HL 34: Spin controlled transport II

Time: Wednesday 14:00–17:00 Location: BEY 118

HL 34.1 Wed 14:00 BEY 118

Spin relaxation and spin orbit coupling in graphene — •Sergej Konschuh, Christian Ertler, Martin Gmitra, and Jaroslav Fabian — Universität Regensburg

We have used ab-initio full potential LAPW technique to calculate the intrinsic spin orbit coupling (SOC) parameter and the Rashba spin splitting in graphene. The Rashba SOC arises only in the presence of an external electric field or ripples and causes spin relaxation via the Dyakonov-Perel mechanism. We calculate the spin relaxation time by performing Monte Carlo simulations, in which the spatial randomness of the electric field is taken into account. We compaire our results tp the experiment on spin injunction in graphene. [N.Tombos et al. Nature 448 (2007)]

HL 34.2 Wed 14:15 BEY 118

Ballistic Intrinsic Spin-Hall Effect in HgTe Nanostructures — •Christoph Brüne[1], Andreas Roth[1], Elena G. Novik[1], Markus König[1], Ewelina Hankiewicz[2], Hartmut Buhmann[1], and Laurens W. Molenkamp[1] — [1]Physikalisches Institut (EP3), Universität Würzburg, 97074 Würzburg, Germany — [2]Institut für Theoretische Physik und Astrophysik, Universität Würzburg, 97074 Würzburg, Germany

Due to their unique band structure and the high spin orbit coupling strength, HgTe/HgCdTe quantum wells provide a good system for the observation of spin dependend transport phenomena. In this work we used nano-scale H-shaped structures built on HgTe/HgCdTe quantum wells to detect the intrinsic spin-Hall effect (ISHE) in a non-local electrical measurement. The strength of the spin orbit coupling was controlled by a top gate, which also made a transition from n- to p-conductance possible. The observed non-local resistance signal in the p-regime is in the order of kΩ. In contrast in the n-regime the signal is at least an order of magnitude lower. These observations are in agreement with bandstructure considerations and are confirmed by detailed Landauer-Büttiker-Keldysh formalism calculations.

HL 34.3 Wed 14:30 BEY 118

Cascaded Y-shaped InAs Spin Filters — •Jan Jacob[1], Guido Meier[1], Marc-Antonio Bisotti[1], Sebastian Peters[1], Toru Matsuyama[1], Ulrich Merkt[1], Aron Cummings[2], Richard Akis[2], and David Ferry[2] — [1]Institut für Angewandte Physik und Zentrum für Mikrostrukturforschung, Universität Hamburg, Germany — [2]Center for Solid State Electronics Research, Department of Electrical Engineering, Arizona State University, Tempe, Arizona 85287-5706

Several all-semiconductor three-terminal devices have been proposed which utilize the intrinsic spin-Hall effect to generate two oppositely spin-polarized currents [1,2]. There are two main obstacles in the experimental realization of these devices: the limitation of electronic transport to only the lowest subband, and the detection of the spin polarization. We present numerical simulations and experimental results of a two-stage cascade of Y-shaped spin-filters based on a two-dimensional electron gas in an InAs heterostructure [3]. The two-stage design allows an all-electrical detection of the spin polarization by using the first filter as a polarizer and the second as an analyzer. The regime of transport in the lowest subband is reached by constricting each part of the device with a quantum-point contact. Experiments and simulations show a high degree of spin polarization for the spin-filter cascade. The influence of magnetic fields is also studied. [1] A. Kiselev and K. Kim, J. Appl. Phys. 94, 4001 (2000) [2] J.I. Ohe et al., Phys. Rev. B 72, 041308(R) (2005) [3] A. Cummings et al., J. App. Phys. 104, 066106 (2008)

HL 34.4 Wed 14:45 BEY 118

Non-local edge state transport in the quantum spin Hall state — •Andreas Roth, Nina Eikenberg, Christoph Brüne, Hartmut Buhmann, and Laurens W. Molenkamp — Physikalisches Institut (EP3), Universität Würzburg, 97074 Würzburg, Germany

In 2007 the quantum spin Hall insulator state was discovered in HgTe quantum well structures as a new state of matter. In contrast to conventional electronic devices where currents flow through the bulk satisfying the classical Ohm's law, in the quantum spin Hall insulator electric currents are confined to flow only along the edges of the sample. In order to verify the concept of edge channel transport we investigate the non-locality in multiterminal devices. The agreement with Landauer-Büttiker calculations confirm the edge channel character of quantum spin Hall states.

15 min. break

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High bandwidth detection of electrically detected magnetic resonance — •Hans Huebl, Robert P. Starrett, Laurens H. Willems van Beveren, Dane R. McCamey, and Andrew J. Fergusson — Centre for Quantum Computer Technology, University of New South Wales, Sydney, Australia

Several proposals discuss the realization of quantum computation with the help of the spin degree of freedom in semiconductors. Electrically detected magnetic resonance (EDMR) provides a well established tool to investigate spin states in semiconductors which was recently extended to investigate the spin dynamics of phosphorus donors in silicon. Typically, the detection bandwidth of EDMR is limited by the characteristic RC time constant of the setup. In this contribution we show that by embedding the sample in a LRC resonant circuit, a so-called tank circuit, it is possible to overcome this limitations. Here, we investigate a silicon MOSFET where the microwave magnetic field to induce the spin transitions is generated on chip by a shorted coplanar stripline[1]. We monitor the spin dependent change in resistance with a current amplifier and simultaneously perform rf-refectometry off the tank circuit. A spin resonance signature was observed in both cases. Investigating the detection bandwidth by using frequency modulation of the microwaves indicates that the spin signature observed is detected up to $f_{mod} = 1$ MHz limited here by the electronic setup used. This shows that this method has the expected high bandwidth opening the view to faster phenomena in EDMR. [1] Willems van Beveren et al., APL **93**, 072102 (2008)

HL 34.6 Wed 15:30 BEY 118

Resonant circular photogalvanic effect in GaN/AlGaN heterojunctions — •B. Wittmann[1], L. Golub[2], S. Danilov[1], J. Karch[1], C. Reitmaier[1], D. Kvon[3], N. Vinh[4], A. van der Meer[4], B. Murdin[5], and S. Ganichev[1] — [1]Terahertz Center, University of Regensburg, Germany — [2]A.F. Ioffe Physico-Technical Institute, St. Petersburg, Russia — [3]Institute of Semiconductor Physics, Novosibirsk, Russia — [4]FOM Institute for Plasma Physics "Rijnhuizen", Nieuwegein, The Netherlands — [5]University of Surrey, Guildford, UK

The resonant circular photogalvanic effect is observed in wurtzite (0001)-oriented GaN/AlGaN heterojunction excited by infrared radiation. The current is induced by angular momentum transfer of photons to the photoexcited electrons at resonant intersubband optical transitions. The signal reverses upon the reversal of the radiation helicity or, at fixed helicity, when the propagation direction of the photons is reversed. Making use of the tunability of the free-electron laser FELIX, we measured the spectral behaviour of the photocurrent in the vicinity of the inter-subband resonance. We observed that the variation of the photon energy results in the change of sign of the photocurrent[1]. This proves that the dominant contribution to the total current is from the asymmetry in momentum distribution of carriers excited in optical transitions. We analyze spin-dependent as well as spin-independent mechanisms giving rise to a resonant photocurrent and demonstrate that, in spite of the weak spin-orbit interaction, the resonant CPGE in GaN is mostly caused by the spin-dependent mechanism.

[1] B. Wittmann, S.D. Ganichev et al., PRB **78**, 205435 (2008)

HL 34.7 Wed 15:45 BEY 118

Theory of spin-Hall effect in HgTe — •Ewelina Hankiewicz[1], Hartmut Buhmann[2], Laurens W. Molenkamp[2], Werner Hanke[1], and Jairo Sinova[3] — [1]Institut für Theoretische Physik, Universität Würzburg, 97074 Würzburg ,Germany — [2]Physikalisches Institut (EP3), Universität Würzburg, 97074 Würzburg, Germany — [3]Department of Physics, Texas A&M University, College Station, USA

We study theoretically a ballistic transport in HgTe H-shaped nanostructures using Landauer-Büttiker formalism. We model inverted HgTe nanostructures using realistic parameters describing properly the spin-orbit splittings and effective mass in these structures. The idea of the transport measurements is as follows. When an electric current flows in one of the legs of the H-bar structure, a transverse spin current due to the intrinsic spin-Hall effect is induced in the connecting part. Subsequently, this spin current produces, due to the inverse spin-Hall effect, a voltage difference in the opposite leg of the H-bar structure which can be measured by a voltmeter. We predict that the spin-Hall effect in H-shaped HgTe/HgCdTe inverted band structure quantum wells can be significant (on the order of a few % of the excitation voltage (microvolts)) if the size of the structure is below a ballistic length.

15 min. break

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Spin-dependent electron-impurity scattering in two-dimensional electron systems — •Andras Palyi — Department of Physics, University of Konstanz, 78457 Konstanz, Germany

We present a theoretical study of elastic spin-dependent electron scattering caused by a charged impurity in the vicinity of a two-dimensional electron gas. We find that the symmetry properties of the spin-dependent differential scattering cross section are different for an impurity located in the plane of the electron gas and for one at a finite distance from the plane. We show that in the latter case asymmetric ('skew') scattering can arise if the polarization of the incident electron has a finite projection on the plane spanned by the normal vector of the two-dimensional electron gas and the initial propagation direction. In specially prepared samples this scattering mechanism may give rise to a Hall-like effect in the presence of an in-plane magnetic field.

HL 34.9 Wed 16:30 BEY 118

Spin currents in diluted magnetic semiconductors — •P. Olbrich[1], S.D. Ganichev[1], S.A. Tarasenko[2], V.V. Bel'kov[2], W. Eder[1], D.R. Yakovlev[2,3], V. Kolkovsky[4], W. Zaleszczyk[4], C. Karczewski[4], T. Wojtowicz[4], and D. Weiss[1] — [1]Terahertz Center, University of Regensburg, Regensburg, Germany — [2]A.F. Ioffe Physico-Technical Institute, Russian Academy of Sciences, St. Petersburg, Russia — [3]Experimental Physics 2, TU Dortmund ,Dortmund, Germany — [4]Institute of Physics,Warsaw, Poland

We report on the observation of spin currents resulting in the zero-bias spin separation [1] in unbiased diluted magnetic semiconductor structures. We demonstrate that an absorption of THz radiation in (001)-grown (Cd,Mn)Te/(Cd,Mg)Te QWs with Mn^{2+} magnetic ions leads to a pure spin current. The effect is investigated in a magnetic field converting the spin separation into a net electric current. We demonstrate that the polarization of the magnetic ion system enhances drastically the conversion due to the spin-dependent scattering by localized Mn^{2+} ions and the giant Zeeman splitting [2]. Both effects disturb the balance of the oppositely directed spin-polarized flows yielding an electric current. In weak magnetic fields for a degenerated electron gas the scattering mechanism dominates the current conversion. We show that the spin-dependent exchange scattering of electrons by magnetic impurities plays an important role in the current generation providing a handle to manipulate the spin-polarized currents.

[1] S.D. Ganichev *et al.*, *Nature Physics* (London) **2**, 609 (2006)
[2] S.D. Ganichev *et al.*, *arXiv:cond-mat/0811.4327*(2008)

HL 34.10 Wed 16:45 BEY 118

Spatial Imaging of Spins Optically Excited by Linearly Polarized Light — •Stefan Göbbels[1,2], Paul Schlammes[1,2], Christian Rodenbücher[1,2], Markus Hagedorn[1,2], Klaus Schmalbuch[1,2], Gernot Güntherodt[1,2], Thomas Schäpers[3,2], Mikhail Lepsa[3,2], and Bernd Beschoten[1,2] — [1]II. Physikalisches Institut, RWTH Aachen, Templergraben 55, 52056 Aachen — [2]Jülich-Aachen Research Alliance, JARA - Fundamentals of Future Information Technology — [3]Institut für Bio- und Nanosysteme IBN-1, Forschungszentrum Jülich, 52425 Jülich

Optical orientation is a well established technique to optically excite electron spins in semiconductors. In conventional all-optical pump-probe experiments a circularly polarized pump beam is used to generate spin-polarized electrons by transferring angular momentum from the photons to the electrons. – We present a new method for optical spin orientation using a linearly polarized pump beam. The polarization mechanism is studied by all-optical time-resolved Faraday microscopy in InGaAs films. Spatial imaging of the spin polarization after optical orientation with linearly polarized light shows a superposition of two spin components. An out-of-plane spin component is found, which depends on the polarization direction of the pump beam. We develop a model ascribing the polarization mechanism of these out-of-plane spins to the internal Dresselhaus field. Furthermore, we observe an in-plane spin component with spins aligned antiparallel when propagating in opposite directions away from the laser spot.

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