HL 74: Quantum dots: Optical properties

Time: Thursday 9:30–12:15 Location: H16

HL 74.1 Thu 9:30 H16

Strongly size dependent polar exciton-LO-phonon interaction in GaN/AlN quantum dots — •Johannes Settke, Andrei Schliwa, Gordon Callsen, Juri Brunnmeier, Axel Hoffmann, and Christian Thomsen — Institut für Festkörperphysik, Technische Universität Berlin, Germany

Recently, strongly size dependent exciton-LO-phonon interaction for epitaxial GaN/AlN quantum dots (QD) was observed experimentally by analyzing the LO-phonon sidebands of single-QD excitonic peaks. Depending on the exciton energy, ranging from 3.2 eV to 4.3 eV, values of the Huang-Rhys parameter S between 0.5 and 0.01 were deduced. Since the polar coupling strength (described by S) for an exciton is proportional to the squared absolute value of the Fourier transformed difference of the probability densities of the electron and hole, S provides a measure for the electron-hole separation.

GaN/AlN QDs are well known for their strong intrinsic piezo- and pyroelectrical fields along the c-axis, giving rise to excitonic charge separation analogous the quantum confined Stark effect. As this charge separation is known to be dependent on the QD height, it is mirrored by a variation of the parameter S.

Here, we calculate the Huang-Rhys parameter for the ground-state exciton as function of size and composition using a strain dependent 3D implementation of the eight-band k*p model taking into account piezo- and pyroelectric effects. We discuss the interrelation of QD size, built-in fields, exciton energy, dipole-moment and Huang-Rhys parameter S.

HL 74.2 Thu 9:45 H16

Spin-flip Raman scattering on Γ-X mixed excitons in indirect band-gap (In,Al)As/AlAs quantum dots — •Dennis Kudlacik[1], J. Debus[1], D. Dunker[1], V. F. Sapega[2], T. S. Shamirzaev[1], E. L. Ivchenko[2], D. R. Yakovlev[1,2], and M. Bayer[1] — [1]Experimentelle Physik 2, Technische Universität Dortmund, 44227 Dortmund, Germany — [2]Ioffe Physical-Technical Institute, Russian Academy of Sciences, 194021 St. Petersburg, Russia

We studied the fine structure of the indirect exciton in self-assembled (In,Al)As/AlAs quantum dots (QDs) by means of spin-flip Raman scattering (SFRS). The QDs are characterized by a type-I band alignment, wherein, dependent on the dot size, a crossover between the energetically lowest conduction-band states of the Γ- and X-valley occurs. This Γ-X mixing of the electron levels is used to optically study the indirect in momentum-space exciton. It has a long recombination lifetime and longitudinal spin relaxation time of up to several milliseconds. Using the resonant SFRS the g-factor tensors of the indirect exciton, Γ-valley heavy-hole, and X-valley electron are determined. The spin-flip scattering mechanisms are based on acoustic phonon interaction in tilted magnetic field geometries. The efficiencies of the electron and heavy-hole spin scattering strongly depend on the excitation energy across the inhomogeneously broadened QD ensemble. The Γ-valley electron cannot be observed because of its short lifetime and the broad dispersion of its g-factor corresponding to the strong variation in the QD sizes, which is evidenced in experiment and theory.

HL 74.3 Thu 10:00 H16

GaAs Quantum Dot Molecules of ultra-low density — •Achim Küster, David Sonnenberg, Andreas Graf, Christian Heyn, and Wolfgang Hansen — Institut für Angewandte Physik, Universität Hamburg, 20355 Hamburg, Germany

We present the fabrication and optical properties of GaAs quantum dot molecules (QDM). The QDM are fabricated by filling nanoholes in an AlGaAs surface with a GaAs/AlGaAs/GaAs layer sequence. The nanoholes are formed using local droplet etching with Al droplets on AlGaAs substrates. By optimizing the arsenic flux during droplet deposition an ultra-low density of some $\cdot 10^6$ cm^{-2} can be achieved [1], allowing the study of single QDM. With our fabrication method we have good and independent control on the dot size and the tunnel barrier in the QDM. The AlGaAs layer between the GaAs layers forms the tunnel barrier with thickness that is tuned from 1 nm to 20 nm in our experiments. Also, the dot size can be tuned separately in these structures. In samples with tunnel barrier thickness below 5 nm we observe non-resonant tunnelling [2] in these QDMs as a clear sign of coupling, while at a barrier thickness of 15 nm the optical spectra show no signature of tunnelling any more. Furthermore, we have integrated the QDMs into Schottky-diode structures and observed strong Stark-shifts up to 25 meV at typical fields of $2 \cdot 10^7$ V/m. [1] D. Sonnenberg et al., APL **101**, 143106 (2012); [2] M. Reischle et al., PRB **76**, 085338 (2007)

HL 74.4 Thu 10:15 H16

MOVPE grown InAs quantum dots with strain reducing layer — •Matthias Paul, Jan Kettler, Michael Jetter, and Peter Michler — IHFG, Universität Stuttgart, Deutschland

In recent years, InAs semiconductor quantum dots (QDs) have been studied extensively due to their potential application in quantum information networks. Based on their good optical properties and small area densities InAs QDs are excellent candidates for sources of entangled or indistinguishable photons. An implementation in fiber-coupled networks, however, requires emission wavelengths of 1310 nm or 1550 nm to minimize absorption losses.

Therefore, typical emission energies of InAs QDs need to be redshifted, e.g. by a strain reducing InGaAs layer on top of the QDs. This leads to both a reduction of the effective band gap and to an increase of the size of the QDs which results in lower emission energies.

The fabrication of InAs QDs for the aforementioned spectral range by metal-organic vapor-phase epitaxy usually leads to high area densities. In this case, a structuring a posteriori is necessary to investigate single QDs. By choosing the presented sample structure and growth parameters our samples show area densities of around 10^6 cm^{-2}. This renders an additional patterning unnecessary. The emission wavelengths of the QDs are around 1050 nm. Distributed Bragg reflectors (DBR), optimized for this spectral range, are used to increase the collection efficiency for micro-photoluminescence measurements. Correlation experiments and time-resolved measurements show the good optical properties of our InAs QDs.

HL 74.5 Thu 10:30 H16

Spectroscopy on single buried InAs quantum dots by scattering scanning near-field infrared microscopy — •Markus Fehrenbacher[1], Rainer Jacob[1], Stephan Winnerl[1], Jayeeta Bhattacharyya[1], Harald Schneider[1], Marc Tobias Wenzel[2], Hans-Georg von Ribbeck[2], Lukas M. Eng[2], Paola Akinson[3], Oliver G. Schmidt[3], and Manfred Helm[1] — [1]Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany — [2]TU Dresden, Dresden, Germany — [3]Leibniz Institute for Solid State and Materials Research, Dresden, Germany

Quantum dots are a highly interesting material system for many application purposes such as single photon emitters in the near-infrared, but also for mid- and far-infrared applications. Studying the linewidth of involved optical transitions offers valuable clues to the dephasing mechanisms of the trapped electrons. However, due to size fluctuations of the quantum dots, inhomogeneous broadening of the signals usually hides this information when investigating ensembles of dots. Therefore, single-dot spectroscopy has to be performed for this purpose. In contrast to studies of interband transitions this is not well established at all for intersublevel transitions. In this work, scattering type scanning near-field optical microscopy (s-SNOM) in combination with a free-electron laser is used to investigate intersublevel transitions in single self-assembled buried InAs quantum dots. Thereby, spectrally resonant optical contrast to the surrounding GaAs substrate is observed at photon energies of 83 meV and 123 meV, which can clearly be assigned to the s-d and p-d transitions of single conduction band electrons.

Coffee break

HL 74.6 Thu 11:00 H16

Tailoring the optical properties of single semiconductor quantum dots with metallic planar- and nano-structures — •Hongyi Zhang[1,3], Klas Lindfors[1,3], Yongheng Huo[2], Armando Rastelli[2], Oliver G. Schmidt[2], Harald Giessen[1,3], and Markus Lippitz[1,3] — [1]Max Planck Institute for Solid State Research — [2]Institute for Integrative Nanosciences, IFW- Dresden — [3]4th Physics Institute, University of Stuttgart

Coupling plasmonic nanostructures with single quantum emitters is of

high interest for both fundamental research and a wide range of applications such as ultra-bright non-classical photon sources. The luminescence properties of the emitter can be significantly modified because of the localized electromagnetic field close to the metal nanostructures.

We have studied the optical properties of single GaAs/AlGaAs QDs at different distances to a gold mirror. Both the luminescence intensity and the recombination rate of the QDs were enhanced because of coupling to surface plasmons. We have also investigated the influence of optical antenna on the luminescence of the QDs. With the help of a state of the art positioning technique, we positioned gold nanorods above single QDs and observed significant modification of the emission properties, which manifests the coupling between the QD and localized plasmons. We have also taken first steps to fabricate plasmonic nanocavities for the self-assembled GaAs QDs.

HL 74.7 Thu 11:15 H16

Fabrication of a thin membrane of InP/AlGaInP quantum dots — •Hendrik Niederbracht, Elisabeth Koroknay, Fabian Hargart, Christian Alexander Kessler, Michael Jetter, and Peter Michler — Institut für Halbleiteroptik und Funktionelle Grenzflächen und SCoPE Forschungszentrum, Universität Stuttgart, Deutschland

For applications based on the single photon emission from quantum dots (QDs) like quantum key distribution or quantum communication high collection efficiency is important. An easy way to achieve this is to guide the emission of semiconductor QDs into the direction of the detection by growing distributed Bragg reflectors below the QDs and using optics with a high numerical aperture. But often the setup can limit the use of such objectives. An alternative is offered by very thin samples in combination with solid immersion lenses.

The QD samples are fabricated via metal-organic vapor-phase epitaxy on a (100) GaAs substrate with a 6 degree miscut. The challenge is the fabrication of the thin membrane of InP/AlGaInP QDs. Therefor the sample is glued topside down on Si and afterwards thinned using mechanical and wet chemical methods. Optical measurements on an 80 nm thick sample are carried out in order to proof the single photon emission and the results are compared with an unprocessed reference.

HL 74.8 Thu 11:30 H16

Optical excitation channels of a single site-controlled quantum dot — •Ole Hitzemann[1], Erik Stock[1], André Strittmatter[1], Andrei Schliwa[1], Jan-Hindrik Schulze[1], Tim D. Germann[1], David Quandt[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

Direct and phonon-mediated channels of optical excitation are studied on a single isolated site-controlled InGaAs/GaAs quantum dot (QD). The nucleation site was precisely defined by a distant buried stressor formed by controlled partial oxidation of a sandwiched AlGaAs layer as part of a mesa structure.

Above a sub-micrometer aperture we observe sharp luminescences lines, originating from a single QD as demonstrated by autocorrelation measurements. Micro photoluminescence excitation spectroscopy shows efficient excitation channels through hybridization with the wetting layer, excited states, and coupling with phonon modes as well as distinctively different photoluminescence spectra for different excitation energies. Excitation power dependent measurements reveal the saturation behavior of excitonic and high excitation luminescence lines.

HL 74.9 Thu 11:45 H16

Cascaded emission of linearly polarized single photons from positioned InP/GaInP quantum dots — •Tristan Braun[1], Vasilij Baumann[1], Sebastian Unsleber[1], Manuel Gschrey[2], Sven Rodt[2], Stephan Reitzenstein[1,2], Sven Höfling[1], Christian Schneider[1], and Martin Kamp[1] — [1]Technische Physik, Physikalisches Institut and Wilhelm Conrad Röntgen-Research Center for Complex Material Systems, Universität Würzburg, Am Hubland, D-97074, Würzburg, Germany — [2]Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstrasse 36, 10623 Berlin, Germany

We report on the in-depth optical characterization of red-emitting site-controlled InP/GaInP Quantum Dots. In order to prove the long-range ordering of the buried emitters scanning cathodoluminescence with a high spatial resolution was performed, revealing a yield of $\approx 90\%$ of optically active QDs on the pre-determined positions and the absence of emitters on interstitial positions. Polarization dependent investigations on the emission of single QDs show a pronounced degree of linear polarization along the (1-10) crystal axis with an average degree of polarization as large as 80%. Photon correlation measurements of the biexcitonic and excitonic emission of a single dot are employed to reveal the single-photon character of each emission line as well as the cascaded nature of the photon pair emission.

HL 74.10 Thu 12:00 H16

Comparison of the energy transfer in colloidal core-shell Q-dots in solution and in a Q-dot layer — •Uwe Kaiser[1], Robert Malinowski[1], Wolfram Heimbrodt[1], Faheem Amin[2], Dorleta Jimnez de Aberasturi Arranz[2], and Wolfgang Parak[2] — [1]Experimental semiconductors group of Philipps-University Marburg — [2]Biophotonics group of Philipps-University Marburg

There is a great interest in functionalized colloidal Q-dots (CQDs) with diameters of a few nanometers for physical as well as biological applications. A fundamental understanding of the energy transfer processes in these materials for different experimental environments is necessary.

We studied the temporal spectral behavior of CdSe quantum dots functionalized with chromophores with time resolved photoluminescence spectroscopy. With a laser pulse of a few nanoseconds we are able to observe the luminescence decay in the range of nanoseconds up to microseconds for the luminescence of the dot as well as for the chromophore.

Measurements have been done for nanoparticles in solution as well as on particles transferred to a substrate. The fluorescence resonant energy transfer (FRET) between the dot and the chromophores has been studied in a temperature range between 10K and room temperature. A detailed comparison of the FRET process will be presented for the Q-dots in different environments.