQS institute, CeOPP, and Department of Physics,Paderborn University, Germany

Although the design and fabrication of nanobeam cavities have been extensively explored since the early 2000s, comparatively little attention has been given to tailoring these structures for the integration of epitaxial III*V semiconductor quantum dots (QDs). This gap largely stems from the realization, around 2018, that QDs experience significant linewidth broadening when placed too close to the etched sidewalls of nanophotonic structures. Such broadening is undesirable, as it degrades photon indistinguishability, which is a key requirement for single-photon sources. In this work, we present design strategies for 1D photonic crystal nanobeam cavities with minimal impact on the optical properties of the embedded QDs.