HL 55: Quantum Dots and Wires, Optical Properties IV: Spin

Time: Thursday 14:00–15:45 Location: H14

HL 55.1 Thu 14:00 H14

Effect of spin relaxation on the exciton dynamics in a charged quantum dot — •Eleftheria Kavousanaki and Guido Burkard — Department of Physics, University of Konstanz, Germany

We theoretically model the exciton dynamics in a semiconductor quantum dot doped with a single electron when the two lowest quantum dot levels are photoexcited by two circularly polarized femtosecond optical pulses in a pump-probe configuration. We calculate the differential transmission spectrum as a function of the time delay between the two pulses by using a density matrix formalism and treating intraband relaxation with the Lindblad semigroup method. We take into account relaxation processes in which the electron relaxes into the lowest quantum dot level either with or without a spin flip and investigate the possibility for spin-dependent blocking of intra-band relaxation due to the presence of the ground state electron. We show that the differential transmission spectrum is initially dominated by the fast no-flip mechanism before the slower spin-flip processes start to contribute at longer time scales, which allows for the spin polarization of the ground state electron to affect the dynamics.

HL 55.2 Thu 14:15 H14

Ultrafast optical rotations of electron spins in an InGaAs/GaAs quantum dot ensemble — •Stefan Spatzek[1], Alex Greilich[1], Sophia E. Economou[2], Dmitri R. Yakovlev[1,3], Dirk Reuter[4], Andreas D. Wieck[4], Thomas L. Reinecke[2], and Manfred Bayer[1] — [1]Experimentelle Physik 2, TU Dortmund, 44221 Dortmund, Germany — [2]Naval Research Laboratory, Washington, DC 20375, USA — [3]3A. F. Ioffe Physico-Technical Institute, RAS, 194021 St. Petersburg — [4]Angewandte Festkörperphysik, Ruhr-Universität Bochum, 44780 Bochum, Germany

We report on fast optical rotation operations on electron spins in a quantum dots ensemble [1]. The spins are initialized in the z direction (quantum dot growth and light propagation direction). The spin vector oscillates about a transversal magnetic field B till a ultrafast 2π-"control" laser pulse induces rotations of the spins about the z axis. The 2π-control pulse rotates the spin without generating a new spin polarization. The rotation angle is determined by the photon energy detuning of the control pulse from the optical resonance. For the first time for optically controlled spins, spin echoes and extension of the dephasing time were seen. By combining the rotation about the two axis a spin rotations about arbitrary axis has been realized. This robust optically controlled single spin rotation gate provides the basis for single-qubit logic operations.

[1] A. Greilich, S. E. Economou, S. Spatzek, D. R. Yakovlev, D. Reuter, A. D. Wieck, T. L. Reinecke and M. Bayer, Nature Physics 5, 262

HL 55.3 Thu 14:30 H14

Spin-ensembles in (In,Ga)As/GaAs quantum dots — •Alexander Schwan[1], Stefan Spatzek[1], Steffen Varwig[1], Sophia E. Economou[2], Alex Greilich[1], Dmitri R. Yakovlev[1], Dirk Reuter[3], Andreas D. Wieck[3], Thomas L. Reinecke[2], and Manfred Bayer[1] — [1]Experimentelle Physik II, TU Dortmund, D-44221 Dortmund, Germany — [2]Naval Research Laboratory, 20375 Washington DC, USA — [3]Angewandte Festkörperphysik, Ruhr-Universität Bochum, D-44780 Bochum, Germany

Optically controlled electron spins in ensembles of quantum dots (QDs) provide an attractive candidate to implement quantum information technologies in a solid-state environment. Electron spin coherence in an inhomogeneous ensemble of singly charged (In,Ga)As/GaAs QDs was studied by means of time-resolved techniques [1][2].

The inhomogeneity of the QDs allows us to address two different spin-ensembles, separated in energy. For the optical orientation of the spin-ensembles we use two synchronized pulsed Ti:Sapphire lasers, which have a well defined spectral detuning. The temporal evolution of the spin precession of the ensembles is measured by time-resolved Faraday-Rotation. Results are reported for a wide range of excitation parameters.

[1] A. Greilich, D. R. Yakovlev, A. Shabaev, Al. L. Efros, I. A. Yugova, R. Oulton, V. Stavarache, D. Reuter, A. Wieck, and M. Bayer, Science 313, 341 (2006)

[2] A. Greilich, A. Shabaev, D. R. Yakovlev, Al. L. Efros, I. A. Yugova, D. Reuter, A. D. Wieck and M. Bayer, Science 317, 1896 (2007)

HL 55.4 Thu 14:45 H14

Electrical spin injection and ultrafast charging of single InAs quantum dots — •Jörg Nannen[1], Tilmar Kümmell[1], Jan Wenisch[2], 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 spin-based devices, which utilize electron spins as information carriers. Due to spin relaxation times up to the ms regime, self-assembled InAs quantum dots are ideal model systems to establish concepts to inject, store and read-out the spin information of single electrons.

We use an all-electrical approach to charge single InAs quantum dots embedded in a p-i-n-diode structure with a single electron. Using micro-photoluminescence spectroscopy, an abrupt switching between the neutral exciton and the negatively charged exciton can be observed. In combination with a diluted magnetic semiconductor (ZnMnSe) as a spin-aligner it is possible to electrically inject spin-polarized electrons with polarization degrees of more than 40 % [1]. An all-optical read-out scheme is demonstrated, which is independent from the injection process and does not destroy the spin information of the injected electron. To use this approach for future spin-based devices, electrical control of the charge state of the SQD's must be accomplished in the GHz-range. By high-frequency adaptation of the sample setups we are able to demonstrate electrical charging of the SQD's in less than 2 ns.

[1] Ghali et al., Appl. Phys. Lett. 93, 073107 (2008)

HL 55.5 Thu 15:00 H14

Creation of mode-locked spins by up to 80 ps pulses — •Steffen Varwig[1], Stefan Spatzek[1], Alexander Schwan[1], Irina A. Yugova[2], Mikhail M. Glazov[3], Dmitri R. Yakovlev[1,3], Dirk Reuter[4], Andreas D. Wieck[4], and Manfred Bayer[1] — [1]Experimentelle Physik II, TU Dortmund, D-44221 Dortmund, Germany — [2]Institute of Physics, St. Petersburg State University, 198504 St. Petersburg, Russia — [3]A. F. Ioffe Physico-Technical Institute, 194021 St. Petersburg, Russia — [4]Angewandte Festkörperphysik, Ruhr- Universität Bochum, D-44780 Bochum, Germany

Precessing electron spins in an ensemble of singly charged quantum dots are of high interest for quantum information processing. To overcome the problem of fast spin dephasing due to inhomogenities within a quantum dot ensemble, it was shown that it is possible to synchronize the precession modes of the electron spins to the repetition rate of the exciting laser [1].

In previous measurements mode-locking was studied by a pump-probe technique with a laser repetition rate of 13.2 ns and a pulse duration of 2 ps. The spectral pulse width was about 1.5 nm. With a smaller bandwidth less quantum dots are excited, thus presumably increasing the spin dephasing time. However, the excitation time has to be short in comparison to a precession period. Hence, we investigated the influence of pulses with durations up to 80 ps and corresponding bandwidths of 0.6 nm on the possibility of mode-locking in spin ensembles.

[1] A. Greilich et al., Science 313, 341 (2006).

HL 55.6 Thu 15:15 H14

Long excitonic spin relaxation in InAs/AlAs quantum dots — •Birgit Brinkmann[1], T. S. Shamirzaev[2], J. Debus[1], D. Dunker[1], D. R. Yakovlev[1], and M. Bayer[1] — [1]Experimentelle Physik II, TU Dortmund, 44227 Dortmund, Germany — [2]Institute of Semiconductor Physics, pr. Lavrentieva, 13, Novosibirsk 630090, Russia

We investigated the excitonic spin relaxation in self-assembled InAs quantum dots, embedded in an AlAs matrix, by means of time-resolved, circularly polarized photoluminescence.

The atomic-like electronic structure of self-assembled quantum dots suppresses not only elastic but also inelastic processes of spin relaxation mechanisms, thus increasing the exciton spin relaxation time τ_s. The experimental determination of τ_s is typically inhibited by the short exciton lifetime of a few nanoseconds. However, the novel InAs/AlAs quantum dot system, characterized by the lowest electron state at the

direct Γ or indirect X conduction band minima, exhibits exciton lifetimes of several milliseconds. At a temperature of 1.8 K the exciton spin relaxation time τ_s is in the range of 100 μs. It strongly depends on the optical excitation density, temperature and quantum dot size.

Differences between the direct and indirect bandgap transitions have been observed in the temporal evolution of the non-equilibrium exciton spin-orientation induced by an external magnetic field or excitation with circularly polarized light. Spectral and temperature dependencies of photoluminescence kinetics are explained in terms of an electron redistribution between long-lived indirect and short-lived direct states of the quantum dot conduction band.

HL 55.7 Thu 15:30 H14

Spin-flip Raman scattering in InGaAs/GaAs quantum dots — •Jörg Debus[1], V. F. Sapega[2], D. R. Yakovlev[1,2], and M. Bayer[1] — [1]Experimentelle Physik II, Technische Universität Dortmund, 44227 Dortmund, Germany — [2]A. F. Ioffe Physical-Technical Institute, Russian Academy of Sciences, 194021 St. Petersburg, Russia

Strong spin-flip Raman scattering (SFRS) from self-assembled n-doped InGaAs/GaAs quantum dots as well as from an undoped sample has been observed in external magnetic fields up to 10 T. In both cases the SFRS exhibits a strong dependence on the geometry of the experiment. The predominant Raman signal is attributed to a spin-flip of a resident electron induced by a photocreated exciton.

The magnetic field dependencies of the electronic Raman shift, measured in Voigt- and tilted Faraday-geometry, demonstrate similar slopes ($|g|^{e}_{||} \approx 0.62$ and $|g|^{e}_{\perp} \approx 0.54$), but tend to different Raman shifts at zero magnetic field. In tilted Faraday-geometry the Raman shift tends to $\delta = 0.4\,\mathrm{cm}^{-1}$, it depends also on the optical excitation energy as well as on the annealing temperature of the samples. The offset at $B = 0$ T can be related to excitonic exchange interaction and to additional nuclear magnetic fields acting on the resident electrons. At $B = 10$ T the electronic spin-flip shift is larger in tilted Faraday- than in Voigt-geometry, which originates from an electron g factor anisotropy.

The electron g factor dispersion has been measured across the emission band of the inhomogeneously broadened quantum dot ensemble.