TT 41: Spintronics: Excitons and Local Spins (jointly with HL, MA)

Time: Tuesday 9:30–11:30 Location: ER 270

TT 41.1 Tue 9:30 ER 270

Transport and manipulation of indirect exciton spins in GaAs double quantum well structures — Adriano Violante, Serkan Büyükköse, Klaus Biermann, and •Paulo Santos — Paul-Drude-Institut für Festkörperelektronik, Berlin, Germany

Indirect excitons in double quantum well (DQW) structures are interesting particles for information storage due to the electrically controlled coupling to photons. Here, we report on the coherent control and transport of IX spins in GaAs DQWs using spatially and polarization resolved photoluminescence (PL). We show that optically IXs spins optically excited by a focused, circularly polarized light spot precess around the spin-orbit magnetic field while moving over distances exceeding 20 μm from the excitation spot. The spatial precession frequency depends on the spin transport direction and can be controlled by the bias applied across the DQW structure. From the dependence of the spin dynamics on transport direction, bias, and external magnetic fields we directly determined the Dresselhaus and Rashba electron spin splitting coefficients for the DQW structure. The long *IX* lifetimes, together with the negligible contribution of holes to the spin dynamics, are attributed to spatial separation of the electron and hole wave functions by the electric field, which reduces the electron-hole exchange interaction. If extended to the single exciton regime, the present results imply that IXs can be used as flying spin qubits for application in the quantum information processing.

TT 41.2 Tue 9:45 ER 270

Spin properties of the indirect exciton in indirect band-gap (In,Al)As/AlAs quantum dot ensembles — •Jörg Debus[1], Victor F. Sapega[2], Timur S. Shamirzaev[3], Daniel Dunker[1], Evgeny L. Ivchenko[2], Dmitri R. Yakovlev[1,2], and Manfred Bayer[1,2] — [1]Experimentelle Physik 2, TU Dortmund, Dortmund, Germany — [2]Ioffe Physical-Technical Institute, St. Petersburg, Russia — [3]Institute of Semiconductor Physics, Novosibirsk, Russia

The band structure of type-I (In,Al)As/AlAs quantum dots with band gap energy exceeding 1.63 eV is indirect in momentum space, leading to long-lived exciton states with potential applications in quantum information. Optical access to these excitons is provided by mixing of the Γ- and X-conduction band valleys. We report on spin properties of the indirect exciton studied by time-resolved photoluminescence (TRPL) and resonant spin-flip Raman scattering (SFRS) [1-3]. The SFRS characterizes the Γ-X-valley electron state mixing, provides access to the fine structure of the indirect exciton and enables the preparation of its spin states as well as the determination of the spin-flip mechanisms. From the TRPL we evaluate very long longitudinal spin relaxation times (200 μs at 4 T and 1.8 K) that are rather robust against temperature changes. The temporal evolution of the circular polarization degree of the photoluminescence moreover changes its sign in the μs-range thus hinting at dark and bright indirect excitons contributing by their different spin dynamics. [1] T. S. Shamirzaev et al., Phys. Rev. B **84**, 155318 (2011). [2] D. Dunker et al., Appl. Phys. Lett. **101**, 142108 (2012). [3] J. Debus et al., Phys. Rev. B **90**, 125431 (2014).

TT 41.3 Tue 10:00 ER 270

Coherent control and readout of single spins in silicon carbide — •Matthias Widmann[1], Sang-Yun Lee[1], Torsten Rendler[1], Nguyen Tien-Son[2], Helmut Fedder[1], Erik Janzén[2], and Jörg Wrachtrup[1] — [1]3.Physikalisches Institut, Universität Stuttgart — [2]Department of Physics, Chemistry and Biology, Linköping University

Single spin manipulation is one of the main subjects in research not only for quantum information processing (QIP) but also for quantum metrology. Having isolated spins in solids has advantages of stability and fabrication. Deep level defects in diamond and impurity donors in silicon have been considered as promising candidates and several key steps towards QIP have been achieved. However, there exist disadvantages which have hindered their successful integration into modern electronic devices; cryogenic temperature mandatory for readout of spins in silicon, and difficulty in electrical initialization and readout in diamond. These motivate to investigate other host materials such as silicon carbide (SiC). SiC combines the advantages of silicon and diamond, because electrical detection and optical access of spin ensembles at room temperature (RT) is possible, and it also benefits from modern fabrication techniques. Addressing individual spin states have not been shown yet, however, is highly demanded to set up a base for scalable atomic-scale quantum technologies. By presenting coherent control and readout of single spins in SiC at RT we prove that SiC is a promising platform for the scalable spintronic devices [1]. [1] M. Widmann et al., Coherent control of single spins in silicon carbide at room temperature, to be published in Nature Materials.

TT 41.4 Tue 10:15 ER 270

Nuclear magetic resonance on a single quantum dot — •Gunter Wüst[1], Mathieu Munsch[1], Andreas Kuhlmann[1], Martino Poggio[1], Arne Ludwig[2], Andreas Wieck[2], Dirk Reuter[3], and Richard J Warburton[1] — [1]University of Basel, Switzerland — [2]Ruhr-Universität Bochum, Germany — [3]Universität Paderborn, Germany

The spin coherence of an electron trapped to a GaAs or InGaAs quantum dot is limited by noise in the nuclear spins of the host material [1]. Understanding and controlling the nuclear spins is therefore important for quantum applications. We report here nuclear magnetic resonance (NMR) experiments on the 100,000 nuclear spins that have a contact hyperfine interaction with a quantum dot electron spin [2]. The main technique is to sweep the frequency of an in-plane magnetic field. In this way, all nuclear spins are addressed despite the presence of four main isotopes with different gyromagnetic ratios. The nuclear spins are polarized and read-out via resonant spectroscopy allowing us to reach a sensitivity to about 1,000 nuclear spins. We evidence a plateau in the NMR sweep rate dependence associated to the existence of quadrupole interactions. Detailed analysis allows the quadrupole distributions for each isotope to be determined, along with an effective nuclear spin temperature following polarization (8 mK) and an In concentration (20%). Ongoing experiments determined in addition the Hahn echo coherence times (1 ms) and their dependence on quantum dot charge.

[1] R. J. Warburton et al, Nature Materials 12, 483-493 (2013) [2] M. Munsch, Nature Nanotechnology 9, 671-675 (2014)

TT 41.5 Tue 10:30 ER 270

Distinct Nuclear Spin Signatures in the Spin Noise of Donor Bound Electrons — •Fabian Berski[1], Pavel Sterin[1], Jens Hübner[1], Andreas Wieck[2], and Michael Oestreich[1] — [1]Institut für Festkörperphysik, Leibniz Universität Hannover, Appelstr. 2, D-30167 Hannover, Germany — [2]Ruhr-Universität Bochum, Angewandte Festkörperphysik, Universitätsstr. 150, D-44780 Bochum, Germany

The hyperfine interaction acts as a main source of decoherence for localized electron spins in III-V semiconductor material systems and is thus a challenge for quantum information processing [1]. However, this interaction can also serve as a subtle probe of nuclear dynamics, which manifests itself in the spin dynamics of electrons.

Here, we study an ensemble of non-interacting donor bound electrons (D^0X) in a strain-free, high purity Gallium Arsenide host matrix, and find intriguing features of the nuclear spin dynamics in the electronic spin noise. The ideal tool to study such an interplay is spin noise spectroscopy, since it allows to control the dissipated amount of energy in the system and is a potential quantum non-demolition measurement [2]. However, by selecting the detuning between the D^0X transition and the energy of the used laser light, we find strong evidence for a significant nuclear polarization, even at low laser power, linearly polarized light and vanishingly small transversal magnetic fields.

[1] Chekhovich, et al., Nature Mat. **12**, 6 (2013).

[2] Hübner, et al., Phys Status Solidi B **251**, 1824 (2014).

TT 41.6 Tue 10:45 ER 270

Spin Dynamic of Electrons and Holes in Single Quantum Dots — •Ramin Dahbashi[1], Julia Wiegand[1], Jens Hübner[1], Klaus Pierz[2], Arne Ludwig[3], Andreas Wieck[3], and Michael Oestreich[1] — [1]Leibniz Universität Hannover, Institut für Festkörperphysik, Abteilung Nanostrukturen, Appelstr. 2, D-30167 Hannover, Germany — [2]Physikalisch Technische Bundesanstalt, Bundesallee 100, D-38116 Braunschweig, Germany — [3]Ruhr-Universität Bochum, Angewandte Festkörperphysik, Universitätsstr. 150, D-44801 Bochum, Germany

We present new insights into single quantum dot (QD) spin noise spectroscopy (SNS) [1]. We have performed world's first measurements of the single heavy hole spin dynamic in an individual (InGa)As QD by SNS [2]. These measurements reveal (a) very long T_1 hole spin lifetimes of up to 180 μs even in the low magnetic field range of up to 30 mT as well as (b) charge fluctuations in the QD surrounding. In order to suppress the parasitic influence of charge fluctuations, we move to QDs embedded in a Schottky diode structure which yields three main advantages: (i) the charge state of the QD, i.e., electron or hole, can be changed facilitating different coupling strength to the nuclear spin bath, (ii) the sharp single QD resonance can be tuned via the quantum confined Stark shift, and (iii) charge fluctuations are strongly reduced.

[1] J. Hübner, F. Berski, R. Dahbashi, and M. Oestreich, physica status solidi (b) **251**, 1824 (2014).

[2] R. Dahbashi, J. Hübner, F. Berski, K. Pierz, and M. Oestreich, Phys. Rev. Lett **112**, 156601 (2014).

TT 41.7 Tue 11:00 ER 270

Induced nuclear spin polarization in ZnSe:F epilayers — •Johan Erik Kirstein[1], Fabian Heisterkamp[1], Evgeny A. Zhukov[1], Alex Greilich[1], Dmitri R. Yakovlev[1,2], Irina A. Yugova[1,3], Vladimir L. Korenev[2], Alexander Pawlis[4], and Manfred Bayer[1] — [1]Experimentelle Physik 2, Technische Universität Dortmund, 44221 Dortmund, Germany — [2]Ioffe Physical-Technical Institute, Russian Academy of Sciences, 194021 St. Petersburg, Russia — [3]Physical Faculty of St. Petersburg State University, 198504 St. Petersburg, Russia — [4]Department Physik, Universität Paderborn, 33098 Paderborn, Germany

We study the interaction of electron and nuclear spins in fluorine-doped ZnSe epilayers. Using the time-resolved optical pump-probe spectroscopy in the regime of resonant spin amplification we are able to resolve nuclear magnetic resonances (NMR) of ^{77}Se and ^{67}Zn isotopes with non-zero spin. The effective nuclear fields show a dispersive form of its strength around NMR as a function of magnetic field. In the RSA signal this leads a shift of the resonances of the electron spins. Dependences are measured as a function of external parameters, like: pump power, polarization modulation frequency and temperature. In a further experiment an external radio frequency field is applied to investigate the strength of the resulting nuclear field. Theoretical considerations support our findings.

TT 41.8 Tue 11:15 ER 270

Effect of electron spin inertia in II-VI semiconductors — •Fabian Heisterkamp[1], Evgeny A. Zhukov[1], Alex Greilich[1], Vladimir L. Korenev[1,2], Dmitri R. Yakovlev[1,2], Alexander Pawlis[3], Grzegorz Karczewski[4], Tomasz Wojtowicz[4], Jacek Kossut[4], and Manfred Bayer[1] — [1]Experimentelle Physik 2, Technische Universität Dortmund, 44227 Dortmund, Germany — [2]Ioffe Physical-Technical Institute, Russian Academy of Sciences, 194021 St. Petersburg, Russia — [3]Department Physik, Universität Paderborn, 33098 Paderborn, Germany — [4]Institute of Physics, Polish Academy of Sciences, 02668 Warsaw, Poland

An electron bound to a fluorine donor impurity in ZnSe has been considered as a good candidate for a quantum bit [1]. We study the spin relaxation time (T_1) in fluorine-doped ZnSe epilayers using optical pump-probe spectroscopy. We fix the time-delay between pump and probe pulse and scan the magnetic field in Faraday geometry to measure the polarization recovery curve for different pump helicity modulation frequencies. While the spin polarization is able to reach its steady-state value for low modulation frequencies, the spins cannot be polarized completely, if the pump helicity changes too fast. We present a theoretical model for this effect of electron spin inertia. To test this approach we determine the spin relaxation time also for resident electrons in CdTe QWs. For further information on the optical properties of the samples we refer to Refs. [2] and [3]. [1] Sanaka et al., Phys. Rev. Lett. 103, 053601 (2009). [2] Greilich et al., Phys. Rev. B 85, 121303(R) (2012). [3] Zhukov et al., Phys. Rev. B 76, 205310 (2007).