FM 8: Enabling Technologies: Sources of Quantum States of Light I

Time: Monday 14:00–16:00 Location: 1010

Invited Talk FM 8.1 Mon 14:00 1010

Quantum dots as sources for quantum light — •PETER MICHLER — University of Stuttgart, Institute for Semiconductor Optics and Functional Interfaces, Stuttgart, Germany

Semiconductor quantum dots (QD) are appealing as a platform for the generation of ultra-bright and pure single and entangled photon pairs. Applying resonant π-pulse excitation, coherent photons are obtained on-demand, being indistinguishable for successively emitted photons. However, in solid state systems, fluctuating magnetic and electric fields in the mesoscopic environment of a quantum emitter cause emission frequency drifts over several time scales. Even for Fourier-limited photons, these fluctuations broaden the emission spectrum and translate in the observation of reduced indistinguishability once larger time-differences between consecutive photons are considered.

In my talk, I will present a comprehensive study on fluctuations in the emission frequency of single quantum dots under resonant π-pulse excitation. Slow-light spectroscopy is introduced which reveals the total time dependence of spectral disusion processes in a single photon-correlation measurement. This technique will serve as a fast and reliable tool for quantifying the effects of frequency fluctuations, especially to predict and understand the time-dependent photon indistinguishability. Furthermore, recent developments on QD telecom-wavelength quantum light sources are reported.

FM 8.2 Mon 14:30 1010

Deterministic integration of QDs into on-chip multimode interference couplers via in-situ electron beam lithography — PETER SCHNAUBER[1], •JOHANNES SCHALL[1], SAMIR BOUNOUAR[1], JIN-DONG SONG[2], THERESA HÖHNE[3], SVEN BURGER[3], TOBIAS HEINDEL[1], SVEN RODT[1], and STEPHAN REITZENSTEIN[1] — [1]Institut für Festkörperphysik, Technische Universität Berlin, Berlin, Germany — [2]Korea Institute of Science and Technology, Seoul, Korea — [3]Zuse Institut Berlin, Freie Universität Berlin, Berlin, Germany

The deterministic integration of quantum emitters into on-chip photonic elements is crucial for the implementation of scalable on-chip quantum circuits. Recent activities include multistep-lithography [1] as well as AFM tip transfer [2]. Here we report on the deterministic integration of single QDs into on-chip beam splitters using single step in-situ electron beam lithography [3]. In order to realize 50/50 coupling elements acting as central building blocks of on-chip quantum circuits we chose tapered multimode interference (MMI) splitters which feature relaxed fabrication tolerances and robust 50/50 splitting ratio. We demonstrate the functionality of the deterministic QD-waveguide structures by μPL spectroscopy and photon cross-correlation between the two MMI output ports. The latter confirms single-photon emission and on-chip splitting associated with $g(2)(0) < 0.5$ [4].

[1] Coles et al., Nature Communications 7, 11183 (2016)
[2] Zadeh et al., Nano Letters 16, 2289 (2016)
[3] Gschrey et al., Nature Communications 6, 7662 (2015)
[4] Schnauber et al., Nano Letters 18, 2336 (2018)

FM 8.3 Mon 14:45 1010

Towards Synchronization of Photons from a SPDC Source — •JANIK WOLTERS[1,3], CHRIS MÜLLER[2], GIANNI BUSER[3], ROBERTO MOTTOLA[3], TIM KROH[2], SVEN RAMELOW[2], OLIVER BENSON[2], and PHILIPP TREUTLEIN[3] — [1]DLR Institut für optische Sensorsysteme, Berlin — [2]HU Berlin, Institut für Physik — [3]Universität Basel, Departement Physik

Photonic quantum technologies have a striking need for photon sources that emit coherent, single mode photons, on demand with high efficiency, and can be built in a reproducible fashion. To satisfy this need, we follow a compound approach [1]: The probabilistic generation of photons by spontaneous parametric downconversion (SPDC) [2] is synchronized with an atomic vapor quantum memory [3].

As a key component of the envisioned compound source, we present an efficient, bright and robust source of photons at the rubidium D1-line (795 nm), based on non-degenerate SPDC in a monolithic cavity.

First experimental results on combining the source with a previously developed Rb vapor memory [3] are presented. Single photons are stored and read out with a signal to noise ratio well above unity. Second order correlation measurements reveal the preservation of nonclassicality after photon readout.

[1] J. Nunn, et al., *Phys. Rev. Lett.* **110**, 133601 (2013).
[2] A. Ahlrichs et al., *Applied. Phys. Lett.* **108**, 021111 (2016).
[3] J. Wolters et al., *Phys. Rev. Lett.* **119** 060502 (2017).

FM 8.4 Mon 15:00 1010

Photonic Quantum Gases in Microstructured Potentials for Light — •ANDREAS REDMANN[1], CHRISTIAN KURTSCHEID[1], DAVID DUNG[1], JULIAN SCHMITT[1,2], FRANK VEWINGER[1], and MARTIN WEITZ[1] — [1]Institut für Angewandte Physik, Universität Bonn, Wegelerstr. 8, D-53115 Bonn — [2]present address: Department of Physics, University of Cambrigde, Cambridge, United Kingdom

In earlier work, Bose-Einstein Condensation of light has been realised in a dye-filled optical microcavity at room temperature. A low-frequency cutoff is introduced by the short mirror spacing and thermal contact to the dye solution is obtained by repeated absorption and re-emission cycles on the dye molecules. Here we report on advances in a spatially resolved delamination-based adaptive optics technique to imprint arbitrarily shaped trapping potentials for light in optical dye microcavities. To characterize the imprinting technique, we have studied the mirror reflectivity versus the delamination height. At present, we have thermalized a photon gas in the low-energy spatial superposition state of a double-well potential, which allows us to demonstrate irreversible splitting of light by cooling. Our technique holds promise for the generation of highly entangled optical many body states.

FM 8.5 Mon 15:15 1010

Heralded dissipative preparation of nonclassical states in a Kerr oscillator — •MARTIN KOPPENHÖFER, CHRISTOPH BRUDER, and NIELS LÖRCH — Department of Physics, University of Basel, Basel, Switzerland

We present a heralded state preparation scheme for driven nonlinear open quantum systems. The protocol is based on a continuous photon counting measurement of the system's decay channel. When no photons are detected for a period of time, the system has relaxed to a measurement-induced pseudo-steady state. We illustrate the protocol by the creation of states with a negative Wigner function in a Kerr oscillator, a system whose unconditional steady state is strictly positive.

FM 8.6 Mon 15:30 1010

D-dimensional frequency-time entangled cluster states with on-chip frequency combs — •MICHAEL KUES[1,2], CHRISTIAN REIMER[2,3], STEFANIA SCIARA[2,4], PIOTR ROZTOCKI[2], MEHEDI ISLAM[2], LUIS ROMERO CORTÉS[2], YANBING ZHANG[2], BENNET FISHER[2], SÉBASTIAN LORANGER[5], RAMAN KASHYAP[5], ALFONSO CINO[4], SAI T. CHU[6], BRENT E. LITTLE[7], DAVID J. MOSS[8], LUCIA CASPANI[9], WILLIAM J. MUNRO[10,11], JOSÉ AZAÑA[2], and ROBERTO MORANDOTTI[2,12,13] — [1]Hannover Center for Optical Technologies — [2]Institut National de la Recherche Scientifique — [3]HyperLight Corporation — [4]University of Palermo — [5]Polytechnique Montreal — [6]City University of Hong Kong — [7]Chinese Academy of Science — [8]Swinburne University of Technology — [9]University of Strathclyde — [10]NTT Corporation — [11]National Institute of Informatics — [12]University of Electronic Science and Technology of China — [13]ITMO University

Cluster states, a specific class of multi-partite entangled states, are of particular importance for quantum science, as such systems are equivalent to the realization of one-way quantum computers. Here, we demonstrated the generation of d-level cluster states using a high-dimensional time-frequency-domain approach in combination with a deterministic controlled phase gate. We then implemented d-level measurement-based quantum computing operations and showed the state*s high tolerance towards noise.

FM 8.7 Mon 15:45 1010

Non-Gaussian Continuous-Variable Graph States — •MATTIA WALSCHAERS, YOUNG-SIK RA, ADRIEN DUFOUR, CLAUDE FABRE, VALENTINA PARIGI, and NICOLAS TREPS — Laboratoire Kastler Brossel - Sorbonne Université, CNRS, Ecole Normale Supérieure, Collège de France, Paris, France

Graph states are the backbone of measurement-based continuous-variable quantum computation. However, experimental realizations of these states induce Gaussian measurement statistics for the field quadratures, which poses a barrier to obtain a genuine quantum advantage. In this contribution, we propose mode-selective photon subtraction as an experimentally feasible pathway to introduce non-Gaussian features in such continuous-variable graph states. In particular, the induced non-Gaussian properties are shown to spread up to next-to-nearest neighbours of the graph's vertex in which the photon was subtracted. Finally, we explore the importance of entanglement in this transfer of non-Gaussianity, as compared to what can be achieved with classical light or classical correlations.