HL 79: Quantum dots and wires IV

Time: Friday 9:30–12:00 Location: POT 151

HL 79.1 Fri 9:30 POT 151

Controlling entanglement in different realms — •Kisa Barkemeyer[1], Samir Bounouar[2], Stephan Reitzenstein[2], Andreas Knorr[1], and Alexander Carmele[1] — [1]Institut für Theoretische Physik, Technische Universität Berlin, Hardenbergstr. 36, 10623 Berlin, Germany — [2]Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstr. 36, 10623 Berlin, Germany

Entanglement lies at the heart of many applications in the field of quantum information processing. As a platform for their implementation, photonic degrees of freedom are promising candidates. Thus, the ability to efficiently control and tailor quantum optical properties is a central goal.

Photon pairs entangled in their polarization degrees of freedom are, for example, generated in a quantum dot biexciton cascade. We study how the measured degree of entanglement is influenced by the properties of the quantum dot as well as by the measurement setup itself [1]. For this system, it is possible to control the entanglement properties using coherent time-delayed feedback [2]. We aim to extend this scheme to a new realm by focussing on energy-time entanglement inspired by the paradigmatic Franson interferometer [3].

[1] S. Bounouar et al., manuscript in preparation.
[2] K. Barkemeyer, R. Finsterhölzl, A. Knorr, and A. Carmele, Adv. Quantum Technol. 1900078 (2019).
[3] J. D. Franson, Phys. Rev. Lett. 62, 2205 (1989).

HL 79.2 Fri 9:45 POT 151

Polarization Resolved Excitation Spectroscopy on GaAs Quantum Dots — •Caspar Hopfmann[1], Robert Keil[1], Nand Lal Sharma[1], Fei Ding[2], and Oliver Schmidt[1,3] — [1]Institute for Integrative Nanosciences, Leibniz IFW Dresden, Helmholtzstraße 20, 01069 Dresden, Germany — [2]Institut für Festkörperphysik, Leibniz Universität Hannover, Appelstraße 2, 30167 Hannover, Germany — [3]Material Systems for Nanoelectronics, Technische Universität Chemnitz, 09107 Chemnitz, Germany

Entangled photon sources based on Aluminum droplet etched GaAs quantum dots embedded in a AlGaAs matrix have attracted considerable research interest for applications such as quantum entanglement swapping [1]. In order to use these devices for more advanced quantum optical experiments - such as photonic cluster states [2] - a keen understanding of the quantum dot electronic structure of both fundamental and excited states is essential. We employ combined quasi-resonant and polarization resolved photo excitation spectroscopy in order to investigate the electronic structure of GaAs quantum dots comprehensively.

[1] Zopf et. al. PRL 123, 160502 (2019)
[2] Schwartz et. al. Science, 354.6311 (2016)

HL 79.3 Fri 10:00 POT 151

Towards photocurrent monitoring of single photon emitters — •Sebastian Krehs, Björn Jonas, Alex Widhalm, Kai Spychala, Timo Langer, Dirk Reuter, and Artur Zrenner — Physics Department, Paderborn University, Warburger Straße 100, 33098 Paderborn, Germany

In the past photocurrent (PC) detection of single quantum dot excitons was limited to the regime of high tunnelling rates and elevated excitation powers, which results for π-pulse excitation in currents in the 10 pA-range. Refined PC detection enabled us to improve the sensitivity down to the fA-range. This allows for ultrasensitive photocurrent detection in the regime of single photon emission and leads to a new concept for the frequency stabilization of single photon emitters.

In this work we have fabricated Schottky photodiodes with embedded high quality MBE grown InAs/GaAs QDs. We have been able to demonstrate exciton ground state linewidths as low as 1.62 μeV by electrically detected laser spectroscopy. Our results are close to the Fourier transform limit of QD systems [1]. Extremely weak electric detection of the resonance position of a single photon emitter is possible down to a regime, where only 0.2% of the excitation is extracted by charge separation. To utilize this, we need to realize a seamless electric field induced transition from the PC- to the PL-regime, which avoids the formation of charged states. To achieve this, we performed band structure engineering for the symmetrisation of electron and hole tunnelling rates.

[1] A.V. Kuhlmann et al. Nature Physics 9, 570-575 (2013)

HL 79.4 Fri 10:15 POT 151

Importance of the effect of correlation on the response of weakly confining QDs to applied magnetic field — •Petr Klenovský[1,2,3], Diana Csontosová[1,2], Daniel Huber[4,5], and Armando Rastelli[4] — [1]Department of Condensed Matter Physics, Faculty of Science, Masaryk University, Kotlářská 267/2, 61137 Brno, Czech Republic — [2]Central European Institute of Technology, Masaryk University, Kamenice 753/5, 62500 Brno, Czech Republic — [3]Czech Metrology Institute, Okružní 31, 63800 Brno, Czech Republic — [4]Institute of Semiconductor and Solid State Physics, Johannes Kepler University Linz, Altenbergerstr. 69, 4040 Linz, Austria — [5]Secure and Correct Systems Lab, Linz Institute of Technology, Altenbergerstr. 69, 4040 Linz, Austria

We study magnetic field response of the charged and neutral excitonic states weakly confined in single GaAs/AlGaAs quantum dots obtained by the Al droplet-etching method. [1] Using direct comparison of the results of single-particle theory and the configuration interaction method, we show that the widely used single-particle Zeeman Hamiltonian cannot be used to extract reliable values of the g-factors and diamagnetic coefficients, nor to single out those for individual electrons and holes. The results are supported by extensive μ-photoluminescence measurements in Voigt and Faraday configurations of the applied magnetic field.

[1] Huber, D., *et al.*, arXiv:1909.04906 (2019).

15 min. break.

HL 79.5 Fri 10:45 POT 151

Radiative Auger Process in the Single Photon Limit on a Quantum Dot — •Matthias C. Löbl[1], Clemens Spinnler[1], Alisa Javadi[1], Liang Zhai[1], Giang N. Nguyen[1,2], Julian Ritzmann[2], Leonardo Midolo[3], Peter Lodahl[3], Andreas D. Wieck[2], Arne Ludwig[2], and Richard J. Warburton[1] — [1]University of Basel, Switzerland — [2]Ruhr-Universität Bochum, Germany — [3]Niels Bohr Institute Copenhagen, Denmark

In a quantum dot (QD), an electron can decay by emitting a photon. In a radiative Auger process, the leftover carriers are in an excited state, and a red-shifted photon is created [1]. Here, we report radiative Auger on trions in individual QDs [2]. For the trion, just one electron is left after the optical recombination. The radiative Auger process promotes this electron to a higher shell of the QD; the emitted photon is red-shifted. We show that radiative Auger directly measures the quantization energies of the single electron. Using resonant excitation, we measure the radiative Auger process on two types of charge-tuneable QDs: InGaAs, GaAs QDs [3]. We rigorously prove the radiative Auger mechanism by measuring the photon statistics and the magnetic field dispersion of the emission. We show how quantum optics applied to the Auger photons gives access to the single-electron dynamics, notably relaxation and tunnelling rates. All these properties of radiative Auger can be exploited on other semiconductor nanostructures. [1] T. Åberg *et al.*, Phys. Rev. Lett. **22**, 1346-1348 (1969). [2] M. C. Löbl *et al.*, arxiv:1911.11784 (2019) [3] Y. H. Huo *et al.*, Appl. Phys. Lett. **102**, 152105 (2013).

HL 79.6 Fri 11:00 POT 151

Semiconductor-based single-photon source for quantum radiometry — •Hristina Georgieva[1], Marco López[1], Beatrice Rodiek[1], Helmuth Hofer[1], Justus Christinck[1], Peter Schnauber[2], Arsenty Kaganskiy[2], Tobias Heindel[2], Sven Rodt[2], Stephan Reitzenstein[2], and Stefan Kück[1] — [1]Physikalisch-Technische Bundesanstalt, 38116 Braunschweig, Germany — [2]Institut für Festkörperphysik, Technische Universität Berlin, 10623 Berlin, Germany

Single-photon sources find application in many fields of quantum information processing. Therefore, there is an increasing need to ensure high accuracy and metrological traceability of measurements involving small photon fluxes. In quantum radiometry, the discrete nature of light in principle enables a direct realization of the radiometric quantities by counting photons. The narrow emission bandwidth of semiconductor quantum dots makes them perfect candidates for the detection efficiency calibration of non-photon-number-resolving detectors. We aim for a high photon flux reaching the detector area by means of an efficient quantum emitter combined with a low-loss optical setup, which uses two ultra-narrow bandpass filters instead of a monochromator to reach fluxes up to 370 kphotons/s. The optical power is determined by an unbroken calibration chain to the primary standards. Furthermore, the ratio of detection efficiencies of two single-photon avalanche photodiodes of the same type has been determined to be 1.061 ± 0.008 using a single quantum dot as a light source. This result is validated by a comparison with a standard calibration using an attenuated laser.

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Least biased steady state of open quantum systems — •Boris Melcher, Boris Gulyak, and Jan Wiersig — Institut für Physik, Otto-von-Guericke-Universität Magdeburg, Postfach 4120, D-39016 Magdeburg, Germany

By applying the principle of maximum entropy [1] we develop a standalone approach to conclude a reasonable guess for the full density matrix of an open quantum system in a steady state. It is centered around the obvious perception that in the steady state all observables are constant in time. This is used as a constraint to deduce the least biased density matrix self-consistently.

In doing so, we circumvent the many-particle hierarchy problem that arises in conventional equation of motion techniques [2]. Furthermore, our approach gives access to the full density matrix and thus all relevant expectation values and correlation functions as well as the full statistics of the investigated system.

We employ the maximum entropy method for quantum dot microcavity lasers and demonstrate excellent agreement with conventional approaches [3]. Beyond that, we study the systems in terms of entropy, mean photon number, autocorrelation functions as well as the full photon statistics, giving insight into the fundamental physical processes operating in these systems.

[1] E. T. Jaynes, Phys. Rev. 106, 620 (1957), 108, 171 (1957)
[2] H. A. M. Leymann et al., Phys. Rev. B 89, 085308 (2014)
[3] B. Melcher et al., Phys. Rev. A 100, 013854 (2019)

HL 79.8 Fri 11:30 POT 151

High-bandwith in an all-optical read-out scheme for quantum events — •Jens Kerski[1], Hendrik Mannel[1], Annika Kurzmann[1,2], Arne Ludwig[3], Andreas D. Wieck[3], Axel Lorke[1], and Martin Geller[1] — [1]Faculty of Physics and CENIDE, University Duisburg-Essen, Germany — [2]Solid State Physics Laboratory, ETH Zurich, Switzerland — [3]Chair of Applied Solid State Physics, Ruhr-University Bochum, Germany

The maximum information about a dynamic quantum system can be drawn from real-time measurements of every single quantum event (random telegraph signal). Such studies are performed on single quantum dots (QDs) to investigate electron transport in an all-electrical measurement [1]. Unfortunately, these methods are either invasive or limited in bandwidth. However, it became recently possible to measure the random telegraph signal in a non-invasive all-optical scheme, using resonance fluorescence and a single self-assembled QD coupled to an electron reservoir [2].

This is a promising approach, as the bandwidth of this technique is given by the averaged number of emitted photons per second, limited ultimately by the spontaneous emission rate ($\sim 1-10\,\mathrm{GHz}$). In this contribution, we demonstrate this behavior by evaluating the random telegraph signal with full counting statistics and intensities up to 2.6 MCounts/second leading to bandwidths of more than 100 kHz.

[1] S. L. Rudge et al. J. Chem. Phys. 151, 034107 (2019).
[2] A. Kurzmann et al., Phys. Rev. Lett. 122, 247403 (2019).

HL 79.9 Fri 11:45 POT 151

Quantum Dot Optomechanics In Suspended Nanophononic Strings — •BENJAMIN MAYER[1], ANJA VOGELE[1], MAXIMILIAN M. SONNER[1], XUEYONG YUAN[1,2], MATTHIAS WEISS[1], EMELINE D. S. NYSTEN[1], SAIMON F. COVRE DA SILVA[2], ARMANDO RASTELLI[2], and HUBERT J. KRENNER[1] — [1]Lehrstuhl für Experimentalphysik 1, Universität Augsburg, 86159 Augsburg, Germany — [2]Institute of Semiconductor and Solid State Physics, Johannes Kepler Universität Linz, 4040 Linz, Austria

The optomechanical coupling of quantum dots and flexural mechanical modes is studied in suspended nanophononic strings. The investigated devices are designed and monolithically fabricated on an (Al)GaAs heterostructure. Radio frequency elastic waves with frequencies ranging between $f = 250$ and 400 MHz are generated as Rayleigh surface acoustic waves (SAW) on the unpatterned substrate and injected as Lamb waves in the nanophononic string. Quantum dots inside the nanophononic string exhibit a 15-fold enhanced optomechanical modulation compared to those dynamically strained by the SAW. Finite element simulations of the phononic mode spectrum of the nanophononic string confirm that the observed modulation arises from valence band deformation potential coupling via shear strain. The corresponding optomechanical coupling parameter is quantified to 0.15 meV nm^{-1}. Using this value, a derived vertical displacement in the range of 10 nm is deduced from the experimental data. (Vogele et al., Adv. Quantum Tech. early view (2019). doi: 10.1002/qute.201900102)