HL 31: Quantum dots and wires: Optical properties III

Time: Wednesday 14:45–18:00 Location: H17

HL 31.1 Wed 14:45 H17

Measurement and control of spin and charge interactions in a single quantum dot molecule — •Emily Clark[1], Hubert Krenner[1], Christoph Scheurer[2], Toshihira Nakaoka[3], Max Bichler[1], Gerhard Abstreiter[1], and Jonathan Finley[1] — [1]Walter Schottky Institut, Technical University of Munich, Am Coulombwall 3, 85748 Garching, Germany — [2]Lehrstuhl für Theoretische Chemie, Technische Universität München, Lichtenbergstraße 4, 85748 Garching, Germany — [3]University of Tokyo, 4-6-1, Komaba, Meguro-ku, Tokyo, 153-8505, Japan

We report experiments in which we electrically manipulate coupled exciton states (neutral and negatively charged single excitons) in individual QD-molecules (QDMs). The samples investigated consist of a single pair of vertically stacked, self assembled $In_{0.5}Ga_{0.5}As$ QDMs embedded into the intrinsic region of an n-type GaAs Schottky photodiode. By tuning the electric field oriented along the axis of the QDM, via the gate voltage, electrons can be predictably injected into the QDM from the back contact. Field dependant micro-Photoluminescence measurements reveal a complex series of anti-crossing features from neutral excitons, negatively charged excitons and double charged excitons as the field is lowered. Each multi-particle configuration couples at a distinct field and unique energetic splitting, allowing for the unambiguous assignment of each spectral feature. We directly probe Coulomb and Pauli blockade effects and inter-dot tunnel coupling using fully optical techniques. See: H.J. Krenner, et. al Phys. Rev. Lett. 97, 076403 (2006)

HL 31.2 Wed 15:00 H17

Polarized emission lines from A- and B-type excitonic complexes in single InGaN/GaN quantum dots — •Momme Winkelnkemper[1,2], Robert Seguin[1], Sven Rodt[1], Andrei Schliwa[1], Lars Reissmann[1], Andre Strittmatter[1], Axel Hoffmann[1], and Dieter Bimberg[1] — [1]Institut für Festkörperphysik, Technische Universität Berlin, D-10623 Berlin, Germany — [2]Fritz-Haber-Institut der Max-Planck-Gesellschaft, D-14195 Berlin, Germany

Nitride-based semiconductor nanostructures have been widely studied in the last decade and revolutionary optoelectronic devices have emerged from this effort.

In this talk we report on a combined experimental and theoretical study of the optoelectronic properties of single InGaN/GaN quantum dots (QDs). Using single-QD cathodoluminescence, complex spectra with up to five emission lines per QD are observed. The lines are polarized along the orthogonal crystal directions [1 1 -2 0] and [-1 1 0 0].

Realistic eight-band k.p calculations reveal that the polarization of the emission lines is owed to the valence band structure of wurtzite group-III nitrides and the strain distribution within the QDs; it can be explained by excitonic recombinations involving hole states which are either formed by the A or the B valence band. The mechanism responsible for the polarization is a general feature of all wurtzite nitride-based QDs and is essential for the understanding of recombination processes in nitride QDs.

HL 31.3 Wed 15:15 H17

Switch-on process of an electrically pumped singlequantum dot — •Erik Stock[1], Anatol Lochmann[1], Till Warming[1], Dieter Bimberg[1], Vladimir A. Haisler[2], A. I. Toropov[2], A.K. Bakarov[2], and A.K. Kalagin[2] — [1]Technische Universität Berlin, Institut fürFestkörperphysik, Sekr. PN 5-2, Hardenbergstr. 36, 10623 Berlin,Germany — [2]Institute of Semiconductor Physics,Lavrenteva avenue 13, 630090 Novosibirsk, Russia

Self-organized single quantum dots (QD) are of great interest for the realization of single-photon sources. One of the main features is the possibility to generate entangled photons, which can be achieved by exciton and biexciton emission of a single QD with a fine structure splitting less then the homogeneous broadening.

We demonstrate electrically pumped single InAs/GaAs QD emission in a pin-diode with submicron oxide current aperture. This QD-LED allows pumping of just one single QD. Via the pump current exciton and biexciton emission can be controlled as required for entangled photons sources. In highly resolved spectra we observe the switch-on of the electroluminescence: First a single emission lines becomes visible. With increasing current this emission shifts towards higher energy and splits into up to three emission lines separated by $\sim 70\mu$eV. At higher current they rejoin to form a single unpolarized emission line and stay on a fixed emission energy. This splitting of emission may influence the entanglement of emitted photon pairs and has to be considered for the development of electrically driven single photon sources.

HL 31.4 Wed 15:30 H17

Enhancement of electron spin coherence by optical preparation of nuclear spins — •Dimitrije Stepanenko[1], Guido Burkard[1], Geza Giedke[2], and Atac Imamoglu[3] — [1]Department of Physics and Astronomy, University of Basel, Klingelbergstrasse 82, 4056 Basel, Switzerland — [2]Max Planck Institute for Quantum Optics, Hans Kopfermann Str. 1, Garching, Germany — [3]Institute of Quantum Electronics, ETH Zurich, 8093 Zurich, Switzerland

We study a large ensemble of nuclear spins interacting with a single electron spin in a quantum dot under optical excitation and photon detection. When a pair of applied laser fields satisfy two-photon resonance between the two ground electronic spin states, detection of light scattering from the intermediate exciton state acts as a weak quantum measurement of the effective magnetic (Overhauser) field due to the nuclear spins. If the spin were driven into a coherent population trapping state where no light scattering takes place, then the nuclear state would be projected into an eigenstate of the Overhauser field operator and electron decoherence due to nuclear spins would be suppressed: we show that this limit can be approached by adapting the laser frequencies when a photon is detected. We use a Lindblad equation to describe the time evolution of the driven system under photon emission and detection. Numerically, we find an increase of the electron coherence time from 5 ns to 500 ns after a preparation time of 10 microseconds.

HL 31.5 Wed 15:45 H17

Reliable parallel electrical initialization of spin-polarized electrons in InGaAs/GaAs quantum dots — W. Löffler, C. Mauser, J. Lupaca-Schomber, S. Li, T. Passow, H. Reimer, C. Klingshirn, M. Hetterich, and •H. Kalt — Institut für Angewandte Physik and DFG Center for Functional Nanostructures (CFN), Universität Karlsruhe (TH), 76128 Karlsruhe, Germany

We show that electron spins can be initialized electrically with near 100% fidelity in InGaAs/GaAs quantum dots. This is done by injecting spin-polarized electrons from a semimagnetic spin-aligner layer (ZnMnSe) into the quantum dots. At a moderate external magnetic field (3-6 Tesla), we observe only emission from one of the Zeeman doublet states in the quantum dot. That means the initialization error is below our experimental resolution of about one percent. This result is surprising as the polarization of quantum dot ensembles is far below unity. To reveal the origin of this discrepancy, statistical analysis of the electron spin in many different quantum dots has been done.

HL 31.6 Wed 16:00 H17

Photon Statistics Of Semiconductor Microcavity Lasers — •Christopher Gies, Jan Wiersig, Michael Lorke, and Frank Jahnke — Institut für Theoretische Physik, Universität Bremen, Deutschland

When it comes to laser phenomena in quantum dot-based systems, usually atomic models are employed to analyze the characteristic behavior. We introduce a semiconductor theory, originating from a microscopic Hamiltonian, to describe lasing from quantum dots embedded in microcavities. The theory goes beyond two-level atomic models and includes modified contributions of spontaneous and stimulated emission as well as many-body effects. An extended version, which incorporates carrier-photon correlations, provides direct access to the photon autocorrelation function and thereby to the statistical properties of the laser emission. In comparison to atomic models, we find deviations in the dependence of the input/output curve on the spontaneous emission coupling factor. Our theory is presented together with measurements of first- and second-order coherence of quantum-dot micropillar lasers, obtained in the group of P. Michler.

15 min. break

HL 31.7 Wed 16:30 H17

Spin dynamics of coupled nuclear-electron system over millitesla magnetic fields in n-doped quantum dots — •Thomas Auer[1], Sergey Verbin[2], Roman Cherbunin[2], Ruth Oulton[3], Dmitri Yakovlev[1], Manfred Bayer[1], Dirk Reuter[4], and Andreas Wieck[4] — [1]Experimentelle Physik 2, Otto-Hahn-Strasse 4, 44227 Dortmund — [2]V. A. Fock Institute, St. Petersburg State University, 198504 St. Petersburg, Russia — [3]University of Sheffield, Hicks Building, Hounsfield Rd, S3 7RH, Sheffield, UK — [4]Angewandte Festkörperphysik, Ruhr-Universität Bochum, 44780 Bochum

The hyperfine interaction between electrons and nuclei in quantum dots has a significant effect on the spin dynamics of both systems. The nuclear system may be polarized by optically pumping with spin polarized electrons, such that the often very large fields generated have a significant effect on the spin dynamics of the electron. In turn, the effective field from the electron (Knight field <1 mT) also strongly influences the spin dynamics of the polarized nuclei. By applying external magnetic fields of the same magnitude (few mT) one may access a rich variety of complex interactions between the two systems. We demonstrate that the Knight field, which is crucial in allowing nuclear polarization to occur at 0T, may be partially compensated by an external field. In addition, we demonstrate that the strongly-coupled electron-nuclear system, which in the absence of applied field forms a stable configuration with a sub-second spin lifetime, is strongly perturbed by the application of mT fields, with the lifetimes dramatically modified depending on field orientation.

HL 31.8 Wed 16:45 H17

Quantum kinetics of polarons in semiconductor quantum dots — •Jan Seebeck[1], Paul Gartner[1,2], and Frank Jahnke[1] — [1]Institute for Theoretical Physics, University of Bremen, Germany — [2]National Institute for Materials Physics, Bucharest-Magurele, Romania

For applications of semiconductor quantum dots (QDs) in optoelectronic devices efficient carrier scattering processes are necessary. We study carrier-phonon scattering within a quantum kinetic theory of the interacting many-body system, where carriers are described as polarons. At elevated temperatures and low carrier densities, the interaction of carriers with LO phonons in semiconductor QDs leads to fast scattering channels even in QDs where the level spacing does not match the LO-phonon energy.

To investigate carrier dynamics experimentally, most pump-probe experiments are performed at low temperatures. We show, that even at low temperatures fast carrier scattering can be obtained with our theory due to the combined influence of polaron satellites and non-Markovian effects.

HL 31.9 Wed 17:00 H17

Influence of a lateral electric field on a semiconductor quantum dot — •Sandra Ritter[1], Norman Baer[1], Paul Gartner[1,2], and Frank Jahnke[1] — [1]Institute for Theoretical Physics, University of Bremen, Germany — [2]National Institute for Material Physics, Bucharest-Magurele, Romania

We study semiconductor quantum dots in a homogeneous electric field which is oriented perpendicular to the growth direction. Assuming a harmonic confinement potential, three different methods for determining the single excitonic ground state are compared.

The first one determines the transition energies of the interacting system where Coulomb matrix elements are calculated from single-particle wave functions in the electric field. It can be solved analytically and gives insight into different physical mechanisms.

The second one minimizes the whole system energetically by using a variational procedure. This method is more accurate since it gives a smaller 1X ground state energy. However, its accuracy relies on a suitable choice of the test function.

For the third method it is assumed that the electron and hole single particle energies are identical. Then the Hamiltonian can be separated into a field independent center-of-mass contribution and a relative motion part that is subject to the electric field. The resulting shifts of the transition energies due to the electric field are determined.

HL 31.10 Wed 17:15 H17

Calculation of the vibronic progressions observed in the photoluminescence of Si nanocrystals — •Davoud Pouladsaz[1,2] and Reinhard Scholz[1] — [1]Walter Schottky Institut, Technische UniversitätMünchen, Am Coulombwall 3, 85748 Garching — [2]Institut für Physik, Technische UniversitätChemnitz, 09107 Chemnitz, Germany

The optical properties of H-passivated silicon nanocrystals are determined by the energetics of the frontier orbitals and their dependence on the deformation in the relaxed excited state. For tetrahedral nanocrystals up to a diameter of 1.5 nm, we have optimized the geometries in the electronic ground state and in the relaxed excited state with density functional theory (DFT) and time-dependent DFT, respectively. In the excited state, the modified occupation numbers of the frontier orbitals define an anisotropic change of the electronic charge density. Therefore, the deformation in the relaxed excited state consists of a symmetry conserving part and of a symmetry-breaking distortion from T_d towards D_{2d}. The projection of these different parts of the deformation pattern onto the vibrational modes in the electronic ground state generates the vibronic progressions observed in photoluminescence (PL). The lineshapes obtained from this projection scheme are compared with available experimental data, resulting in similar PL energies and linewidths.

HL 31.11 Wed 17:30 H17

Room-temperature storage of excitons in elongated semiconductor nanocrystals — •Robert Kraus[1], Pavlos Lagoudakis[1], Andrey Rogach[1], John Lupton[2], Jochen Feldmann[1], Dmitriy Talapin[3], and Horst Weller[3] — [1]Lehrstuhl für Photonik und Optoelektronik, Ludwig-Maximilians-Universität München — [2]Department of Physics, University of Utah, Salt Lake City, USA — [3]Institut für Physikalische Chemie, Universität Hamburg

The excited state of colloidal nanostructures consisting of a spherical CdSe core overgrown with a rod-like CdS shell can be perturbed effectively by electric fields.[1-3] Field-induced fluorescence quenching coincides with a suppression of radiative rate without increasing ionization. After turning off the electric field, a significant fraction of quenched - and therefore stored - excitons recombines radiatively, even for a duration of the electric field pulse of up to 100 μs. Application of an electric field not only promotes the separation of electron and hole wave function but also influences the depopulation dynamics of localised states on the surface of the nanocrystal. This leads to a significant change in the exponent of the characteristic power law decay of the delayed luminescence. Furthermore, exciton storage selects the most polarisable particles, therefore a significant quantum confined Stark shift of ~15 meV along with a correlated broadening of the spectrum is visible in the time-resolved emission of the ensemble at room temperature.

[1] J. Müller et al., Phys. Rev. Lett. 93, 167402 (2004)
[2] R. Kraus et al., Phys. Rev. Lett. in press (2006)
[3] J. Müller et al., NanoLett. 5, 2044 (2005)

HL 31.12 Wed 17:45 H17

Single InGaAs Quantum Dots Embedded in Electrically Active Photonic Crystal Nanocavities — •Felix Hofbauer, Michael Kaniber, Max Bichler, Gerhard Böhm, Gerhard Abstreiter, and Jonathan Finley — Walter Schottky Institut, Am Coulombwall 3, TU München, 85748 Garching, Germany

We present investigations of the coupling of single InGaAs quantum dots (QDs) to both extended and strongly localised optical modes in electrical contacted 2D photonic crystal (PC) nanostructures. The samples investigated consist of an 180nm thick, free-standing GaAs membrane into which a PC is formed by etching a triangular lattice of air holes. Low mode-volume ($V < (\lambda/n)^3$) and high-Q (~ 2000) cavities are introduced by single missing hole defects. Embedding the QDs into the intrinsic region of a p-i-n diode enables us to apply static electric fields to QDs in the cavity and control the energy detuning between the dot and cavity using the quantum confined Stark effect.

The active PC nanocavities were studied using spatially resolved luminescence and photocurrent absorption spectroscopy. Quenching of the PL is observed for fields > 50 kV/cm due to carrier tunneling escape from the dots that occurs over timescales faster than the radiative lifetime. By measuring the PL quenching as a function of position on the PC and nanocavity we electrically probe the local density of photonic states via a shift of the threshold voltage. Also investigations of the exciton lifetime and PL intensity of single QDs as a function of spectral detuning from the cavity mode are made.

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