Q 44: Quantum Optics of Solid State Photon Sources

Time: Thursday 10:30–13:00 Location: HSZ 02

Q 44.1 Thu 10:30 HSZ 02

Solid state single photon sources based on color centers in diamond — •Elke Neu[1], David Steinmetz[1], Christian Hepp[1], Janine Riedrich-Möller[1], Roland Albrecht[1], Jan Meijer[2], Martin Fischer[3], Stefan Gsell[3], Matthias Schreck[3], and Christoph Becher[1] — [1]Universität des Saarlandes, FR 7.2 Experimentalphysik, D-66123 Saarbrücken — [2]RUBION, Ruhr-Universität Bochum, D-44780 Bochum — [3]Universität Augsburg, Lehrstuhl für Experimentalphysik 4, D-86135 Augsburg

Color centers in diamond are promising candidates for practical single photon sources due to room temperature operation and superior photostability. We observe single photon emission from various color centers, produced either by ion-implantation or in-situ doping during CVD-growth. Optimum results are obtained from Silicon-Vacancy (SiV)-centers in isolated nano-diamonds grown on Iridium layers. These centers feature emission predominantly (80-90 %) into the narrow (0.7 nm) zero-phonon-line and high brightness with up to 4.8 Mcps at saturation, thus being the brightest single color centers to date [1]. We observe for the first time the fine structure of a single SiV-center at cryogenic temperatures and perfom detailed spectroscopy investigating level structures, polarization and the influence of spectral diffusion. We discuss strategies for enhancing spectral and spatial emission properties by coupling color centers to micro-cavities e.g. fiber-based or photonic crystal cavities.

[1] E. Neu et al, ArXiv 1008.4736 accepted for publication in *New J. Phys.*

Q 44.2 Thu 11:00 HSZ 02

Quantum Light from a Whispering Gallery Resonator — •Josef Fürst[1], Dmitry Strekalov[2], Dominique Elser[1], Ulrik L. Andersen[1,3], Andrea Aiello[1], Christoph Marquardt[1], and Gerd Leuchs[1] — [1]Max Planck Institute for the Science of Light, Institute for Optics, Information and Photonics, University Erlangen-Nuremberg, Erlangen, Germany — [2]Jet Propulsion Laboratory, California lnstitute of Technology, Pasadena, USA — [3]Department of Physics, Technical University of Denmark, Kgs. Lyngby, Denmark

Optical subharmonic generation, also referred to as parametric down-conversion (PDC) is mediated by an optically nonlinear dielectric medium and connects an optical field to its subharmonic. In this process, one pump photon is converted to two subharmonic photons, called signal and idler. Enclosing the nonlinear medium in a cavity, the setup is called an optical parametric oscillator (OPO). We use a whispering gallery mode (WGM) resonator for our OPO. These WGM cavities offer high quality factors, that enhance the conversion efficiency of the nonlinear process. With a WGM resonator made from Lithium Niobate, we were able to show extremely efficient PDC in our WGM OPO. As the signal and idler photon pairs originate from one pump photon in PDC, they are strongly correlated in photon number. Investigating the quantum properties of the interacting light fields, while driving the OPO above the pump threshold, we observed nonclassical parametric light [1]. We plan to further investigate these quantum properties and will present the latest results.

[1] J. U. Fürst et al., arXiv:1008.0594v6 (2010)

Q 44.3 Thu 11:15 HSZ 02

Studying Photon Number Distributions of (NV-) Single-Photon Centres — •Waldemar Schmunk[1], Marco Gramegna[3], Giorgio Brida[3], Ivo P. Degiovanni[3], Marco Genovese[3], Helmuth Hofer[1], Stefan Kück[1], Lapo Lolli[3], Matteo G.A. Paris[4], Silke Peters[1], Mauro Rajteri[3], Mark Rodenberger[1], Andras Ruschhaupt[2], Emanuele Taralli[3], and Paolo Traina[3] — [1]Physikalisch-Technische Bundesanstalt, 38116 Braunschweig, Germany — [2]Leibniz Universtität Hannover, 30167 Hannover, Germany — [3]L'Istituto Nazionale di Ricerca Metrologica INRIM, 10135 Torino, Italy — [4]Universita degli studi di Milano, 20122 Milano, Italy

Reconstruction of the optical density matrix provides information on photon number distributions of unknown quantum states. In the present work we focus on the photon statistics of different nitrogen vacancies centres in diamond. For that purpose, the diagonal elements of the density matrix were experimentally determined by using a transition-edge sensor (TES), which produces an output pulse proportional to the number of photons absorbed and is therefore capable to resolve the photon number. Additional measurements were performed by on/off-statistics using avalanche photodetection assisted by a maximum likelihood estimation. From the data of the two photon number resolving techniques, values of the second order correlation function $g^{(2)}(t=0)$ were determined and compared with the corresponding values measured by a Hanbury-Brown-Twiss interferometer. In the presentation, the three methods will be described and discussed in detail.

Q 44.4 Thu 11:30 HSZ 02

Realization of photonic crystal microcavities in single crystal diamond — •Janine Riedrich-Möller[1], Laura Kipfstuhl[1], Christian Hepp[1], Martin Fischer[2], Stefan Gsell[2], Matthias Schreck[2], and Christoph Becher[1] — [1]Universität des Saarlandes, Fachrichtung 7.2 (Experimentalphysik), Campus E2.6, 66123 Saarbrücken — [2]Universität Augsburg, Experimentalphysik IV, 86159 Augsburg

Microcavities in two-dimensional photonic crystal slabs allow to strongly confine light in volumes of about one cubic wavelength. They are expected to enable the realization of highly efficient emitters and control of spontaneous emission. Such photonic crystal microcavities are routinely fabricated in semiconductor materials. On the other hand, in recent years diamond has attracted significant interest as material for quantum information processing due to the extraordinary properties of optically active defect centers. These so called colour centers can be employed e.g. for cavity enhanced single photon sources that operate at room temperature or cavity-based atom-photon interfaces. We here investigate the fabrication of photonic crystal cavities in single crystalline diamond grown on an Iridium layer. We produce free-standing diamond membranes by dry-etching techniques and pattern them by focussed ion beam milling (FIB). We both realize 1D nanobeam cavities etched in a freestanding waveguide and 2D cavities with several missing holes in a triangular lattice. For the 2D cavities we experimentally obtain quality factors of Q = 300.

Q 44.5 Thu 11:45 HSZ 02

Photon blockade in a strongly coupled quantum-dot cavity system — •Thomas Volz, Andreas Reinhard, and Atac Imamoglu — Institute of Quantum Electronics, ETH Zurich, 8093 Zurich, Switzerland

A long-standing goal in the field of mesoscopic cavity quantum electrodynamics is the demonstration of photon blockade in a strongly coupled quantum-dot cavity system. While signatures of quantum correlations in resonant scattering have been observed previously, here we demonstrate for the first time strong photon blockade in such a device. Our system consists of a single self-assembled InGaAs quantum dot positioned at the field maximum of a photonic crystal L3 cavity (Q≈24000), leading to a coupling strength of $g \approx 150\ \mu$eV. In order to tune the cavity in resonance with the neutral quantum dot transition we employ a nitrogen tuning technique. We then probe the strongly coupled device with a resonant laser employing a cross-polarization technique to suppress the excitation-laser light. Due to strong classical blinking dynamics of the quantum dot we additionally use a repump laser to enhance the polariton signal. The photons scattered from the strongly-coupled system are analysed in a standard Hanbury-Brown-Twiss correlation setup. Due to the fast decay dynamics of the polaritons we carry out the experiment in pulsed mode. When the laser is resonant with the polaritons we observe strong antibunching - clear signature of photon blockade. Our results pave the way for the realization of non-linear photonic devices, such as a single-photon transistor or the quantum optical Josephson interferometer.

Q 44.6 Thu 12:00 HSZ 02

Deterministic Coupling of Individual Quantum Systems to Photonic Crystal Structures — Janik Wolters[1], •Andreas W. Schell[1], Günter Kewes[1], Nils Nüsse[2], Max Schoengen[2], Bernd Löchel[2], Michael Barth[1], and Oliver Benson[1] — [1]Nano-Optics, Institute of Physics, Humboldt-Universität zu Berlin, Newtonstr. 15, 12489 Berlin — [2]Operator Centre Microtechnology, Helmholtz-Centre Berlin for Materials and Energy, Albert-Einstein-Straße 15, 12489 Berlin

The controlled and scaleable coupling of single quantum emitters to photonic crystal structures is one of the main challenges on the way towards integrated solid-state devices for optical quantum information processing. We tackle this problem by using a hybrid approach, which combines lithographic fabrication techniques with nanomanipulation methods, allowing the deterministic coupling of arbitrary emitters or other nanoscopic objects to the optical modes of photonic crystal cavities. Here we present recent experimental results on the controlled coupling of the zero phonon line emission from a single NV-center in a nanodiamond to such cavities. Our approach is well suited for the creation of improved single photon sources and also complex photonic devices with several emitters coupled coherently via shared cavity modes.

Q 44.7 Thu 12:15 HSZ 02

Deterministic Coupling of Single Nitrogen Vacancy Centres in Diamond Nanocrystals to Bowtie Nanoantennas — •Günter Kewes, Andreas Schell, Thomas Aichele, and Oliver Benson — Humboldt-Universität zu Berlin, Institut für Physik, Nanooptik

Surface plasmons polaritons provide the opportunity to concentrate electromagnetic energy in volumes much smaller than the wavelength of a photon with equal frequency, i.e. focussing beyond Abbe's limit, therefore giving large interaction between light and matter. This can be exploited in the construction of optical antennas which are designed to concentrate excitation energy at an emitter's location and further enhance the emitters output.

We present the coupling of single nitrogen vacancy (NV) centres in nanodiamond with a gold nanoantenna. The NV centres were systematically rearranged through AFM nanomanipulation around the nanoantenna, resulting in maps of excited state lifetime reduction. These maps can give great insight into the near-field properties of such structures allowing for optimization of hybrid emitter-antenna systems. We observe that this reduction is not solely a fluorescence quenching effect, and an overall enchancement of the photon rate by a factor 2.2 was found.

Q 44.8 Thu 12:30 HSZ 02

Quantum key distribution using electrically triggered quantum dot-micropillar single photon sources — •Tobias Heindel[1], Markus Rau[2], Christian Schneider[1], Martin Fürst[2,3], Sebastian Nauerth[2,3], Matthias Lermer[1], Henning Weier[2,3], Stephan Reitzenstein[1], Sven Höfling[1], Martin Kamp[1], Harald Weinfurter[2,4], and Alfred Forchel[1] — [1]Technische Physik and Wilhelm Conrad Röntgen Research Center for Complex Material Systems, Universität Würzburg, Am Hubland, 97074 Würzburg, Germany — [2]Fakultät für Physik, Ludwig-Maximilians-Universität, 80799 Munich, Germany — [3]qutools GmbH, 80539 Munich, Germany — [4]Max-Planck-Institut für Quantenoptik, 85748 Garching, Germany

In 1984, Bennett and Brassard proposed a secret key-distribution protocol (BB84) that uses the quantum mechanical properties of single photons to avoid the possibility of eavesdropping on an encoded message. Due to the lack of efficient single photon sources however most quantum key distribution (QKD) experiments have been performed with strongly attenuated lasers. First experiments utilizing optically pumped solid state based single photon sources affirmed the great potential of QKD but still suffered from the drawbacks of this excitation scheme.

In this work we report on a QKD experiment using highly efficient electrically triggered quantum dot - micropillar single photon sources with $g^{(2)}(0)$-values below 0.5 and sifted key rates in the range of 10 kBit/s.

Q 44.9 Thu 12:45 HSZ 02

Generation of entangled photon pairs from the polariton ground state in a switchable optical cavity — •Adrian Auer and Guido Burkard — Department of Physics, University of Konstanz, D-78457 Konstanz, Germany

Intersubband cavity polaritons are the fundamental excitations of a planar microcavity embedding a sequence of doped quantum wells [1]. They arise from the interaction of cavity photons with intersubband excitations in the quantum wells. The ground state of the system, the polariton vacuum, contains a finite number of photons and, moreover, correlations of two photons having opposite in-plane wave vectors. It was proposed that these photons can be released by a non-adiabatic tuning of the light-matter interaction [1,2]. We theoretically investigate the polariton vacuum state in order to determine the entanglement between two photons, where we restrict our analysis to only two different modes. This could be carried out experimentally by a post-selective measurement. In this case we find that there is some entanglement for photon pairs having exactly opposite in-plane wave vectors which we quantify by the concurrence C. The amount of entanglement depends on the frequency of each photon and can be as high as $C = 0.7$ for experimentally reasonable values. The probability for a successful post-selection is determined to be on the order of 10^{-5}.

[1] C. Ciuti, G. Bastard and I. Carusotto, Phys Rev. B **72**, 115303 (2005).

[2] S. De Liberato, C. Ciuti and I. Carusotto, Phys. Rev. Lett. **98**, 103602 (2007).