HL 16: Quantum dots and wires: Optical properties I

Time: Monday 14:00–17:15 Location: ER 164

HL 16.1 Mon 14:00 ER 164

Optical properties of electrically pumped CdSe quantum dot structures — •Thomas Meeser, Joachim Kalden, Kathrin Sebald, Jürgen Gutowski, Arne Gust, Carsten Kruse, and Detlef Hommel — Institute of Solid State Physics, University of Bremen, P. O. Box 330 440, 28359 Bremen, Germany

CdSe quantum dots (QDs) embedded into MgS barriers possess a high potential as active material for single photon emitters working at room temperature in the green spectral region because of the enhanced confinement of the carriers leading to an improved luminescence stability. We will present micro-electroluminescence (μ-EL) measurements on a resonant-cavity light emitting diode (RCLED) which was grown by molecular beam epitaxy containing an active region consisting of self-assembled CdSe QDs in a cavity and a distributed Bragg reflector. In this presentation we will focus on integrated μ-EL intensity measurements of the QD ensemble and single-QD emission lines in dependence on the applied voltage and sample temperature. The comparison of the results achieved for single QDs leads to an estimate of the sample temperature at the position of the active region during LED operation. In addition, we will compare these results to micro-photoluminescence measurements which were performed at the same sample position including the discussion of the change of PL characteristic by the variation of the external electric field.

HL 16.2 Mon 14:15 ER 164

Triggered polarization-entangled photon pairs from a single quantum dot up to 30 K — •Robert Hafenbrak[1], Sven M. Ulrich[1], Peter Michler[1], Lijuan Wang[2], Armando Rastelli[3], and Oliver G. Schmidt[3] — [1]Institut für Halbleiteroptik und Funktionelle Grenzflächen, Universität Stuttgart, Allmandring 3, 70569 Stuttgart — [2]Max-Planck-Institut für Festkörperforschung, Heisenbergstraße1, 70569 Stuttgart — [3]Institute for Integrative Nanosciences, IFW Dresden, Helmholtzstraße 20, 01069 Dresden

The radiative biexciton-exciton decay in (In,Ga)As semiconductor quantum dots has the potential of being a source of triggered polarization-entangled photon pairs. However, this entanglement is in general reduced by the anisotropy-induced exciton fine structure splitting. Here we present measurements (1) on improved quantum dot structures, providing both significantly reduced inhomogeneous emission linewidths and near-zero fine structure splittings. A high-resolution detection technique is introduced which allows us to accurately determine the fine structure in the photoluminescence emission and therefore select appropriate quantum dots for quantum state tomography. We were able to verify the conditions of entangled or classically correlated photon pairs in full consistence with observed fine structure properties. Furthermore, we demonstrate reliable polarisation-entanglement for elevated temperatures up to 30 K. The fidelity of the maximally entangled state decreases only little from 72% at 4 K to 68% at 30 K.

(1) Hafenbrak et al., New J. Phys. 9 (2007) 315

HL 16.3 Mon 14:30 ER 164

Tailoring of mode-locking by shaping laser pulse sequencies — •Stefan Spatzek, Alex Greilich, Dmitri Yakovlev, and Manfred Bayer — Experimentelle Physik II, Technische Universität Dortmund, D-44221 Dortmund, Germany

Electron spins in ensembles of quantum dots (QDs) provide an attractive proposal to implement quantum information technologies in a solid-state environment. Unfortunately, inhomogeneities within an ensemble lead to the rapid loss of coherence among the phases of the spins.

We report about the mode-locking effect on InGaAs/GaAs QDs, dependent on the temporal pulsewidth at different magnetic fields in a range of 150 - 800 fs measured by time-resolved Faraday rotation. A periodic train of circularly polarized light pulses of mode-locked laser synchronizes the precession of the spins to the laser repetition rate, transferring the mode-locking into the spin system [1]. We have proved, that the mode-locking effect is more pronounced by longer excitation pulses, due to decreasing of the spectral width of the pulse. In the excited inhomogeneous QDs ensemble one observes the spin precessions on different frequencies. Therefore, with decreasing of the spectral pulsewidth one excites smaller distribution of the QDs, that lead to the longer dephasing of the QD ensamble.

[1] A. Greilich, D. R. Yakovlev, A. Shabaev, Al. L. Efros, I. A. Yugova, R. Oulton, V. Stavarache, D. Reuter, A. Wieck, and M. Bayer, Science 313, 341 (2006).

HL 16.4 Mon 14:45 ER 164

Controlled Optical Charging of Single InGaAs Quantum Dots — •Dominik Heiss, Vase Jovanov, Max Bichler, Gerhard Abstreiter, and Jonathan J. Finley — Walter Schottky Institut, Garching, Deutschland

We propose an all optical spin readout concept for individual electron spins in single self assembled quantum dots (QDs). By employing the spin-conditional absorption of a circularly polarized light pulse tuned to the X^{-1} absorption line, we propose to convert the spin information of the resident electron to charge information. Subsequent non-resonant photoluminescence (PL) then directly reveals the charge state of the quantum dot and, therefore, the spin orientation of the resident electron. We have applied time gated PL to confirm that efficient optical charging and non invasive measurement of the charge state can be performed in the same dot. The structures investigated are n-Schottky photodiodes with a dilute ensemble of $In_{0.5}Ga_{0.5}As$ QDs in the intrinsic region. A 20 nm $Al_{0.3}Ga_{0.7}As$ barrier below the dot layer inhibits electron tunnelling escape, whilst holes are efficiently removed when a high electric field ($|E| > 20$ kV/cm) exists in the intrinsic region. This leads to electron accumulation and X^{-n} transitions are prominent in the readout phase of the measurement and our results are in good agreement with a rate equation model of the optical charging process. In contrast, for $|E| < 20$ kV/cm the optical charging rate becomes very low ($\sim 390 s^{-1} W^{-1} cm^2$) demonstrating that the charge and spin state of the dot can be tested via PL over millisecond timescales, without altering it.

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Hot trion and excited exciton states of single InGaAs/GaAs quantum dots — •Elisabeth Siebert, Till Warming, and Dieter Bimberg — TU Berlin, Institute of Solid State Physics, Sekr. EW 5-2, Hardenbergstr. 36, D-10623 Berlin, Germany

For a detailed understanding of the electronic structure of self-organized quantum dots (QDs) high-resolution measurements that reveal the spectrum of excited states are essential. Here, polarized photoluminescence excitation (PLE) spectra of the positive trion and the exciton of a number of MBE-grown single InGaAs/GaAs QDs were recorded and compared to results of 8-band k·p calculations.
The exciton and trion absorption spectra comprise two characteristic parts. ΔE=60 meV above the ground state energy exists a quasi continuous band of absorption features. The corresponding transitions involve hybrid states of QDs and wetting layer. In our study we concentrate on the regime below ΔE=60 meV where the PLE spectrum of the exciton consists of well separated sharp resonances, corresponding to absorptions into excited exciton states, and a broad resonance around 35 meV due to exciton-phonon coupling. Upon adding a positive charge carrier, the PLE spectrum has a more complex structure due to the singlet-triplet splitting of the hot trion states. The sharp resonances, of both trion and exciton show clear dependence on linearly or circularly polarized excitation and detection. Moreover the spectra of different dots, detected on the ground state energy of the same excitonic complex, reveal substantial similarities. This work is partly funded by SANDiE NoE, contr. no. NMP4-CT-2004-500101.

HL 16.6 Mon 15:15 ER 164

Excitonic dynamics in II-VI quantum rods — •Alexander W. Achtstein, Björn Möller, Andrew Ebbens, and Ulrike Woggon — Institute of Physics, Technical University of Dortmund, D-44221 Dortmund, Germany

Highly luminescent colloidal II-VI semiconductor nanorods of large aspect ratio and diameters within the semiconductors exciton Bohr radius are studied by spatially and time-resolved spectroscopy. The influence of rod thickness variation for constant rod aspect ratio is investigated with respect to excitonic confinement and exciton dynamics. High resolution PL measurements show the existence of an excitonic fine structure inside the rods. Possible reasons for its appearance will

be discussed. Temperature dependent cw and time resolved PL measurements are conducted to study the influence of this 1D confinement on the electronic structure of these nanowires. Ultrafast dynamics shows, that deexcitation is mainly provided by two competing relaxation channels. The fast one in the 100ps regime can be attributed to nonradiative processes, whereas the slow one, with time constants of about 1ns, can be assigned to the radiative lifetime, which is much longer than the radiative lifetime for bulk II-VI materials.

15 min. break

HL 16.7 Mon 15:45 ER 164

Nonlinear Optical Microscopy of a Single Self-assembled InGaAs Quantum Dot — •Claudia Ruppert[1], Markus Wesseli[1], Emily C. Clark[2], Jonathan J. Finley[2], and Markus Betz[1] — [1]Physik-Department E11, TU München — [2]Walter Schottky Institut and Physik-Department E24, TU München

Semiconductor quantum dots (QDs) exhibit exciting prospects for solid state qubits. Here we present the first ultrafast all-optical scheme for manipulation and read-out of a single QD and, thereby, pave the way towards a variety of such quantum coherent studies [1].

A single InGaAs/GaAs QD is isolated by an aluminum shadow mask of 450 nm diameter. Optical excitation and read-out is achieved in a nondegenerate pump-probe scheme. Carriers are generated in the wetting layer beneath the QD with a 100 fs pump pulse and captured into the QD. The excitation induced transmission changes are analyzed over a broad range of probe wavelengths and various delay times. In particular, we identify signatures of the single exciton transition at $E_X = 1.374\ eV$ and transitions of several multi-exciton complexes. These bleaching signals are in the order of $\Delta T/T \sim 10^{-5}$ and reveal a picosecond dynamics likely related to intra-QD carrier relaxation.

In the next step, we will analyze QDs with excitonic transitions around 1.3 eV which are characterized by a larger confinement potential and better optical quality. To this end, we have developed a novel femtosecond Ti:Sapphire oscillator that, remarkably, provides ∼30 fs pulses tunable to wavelengths as long as 970 nm.

[1] M. Wesseli et al., Appl. Phys. Lett. **88**, 203110 (2006).

HL 16.8 Mon 16:00 ER 164

Optical properties of InGaN quantum dot stacks — •Joachim Kalden, Henning Lohmeyer, Kathrin Sebald, Thomas Meeser, Jürgen Gutowski, Christian Tessarek, Stephan Figge, and Detlef Hommel — Institute of Solid State Physics, University of Bremen, P.O. Box 330 440, D-28334 Bremen, Germany

In the blue to UV spectral region InGaN quantum dots (QDs) are an up-and-coming material system. Beside research concerning the fundamental properties of these QDs, it is necessary to increase the QD density for laser applications. Hence samples with multiple QD layers are characterized to investigate the influence of stacking on the optical properties. Therefore, we compare micro-photoluminescence (μ-PL) measurements of single and stacked QD layers grown by metal-organic vapor phase epitaxy. The optical emission properties are discussed with respect to polarization and temperature, respectively. In contrast to the single QD layer, no sharp emission lines can be found for the unstructured stacked layers. Their ensemble PL band is easily traceable up to room temperature. To prove the QD origin of these samples mesa structures are prepared by focused-ion-beam etching. As expected, for decreasing mesa diameter the broad emission band of the QD ensemble splits up and individual sharp emission lines can be observed. Their characteristics are comparatively discussed with the results achieved from the single QD layer samples. Additionally, gain measurements on single QD layers and QD stacks will be discussed.

HL 16.9 Mon 16:15 ER 164

High-fidelity all-electrical preparation of spin-polarized electrons in single InAs quantum dots — •W. Löffler[1,3], J. Müller[1], H. Flügge[1], C. Mauser[1], S. Li[2,3], T. Passow[1,3], P. Asshoff[1,3], M. Hetterich[1,3], and H. Kalt[1,3] — [1]Institut für Angewandte Physik, Universität Karlsruhe (TH) — [2]Institut für Hochfrequenztechnik und Quantenelektronik, Universität Karlsruhe (TH) — [3]DFG Center for Functional Nanostructures, CFN, D-76128 Karlsruhe, Germany

Electrical spin-injection devices provide a unique way to prepare spin-polarized electrons in many separated semiconductor quantum-dots at the same time. Using a semimagnetic spin-polarizer like ZnMnSe, the electron spin polarization can easily be prepared to unity. We have shown that these electrons can be injected into InAs quantum dots preserving the polarization. Here, we present recent investigations to enhance the spin-polarization at low magnetic fields and to study the temporal dynamics in these devices. We implemented and optimized the growth of high-quality ZnMnSSe spin-aligner layers and established time-resolved electroluminescence measurements.

HL 16.10 Mon 16:30 ER 164

Optical emission from spin singlet and triplet few electron states of a self-assembled quantum dot molecule — •Emily C. Clark[1], Christoph Scheurer[2], Hubert Krenner[1], Max Bichler[1], Gerhard Abstreiter[1], and Jonathan J. Finley[1] — [1]Walter Schottky Institut, Technical University of Munich, 85748 Garching, Germany — [2]Lehrstuhl für Theoretische Chemie, Technische Universität München, 85748 Garching, Germany

We report magneto-optical investigations of coupled exciton states in individual quantum dot molecules. The samples investigated consist of a single pair of vertically stacked, self assembled In0.5Ga0.5As dots, embedded into the intrinsic region of an n-type GaAs Schottky photodiode.[1] This structure allows us to tune the electric field along the growth axis, switch on an off coupling between the molecular states and controllably add electrons to the molecule. In the absence of a magnetic field a series of characteristic crossings and anti-crossings are observed in the emission spectrum, as neutral and charged exciton states in the dots couple and form molecular orbitals.[2] The magnetic field is shown to mix the s- and p-orbital states in each dot, giving rise to anti-crossings due to hybridization of the mixed s-p orbital states. From our measurements, we deduce the coupling strengths of the mixed states as a function of the magnetic field and extract information about the molecular electronic structure. Our experimental findings will be compared with calculations of the negatively charged exciton states subject to magnetic fields.[1] Krenner et. al Physical Review Letters, 94, 057402, 2005 [2]Krenner et. al Phys. Rev. Lett. 97, 076403, 2006

HL 16.11 Mon 16:45 ER 164

Carrier relaxation in quantum dots by means of time resolved transmission in two color pump probe experiments — •Hannes Kurtze[1], Robert Heinle[1], Manfred Bayer[1], Jan Seebeck[2], Frank Jahnke[2], Dirk Reuter[3], and Andreas Wiek[3] — [1]Experimentelle Physik Universität Dortmund, D-44221 Dortmund, Germany — [2]Institut für Theoretische Physik, Universität Bremen, 28334 Bremen, Germany — [3]Angewandte Festkörperphysik, Ruhr-Universität Bochum, D-44780 Bochum, Germany

Systematic time-resolved pump-probe studies with independent variation of pump and probe energies have been performed on InAs/GaAs quantum dot samples covering a wide range of confinement parameters. From these studies a phonon bottleneck for carrier relaxation can be excluded for small delay times after pump excitation. The use of time resolved transmission instead of time resolved photoluminescence offers also the opportunity to observe optically inactive carrier populations and their dynamics. Typical results of such measurements will be given in this talk.

HL 16.12 Mon 17:00 ER 164

Electrical injection and optical probing of spins in a single quantum dot — •Tilmar Kümmell[1], Mohsen Ghali[1], Robert Arians[1], Jan Wenisch[2], Karl Brunner[2], and Gerd Bacher[1] — [1]Werkstoffe der Elektrotechnik, Universität Duisburg-Essen, D-47048 Duisburg — [2]Experimentelle Physik III, Universität Würzburg, D-97074 Würzburg

In order to use the spin as an information carrier, mechanisms for injection, storage and readout of a single spin are required. We use InAs quantum dots, known for spin relaxation times up to th ms regime, in combination with a diluted magnetic semiconductor (ZnMnSe) that has been proven to be an efficient source of spin polarized carriers. P-i-n-structures allow us to realize both polarized single dot emitters and single spin storage devices.

In the single dot emitter, a spin polarized electron injected from the n-ZnMnSe spin aligner recombines in a single InAs quantum dot with a hole coming from p-GaAs. This results in a significantly polarized electroluminescence from a single quantum dot. Polarization degrees of more than 35% are reached at B=4T, showing an efficient spin injection into the single quantum dot. Similar p-i-n structures are used for electrical charging of a single dot with spin-polarized electrons. Optical probing of a charged single dot using micro-magnetoluminescence exhibits a characteristic polarization pattern of both trionic and excitonic recombination lines. We show that this pattern reflects the polarization of the initially injected electron and can therefore in principle be used for a readout process of a single spin.