HL 37: Quantum Dots and Wires: Optical Properties I (mainly InGaAs Dots)

Time: Tuesday 10:45–13:15 Location: ER 164

HL 37.1 Tue 10:45 ER 164

Time resolved Faraday rotation and ellipticity experiments with two pump excitation of electrons and holes in InGaAs QDs — •Dennis Barmscheid[1], Steffen Varwig[1], Irina A. Yugova[1,2], Alex Greilich[1], Alexander Schwan[1], Crispin Müller[1], Dmitri R. Yakovlev[1], Dirk Reuter[3], Andreas D. Wieck[3], and Manfred Bayer[1] — [1]Experimentelle Physik II, TU Dortmund, D-44221 Dortmund, Germany — [2]Institute of Physics, St. Petersburg State University, 198504 St. Petersburg, Russia — [3]Angewandte Festkörperphysik, Ruhr-Universität Bochum, D-44780 Bochum, Germany

The investigation of charge carrier spin dynamics in quantum dots plays an important role for the developement of spintronics. For this we perform pump-probe Faraday rotation and ellipticity experiments on self-assembled (In,Ga)As/GaAs quantum dot ensembles.

Due to an excitation with a train of pump pulses, the phase of the spin precessions in the inhomogeneous QD-ensemble is synchronized to the laser repetition time T_{R}. By two pump excitation scheme, with pumps separated by delay T_{D}, the spins have to fulfill two phase synchronization conditions simultaneously and show rephasing within T_{D} and $T_{\mathrm{R}} - T_{\mathrm{D}}$. This leads to increases of the signal amplitude, called bunches, every multiple of T_{D}.

It can be shown, that these bunches are different phenomena than the spin echoes, which occur after spin rotations. We show how this method provides an additional opportunity to study the interaction of electrons and holes with the nuclei.

HL 37.2 Tue 11:00 ER 164

Phase synchronization of hole spin precessions in InGaAs quantum dots — •Steffen Varwig[1], Dennis Barmscheid[1], Irina A. Yugova[1,2], Alex Greilich[1], Alexander Schwan[1], Crispin Müller[1], Dmitri R. Yakovlev[1], Dirk Reuter[3], Andreas D. Wieck[3], and Manfred Bayer[1] — [1]Experimentelle Physik II, TU Dortmund, D-44221 Dortmund, Germany — [2]Institute of Physics, St. Petersburg State University, 198504 St. Petersburg, Russia — [3]Angewandte Festkörperphysik, Ruhr- Universität Bochum, D-44780 Bochum, Germany

The spin of charge carriers in semiconductor quantum dots is a promising candidate for implementing a quantum bit. We study the spin coherence of holes in an ensemble of self-assembled (In,Ga)As/GaAs QDs by optical faraday rotation and ellipticity measurements. With a periodic train of short pump pulses it is possible to overcome the obstacle of fast spin dephasing due to inhomogeneities. The phase of the spin precession in an external magnetic field is thereby synchronized and this leads to constructive interference of the single spin contributions to the measured signal. Thus one can observe the spin coherence on a long time scale, offering the ability to measure the coherence time T_2.

HL 37.3 Tue 11:15 ER 164

Spin Noise of Holes in Quantum Dots — •Ramin Dahbashi[1], Jens Hübner[1], Fabian Berski[1], Julia Wiegand[1], Xavier Marie[2], Klaus Pierz[3], Hans Werner Schumacher[3], and Michael Oestreich[1] — [1]Institute for Solid State Physics, Leibniz Universität Hannover, Appelstr. 2, D-30167 Hannover, Germany — [2]Université de Toulouse; INSA, UPS, CNRS; LPCNO, 135 avenue de Rangueil, F-31077 Toulouse, France — [3]Physikalisch Technische Bundesanstalt, Bundesallee 100, D-38116 Braunschweig, Germany

We measure the spin dephasing of holes localized in self-assembled (InGa)As quantum dots by spin noise spectroscopy [1]. The localized holes show a distinct hyperfine interaction with the nuclear spin bath despite the *p*-type symmetry of the valence band states. The experiments reveal a short spin relaxation time of 27 ns and a second, long spin relaxation time which exceeds the first one by more than one order of magnitude. The two times are attributed to heavy hole spins aligned perpendicular and parallel to the stochastic nuclear magnetic field. Intensity dependent measurements and numerical simulations reveal despite low laser intensity and large detuning that the long relaxation time is still obscured by light absorption.

[1] Dahbashi *et al.*, Measurement of heavy-hole spin dephasing in (InGa)As quantum dots, arXiv:1109.0610v1 [cond-mat.mes-hall] (2011, Submitted to APL).
[2] Müller *et al.*,Semiconductor spin noise spectroscopy: Fundamentals, accomplishments, and challenges, Physica E 43, 569 (2010).

HL 37.4 Tue 11:30 ER 164

All optical preparation, storage and readout of a single spin in an individual quantum dot — Vase Jovanov, Florian Klotz, Alexander Bechtold, Stephan Kapfinger, Silvia Spiga, •Sebastian Koch, Daniel Rudolph, Max Bichler, Martin S. Brandt, and Jonathan J. Finley — Walter Schottky Institute and Center for Nanotechnology and Nanomaterials, Technische Universität München, Am Coulombwall 4, 85748 Garching, Germany

We demonstrate all optical preparation and storage of a single electron in an individual self-assembled InGaAs quantum dot (QD) and high fidelity measurement of its spin projection by driving a luminescence recycling transition. Hereby, we optically induce spin-charge conversion to convert the spin information into charge occupancy (1e or 2e) and then repeatedly measure the charge occupancy by pumping an excited state of the negatively charged trion. By probing the temperature and magnetic field dependence of the spin dynamics we extract electron and hole Landé g-factors and map out the spectrum and spin structure of hot trion transitions. The devices investigated are QD spin memory structures that can be switched between two modes of operation; (i) charging, where optically generated holes are removed from the dot whilst electrons remain stored due to the presence of an AlGaAs barrier and (ii) readout, where excitons optically pumped into the dot recombine to produce luminescence. The spin lifetime of the stored electron was measured by monitoring the storage time dependence of the spin blockade as the temperature and magnetic field was varied.

HL 37.5 Tue 11:45 ER 164

Resonant photocurrent spectroscopy of excited states in a single quantum dot molecule — Florian Klotz[1], •Andreas Waeber[1], Kai Müller[1], Gerhard Abstreiter[1], Hubert Krenner[2], Martin Brandt[1], and Jonathan Finley[1] — [1]Walter Schottky Institut, Technische Universität München, Deutschland — [2]Lehrstuhl für Experimentalphysik I, Universität Augsburg, München

We present resonant photocurrent spectroscopy performed on a single quantum dot (QD) molecule consisting of a pair of vertically stacked self-assembled InGaAs quantum dots. The experiments are performed at low temperature by sweeping the electric field to tune the QD transitions in and out of resonance with an excitation laser kept at a fixed wavelength. Besides the expected anti-crossing of direct and indirect exciton states in the molecule, we observe a series of additional anticrossings that we identify as arising from coupling of excited excitonic states in the lower dot of the molecule with the orbital ground state of the neutral exciton in the upper dot. Furthermore, the photocurrent spectra yield first indications of non-radiative Förster coupling within the molecule that manifest as weak anti-crossings. We investigate both effects for applied magnetic fields from 0 up to 10 T allowing us to distinguish them via their individual magnetic field dependence.

HL 37.6 Tue 12:00 ER 164

Symmetry adapted formalisms to calculate elastic and electronic properties of (111)-oriented zincblende quantum dots — •Oliver Marquardt[1], Miguel A. Caro[1,2], Stefan Schulz[1], and Eoin P. O'Reilly[1,2] — [1]Tyndall National Institute, Lee Maltings, Cork, Ireland — [2]University College Cork, Cork, Ireland

(111)-oriented, site-controlled InGaAs quantum dots (QDs) are highly promising candidates for the generation of entangled photons, required for novel quantum logical and quantum cryptographic applications. Whereas conventional zincblende QDs grown along the [001] direction exhibit a non-vanishing fine structure splitting (FSS) intrinsically, the C_{3v}-symmetry of (111)-oriented QDs is high enough to allow for a vanishing FSS, as was recently confirmed experimentally. Due to the extremely small aspect ratio together with the huge size of these structures, the simulation of the electronic structure of such systems is computationally highly expensive. We have therefore analytically rotated the eight-band $\mathbf{k}\cdot\mathbf{p}$ formalism, together with a continuum elasticity model, to allow for an efficient and accurate description of such QDs in a (111)-oriented cell that allows for different discretizations along inplane and growth directions. Here we analyze realistic (111)-grown InGaAs QDs and provide a detailed picture of their elastic and electronic properties. Our formalisms for (111)-oriented zincblende systems also allows us to gain some more insight into the material parameters of wurtzite semiconductor materials.

[1]: O. Marquardt et al., to be submitted.
[2]: S. Schulz et al., Phys. Rev. B **84**, 125312 (2011).

HL 37.7 Tue 12:15 ER 164

Tight binding model of strain-reducing layers in semiconductor quantum dots — •Elias Goldmann and Frank Jahnke — Institute of theoretical physics, Universit of Bremen

In recent years, semiconductor quantum dots have been the subject of intense research. Especially the excitonic fine-structure splitting (FSS) has received much attention due to its influence on the photon pair entanglement of the quantum dot biexciton emission.

We present results of an atomistic empirical tight-binding model (ETB) for the calculation of electronic properties of semiconductor nanostructures. We choose a sp^3s^* basis localized at each atomic site and include next-neighbour-interaction as well as spin-orbit-coupling. The influence of lattice-mismatch induced strain is accounted for on an atomistic scale via the valence-force-field method using the Keating potential. An implementation of the Krylov-Schur algorithm with harmonic extraction in SLEPc [1] is used to compute the interior eigenstates and eigenenergies of the resulting TB-Hamiltonian.

We use the calculated eigenstates as an input for a full configuration interaction treatment to compute the FSS. Within this ETB model we investigate the electronic properties of lens- and trapezoid-shaped self-assembled InGaAs quantum dots in a InGaAs strain-reducing layer [2], embedded in a GaAs matrix and located on top a wetting layer. The influences of dot shape and Indium-concentration on the confined electronic states and optical transitions are presented.

[1] V. Hernandez *et al.*, ACM. Trans. Math. Software: **31** 351 (2005)
[2] A. Amtout *et al.*, J. Appl. Phys. **96** 3782 (2004)

HL 37.8 Tue 12:30 ER 164

Sharp luminescence from a site-controlled single quantum dot — •Ole Hitzemann[1], Alexander Dreismann[1], Erik Stock[1], André Strittmatter[1], Andrei Schliwa[1], Jan-Hindrik Schulze[1], Tim D. Germann[1], Waldemar Unrau[1], Udo W. Pohl[1], Axel Hoffmann[1], Dieter Bimberg[1], and Vladimir Haisler[2] — [1]Institut für Festkörperphysik, Technische Universität Berlin, Germany — [2]Institute of Semiconductor Physics, Russian Academy of Sciences, Novosibirsk, Russian Federation

Site-controlled growth of single quantum dots (QDs) is essential for applications such as single-photon sources. We investigate InGaAs QDs grown by metal organic vapor phase deposition using a buried stressor for lateral positioning. The buried stressor is formed by controlled partial oxidation of an AlGaAs layer to create an AlO_x aperture as it has been used previously for current-confinement in vertical-cavity surface emitting laser diodes. The oxidation reduces the volume of this layer thus inducing strain in adjacent GaAs layers. The QDs are grown on a GaAs surface 150 nm above the oxide layer but the nucleation sites are controlled by the inner boundaries of the oxide aperture.

Using a sub-micrometer oxide aperture we observe only luminescence from a single QD within a 60 meV spectral range. The observed luminescence consists of a doublet of two lines that are 80 μeV apart with a full width at half maximum of 80 μeV each, limited by the spectral resolution of the setup. In autocorrelation measurements using a Hanbury-Brown Twiss setup we demonstrate an antibunching thus proving emission from a single QD.

HL 37.9 Tue 12:45 ER 164

Scanning near-field infrared micro-spectroscopy on buried InAs quantum dots — •Markus Fehrenbacher[1], Rainer Jacob[1], Stephan Winnerl[1], Harald Schneider[1], Manfred Helm[1], Marc Tobias Wenzel[2], Anja Krysztofinski[2], Hans-Georg von Ribbeck[2], and Lukas M. Eng[2] — [1]Institut für Ionenstrahlphysik und Materialforschung, Helmholtz-Zentrum Dresden-Rossendorf, Germany — [2]Institut für Angewandte Photophysik, TU Dresden, Germany

Providing an optical resolution on the nanometer length scale, scanning near-field optical microscopy (SNOM) turned out to be a capable technique to investigate the optical properties of perovskites [1], buried semiconductors [2] and single quantum dots [3]. Thereby, the linewidth of the observed resonances (5 - 8 meV) is significantly smaller than the inhomogeneously broadened line-width of other spectroscopic measurements. Using a scattering-type-SNOM (s-SNOM) combined with a tunable free-electron laser (FEL) light source we investigated the electronic structure of single InAs quantum dots, capped under a 70 nm thick GaAs layer [3]. Spectroscopic near-field scans clearly identified two inter-sublevel transitions within the quantum dots at 85 meV and 120 meV, contrasting from the surrounding medium. Moreover, spatially scanning the s-SNOM tip at fixed excitation energies allowed mapping the 3D distribution of such buried quantum dots.

[1] S. Kehr et al. Nature Comm. 2, 249 (2011) [2] R. Jacob et al., Optics Ex. 18, 26206 (2010) [3] R. Jacob, PhD thesis, TU Dresden (2011)

HL 37.10 Tue 13:00 ER 164

Single site-controlled InGaAs quantum dots: narrow linewidth and electrical current injection — •Alexander Huggenberger[1], Christian Schneider[1], Tobias Heindel[1], Alexander Niederstrasser[1], Stephan Reitzenstein[1,2], Sven Höfling[1], Lukas Worschech[1], Alfred Forchel[1], and Martin Kamp[1] — [1]Wilhelm Conrad Röntgen-Center for Complex Material Systems und Technische Physik, Universität Würzburg — [2]Institut für Festkörperphysik, Technische Universität Berlin

Site-controlled quantum dots (SCQDs) offer a scalable way to integrate single quantum dots (QDs) into devices like single photon sources or sources of entangled photons. There are different ways to direct the QD nucleation to pre-defined positions. In our work we use ebeam lithography and wet etching of nano-holes into a GaAs (100) substrate to obtain both control over the QD position and high optical quality of the SCQDs. With our approach we can reduce the effect of spectral diffusion that broadens the single SCQD emission.

We present our results on the improved optical quality of site-controlled quantum dots that can be excited either optically or electrically. The linewidth of single SCQD photoluminescence could be reduced to only 38 μeV for above bandgap optical excitation. Furthermore, we show the integration of site-controlled QDs into optical cavities and achieve cavity enhanced emission as well as emission of non-classical light under electrical current injection.