Q 56: Nano-Optics III

Time: Thursday 14:30–16:15 Location: C/HSO

Q 56.1 Thu 14:30 C/HSO

Interactions of single molecules with the guided modes of an optical nanofiber — •Sarah Margaretha Skoff, David Papencordt, Hardy Schauffert, and Arno Rauschenbeutel — University of Technology Vienna, Institute for Atomic and Subatomic Physics, Stadionallee 2, 1020 Vienna

Single molecules interfaced with optical nanofibers provide a very versatile system for quantum optics experiments. Single molecules in solids have been shown to be very photostable, have narrow lifetime limited transitions at cryogenic temperatures and nearly unity quantum yield. Optical nanofibers are tapered commercial optical fibers with a waist smaller than the wavelength of light they are guiding. They provide a strong transverse confinement of the light field while an appreciable amount of the intensity is guided outside the fiber surface as an evanescent wave. This ensures strong interactions between the light field and even a single molecule. We will show how single terrylene molecules in p-terphenyl nanocrystals are efficiently interfaced with optical nanofibers. Spectroscopy of single molecules will be presented and the advantageous properties of this system will be explained in detail.

Q 56.2 Thu 14:45 C/HSO

Nonlinear optics with single molecules — •Andreas Maser[1], Benjamin Gmeiner[1], Tobias Utikal[1], Stephan Götzinger[1,2], and Vahid Sandoghdar[1,2] — [1]Max Planck Institute for the Science of Light (MPL), D-91058 Erlangen, Germany — [2]Department of Physics, Friedrich Alexander University of Erlangen-Nürnberg, D-91058 Erlangen, Germany

Investigation of nonlinear effects usually requires the use of macroscopic media and intense light fields. The underlying reason for this is, in addition to the inherently weak nature of nonlinear processes, the weak coupling of light and matter. We report on four-wave mixing in a single organic molecule placed at the tight focus of two near resonant laser beams [1]. A weak probe beam is scanned across the molecular resonance, while a strong pump beam is kept at a fixed detuning. By directly monitoring the intensity of the probe beam after the interaction with the molecule, we observe a rich set of resonance profiles in excellent agreement with theoretical calculations. We discuss future experiments aimed at nonlinear studies with few-photon light fields and single quantum emitters.

[1] A. Maser *et al.*, to be submitted.

Q 56.3 Thu 15:00 C/HSO

Nano-Photonics and -Mechanics with Implanted Spins in Diamond — •Seyed Ali Momenzadeh[1], Rainer Stöhr[1,2], Sen Yang[1], Felipe Favaro de Oliveira[1], Andreas Brunner[1], Andrej Denisenko[1], Philipp Neumann[1], Friedemann Reinhard[1,3], and Jörg Wrachtrup[1,4] — [1]Universität Stuttgart, Stuttgart, Germany — [2]University of Waterloo, Waterloo, Canada — [3]Technische Universität München, München, Germany — [4]Max Planck Institute for Solid State Research, Stuttgart, Germany

The negatively-charged nitrogen vacancy (NV) center in diamond has become an intensely-studied spin qubit due to its outstanding photonic and spin-based properties since the last decade. Among the other applications, NMR-based measurements at nanoscale [1] like single proton spin detection [2] were performed recently using NV centers. On the other hand, these defects were discussed as quantum sensors to monitor the motions of mechanical oscillators [3,4]. In this contribution, we present monolithic diamond photonic structure [5] as a robust bright platform for magnetometry based on shallow implanted NV centers. In addition, we demonstrate our current achievements towards NV-based diamond nanomechanical systems.

[1] T. Staudacher et al. Science DOI:10.1126/science.1231675
[2] M. Loretz et al. Science DOI: 10.1126/science.1259464
[3] P. Ovartchaiyapong et al. NComm DOI:10.1038/ncomms5429
[4] J. Teissier et al. PRL.
DOI: http://dx.doi.org/10.1103/PhysRevLett.113.020503
[5] S. Ali Momenzadeh et al. arXiv:1409.0027

Q 56.4 Thu 15:15 C/HSO

Ultra-bright emission of indistinguishable photons from deterministic quantum-dot microlenses — •Alexander Thoma, Peter Schnauber, Manuel Gschrey, Marc Seifried, Ronny Schmidt, Jan-Hindrik Schulze, Tobias Heindel, Sven Rodt, André Strittmatter, and Stephan Reitzenstein — Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstraße 36, D-10623, Germany

Quantum emitters capable of generating single indistinguishable photons at high rates constitute an essential building block for the field of quantum information technology - and in particular for the quantum repeater concept. Promising candidates to realize such sources are single semiconductor quantum dots (QDs) integrated into photonic microstructures. However, the progress achieved so far in this field is mainly based on devices realized on spatially and spectrally random emitter technologies.

Here, we report on a novel deterministic device concept based on the fabrication of single QD microlenses utilizing in-situ electron beam lithography. We show that such quantum light sources can be realized with very high process yield $> 90\%$ and enable ultra-bright triggered emission. Photon extraction efficiencies up to $(23.3 \pm 3.0)\%$ in combination with a strong suppression of multi-photon emission events $g^{(2)}(0) < 0.01$ are realized. Furthermore Hong-Ou-Mandel-type two-photon interference experiments reveal a visibility of $V = (43 \pm 4)\%$ even at saturation of the QD emitter.

Q 56.5 Thu 15:30 C/HSO

Narrow-band quantum dot single photons at the Cesium D_1 transition using resonant excitation — •Tim Kroh, Andreas Ahlrichs, Andreas W. Schell, Otto Dietz, Thomas Kreissl, Chris Müller, Benjamin Sprenger, and Oliver Benson — AG Nano Optics, Institut für Physik, Humboldt-Universität zu Berlin

Quantum information applications such as quantum repeaters require indistinguishable single photons and photon pairs from distant sources. Semiconductor quantum dots fulfill the claims to have high emission rates and the capability of being integrated into small on-chip devices that emit on demand. Indistinguishability is determined by all of the photon's properties which are the central emission wavelength, the linewidth or coherence time, the polarization as well as the time of emission. While the latter two can be easily controlled by using wave plates and electrical pumping, the emission energy of a quantum dot strongly depends on its vicinity. Optical transitions of inert gases may provide an atomic standard for stabilizing remote quantum systems to a certain wavelength.

In our experiment we investigate quantum dots that can be strain-tuned to the Cesium D_1 transition via a piezoelectric substrate [1]. We use resonant excitation of quantum dots in a liquid-flow Helium cryostat to create narrow-band single photons. With the aid of a Fabry-Pérot resonator system we could resolve the Mollow-triplet indicating the presence of dressed states in the high power excitation regime.

[1] A. Rastelli et al, Phys. Status Solidi B **249**, 687 (2012)

Q 56.6 Thu 15:45 C/HSO

Cold atom-semiconductor hybrid quantum system — •Lucas Béguin[1], Fei Ding[2], Aline Faber[1], Jan-Philipp Jahn[1], Andreas Jöckel[1], Tobias Kampschulte[1], Andreas Kuhlmann[1], Mathieu Munsch[1], Armando Rastelli[3], Nicolas Sangouard[1], Oliver G. Schmidt[2], Philipp Treutlein[1], and Richard J. Warburton[1] — [1]Universität Basel, Departement Physik, CH-4056 Basel — [2]IFW Dresden, Germany — [3]Johannes-Kepler University Linz, Austria

Semiconductor quantum dots are excellent single-photon sources, providing triggered single-photon emission at a high rate and with high spectral purity. Independently, atomic ensembles have emerged as one of the best quantum memories for single photons, providing high efficiency storage and long memory lifetimes. In this project, we combine these two disparate physical systems to exploit the best features from both worlds. On the one hand, we have characterized a new type of self-assembled GaAs/AlGaAs quantum dots that emit anti-bunched, narrow-band single-photons ($\Delta\nu \sim 500$ MHz) at a wavelength compatible with Rb atoms. Fine tuning of the photon frequency is achieved via strain. This allowed us to perform a spectroscopy of the Rb D2-line at the single-photon level, proving that we can address the different hyperfine transitions. On the other hand, we have developed a detailed theory of an EIT-based memory scheme in a dense ultracold ensemble of ^{87}Rb atoms (OD$\geqslant$150) that achieves storage-and-retrieval efficiency

exceeding 28%. In the long term, such a memory will form the basis for experiments on hybrid entanglement and quantum networks.

Q 56.7 Thu 16:00 C/HSO

Quantum optical master equation for solid-state quantum emitters — •Ralf Betzholz[1], Juan Mauricio Torres[2], and Marc Bienert[1] — [1]Theoretische Physik, Universität des Saarlandes, D-66123 Saarbrücken, Germany — [2]Institut für Angewandte Physik, Technische Universität Darmstadt, D-64289 Germany

Solid-state quantum emitters, in particular color centers in diamond such as nitrogen-vacancy (NV) centers, are promising candidates for single photon sources. We provide an elementary description of the dynamics of defect centers in terms of a quantum optical master equation which includes spontaneous decay and a simplified vibronic interaction with lattice phonons [1]. We present the general solution of the dynamical equation by means of the eigensystem of the Liouville operator and exemplify the usage of this damping basis to calculate the dynamics of the electronic and vibrational degrees of freedom and to provide an analysis of the spectra of scattered light. The dynamics and spectral features are discussed with respect to the applicability for color centers, especially for NV centers.

[1] R. Betzholz et al., arXiv:1411.0864 (2014)