HL 26: Spin-controlled Transport II

Time: Tuesday 14:00–16:15 Location: H14

HL 26.1 Tue 14:00 H14

Graphene gets picky with the different formalisms for deriving spin-coherent Boltzmann equations — •Janik Kailasvuori — Max Planck Institut für Physik komplexer Systeme

Semiclassical spin-coherent kinetic equations can be derived from quantum theory with many different approaches. In graphene, where the pseudospin-orbit interaction constitutes the entire kinetic energy, the difference actually manifests itself and determines the precise value of electron-hole coherence authored quantum correction to the Drude conductivity $\sim \frac{e^2}{h}\ell k_F$. We derive this correction analytically for single and multilayer graphene with arbitrary impurities and find different results with different approaches. We also find that the often neglected principal value terms in the collision integral are very important. Neglecting them gives a leading correction only of order $(\ell k_F)^{-1}$, whereas including them can give a correction of order $(\ell k_F)^0$. In the latter scenario the correction could be accurately determined with simple linear regression of the conductivity in the Boltzmann regime. Thus graphene may offer an excellent setting for experimentally settling conflicts between different approaches.

HL 26.2 Tue 14:15 H14

Tight binding model of spin-orbit coupling in graphene — •Sergej Konschuh, Martin Gmitra, and Jaroslav Fabian — Universität Regensburg, Regensburg, Germany

We construct a tight-binding model to explain the spin-orbit coupling effects on the electronic band structure of graphene. We expand the wave functions into a combination of the atomic (s,p,d)-orbitals. We show that the usually neglected d-orbital states contribute to the spin-orbit splitting at the K(K') points in the first order; the s and p orbitals contribute in the second order, qualitatively explaining our recent first-principles results. In contrast, the d-orbitals play no role in the so called extrinsic SOC effect, which is the spin-orbit splitting in the presence of a transverse (to the plane) electric field. Analytical results are derived for the spin-orbit splitting in terms of the atomic energies, hopping and overlap integrals, as well as the atomic spin-orbit splittings.

This work is supported by the DFG SPP1285.

HL 26.3 Tue 14:30 H14

Beating of Friedel oscillations induced by spin-orbit interaction — •Samvel M. Badalyan[1,2], Alex Matos-Abiague[1], Giovanni Vignale[3], and Jaro Fabian[1] — [1]Department of Physics, University of Regensburg, 93040 Regensburg, Germany — [2]Department of Radiophysics, Yerevan State University, 1 A. Manoukian Street, Yerevan, 375025 Armenia — [3]Department of Physics and Astronomy, University of Missouri, Columbia, Missouri 65211, USA

By exploiting our recently derived exact formula for the Lindhard polarization function in the presence of Bychkov-Rashba (BR) and Dresselhaus (D) spin-orbit interaction (SOI), we show that the interplay of different SOI mechanisms induces highly anisotropic modifications of the static dielectric function. We find that under certain circumstances the polarization function exhibits doubly-singular behavior, which leads to an intriguing novel phenomenon, beating of Friedel oscillations. This effect is a general feature of systems with BR+D SOI and should be observed in structures with a sufficiently strong SOI.

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HL 26.4 Tue 14:45 H14

Cu-doped Nitrides: Spinaligner at room-temperature — •Philipp R. Ganz[1,2], Christoph Sürgers[1,3], and Daniel M. Schaadt[1,2] — [1]DFG-Center for Functional Nanostructures, Karlsruher Institute of Technology, 76131 Karlsruhe, Germany — [2]Institut für Angewandte Physik, Karlsruher Institute of Technology, 76131 Karlsruhe, Germany — [3]Physikalisches Institut, Karlsruher Institute of Technology, 76131 Karlsruhe, Germany

Nitride based spintronics is emerging as an interesting alternative to arsenide based spintronics. One reason for this strong interest is the long spin-lifetime in InN quantum dots which is shown to be temperature independent. For spin-injection into these quantum dots, a ferromagnetic spin-aligner which yields high spin-polarization at room-temperature is necessary. Copper doped nitrides are promising candidates as spin-aligners, because non-magnetic material is used, thereby avoiding confusing results due to magnetic clusters, as in the case of Maganese or Gadolinium doped nitrides. Theoretical predictions show the possibility of ferromagnetism and a high spin-polarization for Cu-doped GaN and AlN. A few experimental results have indicated ferromagnetism in both materials. We investigated and optimized the growth of Cu-doped GaN and AlN by plasma assisted molecular beam epitaxy on different substrates. Our Cu-doped films show ferromagnetic behaviour far above room temperature. The influence of growth parameters such as growth temperature, Cu to metal flux ratio and metal to nitrogen flux ratio on the magnetic properties was determined.

15 Min. Coffee Break

HL 26.5 Tue 15:15 H14

An exact solution to the problem of spin edge state — Vahram Grigoryan[1], Alex Matos-Abiague[2], and •Samvel Badalyan[1,2] — [1]Department of Radiophysics, Yerevan State University, 1 A. Manoukian Street, 375025 Yerevan, Armenia — [2]Department of Physics, University of Regensburg, 93040 Regensburg, Germany

We present an exact solution to the problem of spin edge state, which generalizes the bulk solution by Rashba to the important for spin transport case of the current carrying spin channels. The obtained spin edge states are induced by the combined effect of spin-orbit interaction and hard-wall confining potential in a two dimensional system, exposed to a perpendicular magnetic field. We are able to explain exactly how the spin resolved edge states are separated in space, to achieve a deeper intuitive understanding of the exact behavior of spin and spin current components, depending on the electron position with respect to the sample edges and as a function of the Fermi energy of the electron gas. These findings can serve as an effective tool for controlling the spin motion in spintronic devices. The presented exact solution can be a strong input in studying the spin transport through edge channels in semiconductor nanostructures.

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HL 26.6 Tue 15:30 H14

$SU(2)$ symmetry and the Boltzmann equation for the Rashba model — •Cosimo Gorini[1], Peter Schwab[1], and Roberto Raimondi[2] — [1]Institut für Physik, Universität Augsburg, 86135 Augsburg, Germany — [2]CNISM and Dipartimento di Fisica, Università Roma Tre, Via della Vasca Navale 84, 00146 Roma, Italy

Spin-orbit coupling in low-dimensional systems leads to rich physics, interesting from both the fundamental point of view and for applications. Spin-charge coupled dynamics allows to manipulate the spin degrees of freedom by purely electrical means.

The Boltzmmann equation is very useful for the theoretical description of transport properties. However in its standard formulation for the Rashba model the scattering kernel is cumbersome and the physical origin of the electric field induced spin currents is not transparent. We exploit the $SU(2)$ gauge symmetry in the model which allows a symmetric treatment of spin and charge degrees of freedom.

We obtain a Boltzmann equation where the $SU(2)$ magnetic field due to spin-orbit coupling appears explicitly. This generates the spin Hall currents, just as standard Hall currents are generated by the real magnetic field. We derive the coupled spin-charge diffusion equations.

HL 26.7 Tue 15:45 H14

Interference of heavy holes in an Aharonov-Bohm ring — •Dimitrije Stepanenko[1], Minchul Lee[2], Guido Burkard[3], and Daniel Loss[1] — [1]University of Basel, Basel, Switzerland — [2]Kyung Hee University, Yongin, Korea — [3]University of Konstanz, Konstanz, Germany

We study the coherent transport of heavy holes through a one-dimensional ring in the presence of spin-orbit coupling. Spin-orbit interaction of holes, cubic in the in-plane components of momentum, gives rise to an angular momentum dependent spin texture of the eigenstates and influences transport. We analyze the dependence of the resulting differential conductance of the ring on hole polarization of the leads and the signature of the textures in the Aharonov-Bohm oscillations when the ring is in a perpendicular magnetic field. We find that the polarization-resolved conductance reveals whether the dominant spin-orbit coupling is of Dresselhaus or Rashba type, and that the cubic spin-orbit coupling can be distinguished from the conventional linear coupling by observing the four-peak structure in the Aharonov-Bohm oscillations.

HL 26.8 Tue 16:00 H14

Scanning tunneling spectroscopy of a dilute two-dimensional electron system exhibiting Rashba spin splitting — •Stefan Becker, Marcus Liebmann, and Markus Morgenstern — II. Physikalisches Institut B, RWTH Aachen and JARA-FIT, 52074 Aachen

Using scanning tunneling spectroscopy (STS) at 5 Kelvin in B-fields up to 7 Tesla, we investigate the local density of states of a two-dimensional electron system (2DES) created by Cs adsorption on *p*-type InSb(110). Cs induces a large band bending on the *p*-type InSb(110) surface creating a 2DES in the inversion layer, which in contrast to previous STS studies exhibits a 2D Fermi level. The 2DES shows standing waves with wave numbers in accordance with theory. In a perpendicular magnetic field the percolating drift states of the quantum hall transition are observed within the disorder broadened Landau levels. Using a highly doped sample we achieve a steep band bending potential showing Landau levels with a beating pattern attributed to Rashba spin splitting. Due to the high electric field of the potential, a large Rashba parameter in the order of $\alpha = 7\times10^{-11}$ eV$\cdot$m can be estimated. A simulation of the density of states using this value reproduces the observed beating pattern very well.