# HL 19: Spin controlled transport I

Time: Tuesday 10:45–13:00 Location: H14

HL 19.1 Tue 10:45 H14

**Control of electron spin and orbital resonance in quantum dots through spin-orbit interactions** — •Peter Stano and Jaroslav Fabian — University of Regensburg

Dynamics of a single electron in coupled lateral quantum dots in the presence of a static and oscillating electric and magnetic fields as well as phonon-induced relaxation and decoherence is investigated. Using symmetry arguments it is shown that spin and orbital resonance can be efficiently controlled by spin-orbit couplings. The so called easy passage configuration is shown to be particularly suitable for magnetic manipulation of spin qubits, ensuring long spin relaxation time and protecting the spin qubit from electric field disturbances connected with on-chip manipulation.

HL 19.2 Tue 11:00 H14

**Spin transport anisotropy in (110) GaAs** — •Odilon D. D. Couto Jr[1], Fernando Iikawa[2], Jörg Rudolph[1], Rudolf Hey[1], and Paulo V. Santos[1] — [1]Paul-Drude-Institut für Festkörperelektronik, Hausvogteiplatz 5–7, 10117 Berlin, Germany — [2]Universidade Estadual de Campinas, IFGW, CP-6165, Campinas-SP, 13083-970, Brazil

Mobile piezoelectric potentials are used to coherently transport electron spins in GaAs (110) quantum wells (QW) over distances exceeding 60 $\mu$m. We demonstrate that the dynamics of mobile spins under external magnetic fields depends on the direction of motion in the QW plane. The weak piezoelectric fields impart a non-vanishing average velocity to the carriers, allowing for the direct observation of the carrier momentum dependence of the spin polarization dynamics. While transport along [001] direction presents high in-plane spin relaxation rates, transport along [$\bar{1}$10] shows a much weaker external field dependence due to the non-vanishing internal magnetic field. We show that the anisotropy is an intrinsic property of the underling GaAs matrix, associated with the bulk inversion asymmetry contribution to the SO-coupling.

HL 19.3 Tue 11:15 H14

**Magnetotransport through nanoscale constrictions in ferromagnetic (001)-(Ga,Mn)As** — •Markus Schlapps[1], Matthias Döppe[1], Stefan Geissler[1], Thomas Imlohn[1], Janusz Sadowski[2], Werner Wegscheider[1], and Dieter Weiss[1] — [1]Institut für Experimentelle und Angewandte Physik, Universität Regensburg, Germany — [2]Institute of Physics, Polish Academy of Sciences, Warsaw, Poland

The resistance measured across a small (Ga,Mn)As island detached by nanoconstrictions from (Ga,Mn)As input leads displays unusual magnetoresistance (MR) behavior [1,2]. As in previous studies [1] a huge magnetoresistance was found for nanoconstrictions in the tunneling regime. For slightly wider junctions (on the verge of tunneling) we observed an enhanced anisotropic magnetoresistance together with pronounced jumps as a function of the in-plane magnetic field [3]. This behavior is ascribed to in-plane switching of the magnetization into the easy axis. We investigate the angular dependence of the MR for a tunneling device and discuss the correlation to the TAMR (Tunneling Anisotropic Magneto Resistance) that has been reported previously [2]. In addition we present data of (Ga,Mn)As wires with only one nanoconstriction.

[1] C. Rüster et al.: PRL 91, 216602 (2003)
[2] A. D. Giddings et al.: PRL 94, 127202 (2005)
[3] M. Schlapps et al.: phys. stat. sol. (a) 203, No. 14, 3597 (2006)

HL 19.4 Tue 11:30 H14

**Tunneling Anisotropic Magnetoresistance and Spin-Orbit Coupling in tunnel structures with single-crystal GaAs barriers** — •Michael Lobenhofer[1], Jürgen Moser[1], Eva Brinkmeier[1], Alex Matos-Abiague[2], Dieter Schuh[1], Werner Wegscheider[1], Jaroslav Fabian[2], and Dieter Weiss[1] — [1]Institut für Experimentelle und Angewandte Physik, Universität Regensburg, D-93040 Regensburg — [2]Institut für Theoretische Physik, Universität Regensburg, D-93040 Regensburg

We report the observation of tunneling anisotropic magnetoresistance effect (TAMR) in tunnel structures with single-crystal GaAs barriers. A stack of Fe, GaAs and Au, with iron grown epitaxially on the GaAs tunnel barrier, shows pronounced spin-valve-like signatures. Measurements of the tunneling resistance in a constant high in-plane magnetic field show a uniaxial anisotropy depending on the direction of the saturated magnetization of the iron layer. Depending on the bias voltage the high resistance state is either observed for the magnetization **M** oriented in [110] or in [-110] direction. This is the first observation of a TAMR effect in sandwiches involving a conventional ferromagnet like iron. We propose a theoretical model in which the $C_{2v}$ symmetry, resulting from the interference of Bychkov-Rashba and Dresselhaus spin-orbit interactions, is transferred to the tunnelling probability, giving rise to the two-fold symmetry observed in the TAMR experiments.

HL 19.5 Tue 11:45 H14

**Lithographic engineering of anisotropies in (Ga,Mn)As** — •K. Pappert[1], S. Hümpfner[1], M. Sawicki[2], J. Wenisch[1], K. Brunner[1], C. Gould[1], G. Schmidt[1], T. Dietl[2], and Laurens W. Molenkamp[1] — [1]Physikalisches Institut (EP3), Universität Würzburg, Am Hubland, D-97074 Würzburg, Germany — [2]Institute of Physics, Polish Academy of Sciences, al. Lotnikow 32/46, PL-02668 Warszawa, Poland

The focus of ferromagnetic semiconductor research is shifting from material issues towards device functionalities. So far demonstrated device concepts are mainly based on the strong magnetic anisotropy present in materials like (Ga,Mn)As. However, until now all regions of a device always inherited the magnetic anisotropy properties of the (Ga,Mn)As layer. Here we present a method to *locally* engineer the magnetic anisotropy by lithographic patterning and the associated strain relaxation. SQUID magnetometry studies on arrays of structures and transport studies on individually contacted nanobars will be shown, evidencing full anisotropy control over the whole temperature range from 4 K up to the Curie temperature of the material. The nanobars fabricated from standard in-plane (Ga,Mn)As layers show uniaxial magnetic anisotropy along the long axis of the bar irrespective of their crystal orientation. These results pave the way for new, more complex, semiconductor spintronics devices. Allowing the combination of functional elements of different magnetic anisotropy within the same device, this method can form the basis of novel device schemes relying upon the interaction between their tailored components. We acknowledge financial support from the EU (NANOSPIN FP6-IST-015728).

HL 19.6 Tue 12:00 H14

**Transport experiments on ferromagnet/semiconductor hybrid structures** — •Valentin Fedl, Andreas Wittmann, and Dirk Grundler — Physik Department E10, Fakultät für Physik, Technische Universität München, James Franck Str., 85748 Garching

We report transport experiments on ferromagnet/semiconductor hybrid structures. The interface between the two dimensional electron system in InAs and the metal is created by in situ cleavage of the InAs heterostructure followed by thermal evaporation of Fe or Co. Au is taken as a nonmagnetic reference. The InAs/metal interfaces show an Ohmic behavior. To understand the magnetotransport of such hybrid structures we first measure the specific resistance of the metal films as a function of temperature. The data is interpreted using the Fuchs-Sondheimer formalism[1,2]. Second we determine the interface resistance by using the transmission line method[3]. The interface quality is judged through comparison of the experimentally obtained value with the Sharvin resistance[4]. Third we investigate spin injection in mesoscopic devices by exploiting the Hanle effect[5,6]. The aim is to relate the spin injection rate to the interface quality and resistance.

[1] K. Fuchs, Proc. Cambridge Phil. Soc. 34, 100 (1938), [2] E. H. Sondheimer, Advan. Phys. 1, 1 (1952), [3] D. C. Look, Electrical Characterization of GaAs Materials and Devices, John Wiley & Sohns Ltd., Sussex (1989), [4] Yu. V. Sharvin, Sov. Phys. *JETP 21, 655-656 (1965), [5] Johnson & Silsbee, Phys. Rev. B 37, 10 (1987), [6] Lou et al., Phys. Rev. Let. 96, 176603 (2006)

HL 19.7 Tue 12:15 H14

**Anisotropic current-induced spin accumulation in the two-dimensional electron gas with spin-orbit coupling** — •Maxim Trushin and John Schliemann — Institut für Theoretische Physik, Universität Regensburg, D-93040 Regensburg, Germany

We investigate the magnetoelectric (or inverse spin-galvanic) effect in the two dimensional electron gases with both Rashba and Dresselhaus spin-orbit coupling using an exact solution of the Boltzmann equation for electron spin and momentum. Regarding the spin degree of freedom, our solution neglects off-diagonal elements of the semiclassical distribution matrix in the eigenbasis (or helicity basis) of the single-particle Hamiltonian, an approximation which is shown to be valid at sufficiently high temperatures common in experiments. Using this solution, we discover the anisotropy of the current induced spin accumulation, though the conductivity remains isotropic. To conclude, our analytical study is expected to be a reliable starting point for further investigations of spin dependent electron transport. (See cond-mat/0611328 for details.)

HL 19.8 Tue 12:30 H14

**Picosecond Polarization Detector for Infrared and Terahertz Radiation** — •J. Kiermaier[1], W. Weber[1], S.N. Danilov[1], D. Schuh[1], Ch. Gerl[1], W. Wegscheider[1], D. Bougeard[2], Gerhard Abstreiter[2], W. Prettl[1], and S.D. Ganichev[1] — [1]Faculty of Physics, University of Regensburg, 93040 Regensburg, Germany — [2]Walter-Schottky Institute, TU Munich, 85748 Garching, Germany

We report on a room temperature detector allowing to measure and characterize the state of polarization of infrared and terahertz laser radiation with picosecond time resolution. The ellipticity of radiation is analyzed applying simultaneously the circular and the linear photogalvanic effect (CPGE, LPGE) as well as the photon drag effect [1], which are monitored by different units in one single detector. Access to radiation helicity is provided by CPGE in quantum wells (QWs) resulting in a signal proportional to the radiation helicity. To reconstruct the whole state of radiation polarization we use additionally LPGE which is sensitive to linear polarization and the photon-drag effect which is polarization insensitive providing a reference of radiation power. For detector elements based on CPGE and LPGE we applied (113)-grown SiGe or GaAs QWs. The photon drag detector was prepared from germanium crystals irradiated along the [100]-crystallographic axis. The detector units are connected to an analytical part, which converts the measured signals into explicit information about the polarization state of the incoming laser beam.

[1] S.D. Ganichev, and W. Prettl, Intense Terahertz Excitation of Semiconductors, Oxford University Press, (2006).

HL 19.9 Tue 12:45 H14

**Spin Photocurrents and Circular Photon Drag Effect in (110)-grown Quantum Well Structures** — •H. Diehl[1], V. A. Shalygin[2], Ch. Hoffmann[1], S. N. Danilov[1], Th. Herrle[1], S. A. Tarasenko[3], E. L. Ivchenko[3], V. V. Belkov[3], D. Schuh[1], Ch. Gerl[1], W. Wegscheider[1], W. Prettl[1], and S. D. Ganichev[1] — [1]Faculty Physics, University of Regensburg, Regensburg, Germany — [2]St. Petersburg State Polytechnic University, St. Petersburg, Russia — [3]A.F. Ioffe Physico-Technical Institute, St. Petersburg, Russia

We report on the observation of spin photocurrents [1] in (110)-grown GaAs/AlGaAs quantum well structures. Investigated effects comprise the circular photogalvanic effect and the circular photon drag effect predicted long time ago but so far not observed. The measurements of photocurrents are carried out by excitation with infrared or terahertz radiation yielding inter-subband transitions between the lowest and the first excited subbands or intra-subband (Drude-like) absorption of the radiation, respectively. The experimental data are well described by analytical expressions derived from a phenomenological theory. The circular photon drag current in the longitudinal direction reverses its sign as the circular polarization of radiation changes from right handed to left handed and is related to transfer of both linear and angular photon momentum to the electron system. A microscopic model of the circular photon drag effect is developed demonstrating that the generated current has spin dependent origin.

[1] S.D. Ganichev and W. Prettl, Intense Terahertz Excitation of Semiconductors, (Oxford University Press, 2006).