HL 35: Spin controlled transport II

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HL 35.1 Wed 14:15 ER 164

Carrier and magnetization dynamics of magnetic resonant tunneling heterostructures — •Christian Ertler and Jaroslav Fabian — Institut für Theoretische Physik, Universität Regensburg, Universitätstrasse 31, D-93040 Regensburg, Germany

The invention and development of magnetic semiconductors has opened up a vast playground for exploiting the possibilities of utilizing the carriers spin in semiconductor electronics. Especially heterostructures made of both magnetic and nonmagnetic layers bring in many opportunities for controlling spin-dependent transport properties [1]. For example, the spin dependent resonant tunneling in magnetic double barrier structures has been exploited to realize high efficient spin valves or spin filtering devices. In this talk the rich dynamics of an asymmetric double barrier system with a ferromagnetic quantum well is theoretically investigated. In such low dimensional semiconductor systems the transport and magnetic characteristics become closely intertwined, since the magnetic state in the quantum well is mediated by the itinerant carriers. The highly nonlinear coupling of the magnetic, electrostatic, and transport properties can lead to astonishing dynamic behaviours. For instance, a robust oscillating current mode accompanied by an oscillating well magnetization shows up at a constant bias voltage. We demonstrate under which conditions this d.c. driven "breathing" magnetization mode occurs and propose different device setups, which should allow for an experimental observation. This work is supported by the SFB-project 689.

[1] J. Fabian et al., Acta Physica Slovaca, 57, 565-907 (2007).

HL 35.2 Wed 14:30 ER 164

Quasiclassical approach and spin-orbit coupling — •Cosimo Gorini[1], Peter Schwab[1], Michael Dzierzawa[1], and Roberto Raimondi[2] — [1]Institut für Physik, Universität Augsburg, 86135 Augsburg, Germany — [2]Dipartimento di Fisica "E. Amaldi", Università di Roma Tre, 00146 Roma, Italy

We discuss the quasiclassical Green function method for a two-dimensional electron - or hole - gas in the presence of spin-orbit coupling, with emphasis on the meaning of the ξ-integration procedure. As an application we study spin and charge dynamics in such a system, with both magnetic and non-magnetic impurities present. We demonstrate in particular that, within our approach, the spin-Hall conductivity can easily be obtained from the spin-density continuity equation.

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Phonon-induced spin relaxation in graphene — •Sergej Konschuh, Christian Ertler, and Jaroslav Fabian — Institut der Theoretischen Physik, University of Regensburg, Regensburg, Germany

Motivated by the recent experiments on spin injection and spin transport in graphene 1, we investigate spin relaxation (so called T1) processes in this material within the framework of the Elliott-Yafet mechinanism: spin ralaxes via momentum spin-flip scattering processes due to the intra-atomic spin-orbit coupling. At room temperature the momentum scatting is ultimately limited by the phonons. A contuinuum model for the electron-phonon and the effective spin-orbit couplings is derived using a realistic tight-binding model 2, which is employed to calculate the spin relaxation times.

This Work is supported by SPP 1285 and SFB 689.

1 N.Tombros, C. Jozsa, M. Popinciuc, H.T. Jonkman and B.J.van Wees, Nature 448,571-574 (2007). 2 Y. Yao, F. Ye, X. Qi, S. Zhang and Z. Fang, cond-mat/0606350v3 (2007).

HL 35.4 Wed 15:00 ER 164

Microscopic theory of intrinsic spin-Hall effect in semiconductor nanodevices — •Tillmann Kubis and Peter Vogl — Walter Schottky Institut, Technische Universität München, Am Coulombwall 3, 85748 Garching

We have calculated spin-orbit induced spin polarizations in confined mesoscopic systems at low temperatures and in the presence of external magnetic fields. To this end, we have implemented the spin-dependent non-equilibrium Green's function method (NEGF) in open nanometer quantum systems and take into account the coupling of non-equilibrium spin occupancies and spin-resolved electronic scattering states. We have employed both the conventional continuum approximation of the spin-orbit interaction in the envelope function approximation as well as a microscopic relativistic tight-binding approach. The latter ensures the spin-orbit effects are properly taken into account for any degree of charge confinement and localization and to all orders in the electron wave vector. While the quantitative results differ, we show that both methods yield the same qualitative trends in the calculated spin polarization, its dependence on confinement, on the spin-orbit interaction strength and on the charge density. In addition, we show that very significant spin polarizations near spin-neutral contacts can be generated in 3-terminal devices without any external magnetic fields. These devices appear to be promising candidates for efficient semiconductor based spin-polarizers.

HL 35.5 Wed 15:15 ER 164

Dyakonov-Perel Spin Dynamics in Bulk GaAs — •Michael Krauss and Hans Christian Schneider — Fachbereich Physik, TU Kaiserslautern, 67663 Kaiserslautern

We study theoretically the spin-dependent carrier dynamics due to the Dyakonov-Perel mechanism in undoped and n-doped bulk GaAs. By solving a dynamical equation for the k-dependent spin-density matrix including Boltzmann scattering integrals we obtain quantitative results for spin relaxation and dephasing times after optical excitation. We study the influence of excitation conditions, i.e., optical excitation at the band gap vs. excitation in the band, and temperatures on the spin-dependent carrier dynamics. In particular, we find that different excitation conditions lead to relaxation times that differ by up to two orders of magnitude.

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Observation of Spin Pair Generation with Pulsed Electrically Detected Magnetic Resonance — •Jan Behrends[1], Christoph Boehme[1,2], Manfred Schmidt[1], and Klaus Lips[1] — [1]Abt. Silizium-Photovoltaik, Hahn-Meitner-Institut Berlin, Berlin, Germany — [2]Department of Physics, University of Utah, Salt Lake City, UT, USA

Due to its high sensitivity, pulsed electrically detected magnetic resonance (pEDMR) has proven to be an effective method to study paramagnetic defects in semiconductor devices. PEDMR measures changes in the (photo-) conductivity resulting from a spin-resonant alteration of charge carrier transport or recombination rates. The annihilation (recombination, dissociation) dynamics of spin pairs that form during the capture of charge carriers at localised defects have previously been studied in various materials and device structures. In contrast, the creation dynamics of spin pairs has not been investigated with pEDMR since it hardly influences the dynamic parameters measured. We demonstrate in this study a novel pEDMR rotary echo pulse sequence that allows such a quantitative analysis of spin pair generation. This procedure can be applied in principle to all materials and devices that are suitable for pEDMR measurements. The experiments presented here use this new approach for the investigation of the generation of electron spin pairs in amorphous silicon conduction band tail states in the emitters of crystalline silicon/ amorphous silicon heterostructure solar cells. The results will be discussed with regard to findings from previous pEDMR studies on hopping transport in similar devices.

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Spin-Relaxation Dynamics due to Hole-Band Mixing in Bulk GaAs — Michael Krauss and •Hans Christian Schneider — Fachbereich Physik, TU Kaiserslautern, 67663 Kaiserslautern

We study theoretically the spin-dependent hole dynamics in undoped bulk GaAs. The influence of the spin-orbit interaction on the band structure is included by using an 8-band Luttinger Hamiltonian. We calculate the k-dependent occupation numbers for hole-band energy dispersions after optical excitation using Boltzmann scattering integrals. From the microscopic occupation numbers we obtain both the ensemble spin dynamics and the dynamics of the average spin at individual k-points: By examining the ensemble spin dynamics we can compare with exponential fits and determine the validity of a relaxation-time approximation for the hole spin. By examing the average spin at different k-vectors we can determine whether the dynamics is dominated by spin precession (Dyakonov-Perel like) or spin-

dependent scattering (Elliott-Yafet like).

15 min. break

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Optimization of InP/GaInAs structures with respect to Rashba spin-orbit coupling — •Masashi Akabori, Markus Hagedorn, Vitaliy Guzenko, Thomas Schäpers, and Hilde Hardtdegen — Institute of Bio- and Nanosystems (IBN-1) and Centre of Nanoelectronic Systems for Information Technology (CNI), Research Centre Jülich, 52425 Jülich, Germany

In this report we investigated the influence of the channel layer thickness on spin-orbit coupling. To this end a modulation doped heterostructure was deposited by MOVPE which consisted of a 350 nm InP buffer, a 10 nm n-supply layer a 20 nm InP spacer, d nm GaInAs channel layer with 77% In content, and a 150-d nm lattice-matched GaInAs sub-channel, and 10 nm InP cap. The channel thickness d was varied between 2 and 10 nm. We first determined the mobility at room temperature and 77K with van der Pauw geometry: it decreases monotonically with the channel thickness. The result is reasonable because the thinner the channel becomes, the more the electron wave function extends into the GaInAs lattice matched sub-channel. In magnetoresistance measurements around 0.5K, we confirmed a clear shift of the first node position toward high magnetic field in a Hall-bar of the 2 nm channel sample, which indicates large Rashba spin-orbit coupling in spite of the thin high indium content channel. The behavior also agreed well with the theoretical estimation from the calculated band profile of the heterostructure, therefore the Rashba spin-orbit coupling in our InP/GaInAs heterostructures can be enhanced by tuning the channel layer thickness.

HL 35.9 Wed 16:30 ER 164

Spin-dependent transport in Si quantum dots — •Konrad Klein[1], Rui N. Pereira[1], Andre R. Stegner[1], Hartmut Wiggers[2], Martin S. Brandt[1], and Martin Stutzmann[1] — [1]Walter Schottky Institut, Technische Universität München, Garching — [2]Universität Duisburg-Essen, Inst. for Combustion and Gas Dynamics, Duisburg

Phosphorus-doped silicon nanocrystals (Si-ncs) can be used as a model system for studying the electronic transport through doped quantum dots. Electrically-detected magnetic resonance (EDMR) is employed to study the spin-dependent transport in thin films composed of Si-ncs with diameters in the range 4-50nm. We have recently demonstrated that Si dangling bonds and substitutional phosphorus donors contribute to electronic transport through films composed of large ensembles of doped and undoped Si-ncs. As a more detailed understanding of the fundamental transport mechanisms in Si-ncs can only be obtained using a small number of nanocrystals, we have developed methods to perform EDMR measurements on a very small number of Si-ncs. The results of downscaled samples and those observed for large networks of Si-ncs, e.g. quantum-confinement causing an enhancement of the coupling between the electron and the nuclear spin of ^{31}P, are discussed. Already for Si-ncs with a diameter of 17 nm, we observe a significant confinement-induced enhancement of the ^{31}P hyperfine coupling constant by 15% with respect to the bulk value. This is in clear contrast to changes observed in optical transitions such as the bandgap or luminescence peak positions, for which a significant increase is only observed for nanocrystal diameters below 5 nm.

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Robust remanent spin injection in light emitting diodes via Schottky- and MgO-barriers at room temperature — •Stephan Hövel[1], Nils C. Gerhardt[1], Martin R. Hofmann[1], Fang-Yuh Lo[2], Dirk Reuter[2], Andreas D. Wieck[2], Ellen Schuster[3], and Werner Keune[3] — [1]AG Optoelektronische Bauelemente und Werkstoffe, Ruhr-University Bochum, Germany — [2]Lehrstuhl für angewandte Festkörperphysik, Ruhr-University Bochum, Germany — [3]Laboratorium für Angewandte Physik, University Duisburg-Essen, Germany

We report on robust room temperature spin injection in GaAs/AlGaAs-light emitting diodes (LEDs) in a Faraday-geometry. Two different injectors based on a Fe/Tb-multilayer which exhibits a strong perpendicular magnetization in remanence have been grown [1]. Spin injection is accomplished by the Schottky-diode generated by the lowest Fe-layer and the n-AlGaAs and by a MgO-tunnel-barrier between the metal and semiconductor, respectively. For both cases a circular optical polarization degree of 4% is detected up to room temperature even at remanent magnetization, but the results of the tunneling-diode suggest a more stable behaviour of the injecting interface. This work has been supported by the DFG within the SFB491.

[1] N.C. Gerhardt et al, Appl. Phys. Lett. 87, 032502 (2005)

HL 35.11 Wed 17:00 ER 164

Spin-orbit interaction induced anisotropy of the plasmon spectrum — •Samvel Badalyan[1,2], Alex Matos-Abiague[2], Giovanni Vignale[3], and Jaroslav Fabian[2] — [1]Department of Radiophysics, Yerevan State University, 375025 Yerevan, Armenia — [2]Department of Physics, University of Regensburg, 93040 Regensburg, Germany — [3]Department of Physics and Astronomy, University of Missouri - Columbia, Missouri 65211, USA

We have investigated the combined effect of the Rashba and Dresselhaus spin-orbit interaction on the many-body Coulomb interaction in a two-dimensional electron system (2DES). It is shown that the many-body polarization function is strongly anisotropic both in the static and dynamic limits. The dielectric function of a 2DES has been calculated within the random phase approximation and the plasmon energy as a function of the momentum magnitude for its different orientations has been obtained. We have also calculated the dynamical structure factor and have shown its peaked behavior as a function of the polar angle of plasmon momentum. This peak corresponds to the plasmon with finite damping due to the spin-orbit interaction. Thus, we have demonstrated clearly that due to the anisotropy of the spin-orbit interaction, the plasmons with the definite values of energy and momentum can be excited only in the certain direction corresponding to the polar angle, determined from the plasmon spectrum.

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HL 35.12 Wed 17:15 ER 164

Efficient optical spin detection in the absence of magnetic fields at room temperature — •Stephan Hövel[1], Nils C. Gerhardt[1], Martin R. Hofmann[1], Fang-Yuh Lo[2], Dirk Reuter[2], Andreas D. Wieck[2], Ellen Schuster[3], and Werner Keune[3] — [1]AG Optoelektronische Bauelemente und Werkstoffe, Ruhr-University Bochum, Germany — [2]Lehrstuhl für angewandte Festkörperphysik, Ruhr-University Bochum, Germany — [3]Laboratorium für Angewandte Physik, University Duisburg-Essen, Germany

GaAs/AlGaAs-diodes have been used in a Faraday-geometry to transfer a circular optical excitation into a spin current at room temperature. The optical information is transferred into a current density which is dependent on the magnetization of the deposited Fe/MgO/n-AlGaAs-tunneling barrier. Detection is possible for a remanent state of magnetization and the current shows a strong proportionality to the circular state of polarization irradiating the diode. Furthermore, the current signal reproduces the remanent behaviour of the Fe. A comparison with a pure Schottky tunnel contact at a Fe/n-AlGaAs-interface diode shows strong current fluctuations for the latter which indicates a worse interface quality than for the case of an oxide-barrier. Few percent of polarization degree difference are measureable without significant temperature dependence up to room temperature and the sensitivity even rises for higher excitation intensities. This work has been supported by the DFG within the SFB491.

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Spin Coulomb drag in a quasi-two-dimensional electron system beyond RPA — •Samvel Badalyan[1,2], Chang Sub Kim[3], and Giovanni Vignale[4] — [1]Department of Radiophysics, Yerevan State University, 375025 Yerevan, Armenia — [2]Department of Physics, University of Regensburg, 93040 Regensburg, Germany — [3]Department of Physics, Chonnam National University, 500-757 Gwangju, Korea — [4]Department of Physics and Astronomy, University of Missouri - Columbia, Missouri 65211, USA

We study the spin Coulomb drag in a quasi-two-dimensional electron gas of finite transverse width, including local field corrections beyond the random phase approximation (RPA). We find that the finite transverse width of the electron gas causes a significant reduction of the spin Coulomb drag. This reduction, however, is largely compensated by the enhancement coming from the inclusion of many-body local field effects beyond the RPA. Our calculations are in very good agreement with the experimental observations of the spin Coulomb drag by C. P. Weber et al., Nature, 437, 1330 (2005).

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0313681.