HL 55: Quantum dots: Interaction with environment

Time: Wednesday 15:00–16:45 Location: EW 203

HL 55.1 Wed 15:00 EW 203

Influence of crossed excitons on the carrier dynamics in dot-in-well structures — •Mirco Kolarczik, Nina Owschimikow, Yücel Kaptan, Nicolai Grosse, and Ulrike Woggon — Institut für Optik und Atomare Physik, Technische Universität Berlin, Straße des 17. Juni 135, 10623 Berlin, Germany

Quantum dots (QDs) embedded in a quantum well (QW), the so-called DWELL system, are an important class of active media in opto-electronic devices. In addition to strain relaxation, the well provides an efficient way of injecting carriers into the QDs. We investigate the energy level structure formed by the combination of zero-, two- and three-dimensional confinement in an In(Ga)As-based DWELL system embedded in a GaAs matrix by ultrafast two-color pump-probe spectroscopy. We find that "crossed excitons", a Coulomb-correlated electron-hole pair with one carrier localized in the QD, and the complementary carrier in either the QW or the bulk, are formed in these systems [1]. The crossed excitons play an important role in the response of the system to an optical excitation as well as in the lateral coupling between QDs mediated by the well. They create an additional localized density of states around the QDs, that significantly modifies capture and escape processes between QDs and surrounding QW and bulk material.

[1] N. Owschimikow, M. Kolarczik, Y. Kaptan, N. Grosse, and U. Woggon, Appl. Phys. Lett. 105, 101108 (2014)

HL 55.2 Wed 15:15 EW 203

Geometrical Control of the Interatomic Coulombic Decay Process in Quantum Dots — Praphasiri Dolbundalchok[1] and •Annika Bande[1,2] — [1]Theoretische Chemie, Physikalisch-Chemisches Institut, Universität Heidelberg, Im Neuenheimer Feld 229, 69120 Heidelberg, Germany — [2]Institute of Methods for Material Development, Helmholtz-Zentrum Berlin and Joint Lab JuLiq with Department of Physics, FU Berlin, Albert-Einstein-Str. 15, 12489 Berlin, Germany

The elementary physical process of interatomic Coulombic decay (ICD) is recognized as an ultrafast energy transfer process between atoms and molecules induced by long range electron correlation. It was shown to be also possible in arrays of semiconductor quantum dots (QDs). An electron bound to an excited state of one of the QDs decays by transferring its energy to the neighboring QD from which a second electron is emitted.

Different from atomic ICD, ICD in QDs is postulated to find technological application either in infrared photo detectors or solar cells. Most appealing for this technological use is that by geometry variation of the QDs the ICD rate can be controlled.

In this work we present the control of the two-electron ICD process by geometry variation of QDs represented by electron binding potentials in electron dynamics calculations with the highly accurate multiconfiguration time-dependent Hartree (MCTDH) method for antisymmetric electronic wave functions.

HL 55.3 Wed 15:30 EW 203

Effects of inter-nanocrystal distance on luminescence quantum yield in ensembles of Si nanocrystals — •Sebastian Gutsch[1], Daniel Hiller[1], Margit Zacharias[1], Michael Greben[2], and Jan Valenta[2] — [1]Laboratory for Nanotechnology, University of Freiburg, Freiburg, Germany — [2]Laboratory of Optical Spectroscopy, Charles University, Prague, Czech Republic

The absolute photoluminescence (PL) quantum yield (QY) of multilayers of Si nanocrystals (NCs) separated by SiO2 barriers were thoroughly studied as function of the barrier thickness, excitation wavelength, and temperature. By mastering the plasma-enhanced chemical vapor deposition growth we produce a series of samples with the same size-distribution of SiNCs but variable interlayer barrier distance. These samples enable us to clearly demonstrate that the increase of barrier thickness from 1 nm to larger than 2 nm induces doubling of the PL QY value which corresponds to the change of number of close neighbors in the hcp structure. The temperature dependence of PL QY suggests that the PL QY changes are due to a thermally activated transport of excitation into non-radiative centers in dark NCs or in the matrix. We estimate that dark NCs represent about 68 % of the ensemble of NCs. The PL QY excitation spectra show no significant changes upon changing the barrier thickness and no clear carrier multiplication effects. The dominant effect is the gradual decrease of the PL QY with increasing excitation photon energy.

HL 55.4 Wed 15:45 EW 203

Signatures of Förster and Dexter transfer processes in two coupled quantum dots for linear and two-dimensional coherent optical spectroscopy — •Judith Specht, Andreas Knorr, and Marten Richter — Institut für Theoretische Physik, Nichtlineare Optik und Quantenelektronik, Technische Universität Berlin, Hardenbergstrasse 36, 10623 Berlin, Germany

An in-depth investigation of the spin-dependent exciton dynamics in coupled nanostructures driven by coherent, ultrafast laser pulses is crucial for future applications e.g. in the field of quantum information processing. Two-dimensional coherent optical spectroscopy techniques serve as a powerful tool to study the microscopic coupling processes and the underlying excitation pathways. We show theoretically that it is possible to distinguish the signatures of the two different Coulomb induced resonance energy transfer mechanisms: Förster and Dexter coupling, using double quantum coherence spectroscopy.

Förster transfer denotes a purely dipole-dipole mediated interaction which can either transfer or flip the spin state of the excited electron, whereas Dexter coupling describes a direct exchange of electrons between the nanostructures. The possible excitation transfer pathways are selected by the polarizations of the exciting laser pulses and the mutual orientations of the two quantum dots.

We show that spectroscopic signatures reveal the type of excitation transfer process and the limitations imposed on the optical selection rules in the non-linear response.

HL 55.5 Wed 16:00 EW 203

Near unity fidelity single hole spin preparation on picosecond timescales — •Tobias Simmet[1], Per-Lennart Ardelt[1], Kai Müller[2], Alexander Kleinkauf[1], Alexander Bechtold[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

An isolated heavy-hole spin in optically active self-assembled InGaAs-GaAs quantum dots has emerged as a viable spin qubit, whereby the timescales for spin initialization, manipulation and read-out are crucial parameters. Here, we present a scheme for all optical, near fidelity heavy-hole spin initialization within ~3ps by tunneling ionization from the optically prepared exciton state. By optimizing the thickness and Al-content of an AlGaAs tunneling barrier immediately adjacent to the quantum dot, we tailor the comparative tunneling escape rates of electron and heavy holes such that hole spins can be initialized with a fidelity >99% - even at zero magnetic fields - where optical spin initialization may be limited by electron-hole exchange interaction for the neutral exciton. Finally, we present how single heavy-hole spin storage and optical read-out via photocurrent can be optimized by time-gating the electric field using a spin storage device.

HL 55.6 Wed 16:15 EW 203

Excitation of complex spin dynamics patterns in a quantum-dot electron spin ensemble — •Henning Moldenhauer[1], Steffen Varwig[1], Irina A. Yugova[2], Alexandre René[1], Tomasz Kazimierczuk[1], Alex Greilich[1], Dmitri R. Yakovlev[1,3], Dirk Reuter[4], Andreas D. Wieck[4], and Manfred Bayer[1,3] — [1]Experimentelle Physik 2, Technische Universität Dortmund, 44221 Dortmund, Germany — [2]Spin Optics Laboratory, Saint-Petersburg State University, 198504 St. Petersburg, Russia — [3]Ioffe Physical-Technical Institute, Russian Academy of Sciences, 194021 St. Petersburg, Russia — [4]Angewandte Festkörperphysik, Ruhr-Universität Bochum, 44780 Bochum, Germany

We investigate on special periodic pulsed laser excitation protocols in (In,Ga)As/GaAs quantum dot spin ensembles to access more complex nontrivial dynamic patterns. Using a pump-probe setup we apply an additional rectification pulse to generate higher harmonics in the observed spin precession reflecting the orientation patterns of mode-locked spins in a dephased spin ensemble.

HL 55.7 Wed 16:30 EW 203

Formation of bound continuum excitons due to excitonic effects in intraband quantum dot spectroscopy. — •Sandra Kuhn and Marten Richter — Institut für Theoretische Physik, Nichtlineare Optik und Quantenelektronik, Technische Universität Berlin, Hardenbergstrasse 36, 10623 Berlin, Germany

Coulomb induced effects on intraband transitions between bound quantum dot and unbound continuum states of the host material can play a role in a variety of experiments, due to their relevance to the dephasing properties of the quantum dot states as well as for bound to continuum intraband spectroscopy.

We present a theory based on the density matrix formalism to calculate bound to continuum intraband absorption spectra including Coulomb interaction. We study several bound to continuum quasi particles such as trions, biexciton or exciton, resulting in characteristic spectral signatures. In particular, our results show signatures of a bound exciton consisting of a localized carrier inside the quantum dot and a delocalized carrier of the continuum. To get information about the localization of this exciton we discuss the bound to continuum exciton wave function, which shows that the exciton is spatially delocalized in the vicinity of the quantum dot. Especially for the energetically higher states, the spatial extension of the exciton is much larger than the quantum dot extension of 10 nm, often up to 100 nm. This large wave function extension opens a way to study a new possibility of electronic coupling between different quantum dots.