# Q 16: Solid State Photon Sources

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

Q 16.1 Tue 10:30 HSZ 02

**Optical Processes in OLEDs: Molecular Photonics** — •Michael Flämmich, Dirk Michaelis, and Norbert Danz — Fraunhofer Institute for Applied Optics and Precision Engineering, 07745 Jena, Germany

Following the OLED display market take-off, huge world wide efforts are spent to develop OLEDs towards competitive sources for general lighting applications. In this context, the light outcoupling problem is well known as the key parameter to improve OLED efficiency in order to tackle existing lighting schemes. From the optical point of view, the device performance is driven (i) by the architecture of the OLEDs layered system and (ii) by the internal features of the emissive material. Studies in recent years have shown that the latter attributes (which are the internal electroluminescence spectrum, the profile of the emission zone, the orientation of the transition dipole moments and the internal luminescence quantum efficiency q) can be determined in situ by measurements of the far-field emission pattern generated by active OLEDs (i.e. in electrical operation) and corresponding optical reverse simulations. Starting from basic considerations of the dipole radiation characteristics, we elaborate specifically how the orientation distribution of the dipole transition moments in the layered system can be analyzed in situ, providing insight into the internal photo-physical processes on the molecular scale of the emitter.

Q 16.2 Tue 11:00 HSZ 02

**Single Photon Source with Diamond Nanocrystals on Tapered Optical Fibers** — •Almut Tröller[1], Juliane Hermelbracht[1], Markus Weber[1], Wenjamin Rosenfeld[1], Ariane Stiebeiner[3], Arno Rauschenbeutel[3], James Rabeau[4], and Harald Weinfurter[1,2] — [1]Ludwig-Maximilians-Universität, München — [2]Max-Planck-Institut für Quantenoptik, Garching — [3]Johannes-Gutenberg-Universität, Mainz — [4]Macquarie University, Sydney

The development of reliable devices generating single photons is crucial for applications in quantum information as well as for fundamental experiments in quantum optics. Due to its properties the nitrogen-vacancy (NV) color center in diamond is considered a promising candidate for the implementation of such a device. Those properties include an optical transition at 637 nm with a fluorescence lifetime of 11.6 ns, high photostability and the possibility to work at room temperature.

However, the collection efficiency of the fluorescence light in bulk diamond is limited by the high refractive index of diamond. To resolve this issue we use diamond nanocrystals, which – being smaller than the wavelength of the fluorescence light – are not subject to refraction. In order to further enhance the single photon collection efficiency we aim at coupling the emission of a single NV center to the evanescent field of a tapered optical fiber. Here we present data on diamond nanocrystals containing NV centers and the first attempts towards their application to tapered fibers.

Q 16.3 Tue 11:15 HSZ 02

**Fiber-integrated diamond-based single photon source** — •Tim Schröder, Andreas Wolfgang Schell, Günter Kewes, Thomas Aichele, and Oliver Benson — Nano Optics Group, Institut für Physik, Humboldt-Universität zu Berlin, Newtonstr. 15, 12489 Berlin, Germany

The most direct approach to fabricate a reliable single photon source is to mount a single quantum emitter on an optical fibre. It integrates easily into fibre optic networks for quantum cryptography or quantum metrology applications . For the first time such a fibre-integrated single photon source operating at room temperature is demonstrated. It consists of a single nitrogen vacancy defect centre in a nanodiamond which is directly near-field coupled to the guiding modes of a commercial optical fibre. The coupling is achieved in a bottom-up approach by placing a pre-selected nanodiamond directly on the fibre facet. This configuration is ultra-stable and realignment-free. Its high photon collection efficiency is equivalent to a far-field collection via an objective with a numerical aperture of 0.82. Furthermore, simultaneous excitation of the single defect centre and recollection of its fluorescence light through the fibre is possible introducing a fibre-connected single emitter sensor.

Q 16.4 Tue 11:30 HSZ 02

**Near-field infrared spectroscopy of single InAs quantum dots** — Rainer Jacob[1], •Stephan Winnerl[1], Harald Schneider[1], Manfred Helm[1], Marc Tobias Wenzel[2], Hans-Georg v. Ribbeck[2], and Lukas M. Eng[2] — [1]Institut für Ionenstrahlphysik und Materialforschung, Helmholtz-Zentrum Dresden-Rossendorf, Postfach 51 01 19, 01314 Dresden, Germany — [2]Institut für Angewandte Photophysik, TU Dresden, George-Bähr-Straße 1, 01069 Dresden, Germany

Scattering-type scanning near-field optical microscopy (s-SNOM) is a versatile technique in optical sciences. It provides optical resolution in the nanometer range, while offering spectroscopic application when combined with a tunable light source. Here, we exploit the combination of a s-SNOM with a widely tunable free-electron laser. With this setup, we were able to perform optical spectroscopy of single InAs quantum dots by means of their near-field signature in the mid infrared. The sample was composed of a single layer of self-assembled InAs quantum dots that were capped by a 70 nm thick GaAs layer. In the s-SNOM-measurements we could obtain a clear near-field contrast between the dots and the surrounding medium at 10.2 um which corresponds to 120 meV. Another clear contrast could be obtained for 85 meV. Both signatures could be attributed to intersublevel transitions in the quantum dot [1]. To our knowledge this is the first time that an optical near-field signature of an intersublevel transition could be demonstrated at a single InAs quantum dot.

[1] P. Boucaud et al., C. R. Physique 9, 840 (2008)

Q 16.5 Tue 11:45 HSZ 02

**Quantum-Dot Pyramidal Microcavities as Candidates for Electrically Pumped Efficient Single-Photon Sources** — •Daniel Rülke, Christoph Reinheimer, Florian Stockmar, Daniel M. Schaadt, Heinz Kalt, and Michael Hetterich — Institut für Angewandte Physik and DFG Center for Functional Nanostructures, Karlsruhe Institute of Technology (KIT), Wolfgang-Gaede-Straße 1, 76131 Karlsruhe (Germany)

We have investigated InAs-QDs embedded in reversed pyramidal GaAs microcavities in order to fabricate optically and electrically pumped single-photon sources. As a great advantage of the pyramidal shape the total number of QDs inside the cavity can be controlled by the position of the QD layer during molecular-beam epitaxial growth. Thus, by placing the QD layer close to the tip of the reversed pyramid, a very low number of QDs in the cavity can be achieved, while the facets act as a retroreflector for the emitted light. The pyramidal cavities were fabricated by a a combination of e-beam lithography and a selective wet-chemical etching process. In order to pump QDs electrically they have been embedded in the intrinsic layer of a pin-junction and individual cavities have been connected via bridges to a larger contact pad. To this end, a second non-critical e-beam alignment step had to be added after the wet-chemical etching process before metalisation and a subsequent lift-off process.

Q 16.6 Tue 12:00 HSZ 02

**Realisation of a robust and compact fibre-coupled diamond based single photon source implemented with gradient-index lenses** — •Philip Engel, Tim Schröder, and Oliver Benson — Nano Optics Group, Institut für Physik, Humboldt-Universität zu Berlin, Newtonstr. 15, 12489 Berlin

Single photons play an important role for many quantum information technologies. Quantum cryptography schemes and other experiments with single photons have already been implemented in rather large laboratory setups. To reduce the size and cost and increase the scalability of such experiments we designed a diamond based single photon source which uses gradient-index (GRIN) lenses with integrated thin film filters to collect and couple single photons into a single-mode fibre. GRIN lenses can be fabricated in such a way that a collimated incoming beam has its focal plane overlaying with the surface of the lens where nanodiamonds containing single defect centres can be deposited via spin-coating. In this manner the GRIN lens serves as holder for single photon emitters as well as light collection objective. Furthermore a solid immersion lens like behaviour increases the emission of a dipole into the direction of the GRIN lens. Depending on the defect centre type we expect more than 100 kcts/s of fibre coupled single photons. This high count rate combined with its easy experimental realisation, moderate cost for components and its small dimensions of about 3 mm by 3 mm by 30 mm makes this device interesting for robust and low cost single photon implementations.

Q 16.7 Tue 12:15 HSZ 02

**A spintronic circularly-polarized single-photon source** — •Andreas Merz, Pablo Asshoff, Robin Schwerdt, Heinz Kalt, and Michael Hetterich — Karlsruhe Institute of Technology (KIT)

Diluted magnetic semiconductors (DMS) are among the most promising materials for efficient spin-injection into semiconductors. They are thus ideal materials for designing a spin-polarized single photon source pumped by an electrical current. As a model system we investigate a spin light-emitting diode with the DMS ZnMnSe and an InGaAs quantum dot as single photon source. With an applied magnetic field of 2 T, a pronounced spin-polarization of $\sim$ 65 % is achieved, while at B = 6 T it even approaches 95 %. Autocorrelation measurements in pulsed operation mode prove the light emitted being non-classical.

Q 16.8 Tue 12:30 HSZ 02

**On-demand single photon source in (311)A GaAs quantum dots** — •Snežana Lazić, Rudolf Hey, and Paulo Santos — Paul-Drude-Institut für Festkörperelektronik, Hausvogteiplatz 5–7, 10117 Berlin, Germany

We demonstrate the generation of single photons on demand using an acousto-electric effect in GaAs/AlGaAs quantum well (QW) grown by molecular beam epitaxy on pre-patterned (311)A GaAs substrates. In this process, a surface acoustic wave (SAW) is employed to control the transfer of carriers, photogenerated in the QW, to an array of quantum dots (QDs) embedded at well-defined positions within the high-mobility QW transport channel. The embedded QD arrays form during the growth at the edges of etched triangular trenches due to monolayer fluctuations of the QW thickness. The photoluminescence from these acoustically-pumped arrays of QDs consists of a series of sharp lines which are attributed to the recombination of carriers in discrete quantum states. Time-resolved studies show that the population of the emitting states within the array, as well as the subsequent emission of single photons is governed by the SAW. The photons are emitted when the electrons captured within the array recombine with holes brought in a subsequent SAW cycle. The mechanism for the emission of non-classical light from QD arrays was investigated by analyzing the statistics of the emitted photons using the Hanbury Brown and Twiss approach.

Q 16.9 Tue 12:45 HSZ 02

**Tunnel Injection in Electrically Pumped Single Photon Emitters** — •Alexander Dreismann[1], Murat Öztürk[1], Ole Hitzemann[1], Erik Stock[1], Waldemar Unrau[1], Askhat K. Bakarov[2], Aleksandr I. Toropov[2], Ilia A. Derebezov[2], Vladimir Haisler[2], and Dieter Bimberg[1] — [1]Institut für Festkörperphysik, TU-Berlin, 10623 Berlin, Germany — [2]Institute of Semiconductor Physics, 630090 Novosibirsk, Russia

Electrically pumped InGaAs/GaAs quantum dot (QD) based Resonant-Cavity LEDs (RC-LEDs) represent powerful semiconductor based single photon and potential entangled photon emitters with high out-coupling efficiencies as required for quantum key distribution [1]. To achieve high photon emission rates the exciton luminescence intensity should be as high as possible; in the case of entangled photon sources exciton and biexciton luminescence intensities should be comparable.

To optimize the operation of our RC-LED in this regard we investigate the dependence of the luminescence intensity on the applied bias as well as on the temperature. We observe resonant tunneling injection of charge carriers into the QDs before the flat band condition of the diode structure is reached [2]. The influence of the dark state of the exciton on the luminescence is studied by comparing experimental data with a rate equation model. This work was partly funded by the SFB 787.

[1] D. Bimberg et. al., IEEE Photonics Journal, 1, 58 (2009)
[2] A. Baumgartner et. al., Phys. Rev. Lett. accepted (2010)