HL 12: Spin controlled transport I

Time: Tuesday 9:30–12:30 Location: BEY 81

HL 12.1 Tue 9:30 BEY 81

Electrical detection of coherent spin currents across an Fe/GaAs Schottky contact — •I. Burkart[1,2], C. Schwark[1,2], G. Güntherodt[1,2], C. Adelmann[3], C.J. Palmstrøm[3,4], X. Lou[5], P.A. Crowell[5], and B. Beschoten[1,2] — [1]Physikalisches Institut IIA, RWTH Aachen University, Templergraben 55, 52056 Aachen, and JARA-Fundamentals of Future Information Technology, Germany — [2]Virtual Institute for Spin Electronics (ViSel), Aachen - Jülich - Göttingen — [3]Department of Chemical Engineering and Material Science, University of Minnesota, Minneapolis 55455, USA — [4]Departments of Electrical and Computer Engineering and Materials, University of California, Santa Barbara, CA 93106, USA — [5]School of Physics and Astronomy, University of Minnesota, Minneapolis, Minnesota 55455, USA

Most previous experiments on electrical detection of spin currents in ferromagnet/semiconductor devices focus on the DC transport regime. Here, we present a new time-resolved method, which allows to electrically probe coherent spin currents across an Fe/GaAs Schottky contact, after optical excitation by circularly polarized laser pulses. Coherent spin precession can be identified in the magnetic-field dependent photo-current using resonant spin amplification. Based on this technique we are able to observe multiple Larmor precessions which can be associated with electron spin precession in the GaAs layer.

Work supported by BMBF, HGF and DFG.

HL 12.2 Tue 9:45 BEY 81

Magnetic field dependence of the tunneling anisotropic magnetoresistance effect in Fe/GaAs/Au tunnel junctions — •Michael Wimmer[1], Michael Lobenhofer[2], Alex Matos-Abiague[1], Jaroslav Fabian[1], Dieter Weiss[2], and Klaus Richter[1] — [1]Institut für Theoretische Physik, Universität Regensburg, 93040 Regensburg — [2]Institut für Experimentelle und Angewandte Physik, Universität Regensburg, 93040 Regensburg

Recent experiments on the tunneling anisotropic magnetoresistance (TAMR) effect in Fe/GaAs/Au tunnel junctions found a peculiar magnetic field dependence in high fields: Depending on the bias voltage, the TAMR effect may increase or decrease linearly with magnetic field.

We explain these findings by including the orbital effects of the magnetic field in a previously developed theoretical description of the TAMR effect in terms of Rashba and Dresselhaus spin-orbit coupling [1]. Both numerical simulations as well as a phenomenological model agree well with experiment. The high-field behavior is found to be dominated by an interplay between the Dresselhaus spin-orbit coupling in the GaAs barrier and the orbital effects of the magnetic field.

[1] J. Moser *et al.*, Phys. Rev. Lett. **99**, 056601 (2007).

HL 12.3 Tue 10:00 BEY 81

Electrical triggering of phase-coherent spin packets by pulsed electrical spin injection across an Fe/GaAs Schottky contact — •C. Schwark[1,2], I. Burkart[1,2], J. Moritz[1,2], L. Schreiber[1,2], G. Güntherodt[1,2], C. Adelmann[3], C. Palmstrøm[3,4], P.A. Crowell[5], and B. Beschoten[1,2] — [1]Physikalisches Institut IIA, RWTH Aachen University, Templergraben 55, 52056 Aachen, and JARA-Fundamentals of Future Information Technology, Germany — [2]Virtual Institute for Spin Electronics (ViSel), Aachen - Jülich - Göttingen — [3]Department of Chemical Engineering and Material Science, University of Minnesota, Minneapolis 55455, USA — [4]Departments of Electrical and Computer Engineering and Materials, University of California, Santa Barbara, CA 93106, USA — [5]School of Physics and Astronomy, University of Minnesota, Minneapolis, Minnesota 55455, USA

Efficient electrical spin injection from a ferromagnet into a semiconductor has been demonstrated for various material systems by steady-state experiments. Here, we introduce a novel time-resolved technique based on electrical pumping and optical probing. Coherent spin packets are injected from an Fe layer through a reverse biased Schottky barrier into an n-GaAs layer by applying ultrafast current pulses at low temperature (20K). Spin coherence is probed by time-resolved Faraday rotation. Based on this technique we are able to observe multiple Larmor precessions and spin dephasing times greater than 50ns.

Work supported by BMBF, HGF and DFG.

HL 12.4 Tue 10:15 BEY 81

Prediction of giant intrinsic spin-Hall effect in strained p-GaAs quantum wells — •Christoph Schindler, Tillmann Kubis, and Peter Vogl — Walter Schottky Institut, Technische Universität München, Am Coulombwall 3, 85748 Garching, Germany

We present a systematic study of the intrinsic spin-Hall effect and its inverse effect in various two dimensional nanostructures using the non-equilibrium Green's function technique. We include elastic impurity scattering as well as inelastic acoustical phonon scattering. The parameters for the Dresselhaus and Rashba spin-orbit coupling are obtained from an atomistic tight binding calculation. We predict exceptionally large spin polarization effects in specially band engineered and geometrically designed nanostructures. In strained p-GasAs, we find a k-linear spin splitting that is enhanced by a factor of 50 compared to the unstrained case. We propose a "T" shaped three-terminal device that acts as a spin polarizer without external magnetic field. Optimizing the geometry with respect to the spin-precession length results in a spin accumulation at the drain contacts of up to 25%. We also study the inverse intrinsic spin-Hall effect. In a four-terminal "H" shaped structure it can be used to measure the direct spin-Hall effect by simply applying a gate voltage. For such a measurement, we predict a threshold value for the spin-orbit coupling strength that cannot be met by simple n-GaAs systems.

15 min. break

HL 12.5 Tue 10:45 BEY 81

Time-resolved studies of current induced spin polarization in strained InGaAs structures — •Markus Hagedorn[1,2,3], Marten Patt[1,3], Klaus Schmalbuch[1,3], Gernot Güntherodt[1,3], Mihail Lepsa[2,3], Thomas Schäpers[2,3], and Bernd Beschoten[1,3] — [1]II. Physikalisches Institut, RWTH Aachen — [2]Institut für Bio- und Nanosysteme (IBN-1), Forschungszentrum Jülich — [3]JARA - Fundamentals of Future Information Technology

The fundamental understanding of electron spin interactions in non-magnetic semiconductor heterostructures and the controlled manipulation of spins are crucial for realizing novel spintronic devices.

The well established all-optical pump/probe schemes as experimental methods for the creation and detection of coherent spins are nowadays supplemented by means of electrical pumping.

The underlying mechanisms which enable the so-called current induced spin polarization (CISP) are internal effective magnetic fields evoked by the broken inversion symmetry of the zinc-blende structure in III-V semiconductor materials (Dresselhaus term) and additionally by the strain in, e.g., InGaAs/GaAs heterostructures.

We report on detection and manipulation of electron spins by time-resolved CISP. Spins are generated by ultrafast current pulses. The spin polarization is probed spatio-temporally by Faraday rotation in polar geometry.

Work supported by DFG through FOR912.

HL 12.6 Tue 11:00 BEY 81

Observation of the orbital circular photogalvanic effect in Si-MOSFETs — •J. Karch[1], P. Olbrich[1], C. Reitmaier[1], D. Plohmann[1], S. A. Tarasenko[2], Z. D. Kvon[3], and S. D. Ganichev[1] — [1]Terahertz Center, University of Regensburg, Regensburg, Germany — [2]A. F. Ioffe Physico-Technical Institute, St. Petersburg, Russia — [3]Institute of Semiconductor Physics, Novosibirsk, Russia

We report on the observation of the orbital circular photogalvanic effect (CPGE). The experiments are carried out on (001) oriented and miscut Si-MOSFETs. The fact of the existence of the CPGE in such structures is of particular importance. So far, the CPGE has only been detected in materials with strong spin-orbit coupling and described by microscopic mechanisms based on spin-related processes. In Si-MOSFETs the spin-orbit coupling is known to be vanishingly small, therefore, these mechanisms of the CPGE become ineffective. We demonstrated that in our structures in spite of the fact that the photocurrent is caused by transfer of the photon angular momentum to free carriers, it is not due to spin orientation but has a pure orbital origin. It results from the quantum interference of different pathways contributing to the free-carrier absorption of monochromatic radiation. For excitation we use terahertz radiation of a molecular optically pumped laser in the wavelength range between 77 and 280 μm. Depending on temperature and gate voltage, which varies the separation between size-quantized subbands, we induce Drude-like as well as direct intersubband transitions. We developed both microscopic and phenomenological theories well describing all observed features of the orbital CPGE.

HL 12.7 Tue 11:15 BEY 81

Observation of tunnel rates of phosphorus dopants using silicon SETs — •H. Huebl[1], C. D. Nugroho[1], A. Morello[1], C. Escott[1], C. Yang[2], J. van Donkelaar[2], A. Alves[2], D. Jamieson[2], A. S. Dzurak[1], R. G. Clark[1], and M. Eriksson[3] — [1]Centre for Quantum Computer Technology, University of New South Wales, Sydney, Australia — [2]Centre for Quantum Computer Technology, University of Melbourne, Melbourne, Australia — [3]Department of Physics, University of Wisconsin, Madisson, Wisconsin, USA

Charge centres, such as donors in semiconductors, have significant potential for quantum information processing. In silicon, which can be produced nuclear-spin free, phosphorus donors are a prime candidate for implementation of a qubit, due to their long spin coherence times. In this presentation we will discuss a hybrid structure, consisting of implanted phosphorus donors controlled by a gate potential in close vicinity to a gate-induced, MOS-based silicon single electron transistor (Si-SET). We study the dual functionality of the nearby Si-SET as a sensitive charge detector as well as a gate-induced electron reservoir. Experimentally, we observe shifts in the position of the Coulomb peaks of the Si-SET corresponding to 20% of an electron charge. We attribute these shifts to charge transfers between the Si-SET island reservoir and the nearby phosphorus donors. Pulsed voltage spectroscopy on one of these charge transitions allows us to investigate the capture and emission times of a donor resulting in a capture rate of 3000 s^{-1} and an emission rate of 1000 s^{-1} corroborating expectations from device modelling.

15 min. break

HL 12.8 Tue 11:45 BEY 81

Controlable Manipulation of Structure Inversion Asymmetry (SIA) of Quantum Wells (QWs) by Shifting the Position of δ-doping Layer — •V. Lechner[1], S.D. Ganichev[1], V.V. Belkov[2], P. Olbrich[1], L.E. Golub[2], S.A. Tarasenko[2], D. Schuh[1], W. Wegscheider[1], D. Weiss[1], and W. Prettl[1] — [1]Terahertz Center, University of Regensburg, Germany — [2]A.F. Ioffe Physico-Technical Institute, Russian Academy of Sciences, St. Petersburg, Russia

We demonstrate that the growing of semiconductor QWs with various δ-doping layer positions accompanied by measurements of magnetogyrotropic photogalvanic effect (MGPE) [1] allows the controle of SIA. The MPGE originates from bulk inversion asymmetry (BIA) and SIA and therefore reflects their behaviour. We show that for a proper experimental geometry, currents measured along and perpendicular to B, are proportional to BIA and SIA, respectively. Our experiments prove that shifting the δ-doping layer from one side of the QW to the other results in a change of sign of the SIA-caused MPGE. Our measurements show that while nominally symmetrically doped (001)-grown structures have an essential structural asymmetry, (110)-grown structures are almost symmetrical. Our results allow the growth of perfectly symmetric structures without Rashba constant and structures with equal Rashba and Dresselhaus spin splittings. Experiments were carried out at room temperature on n-type GaAs quantum wells.

[1] V.V. Bel'kov, and S.D. Ganichev, review in Semicond. Sci. Technol. **23**, 114003 (2008).

HL 12.9 Tue 12:00 BEY 81

Weak Value of electrons spin in a double quantum dot — •Alessandro Romito[1], Yuval Gefen[1], and Yaroslav Blanter[2] — [1]Department of Condensed Matter Physics, Weizmann Institute of Science, Rehovot 76100, Israel — [2]Kavli Institute of Nanoscience, Delft University of Technology, Lorentzweg 1, 2628 CJ Delft

The measurement of an observable in quantum mechanics is described by the projection postulate. In contrast, a weak measurement (i.e. a continuos measurement performed by a weakly coupled detector) allows us to weakly disturb the system, while acquiring only partial information about the state of the system. It has been shown that a weak measurement performed on pre and post-selected states consistently defines a new kind of value, the " weak value", of the measured quantum variable [1]. Weak values may lie well beyond the range of strong values and may happen to be complex.

Here we present the first proposal to observe the weak value of electron spin in a double quantum dot with a quantum point contact to be used as a detector. The required control on the electons' spin state has been demonstrated experimentally. Anomalously large values of the electronic spin are predicted, as well as negative values for the total spin. We also show how to incorporate the adverse effect of decoherence into this procedure.

[1] Y. Aharonov, D. Z. Albert, L. Vaidman, Phys. Rev. Lett. 60, 1351-1354 (1988).

[2] A. Romito, Y. Gefen, and Ya. Blanter, Phys. Rev. Lett. 100, 056801 (2008).

HL 12.10 Tue 12:15 BEY 81

All-electrical detection of the relative strength of Rashba and Dresselhaus spin-orbit interaction in quantum wires — •Matthias Scheid[1,2], Makoto Kohda[1], Yoji Kunihashi[1], Klaus Richter[2], and Junsaku Nitta[1] — [1]Graduate School of Engineering, Tohoku University, 6-6-02 Aramaki-Aza Aoba, Aoba-ku, Sendai 980-8579, Japan — [2]Institut für theoretische Physik, Universität Regensburg, 93040 Regensburg, Germany

We numerically study the conductance of diffusive quantum wires with Rashba and/or Dresselhaus spin-orbit interaction based on the Landauer formalism. We confirm previous results showing the suppression of weak antilocalization in narrow quantum wires [1] or at equal strength of Rashba and Dresselhaus spin-orbit interaction [2].

As a main result, we propose a method to determine the relative strength of Rashba and Dresselhaus spin-orbit interaction from transport measurements without the need of fitting parameters. To this end, we make use of the conductance anisotropy in narrow quantum wires with respect to the directions of an in-plane magnetic field, the quantum wire and the crystal orientation. We show the applicability of the method in a wide range of parameters (elastic mean free path, spin-orbit interaction strength, Fermi energy).

[1] Th. Schäpers, V. A. Guzenko, M. G. Pala, U. Zülicke, M. Governale, J. Knobbe and H. Hardtdegen, Phys. Rev. B 74, 081301 (2006).

[2] F. G. Pikus and G. E. Pikus, Phys. Rev. B 51, 16928 (1995).

[3] M. Scheid, M. Kohda, Y. Kunihashi, K. Richter and J. Nitta, Phys. Rev. Lett. (in press).