HL 37: Quantum Dots and Wires: Optical Properties III

Time: Wednesday 9:30–12:45 Location: H15

HL 37.1 Wed 9:30 H15

Vanishing Excitonic Fine Structure Splitting in In(Ga)As/GaAs Quantum Dots Grown on (111) GaAs Substrates — •Murat Öztürk[1], Erik Stock[1], Jan A. Töfflinger[1], Till Warming[1], Irina Ostapenko[1], Sven Rodt[1], Andrei Schliwa[1], Aleksandr I. Toropov[2], Sergej A. Moschenko[2], Dimitry V. Dmitriev[2], Vladimir A. Haisler[2], and Dieter Bimberg[1] — [1]Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstrasse 36, 10623 Berlin, Germany — [2]Institute of Semiconductor Physics, Lavrenteva av 13, Novosibirsk 630090, Russia

Non-classical correlated photons are of largest importance for quantum key distribution. A source of entangled photon pairs can be based on the biexciton (XX)→ exciton (X)→ 0 recombination cascade, if the fine structure splitting (FSS) of the exciton bright states is below the homogeneous linewidth. Symmetrically shaped In(Ga)As/GaAs quantum dots (QDs) grown on GaAs (111) substrates are expected to exhibit zero FSS due to the C_{3V} symmetry of the confinement potential. Here, we present In(Ga)As/GaAs QDs grown on GaAs (111) substrates with a low spatial density ($<10^9\,cm^{-2}$). Single photon emission is proved with a $g^2(0) \leq 0.3$. Micro-photoluminescence from a number of single QDs reveals similar luminescence line patterns for several QDs and therefore allows the assignment to transitions of specific excitonic complexes. Polarization dependent measurements reveal the FSS down to less than 10 μeV, limited by the spectral resolution of our setup. The nonzero splitting is understood in terms of shape and strain as symmetry of the QDs. This work is partly funded by the SFB 787.

HL 37.2 Wed 9:45 H15

Fine Structure Splitting of Neutral Excitons in GaAs/AlGaAs Quantum Dots — •Johannes D. Plumhof[1], Vlastimil Krapek[1,2], Lijuan Wang[1,3], Andrei Schliwa[4], Armando Rastelli[1], and Oliver G. Schmidt[1] — [1]Institute for Integrative Nanosciences, IFW Dresden, Helmholtzstr. 20, D-01069 Dresden — [2]Institute of Condensed Matter Physics, Masaryk University, Kotlarska 2, 61137 Brno, Czech Republic — [3]Max Planck Institute for Solid State Research, Heisenbergstr. 1, D-70569 Stuttgart — [4]Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstrasse 36, D-10623 Berlin

For the generation of polarization entangled photon pairs using self-assembled semiconductor quantum dots (QDs) it is important to decrease the fine structure splitting (FSS) energy of the neutral exciton to values lower than the emission linewidth. We study here the behaviour of the FSS of strain-free, molecular beam epitaxy grown GaAs/AlGaAs QDs. We use polarization-dependent photoluminescence spectroscopy to investigate the FSS of a large number of QDs. Based on AFM images of QDs grown under nominally same conditions we demonstrate the statistic interrelation of QD-shape and FSS. Due to the well known shape and composition profile of the QDs we are able to reproduce the experimental results with 8 band kp-simulations using the realistic structure as input. We also study the polarization of the light emitted by excitons confined in quantum well thickness fluctuations with not well defined shape to estimate the possible influence of effects on FSS other than shape, such as alloy ordering.

HL 37.3 Wed 10:00 H15

Remote pumping of self-assembled InGaAs Quantum Posts — •F. Knall[1], S. Völk[1], F. J. R. Schülein[1], H. Kim[2], T. A. Truong[3], J. He[3], P. M. Petroff[3], A. Wixforth[1], and H. J. Krenner[1] — [1]Lehrstuhl für Experimentalphysik I, Universität Augsburg, 86159 Augsburg, Germany — [2]Physics Department, UC Santa Barbara, Santa Barbara CA 93106, United States — [3]Materials Department, UC Santa Barbara, Santa Barbara CA 93106, United States

Oscillating electric fields in piezoelectric semiconductors such as GaAs can be induced by using surface acoustic waves (SAW). These fields modulate the band edges of a quantum well (QW) and thus, spatially separate excitons into electrons and holes, which propagate along the SAW direction. Therefore, recombination will be suppressed and the photogenerated charge carriers are transported to a quantum post (QP) located away from the point of excitation. The carriers relax into the confined states of the QP where they radiatively recombine. Using a spatially resolved detection we demonstrate remote pumping of individual QPs by the SAW. QPs are ideal candidates for acoustic charge conveyance driven single photon generation since they combine the superior optical quality of conventional self-assembled quantum dots and direct lateral embedding within a wide quantum well.

HL 37.4 Wed 10:15 H15

Quantum efficiency and oscillator strength of site-controlled InGaAs quantum dots — •Ferdinand Albert[1], Christian Schneider[1], Søren Stobbe[2], Sven Höfling[1], Stephan Reitzenstein[1], Peter Lodahl[2], Lukas Worschech[1], and Alfred Forchel[1] — [1]Technische Physik, Universität Würzburg, Am Hubland, 97074 Würzburg, Germany — [2]DTU Fotonik, Department of Photonics Engineering, Technical University of Denmark, Ørsteds Plads 343, DK-2800 Kgs, Lyngby, Denmark

Quantum dots (QDs) are fascinating nanoscopic structures for future quantum information technology. Even though tremendous progress has been achieved in understanding their properties and integrating them into devices like single photon sources, their random position inhibits a large scale fabrication. Thus a great challenge is the precise control of their position. Recently several groups succeeded in the growth of site-controlled quantum dots (SCQDs), but a complete characterization of their intrinsic parameters is still missing. In the present work we apply a recently developed method of determining the oscillator strength and the quantum efficiency of QDs on In(Ga)As SCQDs by means of time resolved spectroscopy on samples with varying thickness of the capping layer [1]. The modification of the local density of optical states as a function of the distance between the SCQDs and the GaAs-air interface enables us to extract the radiative and nonradiative decay rates, from which we calculate a quantum efficiency of 47% and the oscillator strength of 10 for the excitonic transition in SCQDs.

[1] J. Johansen et al., Phys. Rev. B 77, 073303 (2008)

HL 37.5 Wed 10:30 H15

Intraband resonances of GaAs/InAs quantum dots detected via photo induced current changes — •Boris Eichenberg[1], Heiko Wunderlich[1], Sabine Dobmann[1], Alois Seilmeier[1], Vadim Yu. Panevin[2], Leonid E. Vorobjev[2], Dmitry A. Firsov[2], and Alexander A. Tonkikh[3] — [1]Physikalisches Institut, Universität Bayreuth, 95440 Bayreuth, Deutschland — [2]St. Petersburg State Polytechnic University, St. Petersburg 195251, Russia — [3]Ioffe Physico-Technical Institute, St. Petersburg 194021, Russia

The investigation of intraband (IB) transitions in semiconductor quantum dots (QD) via fourier transform infrared (FTIR) spectroscopy often suffers from very low absorption signals due to moderate absorption cross sections and a low dot sheet density. In this contribution we discuss a photocurrent method, which provides clear signals at the frequency positions of IB absorption lines. The QD sample is laterally contacted at the processed surface and biased by several 10V. Current changes due to excitation by intense picosecond mid infrared laser pulses monitor the IB transitions. Enhanced current signals are observed at frequencies of both bound to bound and bound to continuum IB transitions. Data taken at 77K and at 300K on highly doped GaAs/InAs QD samples, in which up to five QD levels are occupied, are presented. This technique provides interlevel spectra of QDs in the mid infrared with a considerably improved signal to noise ratio compared to FTIR measurements. The experimentally observed IB transition frequencies nicely agree with those from calculated QD levels.

HL 37.6 Wed 10:45 H15

Dependence of spectral diffusion on excitation mechanisms in InGaAs/GaAs quantum dots — •Irina Ostapenko[1], Jan Amaru Töfflinger[1], Murat Öztürk[1], Erik Stock[1], Sven Rodt[1], Till Warming[1], Paola Atkinson[2,3], Oliver G. Schmidt[2], and Dieter Bimberg[1] — [1]Institut für Festkörperphysik, TU Berlin, Hardenbergstr. 36, 10623 Berlin, Germany — [2]Institute for Integrative Nanosciences, IFW Dresden, Helmholtzstrasse 20, 01069 Dresden — [3]Max-Planck-Institut für Festkörperforschung, Heisenbergstr. 1, 70569 Stuttgart, Germany

The discrete energy levels and sharp luminescence lines of self organized quantum dots (QDs) allow the development of new nanophotonic devices such as emitters of entangled or single photons. Fluc-

tuating fields in the sample may cause a spectral diffusion (jitter) of the lines: their energetic positions shift and the intensities vary. If the characteristic jitter timescale is smaller than the integration time of a given application, the luminescence line is inhomogeneously broadened which might hinder the use of single QD-based devises. Therefore the understanding of the intrinsic mechanisms of jitter is essential for the realization of such devices. Here we compare the spectral diffusion of the same QDs under optical and, what is more substantial for real applications, electrical excitation conditions in electro-, cathode- and micro-photoluminescence experiments. The key element is an electrically driven device with a low density of QDs and the possibility to probe the same QD with different excitation methods.

15 Min. Coffee Break

HL 37.7 Wed 11:15 H15

Single As-grown $Al_xGa_{1-x}As$ Nanowires Probed by Raman Spectroscopy — •Benjamin Buick[1], Eugen Speiser[1,2], Paola Prete[3], Pasquale Paiano[4], Nicola Lovergine[4], and Wolfgang Richter[1] — [1]Università di Roma Tor Vergata, Rome, Italy — [2]ISAS Department Berlin, Berlin, Germany — [3]IMM-CNR di Lecce, Lecce, Italy — [4]CNISM di Lecce and Università del Salento, Lecce, Italy

III-V compounds nanowires (NWs) are of central interest due to their innovative physical properties and potential applications in electronic and photo-electronic devices. Freestanding AlGaAs NWs were grown by MOVPE by the Vapor Liquid Solid method along the (111) direction on GaAs(111) substrates.

Raman measurements were performed on single as-grown NWs with a scanning confocal micro-Raman spectrometer. Rayleigh imaging, was applied to locate individual NWs and define their position for Raman measurements.

The spectra of the AlGaAs NWs exhibit two-mode behavior: GaAs- and AlAs-like modes which were exploited to determine the stoichiometry. Its dependence on the growth temperature was determined. The Raman spectra show two sets of GaAs- and AlAs-like modes indicating regions with different stoichiometries within a single NW. The composition gradient oft the NWs can be understood as the unintentional formation of a core-shell structure. Furthermore, the presence of coupled plasmon-LO phonon peaks in the spectra was related to (unintentional) doping of the NWs.

HL 37.8 Wed 11:30 H15

Tunable exciton g-factor in height and composition engineered quantum dots — •Vase Jovanov[1], Florian Klotz[1], Emily Clark[1], Daniel Rudolph[1], Johannes Kierig[1], Paul M. Koenraad[2], Max Bichler[1], Martin S. Brandt[1], Gerhard Abstreiter[1], and Jonathan J. Finley[1] — [1]Walter Schottky Institut, TU München, Am Coulombwall 3, 85748 Garching, Germany — [2]Eindhoven University of Technology, P.O. Box 513, 5600 MB Eindhoven, The Netherlands

We present experimental and theoretical investigations of the influence of static electric and magnetic fields on the exciton g-factor ($g_{ex,zz}$) of self-assembled InGaAs-GaAs quantum dots. The use of a novel growth procedure allows us to precisely control the dot height (h=2-6 nm) by partially capping the dots with GaAs before introducing a growth interruption and annealing step to remove Indium from the growth surface ("In-flush" method). By performing single quantum dot photoluminescence and photocurrent absorption measurements with magnetic fields up to 15T applied parallel to the quantum dot growth axis we show that the $g_{ex,zz}$ can be tuned from 0.4 to -0.4 by applying static electric fields$\leq$70kV/cm. Microscopically, the effect is caused by pushing the electron and hole components of the exciton wavefunction into different regions of the dot, with differing local In-Ga composition. For the tallest dots (h=6nm) we find that $|g_{ex,zz}|$ is also influenced by the static magnetic field. Our experimental findings are in good qualitative agreement with detailed 3D eight-band k·p calculations that incorporates the magnetic field in a fully gauge invariant manner.

HL 37.9 Wed 11:45 H15

Electrically controllable g-factor of single quantum dots and quantum dot molecules — •Thomas Eissfeller, Till Andlauer, and Peter Vogl — Walter Schottky Institut, TU München, 85748 Garching

We predict the exciton g-tensor of single self-assembled InAs/GaAs quantum dots and molecules of vertically coupled quantum dot pairs in an external magnetic and electric field. The calculations are carried out in terms of a detailed 3D electronic structure theory that includes strain, piezoelectric charges and an eight-band k.p envelope function model. The magnetic field is incorporated in a manifestly gauge-invariant manner. For zero effective electric field, we find a linear dependence of the exciton g-factor on the exciton energy for single quantum dots. Importantly, we predict a giant bias controlled exciton g-factor tunability for certain quantum dot shapes and compositions. This is in excellent agreement with recent experiments. Secondly, we present quantitative theoretical results for the bias controlled anisotropic exciton g-tensor of vertically coupled quantum dot pairs. We find a giant g-factor tunability for vertical magnetic fields and a very pronounced g-tensor anisotropy for horizontal magnetic fields. This g-tensor tunability is more robust for quantum dot molecules than for single quantum dots. These results indicate that quantum dot molecules are promising candidates for the realization of g-factor engineered qubit gates.

HL 37.10 Wed 12:00 H15

Exciton mediated dynamic nuclear polarzation in an individual self-assembled quantum dot — Florian Klotz, Vase Jovanov, •Johannes Kierig, Emily C. Clark, Daniel Rudolph, Dominik Heiss, Max Bichler, Gerhard Abstreiter, Martin S. Brandt, and Jonathan J. Finley — Walter Schottky Institut, Am Coulombwall 3, 85748 Garching, Germany

We present investigations of dynamic nuclear polarization (DNP) in a single self-assembled InGaAs/GaAs quantum dot subject to an external magnetic field (B_0) and electric field parallel to B_0. Resonant excitation of the neutral exciton (X^0) is shown to lead to a buildup of nuclear spin orientation due to tunneling escape of photoexcited carriers that serves to recycle dark states formed by hyperfine-mediated electron-nuclear spin flip-flop processes. DNP was achieved by tuning one Zeeman level of X^0 into resonance with a single frequency laser to optically pump spin-polarized carriers. We estimated the resulting Overhauser field B_N by locating both Zeeman branches relative to a measurement where DNP was inhibited. The saturation value of B_N depends on whether sweeps are performed from low to high electric fields or vice versa, B_0 and the timescale over which the sweeps are performed. B_N is always found to be oriented parallel to B_0 with magnitude $B_N \sim 3-5$ T. In addition, we also performed time resolved measurements of the nuclear spin orientation dynamics and found B_N to increase over timescales ranging from a few seconds to several minutes depending on the excitation intensity, electric field and detuning from resonance.

HL 37.11 Wed 12:15 H15

Magnetic field controlled interaction strength of a strongly coupled quantum dot-micropillar system — •Steffen Münch, Stephan Reitzenstein, Philipp Franeck, Andreas Löffler, Sven Höfling, Lukas Worschech, and Alfred Forchel — Technische Physik, Universität Würzburg, Am Hubland, D-97074 Würzburg, Germany

So far most experimental studies of strong coupling in QD-microcavity systems have relied on temperature tuning or electro-optical resonance tuning based on the quantum confined Stark effect. In this work we demonstrate that an external magnetic field provides a further degree of freedom to fully explore the potential of coherently coupled QD-microcavity system. We investigated magneto-optical resonance tuning of a laterally extended $In_{0.3}Ga_{0.7}As$ QD embedded in the active layer of a micropillar cavity with a Q-Factor of 11000 which corresponds to a cavity mode linewidth of γ_C=120 μeV. Strong coupling with a QD exciton was observed at zero magnetic field exhibiting a Vacuum Rabi splitting (VRS) of 105 μeV. Magnetic field dependent studies show that the VRS and the associated coupling strength g decrease when magnetic confinement becomes significant above 3 T. This effect is explained in terms of a magnetic field dependent oscillator strength of the extended QDs. In this sense the magnetic field not only acts as a tuning parameter but also opens a way of in situ modifying the coupling strength of the interacting system. In a further approach we demonstrated spin-selective strong coupling by tuning Zeeman-split exciton lines sequentially through the cavity resonance.

HL 37.12 Wed 12:30 H15

Excited state spectroscopy of single lateral InGaAs quantum dot molecules — •Matthias Heldmaier[1], Claus Hermannstädter[1], Marcus Witzany[1], Jie Peng[2], Gabriel Bester[2], Lijuan Wang[3], Armando Rastelli[3], Oliver G. Schmidt[3], and Peter Michler[1] — [1]Institut für Halbleiteroptik und

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The investigated structures contain self-assembled laterally coupled InGaAs quantum dots embedded in a planar microcavity, which are grown using a combination of metal-organic vapor phase and molecular beam epitaxy. The individual quantum dot molecules (QDMs) consist of two single dots that are coupled along the [1-10] crystal direction via electron tunneling. The coupling strength and the ground and excited state energies of the QDMs can be manipulated by applying a lateral electric field. A change in the relative intensities of the excitonic emission lines is observed in the photoluminesence (PL) spectra. PL excitation measurements were conducted using a wide-range tunable Ti:Sapphire laser to obtain information about excited states confined in the QDM. The results of these measurements are compared with the energies of the single-particle and correlated exciton states in the system obtained by an empirical pseudo-potential calculations using a random composition of the QDMs.