FM 53: Enabling Technologies: Sources of Quantum States of Light III

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

Invited Talk FM 53.1 Wed 14:00 1010

Efficient single photon sources for quantum information science — •Tobias Huber[1], Jan Donges[1], Simon Betzold[1], Magdalena Moczała-Dusanowska[1], Łukasz Dusanowski[1], Stefan Gerhardt[1], Jonathan Jurkat[1], Andreas Pfenning[1], Christian Schneider[1], and Sven Höfling[1,2] — [1]Lehrstuhl für Technische Physik, Universität Würzburg, Würzburg, Germany — [2]SUPA, School of Physics and Astronomy, University of St Andrews, St Andrews, UK

Self-assembled semiconductor quantum dots are good sources of indistinguishable single photons and entangled photon pairs. Furthermore, the ground state spin of a trapped electron or hole can be used as a spin qubit. Due to the high refractive index of the host material, only a small fraction of light can be collected and used in further experiments. So solve this issue, quantum dots have been embedded into various kinds of photonic structures to enhance their photonic properties due to cavity quantum electrodynamics.

Here, we present our latest results in strain tunability of quantum dots when embedded in micropillar cavities as well as some preliminary data on quantum dots in circular grating cavities.

FM 53.2 Wed 14:30 1010

Towards Coupling Quantum Dots to a Rb-Memory — •Liang Zhai[1], Matthias C. Löbl[1], Giang N. Nguyen[1,2], Jan-Philipp Jahn[1], Julian Ritzmann[2], Andreas D. Wieck[2], Armando Rastelli[3], Arne Ludwig[2], and Richard J. Warburton[1] — [1]University of Basel, 4056 Basel, Switzerland — [2]Ruhr-Universität Bochum, 44780 Bochum, Germany — [3]Johannes Kepler University Linz, 4040 Linz, Austria

Combining a solid-state quantum dot (QD) with an atomic memory is a promising hybrid-system for application in quantum communication [1]. Coupling the QD to a quantum memory, such as a Rb-memory, can circumvent the short coherence time of QDs. For coupling both systems, the photons emitted by the QD have to match the atomic ensemble in bandwidth and frequency [2,3].
We use droplet-etched GaAs QDs embedded in AlGaAs as a source of coherent single photons and investigate how their optical properties are connected to the QD-growth [4]. For tuning the QD-frequency we present two approaches: Applying mechanical strain to the sample [5] and applying an electric field to QDs in a diode structure [6,7].

[1] N. Sangouard *et al.*, Phys. Rev. A **76**, 050301 (2007).
[2] J.-P. Jahn *et al.*, Phys. Rev. B **92**, 245439 (2015).
[3] L. Beguin *et al.*, Phys. Rev. B **97**, 205304 (2018).
[4] M. C. Löbl *et al.*, arXiv:1902.10145 (2019).
[5] D. Huber *et al.*, Phys. Rev. Lett. **121**, 033902 (2018).
[6] L. Bouet *et al.*, Appl. Phys. Lett. **105**, 082111 (2014).
[7] F. Langer *et al.*, Appl. Phys. Lett. **105**, 081111 (2014).

FM 53.3 Wed 14:45 1010

Prospects of GaAs-based quantum dots emitting in the telecom wavelength regime for quantum communication schemes — •Cornelius Nawrath[1], Jingzhong Yang[2], Robert Keil[3], Michael Zopf[2], Fabian Olbrich[1], Matthias Paul[1], Fei Ding[2], Michael Jetter[1], Simone Luca Portalupi[1], Oliver Schmidt[3], and Peter Michler[1] — [1]Institut für Halbleiteroptik und Funktionelle Grenzflächen, Center for Integrated Quantum Science and Technology (IQST) and SCoPE, University of Stuttgart, Allmandring 3, 70569 Stuttgart — [2]Institute for Solid State Physics, Leibniz University of Hannover, Appelstr. 2, 30167 Hannover — [3]IFW Dresden, Helmholtzstraße 20, 01069 Dresden

The emission of semiconductor quantum dots (QDs) has been shown to exhibit excellent properties in terms of single photon purity, photon indistinguishability and entanglement fidelity, i.e. essential prerequisites for quantum communication. Emission in the telecom O- or C-band will boost the range of communication schemes due to the favourable absorption and dispersion properties of silica fibers employed in the existing global fiber network. The coherence properties of photons emitted by InAs/InGaAs QDs emitting directly in the telecom C-band, are examined under above-band excitation and in resonance fluorescence. Furthermore, under two-photon excitation, the single-photon purity and post-selected degree of indistinguishability are determined. To boost the extraction efficiency, the applicability of an approach combining a nano-membrane containing QDs, with a GaP hemispherical lens is presented for a sample emitting in the telecom O-band.

FM 53.4 Wed 15:00 1010

Ultrafast high-frequency electronics in cryogenic environments: Perspectives for Quantum Technologies — •Kai J. Spychala, Alex Widhalm, Björn Jonas, Sebastian Krehs, and Artur Zrenner — Department of Physics, University of Paderborn, Warburger Str. 100, D-33098 Paderborn, Germany

The implementation of quantum effects in computation, simulation, sensing and communication requires a miniaturization and standardization effort, which makes it compatible with existing technologies. Beside the efforts to operate communication systems in the telecom bands, a very important prerequisite for scalability is the application of state of the art electronics for steering, read-out, as well as pre- and post-processing, in order to benefit from existing semiconductor technologies. As quantum phenomena are mostly short-lived and observed under cryogenic environments, robust high-frequency electronics, which can operate in the cryogenic regime, is needed.
We report our results on the design of ultrafast BiCMOS chips and their application for the steering of single self-assembled semiconductor QDs and QD molecules for quantum communication purposes. We show results on the ultrafast electric phase manipulation of an exciton qubit [1], the rapid adiabatic passage of an exciton qubit and present a scheme for Ramsey-based optoelectronic sampling. We also present a chip design for the implementation of an electric pulse protocol, that can be used to entangle spin-qubits in a QD molecule, in order to get a spin-photon interface for future quantum repeater applications.
Ref: [1] A. Widhalm et al., APL 112, 111105 (2018).

FM 53.5 Wed 15:15 1010

Towards a single-photon source electrically driven by a single-electron pump — •Eric Reutter[1], Julian Maisch[2], Simone L. Portalupi[2], Peter Michler[2], and Jürgen Weis[1] — [1]Max Planck Institute for Solid State Research, Heisenbergstraße 1, 70569 Stuttgart, Germany — [2]Institut für Halbleiteroptik und Funktionelle Grenzflächen, IQST and SCoPE, University of Stuttgart, Allmandring 3, 70569 Stuttgart, Germany

Integrated photonic circuits step up to be a very promising candidate for future applications in quantum computing, quantum simulation, and quantum key distribution in telecommunication. In particular this requires the integration of devices for the generation of single photons on demand, optically passive and active components allowing photons to interact, and finally devices for the detection of single photons.

We investigate the feasibility of electrically pumping a quantum dot single-photon source by a single-electron pump. We will discuss fundamental requirements, restraints and limits of such a device operated under a large applied bias. Monte-Carlo rate equation simulations of the complex electrical circuit, incorporating all parts of the system, are presented to further understand the single-electron tunnelling dynamics and single-photon emission of such a system. From simulations and model, the constraining design features for such a device are determined. A prospect of a suitable material platform is given and discussed.

FM 53.6 Wed 15:30 1010

Photon-pair generation mediated by coupling of emitters to nonlinear photonic nanostructures — •Sina Saravi[1,4], Alexander Poddubny[2,3], Thomas Pertsch[1], Frank Setzpfandt[1], and Andrey A. Sukhorukov[4] — [1]Institute of Applied Physics, Abbe Center of Photonics, Friedrich Schiller University Jena, Jena, Germany — [2]ITMO University, St. Petersburg, Russia — [3]Ioffe Institute, St. Petersburg, Russia — [4]Nonlinear Physics Centre, Research School of Physics and Engineering, Australian National University, Canberra, Australia

We theoretically investigate a hybrid system of an atom-like emitter coupled to a nanostructured nonlinear photonic system. In our proposed configuration, the response of the nonlinear optical system is suppressed to achieve a regime where the response of the hybrid system is dominating. Using a rigorous Green's function quantization method to model the system, we show that in photonic nanostructures with spectral gaps with zero optical density-of-states, nonlinear effects like spontaneous photon-pair generation are prohibited if the frequency of one of the generated photons is in the gap. Moreover, we show that a coupled emitter with a transition frequency in the photonic gap mediates the otherwise forbidden generation of photon pairs, where one photon directly excites the emitter and the other occupies an optical mode. This effect can serve as a sensitive indicator for the presence and excitation of single atoms. Furthermore, this scheme could be used to directly interface quantum memories with photon-pair sources or to realize a deterministic and tunable single-photon source.

FM 53.7 Wed 15:45 1010

Imaging quantum emitters with parabolic mirrors — •Markus Sondermann[1,2] and Gerd Leuchs[1,2,3] — [1]Friedrich-Alexander-University of Erlangen-Nürnberg, Department of Physics, Germany — [2]Max Planck Institute for the Science of Light, Erlangen, Germany — [3]Department of Physics, University of Ottawa, Canada

Quantum emitters naturally radiate photons into the full solid angle. Therefore, in our experiments we collect the photons emitted by such sources with a deep parabolic mirror. This enables the imaging of the full spherical emission pattern onto a plane or, alternatively, the localization of the source with high spatial precision.

We discuss two examples of applications that benefit from such a set-up. The first one is imaging a single ion held in a radio frequency trap and determining its temperature as well as the excess heating rate, including the case of extremely weak excitation of the ion. The second example treats the imaging of nano-rod quantum-emitters held in an optical trap. Here, the imaging process enables the verification of the alignment of such rods along the electric field of the trap laser and yields the decomposition of the nano-rod emission into its constituting linear and circular dipole components.