HL 64: Quantum Dots and Wires: Optical Properties VI

Time: Friday 10:15–13:00 Location: H14

HL 64.1 Fri 10:15 H14

Elastic strain engineering of quantum dot excitonic emission in nanomembranes and optical resonators — •Fei Ding[1], Ranber Singh[2], Johannes Plumhof[1], Tim Zander[2], Gabriel Bester[2], Armando Rastelli[1], and Oliver Schmidt[1] — [1]Institute for Integrative Nanosciences, IFW Dresden, Helmholtzstr. 20, D-01069 Dresden, Germany — [2]Max-Planck-Institut fuer Festkoerperforschung, Heisenbergstr. 1, D-70569 Stuttgart, Germany

We study the effect of an external biaxial stress on the light emission of single InGaAs/GaAs (001) quantum dots (QD) embedded in a 200 nm-thick-membrane. Reversible and bi-directional spectral tuning of QD excitonic emission is demonstrated via a simple electro-mechanical device. The most intriguing finding is that biaxial strain is a reliable tool to engineer the QD electronic structure and reach color coincidence between exciton and biexciton emission, providing a vital prerequisite for the generation of polarization entangled photon pairs through a time reordering strategy. The physical origin of this new phenomenon is discussed based on the empirical pseudopotential calculations.

With similar technique we study the effect of biaxial stress on single QDs embedded in microring resonators. The microrings can be reversibly stretched or squeezed, resulting in a controllable engineering of both QD emissions and optical modes. Our results open up a new tuning strategy to study cQED with semiconductor quantum dots.

HL 64.2 Fri 10:30 H14

Effect of substrate thickness on uniaxial strain–induced single quantum dot emission energy tuning — •Klaus D. Jöns[1], Robert Hafenbrak[1], Sven M. Ulrich[1], Lijuan Wang[2], Fei Ding[2], Johannes D. Plumhof[2], Armando Rastelli[2], Oliver G. Schmidt[2], and Peter Michler[1] — [1]Institut für Halbleiteroptik und Funktionelle Grenzflächen, Universität Stuttgart, Allmandring 3, 70569 Stuttgart, Germany — [2]Institute for Integrative Nanosciences, IFW Dresden, Helmholtzstraße 20, 01069 Dresden, Germany

The ability to tailor the optical properties of epitaxially grown quantum dots (QDs) is one of the huge advantages of these kind of solid state quantum emitters. In particular, the possibility to tune the emission energy is an important prerequisite to generate indistinguishable photons from two different quantum emitters. In our work we present in–situ emission energy tuning of self–assembled InGaAs/GaAs QDs by uniaxial strain. For this purpose we glued the sample tightly on a piezo stack. Our technique allows to apply tunable tensile and compressive uniaxial strain along the [110] crystal axis perpendicular to the growth direction. The applied strain changes the emission energy of the QD by enlarging respectively reducing the lattice constant and thus the band gap. Micro–photoluminescence measurements at $T = 10\,K$ show that the spectral emission of the QDs can be reversibly shifted in a controlled way. We use different substrate thinning techniques to increase the uniaxial strain at the lattice plane of the QDs. This leads to an increased tuning range of the emission energy. Samples with completely removed substrate show an emission tuning range up to 2.8 meV.

HL 64.3 Fri 10:45 H14

Strain tuneable photoluminescence from natural InAs quantum dots — •Matthias Klingbeil, Matthias Grave, Sven Wildfang, Wolfgang Hansen, Detlef Heitmann, and Stefan Mendach — Institut für Angewandte Physik,Jungiusstr 11, 20355 Hamburg

The growth of self-assembled InAs-quantum dots on a GaAs substrate is inherently connected to the formation of an InAs wetting layer. Recently it was shown that fluctuations in the composition and thickness of this wetting layer lead to the formation of shallow zero dimensional confinements [1], so called natural InAs quantum dots [nQD]. The photoluminescence of these nQD is typically located in the low energy tail of the wetting layer emission. Here, we show that the nQD emission can be shifted away from the wetting layer and increased in intensity by the application of stress. For this purpose we embed the nQD in free standing lamellae that can be bent by a glass needle during the photoluminescence experiment. In the unstrained state all nQDs exhibit a low intensity. The application of strain amplifies the luminescence of certain nQDs and red shifts their emission away from the wetting layer signal by up to 40 meV.

[1] Babinski et al., Appl. Phys. Lett. 92, 171104 (2008).

HL 64.4 Fri 11:00 H14

Effect of biaxial stress on single particle states and binding energies of charged excitons and biexciton in In(Ga)As/GaAs(001) self-assembled quantum dots — •Ranber Singh[1], Fei Ding[2], Johannes Plumhof[2], Tim Zander[2], Gabriel Bester[1], Armando Rastelli[2], and Oliver Schmidt[2] — [1]Max-Planck-Institut für Festkörperforschung, Heisenbergstrasse 1, 70569 Stuttgart, Germany — [2]Institute for Integrative Nanosciences, IFW Dresden, Helmholtzstr 20, D-01069 Dresden, Germany

We study the effect of an external biaxial stress on single particle states and binding energies of charged excitons and biexciton relative to that of neutral exciton in In(Ga)As/GaAs(001) quantum dots. We performed million-atom empirical pseudopotential calculations on *realistic* In(Ga)As/GaAs(001) quantum dots. We find that compressive biaxial stress increases the electron localization and hole delocalization. The binding energies of the positive trion and biexciton increase under compressive stress. Depending upon the value of binding energy of biexciton and available biaxial stress, the binding energy of biexciton can be tuned to zero which allows for the generation of entagnled photon pairs across generations in biexciton cascade process in In(Ga)As/GaAs(001) self-assembled quantum dots.

HL 64.5 Fri 11:15 H14

Cascaded exciton emission of an individual strain-induced quantum dot — •Florian J. R. Schülein[1], A. Laucht[2], M. Mattila[3], J. Riikonen[3], M. Sopanen[3], H. Lipsanen[3], J. J. Finley[2], A. Wixforth[1], and H. J. Krenner[1] — [1]Lehrstuhl für Experimentalphysik I, Universität Augsburg, Universitätsstr. 1, 86159 Augsburg, Germany — [2]Walter Schottky Institut, Technische Universität München, Am Coulombwall 3, 85748 Garching, Germany — [3]Department of Micro and Nanosciences, Micronova, Helsinki University of Technology, P.O. Box 3500, FIN-02015 TKK, Finland

Individual strain-induced quantum dots defined by InP stressors in an InGaAs/GaAs quantum well are isolated by electron beam lithography and selective wet chemical etching of stressors from an ensemble. Single exciton (1X) and biexciton (2X) are identified by power-dependent photoluminescence spectroscopy and do not show any finestructure splitting. Time-resolved PL spectroscopy performed at different excitation powers shows clear indications of cascaded emission of unpolarized photons in the transition from the triexciton back to the crystal ground state: The onset of the 1X emission is delayed with respect to the laser excitation pulse and the decay of the higher exciton levels at higher excitation powers. The decay time of one transition agrees with the rising time of the next lower transition of the cascade. This observation is characteristic for a the cascaded emission of single photons. Furthermore, we can reproduce this behavior using a rate equation model for a three-step cascade. Our system is a potential candidate for a source of polarization entangled photon pairs.

15 Min. Coffee Break

HL 64.6 Fri 11:45 H14

Optical properties of GaAs quantum dots fabricated by filling of self-assembled nanoholes — •Christian Heyn[1], Andrea Stemmann[1], Tim Köppen[1], Christian Strelow[1], Tobias Kipp[1], Matthias Grave[1], Matthias Klingbeil[1], Stefan Mendach[1], Andreas Schramm[2], and Wolfgang Hansen[1] — [1]Institut für Angewandte Physik,Jungiusstr 11, 20355 Hamburg — [2]Optoelectronics Research Centre, Tampere University of Technology, Finnland

Local droplet etching (LDE) is a very powerful technique which allows the self-assembled patterning of GaAs or AlGaAs surfaces without any lithographic steps. The LDE process starts with the generation of Ga, Al, or In droplets on the surface. Using appropriate process temperatures, deep nanoholes are drilled beneath the liquid droplets into the substrate. The method was introduced by Wang et al. [1] for etching of GaAs surfaces with Ga droplets. We have expanded the range of materials [2] and studied the time evolution of the LDE process [3]. By filling of nanoholes in AlGaAs with GaAs, we have fabricated GaAs quantum dots (QDs).[4] Dependent on the process parameters, ensembles of these LDE QDs show either broadband optical emission

or very sharp lines up to room temperature. Furthermore, the optical fine-structure of single LDE QDs is studied.

[1] Zh. M. Wang et al., Appl. Phys. Lett. 90, 113120 (2007).
[2] A. Stemmann et al., Appl. Phys. Lett. 93, 123108 (2008).
[3] Ch. Heyn et al., Appl. Phys. Lett. 95, 173110 (2009)
[4] Ch. Heyn et al., Appl. Phys. Lett. 94, 183113 (2009).

HL 64.7 Fri 12:00 H14

Nuclear spin-polarization of InGaAs quantum dots due to electrical spin-injection — Pablo Asshoff, •Andreas Merz, Gunter Wüst, Heinz Kalt, and Michael Hetterich — Karlsruhe Institute of Technology (KIT) and DFG Center for Functional Nanostructures (CFN), 76131 Karlsruhe, Germany

For quantum information processing, the electronic spin states in semiconductor quantum dots can be used as two-level systems. Polarization of the nuclei resulting from spin-flip processes of the electrons is regarded to be detrimental to this. On the other hand, this interaction provides an easy access to the spin states of the nuclei. In this contribution, we demonstrate that electrical pumping of the quantum dots with spin-polarized electrons in a spin-injection light-emitting diode (spin-LED, [1]) can be used to achieve a nuclear spin polarization.

[1] M. Hetterich et al., in Advances in Solid State Physics, edited by R. Haug (Springer, Berlin, 2009), Vol. 48, p. 103

HL 64.8 Fri 12:15 H14

Proposal for a nanowire-based terahertz quantum cascade laser — •Thomas Grange and Peter Vogl — Walter Schottky Institut, Technische Universität München, 85748 Garching, Germany

In spite of many efforts of optimization in the past few years, operation of terahertz quantum cascade laser (THz QCL) is still limited to cryogenic temperature. In THz QCLs, the lasing transition occurs between two subbands which are separated by less than the optical phonon energy. As the temperature increases, electrons gain sufficient in-plane kinetic energy in order to scatter efficiently between subbands by emitting optical phonons, reducing drastically the population inversion. An efficient way to circumvent this limitation is to use a structure in which the lateral motion of electrons is quantized. The use of an array of nanowires seems an appealing solution. In the present work, we calculate the transport and optical gain in nanowire heterostructures. Our calculation is made in the non-equilibrium green function (NEGF) framework. We incorporate scattering mechanisms due to interaction with phonons. Anharmonic interaction between phonons is also taken into account since it leads to scattering between the polaron states formed by electrons interacting with polar optical phonons [1,2]. We propose a structure that yields optical gain up beyond room temperature in the THz range. We highlight the physical differences with usual QCLs based on homogeneous 2-D layers.

[1] T. Grange, R. Ferreira and G. Bastard, Phys. Rev. B **76**, 241304(R) (2007).
[2] E. A. Zibik *et al.*, Nature Materials **8**, 803 (2009).

HL 64.9 Fri 12:30 H14

Light Harvesting in SC Core-Shell Nanocrystals — •Peter Lemmens[1], Hongdan Yan[1], Abhinandan Makhal[2], and Samir Kumar Pal[2] — [1]IPKM, TU-BS, Braunschweig — [2]SNBC, Kolkata, India

The effect of capping and functionalization of core/shell type CdSe/ZnS semiconductor QDs is investigated by coupling/complexation with benzoquinone and TiO_2 nanoparticles using ps resolved time correlated single photon counting and fs carrier dynamics. Our aim is to improve photostability and understand energy transfer involved in light harvesting. Work supported by DFG.

HL 64.10 Fri 12:45 H14

Electroluminescence from silicon nanoparticles — •Jens Theis[1], Cedrik Meier[2], Axel Lorke[1], and Hartmut Wiggers[3] — [1]Experimental Physics and CeNIDE, University of Duisburg-Essen — [2]Nanophotonics & Nanomaterials Group, University Paderborn — [3]Institute of Combustion and Gas Dynamics and CeNIDE, University of Duisburg-Essen

We have fabricated an electroluminescence device based on silicon nanoparticles on a micropatterned GaAs heterostructure. The Si nanoparticles have been synthesized from the gas phase in a low-pressure microwave plasma using SiH_4 as a precursor. The nanoparticles were dispersed from an aqueous solution onto the patterned GaAs sample. For carrier injection, the particle layer was incorporated into a capacitor-like structure, where a transparent ITO layer served as the top-electrode. An AC-voltage accelerates electrons from the top gate to the GaAs-back contact. These electrons generate secondary electrons and holes by impact ionization and thus induce electron-hole pair recombination in the nanoparticles. For further analysis an optical, high resolution two-dimensional scans of the electroluminescence device was performed in a μ-Photoluminescence setup. Additionally, we study the influence that waveform, frequency and amplitude of the AC voltage on the electroluminescence. PL measurements made on separate samples of the same nanoparticles were also conducted. As a result, we conclude that the electroluminescence light around 700 nm and around 850 nm arise from the nanoparticles and the GaAs substrate, respectively.