HL 26: Quantum Dots and Wires 5: Optics 2

Time: Thursday 9:30–12:45 Location: H32

HL 26.1 Thu 9:30 H32

All-optical polarization control of single photons emitted by a quantum dot — •Björn Jonas, Dirk Heinze, Eva Schöll, Patricia Kallert, Timo Langer, Sebastian Krehs, Alex Widhalm, Klaus D. Jöns, Dirk Reuter, Stefan Schumacher, and Artur Zrenner — Paderborn University, Physics Department, Warburger Straße 100, 33098 Paderborn, Germany

In our work we employ an all-optical approach based on nonlinear principles to control the polarization of single photon emission from a single quantum dot. To achieve this, we make use of a nonlinear down-conversion process from the biexciton to the ground state [1]. This opens an alternative decay path in addition to the biexciton cascade. Previous theoretical work suggests the possibility to manipulate the properties of the emitted photons by tuning the respective properties of a control laser [2].
By exploiting this mechanism, we were able to demonstrate polarization control of the emitted photons for linear and circular polarization. Our findings show no influence of the fine-structure splitting on the polarization of the emitted photons. We furthermore present a theoretical model to describe our results and we find excellent agreement between experiment and theory.

[1] B. Jonas et al., Nature Communications **13**, 1387 (2022)
[2] D. Heinze et al., Nature Communications **6**, 8473 (2015)

HL 26.2 Thu 9:45 H32

Temporal evolution of line broadening in charge controlled quantum dots — •Tim Strobel[1], Jonas H. Weber[1], Marcel Schmidt[2], Lukas Wagner[1], Andreas D. Wieck[2], Michael Jetter[1], Simone L. Portalupi[1], Arne Ludwig[2], and Peter Michler[1] — [1]Institut für Halbleiteroptik und Funktionelle Grenzflächen, Center for Integrated Science and Technology (IQST) and SCoPE, University of Stuttgart, Allmandring 3, 70569 Stuttgart, Germany — [2]Lehrstuhl für Angewandte Festkörperphysik, Ruhr-Universität Bochum, D-44780 Bochum, Germany

Self-assembled semiconductor quantum dots (QDs) present themselves as an attractive platform for the implementation of scalable hybrid quantum-information schemes. On-demand emission of high-quality single photons demonstrates the potential of such systems. Sources of noise, caused by the interaction with the solid-state environment can lead to an inhomogeneous broadening of the emission line. The magnitudes and timescales of such dephasing mechanisms vary strongly with the material composition and heterostructure of a sample. Here, we employ Photon-correlation Fourier spectroscopy as a powerful experimental method to study the spectral dynamics of single emitters, with high spectral and temporal resolution. In particular, the broadening mechanisms of QDs embedded in a novel type of gated structure, based on a n-i-n-diode are investigated.

HL 26.3 Thu 10:00 H32

High-quality single-photons from hybrid MOVPE/MBE grown n-i-n quantum-dot structures — •Lukas Wagner[1], Tim Strobel[1], Marcel Schmidt[2], Jonas H. Weber[1], Lena Engel[1], Andreas D. Wieck[2], Michael Jetter[1], Simone L. Portalupi[1], Arne Ludwig[2], and Peter Michler[1] — [1]Institut für Halbleiteroptik und Funktionelle Grenzflächen (IHFG), Center for Integrated Quantum Science and Technology (IQST) and SCoPE, University of Stuttgart, Allmandring 3, 70569 Stuttgart, Germany — [2]Lehrstuhl für angewandte Festkörperphysik, Ruhr-University Bochum, Universitätsstraße 150, 44801 Bochum, Germany

Photonic quantum operations require sources of photons with Fourier-limited linewidth and high brightness. Stark-shift tuning of the emission wavelength can be of interest in upscaling the complexity, employing multiple quantum dots (QDs) tuned at the same emission wavelength. QDs in gated structure can provide a stabilization of the electric field environment, pushing the photon linewidth close to the Fourier limit. In addition, the embedding diode structure can be used to electrically tune the emission wavelength. The growth of self-assembled semiconductor QDs is usually carried out via metal-organic vapor-phase epitaxy (MOVPE) or molecular-beam epitaxy (MBE). This work combines MOVPE and MBE techniques for hybrid growth of gated semiconductor QD samples. This provides spectrally tunable InAs QDs with narrow emission linewidth. High single-photon purity and indistinguishability are proven via Hanbury-Brown and Twiss, and Hong-Ou-Mandel experiments in resonant excitation.

HL 26.4 Thu 10:15 H32

Ultrafast electric control of cavity mediated photons from a semiconductor quantum-dot — •David Bauch[1], Dirk Heinze[1], Jens Förstner[1], Klaus D. Jöns[1], and Stefan Schumacher[1,2] — [1]Department of Physics and CeOPP, Paderborn University, Germany — [2]College of Optical Sciences, University of Arizona, Tucson, USA

On demand sources for single photon and photon pairs are essential for quantum communication protocols. Exciton and cascaded biexciton-exciton transitions in semiconductor quantum dots offer the potential for optically controlled generation of a single photon [1] and polarization-entangled twin photons [2]. In addition to pure optical control, externally applied time-dependent electric fields enable control of the (bi-)exciton resonance through the quantum confined Stark effect, resulting in changes of the (bi-)exciton dynamics and the resulting photon emission. Here we investigate theoretically the optical excitation of the (bi-)exciton state off-resonant to a cavity mode followed by ultrafast control of the states, which then allows for cavity-resonant emission of the photons. Our scheme allows for high preparation fidelities followed by the generation of highly indistinguishable single photons and polarization entangled twin-photons via the biexciton-exciton cascade and biexciton two-photon emission with high emission probabilities [3].

[1] D. Heinze, D. Breddermann, A. Zrenner, S. Schumacher, Nat. Commun. 6, 8473 (2015). [2] D. Heinze, A. Zrenner, S. Schumacher, Phys. Rev. B 95, 245306 (2017). [3] D. Bauch, D. Heinze, J. Förstner, K. D. Jöns, S. Schumacher, Phys. Rev. B 104, 085308 (2021).

HL 26.5 Thu 10:30 H32

Sub- and Superradiant Effects in Bimodal Quantum-Dot Microcavity Lasers — •Isa Hedda Grothe and Jan Wiersig — Institut für Physik, Otto-von-Guericke-Universität Magdeburg, Germany

In standard nanolasers with a single cavity mode a strong influence of inter-emitter correlations on the input-output dynamics as well as the statistical properties of the emitted light has been described [1]. Below threshold subradiant emission emerges with superthermal values of the autocorrelation function $g^{(2)}(0)$, which is associated with strong bunching of the emitted photons. Similarly high values of $g^{(2)}(0)$ have also been found for the weak mode in micropillar lasers with two orthogonally polarized modes [2,3]. Here, however, this phenomenon is rooted in the interaction of both modes with a common gain medium which leads to gain competition between the two modes.

Making use of a theoretical semiconductor laser model based on the cluster-expansion method, we include correlations between the emitters in the description of bimodal microcavity lasers. This enables us to compare the influence of sub- and superradiant effects on the emission of bimodal lasers to that on lasers with a single mode. Additionally, we are able to distinguish features of the statistical properties of the emitted light that characterize either subradiance or gain competition as the source of superthermal photon bunching in bimodal lasers.

[1] H. A. M. Leymann et al., Phys. Rev. Applied **4**, 044018 (2015).
[2] H. A. M. Leymann et al., Phys. Rev. A **87**, 053819 (2013).
[3] M. Schmidt et al., Phys. Rev. Research **3**, 013263 (2021).

HL 26.6 Thu 10:45 H32

GaAs Droplet Epitaxy Quantum Dots as Deterministic Single Photon Sources for Entangling SiV-Centers in Diamond — •Manuel Rieger[1], Viviana Villafane[1], Andreas Nickl[1], Christian Dangel[1], Hans-Georg Babin[2], Tim Schröder[3], Arne Ludwig[2], Andreas Wieck[2], Kai Müller[1], and Jonathan Finley[1] — [1]Walter Schottky Institut/Physik Department, TUM, 85748 Garching, Germany — [2]Physik Department, RU Bochum, Universitätsstraße 150, 44801 Bochum, Germany — [3]Physik Department, HU Berlin, Newtonstraße 15, 12489 Berlin, Germany

Quantum algorithms promise acceleration of tasks like computational chemistry and machine learning. In this context, diamond-based quantum hardware capable of interfacing spins and photons in a scalable network [1] is particularly advantageous since it combines excellent coherence times, gate fidelities and the possibility for on-chip integration. We demonstrate GaAs based quantum dot (QD) deterministic single photon sources grown using droplet epitaxy (DE) and resonant with the the SiV- center in diamond at 737nm. By characterizing single dots using low temperature optical spectroscopy, we measure a non-classical second order photon intensity correlation function ($g^2(0)<0.3$), demonstrate electrical tunability of the charge occupancy and show wide tunability of the emission frequency over 250GHz. Furthermore, we show that the optical lifetimes of the DE-QDs lie in the range 1-1.5ns, similar to those of SiV^- (1-2ns), a prerequisite for high-fidelity photon mediated entanglement [1,2]. [1] K. Nemoto et al., Phys. Rev. X (2014). [2] C. Dangel et al., arXiv preprint (2022).

30 min. break

HL 26.7 Thu 11:30 H32

To boldy excite where no one has excited before — Thomas K. Bracht[1], Yusuf Karli[2], Florian Kappe[2], Vikas Remesh[2], Tim Seidelmann[3], Armando Rastelli[4], Gregor Weihs[2], Vollrath Martin Axt[3], and •Doris E. Reiter[1,5] — [1]Institut für Festkörpertheorie, Universität Münster, 48149 Münster, Germany — [2]Institute für Experimentalphysik, Universität Innsbruck, Innsbruck, Austria — [3]Institute of Semiconductor and Solid State Physics, JKU Linz, Linz, Austria — [4]Theoretische Physik III, Universität Bayreuth, 95440 Bayreuth, Germany — [5]Condensed Matter Theory, TU Dortmund, 44221 Dortmund, Germany

In the Rabi scheme, off-resonant excitations of a two-level system do not lead to a full inversion, when no further auxiliary particles are participating. Surprisingly, the Swing-UP of the quantum EmitteR population (SUPER) scheme uses off-resonant excitations to fully bring a two-level system from the ground to excited state [PRX Quantum 2, 040354 (2021)]. The scheme relies on a gradual swing-up, which can be achieved by modulation of the excitation frequency or amplitude. Here, we discuss the theory of the SUPER scheme and how it can implemented for a semiconductor quantum dot by using a two-color excitation with pulses detuned by several meV. Due to the electron-phonon interaction, the SUPER scheme results in the emission of phonon wave packets [pssb, 2100649 (2022)], but overall the phonon influence is rather small. The experimental realization of SUPER scheme [arXiv:2203.00712 (2022)], as will be presented in a different contribution, shows great agreement with the theoretical prediction.

HL 26.8 Thu 11:45 H32

Internal Photoeffect from a Single Quantum Emitter — Pia Lochner[1], Jens Kerski[1], Annika Kurzmann[2], Hendrik Mannel[1], •Marcel Zöllner[1], Andreas D. Wieck[3], Arne Ludwig[3], Martin P. Geller[1], and Axel Lorke[1] — [1]University of Duisburg-Essen and CENIDE, Germany — [2]RWTH Aachen University, Germany — [3]Ruhr-University Bochum, Germany

As quantum information technologies require long spin coherence times in qubits and highly indistinguishable photons [1], we present a new and mostly neglected mechanism in self-assembled quantum dots that fundamentally limits the coherence times in optical quantum devices. By time-resolved resonance fluorescence (RF) measurements on a single quantum dot, we demonstrate an internal photoeffect [2] that emits electrons from the dot by an intra-band excitation. While the tunneling rate of an electron into the quantum dot is constant for increasing non-resonant laser intensity, the emission rate by the photoeffect increases linearly with increasing excitation intensity. This way, the emission rate is tunable over several orders of magnitude by adjusting the non-resonant laser excitation intensity.
Our findings show that a process, which is well known in single atom spectroscopy (i.e. photo ionization) can also be observed for a solid-state quantum emitter and has to be avoided or reduced to push the limits towards long qubit coherence times.

[1] T. D. Ladd et al., Nature 464, 45-53 (2010)
[2] P. Lochner et al., Phys. Rev. B 103, 075426 (2021)

HL 26.9 Thu 12:00 H32

Nuclear Spin Polarization by Electron Spin Mode Dragging in an Ensemble of (In,Ga)As Quantum Dots — •Eiko Evers[1], Nataliia E. Kopteva[1,2], Irina A. Yugova[2,3], Dmitri R. Yakovlev[1,4], Manfred Bayer[1], and Alex Greilich[1] — [1]Experimentelle Physik 2, TU Dortmund, 44221 Dortmund, Germany — [2]Spin Optics Laboratory of St. Petersburg State University, 198504 St. Petersburg, Russia — [3]St. Petersburg, Russia — [4]St. Petersburg, Russia

The electron-nuclear spin system in singly charged (In,Ga)As quantum dots (QDs) promises to combine the efficient optical electron spin (ES) orientation with the long coherence time in the nuclear spin (NS) system [1]. To come closer to a state of large NS polarization, we synchronize an ensemble of QDs, inhomogeneous in size, g factor, and resident ES precession frequency in a transverse external field, to a laser with a pulse repetition frequency of 1 GHz. As a result, the ensemble of ESs is homogenized by focusing it on a single precession mode by nuclei-induced frequency focusing [2]. In a substantial external field range, the single mode is fixed by a simultaneous build-up of an anti-parallel Overhauser field B_N caused by the polarization of NSs. The Overhauser field achievable in each QD differs and leads to the surprising emergence of equally spaced ES precession components in the ensemble.

[1] D. Gangloff et al., Science **364**, 62 (2019)
[2] A. Greilich et al., Science **317** 1896 (2007)

HL 26.10 Thu 12:15 H32

Auger-assisted electron spin-flips in a single quantum dot — •Hendrik Mannel[1], Jens Kerski[1], Pia Lochner[1], Marcel Zöllner[1], Fabio Rimek[1], Arne Ludwig[2], Andreas Wieck[2], Axel Lorke[1], and Martin Geller[1] — [1]Faculty of Physics and CENIDE, University of Duisburg-Essen, Duisburg, Germany — [2]Chair of Applied Solid State Physics, Ruhr-University Bochum, Germany

A long electron spin coherence lifetime is the key requirement for future solid-state spin qubits. However, for instance, in self-assembled quantum dots the coupling to nuclei, co-tunneling with a nearby reservoir, and spin-orbit coupling limit the spin-lifetime.

Using resonance fluorescence, we here demonstrate an additional fundamental process that can lead to a single electron spin-flip via an Auger recombination [1]. The quantum dot is placed in a magnetic field in Faraday geometry and charged with one (spin-up or spin-down) electron [2]. In time-resolved resonant fluorescence measurements and using a rate equation model, we can determine the Auger and spin-flip rates in a magnetic field.

Our results reveal an additional, so far neglected Auger-assisted spin-flip process: Auger recombination with subsequent electron tunneling from the reservoir. The present dot is weakly coupled to an electron reservoir. A strong coupling will enhance this Auger-assisted spin-flip rate and thus reveal an important mechanism limiting the spin lifetime due to a strong coupling to a nearby reservoir.

[1] A. Kurzmann et al., Nano Lett. **16**, 3367 (2016). [2] J. Dreiser et al., Phys. Rev. B **77**, 075317 (2008).

HL 26.11 Thu 12:30 H32

Spin control of single spins in semiconductor quantum dots placed in a microcavity — •Marco De Gregorio, Tobias Huber, and Sven Höfling — Technische Physik, Julius-Maximilians-Universität, Würzburg, Deutschland

Implementation of secure communication with entangled photons is a continuously evolving field. Different platforms have been investigated during the last decades and quantum dots have been proven to be a promising candidate as source for entangled photons. Despite their deterministic photon creation and excellent multi-photon suppression, quantum dot sources suffer from outcoupling efficiencies, when not embedded into photonic structures. Here, we present a low quality factor micropillar cavity, which is broadband, but still enhances the photon extraction efficiency. Analysis of deterministically placed low-q micropillars, characterization and optimization of the emission behavior and control of the spin are necessary steps paving the way towards the generation of a quantum repeater.