HL 33: Quantum light sources

Time: Wednesday 15:00–17:30 Location: H34

HL 33.1 Wed 15:00 H34

Development of Plug-and-Play Single-Photon Sources for Quantum Communication — •Lucas Rickert, Timm Kupko, Stephan Reitzenstein, and Tobias Heindel — Institut für Festkörperphysik, Technische Universität Berlin, 10623 Berlin, Germany

Quantum light sources are essential building blocks for novel applications in the fields of communication, metrology and sensing. The future success of quantum technologies, however, will critically rely on the applicability of quantum light sources outside shielded lab environments. First steps in this direction are very promising [1], but further developments are necessary to realize devices suitable for quantum communication scenarios.
In this work, we report on our recent progress in the development of plug-and-play single-photon sources (SPSs) based on semiconductor quantum dots. A compact Stirling cryocooler is employed as basis for user-friendly operation of our SPSs at cryogenic temperatures. We address the direct coupling of the SPS emission to optical single-mode fibers, representing a crucial step for applications. Furthermore we discuss approaches to realize compact spectral filtering based on interference bandpass filters or transmission gratings as well as the implementation of electrical operation. All these elements can finally be integrated into a single plug-and-play system, which would represent a major step towards the development of QKD-secured communication networks based on quantum-light sources.

[1] A. Schlehahn et al., Scientific Reports **8**, 1340 (2018)

HL 33.2 Wed 15:15 H34

Integrated quantum photonics based on InAs/GaAs quantum dots monolithically coupled to ridge waveguides — •Dominik Koeck[1], Lukasz Dusanowski[1], Soon-Hong Kwon[2], Christian Schneider[1], and Sven Hoefling[1] — [1]Technische Physik, University of Wuerzburg, Physikalisches Institut and Wilhelm-Conrad-Roentgen-Research Center for Complex Material Systems, Am Hubland, D-97074 Wuerzburg, Germany — [2]Department of Physics, Chung-Ang University, 156-756 Seoul, Korea

Hereby we show our recent advances in fabrication and optical characterization of InAs/GaAs QDs monotonically integrated with single- and multimode distributed Bragg reflector ridge waveguides. Identification of excitonic and biexcitonic transitions have been performed by power- and polarization-resolved microphotoluminescence studies. In order to evaluate the non-classicality of QD transitions, second-order auto-correlation measurements where performed in Hanbury Brown and Twiss configuration. In case of both, continuous and pulsed excitation of the QD's transitions we observed clear signatures of single photon emission with $g^{(2)}(0)$ values below 0.1, confirming pure single photon character of the emitted light. Future directions include efforts towards more advanced integrated functionalities such as ring resonators and directional couplers needed for on-chip single photon processing.

HL 33.3 Wed 15:30 H34

Characterization of deterministically fabricated quantum dot microlenses under mechanical strain tuning — •Marco Schmidt[1,2], Sarah Fischbach[1], Martin von Helversen[1], Arsenty Kaganskiy[1], Sven Rodt[1], Tobias Heindel[1], and Stephan Reitzenstein[1] — [1]Institut für Festkörperphysik, Technische Universität Berlin, 10623 Berlin, Germany — [2]Physikalisch-Technische Bundesanstalt, Abbestraße 2-12, 10587 Berlin, Germany

Quantum dots (QPs) are sources of single, indistinguishable photons as well as polarization entangled photon pairs. These highly efficient QP emitters are of highest interest for future quantum communication systems allowing for the interception-proof exchange of information by single photons. The spectral properties of QPs determined by the self-assembled growth and can be manipulated in limited range by experimental methods, e.g. temperature variation. The emission energy can also be tuned more elegantly to a target wavelength by applying external mechanical strain, while maintaining the good optical quality. We demonstrate a tunable single-photon source based on a deterministically fabricated QD microlens which is positioned on top of a piezoactuator by a flip-chip goldbonding technique. A control loop is implemented which stabilizes the strain and the emission wavelength of the QD. Characterizations of the system in terms of stability, modulation ranges, transfer functions and spectroscopic investigations will be presented.

HL 33.4 Wed 15:45 H34

Deterministically positioned InAs quantum dots in heterogeneous GaAs silicon integrated quantum photonic devices — •Peter Schnauber[1], Anshuman Singh[2,3], Johannes Schall[1], Jin-Dong Song[4], Sven Rodt[1], Kartik Srinivasan[2], Stephan Reitzenstein[1], and Marcelo Davanco[2] — [1]Inst. fuer Festkoerperphysik, TU Berlin — [2]Nat. Inst. of Standards and Technology, Gaithersburg — [3]MD NanoCenter, Uni. of Maryland — [4]KIST, Seoul

Through heterogeneous integration, III-V single photon emitters based on quantum dots (QDs) can be combined with low-loss, mature silicon-based photonic chips[1]. Recently, GaAs with InAs QDs has been wafer-bonded on SiN-SiO_2, and on the wafer-stack hybrid photonic devices were produced in which single photon emission from randomly aligned QDs is first captured into GaAs waveguides (WGs), then directed into SiN WGs via adiabatic mode transformers[2]. Here, using in-situ electron beam lithography[3] we integrate single pre-selected InAs QDs inside GaAs WG tapers and combine them with SiN WGs in such a hybrid system. High resolution micro-PL in p-shell excitation shows QD linewidthes down to 2 GHz, which indicates that the QD coherence properties are maintained during fabrication. Pulsed autocorrelation measurements with $g^{(2)}(0) < 0.1$ show triggered single-photon emission and two-photon interference (TPI) experiments in CW excitation reveal a raw TPI visibility of ≈ 40 % at zero time delay.

[1] Zadeh et al., Nano Letters 16, 2289 (2016)
[2] Davanco et al., Nature Communications 8, 889 (2017)
[3] Schnauber et al., Nano Letters 18, 2336 (2018)

HL 33.5 Wed 16:00 H34

MOVPE-grown single InGaAs quantum dots emitting in the telecom O-band with an AlAs monolayer anti-diffusion cap — •Jan Grosse, Nicole Srocka, Max Schlösinger, and Stephan Reitzenstein — Technische Universität Berlin, Institute for Solid State Physics, Hardenbergstraße 36, 10623 Berlin, Germany

Epitaxially grown InAs/InGaAs quantum dots (QDs) are highly attractive for the realization of bright single-photon sources in the telecom O-band at 1.3 um [1]. However, their fabrication is very challenging because they suffer from major indium diffusion problems during the deposition of a strain-reducing layer (SRL). This leads to a clustering and coupling process during the overgrowth process, which diminishes the optical quality (brightness and spectral separability) of the final QD/SRL system. Here, we present an advanced growth concept which is based on the introduction of a monolayer of AlAs between the QDs and the SRL to counteract the high surface mobility of the indium atoms. We present results on the optical and structural characterization of the modified system and discuss the effects of the AlAs monolayer on QD density and quality.

[1] Bloch, J. et al. Appl. Phys. Lett. 75, 2199 (1999).

15 min. break

HL 33.6 Wed 16:30 H34

Wigner time delay induced by a single quantum dot — •Marcel Hohn[1], Max Strauss[1], Alexander Carmele[2], Julian Schleibner[2], Christian Schneider[3], Sven Höfling[3], Janik Wolters[1,4], and Stephan Reitzenstein[1] — [1]Institut für Festkörperphysik, Technische Universität Berlin, D-10263 Berlin, Germany — [2]Institut für Theoretische Physik, Technische Universität Berlin, D-10263 Berlin, Germany — [3]Technische Physik, Physikalisches Institut, Wilhelm Conrad Röntgen Center for Complex Material Systems, Universität Würzburg, D-97074, Germany — [4]Department of Physics, University of Basel, Klingelbergstrasse 82, CH-4056 Basel, Switzerland

Resonant scattering of weak coherent laser pulses on a single two-level system (TLS) realized in a semiconductor quantum dot is investigated with respect to a time delay between incoming and scattered light [1]. This type of time delay was predicted by Wigner in 1955 for purely coherent scattering and was confirmed for an atomic system [2]. In presence of electron-phonon interaction we observe deviations from Wigner's theory related to incoherent and strongly non-Markovian scattering processes which are hard to quantify in a phenomenological T_2-time. We observe Wigner delays of up to 530 ps in our experiments which quantifies the effective pure dephasing constant to $T_2 = (445 \pm 16)$ ps, supported by microscopic theory.

[1] M. Strauss et al., arXiv:1805.06357
[2] R. Bourgain et al., Opt. Lett. 38, 1963-5 (2013)

HL 33.7 Wed 16:45 H34

Chiral light-matter coupling in deterministic quantum dot waveguides — •Paweł Mrowiński[1], Peter Schnauber[1], Arsenty Kaganskiy[1], Philipp Gutsche[2], Sven Burger[2], Sven Rodt[1], and Stephan Reitzenstein[1] — [1]Technische Universität Berlin, Hardenbergstraße 36, D-10623 Berlin, Germany — [2]Zuse Institute Berlin, Takustraße 7, D-14195 Berlin, Germany

Quantum dots embedded in waveguides can exhibit directional emission or non-reciprocal transmission on a single-photon level via chiral light-matter interactions, which is important for realization of large-scale on-chip quantum circuits [1,2]. In this work, we study directional emission of a single InAs/GaAs quantum dot (QD) in a ridge waveguide (WG) structure with bottom AlGaAs/GaAs DBR mirror (cf. Fig. 1a). The QD is pre-selected and deterministic integrated into the WG by using in-situ electron-beam lithography, as described in [3]. We fabricated a series of WG structures containing single QD varying the in-plane position to explore the position dependence on directional emission. The directional propagation is reflected in the polarization resolved photoluminescence for the outcoupled light influenced by the external magnetic field applied in Faraday configuration. A significant contrast (C) of 90 % is observed for right/left circularly polarized QD emission from charged exciton in case of QD located at highly off-center position, which indicates chiral coupling in this system (cf. Fig 1b). Furthermore, we studied in detail the contrast vs QD position dependence and we obtain agreement with the calculated dependence by Finite Element Method (JCMwave).

HL 33.8 Wed 17:00 H34

Impact of the excitonic spin dynamics on the entanglement from a InGaAs quantum dot — •Samir Bounouar[1], Gabriel Rein[1], Julian Schleibner[2], Alexander Carmele[2], Peter Schnauber[1], Andre Strittmatter[1,3], Sven Rodt[1], and Stephan Reitzenstein[1] — [1]Institut für Festkörperphysik, Technische Universität Berlin, Berlin, Germany — [2]Institut für Theoretische Physik, Technische Universität Berlin, Berlin, Germany — [3]Abteilung für Halbleiterepitaxie, Otto-von-Guericke, Universität, Magdeburg, Germany

Maximal entanglement is an important resource in photonic quantum technology and can be in principal generated by a semiconductor quantum dot even in the presence of finite fine structure splitting [1]. However, the exciton spin dynamics constitutes an important obstacle to perfect entanglement. We report on photon-correlation experiments performed on single InGaAs quantum dots integrated deterministically into monolithic microlenses. Non-phonon-mediated spin decoherence processes are systematically investigated and their influence on the quality of the generated entanglement by quantum dots is evaluated. In particular, exchange interaction, decoherence and nuclear spin induced precessions are evidenced through a series of tomography measurements on a large number of single quantum dots. A drop of the entanglement due to these processes is evidenced for small excitonic fine structure splittings and is discussed by a theoretical model introducing exchange interaction.

[1] S. Bounouar et al., Applied Physics Letters 112, 153107 (2018)

HL 33.9 Wed 17:15 H34

Quantum Metrology of Solid-State Single-Photon Sources using Photon-Number-Resolving Detectors — •Martin von Helversen[1], Jonas Böhm[1], Marco Schmidt[1], Manuel Gschrey[1], Jan-Hindrik Schulze[1], André Strittmatter[1,3], Sven Rodt[1], Jörn Beyer[2], Tobias Heindel[1], and Stephan Reitzenstein[1] — [1]Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstraße 36, 10623 Berlin, Germany — [2]Physikalisch Technische Bundesanstalt, Abbestraße 2-12, 10587 Berlin, Germany — [3]Institut für Experimentelle Physik, Otto-von-Guericke Universität Magdeburg, PF4120, Magdeburg, Germany

Quantum-light sources based on semiconductor quantum dots (QDs) are promising candidates for applications in quantum photonics and quantum communication. Important emission characteristics of such emitters, namely the single-photon purity and photon indistinguishability, are usually assessed via time-correlated measurements using standard 'click' detectors in Hanbury-Brown and Twiss (HBT-) or Hong-Ou-Mandel (HOM-) type configurations. In this work, we employ a state-of-the-art photon-number-resolving (PNR) detection system based on superconducting transition-edge sensors (TESs) to directly access the photon-number distribution of deterministically fabricated solid-state single-photon sources. The obtained results reveal excellent quantitative agreement of the degree of indistinguishability obtained with PNR (90 ± 7 %) and standard detectors (90 ± 5 %). Our work demonstates that TES-based detectors are perfectly suitable for the quantum metrology of non-classical light sources.