HL 40 Quantum dots and wires: Optical properties III

Time: Thursday 11:00–13:15 Room: POT 151

HL 40.1 Thu 11:00 POT 151

Quantum Theory of Quantum Dot Emission — •Lukas Schneebeli, Thomas Feldtmann, Mackillo Kira, and Stephan W. Koch — Department of Physics and Material Sciences Center, Philipps-Universität Marburg

The microscopic theory of semiconductor quantum dots is formulated including Coulomb interaction and quantum optical coupling effects. Several examples of optical excitations are evaluated using the generalized semiconductor Bloch and luminescence equations [1,2]. Absorption and photoluminescence spectra are discussed for several quantum dot realizations.

[1] M. Kira et al./Progress in Quantum Electronics 23 (1999) 189-279
[2] M. Kira and S.W. Koch Eur. Phys. J.D 36, 143-157 (2005)

HL 40.2 Thu 11:15 POT 151

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

Applications of semiconductor quantum dots (QDs) require efficient carrier scattering processes. We investigate the interaction of carriers with LO phonons in semiconductor QDs, which dominates at low carrier densities and elevated temperatures and leads to fast scattering channels even in QDs where the level spacing does not match the LO-phonon energy.

A quantum kinetic theory of the interacting many-body system is presented, where carriers are described as polarons. The relaxation of a nonequilibrium carrier distribution due to optical pulse excitation is investigated within the full 2-time Green's function formalism and a 1-time approximation using the generalized Kadanoff-Baym ansatz.

It is shown that the 2-time approach leads to a thermalization in terms of the Kubo-Martin-Schwinger condition, while the 1-time approach fails in the intermediate-coupling regime, event though a steady state carrier distribution is obtained.

HL 40.3 Thu 11:30 POT 151

Exciton Aharonov-Bohm Effect in Type I and II Nanorings — •Michal Grochol, Frank Grosse, and Roland Zimmermann — Institut für Physik der Humboldt-Universität zu Berlin, Newtonstr. 15, 12489 Berlin, Germany

The exciton Aharonov-Bohm effect (x-ABE), an oscillatory dependence on the magnetic field, in semiconductor nanorings presents an open question. Although theoretical studies on infinitely narrow nanorings [1] have predicted the x-ABE, more realistic calculations including the finite width of the rings [2] could not confirm these findings.

We present calculations of absorption spectra for realistic ring geometries and material parameters for type I and type II band alignments [3]. x-ABE oscillations are found in both types of structures. Their amplitudes are larger for type II nanorings and increase with decreasing the ring radius. In specific type II nanorings the hole position in the lowest optically active exciton state changes from the center of the ring to the outside by increasing the magnetic field. Possible strategies for observing experimentally the Aharonov-Bohm effect for excitons in semiconductor nanorings are proposed.

[1] L. G. G. V. D. da Silva, S. E. Ulloa, and T. V. Shahbazyan, B **72**, 125327 (2005)

[2] J. Song and S. E. Ulloa, Phys. Rev. B **63**, 125302 (2001)

[3] M. Grochol, F. Grosse, and R. Zimmermann, cond-mat/0511324

HL 40.4 Thu 11:45 POT 151

Optical properties of semiconductor microcavities — •J. Wiersig[1], N. Baer[1], P. Gartner[1], F. Jahnke[1], and M. Hentschel[2] — [1]Institut für Theoretische Physik, Universität Bremen,* 28334 Bremen — [2]Universität Regensburg

Optical microcavities are fundamental tools to study and tailor the emission characteristics of semiconductor quantum dots. The dielectric environment allows to enhance or inhibit light-matter interaction by modifying the optical density of states available for optical transitions, and it permits directed emission of photons by changing the spatial profile of the optical modes. Both aspects will be studied numerically for two different sorts of cavities: micropillars and microdisks with air holes. The spatial profile of the electromagnetic field, quality factors and Purcell factors of micropillars are computed using a vectorial transfer matrix approach. The influences of conical deformations of the boundary, layer-thickness fluctuations and residual absorption are investigated. Microdisks with air holes are analyzed using the extended boundary element method. Unidirectional light emission and ultra-high quality factors are observed. This surprising finding is explained by enhanced dynamical tunneling near an avoided resonance crossing.

HL 40.5 Thu 12:00 POT 151

Effect of Size and Shape on the Single-Particle Spectrum of InAs/GaAs Quantum Dots: A Tight-Binding Study — •Alexander Kleinsorge[1], Peter Kratzer[1], Matthias Scheffler[1], Roberto Santoprete[2], and Belita Koiller[2] — [1]Fritz-Haber-Institut der MPG, Faradayweg 4-6, D-14195 Berlin, Germany — [2]Instituto de Fisica, Universidade Federal do Rio de Janeiro, Brazil

With the help of electronic structure calculations, the electronic and optical properties of quantum dots (QDs) can be related to their atomic structure. We employ the empirical sp^3s^* tight-binding approach, including second-nearest neighbor interactions and spin-orbit coupling, preceded by structural relaxation using a potential of the Abell-Tersoff type to obtain the atomic positions. The folded-spectrum method to calculate selected eigenstates of the Hamiltonian allows us to treat large systems (up to 10^6 atoms). We apply our method to buried InAs quantum dots in GaAs, comparing pyramidal shapes with {101} or {111} side facets with more realistic truncated pyramids, hut-like, or dome-like shapes. The total number of electron and hole bound states, their energy and spatial extent are determined as a function of the QD size and shape. In particular, we find that energy splitting between p-like electron states is due to the symmetry properties of the zincblende lattice, rather than the symmetry of the QD shape. Piezoelectric effects arising from shear strain (treated as an external potential) are included, but found to be small (≈ 5 meV) for the QD sizes considered. Moreover, we compare the wavefunctions in free standing dots to experimental STM images.

HL 40.6 Thu 12:15 POT 151

Exciton Dephasing in Quantum Dots: An Exactly Solvable Model — •Egor Muljarov and Roland Zimmermann — Institut für Physik der Humboldt-Universität zu Berlin, Newtonstr. 15, D-12489 Berlin

In quantum dots, the nondiagonal phonon coupling is responsible for the two main mechanisms of the dephasing - real and virtual phonon-assisted transitions between different excitonic states which have been recently treated in an approximate way [1]. It turns out, however, that virtual transitions alone can be taken into account by mapping the nondiagonal coupling into a level-diagonal quadratic interaction which can be solved exactly. Surprisingly, the quadratic coupling in quantum dots leads to qualitatively different results in case of acoustic and optical phonons. As shown in [2], virtual transitions with acoustic phonon assistance result in an exponential decay of the optical polarization and a broadening of the zero-phonon line. In contrast, the quadratic coupling to dispersionless optical phonons gives no dephasing at all, which rectifies an approximate treatment by Uskov *et al.* [3]. In fact, the exact solution shows that the polarization is almost perfectly periodic in time domain, and the absorption spectrum consists of an infinite set of discrete unbroadened lines.

[1] E. Muljarov, T. Takagahara, and R. Zimmermann, Phys. Rev. Lett. **95**, 155405 (2005).
[2] E. Muljarov and R. Zimmermann, Phys. Rev. Lett. **93**, 237401 (2004).
[3] A.V. Uskov *et al.*, Phys. Rev. Lett. **85**, 1516 (2000).

HL 40.7 Thu 12:30 POT 151

Microscopic Dynamics of two Coupled Quantum Dots — •Sandra Ritter, Kwang Jun Ahn, Juliane Danckwerts, and Andreas Knorr — Institut für Theoretische Physik,Nichtlineare Optik und Quantenelektronik,Technische Universität Berlin,Hardenbergstr. 36, 10623 Berlin, Germany

Within a density-matrix approach, we investigate the quantum kinetics of two Förster coupled semiconductor quantum dots. For the longitudinal Coulomb interaction, the Förster process leads to excitation energy transfer between the two quantum dots. Depending on resonant or nonresonant coupling, a qualitatively different behavior can be observed. Furthermore, we study the combined effects related to Förster transfer and dephasing processes.

HL 40.8 Thu 12:45 POT 151

Theory of Sonoluminescence of Semiconductor Quantum Dots — •Frank Milde, Kwang Jun Ahn, Valentin Flunkert, and Andreas Knorr — Institut für Theoretische Physik, Nichtlineare Optik und Quantenelektronik, Technische Universität Berlin, Hardenbergstr. 36, 10623 Berlin, Germany

The dynamics of resonance fluorescence spectra of acoustically excited intersubband electronic transitions in semiconductor quantum dot is discussed. Since the frequency of the used acoustic waves is well off-resonant to all electronic transitions higher-order harmonics (many phonon absorption) dominate the nonlinear excitation regime.

The derivation of the equations of motion for the photon number of the quantized field is performed in the density matrix formalism. Numerical simulations predict a conversion of incident acoustic into electromagnetic energy over a broad spectral Terahertz range.

HL 40.9 Thu 13:00 POT 151

Optical and electronic properties of self-organized wurtzite InN/GaN quantum dots — •Stefan Schulz, Norman Baer, Stefan Schumacher, Paul Gartner, Frank Jahnke, and Gerd Czycholl — Institute for Theoretical Physics, University of Bremen

In recent years, semiconductor quantum dots (QDs) have been the subject of intense experimental and theoretical research. As a new material system, group-III nitride based devices are of particular interest due to their wide range of emission frequencies from red to ultraviolet and their potential for high-power electronic applications.

We investigate the electronic and optical properties of self-assembled InN/GaN quantum dots [1]. The one-particle states of the low-dimensional heterostructures are provided by a tight-binding model that fully includes the wurtzite crystal structure on an atomistic level. Optical dipole and Coulomb matrix elements are calculated from these one-particle wave functions and serve as an input for full configuration interaction calculations. We present multi-exciton emission spectra and discuss in detail how Coulomb correlations and oscillator strengths are changed by the piezoelectric fields present in the structure. Vanishing exciton and biexciton ground state emission for small lens-shaped dots is observed.

[1] N.Baer, S. Schulz, S. Schumacher, P. Gartner, G. Czycholl, and F. Jahnke, Appl. Phys. Lett. **87** (2005).