HL 71: Quantum Dots and Wires: Optical Properties

Time: Thursday 9:30–13:00 Location: H15

HL 71.1 Thu 9:30 H15

Exciton dynamics in colloidal CdSe nanoplatelets — •Sebastian Kickhöfel[1], Riccardo Scott[1], Artisom Antanovich[2], Anatol Prudnikau[2], Mikhail Artemyev[2], Alexander Achtstein[1], and Ulrike Woggon[1] — [1]Institute of Optics and Atomic Physics, Technical University of Berlin, 10623 Berlin, Germany — [2]Institute for Physicochemical Problems, Belarusian State University, 220030 Minsk, Belarus

Colloidal nanoplatelets are an active field of optoelectronic research. They combine advantages of colloidal systems like quantum dots and strongly confined 2D semiconductor quantum wells. Their optical absorption and emission can be tailored in a wide range[1]. As there is an increased number of reports showing unique optoelectronic properties like low lasing thresholds and strong electrooptic effects[2,3], a deeper understanding of the electronic structure and carrier dynamics is necessary for understanding these effects. We report the results of time-integrated and time-resolved photoluminescence investigations and modeling, giving a deeper understanding to the charge carrier dynamics in CdSe nanoplatelets. The influence of phonons to that will be discussed. The reported carrier dynamics is an essential prerequisite to understand the optoelectronic processes in CdSe nanoplateles like lasing or their potential use as optically active modulators media.

Literature:

[1] Ithurria, S., et al., Nature Materials 10(12) (2011): 936-941.
[2] Grim, J. Q., et al., Nature Nanotechnology 9(11) (2014): 891-895.
[3] Achtstein, A. W., et al., ACS Nano 8(8) (2014): 7678-7686.

HL 71.2 Thu 9:45 H15

Efficient numerical method for calculating Coulomb coupling elements and its application to two dimensional spectroscopy — •Anke Zimmermann and Marten Richter — Institut für Theoretische Physik, Nichtlineare Optik und Quantenelektronik, EW 7-1, Technische Universität Berlin, Germany

The Coulomb coupling is essential for the understanding of several physical processes and plays an important role in a variety of nanostructures. Typically, to calculate the matrix elements of the two-particle Coulomb interaction, a six dimensional spatial integral appears. If the system requires the calculation of a high number of coupling elements, an efficient method for a fast numerical calculation of the Coulomb interaction is needed.

To reduce the numerical complexity of the calculation of Coulomb coupling elements in real space, a Green's function formulation of a generalized Poisson equation is used. The presented method, which is flexible and works for arbitrary geometries and inhomogeneous media, enables a fast calculation of Coulomb coupling elements, since the number of integrals is decreased.

The Coulomb interaction between two colloidal quantum dots depends on the spatial distance and the relative dipole orientation of the nanostructures. To identify the effects of the spatially dependent Coulomb coupling on single excitons and biexcitons, two dimensional spectroscopy can be used. The characteristic optical signatures of different spatial arrangements of the colloidal quantum dots are calculated and discussed.

HL 71.3 Thu 10:00 H15

Time-resolved, temperature-dependent photoluminescence of F- and SiO_2-capped silicon nanoparticles — Robert Niemöller, Daniel Braam, •Günther M. Prinz, and Axel Lorke — Experimentalphysik und CENIDE, Universität Duisburg-Essen

Silicon is the most important semiconductor in today's microelectronics. A major disadvantage is its indirect bandgap, hindering the fabrication of efficient optoelectronic devices. Instead, silicon nanoparticles show bright luminescence with high quantum yield.

Here, we present time-resolved and temperature dependent photoluminescence (PL) measurements of silicon nanoparticles, capped with fluorinated silicon oxide or silicon dioxide. Apart from a stretched exponential time decay of the PL, we observe, that the intensity for the silicon dioxide-capped nanoparticles shows a maximum at 75K, while the PL intensity for the fluorinated-shell capped silicon nanocrystals increases up to room temperature.

The measured data is fitted with a combination of two models given by Lüttjohann et al. [1] and Suemoto et al. [2]. With this combined model, we can not only simulate the time dependent recombination but also the temperature dependent PL intensity. This simulation fits the luminescence data for both types of silicon nanocrystals, explaining why the fluorinated-shell capped silicon nanocrystals exhibit better luminescence properties.

[1] S. Lüttjohann, et al., EPL 79, 37002 (2007).
[2] T. Suemoto et al., Phys. Rev. B 49, 11005 (1994).

HL 71.4 Thu 10:15 H15

Consequences of light-hole and heavy-hole mixing on the optical properties of III-V-semiconductor quantum dots — •Fritz Weyhausen-Brinkmann[1], Ranber Singh[1,2], and Gabriel Bester[1,2] — [1]Universität Hamburg, Grindelallee 117, 20146 Hamburg, Germany. — [2]The Hamburg Centre for Ultrafast Imaging, Luruper Chaussee 149, 22761 Hamburg, Germany.

We calculate the spin-resolved light-hole and heavy-hole (LH-HH) band mixing in III-V-semiconductor quantum dots (QDs). The exciton emission spectrum of these QDs show optical anisotropy in their growth plane and the directions of polarization are strongly influenced by the LH-HH mixing. In the field of quantum information and quantum processing QDs are hot candidates, e.g. as single photon sources or quantum repeaters, which requires a good understanding of their optical properties. We are using the atomistic empirical pseudopotential approach including spin-orbit coupling to determine the spin-resolved LH-HH mixing of the single particle wave function as a function of strain for different types of QDs [1]. We find that the parallel spin of the light-hole is not negligible in contradiction to earlier model [2] and highlight the consequences of this finding on the polarization anisotropy.

[1] Y. Huo et al. Nature Physics 10, 46-51 (2014).
[2] C. Tonin, R. Hostein, V. Voliotis, R. Grousson, A. Lemaitre, and A. Martinez, Phys. Rev. B 85, 155303 (2012).

HL 71.5 Thu 10:30 H15

Polarization anisotropy of the emission from type-II quantum dots — •Petr Klenovsky[1,2], Dusan Hemzal[1,2], Petr Steindl[1,2], Marketa Zikova[3], Vlastimil Krapek[4], and Josef Humlicek[1,2] — [1]Central European Institute of Technology, Masaryk University, Kamenice 753/5, 62500 Brno, Czech Republic — [2]Department of Condensed Matter Physics, Faculty of Science, Masaryk University, Kotlářská 2, 61137 Brno, Czech Republic — [3]Institute of Physics CAS, Cukrovarnická 10, Praha 6, 162 00, Czech Republic — [4]Central European Institute of Technology, Brno University of Technology, Technická 10, 61600 Brno, Czech Republic

We study the polarization response of the emission from type-II GaAsSb capped InAs quantum dots. We theoretically predict the polarization anisotropy of the emission from this system, experimentally verify it by polarization resolved photoluminescence measurements on samples with the type-II confinement, and show that the polarization anisotropy might be utilized to find the vertical position of the hole wavefunction, solving thus the long standing problem of this system. A proposition for usage in the information technology as a room temperature photonic gate operating at the communication wavelengths as well as a simple model to estimate the energy of fine-structure splitting for type-II GaAsSb capped InAs QDs are given.

HL 71.6 Thu 10:45 H15

Quenching the PL emission of GaN QDs by local FIB-implantation — •Charlotte Rothfuchs[1], Tristan Koppe[2], Nadezhda Kukharchyk[1], Hans-Werner Becker[3], Fabrice Semond[4], Mathieu Leroux[4], Sarah Blumenthal[5], Donat Josef As[5], Hans Hofsäss[2], Andreas D. Wieck[1], and Arne Ludwig[1] — [1]Angewandte Festkörperphysik, Ruhr-Universität Bochum, D-44780 Bochum — [2]II. Physikalisches Institut, Georg-August-Universität Göttingen, D-37077 Göttingen — [3]RUBION, Ruhr-Universität Bochum, D-44780 Bochum — [4]CNRS-CRHEA, F-06560 Valbonne — [5]Department Physik, Universität Paderborn, D-33098 Paderborn

Nowadays, there is an increasing interest in quantum communication technology. GaN QDs as single semiconductor photon sources could be key components for such applications. One possible pathway towards the realization is the post-selection of molecular beam epitaxy-grown QDs by focused ion beam (FIB) implantation. This approach aims for the disabling of all QDs around an intentional one, based on the creation of non-radiative defects in the irradiated regions. Here, we present an unprecedented study on the lattice disorders in the vicinity of both hexagonal and cubic self-assembled GaN/AlN QDs introduced by FIB implantation of gallium ions amongst others. The impact of the ion implantation is investigated by low-temperature and additional temperature-dependent PL measurements. We extend a simple model for the PL degradation of InAs QDs to describe the quenching of the PL emission in the GaN/AlN material system. In particular, the quantum confined Stark effect in the hexagonal QDs is taken into account.

30 min. Coffee Break

HL 71.7 Thu 11:30 H15

Optical investigation of surface Fermi level-pinning in high-periodicity InGaAs nanowire arrays — •Maximilian Sonner, Maximilian Speckbacher, Julian Treu, Stefanie Mörkötter, Kai Saller, Hubert Riedl, Gerhard Abstreiter, Jonathan Finley, and Gregor Koblmüller — Walter Schottky Institut and Physik Department, Tu München, Garching, Germany

Optical investigations of surface Fermi level pinning related effects in InGaAs nanowires (NWs), site-selectively grown by molecular beam epitaxy (MBE) directly on Si (111) substrates, were performed using micro-photoluminescence spectroscopy (PL). In particular, we show that due to the large surface to volume ratio high densities of surface states can lead to pronounced Fermi level pinning and non-radiative recombination, limiting the radiative efficiency of the as-grown NWs. To study these effects in more detail, we provide systematic studies of (i) the diameter dependency and (ii) the InGaAs composition by correlating the luminescence properties in as-grown NWs with NWs passivated by hydrofluoric acid. Power- and temperature-dependent studies show two dominating recombination mechanisms present for NW PL emission: spatially indirect recombination via surface states for small diameters and bulk-like, excitonic transition from WZ/ZB stacking faults [1]. Correlating these results with structural analysis and a tuned carrier concentration via doping experiments will allow further new insights. [1] M. Speckbacher, et al., in preparation (2015)

HL 71.8 Thu 11:45 H15

Spin-lattice relaxation time of InGaAs quantum dots — •Daniel A. Lübke[1], Evgeny A. Zhukov[1], Alex Greilich[1], Erik Kirstein[1], Fabian Heisterkamp[1], Tomasz Kazimierczuk[1], Vladimir L. Korenev[1,2], Dirk Reuter[3], Andreas D. Wieck[3], Dmitri R. Yakovlev[1,2], and Manfred Bayer[1,2] — [1]Experimentelle Physik 2, Technische Universität Dortmund, 44221 Dortmund, Germany — [2]Ioffe Institute, Russian Academy of Sciences, 194021 St. Petersburg, Russia — [3]Angewandte Festkörperphysik, Ruhr-Universität Bochum, 44780 Bochum, Germany

We demonstrate measurements of the spin relaxation time (T_1) of resident electrons and holes in ensembles of InGaAs quantum dots. These measurements are done using a new method exploiting the spin inertia, based on the pump-probe type of measurements. Here the helicity of the pump laser is switched between both circular polarizations with variable frequency, at fixed pump-probe delay. At low frequencies of modulation, the created spin polarization is able to reach its steady state value, the maximal signal. If the pump helicity changes faster, so that the spin polarization cannot reach its steady state, it results in a decreased signal. We use this technique to evaluate the T_1 time in dependence on the longitudinal magnetic field in the range of $\pm 300\,\mathrm{mT}$.

HL 71.9 Thu 12:00 H15

Decay and persistance of spatial coherence in laterally spaced quantum dots — •Pawel Karwat[1], Tilmann Kuhn[2], and Pawel Machnikowski[1] — [1]Department of Theoretical Physics, Wroclaw University of Technology, Wybrzeze Wyspianskiego 27, 50-370 Wroclaw, Poland — [2]Institut für Festkörpertheorie, Westfälische Wilhelms-Universität Münster, Wilhelm-Klemm-Strasse 10, 48149 Münster, Germany

Some experiments show that collective emission effects [1] play a role in the optical response of systems consisting two (or more) Quantum Dots (QDs), which suggests that they cannot be treated as ensembles of independent emitters. One of the interesting features observed in the experiment is the difference between the time resolved emission under quasi-resonant (optical transition to higher confined shells) and non-resonant (transition to wetting layer or bulk states) excitation. This suggests that spatial coherence, which is lost during carrier capture to the QDs, must be to some extent conserved during relaxation between confined states. In this contribution, we take into consideration the realistic system consisting of two horizontally placed InGaAs QDs, coupled not only to the acoustic phonon reservoir, but also to optical phonons. Using the method of collective modes, we study theoretically the relaxation of polarons in the system. In particular, we investigate the impact of polaron effects into the evolution of spatial coherence. The model allows us to make simulations beyond the Markov limit (by using correlation expansion method).

[1] P. Karwat, P. Machnikowski, Phys. Rev. B 91, 125428 (2015).

HL 71.10 Thu 12:15 H15

Time-integrated and time-resolved luminescence studies of carbon nanodots — •Angelina Vogt[1], Kseniia Sergeeva[1], Frank Dissinger[2], Sebastian Resch[2], Siegfried Waldvogel[2], and Tobias Voss[1] — [1]Institute of Semiconductor Technology and LENA, TU Braunschweig — [2]Institute of Organic Chemistry, Johannes Gutenberg University Mainz

Strongly luminescent and environmentally friendly carbon nanodots (C-dots) with diameters below 10 nm offer a great potential for optimized color conversion in LED displays and selective gas detection in sensing devices. Low toxicity, biocompatibility, excellent chemical and photo stability, inexpensive large-scale fabrication schemes and tunable photoluminescence (PL) emission are among their outstanding properties. Here, we study the luminescence properties of C-dots dissolved in distilled water for different concentrations of the C-dots, different excitation wavelengths and as a function of the laser power. The C-dots were hydrothermally synthesized and measured in the as-grown or a reduced state. In addition, we performed time-resolved studies of the luminescence dynamics with a femtosecond laser system to obtain a better understanding of the excitation and relaxation pathways of the photo-excited electrons, which is still controversially discussed in literature. The results show a luminescence decay time of several nanoseconds with a slightly faster decay on the high energy side of the PL emission. These results are analyzed with a model which takes into account electronic states of different sp2-hybridized carbon molecules which are believed to form the core of the C-dots.

HL 71.11 Thu 12:30 H15

Optical and electrical characterization of single AlGaN/GaN nanowire heterostructures — •Jan Müssener, Pascal Hille, Marius Günther, Daniel Stock, Markus Schäfer, Jörg Schörmann, Jörg Teubert, and Martin Eickhoff — I. Physikalisches Institut, Justus-Liebig-Universität Gießen, 35392 Gießen, Germany

We report on the photoluminescence (PL) characterization of single GaN nanowires (NWs) with embedded AlGaN/GaN heterostructures under application of an external electric field. Group III-nitrides exhibit strong internal polarization-induced electric fields which influence the optical properties via the quantum confined Stark effect (QCSE). Here we present a controlled modification of the internal fields via externally applied axial voltage on a single NW basis. The NWs were grown by plasma assisted MBE and consist of a single nanodisc (ND) embedded in AlGaN barriers. Single NWs were isolated for μ-PL measurements and electrical contacts for bias application were formed using electron beam lithography. The external electric field leads to a suppression or an enhancement of the QCSE which allows for determining the direction (polarity) and magnitude of the internal field. We also report on analogous measurements on 40-fold AlN/GaN heterostructures embedded in GaN NWs. Their complex bandprofile gives rise to numerous contributions in the PL spectrum originating from direct and indirect ND transition or 2DEG states. As each transition exhibits specific and distinct behavior under external electric field, bias-depended μ-PL allows the assignment of different recombination paths.

HL 71.12 Thu 12:45 H15

Characterization of nanocrystalline Si/SiC layers through optical measurements and simulations — •Johannes Hofmann, Charlotte Weiss, and Stefan Janz — Fraunhofer Institute for Solar Energy Systems, Heidenhofstraße 2, 79110 Freiburg, Germany

Silicon (Si) nanocrystal materials are subject to intense research concerning their application in Si-based tandem solar cells, since exploiting finite size effects in the Si nanostructures allows for modifying band structure properties and thus tailoring absorption characteristics.

Annealing of sub-micrometer amorphous-Si_xC_{1-x}:H layers ($x > 0.5$) deposited by plasma-enhanced chemical vapor deposition yields layers comprising a silicon carbide (SiC) matrix and therein embedded Si nanoclusters with a characteristic size of a few nanometers. For this work we investigate the optical properties of such layers by spectral ellipsometry, spectrophotometry measurements as well as photoluminescence measurements; structural characterization (X-ray diffraction, Fourier transform infrared spectroscopy) is also performed. Thickness variation sample series are analyzed by means of model based spectrum simulation and subsequent regression analysis. Scanning electron microscopy cross section images serve as references for thickness determination. Consequently, an optical thickness measuring method for annealed layers depending on their composition is provided. It is furthermore aimed at detecting the contribution of finite size effects in Si nanocrystals to the optical properties of the layers.