Q 6: Quantum Optics (Miscellaneous) I

Time: Monday 14:00–16:00 Location: Q-H14

Invited Talk Q 6.1 Mon 14:00 Q-H14

Quantum Cooperativity: from ideal quantum emitters to molecules — •Claudiu Genes — Max Planck Institute for the Science of Light, Erlangen, Germany

Light-matter platforms provide an optimal playground for the observation and exploitation of quantum cooperative effects. Quantum light, either multimode, as naturally arising in the quantum electromagnetic vacuum or single mode, as confined in the small volume of an optical resonator, can induce strong interactions among quantum emitters. At the level of ideal quantum emitters, recent proposals employing cooperativity aim at the design of extremely thin atom-thick metasurfaces with applications in nonlinear quantum optics or nano-optomechanics or acting as platforms for the study of topological quantum optics effects. For more complex quantum emitters, such as molecules, recent experiments hint towards strong modifications of material properties such as chemical reactivity, charge conductivity and energy transfer. In this talk, I will introduce the basic concepts of quantum cooperativity with emphasis on light-molecule platforms. Aside from a quick introduction into the physics of electron-vibron interactions, I will present recent results on cavity quantum electrodynamics with systems ranging from single molecules to mesoscopic ensembles.

Q 6.2 Mon 14:30 Q-H14

A Quantum Optical Microphone in the Audio Band — •Raphael Nold[1,2], Charles Babin[1,2], Joel Schmidt[1,2], Tobias Linkewitz[1,2], Mariá T. Pérez Zaballos[3], Rainer Stöhr[1,2], Roman Kolesov[1,2], Vadim Vorobyov[1,2], Daniil M. Lukin[4], Rüdiger Boppert[5], Stefanie Barz[2,6], Jelena Vučković[4], Christof M. Gebhardt[2,7], Florian Kaiser[1,2], and Jörg Wrachtrup[1,2] — [1]3rd Institute of Physics, University of Stuttgart, Stuttgart, Germany — [2]Center for Integrated Quantum Science and Technology (IQST), Germany — [3]The Old Schools, Cambridge CB2 1TN, Reino Unido , UK — [4]Ginzton Laboratory, Stanford University, Stanford, CA, USA — [5]Department of Pediatric Audiology and Neurotology, Olgahospital, Stuttgart, Germany — [6]Institute for Functional Matter and Quantum Technologies, University of Stuttgart, Stuttgart, Germany — [7]Institute of Biophysics, Ulm University, Ulm, Germany

We introduce a easy-to-use nonlinear interferometer, that infers optical phase shifts through intensity measurements and sampling rates up to 100 kHz, while still maintaining a quantum advantage in the measurement precision. Capitalising on this, we present an application as a quantum microphone in the audio band. Recordings of both, the quantum sensor and an equivalent classical counterpart are benchmarked with a medically-approved speech recognition test. The results show that the quantum sensor leads to a by $0.57\,\mathrm{dB_{SPL}}$ reduced speech recognition threshold. These results open the door towards applications in quantum nonlinear interferometry, and additionally show that quantum phenomena can be experienced by humans.

Q 6.3 Mon 14:45 Q-H14

Many-particle coherence and higher-order interference — •Marc-Oliver Pleinert[1], Eric Lutz[2], and Joachim von Zanthier[1] — [1]Institut für Optik, Information und Photonik, Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), 91058 Erlangen, Germany — [2]Institute for Theoretical Physics I, University of Stuttgart, 70550 Stuttgart, Germany

Quantum mechanics is based on a set of only a few postulates, which can be separated into two parts: one part governing the 'inner' structure, i.e., the definition and dynamics of the state space, the wave function and the observables; and one part making the connection to experiments. The latter is known as Born's rule, which - simply put - relates detection probabilities to the modulus square of the wave function. The resulting structure of quantum theory permits interference of indistinguishable paths; but, at the same time, limits such interference to certain interference orders. In general, quantum mechanics allows for interference up to order $2M$ in M-particle correlations. Depending on the mutual coherence of the particles, however, the related interference hierarchy can terminate earlier. Here, we show that mutually coherent particles can exhibit interference of the highest orders allowed. We further demonstrate that interference of mutually incoherent particles truncates already at order $M+1$ although interference of the latter is principally more multifaceted due to a significantly higher number of different final states. Finally, we demonstrate the disparate vanishing of such higher-order interference terms as a function of coherence in experiments with mutually coherent and incoherent sources.

Q 6.4 Mon 15:00 Q-H14

Information Extraction in Photon Counting Experiments — •Timon Schapeler and Tim Bartley — Mesoscopic Quantum Optics, Department of Physics, Paderborn University, Warburger Str. 100, 33098 Paderborn, Germany

How much information out of the total available Hilbert space can be extracted with a certain detection architecture in photon-counting experiments? The answer to this question can quantify the photon-number resolution of the detector under test. We use quantum detector tomography, which yields a quantum mechanical description of a detector in terms of its positive operator valued measures (POVMs), to compare the quality of five different multiplexed detectors. Quantum detector tomography yields the conditional probabilities of different detection outcomes occurring given a certain number of incident photons, which can directly be used to determine figures of merit such as efficiency, dark counts and cross-talk. These measures provide an intuition of the quality of the detector; however, it may be unclear how they combine to determine the utility of certain detection outcomes. Here, the concept of information is much more useful. From the POVMs we can calculate the amount of information that can be extracted out of the Hilbert space by certain detection outcomes.

Q 6.5 Mon 15:15 Q-H14

Parametrically driven dissipative three-level Dicke Model — •Jim Skulte[1,2], Phatthamon Kongkhambut[1], Hans Kessler[1], Andreas Hemmerich[1,2], Ludwig Mathey[1,2], and Jayson G. Cosme[3] — [1]Zentrum für Optische Quantentechnologie and Institut für Laser-Physik, University of Hamburg, Hamburg, Germany — [2]The Hamburg Center for Ultrafast Imaging, University of Hamburg, Hamburg, Germany — [3]National Institute of Physics, University of the Philippines, Diliman, Philippines

In this talk, we discuss the three-level Dicke model, which describes a fundamental class of light-matter systems. We determine the phase diagram in the presence of dissipation, which we assume to derive from photon loss. Utilizing both analytical and numerical methods we characterize the incommensurate time crystalline, light-induced, and light-enhanced superradiant states in the phase diagram for the parametrically driven system. As a primary application, we demonstrate that a shaken atom-cavity system is naturally approximated via a parametrically driven dissipative three-level Dicke model.

Q 6.6 Mon 15:30 Q-H14

N-photon Subtractor Using a 1D Rydberg Superatom Chain — •Nina Stiesdal[1], Lukas Ahlheit[1], Hannes Busche[1], Kevin Kleinbeck[2], Jan Kumlin[2], Hans-Peter Büchler[2], and Sebastian Hofferberth[1] — [1]Institute for Applied Physics, University of Bonn — [2]Institute for Theoretical Physics III, University of Stuttgart

Here we present our experiments with a 1D chain of Rydberg superatoms coupled to a few-photon probe field. Our Rydberg superatoms consist of thousands of atoms collectively acting as a single two-level system because of the Rydberg blockade.

Due to the collective nature of the excitation, we reach very high coupling between the light field and our superatoms and strongly directional emission back into the initial probe mode. Thus, our system resembles a system of emitters coupled to a single-mode waveguide - but in free space.

We discuss how this waveguide description can lead to insights into the internal dymanics of the Rydberg superatom, and show how we can use our cascaded system to realize a N-photon subtractor.

Q 6.7 Mon 15:45 Q-H14

Transient dipolar interactions in a thin thermal vapor — •Felix Moumtsilis[1], Max Mäusezahl[1], Florian Christaller[1], Hadiseh Alaeian[2], Harald Kübler[1], Robert Löw[1], and Tilman Pfau[1] — [1]5. Physikalisches Institut and Center for Integrated Quantum Science and Technology IQST, Universität Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany — [2]Departments of Electrical & Computer Engineering and Physics & Astronomy, Purdue University, West Lafayette, IN 47907, USA

Micrometer-sized cells for atomic vapors are powerful devices in the realm of fundamental research and applied quantum technology. The effect of light-induced atomic desorption (LIAD) is exploited to produce high atomic densities (n $\gg k^3$) in a rubidium vapor cell. An intense off-resonant laser is pulsed on a micrometer-sized sapphire-coated cell, which results in the desorption of atomic clouds from both internal surfaces. The resulting transient (LIAD-induced) atomic densities are investigated by time-resolved absorption spectroscopy for the D1 and D2 line respectively [1]. This time dependent broadening and line shift is attributed to dipole-dipole interactions. As this timescale is much faster than the natural atomic lifetime, the experiment probes the dipolar interaction in a non-equilibrium situation beyond the usual steady-state, assumed in the derivation of the Lorentz-Lorenz shift. This fast switching of the atomic density and dipolar interactions could be the basis for future quantum devices based on the excitation blockade.

[1] Christaller et al., arXiv:2110.00437 (2021)