Q 17: Quantum Optics (Miscellaneous) III

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

Invited Talk Q 17.1 Tue 10:30 Q-H14

Superradiant lasing in presence of atomic motion — •Simon B. Jäger[1,2], Haonan Liu[2], John Cooper[2], and Murray J. Holland[2] — [1]Physics Department and Research Center OPTIMAS, Technische Universität Kaiserslautern, 67663 Kaiserslautern, Germany — [2]JILA and Department of Physics, University of Colorado, Boulder, Colorado 80309-0440, USA

Advances in time and frequency standards require the realization of extremely stable high-Q oscillators. For lasers this high-Q oscillator is usually a narrow-linewidth resonator mode while the laser linewidth is limited by fluctuations of the resonator length. Remarkably, these limitations can be softened by coupling many atoms to a rather broad-linewidth cavity mode and storing the coherence in the collective dipole of the atoms. In this superradiant regime, we discuss the effects of atomic motion resulting in inhomogeneous broadening of the emission frequencies. We show that the superradiant laser can overcome this broadening using a phase synchronization mechanism. Our theoretical analysis shows the possibility to build rugged, continuous-wave superradiant lasers based on a thermal atomic beam source. In addition, we study different superradiant phases that rely on Doppler effects where we observe polychromatic light emission and mode-hopping dynamics. We discuss the relevance of these effects for laser-based gyroscopes and sensors.

Q 17.2 Tue 11:00 Q-H14

Exploring precise loss characterization methods for LNOI waveguides — •Silia Babel, Laura Padberg, Marcello Massaro, Christof Eigner, and Christine Silberhorn — Paderborn University, Integrated Quantum Optics, Institute of Photonic Quantum Systems (PhoQS), Warburger Str. 100, 33098 Paderborn

Lithium Niobate (LN) has been a groundbreaking and benchmarking material platform for numerous integrated optical devices due to its great property portfolio, e.g. its large second-order nonlineartiy and electro-optical coefficients. A miniaturization of the current devices is desirable as this reduces the footprint and allows to integrate more complex structures on a chip, to increase the efficiency and to reduce the energy consumption. Here, the novel material platform Lithium Niobate on Insulator (LNOI) allows an tremendous step towards a further significant reduction as it combines the advantages of LN with a high index contrast change of the waveguides which makes it a very promising material for integrated photonic quantum technologies. For quantum applications low-loss optical devices are indispensable. This includes an optimization of waveguide propagation losses. In literature, different methods are used for estimating the propagation losses in LNOI waveguides. Yet, the question for a profound comparison between different methods remains unanswered. In order to provide this, we explore and compare different methods for waveguide loss characterization in LNOI waveguides, such as Fabry-Pérot or ring resonator method. These different methods will later set the ground for a versatile toolbox for nano-waveguide characterization.

Q 17.3 Tue 11:15 Q-H14

Exploiting electro-optic modulators in $LiNbO_3$ for quantum-optics applications — •Felix vom Bruch, Christof Eigner, Harald Herrmann, and Christine Silberhorn — Paderborn University, Integrated Quantum Optics, Institute of Photonic Quantum Systems (PhoQS), Warburger Str. 100, 33098 Paderborn

Within the last decades, research and development on quantum technologies has been a vivid field and the interest and investment in those technologies has been steadily increasing. Many of the most promising approaches are based on using and manipulating light and its properties. In many quantum optic setups, the manipulation is performed by means of bulk optic modulators. Yet, the performance limitations hinder further development in terms of data processing rates. Here, we present our latest progress in replacing bulk optic modulators by their integrated counterparts in free space setups and exploit the accompanied benefits of these novel hybrid approaches.
The used platform on which our modulators are implemented is titan-in-diffused waveguides in $LiNbO_3$. Here, different crystal cuts enable us to implement different types of modulators such as electro-optic polarization converters. Challenges that need to be overcome are spectral limitations, switching speed and electro-optic performance as well as device stability. Additionally, maintaining full applicability even on a single photon regime, requires very low optical losses. We are focusing on comparing advantages and disadvantages of different modulator architectures and further exploit their experimental implementation in quantum optic experiments.

Q 17.4 Tue 11:30 Q-H14

Superradiance in an ensemble of multilevel atoms — •Aleksei Konovalov and Giovanna Morigi — University Des Saarlandes

We derive a master equation for a superradiant medium which includes multilevel interference between the individual scatterers. The derivation relies on the Born-Markov approximation and implements the coarse-graining formalism. The master equation fulfills the Lindblad form and contains terms describing multilevel interference between parallel transitions of a single atom, multiatom interference between identical transitions, and multiatom interference between different electronic transitions with parallel dipoles. This formalism is then applied to determine the excitation spectrum of two emitters using the parameters of the hydrogen transitions 2S1/2 ? 4P1/2 and 2S1/2 ? 4P3/2, where the gap between the parallel dipoles is of the order of GHz. The distortion of the signal due to the interplay of multilevel and multiemitter interference is analyzed as a function of their distance. We then derive the limit in which the atomic transitions can be described by oscillators and analyse the predictions for an ensemble of Rb87 atoms driven by a laser below saturation.

[1] Aleksei Konovalov and Giovanna Morigi Phys. Rev. A 102, 013724 (2020)

Q 17.5 Tue 11:45 Q-H14

Engineering the photon statistics by destructive and constructive two-photon interference — •Max Schemmer, Martin Cordier, Philipp Schneeweiss, Jürgen Volz, and Arno Rauschenbeutel — Department of Physics, Humboldt-Universität zu Berlin, 10099 Berlin, Germany

Interference phenomena are at the origin of for many intriguing effects in physics and in particular in the field of quantum optics (e.g., double-slit experiment). Here, we demonstrate a type of quantum interference that allows us to engineer the photon statistics of a laser light field via the interaction with an ensemble of cold atoms. When probing the ensemble with resonant light (D2 line of Cesium), entangled photon-pairs can be generated that will interfere with the two-photon components of the incoming light [1]. Here we show how the relative amplitude and phase of these entangled photon-pairs can be tuned by controlling the number of atoms and the detuning of the laser light. Using this effect, the photon-statistics can be tuned from bunching to antibunching. Our results open new routes for realizing nonclassical light sources with variable $g^{(2)}(\tau)$ based on weak, collectively enhanced nonlinearities.

[1] Prasad et al., Nature Photonics 1 (2020).

Q 17.6 Tue 12:00 Q-H14

Polarization-entangled photons from nanoscale nonlinear layers — •Vitaliy Sultanov[1,2], Tomás Santiago-Cruz[1,2], and Maria V. Chekhova[1,2] — [1]Max-Planck Institute for the Science of Light, Erlangen, Germany — [2]Friedrich-Alexander University Erlangen-Nuremberg, Erlangen, Germany

Entanglement is a crucial feature of quantum systems essential for various applications of quantum technologies. One of the most convenient platforms for quantum entanglement realization is photon pairs generated via spontaneous parametric down-conversion (SPDC). However, the phase-matching condition limits the existing bulk SPDC-based sources of entangled photons. The restrictions can be overcome by utilizing phase-matching-free SPDC in nano-scale nonlinear layers.

In this work, we demonstrate, for the first time, polarization-entangled photons from a 400 nm nonlinear layer of gallium phosphide. We achieve an unprecedented tunability of the two-photon polarization state not possible in common bulk sources of photon pairs. The polarization adjustability shown in this work gives an opportunity to easily change a degree of polarization entanglement on demand, making such sources a unique, promising platform for the realization of miniaturized quantum light generators for integrated photonics.

Q 17.7 Tue 12:15 Q-H14

A remedy to finite coupling master equations for open quantum systems — •Becker Tobias[1], Alexander Schnell[1], Juzar Thingna[2], and André Eckardt[1] — [1]Institut für Theoretische Physik, Technische Universität Berlin, Hardenbergstrasse 36, 10623 Berlin, Germany — [2]Center for Theoretical Physics of Complex Systems, Institute for Basic Science (IBS), Daejeon 34126, Republic of Korea

For the description of open quantum systems master equations are used that are derived perturbatively to some order of the system-bath coupling strength. The Bloch-Redfield master equation and all other first order expansions give an adequate description only in trivial order of the coupling strength that is for almost vanishing coupling. Attempts to increase the accuracy beyond the Bloch-Redfield equation must go beyond first order perturbation theory. However, for a wide range models, rigorous higher order expansions are hardly possible. We develop a master equation for finite coupling that is easily obtained within the Bloch-Redfield formalism. We benchmark our results against the exact solution of the damped harmonic oscillator that also features non-Markovian behaviour.