Q 5: Quantum Optics I

Time: Monday 11:00–13:00 Location: f442

Q 5.1 Mon 11:00 f442

Towards the Realization of a Vacuum-Ultraviolet Photon Bose-Einstein Condensate — •Christian Wahl, Rudolf Brausemann, Johannes Koch, Stavros Christopoulos, and Martin Weitz — University of Bonn, Germany

We propose a new approach for photon Bose-Einstein condensation, based on thermalisation of photons in a noble gas filled optical microcavity, suitable for the vacuum-ultraviolet spectral regime, i.e. in the 100-200nm wavelength regime. While current experiments on photon Bose-Einstein condensation use thermalisation of photons in a dye solution filled optical microcavity in the visible spectral regime [1],we plan to use absorption re-emission cycles on the transition from the ground to the lowest electronically excited state of noble gases, e.g. xenon, for thermalisation. In order to achieve a sufficient spectral overlap between the lowest atomic absorption and the di-atomic excimer emission, centered at 147nm and 170nm respectively [2], a noble gas pressure of up to 60 bar will be created inside the cavity. We are currently in the process of setting up an experiment to study absorption and emission spectra at the relevant noble gas pressures in the vacuum-ultraviolet regime. Current experimental progress will be reported.

References:
[1]: J. Klaers et al. Nature 468, 545-548 (2010)
[2]: M. Kink et al. Physica Scripta 45, 79-82 (1992)

Q 5.2 Mon 11:15 f442

Dissipative Two-Mode Tavis-Cummings Model with Time-Delayed Feedback Control — •Wassilij Kopylov[1], Milan Radonjić[2,3], Tobias Brandes[1], Antun Balaž[3], and Axel Pelster[4] — [1]Institut für Theoretische Physik, TU Berlin — [2]Faculty of Physics, University of Vienna, Austria — [3]Institute of Physics Belgrade, University of Belgrade, Serbia — [4]Physics Department and Research Center OPTIMAS, TU Kaiserslautern

We investigate the dynamics of a two-mode laser system by extending the two-mode Tavis- Cummings model [1] with dissipative channels and incoherent pumping and by applying the mean-field approximation in the thermodynamic limit [2]. To this end we analytically calculate up to four possible non-equilibrium steady states (fixed points) and determine the corresponding complex phase diagram. Various possible phases are distinguished by the actual number of fixed points and their stability. In addition, we apply three time-delayed Pyragas feedback control schemes [3,4]. Depending on the time delay and the strength of the control term this can lead to the stabilization of unstable fixed points or to the selection of a particular cavity mode that is macroscopically occupied.

[1] W. Kopylov, M. Radonjić, T. Brandes, A. Balaž, and A. Pelster, Phys. Rev. A (in press), arXiv:1507.01811
[2] M. Tavis and F.W. Cummings, Phys. Rev. 170, 379 (1968)
[3] K. Pyragas, Phys. Lett. A 170, 421 (1992)
[4] W. Just, A. Pelster, M. Schanz, and E. Schöll, Phil. Trans. Roy. Soc. A 368, 303 (2010)

Q 5.3 Mon 11:30 f442

Quantum phase transition and universal dynamics in the Rabi model — •Ricardo Puebla, Myung-Joong Hwang, and Martin B. Plenio — Institut für Theoretische Physik and IQST, Albert-Einstein-Allee 11, Universität Ulm, D-89069 Ulm, Germany

We consider the Rabi Hamiltonian, which undergoes a quantum phase transition (QPT) despite consisting only of a single-mode cavity field and a two-level atom. We prove QPT by deriving an exact solution in the limit where the atomic transition frequency in the unit of the cavity frequency tends to infinity. The effect of a finite transition frequency is studied by analytically calculating finite-frequency scaling exponents as well as performing a numerically exact diagonalization. Going beyond this equilibrium QPT setting, we prove that the dynamics under slow quenches in the vicinity of the critical point is universal; that is, the dynamics is completely characterized by critical exponents. Our analysis demonstrates that the Kibble-Zurek mechanism can precisely predict the universal scaling of residual energy for a model without spatial degrees of freedom. Moreover, we find that the onset of the universal dynamics can be observed even with a finite transition frequency.

Q 5.4 Mon 11:45 f442

The Quantum Pulse Gate - A versatile non-linear platform for quantum optics — Markus Allgaier[1], •Vahid Ansari[1], Viktor Quiring[1], Raimund Ricken[1], Linda Sansoni[1], Benjamin Brecht[2,1], and Christine Silberhorn[1] — [1]Universität Paderborn, Integrierte Quantenoptik, Warburger Str. 100, D-33098 Paderborn — [2]Clarendon Laboratory, University of Oxford, Parks Road, Oxford OX1 3PU, UK

We present experimental results and methods on the Quantum Pulse Gate (QPG) recently introduced [1]. The QPG relies on group-velocity matched, dispersion-engineered sum-frequency generation in Lithium-Niobate waveguides. By being able to select a single Schmidt mode from a multimode quantum state in the telecom regime and convert it into the visible range it offers operation on time-frequency modes recently established as a framework for Quantum Information Processing [2]. Moreover, the QPG allows efficient real-time temporal characterization of single photons with a resolution as short as 150 femtoseconds.

[1] B. Brecht, et al., Phys. Rev. A 90, 030302(R) (2014)
[2] B. Brecht, et al., Phys. Rev. X 5, 041017 (2015)

Q 5.5 Mon 12:00 f442

A Source for Mesoscopic Quantum Optics — •Johannes Tiedau[1], Georg Harder[1], Adriana E. Lita[2], Sae W. Nam[2], Thomas Gerrits[2], Tim J. Bartley[1,2], and Christine Silberhorn[1] — [1]Universität Paderborn, Integrierte Quantenoptik, Warburger Str. 100, D-33098 Paderborn — [2]National Institute of Standards and Technology, Boulder, CO 80305, USA

Parametric down-conversion (PDC) is an established process to generate non-classical states. We present the generation of large, two-mode states in a single spatio-spectral mode from pulsed, single -pass (type II) PDC. Using transition edge sensors, we measure photon number correlations up to 80 photons in each of the two modes, allowing us to calculate correlation functions up to 40th order and herald non-classical distributions with 50 photons per pulse. We achieve these results with 64% detection efficiency in the telecom regime. The mode definition of this source is ideal for non-Gaussian measurements without requiring additional filtering.

Q 5.6 Mon 12:15 f442

Quantum State Tomography for Optical Soliton Molecules — •Oskar Schlettwein, Kai Barnscheidt, Jakob Studer, and Boris Hage — Arbeitsgruppe Experimentelle Quantenoptik, Institut für Physik, Universität Rostock, D-18059 Rostock, Germany

Bright pulses in optical fibers mainly experience dispersion, the Kerr-effect as well as (stimulated) Brillouin and Raman scattering. The scattering processes introduce phase noise which becomes important for applications at or below the shot noise limit. In contrast to Brillouin scattering the impact of the Raman effect on quantum states is not clear. Numerical simulation as well as a quantum state tomographic setup for bright pulsed signals will be presented to provide deeper insight about it. The setup allows a full quantum state reconstruction of Kerr squeezed states.

Utilizing dispersion managed (DM) fibres the quantum state of DM-solitons can be studied. Extending our system to a two mode quantum state tomograph will lead the way to probe quantum correlations in soliton molecules. This stable configuration of two or more DM-solitons could provide a fruitful source for new fiber based quantum communication application.

Q 5.7 Mon 12:30 f442

Low-noise quantum frequency down-conversion of indistinguishable photons — •Benjamin Kambs[1], Jan Kettler[2], Matthias Bock[1], Jonas Becker[1], Carsten Arend[1], Michael Jetter[2], Peter Michler[2], and Christoph Becher[1] — [1]Fachrichtung 7.2 (Experimentalphysik), Universität des Saarlandes, Campus E 2.6, 66123 Saarbrücken, Germany — [2]Institut für Halbleiteroptik und Funktionelle Grenzflächen, Research Centers SCoPE und IQST, University of Stuttgart, Allmandring 3, 70569 Stuttgart, Germany

Single-photon sources based on quantum dots have been shown to exhibit almost ideal properties such as high brightness and purity in terms of clear anti-bunching and high two-photon interference visibilities of the emitted photons. In order to prepare them for quantum communication applications including long-haul photon transmission via optical fibers, quantum frequency down-conversion (QFDC) has been used to alter the wavelength of single photons to the telecom wavelength range while conserving their nonclassical properties. Here we present experimental results on QFDC of single photons emitted by a p-shell excited InAs/GaAs quantum dot at 903.6 nm. The fluorescence photons were down-converted to 1557 nm with an efficiency >25 %. An indistinguishability measurement revealed two-photon interference contrasts of more than 40 % prior to and after the down-conversion. As a result, we demonstrate that our scheme preserves photon indistinguishability and can be used to establish a versatile source of indistinguishable single photons at the telecom C-Band.

Q 5.8 Mon 12:45 f442

Quantum imaging via frustrated two photon generation — •Axel Heuer and Florian Krause — Experimentelle Quantenphysik, Institut für Physik und Astronomie, Universität Potsdam, D-14469 Potsdam, Germany

Recently, G. B. Lemos et al. [1] presented a quantum imaging setup which allows for image reconstruction using single photons which do not interact with the object. The basic concept of this imaging setup is induced coherence without stimulated emission between two separately pumped nonlinear down-conversion crystals. Here we introduce a related quantum imaging scheme based on frustrated two photon generation [2]. Our setup uses a single down-conversion crystal in conjunction with mirrors. The down converted signal and idler photons as well as the pump light are back-reflected into the crystal by three different mirrors, one for each beam. The arrangement allows for two indistinguishable paths, forwards and reflected beam, by which a photon pair can be created. If both paths are overlapped and the time delays are equal, the interference between these alternative ways produces suppression or enhancement of the pair creation. This interference can be detected in coincidence as well as a single photon signal with one detector only. Imaging is achieved by placing an object in the return path of either the signal or the idler photons.

[1] G. B. Lemos,V. Borish, G. D. Cole, S. Ramelow, R. Lapkiewicz and A. Zeilinger, Nature (London) 512, 409 (2014).

[2] T. J. Herzog, J.G. Rarity, H. Weinfurter and A. Zeilinger , PRL 72, 629 (1994)