HL 7 Quantum dots and wires: Optical properties I

Time: Monday 10:15–13:00 Room: POT 151

HL 7.1 Mon 10:15 POT 151

Spectral jitter in cathodo- versus photoluminescence of single InGaAs quantum dots — •Erik Stock, Till Warming, Robert Seguin, Sven Rodt, Konstantin Pötschke, and Dieter Bimberg — Institut für Festkörperphysik, TU Berlin, Hardenbergstr. 36, D-10623 Berlin

Spectral jitter in the lumiscence of single quantum dots (QD) has been regulary observed. This jitter is attributed to the quantum confined Stark effect, induced by local electrical fields near the QDs. For future single QD devices this jitter might be harmfull (for example for coupling to a microcavity) Here we present a comparison of the jitter of the same single QD using cathodoluminescence (CL) and micro-photoluminescence (PL). In CL the primary electrons have larger energy, then the exciting photons in PL. We observe that the amplitude of the jitter in CL is much larger then in PL experiments. We conclude that it is impossible to extract information about the structural quality of QD heterostructures by comparison of the jitter in single dot luminescence measurements, done with different excitation sources.

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HL 7.2 Mon 10:30 POT 151

Impact of Piezoelectricity on Shape and Order of Wavefunctions in Uncapped InAs/GaAs Quantum Dots — •Andrei Schliwa[1], Theophilos Maltezopoulos[2], Markus Morgenstern[3], Roland Wiesendanger[2], and Dieter Bimberg[1] — [1]Institut für Festkörperphysik, Technische Universität*Berlin — [2]Institute of Applied Physics, University of Hamburg — [3]II. Inst. of Physics B, RWTH Aachen University

Recently it became possible to map the shape of electron wavefunctions in uncapped InAs/GaAs quantum dots (QDs) by using scanning tunneling spectroscopy (STS) [1]. These measurement revealed an anomalous order of the single particle states in most of the investigated QDs which triggered the here presented theoretical investigations based on the eight-band-$\mathbf{k}\cdot\mathbf{p}$ model.

The outer shape of the model-QD is specified by using the morphological data, recorded as a byproduct of the STS-method, whilst the composition profile has been treated as variable. All of the measured QDs are elongated in $[1\bar{1}0]$ direction with a larger in-plane anisotropy-ratio at the QD-apex than at the bottom. This alone however is not sufficient to explain the observed wavefunction order. It requires the inclusion of the strain induced piezoelectric field to amplify the already present confinement anisotropy to finally obtain the anomalous order of the electron orbitals in the simulation.

[1] Maltezopoulos T., Bolz A., Meyer C., Heyn C., Hansen W., Morgenstern M., Wiesendanger R., Phys. Rev. Lett. 91, p.196804 (2003)

HL 7.3 Mon 10:45 POT 151

Noise properties of ultrabroadband Quantum Dot Superluminescent Light Emitting Diodes — •Martin Blazek, Joachim Kaiser, Tobias Gensty, and Wolfgang Elsässer — Institut für Angewandte Physik, Technische Universität Darmstadt, Schloßgartenstraße 7, D-64289 Darmstadt

Incoherent light applications, for example, Optical Coherence Tomography (OCT), require high power, low noise, and broad bandwidth light sources. We experimentally investigate the intensity noise properties of ultrabroadband Superluminescent Light Emitting Diodes (SLEDs), which are based on Quantum Dot structures. The spectral emission bandwidth of more than 50 nm (FWHM) is associated with a short coherence length guaranteeing a high axial resolution in OCT operation. The examined SLEDs emit more than 30 mW centered around 1300 nm. In a direct noise detection setup, we use a large area InGaAs photodiode to detect the emitted light. The amplified photocurrent noise is measured with an Electrical Spectrum Analyzer and normalized to the shot noise level. Spatially, spectrally and polarization resolved measurements are performed to reveal relations between the noise behavior and the SLEDs specific spatial and spectral emission properties. The results will be discussed with respect to device characteristics and OCT applications.

HL 7.4 Mon 11:00 POT 151

Optical Nearfield Spectroscopy of Individual InAs/GaAsQuantum Dots at Low Temperatures — •Omar Al-Khatib, Kai Hodeck, and Mario Dähne — Technische Universität Berlin, Institut fürFestkörperphysik, Hardenbergstr. 36, 10623 Berlin, Germany

Semiconductor quantum dots attract considerable interest for future technical purposes. In particular the possibility to realise discrete energy levels in solid-state matter promises to provide a basis for innovations like new laser sources or quantum information technology. We report on photoluminescence spectroscopy of individual MOCVD-grown InAs/GaAs-dots. For that purpose we use Scanning Nearfield Optical Microscopy (SNOM) in the range from 10 K up to 300 K [1]. We focus on the investigation of relatively large quantum-dots, which are grown with low dot density and display ground-state emission of 1300 nm wavelength at room-temperature, thus matching telecommunication fiberoptic requirements. By taking single-dot spectra under varying excitation intensity, we observe photoluminescence emissions from different recombination processes, in particular biexciton and trion recombination, and discuss the data with theoretical models of multiexciton complexes. We would like to thank Konstantin Pötschke and Prof. Dr. D. Bimberg for providing the samples.

[1] K. Hodeck et al., phys. stat. sol. (c)No.4, 1209 (2003)

HL 7.5 Mon 11:15 POT 151

InP-Quantum Dots in AlGaInP — •Wolfgang-Michael Schulz[1,2], Robert Rossbach[1,2], Michael Jetter[1,2], and Peter Michler[2] — [1]4^{th} Physics Institute, University Stuttgart, Pfaffenwaldring 57, 70550 Stuttgart, Germany — [2]5^{th} Physics Institute, University Stuttgart, Pfaffenwaldring 57, 70550 Stuttgart, Germany

In recent years low dimensional structures have attracted great interest in research and device fabrication because of the strong change in the density of states and the associated effects. One major issue of the quantum dots (QDs) is the emission at elevated temperatures, especially for further applications towards single-photon devices in the visible spectral range. The InP-material system can fulfill these requirements. Therefore, to achieve a high electron confinement we grew InP-QDs embedded in high band gap AlGaInP. The samples were structurally investigated by atomic force microscopy as well as optically by power-, temperature-dependent and time-resolved photoluminescence. By analysing the temperature behaviour we found that even at high aluminum containing barriers the carriers can only escape to the direct Γ-band of the AlGaInP. We could also observe single-photon emission in the wavelength range from 670 nm up to 565 nm.

HL 7.6 Mon 11:30 POT 151

Diamagnetic shift of disorder-localized excitons in narrow quantum wells — •M. Erdmann[1], M. Wenderoth[1], R. G. Ulbrich[1], S. Malzer[2], and G. Döhler[2] — [1]Universität Göttingen, IV. Physikalisches Institut, Germany — [2]Universität Erlangen-Nürnberg, Institut für technische Physik, Germany

Magneto-μ-photoluminescence (μPL) experiments on narrow $GaAs/Al_{0.3}Ga_{0.7}As$ quantum wells reveal an increase in diamagnetic shift of localized exciton states with emission energy. In a narrow GaAs/AlAs double quantum well, even negative diamagnetic shift is observed. μPL spectra were obtained in a confocal setup with a magnetic field applied perpendicular to the quantum well plane. This is the first experimental evidence that the diamagnetic shift of disorder-localized excitons is a sum of two contributions: A positive shift from the relative motion, and a negative center-of-mass shift resulting from disorder. [1]

[1] M. Grochol, F. Grosse, and R. Zimmermann, PRB 71, 125339 (2005)

HL 7.7 Mon 11:45 POT 151

Resonant Rayleigh scattering from single excitons in disordered GaAs/AlGaAs quantum wells — •Daniel Schwedt[1], Rico Schwartz[1], Heinrich Stolz[1], Dirk Reuter[2], Andreas Wieck[2], Galina Khitrova[3], and Hyatt M. Gibbs[3] — [1]Universität Rostock, Institut für Physik, Universitätsplatz 3, 18051 Rostock — [2]Ruhr-Universität Bochum — [3]College of Optical Sciences, Tucson, Az.

We report on experiments performed on MBE-grown quantum well samples exhibiting different kinds of disorder such that the excitons be-

come localized either in the nano-roughness of the interfaces or in slightly larger islands of monolayer steps, i.e. interface fluctuation quantum dots. The excitons have been excited resonantly in Brewster geometry and the elastically scattered signal, i.e. resonant Rayleigh scattering (RRS), has been observed in normal direction with microscopic resolution. The limitation of spatial resolution by diffraction is counterbalanced with high spectral resolution limited only by the linewidth of the exciting cw laser (less than 20 μeV in this case) so that the determined RRS spectra break up into single exciton lines. Thus, important sample parameters like the homogeneous exciton linewidth or relative oscillator strengths are directly measureable by a straight forward resonance scan of the excitation energy. Moreover, microscopically resolved RRS may become a tool for determination of the extension of the exciton's center-of-mass wave functions as well as local energy distribution of the exciton states and such giving insight to the underlying disorder potential.

HL 7.8 Mon 12:00 POT 151

Strong and weak coupling of quantum dot excitons in pillar microcavities — •Stephan Reitzenstein[1], Carolin Hofmann[1], Andreas Löffler[1], Alexander Kubanek[1], Johann Peter Reithmaier[1,2], Martin Kamp[1], Vladimir Kulakovskii[3], Leonid Keldysh[4], Thomas Reinecke[5], and Alfred Forchel[1] — [1]Technische Physik, Universität Würzburg, Würzburg, Germany — [2]Technische Physik, Universität Kassel, Kassel, Germany — [3]Institute of Solid State Physics, RAS, Chernogolovka, Russia — [4]Lebedev Physical Institute, RAS, Moscow, Russia — [5]Naval Research Laboratory, Washington DC, USA

We report on strong as well as weak coupling of self assembled InGaAs quantum dots in high-Q semiconductor micropillar cavities. The micropillar cavities are based on a planar microcavity structure grown by molecular beam epitaxy. The planar structure consists of a GaAs λ-cavity centered between a lower and an upper distributed GaAs/AlAs Bragg reflector. In the center of the GaAs λ-cavity a low density layer of InGaAs QDs is introduced. By means of electron beam lithography and deep plasma etching we realized micropillars with Q-factors of about 5.000 to 35.000. The low quantum dot density allows us to investigate the interaction of single QD excitons and the vacuum field of the microcavity by temperature tuning. In addition to simple cases of strong coupling with a vacuum Rabi splitting of up to 140 μeV we will present examples of sequential coupling where QD excitons with different emission energies show strong or weak coupling with the optical mode of the same micropillar at different resonance temperatures.

HL 7.9 Mon 12:15 POT 151

Micro-photoluminescence investigations on single InGaN quantum dots up to 150 K — •K. Sebald, H. Lohmeyer, J. Gutowski, T. Yamaguchi, and D. Hommel — Institute of Solid State Physics, University of Bremen, Germany

To fully utilize the potential of InGaN quantum dot (QD) samples for future device applications their optical properties must be studied thoroughly. We will present micro-photoluminescence (μ-PL) measurements on single InGaN QDs. The QD samples were grown by MOVPE on sapphire (0001) substrates. The InGaN is deposited on a GaN buffer at a temperature of 700°C. The InGaN QD layer is stabilized by a novel kind of capping layer. For the final GaN capping the growth temperature is increased up to 820°C. Mesa structures with diameters down to 200 nm have been fabricated by focused-ion-beam etching after evaporation of an Al_2O_3 protection layer. Due to the low spatial surface density of the QDs one gets access to the optical properties of isolated QDs already at mesa diameters of 600 nm. The emission peaks possess linewidths down to 0.2 meV which is in the order of the spectral resolution of the experimental setup. μ-PL measurements on single InGaN QDs were carried out in dependence on the excitation density. We report on the observation of binding and antibinding multiexcitonic states. Furthermore, we were able to analyse the emission of single QDs up to 150 K and to quantify their activation energy.

HL 7.10 Mon 12:30 POT 151

Excited state emission and carrier dynamics of single InP/GaInP quantum dots — •Matthias Reischle[1], Gareth J. Beirne[1], Robert Rossbach[2], Michael Jetter[2], and Peter Michler[1] — [1]5. Physikalisches Institut, Universität Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany — [2]4. Physikalisches Institut, Universität Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany

InP quantum dots (QDs) are promising candidates for lasers and single photon sources in the visible spectral range. To proceed towards a room temperature operating device first the complex carrier dynamics have to be understood. Therefore we have performed power dependent-, temperature dependent-, and time-resolved measurements on single QDs. Approximately 50% of the dots exhibit a number of additional recombination-lines which emerge at high power-densities and are thought to originate from excited states. In general we have observed up to four distinct excited states from these dots. Furthermore, we have observed a strong correlation between the level spacings and the activation energies obtained from fitting the temperature dependence of the emission intensity using an Arrhenius model. This indicates, that at elevated temperatures carriers can occupy succesively higher excited states and thereby eventually escape from the dot.

HL 7.11 Mon 12:45 POT 151

Spin coherence in spherical CdS quantum dots — •P. Nahalkova[1,2], D. Sprinzl[1], P. Nemec[1], P. Maly[1], V. N. Gladilin[2], and J. T. Devreese[2] — [1]Charles University in Prague, Ke Karlovu 3, 121 16 Prague 2, Czech Republic — [2]Universiteit Antwerpen, Universiteitsplein 1, B-2610 Antwerpen, Belgium

Spin coherence in quasi-spherical CdS quantum dots (QDs) in a glass matrix has been investigated. Time-resolved differential transmission experiments were performed to measure the decay of the degree of circular (linear) polarization DCP (DLP). We show that due to the nearly spherical shape of our QDs, the properties of DCP and DLP differ considerably from those of the most often investigated pyramidal self-assembled QDs. Namely, the electron spin relaxation time of $\sim$ 10 ns can be deduced from the DCP decay. The DCP dynamics measured on ns timescale can be explained well by intralevel exciton transitions with electron spin flip, driven by the electron-hole exchange interaction and assisted by two LO phonons. Two-phonon processes contribute significantly also to exciton transitions without electron spin flip, which are manifested in DCP and DLP dynamics on ps timescale. We also discuss the influence of attractive interaction between electron-hole pairs on DCP and DLP. This work was supported by the Ministry of Education of the Czech Republic in the framework of the research plan MSM 0021620834 and the research centre LC510, as well as by the Bijzonder Onderzoeksfonds of the Universiteit Antwerpen, BOF NOI UA 2004, IUAP (Belgium), and the European Commission SANDiE Network of Excellence, contract No. NMP4-CT-2004-500101.