HL 9: Quantum dots: Optical properties

Time: Monday 10:00–13:00 Location: EW 203

HL 9.1 Mon 10:00 EW 203

Advanced in-situ elctron-beam lithography on pre-selected quantum dots by cathodoluminescence spectroscopy — •Arsenty Kaganskiy, Manuel Gschrey, Alexander Schlehahn, Jan-Hindrik Schulze, Ronny Schmidt, Tobias Heindel, Sven Rodt, André Strittmatter, and Stephan Reitzenstein — Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstraße 36, D-10623

Future quantum technology will rely crucially on the development of sources for indistinguishable and entangled photon pairs based on self-assembled quantum dots (QDs). To boost their photon extraction efficiency QDs need to be embedded in a precise and controlled way into photonic structures. In order to meet this requirement we developed and further advanced a deterministic technology platform named in-situ cathodoluminescence lithography (CLL) [1]. In the advanced CLL technique we are now able to fully characterize single QDs in a pre-registering process before integrating them with high alignment accuracy, e.g. into microlenses. The pre-characterization comprises measurement of the fine-structure splitting, time resolved luminescence, and second-order photon autocorrelation. Thus, advanced CLL combines the advantage of integrating individual QDs deterministically into nanostructures with a thorough pre- and post-characterization process. Within this scheme it is possible to directly evaluate the change in optical properties, e.g. in terms of the Purcell effect induced by the photonic structures.

[1] M. Gschrey et al., APL 102, 251113 (2013).

HL 9.2 Mon 10:15 EW 203

Processing and optical characterisation of InGaN quantum dots with AlGaN barrier layers — •Elahe Zakizadeh, Carsten Laurus, Stephan Figge, Kathrin Sebald, and Jürgen Gutowski — Institute of Solid State Physics, University of Bremen, Germany

InGaN quantum dots are promising candidates to realize single photon emission at elevated temperatures due to their large bandgap and high exciton binding energies. Single line emission from InGaN quantum dots was already observed up to 150 K.

Here, we report on samples for which an additional AlGaN barrier layer was grown below the InGaN quantum dot layer by metal organic vapor phase epitaxy in order to increase the carrier confinement which might result in single photon emission at elevated temperatures.

For single quantum dot spectroscopy the optically excited quantum dots density must be reduced. One possibility is the creation of shadow masks on the sample. In this contribution different lithographic methods for producing the shadow masks and micro-photoluminescence measurements on the InGaN quantum dots will be presented.

HL 9.3 Mon 10:30 EW 203

Dissipative preparation of the exciton and biexciton in a single self-assembled quantum dot — •Lukas Hanschke[1], Manuel Koller[1], Per-Lennart Ardelt[1], Kevin A. Fischer[2], Kai Müller[2], Alexander Kleinkauf[1], Alexander Bechtold[1], Tobias Simmet[1], Jakob Wierzbowski[1], Gerhard Abstreiter[1], and Jonathan J. Finley[1] — [1]Walter Schottky Institut and Physik-Department, Technische Universität München, Am Coulombwall 4, 85748 Garching, Germany — [2]E. L. Ginzton Laboratory, Stanford University, Stanford, California 94305, USA

Pulsed resonant fluorescence is used to probe ultrafast phonon-assisted exciton and biexciton preparation in individual self-assembled InGaAs quantum dots. By driving the system using large area ($>10\pi$) near resonant optical pulses, we experimentally demonstrate how phonon mediated dissipation within the manifold of dressed excitonic states can be used to prepare the neutral exciton with a fidelity 70%. By comparing the phonon-assisted preparation with resonant Rabi oscillations we show that the phonon-mediated process provides the higher fidelity preparation for large pulse areas and is less sensitive to pulse area variations. By detuning the laser with respect to the exciton transition we map out the spectral density for exciton coupling to the bulk LA-phonon continuum. Similar phonon mediated processes are shown to facilitate direct biexciton preparation via two photon biexciton absorption, with fidelities $> 80\%$. Our results are found to be in very good quantitative agreement with simulations that model the quantum dot-phonon bath interactions with Bloch-Redfield theory.

HL 9.4 Mon 10:45 EW 203

Neutral and charged biexciton-exciton-cascade of near-telecom wavelength MOVPE-grown InGaAs QDs — •Jan Kettler, Matthias Paul, Fabian Olbrich, Katharina Zeuner, Michael Jetter, and Peter Michler — Institut für Halbleiteroptik und funktionelle Grenzflächen (IHFG), Universität Stuttgart, Allmandring 3, 70569 Stuttgart

The implementation of large-scale fiber-based quantum information networks requires sources of single and entangled photons that show little absorption and dispersion in standard glass fibers. InGaAs quantum dots (QDs) have shown to be bright and flexible sources of non-classical light with typical emission wavelengths below 1 μm.

Here we demonstrate InGaAs QDs grown by industrial standard metal-organic vapor phase epitaxy (MOVPE) that are covered with a thin Indium-rich layer, leading to red-shifted emission wavelengths. The QDs can be grown with an ultra-low lateral density ($< 10^7$ cm^{-2}) and show single-photon emission at the telecom O-band (1.3 μm). We further investigate cascaded photon emission from the biexciton-exciton cascade which is a prerequisite to the generation of polarization-entangled photon pairs.

HL 9.5 Mon 11:00 EW 203

Exciton dynamics in a single site-controlled quantum dot — •Ole Hitzemann, Andrei Schliwa, André Strittmatter, Jan-Hindrik Schulze, David Quandt, Waldemar Unrau, Udo W. Pohl, and Axel Hoffmann — Institut für Festkörperphysik, Technische Universität Berlin, Germany

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 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. The decay dynamics of different exciton related luminescence lines are studied by time-resolved micro photoluminescence spectroscopy.

HL 9.6 Mon 11:15 EW 203

Infrared transmission spectroscopy to measure intersublevel spacings in InAs self-assembled quantum dots — •Shovon Pal[1,2], Sascha R. Valentin[1], Nadezhda Kukharchyk[1], Hanond Nong[2], Alireza B. Parsa[3], Gunther Eggeler[3], Arne Ludwig[1], Nathan Jukam[2], and Andreas D. Wieck[1] — [1]Lehrstuhl für Angewandte Festkörperphysik, Ruhr-Universität Bochum, Germany. — [2]AG Terahertz Spektroskopie und Technologie, Ruhr-Universität Bochum, Germany. — [3]Institut für Werkstoffe, Ruhr-Universität Bochum, Germany.

For over a decade, zero-dimensional semiconductor quantum dots have broadened the horizon of device applications from simple electronic memories to many optoelectronic devices like single photon emitter and photodetectors. The working principle of all these devices relies on the quantization resulting from confinement in such nanostructures. In this study, we employ Fourier transform infrared transmission spectroscopy to investigate the intersublevel spacings in the conduction band of self-assembled InAs quantum dots. Epitaxial, complementary-doped and semi-transparent electrostatic gates are grown on top of the sample within the ultra high vacuum conditions of the molecular beam epitaxy. These gates enable voltage tuning of the device with a better optical transmission [1].

[1] S. Pal et al., Infrared transmission spectroscopy of charge carriers in self-assembled InAs quantum dots under surface electric fields, J. Phys.: Condens. Matter 26 (2014) 505801.

Coffee break

HL 9.7 Mon 11:45 EW 203

Applying pump-probe quantum state tomography to a semi-

conductor optical amplifier — •Nicolai B. Grosse[1], Nina Owschimikow[1], Roland Aust[2], Benjamin Lingnau[2], Alexej Koltchanov[1], Mirko Kolarczik[1], Kathy Lüdge[2], and Ulrike Woggon[1] — [1]Institut für Optik und Atomare Physik, Technische Universität Berlin, Germany — [2]Institut für Theoretische Physik, Technische Universität Berlin, Germany

We have combined the techniques of pump-probe and quantum state tomography to observe how an In(Ga)As based quantum-dot semiconductor optical amplifier can transform the quantum state of a probe pulse that is tuned to the quantum dots' ground state, while optically pumping the quantum dots' excited state. From the Wigner functions thus obtained, the device gain, the amplified noise, and the excess noise due to amplified spontaneous emission could be measured relative to the quantum noise limit and on an ultrafast time scale. This information was used to infer the degree of population inversion in the gain medium, which revealed a depletion and recovery of the population inversion on the sub-picosecond time scale.

HL 9.8 Mon 12:00 EW 203

Pulsed ODNMR in (In,Ga)As/GaAs-QDs — •Eiko Evers[1], Tomasz Kazimierczuk[1,2], Steffen Varwig[1], Alex Greilich[1], Dmitri Yakovlev[1,3], Dirk Reuter[4,5], Andreas Wieck[5], and Manfred Bayer[1,3] — [1]Experimentelle Physik 2, Technische Universität Dortmund, 44221 Dortmund, Germany — [2]Institute of Experimental Physics, Faculty of Physics, University of Warsaw, ul. Hoza 69, 00-681 Warszawa, Poland — [3]Ioffe Physical-Technical Institute, Russian Academy of Sciences, 194021 Saint Petersburg, Russia — [4]Department Physik, Universität Paderborn, Warburger Straße 100, 33098 Paderborn, Germany — [5]Angewandte Festkörperphysik, Ruhr-Universität Bochum, 44780 Bochum, Germany

The spin of electrons in singly charged quantum dots is surrounded by a nuclear spin-bath, which limits the spin-coherence time T_{2,e^-}. The spin dynamics of surrounding isotopes in an ensemble of self-assembled (In,Ga)As/GaAs QDs is investigated using a combination of optically detected e^--spin polarization via Faraday rotation and pulsed, coherent radio frequency NMR control of nuclear-spin orientation. This allows to directly observe the influence of the nuclear-spin bath on the e^--spin polarization in the time domain and to identify the isotopes interacting with the electron spin. We measured a coherence time $T_{2,^{75}\mathrm{As}}$ of up to 6 ms.

HL 9.9 Mon 12:15 EW 203

Random-alloying induced optical fingerprints in colloidal quantum dots — •Daniel Mourad[1], Tangi Aubert[2], Antoine Guille[2], Edouard Brainis[2], Zeger Hens[2], and Gabriel Bester[1] — [1]Institut für Physikalische Chemie, Universität Hamburg — [2]Physics and Chemistry of Nanostructures, Ghent University

Monodisperse, homogeneously alloyed quantum dots (QDs), which can be grown by means of colloidal synthesis, allow for a tayloring of the absorption/emission properties by variation of the composition. However, distinguishing a random alloy from, e.g., a core/shell nanocrystal is difficult and requires advanced characterization tools such as Raman spectroscopy [Aubert *et al.*, Chem. Mater. 25(12), 2388 (2013)]. We show that randomly alloyed Cd(Se,S) QDs exhibit fingerprints of random alloying in their absorption spectrum. Furthermore, we demonstrate that a stochastical empirical tight-binding scheme can reproduce these features without additional free parameters and link them to symmetry breaking intrinsic to random alloying [Mourad *et al.*, Chem. Mater., DOI: 10.1021/cm5035408]. When complemented by many-particle calculations in the configuration interaction framework, excited-state properties like the bowing of the optical gap are also in very good agreement with the experiment. Since symmetry breaking is inherent to random alloys, our method may provide a general framework where theory can be used to predict random alloying fingerprints in absorption spectra of different nanomaterials. We discuss the effects of size variations, different composition profiles and further material systems.

HL 9.10 Mon 12:30 EW 203

Electron-Phonon coupling in colloidal CdSe/CdS quantum dots — •Steffen Westerkamp, Axel Hoffmann, and Andrei Schliwa — Institut für Festkörperphysik, TU Berlin

The Huang-Rhys-factors of electron-phonon coupling in colloidal CdSe/CdS quantum dots are calculated for various sizes, core-shell ratios, and interface transitions both for the zincblende and the wurtzite phase. Electron and hole wavefunctions are obtained using strain dependent 8-band-kp theory. Phonon eigenmodes and frequencies are calculated using an atomistic model employing pseudopotentials. In particular we discuss the consequences of the lower symmetry of the wurtzite phase compared to zincblende with respect to the electronic spectrum, the phonon frequencies and the coupling strength.

HL 9.11 Mon 12:45 EW 203

Radiation pattern for epitaxial Quantum Dots — Ludwig Albrecht Thorsten Greif, Stefan Jagsch, Axel Hoffmann, and •Andrei Schliwa — TU Berlin, Germany

Effective interaction between an exciton (X_0) localized in a quantum dot (QD) and a cavity mode (CM) requires i) resonance between X_0 and CM, ii) optimal spatial overlap of QD and CM, and iii) a transition dipole moment which is collinear to the electric field of the CM. The latter is closely related to the angular-resolved radiation characteristics of the X_0, which will be discussed here for epitaxial QDs of different chemistry, crystal structure and shape using eight-band kp theory.