HL 109: Quantum dots and wires: Quantum communication and quantum information science

Time: Friday 11:15–13:15 Location: ER 164

HL 109.1 Fri 11:15 ER 164

Optical Tomography of Electron Spins in (In,Ga)As Quantum Dots — •Janina Schindler[1], Steffen Varwig[1], Alexandre René[1], Sophia Economou[2], Alex Greilich[1], Dmitri Yakovlev[1,3], Dirk Reuter[4], Andreas Wieck[4], Thomas Reinecke[2], and Manfred Bayer[1] — [1]Experimentelle Physik II, TU Dortmund, D-44221 Dortmund, Germany — [2]Naval Research Laboratory, Washington D.C. 20375, USA — [3]Ioffe Physical Technical Institute, Russian Academy of Sciences, 194021 St. Petersburg, Russia — [4]Angewandte Festkörperphysik, Ruhr-Universität Bochum, D-44780 Bochum, Germany

Electron spins in quantum dots are considered as a promising candidate for implementing quantum bits in semiconductors. As already has been shown in preceding experiments, their control, manipulation and read-out can be achieved purely optical. For the implementation of quantum gates, two interacting qubits are required. There has already been evidence for interaction between two qubits, which are realized by electron spin ensembles of self-assembled (In,Ga)As quantum dots. To scrutinise the interaction between these ensembles, we perform optical time-resolved pump-probe ellipticity measurements on the spin polarisation. More precisely, we study the time evolution of a spin component along the magnetic field based on optically induced spin rotations to read out all spin-vector components.

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Properties of excitonic V-shaped quantum dot systems for optical switches — •Yves Alexander Leier[1], Dirk Mantei[1], Jens Förstner[1], Simon Gordon[1], Dirk Reuter[1], Andreas D. Wieck[2], and Artur Zrenner[1] — [1]Center for Optoelectronics and Photonics Paderborn (CeOPP), Universität Paderborn, Warburger Straße 100, 33098 Paderborn, Germany — [2]Ruhr-Universität Bochum, Universitätsstraße 150, Gebäude NB, 44780 Bochum, Germany

For the optical manipulation of a single quantum system, diverse approaches such as Rabi Oscillations and the Adiabatic Rapid Passage are well established techniques. To achieve an inversion as complete as possible we present a new possibility by examining a single quantum system with V-type three level scheme, a common ground state and two distinguishable and separately excitable transitions. Their sequential, pulsed excitation allows for the preparation of a robust, fault-tolerant and phase-insensitive inversion. In our contribution we demonstrate this concept, which is based on the polarization-selective excitation of a fine structure split exciton ground state in a single InGaAs quantum dot. We further propose a scheme for a robust optical switch, which is based on a related approach. A first horizontally polarized pi-pulse excites completely one of the fss-transitions of a quantum dot ensemble. Because of Pauli blocking a second pulse with orthogonal polarization can therefore not change the occupation of the quantum dot and passes the quantum dot without absorption.

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Resonance Fluorescence from Quantum Dots embedded in GaAs/AlGaAs Ridge Waveguide Structures — •Mario Schwartz, Ulrich Rengstl, Matthias Paul, Michael Jetter, and Peter Michler — Institut für Halbleiteroptik und Funktionelle Grenzflächen, Allmandring 3, 70569 Stuttgart, Germany

The implementation of a logical quantum CNOT gate on-chip is one of the major goals in quantum information science. Requirements for such a gate are the generation, guiding and detection of indistinguishable single-photons on-chip. Due to photons from a QD have the best coherence properties under resonant excitation, this excitation method is a requirement for highly indistinguishable single-photons.

Here, we demonstrate resonance fluorescence (RF) of InAs QDs embedded in a GaAs/AlGaAs ridge waveguide (WG). Low propagation losses along the WG exhibit the suitability of the QD/WG system. The additional use of a weak off-resonant laser, acting as an optical gate for the RF is documented.

HL 109.4 Fri 12:00 ER 164

Ultra-bright emission of indistinguishable photons from deterministic quantum-dot microlenses — •Alexander Thoma, Peter Schnauber, Manuel Gschrey, Marc Seifried, Ronny Schmidt, Jan-Hindrik Schulze, Tobias Heindel, Sven Rodt, André Strittmatter, and Stephan Reitzenstein — Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstraße 36, D-10623, Germany

Non-classical light sources emitting single indistinguishable photons at high flux rates are key components for concepts in the field of quantum information technology such as the quantum repeater. Single self-organized semiconductor quantum dots (QDs) integrated into microcavity systems are promising candidates to realize such sources. In recent years significant progress has been achieved in this field, however, most of the realized devices are based on spatially and spectrally random quantum emitters. In this work we report on a versatile device concept that is based on deterministically fabricated single QD microlenses using in-situ electron beam lithography. These quantum light sources can be realized with very high process yield $> 90\%$ and allow for ultrabright emission on demand. We observe photon extraction efficiencies of up to $(23.3 \pm 3.0)\%$ in combination with a strong suppression of multi-photon emission events $g^{(2)}(0) < 0.01$. A Hong-Ou-Mandel-type two-photon interference experiment reveals a visibility of $V = (43 \pm 4)\%$ even in saturation of the active QD.

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A quantum dot single-photon source with on-the-fly all-optical polarization control — •Dirk Heinze, Dominik Breddermann, Artur Zrenner, and Stefan Schumacher — Physics Department and Center for Optoelectronics and Photonics Paderborn (CeOPP), University of Paderborn, Warburger Strasse 100, 33098 Paderborn, Germany

Semiconductor quantum dots have been highlighted as efficient on demand sources for single photons. In contrast to the usual cascaded biexciton-exciton emission, here we study the direct two-photon emission from the biexciton. We show that emission through this higher-order transition is a promising and in certain ways superior alternative to generate a single photon. In the scheme we propose, the two-photon emission from the biexciton is enabled by a laser field (or laser pulse) driving the system into a virtual state inside the band gap. From this intermediate virtual state, the single photon of interest is then spontaneously emitted as the quantum dot relaxes to its electronic ground state. The big advantage of this scheme lies in the fact that the properties of the emitted photon (such as polarization state, time of emission, frequency) can be controlled all-optically by the classical laser field enabling the emission. This gives our scheme great potential to be used in the next generation of flexible semiconductor single-photon sources.

HL 109.6 Fri 12:30 ER 164

Coherent photocurrent spectroscopy of single InAs quantum dots at 1500 nm — •Simon Gordon[1], Matusala Yacob[2], Yves Alexander Leier[1], Mohamed Benyoucef[2], Johann Peter Reithmaier[2], and Artur Zrenner[1] — [1]CeOPP, Universität Paderborn, Paderborn, Germany — [2]INA, Universität Kassel, Kassel, Germany

For long distance quantum communication it is essential to use flying qubits in the telecom wavelength bands. Quantum emitters or detectors in this wavelength regime can be realized with InAs quantum dots on InP substrate. In this work, such InAs quantum dots are investigated by low-temperature photocurrent spectroscopy. Suitable p-i-n diode structures with self-assembled quantum dots have been grown by molecular beam epitaxy on InP(100) substrates. The layer sequence of the diodes consists of an n-InP back contact, an intrinsic region of lattice-matched InAlGaAs, which contains the quantum dots, and a p-InP front contact. The quantum dots are coherently excited by an optical parametric oscillator. By changing the applied reverse voltage the resonance energy of the quantum dot is tuned by the quantum confined Stark effect to the energy of the light pulse. Increasing the power of the excitation light pulses leads to a nonlinear response of the photocurrent. We observe a clear signature of Rabi oscillations. By measuring the photocurrent it is also possible to determine the occupancy of the two level quantum system after coherent excitation.

HL 109.7 Fri 12:45 ER 164

Toward long-lived excitonic qubits in deterministic quantum-dot microlenses — •Tobias Heindel[1], Alexander Thoma[1], Emma Schmidgall[2], Liron Gantz[2], Ido Schwartz[2], Manuel

Gschrey[1], Peter Schnauber[1], Jan-Hindrik Schulze[1], André Strittmatter[1], Sven Rodt[1], David Gershoni[2], and Stephan Reitzenstein[1] — [1]Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstraße 36, D-10623, Germany — [2]Department of Physics, Technion, Haifa 32000, Israel

In recent years the coherent properties of bright exciton (BE) states in self-assembled semiconductor quantum dots (QD) have been explored [1]. However, the use of BEs for quantum information processing tasks is limited due to their relatively short lifetime - set by its radiative recombination rate. On the other hand, dark exciton states have already proven to constitute an extremly long-lived qubit which is optically accesible via specific biexcitonic states [2].
In this work we report on the exploration of such biexcitonic triplet states in single QDs integrated deterministically into microlenses with enhanced photon-extraction efficiency. In contrast to the common spin-singlet biexciton state, the triplet states are constituted of two s-shell electrons and two holes having parallel spins - thus one hole must be located in the p-shell due to Pauli exclusion principle. A detailed analysis of the dynamics of these spin-blockaded biexciton states is presented via polarization resolved photon-crosscorrelation measurements.
[1] Kodriano et al., Semicond. Sci. Technol. 29, 053001 (2014)
[2] Poem et al., Nature Physics 6, 993 (2010)

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Fiber-coupled quantum dot based single-photon sources operated by a Stirling cryocooler — •Alexander Schlehahn, Esra Tauscher, Thomay Megas, Manuel Gschrey, Jan-Hindrik Schulze, André Strittmatter, Sven Rodt, Tobias Heindel, and Stephan Reitzenstein — Technische Universität Berlin, Institut für Festkörperphysik, 10623 Berlin, Germany

Easy-to-operate single-photon sources are one of the key components in quantum communication. Up till now such non-classical light sources have been operated almost exclusively in shielded lab-environments and practical concepts appeared elusive. Here we report on the application of a compact and user-friendly Stirling cryocooler in the field of nanophotonics. It is capable of operating single-photon emitters at a base temperature well below 30 K with high purity ($g^{(2)}(0) = 0.04$), while offering cost efficiency and independence from liquid helium supply. A method for direct fiber coupling of single quantum emitters inside the Stirling cryostat is introduced. Sample alignment is obtained by an innovative two-step deep-etching process for GaAs. It allows us to deterministically position single quantum dot structures within a few tens of micrometers precision on a 2.5 mm diameter, racket-shaped sample. Mounting sample and fiber into standard ceramic fiber sleeves with sub-micrometer diameter deviation achieves excellent alignment of fiber core and mesa. Laser excitation and quantum dot emission are guided via the same optical fiber, leading to a drift- and vibration-unaffected signal. This demonstration paves the way towards user-friendly and high-quality table-top non-classical light sources.