TT 10: Spintronics II (joint session DS, HL, MA, TT, organized by HL)

Time: Monday 14:45–17:00 Location: POT 151

TT 10.1 Mon 14:45 POT 151

Observation of suppressed electron giant-Zeeman splitting in a (Cd,Mn)Te/(Cd,Mg)Te quantum well — •Janina J. Schindler[1], Jörg Debus[1], Victor F. Sapega[2], Dmitri R. Yakovlev[1,2], Grzegorz Karczewski[3], Tomasz Wojtowicz[3], and Manfred Bayer[1,2] — [1]Experimental Physics 2, TU Dortmund University, Dortmund, Germany — [2]Ioffe Institute, Russian Academy of Sciences, St. Petersburg, Russia — [3]Institute of Physics, Polish Academy of Sciences, Warsaw, Poland

We have studied the electron spin properties in a (Cd,Mn)Te/(Cd,Mg)Te quantum well modulation-doped with a high-mobile, highly concentrated two-dimensional electron gas by means of resonant spin-flip Raman scattering (SFRS). Resonant SFRS is a spin manipulating optical tool that also provides insight in spin interaction processes and spin-level structures. Two electron-SFRS signals with sharp resonance profiles at about 1.594eV and 1.599eV are observed, both showing no exciton-exchange energy offset at 0 T. The Mn-ion interactions with carriers in diluted magnetic semiconductors (DMS) lead typically to the giant Zeeman splitting of the electron and hole spin states with effective g-factors in the range of 10 to 80. However, the electron-SFRS signals demonstrate an effective g-factor of -1.7, which is characteristic for non-magnetic II-VI quantum wells. The optical selection rules derived from the circular polarization features let us assume that the SFRS processes involve a negative trion with componensated electron spins or a highly localized exciton bound to an impurity in the (Cd,Mn)Te quantum well.

TT 10.2 Mon 15:00 POT 151

Optical control of a strongly coupled spin-spin system in ZnO — Jan Heye Buss[1], Jörg Rudolph[1], Thomas A. Wassner[2], Martin Eickhoff[3], and •Daniel Hägele[1] — [1]Spektroskopie der kondensierten Materie, Ruhr-Universität Bochum, D-44780 Bochum — [2]Walter Schottky Institut, Technische Universität München, D-85748 Garching — [3]Justus-Liebig-Universität Gießen, I. Physikalisches Institut, D-35392 Gießen

The electron spin of the indium donor in ZnO couples strongly to the 9/2 nuclear spin of indium providing a non-trivial quantum system that can be optically manipulated and read out. Time-resolved Kerr-rotation measurements show directly a complex beating behavior of the electron spin under the application of an external magnetic field. The beat-structure provides a fingerprint of the 10 nuclear spin levels. We find evidence for an efficient optical pumping of the nuclear spin state via the optically pumped donor electron. A modulated pump pulse polarization reduces the nuclear spin polarization starting at frequencies above 100 kHz reaching zero polarization at 8 MHz. A full quantum mechanical modeling of the system including spin relaxation, optical pumping, and electron hopping exhibits excellent agreement with experiment [1]. Prospects for creating non-classical nuclear spin states will be discussed.

[1] J. H. Buß, J. Rudolph, T. A. Wassner, M. Eickhoff, and D. Hägele, Phys. Rev. B 93, 155204 (2016)

TT 10.3 Mon 15:15 POT 151

Design of polarization degenerate photonic nanocavities for cavity-enhanced optical spin-pumping — •Tobias M. Petzak[1], Sebastian Hammer[1,2], and Hubert J. Krenner[1,2] — [1]Lehrstuhl für Experimentalphysik 1, Institut für Physik, Universität Augsburg, Universitätsstr. 1 86159 Augsburg, Germany — [2]Nanosystem Initiative Munich (NIM), Schellingstraße 4, 80339 München, Germany

Defect cavities in photonic crystal membranes exhibit high quality factors and enable the efficient confinement of light within small volumes. Therefore, these nanoscale optical cavities can enhance the light-matter interaction between cavity photons and optical excitations of embedded semiconductor nanosystems.

Here, we propose and demonstrate by finite-difference-time-domain (FDTD) simulations, that a crossed-beam cavity design [1] allows to obtain polarization-degenerate photonic modes. This is achieved by varying the geometry of the two perpendicular cavities. The resulting tunable superposition of two linear polarized modes permits for the formation of a single and completely unpolarized mode. Such polarization properties are highly desirable for optically addressing spin- and valley degrees of freedom e.g. in monolayer transition metal dichalcogenides [2]. We show that our design can be implemented on thermally grown SiO_2 for which our FDTD simulations predict quality factors exceeding 300 for cavities resonant with the exciton transition of WS_2.

References:
[1] K. Riviore et al., *Appl. Phys. Lett.* **99**, 013114 (2011)
[2] K. F. Mak et al., *Nature Nanotechnology* **4**, 494-498 (2012)

TT 10.4 Mon 15:30 POT 151

Anisotropy of the spin diffusion in GaAs-based two-dimensional electron gases — •Markus Schwemmer[1], Andreas Hanninger[1], Dieter Schuh[1], Werner Wegscheider[2], Tobias Korn[1], and Christian Schüller[1] — [1]Institute of Experimental and Applied Physics, Faculty of Physics, University of Regensburg, Germany — [2]ETH Zurich, Switzerland

The combination of a femtosecond pulsed TiSa-Laser system with a magneto-optical Kerr effect microscope setup allows us to study time- and space-resolved propagation of an optically injected electron spin packet in a two-dimensional electron system (2DES) based on a modulation-doped AlGaAs/GaAs quantum well. The electron spin dynamics, and thus the electron spin diffusion, is determined by the interplay between Dresselhaus and Rashba fields. The geometry of the Dresselhaus field, which arises due to the bulk inversion asymmetry, is mostly determined by the growth direction of the quantum well. The Rashba field instead is caused by a structure inversion asymmetry, which can be controlled, e.g. by the modulation doping. For the specific case of a symmetrically modulation-doped, (110)-grown GaAs quantum well, optically injected electron spins align parallel or antiparallel to the spin-orbit field. Therefore, D'yakonov-Perel spin dephasing is suppressed and a long spin coherence time can be attained. For such a system one would expect naively isotropic electron spin diffusion in the quantum well plane. Nevertheless a strongly direction-dependent behaviour of the electron spin diffusion is observed.

Coffee Break

TT 10.5 Mon 16:15 POT 151

Higher-order quantum theory of spin noise spectroscopy — •Daniel Hägele — Spektroskopie der kondensierten Materie, Ruhr-Universität Bochum, D-44780 Bochum

Spin noise spectroscopy has recently evolved into a versatile tool for studying spin dynamics in atoms and solids with minimal perturbation of the quantum system. A fully quantum mechanical theory of the detector output $z(t)$ is highly desirable for calculating higher order spectra of complex spin systems taking into account measurement back-action and relaxation. Treating spin noise spectroscopy within a stochastic master equation approach we find $z(t)$ in all orders of the measurement strength β [1]. This continuous quantum noise formula (CQNF) depends non-linearly on the equilibrium density matrix ρ_0 and contains as further ingredients the system propagator $G(t)$, the measurement operator σ_z, and multiple convolutions with white Gaussian noise $\Gamma(t)$. The CQNF allows for a systematic derivation of the spin noise spectrum $S_q(\omega) = \frac{1}{2}\left(\mathrm{Tr}\left[(\sigma_z - \mathrm{Tr}(\sigma_z\rho_0))G(\omega)(\sigma_z\rho_0 + \rho_0\sigma_z)\right] + \mathrm{c.c.}\right)$ and higher order spectra such as the bispectum and trispectrum. The CQNF may also be applied to transport theory and measurement theory in general.

[1] D. Hägele, https://arxiv.org/abs/1611.02077

TT 10.6 Mon 16:30 POT 151

Off-diagonal g-tensor components in [113]-grown two-dimensional hole systems — •Christian Gradl[1], Michael Kempf[1], Johannes Holler[1], Roland Winkler[2], Dieter Schuh[1], Dominique Bougeard[1], Christian Schüller[1], and Tobias Korn[1] — [1]Universität Regensburg, 93040 Regensburg, Germany — [2]Department of Physics, Northern Illinois University, DeKalb, Illinois 60115, USA

Due to its p-like character, the valence band in GaAs-based heterostructures offers rich and complex spin-dependent phenomena. Especially for some low-symmetry growth directions, off-diagonal components of the hole g-tensor are theoretically predicted. Therefore, we perform time-resolved Kerr rotation measurements on an undoped [113]-grown double quantum well (QW) structure to resolve the spin dynamics of hole ensembles at low temperatures. By varying the direction of the applied magnetic field, we observe a non-diagonal hole g-tensor and quantify the individual tensor components, which are in very good agreement with our theoretical calculations.

TT 10.7 Mon 16:45 POT 151

An origin of large spin accumulation voltage in non-degenerate Si MOSFET at room temperature — •Masashi Shiraishi[1], Yuichiro Ando[1], Takayuki Tahara[1], and Hayato Koike[2] — [1]Kyoto University, Japan — [2]TDK Corporation, Japan

Si spintronics has been attracting much attention in a decade, and recent success of room temperature operation of Si spin MOSFET [1] can accelerate its progress. In this presentation, a large spin accumulation voltage of more than 1.5 mV at 1 mA measured in non-degenerate Si-based lateral spin valves (LSVs) at room temperature is introduced [2]. The notable is that this is the largest spin accumulation voltage measured in semiconductor-based LSVs in our best knowledge. The modified spin drift-diffusion model, which successfully accounts for the spin drift effect, explains the large spin accumulation voltage and significant bias-current-polarity dependence. The model also shows that the spin drift effect enhances the spin-dependent magnetoresistance in the electric two-terminal scheme. This finding provides a useful guiding principle for spin metal-oxide-semiconductor field-effect transistor operations. The detail of experiments and theoretical considerations will be introduced in the presentation. Reference:[1] T. Tahara, M. Shiraishi et al., APEX8, 113004 (2015). [2] T. Tahara, M. Shiraishi et al., Phys. Rev. B93, 214406 (2016).