Q 30: Quantum Optics (Miscellaneous) IV

Time: Wednesday 10:30–12:30 Location: Q-H14

Invited Talk Q 30.1 Wed 10:30 Q-H14

Optical properties of porous crystalline nanomaterials modeled across all length scales — •Marjan Krstić — Karlsruhe Institute of Technology, Institute of Theoretical Solid State Physics, Karlsruhe, Germany

Zeolites and metal-organic frameworks have enormous application potential due to their variety and porosity. Recently, their optical properties came into the focus of attention that can be quenched or enhanced. Such control is possible by tailoring the intrinsic material properties and the photonic environment into which the molecules are placed. The enhancements of luminescence, Raman scattering, second-harmonic generation, or more general sensing are just a few examples of considered properties. To guide future developments, suitable computational tools are needed. Such tools must be interdisciplinary and should cover multiple lengths scales intrinsic to such optical devices. Naturally, the molecular building blocks, governed by quantum effects, must be correctly described. But the molecular materials are also integrated into an advanced photonic environment, and optical simulations on macroscopic length scales must be performed. Such a setting prompts for a scale-bridging modeling approach. The theory should be used to unravel and understand complex optical processes in the nanomaterials and optimize materials and devices for selected applications. These aspects render the efficient and accurate modeling of such materials and devices a prime challenge. In my contribution, I will overview recent developments of such tools based on DFT/TD-DFT methods and explore three examples for applications of such materials.

Q 30.2 Wed 11:00 Q-H14

Nonequilibrium time-crystal quantum engine — •Federico Carollo[1], Kay Brandner[2], and Igor Lesanovsky[1] — [1]Institut für Theoretische Physik, Universität Tübingen, Auf der Morgenstelle 14, 72076 Tübingen, Germany — [2]School of Physics and Astronomy, University of Nottingham, Nottingham, NG7 2RD, UK

Nonequilibrium many-body quantum systems can host intriguing phenomena such as transitions to exotic dynamical phases of matter. Although this emergent behaviour can nowadays be observed in experiments, its potential for technological applications is largely unexplored. Here, we propose a new type of nonequilibrium many-body quantum engine and investigate the impact of collective effects on its working principles as well as on its power output. For concreteness, we consider an optomechanical cavity setup with an interacting atomic gas as a working fluid and we demonstrate theoretically that such engines produce work under periodic driving. The stationary cycle of the working fluid features nonequilibrium phase transitions, resulting in abrupt changes of the power output. Remarkably, we find that our many-body quantum engine operates even without periodic driving. This phenomenon occurs when its working fluid enters a phase that breaks continuous time-translation symmetry: this so-called emergent time-crystalline phase can sustain the motion of a load generating mechanical work. Our findings pave the way for designing novel nonequilibrium quantum machines.

Q 30.3 Wed 11:15 Q-H14

Simulation and fabrictaion of periodically poled waveguides in KTP for quantum state preparation — •Johannes Otte, Laura Padberg, Christof Eigner, and Christine Silberhorn — Paderborn University, Integrated Quantum Optics, Institute of Photonic Quantum Systems (PhoQS), Warburger Str. 100, 33098 Paderborn

Photonic quantum communication and computing require reliable and highly quality quantum state preparation. Therefore, highly efficient sources of photons with high purity and brightness are necessary. One of the materials of choice for such a photon pair source is KTP. It offers the advantages of a wide transparency range from IR to UV, high mechanical and chemical resistance, large non-linear coefficients and low refractive index change with temperature. The dispersion properties makes it unique for quantum state generation, e.g. for decorelated photon pairs at 1550 nm. Waveguides fabrication as well as period poling for quasi-phase-matching is possible in KTP, which drastically increases the efficiency of photon sources. Thus, photon sources in periodically poled KTP are highly desirable for quantum optics applications. However, the fabrication of periodocally poled waveguides in KTP is still a challenging task, which requries a profound understanding of the material behaviour. For an improvement of the fabrication of periodically poled KTP waveguides, simulations of the poling behaviour near the crystall surface leading to a better understanding of the generated domain structure. We show our recent results of the modelling for poling dynamics in rubidium exchanged waveguides.

Q 30.4 Wed 11:30 Q-H14

Single ion wave packet super-resolution imaging — •Maurizio Verde[1], Martín Drechsler[2], Milton Katz[2], Felix Stopp[1], Sebastian Wolf[1], Christian Schmiegelow[2], and Ferdinand Schmidt-Kaler[1] — [1]QUANTUM, Institut für Physik, Universität Mainz, Germany — [2]Departmento de Física, Universidad de Buenos Aires, Argentina

We present super-resolution microscopy method which enables imaging quantum wave packets of single ions in an analogous manner to STED [1]. Using hollow beams to excite single $^{40}Ca^{+}$ ions, it has been shown recently that one can excite transitions in the beam's dark center, where the transverse gradients can drive quadrupole transitions [2]. Conversely, here we use a hollow light beam to strongly saturate a dipole-forbidden transition $|4S_{1/2}, m=-1/2\rangle \leftrightarrow |3D_{5/2}, m=-3/2\rangle$ of an ion except at a sub-diffraction limited area around the beam's center. This beam shelves the ion into a metastable state which does not fluoresce. Next by shining a laser resonant on a dipole-allowed transition we observe scattered photons only of ions which where in this sub-diffraction limited area. This allows us to experimentally resolve about 30 nm and sense the wave packet of a single ion either Doppler or ground state cooled [3]. The theoretical estimated resolution limit of our method is few nm, which is allowing us to explore the direct imaging of non-classical quantum mechanical matter wave Fock states.

[1] S. W. Hell and J. Wichmann, Opt. Lett. **19**, 780 (1994)
[2] C. T. Schmiegelow et al., Nat Commun **7**, 12998 (2016)
[3] M. Drechsler et al., Phys. Rev. Lett. **127**, 143602 (2021)

Q 30.5 Wed 11:45 Q-H14

Adaptive optics in Confocal microscopy and Fluorescence correlation spectroscopy — •Julius Trautmann[1], Philipp Kellner[1], Tiemo Anhut[2], Daniel Schwedt[2], and Christian Eggeling[1] — [1]Institut für Angewandte Optik und Biophysik, Friedrich-Schiller-Universität Jena, Philosophenweg 7, 07743 Jena — [2]Carl Zeiss Microscopy GmbH, Carl-Zeiß-Promenade 10, 07745 Jena

Adaptive optics has been widely used in astronomy for the last three decades. In recent years however, it has also established itself as an important feature for high resolution microscopy. The opportunity to correct for optical aberrations is particularly useful when imaging samples with inhomogeneous refractive index structures such as cells and especially cell tissue.

Adaptive optics includes elements such as deformable mirrors (DMs) and spatial light modulators (SLMs) which can dynamically correct for aberrations.

This talk will cover the basic idea of including a deformable mirror (DM) in a confocal microscope. The optical setup will be presented and the employment of fluorescence correlation spectroscopy (FCS) will be highlighted.

Q 30.6 Wed 12:00 Q-H14

Gravitational effects on time-frequency bandwidth relations in Earth-to-space telecommunications — •Mohsen Esmaeilzadeh[1,2], Roy Barzel[4], David E. Bruschi[3], Claus Lämmerzahl[4], Frank K. Wilhelm[3], and Andreas W. Schell[1,2] — [1]Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig — [2]Institute for Solid State Physics, Leibniz University Hannover, Appelstr. 2, 30167 Hannover — [3]Institute for Quantum Computing Analytics (PGI-12), Forschungszentrum J*ulich, 52425 Jülich, Germany — [4]ZARM, University of Bremen, 28359 Bremen, Germany

We study the space-time curvature effects on satellite communication with single photons. We proposed a model of communication between Earth and the satellite between users using a traveling string of photon pulses. Since our quantum systems propagate in the space-time of a curved background, the propagating wave-packets are deformed because of the influence of the gravitational red-shift that also changes their time-bandwidth relation.

We provide a theoretical understanding of how the gravitational red-shift affects the overlapping pulses. The antibunching behavior of them and the impact of the deformation on the intensity correlation function are studied. Moreover, we try to take the advantage of the Wigner function as a measure for quantumness to investigate the changes in the pulses after getting gravitational red-shift.

Q 30.7 Wed 12:15 Q-H14

Exploring the temporal-mode selective frequency conversion of PDC states — •Patrick Folge, Matteo Santandrea, Michael Stefszky, Benjamin Brecht, and Christine Silberhorn — Paderborn University, Department of Physics, Integrated Quantum Optics, Institute for Photonic Quantum Systems (PhoQS), Warburger Straße 100, 33098 Paderborn, Germany

Nonlinear optical elements are an essential component in many emerging quantum technologies because they can produce and probe light with non-classical features. Of central importance are parametric down-conversion (PDC) sources, which are able to generate squeezed states of light. In a multimode framework the PDC sources introduces quantum correlations between sets of field-orthogonal temporal-modes. A different non-linear element considered here is the quantum pulse gate (QPG), which is a specially engineered frequency conversion (FC) process. It allows for the temporal-mode selective conversion of light. Therefore, by applying the QPG to the squeezed light produced by a PDC source, one can transfer the squeezing properties of any mode to the output mode of the QPG. Here, we theoretically investigate which modes are best suited to transfer the squeezing properties to the output of the QPG. Further, we look at realistic scenarios and explore the limits of this scheme.