HL 47: Quantum dots and wires: Optical properties II

Time: Friday 9:30–13:00 Location: H34

HL 47.1 Fri 9:30 H34

Investigation of spectral diffusion by slow-light photon correlation — •Julian Maisch[1], Hüseyin Vural[1], Simon Kern[1], Jonas H. Weber[1], Jörg Wrachtrup[2], Ilja Gerhardt[2], Michael Jetter[1], Simone L. Portalupi[1], and Peter Michler[1] — [1]Institut für Halbleiteroptik und Funktionelle Grenzflächen, Center for Integrated Quantum Science and Technology (IQST) and SCoPE, University of Stuttgart, Allmandring 3, 70569 Stuttgart, Germany — [2]3. Institute of Physics, University of Stuttgart, IQST and SCoPE

Highly complex quantum applications require single coherent photons. One promising type of sources are semiconductor quantum dots (QDs). Due to the fact that they are embedded in a solid-state matrix, the emission is generally influenced by the environment e.g. fluctuating electrical and magnetic fields. These fluctuations cause random shifts of the emission frequency resulting in a broadened spectrum.

This so-called spectral diffusion is well known. Still, the charactersitic time scales are of interest. This talk presents a method to use a slow-light medium (here: cesium vapor) to make the effect of spectral wandering visible in a typical second-order correlation measurement. The dispersion of the atomic medium transfers spectral differences into the time signal of the photons. Therefore, the correlation reveals diffusion dynamics. Both experimental and supporting simulation results are presented.

HL 47.2 Fri 9:45 H34

High-resolution measurement of quantum dot emission spectra after resonant excitation — •Tim Strobel, Stephan Simmler, Simon Kern, Jonas H. Weber, Hüseyin Vural, Simone L. Portalupi, and Peter Michler — Institut für Halbleiteroptik und Funktionelle Grenzflächen, Center for Integrated Quantum Science and Technology (IQST) and SCoPE, University of Stuttgart, Allmandring 3, 70569 Stuttgart, Germany

Photonic quantum information technologies rely on two-photon inteference (TPI) as their key building block. Actual quantum applications highly depend on the indistinguishability of single photons. In this respect single semiconductor quantum dots (QDs) are well-established quantum emitters of high interest. They can be used as on-demand single sources of indistinguishable photons. This property is inevitable to successfully carry out two-photon inteference (TPI) experiments with the perspective of scaling up the complexity. To reach high indistinguishability, Fourier-limited emission spectra are desired. However, dephasing such as charge and spin noise broaden the linewidth of such single photon emitters drastically. Therefore, it is crucial to have knowledge about the influence of these effects on the emission spectrum. Here, we present a monolithic Fabry-Pérot interferometer which can be used to capture high-resolution spectra of semiconductor quantum dots. The inteferometer has a resolution even below the bandwith of the single Fourier-limited photons.

HL 47.3 Fri 10:00 H34

Determination of doping profiles in axial GaAs Nanowires by 4-point-probe and Luminescence Measurements — Andreas Nägelein[1], •Peter Kleinschmidt[1], Cornelia Timm[1], Matthias Steidl[1], Klaus Schwarzburg[2], and Thomas Hannappel[1] — [1]TU Ilmenau, Institut für Physik, 98693 Ilmenau, Germany — [2]Helmholtz-Zentrum Berlin für Materialien und Energie, 14109 Berlin, Germany

Semiconductor devices depend crucially on the controlled incorporation of dopants and their spatial distribution. In the case of III-V nanowires (NWs), a number of techniques have been developed to analyze this property, but precise, rapid and non-destructive doping profiling is still challenging. Here, we investigate axial pn-junctions in GaAs-NWs, on the one hand electrically by a multi-tip scanning tunneling microscope (MT-STM) operated as a four-point nanoprober and on the other hand optically by room-temperature photoluminescence (PL) and cathodoluminescence (CL) microscopy spectroscopy. We fabricate the NWs by metalorganic vapor phase epitaxy in the vapor liquid solid growth mode. The MT-STM is accessible via a contamination-free UHV transfer, while optical characterization is performed in ambient air. Both approaches provide complementary information on doping distribution. Analysis of the MT-STM measurements involves a transport model, whereas analyzing the PL and CL data relies on semi-empirical equations taking the Burstein-Moss shift and the bandgap narrowing into account. Combining these results reveals a constant hole concentration in the p-dope base of the NWs and an axial variation in the electron concentration in the n-doped top part of the NWs.

HL 47.4 Fri 10:15 H34

Generation of single-photon and two-photon pulses from a quantum two-level system — •Katarina Boos[1], Lukas Hanschke[1], Kevin Andrew Fischer[2], Jakob Wierzbowski[1], Stefan Appel[1], Daniil Lukin[2], Shuo Sun[2], Rahul Trivedi[2], Malte Kremser[1], Tobias Simmet[1], Constantin Dory[2], Jelena Vuckovic[2], Jonathan Finley[1], and Kai Müller[1] — [1]Walter Schottky Institut and Physik Department, Technische Universität München, 85748 Garching, Germany — [2]E.L. Ginzton Laboratory, Stanford University, Stanford, CA 94306, USA

Resonantly driven quantum two-level transitions in quantum dots are promising single-photon sources [1]. Here, we demonstrate that they can surprisingly also operate in a two-photon bundling regime. Specifically, when exciting with a 2pi pulse emission of a photon during the presence of the laser pulse restarts the Rabi oscillation and leads to a second emission of a photon with near-unity probability [2,3]. Finally, we demonstrate single-photon generation from self-assembled quantum dots with ultra-low multi-photon probability. Using two-photon excitation of the bi-exciton suppresses the re-excitation and improves the single photon purity by several orders of magnitude for short pulses [4].

[1] K. A. Fischer, et al., New J. Phys. 18, 113053 (2016)
[2] K. A. Fischer, et al., Nature Physics 13, 649-654 (2017)
[3] K. A. Fischer, et al., Quantum Sci. Technol. 3, 014006 (2017)
[4] L. Hanschke, et al., npj Quantum Information 4, 43 (2018)

HL 47.5 Fri 10:30 H34

Optical spectroscopy of type-II semiconductor ZnSe/CdS dot-in-rod nanostructures — •Hans Werners, Sven Lohmann, Christian Strelow, Alf Mews, and Tobias Kipp — Institut für Physikalische Chemie, Universität Hamburg, Germany

In type-II semiconductor heterostructures the band offset leads to a spatial separation of electrons and holes. This charge separation makes type-II systems particularly useful, e. g., as light-harvesting materials in photovoltaic devices. Nanoparticles consisting of a spherical ZnSe core surrounded by a rod-shaped CdS shell, so-called dot-in-rods (DRs), represent a quantum system with an intrinsic type-II band alignment at the core/shell interface. This should allow for an efficient manipulation of exciton properties by, e.g., external fields.

We use time-, energy-, and space-resolved confocal fluorescence spectroscopy at room and cryogenic temperatures to investigate individual ZnSe/CdS DRs. The DRs show a high photostability while emitting linearly polarized light at about 2.16 eV, with quantum yields above 35%. Compared to the more conventional type-I CdSe/CdS DR system [1], ZnSe/CdS DRs exhibit increased fluorescence lifetimes. At 8 K, the lifetime is decreased compared to room temperature measurements. Furthermore, at low temperature, we observe abrupt spectral shiftings of the emission line over time, superimposed on smoother spectral diffusion processes. The spectral diffusion covers a larger range in energy than for type-I CdSe/CdS DRs, indicating the larger susceptibility of type-II structures to external stimuli, like surface charges.

[1] S. Lohmann et al., ACS Nano 11, 12185-12192 (2017).

HL 47.6 Fri 10:45 H34

Quantum dots as charge detectors for nanoscale defect tomography — •Jens Kerski[1], Pia Lochner[1], Arne Ludwig[2], Andreas D. Wieck[2], Annika Kurzmann[1], Axel Lorke[1], and Martin Geller[1] — [1]Faculty of Physics and CENIDE, University Duisburg-Essen, Germany — [2]Chair of Applied Solid State Physics, Ruhr-University Bochum, Germany

Self-assembled semiconductor quantum dots (QDs) can be used as single-photon sources in visionary applications in quantum information technologies. However, spin and charge noise in the vicinity destroy the needed fourier-transform limited linewidth [1].

In this contribution, we use a single quantum dot as nanoscale electrometer to investigate the charging process of individual defects by the nearby n-doped back contact. Spectral and time-resolved resonance fluorescence measurements allowed us to identify four nearby defect

states by small shifts of the resonance energy of the exciton transition [2]. From the occupation probability of the individual states, the position of these defects in the growth direction, as well as their binding energy were determined. Their position allowed to identify the states as defects.

Our results give rise to further investigations, e.g. triangulation of individual defects by using multiple QDs, optical transport measurements at a single QD and nanoscale deep level transient spectroscopy.

[1] A. V. Kuhlmann et al., Nature Physics 9, 570-575 (2013).
[2] J. Houel et al., Phys. Rev. Lett. 108, 107401 (2012).

15 min. break

HL 47.7 Fri 11:15 H34

Distributed Bragg Reflectors in Nanowires towards Impurity Nanolasers — •Maximilian Zapf[1], Oscar Kennedy[2], Robert Röder[1], Robert Buschlinger[3], Ulf Peschel[3], Paul Warburton[2], and Carsten Ronning[2] — [1]Institute of Solid State Physics, Friedrich Schiller Universität Jena — [2]London Centre for Nanotechnology, University College London — [3]Institute for Solid State Theory and -Optics, Friedrich-Schiller-Universität Jena

Nanoscale coherent light sources are key components in novel photonic concepts for integrated photonic circuits and lab-on-a-chip devices. Optically one-dimensional nanolasers are currently realized using semiconductor nanowires (NWs) under intense optical excitation. Distributed Bragg reflectors (DBRs), where the nanowire is periodically cut, have higher reflectivity than a single end facet at wavelengths pre-determined by the spacing of cuts. These wavelength-selective mirrors can be combined with gain from the semiconductor material or from dopants ion implanted into the NW to shift laser emission within a broad spectral range. Finite-difference time-domain calculations were performed to simulate the wavelength-dependent reflections occurring at an air - ZnO DBR structure. Such DBR structures were milled into ZnO nanowires using inert-gas focused ion beam providing the high refractive index contrast between the ZnO material and air. Subsequently, reflection and transmission properties of the DBR structures have been studied. Enhanced wavelength-dependent end facet reflections allow reducing laser thresholds in nanowire lasers as well as tailorable nanoscale wavelength filtering, and spectral emission tuning.

HL 47.8 Fri 11:30 H34

Cutting of halide perovskite nanowires into single photon emissive low-aspect-ratio CsPbX3 (X=Cl, Br I) perovskite nanorods — •Philipp Konrad, Aurora Manzi, Yu Tong, Ming Fu, Eva Bladt, He Huang, Alexander Richter, Kun Wang, Peter Müller-Buschbaum, Sara Bals, Philippe Tamarat, Brahim Lounis, Jochen Feldmann, and Lakshminarayana Polavarapu — Chair for Photonics and Optoelectronics, Ludwig-Maximilians-Universität, München, Deutschland

Colloidal perovskite nanocrystals (NCs) have been highly investigated within the past few years due to their unique optical properties which make them favorable for LED and lasing applications. Their optical properties are strongly dependent on their dimensions. Despite rapid advances in the shape-control of perovskite NCs ranging from nanocubes to nanowires and nanoplatelets, it is hardly possible to obtain colloidal perovskite nanorods (NRs).

In this presentation, we will present our finding about the ligand-induced cutting of CsPbBr3 perovskite nanowires (NWs) into low aspect-ratio CsPbBr3 (X=Cl, Br and I) NRs. The shape transformation of Nws to NRs resulted in an increase of photoluminescence efficiency and longer exciton lifetimes compared to that of NWs. This indicates that the defect parts of the NWs gets separated during their breaking into NRs, otherwise the excitons are more likely to find a trap owing to large exciton diffusion lengths in perovskites. Interestingly, those NRs exhibit single photon emission as revealed by photon antibunching measurements, which is not detected in their parent NWs.

HL 47.9 Fri 11:45 H34

Effect of Methyl Viologen on Electronic and Vibrational Spectra of Glutathione-stabilized Ag-In-S and Ag-In-S/ZnS Core-shell Quantum Dots — •Oleksandr Selyshchev[1], Volodymyr Dzhagan[1,2], and Dietrich R.T. Zahn[1] — [1]Semiconductor Physics, TU Chemnitz, Chemnitz D-09107, Germany — [2]V. Lashkaryov Institute of Semiconductor Physics, Nat. Acad. Sci. of Ukraine, 03028 Kyiv, Ukraine

One of the challenges on the way to the application of colloidal quantum dots (QDs) in electronic devices, such as solar cells and field effect transistors, is their low electrical conductivity hindered by dielectric organic ligands. The idea of the current study is to modify the surface of colloidally synthesized QDs by another organic ligand, methyl viologen that possesses electron accepting properties and could act as an electrical linker. Here we investigate the effect of methyl viologen on the spectral characteristics of nonstoichiometric Ag-In-S and Ag-In-S/ZnS core-shell QDs stabilized by glutathione as the native ligand. Methyl viologen results in strong quenching of the QD photoluminescence (PL), while the QD absorption spectra remain without changes. This behaviour indicates photoinduced electron transfer from QDs (donor) to methyl viologen (acceptor). A decrease of the average lifetime of the PL additionally confirms the interaction via photoexcited states. Raman and FTIR spectroscopies show that glutathione ligands are still present on the QD surface, therefore the interaction of the methyl viologen (cations) with the QDs is realized via electrostatic bonding to negatively charged functional groups of glutathione.

HL 47.10 Fri 12:00 H34

Highly luminescent halide perovskite Supercrystals: Toward Filling the Green Gap — •Maximilian Feil, Aurora Manzi, Yu Tong, Julius Feucht, En-Ping Yao, Markus Döblinger, Lakshminarayana Polavarapu, Alexander Urban, and Jochen Feldmann — Ludwig-Maximilians-Universität München, Munich, Germany

Self-assembly of nanoscale building blocks into ordered nanoarchitectures has emerged as a powerful approach for tailoring the nanoscale optical properties and using them for the development of novel optical devices [1, 2]. In our studies, we aim to uncover the optical properties of $CsPbX_3$ (X= Cl, Br, I) perovskite nanocubes (NCs) assembling into 3D superlattices commonly referred to as supercrystals (SCs). In this presentation, we will show a new one-pot synthesis method to obtain colloidal $CsPbX_3$ perovskite SCs by spontaneous self-assembly of individual NCs. The SCs retain the high photoluminescence efficiency of their NC subunits, however also exhibit a redshifted emission compared to that of the individual NCs due to miniband formation via electronic coupling between the NC subunits [1]. This redshift makes the SCs pure green emitters filling the so-called Green Gap, while the individual NCs emit a cyan-green color.

[1] Y. Tong, E.-P. Yao, A. Manzi, E. Bladt, K. Wang, M. Doblinger, S. Bals, P. M. Buschbaum, A. S. Urban, L. Polavarapu, J. Feldmann, Adv. Mater. 30, 1801117 (2018) [2] A. Manzi, Y. Tong, J. Feucht, E.-P. Yao, L. Polavarapu, A. S. Urban, J. Feldmann, Nat. Commun. 9 (1), 1518 (2018)

HL 47.11 Fri 12:15 H34

Dephasing dynamics of optically active hole spin qubits in self-assembled quantum dots — •Friedrich Sbresny[1], Tobias Simmet[1], William Rauhaus[1], Malte Kremser[1], Fuxiang Li[2], Nikolai Sinitsyn[2], Kai Müller[1], and Jonathan Finley[1] — [1]Walter Schottky Institut and Physik Department, Technische Universität München, 85748 Garching, Germany — [2]Theoretical Division, Los Alamos National Laboratory, Los Alamos, New Mexico, 87545 USA

Single spins in self-assembled InGaAs quantum dots (QDs) are promising candidates for spin-photon interfaces with applications in quantum technologies. While an electron spin in a QD rapidly dephases within $T_2^* = 2$ns [1], it was predicted that a single heavy hole spin would exhibit two orders of magnitude longer dephasing times. At zero magnetic field, through time-domain measurements of the net hole spin projection we find a hole spin dephasing time of 300ns. This largely reduced dephasing rate can be explained by the much weaker hyperfine contact interaction of a valence band hole with the nuclei. Measurements of T_2^* through time-resolved Ramsey interference show faster dephasing rates with increasing magnetic field. We attribute this to electronic noise, which broadens the distribution of Zeeman frequencies via the linear coupling of the hole g-tensor to the local electric field. Strategies to counteract this noise source as well as spin-echo measurements to obtain the single spin coherence time T_2 are discussed [2].

[1] A. Bechtold et al., Nature Physics 11, 1005-1008 (2015)
[2] T. Simmet et al, in preparation

HL 47.12 Fri 12:30 H34

Antenna-Controlled Antibunching in the Photoluminescence of Single Carbon Nanotubes — •Lucas Lange, Frank Schäfer, Alexander Biewald, Richard Ciesielski, and Achim Hartschuh

— Department of Chemistry and CeNS, LMU Munich, Germany

Photon antibunching in the photoluminescence (PL) from semiconducting single-walled carbon nanotubes (SWCNTs) attracted considerable attention because of potential applications of SWCNTs as single-photon-sources [1]. Known for single point-like quantum systems, the observed antibunching from a 1D nano material also raised fundamental questions regarding the underlying mechanism. In general, antibunching is thought to require the efficient localization of the excited state energy at local minima in the exciton energy landscape or at chemical dopant sites and was reported for different nanotube materials and configurations upon optical as well as electrical excitation [2]. We performed photon-correlation experiments in a Hanbury-Brown-Twiss setup. A sharp laser-illuminated metal tip operated in a scanning probe scheme acted as optical antenna providing near-field PL enhancement with a spatial range around 20 nm [3]. In the near-field of the tip, the second order correlation at zero delay $g^{(2)}(0)$ was found to be substantially reduced. We discuss possible mechanisms of antenna-controlled antibunching including localized exciton-exciton annihilation [3] and applications to other low-dimensional materials.

[1] A. Högele, et al., PRL 100, 217401 (2008).
[2] A. Ishii, et al., PRA 8, 054039 (2017).
[3] N. Mauser, et al., Chem. Soc. Rev. 42, 1248 (2014).

HL 47.13 Fri 12:45 H34

Synthesis and Characterization of Lead Chalcogenide Nanocrystals for Short-Wavelength Infrared Photodetectors — •Martin Sarott[1,2], Tianshuo Zhao[2], and Cherie Kagan[2] — [1]Laboratory of Multifunctional Ferroic Materials (M. Fiebig), ETH Zurich, Switzerland — [2]Department of Materials Science and Engineering, University of Pennsylvania, USA

Recent advances in the characterization and synthesis of solution-processable semiconductor nanocrystals (NCs) have increased the interest in this class of materials for optoelectronic device applications including solar cells, light-emitting diodes, and photodetectors. In particular, lead chalcogenide NCs are promising candidates with a broadly tuneable spectral response from visible (VIS) to infrared (IR) depending on the NC size. In this study, we prepare PbS, PbSe, and PbTe NCs with a first excitonic absorption peak in the short-wavelength infrared range at 1.55um. For a variety of ligand chemistries, charge transport and doping properties of NC films are measured on a field-effect transistor (FET) geometry. Vertically stacked p-n and p-i-n heterojunction photodiodes are fabricated using an n-type ZnO film as electron transport layer. Current-voltage characteristics reveal that the degree of rectification, noise, and dark current level strongly depend on the choice of ligand, air-exposure, and electron blocking layers (MoO3) within the diode stack.