HL 38: Quantum light sources based on solid state systems: Status and visions I (Focus session with TT)

Non-classical quantum light sources with the ability to efficiently generate photon states with tailored properties (e.g. well defined photon-number Fock states, mutually highly indistinguishable photons, or high fidelity quantum entangled states, etc.) are among the fundamental building blocks of numerous proposed applications in the field of quantum information processing – particularly quantum computing and quantum cryptography. The aim of this focus session is to bring together the ideas, concepts and results of leading national and European research groups on semiconductor and solid state-based quantum light sources and to discuss the current status and future goals in this highly topical field of research.

Organizers: Sven Ulrich, Universität Stuttgart, and Christoph Becher, Universität des Saarlandes, Saarbrücken.

Time: Tuesday 9:30–11:15 Location: POT 251

Topical Talk HL 38.1 Tue 9:30 POT 251

Nonclassical light from semiconductor quantum dots — •Gregor Weihs[1,2], Tobias Huber[1], Harishankar Jayakumar[1], Thomas Kauten[1], and Ana Predojević[1] — [1]Institut für Experimentalphysik, Universität Innsbruck, Technikerstr. 25, 6020 Innsbruck, Austria — [2]Institute for Quantum Computing, University of Waterloo, 200 University Ave W, Waterloo, ON N2L 3G1, Canada

For fundamental tests of quantum physics as well as for quantum communications non-classical states of light are an important tool. In our research we focus on developing semiconductor-based and integrated sources of single photons and entangled photon pairs.

In this talk we will present our work on single InAs/GaAs quantum dots. For the highest degree of quantum control we use resonant two-photon excitation to deterministically trigger a biexciton-exciton cascade. We block the pump light from the detectors by using side excitation through the waveguide mode of a planar microcavity. We demonstrate Rabi oscillations, Ramsey interference and all-optical coherent control of the quantum dot resulting in single and paired photons with a high degree of indistinguishability [1]. Using novel quantum optical assessment tools we are then able to show the non-classical and non-Gaussian characteristics of the emitted photons.

This indistinguishability eventually results in time-bin entangled photon pairs through the biexciton-exciton cascade. Time-bin entanglement is a useful variant for long distance communication because it is robust against decoherence in optical fibers. Two successive coherent pulses excite the dot ei-ther in the early or in the late pulse. The emitted photons pass imbalanced interferometers for analy-sis in the energy basis. Through quantum state tomography we are able to demonstrate significant entanglement of the emitted pairs.

This work was supported by the ERC and CIFAR.

[1]H. Jayakumar, A. Predojevic, T. Huber, T. Kauten, G. S. Solomon & G. Weihs, Deterministic Photon Pairs and Coherent Optical Control of a Single Quantum Dot, Phys. Rev. Lett. 110, 135505 (2013).

HL 38.2 Tue 10:00 POT 251

On-demand generation of indistinguishable polarization-entangled photon pairs — •Markus Müller[1], Samir Bounouar[1], Klaus D. Jöns[1], Martin Glässl[2], and Peter Michler[1] — [1]Institut für Halbleiteroptik und Funktionelle Grenzflächen, Universität Stuttgart, Allmandring 3, 70569 Stuttgart, Germany — [2]Institut für Theoretische Physik III, Universität Bayreuth, Universitätsstraße 30, 95440 Bayreuth, Germany

The development of quantum information science using linear optics has made substantial progress in the recent past. This advance is mainly based on the ability to generate high-quality photonic qubits from various kinds of different sources. Furthermore, for practical quantum information operations it is essential to create the qubits deterministically. In this work we show that semiconductor quantum dots (QDs) are suitable to fulfill both of this elementary requirements. To exploit their remarkable properties, a coherent resonant two-photon excitation scheme is applied. Thereby the biexciton state of an InGaAs QD is populated with a near unity preparation efficiency. Because of this individual and coherent addressing, the photons emitted by the biexciton-exciton cascade show enhanced optical and quantum-optical qualities. This is reflected in pure single-photon emission, long coherence times and high indistinguishability visibilities ($V_{\mathrm{HOM}} = 0.86 \pm 0.03$ and 0.71 ± 0.04) for the biexcitonic and excitonic emission, respectively. Taking advantage of a QD without fine structure splitting, we can demonstrate the on-demand generation (pair-efficiency = 0.86 ± 0.08) of high fidelity (0.81 ± 0.02) polarization-entangled photon pairs.

HL 38.3 Tue 10:15 POT 251

Feedback-Enhanced Entanglement of Photons from a Biexciton Cascade — •Sven Moritz Hein[1], Franz Schulze[1], Alexander Carmele[2], and Andreas Knorr[1] — [1]Technische Universität Berlin, Institut für theoretische Physik, Nichtlineare Optik und Quantenelektronik, Hardenbergstraße 36, 10623 Berlin, Germany — [2]Institut für Quantenoptik und Quanteninformation, Technikerstraße 21a, 6020 Innsbruck, Austria

Coherent quantum feedback [1] is a method to control and stabilize quantum-mechanical systems by the use of a feedback mechanism that does not rely on measurement, but is completely quantum-mechanical itself. We utilize such a feedback scheme to enhance the entanglement of photons from a biexciton cascade in a quantum dot. The achievable photon entanglement is usually diminished substantially by exciton fine-structure splitting. We demonstrate that it is possible to increase photon entanglement by feeding the emitted light back into the quantum dot after a certain feedback time, e.g. by using a mirror at a specific distance from the emitter [2]. The complex interplay between original and reflected field modifies the emission spectrum in a way that the achievable entanglement is strongly enhanced. We present a full quantum-mechanical theory of the system, including the feedback-induced modification of the photon mode continuum. We analyze the influence of feedback delay and phase and discuss the involved mechanisms in detail.

[1] S. Lloyd, Phys. Rev. A 62, 022108 (2000).
[2] A. Carmele et al., Phys. Rev. Lett. 110, 013601 (2012).

HL 38.4 Tue 10:30 POT 251

Emission of polarization-entangled photons from biexcitons: two-photon processes and phonon-assisted cavity feeding — •Dirk Heinze, Artur Zrenner, and Stefan Schumacher — Department of Physics and CeOPP, University of Paderborn, Warburger Str. 100, 33098 Paderborn

Semiconductor quantum dots are promising sources for generation of pairs of polarization-entangled photons. In [1] we have shown theoretically that using a direct two-photon emission process inside a high-quality optical microcavity, the degree of achievable polarization-entanglement can be rendered insensitive to exciton fine-structure splitting (in contrast to the usual cascaded emission). The results in [1] were obtained for realistic quantum-dot and cavity parameters but neglecting the influence of phonon-assisted cavity feeding. Here we extend our previous study and include the interaction with a bath of acoustic phonons in a Born-Markov approximation in the master-equation for the system density operator. Our analysis shows the detrimental influence of phonons on the polarization entanglement with increasing temperature. However, it also demonstrates that at low temperature the influence of phonons on the scheme proposed in [1] is strongly suppressed such that high degrees of entanglement can be achieved.

[1] S. Schumacher, J. Förstner, A. Zrenner, M. Florian, C. Gies, P. Gartner, and F. Jahnke. Cavity-assisted emission of polarization-

entangled photons from biexcitons in quantum dots with fine-structure splitting. Optics Express, **20**, 5335 (2012).

Topical Talk HL 38.5 Tue 10:45 POT 251

Taming single photons emitted by solid state systems —
•Stephan Götzinger — Max Planck Institute for the Science of Light and Friedrich-Alexander-Universitaet Erlangen-Nuernberg (FAU), D-91058 Erlangen, Germany

In the first part of this talk we will discuss single-photon sources with near-unity efficiency. These sources are based on the concept of metallo-dielectric antennas. Then we will present experiments where photons and single solid state emitters strongly interact.