Q 43: Nano-Optics (Single Quantum Emitters)

Time: Wednesday 14:00–16:15 Location: K 0.023

Group Report Q 43.1 Wed 14:00 K 0.023

Towards Energy Transfer-based Sensing and Imaging with Color Centers in Single-Crystal Diamond — •Richard Nelz, Michel Challier, Ettore Bernardi, and Elke Neu — Universität des Saarlandes, Fakultät NT - Fachrichtung Physik, Campus E2.6, 66123 Saarbrücken

Individual nitrogen vacancy (NV) color centers in diamond are bright, photo-stable dipole emitters [1]. Consequently, they represent optimal candidates for novel scanning near field microscopy techniques [2]. Here, NV centers form one member of a Förster Resonance Energy Transfer (FRET) pair. Due to their broadband emission ($>$ 100 nm), NVs are versatile donors for FRET to systems absorbing in the near infrared spectral range. Promising applications include, e.g., nanoscale imaging of fluorescent molecules or nanomaterials like graphene [2].

Critical parameters for FRET are the NV's quantum efficiency, charge state stability and distance to the sample. Previous experiments used NVs in nanodiamond for FRET [2], however these NVs might suffer from quenching, instability and bad control of surface termination. We here adress this issue demonstrating quenching of NVs in single crystal diamond by applying graphene to the surface.

To bring NVs close ($<$ 10 nm) to the sample, we establish optimized approaches in fabricating cylindrical nanostructures as scanning probes.

[1] Bernardi et al., Crystals **7** 124 (2017).
[2] Tisler et al., Nano Lett. **13** 3152-3156 (2013).

Q 43.2 Wed 14:30 K 0.023

Optimization of diamond nanopillars for nanoscale sensing applications — •Philipp Fuchs, Michel Challier, and Elke Neu — Universität des Saarlandes, Fakultät NT - Fachrichtung Physik, Campus E2.6, 66123 Saarbrücken

The negatively-charged nitrogen vacancy center (NV) in diamond has become a very promising candidate for the implementation of nanoscale quantum sensors. Especially its electronic spin system is highly-suitable for magnetic field sensing and can be read out using the NV's luminescence. To fully harness the NV's nanoscale sensing capabilities, we use cylindrical diamond structures, so-called nanopillars, on thin diamond membranes as atomic force microscopy probes. Placing an NV shallowly below the top facet of such a pillar enables sensing and imaging with nanoscale spatial resolution. To achieve maximum sensitivity, it is crucial to maximize the absolute number of collected NV luminescence photons. In this talk, we show results from comprehensive simulations aiming towards the optimization of the photonic properties of such pillars to reach this goal. Besides a detailed analysis of the influence of different geometric parameters, e. g. length, diameter and taper angle, we also show an optimized set of parameters which maximizes the collectible NV luminescence.

Q 43.3 Wed 14:45 K 0.023

Parabolic reflectors and nanostructures in bulk diamond for efficient single photon extraction and cavity coupling — •Tim Schröder[1,2], Noel H. Wan[1], Brendan J. Shields[3], Donggyu Kim[1], Sara Mouradian[1], Benjamin Lienhard[1], Michael Walsh[1], Hassaram Bakhru[4], and Dirk Englund[1] — [1]RLE, Massachusetts Institute of Technology, USA — [2]Niels Bohr Institute, University of Copenhagen, Denmark — [3]Department of Physics, University of Basel, Switzerland — [4]SUNY Polytechnic Institute, USA

We present micro- and nanofabrication schemes of photonic devices in bulk diamond. Via high-throughput grey-scale lithography parabolic reflectors are fabricated that allow for simulated broadband collection >75% of the emission of defect centres in diamond [1]. The parabolic diamond-air interface redirects the emission of a defect located at the focal point into a small numerical aperture, reaching a photon extraction efficiency of (48 ± 5)%. For a nitrogen-vacancy centre (NV) the overall detection efficiency is (12 ± 2)%, enabling single photon count rates of up to $(5.7 \pm 1.0) \times 10^6$ per second. For the fabrication of photonic crystal cavities from bulk diamond we apply an isotropic undercut process. This process enables instrument-limited optical quality factors exceeding 14 000 within 1 nm of the NV zero phonon line, as well as uniform nanocavity fabrication across a full chip [2].

[1] N. H. Wan, B. J. Shields, D. Kim, S. Mouradian, B. Lienhard, M. Walsh, H. Bakhru, T. Schröder, and D. Englund, arXiv:1711.01704 (2017). [2] S. Mouradian, N. H. Wan, T. Schröder, and D. Englund, Appl. Phys. Lett. 111, 021103 (2017).

Q 43.4 Wed 15:00 K 0.023

Efficient solid-state single-photon sources based on diamond colour centers coupled to plasmonic bullseye resonators — •Martin Zeitlmair[1], Florian Fertig[1], Philipp Altpeter[1], and Harald Weinfurter[1,2] — [1]Ludwig-Maximilians-Universität, München — [2]Max-Planck-Institut für Quantenoptik, Garching

Efficient single-photon sources are a key building block for many applications in quantum information science and ultra-sensitive phase, absorption, and fluorescence spectroscopy. Here, solid-state based sources employing defect centers in nanodiamonds are advantageous due to their emission of single photons even at room temperature. The isotropic emission behaviour, however, requires the efficient redirection of the emission by means of photonic or plasmonic nanostructures.

We couple single nitrogen-vacancy centers hosted in nanodiamonds to aluminium bullseye structures employing an AFM-based pick-and-place technique. The plasmonic resonator is realized by an electron-beam lithography based fabrication method on dielectric mirror substrates. By optimizing the design parameters of the nanoplasmonic device, strong redirection and self-focusing of light emitted by the defect center can be achieved over a broad spectral range.

Q 43.5 Wed 15:15 K 0.023

Fourier limited lines in hBN at cryogenic temperatures — •Andreas Dietrich[1], Markus Bürk[1], Elena Steiger[1], Igor Aharonovich[2], Fedor Jelezko[1], and Alexander Kubanek[1] — [1]Institute for Quantum Optics, Ulm University, D-89081 Ulm, Germany — [2]School of Mathematical and Physical Sciences, University of Technology Sydney,Ultimo, New South Wales 2007, Australia

Defect centers in layered hexagonal boron nitride (hBN) are among the most promising candidates as single photon sources in Quantum Optics applications [1]. Very recently resonant excitation of single defect centers in 2D-material hBN has been demonstrated [2], with linewidth $\sim$ 1 GHz being limited by rapid spectral diffusion. Here we present our recent results on resonant excitation on defects in hBN in absence of spectral diffusion or dephasing for as long as 30 s at cryogenic temperatures, enabling us to measure Fourier limited lines of 55 MHz $\pm$ 10 MHz. Additional we report single photon emitters in hBN over a wide optical range and investigate phonon side-band emission. Fourier limited lines in a wide optical range with potentialy long coherence times [3] make hBN a promising candidate for applications such as quantum repeaters.

[1] Tran, Toan Trong, et al. Nature nanotechnology 11.1 (2016): 37-41.
[2] Tran, Toan Trong, et al. ACS Photonics (2017).
[3] Abdi, Mehdi, et al. arXive preprint arXiv:1704.00638 (2017)

Q 43.6 Wed 15:30 K 0.023

Resonant excitation studies of single dichroic vacancy centres in silicon carbide — Roland Nagy[1], •Florian Kaiser[1], Matthias Niethammer[1], Matthias Widmann[1], Durga Dasari[1], Ilja Gerhardt[1], Öney Soykal[2], Nguyen Tien Son[3], Christian Bonato[4], Sang-Yun Lee[5], and Jörg Wrachtrup[1] — [1]3. Physikalisches Institut, Universität Stuttgart — [2]Naval Research Laboratory, Washington, USA — [3]Department of Physics, Chemistry and Biology, Linköping University, Sweden — [4]IPAQS, SUPA, Edinburgh, UK — [5]CGI, KIST, Seoul, Korea

Solid-state color centres are promising systems for scalable quantum information architectures. The ideal system meets three key features:

first, millisecond electron spin coherence times to permit quantum state manipulation and coupling to other spins; second, a large fraction of photons must be emitted in the zero phonon line to generate spin-photon entanglement; third, excellent spectral stability.

We show that all three criteria are met by the dichroic vacancy defect center (V1) in 4H-SiC [1]. The V1 center is a S=3/2 spin system with well-separated optical transitions at 861 nm [2]. We perform resonant optical excitation studies on single V1 centers to explore the ground and excited state level structures. We study also the spin dynamics and note that no spectral diffusion has been observed. Therefore, our

results pave the way for a robust and scalable quantum information platform based on color centers in silicon carbide.

[1] R. Nagy et al., arxiv:1707.02715 (2017)
[2] M. Widmann et al., Nat. Mater. 14, 164 (2015)

Q 43.7 Wed 15:45 K 0.023

Two-photoninterference in an atom- quantum dot hybrid system — •Hüseyin Vural[1], Simone L. Portalupi[1], Julian Maisch[1], Simon Kern[1], Jonas H. Weber[1], Markus Müller[1], Michael Jetter[1], Jörg Wrachtrup[2], Robert Löw[3], Ilja Gerhardt[2], and Peter Michler[1] — [1]Institut für Halbleiteroptik und Funktionelle Grenzflächen, IQST and SCoPE, Universität Stuttgart, Allmandring 3, 70569 Stuttgart, Germany — [2]3. Physikalisches Institut and IQST, Universität Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart — [3]5. Physikalisches Institut and IQST, Universität Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart

Future quantum networks require flying qubits and stationary nodes. Hybridization of single semiconductor quantum dots (QD), which provide ultra-bright on-demand single-photon emission, and alkali vapors with their possibility of broadband photon storage capabilities constitute a reasonable platform for networks. However, spectral diffusion, inherent in most solid-state emitters, is a limiting aspect to the photonic quantum optical properties. Here, we investigate the role of spectral diffusion of QDs on the hybridization with a cesium (Cs)-vapor. Fine-tuning the QD emission between the Cs-D1 transitions enables a temperature dependent delay on the single quanta. The strong dependence of this effect on the photon's frequency is used to map spectral domain into temporal one, thus revealing insight into the diffusion dynamics. Moreover coherence of photon-vapor interaction is proved to be conserved by means of two-photon interference measurements. Theoretically achievable performances are presented.

Q 43.8 Wed 16:00 K 0.023

Exciton-exciton dynamics in para-xylylene bridged perylene bisimide macrocycles — •Ulrich Müller[1], Peter Spenst[2], Matthias Stolte[2], Frank Würthner[2], and Jens Pflaum[1,3] — [1]Experimentelle Physik VI, Julius-Maximilians-Universität, Würzburg — [2]Institut für Organische Chemie, Julius-Maximilians-Universität, Würzburg — [3]ZAE Bayern, Würzburg

Multi-chromophoric systems serve as strong links between free photons and excitonic excitations in nature and define promising compounds for non-classical light sources in quantum optics. In this context, we have identified Perylene Bisimides (PBIs) as a model system for strong absorption and efficient single photon emission at room temperature promoted by their chemical tunability and high photostability [1]. We compare para-xylylene bridged PBI-macrocycles to single chromophores by means of fluorescence correlation measurements. PBI-macrocycles act as bright single photon emitters since ultra-fast exciton-exciton-annihilation significantly suppresses the simultaneous emission of two photons. However, approaching single-excited state saturation by increasing the excitation intensity the co-existence of multi-excitonic states becomes more likely and controls the emission characteristics of the macrocycles while the emission of single chromophores remains largely unchanged. We consistently explain our observations by a stochastic Markov model and advance the understanding of excitation and relaxation processes in multi-chromophoric systems.

[1] F. Schlosser et al., *Chem. Sci.* **3**, 2778 (2012)