HL 25: Quantum dots and wires: Optical properties II

Time: Tuesday 14:00–17:00 Location: H17

HL 25.1 Tue 14:00 H17

Raumtemperatur-Emission von CdSe/ZnSSe/MgS Einzel-Quantenpunkten — •Robert Arians[1], Tilmar Kümmell[1], Gerd Bacher[1], Arne Gust[2], Carsten Kruse[2] und Detlef Hommel[2] — [1]Werkstoffe der Elektrotechnik, Universität Duisburg-Essen, 47057 Duisburg — [2]Institut für Festkörperphysik, Universität Bremen, 28359 Bremen

Ein essentieller Schritt zur Realisierung einer auf Quantenpunkten basierenden Raumtemperatur-Einzelphotonenquelle ist die Detektion des Emissionssignals eines einzelnen Quantenpunktes bei Raumtemperatur. Hierzu sind Materialsysteme mit großem elektronischen Einschluss und hoher Quantenausbeute erforderlich.

Wir untersuchen selbstorganisierte, epitaktisch gewachsene CdSe-Quantenpunkte mittels Mikro-Photolumineszenz-Messungen. Im Vergleich zu CdSe/ZnSe-Quantenpunkten zeigen Quantenpunkte, die in ZnSSe/MgS-Barrieren eingebettet sind, eine deutlich erhöhte Quantenausbeute bei 300 K. Zwischen 4 K und 300 K wird eine Reduktion der Emissionsintensität von lediglich einem Faktor 3 beobachtet. Dadurch ist es gelungen, Raumtemperatur-Emission von einzelnen Quantenpunkten nachzuweisen. Bei Raumtemperatur finden wir eine Linienbreite von 25 meV, vergleichbar mit der Biexziton-Bindungsenergie in diesem Materialsystem. Diese Eigenschaften machen das System CdSe/ZnSSe/MgS zu einem attraktiven Kandidaten für Einzelphoton-Bauelemente.

HL 25.2 Tue 14:15 H17

Optical properties of single InGaN quantum dots — •Sandra Herlufsen, Kathrin Sebald, Henning Lohmeyer, Jürgen Gutowski, Tomohiro Yamaguchi, and Detlef Hommel — Institute of Solid State Physics, University of Bremen, Germany

InGaN quantum dots (QDs) are a promising material for laser structures in the blue to UV spectral region. Before the development of such devices, it is necessary to fully understand the optical properties of the QDs. We will present micro-photoluminescence (μ-PL) measurements on single InGaN QDs grown by metal-organic vapor phase epitaxy. Access to their optical properties can be obtained through the investigations of mesa structures prepared by focused-ion-beam etching. Results achieved by μ-PL measurements will be reported in dependence on the excitation density. The observation of antibinding multiexciton complexes as well as indications for recombination processes from excited states of these complexes will be discussed. The assignment of different emission lines to the same QD was possible on the base of the investigation of the spectral diffusion which occurs due to temporal trapping of carriers in the vicinity of the QD. Temperature dependent μ-PL measurements give indications for the localisation depth of the QDs. Furthermore, the polarisation characteristics of single-QD emission was investigated in order to gain information about the shape and the orientation of the QDs in the sample.

HL 25.3 Tue 14:30 H17

Optically detected resonance studies of diluted magnetic semiconductor quantum dots — •Michael Gerbracht[1], Gregor Bartsch[1], Piotr Wojnar[2], Dmitri Yakovlev[1], Ulrike Woggon[1], Jacek Kossut[2], and Manfred Bayer[1] — [1]Experimentelle Physik II, Universität Dortmund, Otto-Hahn-Str. 4, D-44227 Dortmund, Germany — [2]Institute of Physics, Polish Academy of Sciences, Al. Lotników 32/46, 02-668 Warszawa, Poland

Diluted magnetic semiconductor quantum dots (Cd,Mn)Te/ZnTe grown by molecular-beam epitaxy have been studied by optically detected resonance (ODR) technique in magnetic fields up to 15 T. The photoluminescence (PL) of samples has been measured with and without additional illumination of far infrared (FIR) radiation with photon energies of 7.6, 10.5 and 12.8 meV. Strong changes of the excitonic photoluminescence induced by FIR radiation have been found at magnetic fields below 1T. Measurements performed for different FIR energies, various temperatures and for samples with different Mn contents varied from 0 up to 4% allow us to conclude that the ODR signal is caused by heating of the spin system of magnetic Mn ions. Also the competition of intrinsic and exchange contributions to the Zeeman splitting of excitonic states have been recognized as a decrease of the Zeeman splitting at high magnetic fields.

HL 25.4 Tue 14:45 H17

Low treshold stimulated emission in Yb-doped ZnO-nanowires — •Sebastian Geburt[1], Daniel Stichtenoth[1], Sven Müller[1], Wilma Dewald[1], Carsten Ronning[1], Juan Wang[2], and Quan Li[2] — [1]II. Institute of physics, University of Göttingen, Friedrich-Hund-Platz 1, 37077 Göttingen, Germany — [2]Department of Physics, Chinese University of Hong Kong, Shatin, Hong Kong

Rare earth elements embedded in suitable matrices show optical active intra-4f-transitions with long life-times. Such states are necessary e.g. for the realization of Nd:YAG-lasers. Because of their geometry, semiconductor nanowires could act as cavity; therefore, rare earth doped semiconductor nanowires may be suitable for nanosized lasers.

ZnO nanowires were grown by the VLS mechanism using the vapour transport technique, dispersed in 2-propanol and spincoated on clean Si-substrates. Yb was implanted with a box like profile and different fluences. In order to remove the implantation damage, the nanowires were annealed at 700°C for 30min in oxygen atmosphere.

The morphology was examined by SEM and HR-TEM. The remaining implantation damage increased with increasing fluences, thin nanowires showed a stronger morphology change and roughening of the surface occured. EDX and EELS measurements showed effective incorporation of the RE elements with the desired concentrations. The optical properties were investigated using PL. The measurements showed a sharp intense peak at 1.26eV associated with intra-4f-transitions of Yb with a low quenching up to room temperature. The power dependend measurements indicate stimulated emission.

HL 25.5 Tue 15:00 H17

Thermal annealing of selected individual quantum dots — •Robert Seguin, Andrei Schliwa, Tim Germann, Sven Rodt, Konstantin Pötschke, Udo Pohl, and Dieter Bimberg — Technische Universität Berlin, Institut für Festkörperphysik, Hardenbergstr. 36, D-10623 Berlin, Germany

Cathodoluminescence spectra of single InAs/GaAs quantum dots were recorded before and after consecutive thermal annealing steps. The annealing process leads to an overall blueshift of the spectra indicating In/Ga interdiffusion. Excitonic fine-structure splitting and binding energies of charged and neutral excitonic complexes were monitored. A drastic reduction of the fine-structure splitting from 170 μeV to less than 20 μeV can be observed accompanied by a change of the character of the biexciton from anti-binding to binding with respect to the exciton. Tailoring the fine-structure splitting is especially important for the use of single quantum dots in opto-electronic devices for quantum key distribution where a degeneracy of the exciton ground state (i.e. a fine-structure splitting below the homogeneous linewidth) is required for the on-demand production of entangled photon pairs.

HL 25.6 Tue 15:15 H17

Temperature-induced crossover between bright and dark exciton emission in silicon nanoparticles — •Cedrik Meier[1], Stephan Lüttjohann[1], Matthias Offer[1], Axel Lorke[1], and Hartmut Wiggers[2] — [1]Physics Department, University of Duisburg-Essen, D-47048 Duisburg, Germany — [2]Combustion \& Gas Dynamics, University of Duisburg-Essen, D-47048 Duisburg, Germany

Silicon nanoparticles are attractive candidates for photovoltaic and optoelectronics applications, as they allow to combine the advantages of a semiconducting material with the ease of handling of dispersed particles. Moreover, the availability of silicon and the scalability of heterogenous gas-phase synthesis routes are promising for low-cost devices. We have studied the excitonic fine structure of silicon nanoparticles by time-resolved and magnetic-field dependent photoluminescence. The results are analyzed using the common model of an excitonic fine structure consisting of a bright and a dark exciton. We find that the radiative recombination rates of both excitons differ only by a factor of eight. This makes it possible to thermally switch the nature of the recombination from bright-exciton-like to dark exciton-like. The validity of our model is further supported by magnetic-field dependent measurements, in which effects of state mixing are observed. We show that silicon nanoparticles offer a unique possibility to directly assess dark exciton photoluminescence.

15 min. break

HL 25.7 Tue 15:45 H17

Influence of $In_{0.15}Ga_{0.85}As$ capping layers on the valence and conduction band structure of InAs quantum dots — •Mirja Richter[1,2], Dirk Reuter[1], Jean-Yves Duboz[2], and Andreas D. Wieck[1] — [1]Lehrstuhl für Angewandte Festkörperphysik, Ruhr-Universität Bochum, D-44780 Bochum — [2]Centre de Recherche sur l'Hétéro-Epitaxie et ses Applications, CNRS, Sophia-Antipolis, F-06560 Valbonne

We have prepared self-assembled InAs quantum dots (QDs) capped by GaAs and $In_{0.15}Ga_{0.85}As$, respectively, by molecular beam epitaxy. The $In_{0.15}Ga_{0.85}As$ cap layer shifts the ground state photoluminescence (PL) emission from 1261 nm to 1319 nm, which might be useful for telecommunication purposes. The QDs were embedded into n- or p-type capacitance-voltage ($C(V)$) structures to investigate the conduction and valance band states, respectively. The red-shift of the interband transitions due to the $In_{0.15}Ga_{0.85}As$ layer observed in PL is compared to the shift of the corresponding energy levels obtained from $C(V)$ measurements. The shifts of the ground states obtained from $C(V)$ spectroscopy sum up to 42 meV, which is in good agreement with 43 meV observed in PL measurements. A small difference could be caused by a change in the exciton binding energy. From the 42 meV overall red-shift, 83 % originate from the conduction and only 17 % from the valence band. This is probably due to the smaller effective mass in the conduction band, so that here changes in the confinement potential result in larger changes in the energy levels.

HL 25.8 Tue 16:00 H17

Optical Investigations of Single Pairs of Vertically Stacked Asymmetric InP Quantum Dots — •Matthias Reischle[1], Gareth Beirne[1], Robert Rossbach[1], Michael Jetter[1], Heinz Schweizer[2], and Peter Michler[1] — [1]Institut für Strahlenphysik, Allmandring 3, 70569 Stuttgart, Germany — [2]4. Physikalisches Institut, Pfaffenwaldring 57, 70569 Stuttgart, Germany

Coupled quantum dots (QD) are interesting candidates for future devices, such as, quantum gates for quantum computers. While most of the previous studies concentrated on double dot systems with similar dot sizes relatively few studies have concentrated on asymmetric quantum dot pairs. Nevertheless, this system is easier to realize, as QDs naturally exhibit size inhomogenities.

Single vertically stacked pairs of InP QDs that are separated by different barrier widths have been investigated. We could, on average, produce smaller upper dots that emit at higher energies than the bottom layer of dots. This arrangement allows for the tunneling of carriers from the small dots to the large dots. We have found that coupling is clearly present for a small barrier width, while for a large barrier width the dots are found to act independently. A transition from primarily electron tunneling to exciton tunneling with decreasing barrier width has also been found by comparing the photoluminescence spectra. In addition, from time-resolved measurements we could estimate the tunneling times which are in accordance with those presented previously in the literature. Finally we simulate our results using a simple rate equation model which supports the proposed tunneling mechanism.

HL 25.9 Tue 16:15 H17

Time-resolved optical spectroscopy of lateral InGaAs quantum dot molecules — •Claus Hermannstädter[1], Gareth Beirne[1], Lijuan Wang[2], Armando Rastelli[2], Oliver Schmidt[2], and Peter Michler[1] — [1]Institut für Strahlenphysik, Universität Stuttgart, Allmandring 3, 70569 Stuttgart, Germany — [2]Max-Planck-Institut für Festkörperforschung, Heisenbergstr. 1, 70569 Stuttgart, Germany

We demonstrate direct control over the level of lateral quantum coupling between two self-assembled InGaAs/GaAs quantum dots. These coupled systems which we refer to as lateral quantum dot molecules are, due to their unique growth technique, all aligned along the [1-10] crystal direction. Electrodes on the sample surface allow for the application of a lateral electric field. By applying an electric field parallel to the coupling-axis the degree of coupling can be manipulated as manifested by the shift of the emission energies and relative intensities of the characteristic photoluminescence lines [1]. Time-correlated single-photon counting experiments performed on single molecules provide access to both the rise and decay characteristics of the molecule emission lines. Typical decay times for the excitonic recombination are on the order of 1 ns, about half the latter value for biexcitonic recombination, and intermediate for charged excitonic recombination. An analysis of the exciton rise behavior strongly indicates that electron tunneling is the predominant coupling mechanism in the molecules.

[1] G. J. Beirne, C. Hermannstädter, L. Wang, A. Rastelli, O. G. Schmidt and P. Michler, Phys. Rev. Lett. 96, 137401 (2006).

HL 25.10 Tue 16:30 H17

Gain reduction in Semiconductor Quantum Dots — •Michael Lorke, Jan Seebeck, Paul Gartner, and Frank Jahnke — Institut für Theoretische Physik, Universität Bremen

In recent years, semiconductor quantum dots (QDs) have been studied extensively due to possible applications in optoelectronic devices like LEDs, lasers, or amplifiers. In the rapid emerging field of quantum information technology, QDs have been successfully used to demonstrate the generation of single photons or correlated photon pairs. Furthermore, the strong coupling regime for QD emitters in optical microcavities has been demonstrated. A common aspect in these fundamental studies and for practical applications of QDs is the critical role of dephasing processes. They determine the homogeneous linewidth of the QD resonances, limit the coherence properties of QD lasers and theirultrafast emission dynamics, and have a strong influence on coherentoptical nonlinearities.

A microscopic theory is used to study the optical properties of semiconductor quantum dots. The dephasing of a coherent excitation and line-shifts of the interband transitions due to carrier-carrier Coulomb interaction and carrier-phonon interaction are determined from a quantum kinetic treatment of correlation processes which includes non-Markovian effects.

We find a strong saturation and even reduction of the optical gain with increasing carrier density. For this dependencies of the peak gain on carrier density we present new fitting functions for these dependencies.

HL 25.11 Tue 16:45 H17

Phonon interactions in InGaAs/GaAs quantum dots — •Stefan Werner, Patrick Zimmer, André Strittmatter, and Axel Hoffmann — Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstr. 36, D-10623, Berlin, Germany

In recent years, carrier-phonon interactions in semiconductor quantum dots have attracted considerable attention. They are important to understand the electronic properties of such systems, like carrier relaxation processes. Some are convinced that carriers confined in quantum dots are strongly coupled to the longitudinal optical (LO) vibrations of the semiconductor lattice. We report on exciton-phonon interactions in InGaAs/GaAs quantum dots. Photoluminescence and time-resolved experiments were performed on different MOCVD-grown InGaAs/GaAs samples to observe and investigate varying phonon interactions. In our measurements we observed photoluminescence peaks constantly shifting with varied excitation energy. The energy gap between the laser-peak and the observed two-peak structure remained unchanged. The ΔE-values of 33,8 meV and 36,9 meV precisely fit to the QD LO-Phonon mode and to the interface mode, respectively. The very short radiative lifetime also points to inelastically scattered phonons, i.e. Raman scattering.