HL 71: Quantum Dots: Optical Properties

Time: Thursday 10:15–13:15 Location: POT 251

HL 71.1 Thu 10:15 POT 251

Simultaneous control of single self-assembled quantum dots by strain and electric fields — •Rinaldo Trotta, Paola Atkinson, Johannes D. Plumhof, Santosh Kumar, Roman Rezaev, Eugenio Zallo, Andreas Herklotz, Kathrin Dörr, Armando Rastelli, and Oliver G. Schmidt — Institute for Integrative Nanosciences, IFW Dresden, Helmholtzstrasse 20, D-01069 Dresden, Germany

The possibility to control the physical properties of semiconductor quantum dots (QDs) through external perturbations has led to an explosion of research interest from both fundamental and technological standpoints. Here we will report on the fabrication of a novel device, which allows applying strain and electric fields on a single QD simultaneously. Diode-like-nanomembranes containing quantum dots are integrated onto piezoelectric actuators via gold thermo-compression bonding. Different diode-like-structures (n-i-Schottky and p-i-n diodes) will be presented and the optical properties of embedded dots will be discussed. By applying biases to the piezoelectric actuator we can reversibly shift the emission energy of a single QD by more than 10 meV, while by applying a bias to the diode structure we can control the charge state of the QD or excite electroluminescence. The latter result represents the first demonstration of a strain-tuneable Light-Emitting Diode (LED) based on single quantum dots, a device which might be of high potential interest for quantum information technology.

HL 71.2 Thu 10:30 POT 251

Dynamic control of charge carrier injection into individual quantum dots and quantum posts by surface acoustic waves — •Florian J. R. Schülein[1], Stefan Völk[1], Florian Knall[1], Dirk Reuter[2], Andreas D. Wieck[2], Tuan A. Truong[3], Heejung Kim[3], Pierre M. Petroff[3], Achim Wixforth[1], and Hubert J. Krenner[1] — [1]Lehrstuhl für Experimentalphysik I, 86159 Augsburg, Germany — [2]Lehrstuhl für Angewandte Festkörperphysik, 44780 Bochum, Germany — [3]Materials Department, University of California, Santa Barbara, CA 93106, United States

We present a detailed study of the surface acoustic wave (SAW) power dependence on the carrier injection into and recombination in self-assembled quantum posts (QPs) and quantum dots (QDs). The matrix quantum well of QPs is a wide ($\sim$ 23nm) confinement potential, in contrast to the wetting layer of QDs. Thus, the energy levels of the thin ($\sim 1-2$nm) wetting layer is modulated by monolayer fluctuations giving rise to charge carrier traps and very low overall mobility. For both systems we observe a clear switching between different states (X^0 and $X^{+/-}$) with increasing SAW power. This switching is symmetric in SAW power for QPs and shows a broad hysteresis for QDs. This can be explained by SAW driven ionization of traps within the wetting layer during the up-sweep of the SAW power. With a laser excitation scheme for which the phase of the SAW is locked to the excitation laser, we are able to resolve the full phase information of this dynamically driven carrier injection.

HL 71.3 Thu 10:45 POT 251

Built-in dipole moments of InGaN/GaN single quantum dot excitons — •Irina A. Ostapenko, Christian Kindel, Gerald Hönig, Sven Rodt, André Strittmatter, Axel Hoffmann, and Dieter Bimberg — Institut für Festkörperphysik, TU Berlin, Hardenbergstr 36, 10623 Berlin, Germany

We report on direct determination of intrinsic dipole moments of excitonic complexes in InGaN/GaN quantum dots from cathodoluminescence experiments. Single nitride-based QDs show large potential as sources of entangled photon pairs at room temperature for quantum information processing and cryptography applications [1]. The built-in piezoelectric and pyroelectric fields tremendously affect electro-optical properties of nitride heterostructures [2]. The insight into interplay between confined charge carriers and electric fields is crucial for improvement and control of nitride QD-based devices. Only in cathodoluminescence we observe a re-occurring characteristic pattern in temporal traces of emission lines and explain this feature with a model of interaction between an exciton in a quantum dot and a gradually changing electric field of a charge carrier, moving through the material. We derive the magnitude of the built-in excitonic dipole moments as 0.7-7*10-28C*m*0.3-3 e*nm. These values are in good agreement with calculations based on 8-band k*p, extended by a self-consistent Hartree formalism. [1] C. Kindel, S. Kako, T. Kawano, H. Oishi, Y. Arakawa, G. Hönig, M. Winkelnkemper, A. Schliwa, A. Hoffmann, and D. Bimberg, Phys. Rev. B 81, 241309(R) (2010) [2] M. Winkelnkemper, A. Schliwa, and D. Bimberg, Phys. Rev. B 74,155322 (2006)

HL 71.4 Thu 11:00 POT 251

GaInN quantum dots as optochemical transducers — •Jörg Teubert[1], Sebastian Koslowski[1], Aparna Das[2], Eva Monroy[2], Philomela Komninou[3], and Martin Eickhoff[1] — [1]I. Physikalisches Institut, Justus-Liebig-Universität Gießen, Germany — [2]CEA-CNRS, INAC/SP2M/NPSC, CEA-Grenoble, France — [3]Department of Physics, Aristotle University of Thessaloniki, Greece

We report on the sensitivity of photoluminescence (PL) properties of polar InGaN/GaN quantum dot (QD) super-lattices to changes in the chemical environment. III-N QD structures arouse increasing interest e.g. as light emitters in optoelectronics and telecommunication. Here we address the potential of these nanostructures in the field of chemical sensing. We studied the PL response of III-N QDs upon pH-variations in liquid environment. The experimental results demonstrate that InGaN-quantum dot super-lattices (QDSL) are well suited for the fabrication of novel opto-chemical transducers. InGaN/GaN QDSLs were grown by plasma assisted molecular beam epitaxy on AlN-on-sapphire templates. Measurements in liquid environment were performed using a standard three electrode setup and PBS-buffer with HCl admixture as electrolyte. In order to obtain a deeper understanding of the underlying mechanisms, external electric fields were applied in liquid environment along the QDSL. They reveal a superlinear increase of the PL intensity by more than one order of magnitude when changing the bias voltage by only 600 mV. The underlying mechanism will be discussed in terms of an enhanced carrier confinement under applied bias using numerical simulations of the quantum confinement.

HL 71.5 Thu 11:15 POT 251

Observation of nuclear spin-polarization through electrical and optical injection of spin-polarized electrons in a spin-LED — •Pablo Asshoff, Gunter Wüst, Andreas Merz, Christoph Krämmer, Heinz Kalt, and Michael Hetterich — Karlsruhe Institute of Technology (KIT)

We present a detailed investigation of spin-polarization of quantum dot nuclei in a spin light-emitting diode by analyzing the Overhauser shift. Pumping of the nuclear spins is achieved with either electrical or optical excitation. Typical quantum dots exhibit a behavior where both excitation modes result in an asymmetrical Overhauser shift of comparable magnitude, which we analyze in a theoretical framework.

15 min. break

HL 71.6 Thu 11:45 POT 251

Off-resonant generation of electron spin coherence in InAs quantum dots — •Britt-Marie Meiners[1], Alexander Schwan[1], Stefan Spatzek[1], Steffen Varwig[1], Dmitri Yakovlev[1], Andre Henriques[2], and Manfred Bayer[1] — [1]Experimentelle Physik 2, U Dortmund,D-44227 Dortmund, Germany — [2]Instituto de Física, Universidade de São Paulo, 05315-970 São Paulo, SP, Brazil

Studies of electron spin dynamics in solids have recently become a rapidly developing field of condensed-matter physics. We studied electron spin coherence in an inhomogeneous ensemble of singly charged (In,Ga)As/GaAs QDs by means of time-resolved techniques. The temporal evolution of the spin precession is measured by two-colour Faraday rotation and ellipticity.

Excitation energy was varied in an wide range up to 100 meV above the QDs resonances and even beyond the GaAs barrieer band gap, while the signal was detected on QD trion resonances. Surprisingly, we find that the electron spin coherence can be very efficiently excited even for strong detuning of the pump laser energy. This means that the electrons do not loose their spin coherence in the course of the energy relaxation of more than 100 meV.Also energy dispersion of the electron g-factors across the QD photoluminescence band has been measured and analyzed.

HL 71.7 Thu 12:00 POT 251

Faraday rotation and ellipticity signals of mode-locked spins in InGaAs quantum dots — •Steffen Varwig[1], Stefan Spatzek[1], Alexander Schwan[1], Mikhail M. Glazov[2], Irina A. Yugova[3], Dmitri R. Yakovlev[1], Dirk Reuter[4], Andreas D. Wieck[4], and Manfred Bayer[1] — [1]Experimentelle Physik II, TU Dortmund, D-44221 Dortmund, Germany — [2]A. F. Ioffe Physico-Technical Institute, 194021 St. Petersburg, Russia — [3]Institute of Physics, St. Petersburg State University, 198504 St. Petersburg, Russia — [4]Angewandte Festkörperphysik, Ruhr- Universität Bochum, D-44780 Bochum, Germany

We have studied the pump-probe Faraday rotation and ellipticity signals of electron spins in ensembles of singly charged (In,Ga)As/GaAs quantum dots.

For degenerate pump and probe we observe that the Faraday rotation signal amplitude first grows with increasing the time separation between pump and probe before a decay is observed for large temporal separations. The temporal behavior of the ellipticity signal, on the other hand, is regular: its amplitude decays with the separation. By contrast, for detuned pump and probe the Faraday rotation and ellipticty signals both exhibit similar and conventional behavior. The comparison between calculations and experimental data allows us to provide insight into the spectral dependence of the electron spin precession frequencies and extract the electron g factor dependence on energy [M. M. Glazov et al., Phys. Rev. B 82, 155325 (2010)].

HL 71.8 Thu 12:15 POT 251

Asymmetric optical nuclear spin pumping in a single uncharged quantum dot — •Florian Klotz[1], Vase Jovanov[1], Johannes Kierig[1], Emily Clark[1], Max Bichler[1], Gerhard Abstreiter[1], Heike Schwager[2], Geza Giedke[2], Martin Brandt[1], and Jonathan Finley[1] — [1]Walter Schottky Institut, Technische Universität München, Am Coulombwall 3, 85748 Garching — [2]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Straße 1, 85748 Garching

We present the observation of a unipolar optically pumped dynamic nuclear polarization (DNP) in a single self assembled InGaAs quantum dot (QD). Electrons are resonantly excited in the QD and polarize the nuclear spin system via the hyperfine contact coupling, creating an Overhauser magnetic field. Remarkably, we observe a strong asymmetry in nuclear spin pumping for excitation of the two Zeeman-split neutral exciton states. Hereby, pumping the higher energy Zeeman branch effectively polarizes the nuclear spin system, whereas the lower energy branch does not. We also find a characteristic dependence of the observed DNP on the applied magnetic field where optically induced nuclear spin pumping is most efficient for an intermediate regime of 4 - 6 T, with a polarization of the nuclear spin bath of 53%. A theoretical model is developed that successfully explains the empirically found features based on the exciton level structure of the system.

HL 71.9 Thu 12:30 POT 251

Subnanosecond electrical charge control in a single InGaAs quantum dot — •Jörg Nannen[1], Wolf Quitsch[1], Sven Eliasson[1], Tilmar Kümmell[1], Karl Brunner[2], and Gerd Bacher[1] — [1]Werkstoffe der Elektrotechnik & CeNIDE, Universität Duisburg-Essen, Bismarckstr. 81, 47057 Duisburg — [2]Experimentelle Physik III, Universität Würzburg, Am Hubland, 97074 Würzburg

Single quantum dots (SQD's) are highly interesting candidates for future memory devices, which utilize single electrons or single holes as information carriers. The possibility to electrically and optically address SQD's in charge-tunable semiconductor heterostructures has led to different new concepts to inject, store and read-out the information of a single carrier in a SQD.

We use a high frequency adapted charge-tunable device in order to get electrical access to self-assembled single InGaAs quantum dots in the GHz regime [1]. Under high reverse bias we are able to optically prepare a single hole in the SQD. By the application of a subsequent high frequency voltage pulse, controlled electron tunneling into the SQD is achieved. We demonstrate that depending on the applied voltage either one or two electrons can tunnel into the SQD. It is shown that the electrons can be transported into and out of the quantum dot on time scales down to 300 ps.

[1] Nannen et al., Appl. Phys. Lett. 97, 173108 (2010)

HL 71.10 Thu 12:45 POT 251

Transient Differential Reflection Spectroscopy of Single Lateral InGaAs Quantum Dot Molecules — •Christian Wolpert[1,2], Lijuan Wang[3], Paola Atkinson[3], Armando Rastelli[3], Oliver G. Schmidt[3], and Markus Lippitz[1,2] — [1]Max-Planck Institut für Festkörperforschung, Stuttgart, Germany — [2]4. Physikalisches Institut, Universität Stuttgert, Germany — [3]Institut für Integrative Nanowissenschaften, IFW Dresden, Germany

We use a reflective all-optical pump-probe technique in order to characterize single lateral quantum dot molecules (QDMs), which are coupled by electron tunneling. By applying a bias voltage along the molecular axis one can control the coupling strength as well as the energies of the confined states. This becomes manifest in a strong dependence of the photoluminescence (PL) spectrum with respect to the bias voltage. The emission can be switched from one dot to the other as one passes the bias value at which the electron states are energetically aligned. Our interest lies in the understanding of this switching behavior. Differential reflection spectroscopy is well suited for this problem, as it does not depend on the emission of a photon but rather probes the QD's absorption directly. Furhermore one can capture the kinetics of the process by varying the delay time between pump and probe pulses and thus characterize the system beyond PL.

HL 71.11 Thu 13:00 POT 251

Time-resolved photoluminescence quenching measurements in InAs/GaAs quantum dots using terahertz laser pulses — •Jayeeta Bhattacharyya[1], Sabine Zybell[1], Martin Wagner[1], Manfred Helm[1], Mark Hopkinson[2], Luke R Wilson[2], and Harald Schneider[1] — [1]Helmholtz-Zentrum Dresden-Rossendorf, Germany — [2]University of Sheffield, Sheffield, UK

Carrier dynamics and relaxation processes in self assembled quantum dots (QDs) are of fundamental interest due to their influences on the performances of optoelectronic devices. The intersublevel relaxation mechanisms influence the temporal response of the photoluminescence (PL). In this paper we present our work on time-resolved PL quenching measurements on QD ensembles using terahertz pulses. A Ti:Sapphire laser was used for interband excitation and the PL was measured by a streak camera. Terahertz pulses obtained from a Free Electron Laser were tuned to excite intersublevel transitions in the QDs which caused partial depletion of the electronic ground state resulting in quenching of the interband PL. The samples studied consisted of self-assembled InAs/GaAs QDs for which the intersublevel relaxation times varied from few ps to ns. Simultaneous time and wavelength resolved measurements enabled us to study the carrier redistribution by the terahertz pulse and their dynamics. The PL transients were fitted using exponential functions convoluted with a Gaussian system response and the PL quenching depth and recovery times were extracted. We will present a comparative analysis for different QD samples, with emphasis on the effect of intersublevel relaxation times on the carrier dynamics.