HL 81: Graphene: Transport incl. Spin Physics and Magnetic Fields I

Time: Thursday 15:00–16:45 Location: ER 270

HL 81.1 Thu 15:00 ER 270

Aharonov-Bohm effect in an electron -hole graphene system

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We analyze the electronic properties of a monolayer graphene ring. The sample and structured by standard procedures: micro-mechanical cleavage for preparation on a Si-wafer with a 285 nm thick layer of SiO2, electron beam lithography, active oxygen etching for structuring and contacting the ring shaped sample. The sample is measured in a He3-cryostat system with a base temperature of 500 mK and is identified as monolayer first via optical microscopy and later based on the magnetotransport measurements. In addition to the Si-backgate we place a topgate on top of one arm of the ring to manipulate the charge carrier concentration and to be able to create a pnp- (npn-) junction inside the ring. We observe Aharonov-Bohm oscillations by variation of the magnetic field around 0 T. The period of the oscillation is approx. 16.5 mT and fits the size of the ring well. The maximum visibility of the oscillations in all measurements is about 1%. We are also able to observe the oscillations when a pnp-junction is created inside the ring. The period is independent of the existence of a pnp-junction and stays constant in all situations. We analyze the amplitude in dependence of the charge carrier type and concentration. The absolute amplitude is constant in the bipolar and unipolar region. The relative amplitude has a dependence that is based on the changing background resistance.

HL 81.2 Thu 15:15 ER 270

Magnetotransport through graphene nanoribbons at high magnetic fields

— •Silvia Schmidmeier[1], Sung Ho Jhang[1], Jürgen Wurm[2], Iurii Skourski[3], Joachim Wosnitza[3], Christoph Strunk[1], Dieter Weiss[1], Klaus Richter[2], and Jonathan Eroms[1] — [1]Institute of Experimental and Applied Physics, University of Regensburg, Germany — [2]Institute of Theoretical Physics, University of Regensburg, Germany — [3]Dresden High Magnetic Field Laboratory, Helmholtz-Zentrum Dresden-Rossendorf, Germany

For the application of graphene in nanoelectronics one has to understand the behavior of graphene nanostructures, in particular graphene nanoribbons. They were theoretically predicted to show either metallic or insulating behavior around the charge neutrality point, depending on their crystallographic orientation. In experiment, however, graphene nanoribbons always exhibit an insulating state close to the charge neutrality point, which is dominated by disorder rather than a confinement-induced gap in the spectrum. At present, the behavior of GNRs is mainly governed by extrinsic defects rather than their intrinsic properties, and information on the nature of those defects is highly desired.

We have investigated the magnetoresistance of lithographically prepared single-layer graphene nanoribbons as narrow as 70 nm in pulsed, perpendicular magnetic fields up to 60 T and performed corresponding transport simulations using a tight-binding model and several types of realistic bulk and edge disorder. Thus we can disentangle their contributions to transport in graphene nanoribbons.

HL 81.3 Thu 15:30 ER 270

Terahertz radiation driven chiral edge currents in graphene

— •C. Drexler[1], J. Karch[1], P. Olbrich[1], M. Fehrenbacher[1], M. Hirmer[1], M. M. Glazov[2], S. A. Tarasenko[2], B. Birkner[1], J. Eroms[1], D. Weiss[1], R. Yakimova[3], S. Lara-Avila[4], S. Kubatkin[4], M. Ostler[5], T. Seyller[5], E. L. Ivchenko[2], and S. D. Ganichev[1] — [1]Terahertz Center, Regensburg, Germany — [2]Ioffe Institute, St. Petersburg, Russia — [3]Linköping University, Linköping, Sweden — [4]Chalmers University of Technology, Göteborg, Sweden — [5]University of Erlangen-Nürnberg, Erlangen, Germany

Here we report on photocurrents induced in single layer graphene samples by illumination of the graphene edges with circularly polarized terahertz radiation at normal incidence. The photocurrent flows along the sample edges and forms a vortex. Its winding direction reverses by switching the light helicity from left- to right-handed. We demonstrate that the effect is directly coupled to electron scattering at the graphene edge which reduces the spatial symmetry and vanishes in bulk graphene. The developed theory based on Boltzmann's kinetic equation is in good agreement with the experimental findings. Our results suggest that the circular photocurrents can be effectively used to study edge transport in graphene even at room temperature.

[1] J. Karch *et al*, *Phys. Rev. Lett.* (in print); arXiv:1107.3747v1

HL 81.4 Thu 15:45 ER 270

Spin transport and relaxation in single and bilayer graphene

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We achieved electrical spin injection with a DC current from a ferromagnetic material (Co) into both single layer graphene (SLG) and bilayer graphene (BLG). In order to circumvent the conductivity mismatch problem a thin AlOx tunnel barrier is placed in between graphene and the ferromagnetic contacts. This AlOx layer is produced by depositing Al atoms over the entire sample at 180 K and subsequent oxidation at room temperature. For both SLG and BLG, we obtain a clear switching of the non-local magnetoresistance whose sign depends on the magnetization orientation (parallel/antiparallel) of the ferromagnetic electrodes. By applying a perpendicular magnetic field we also detect spin precession (Hanle effect). Fitting of these Hanle curves yields the spin relaxation time and the spin injection efficiency as well as the spin diffusion constant. The latter is nearly identical with the charge diffusion constant in SLG. For BLG this is also valid if one considers a realistic band structure with a bandgap. Furthermore we find by analyzing the relationship between spin and momentum scattering that the Elliot-Yafet spin relaxation mechanism dominates in SLG at low temperature. In contrast to this result, we find a opposite behavior of the temperature dependence of the spin relaxation time and the diffusion constant which suggests the importance of the Dyakonov-Perel mechanism in BLG.

HL 81.5 Thu 16:00 ER 270

Temperature Dependent Magnetotransport Studies of Graphene on GaAs

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We utilize temperature dependent magnetotransport measurements to investigate the electronic properties of graphene on (001)-GaAs. Our substrates contain a Si-doped GaAs backgate grown by means of molecular beam epitaxy. The investigated graphene flakes were prepared by mechanical cleavage of natural graphite. We were able to determine the number of layers of the graphene flakes by using Raman spectroscopy.

Shubnikov-de Haas oscillations in the longitudinal resistance allow for determination of the charge carrier densities and subsequently the carrier mobilities. The gate-voltage dependency of the resistance suggests that the samples are p-doped. The observed weak localization enables the extraction of the temperature dependent dephasing time τ_ϕ. The temperature dependency reveals diffusive electron-electron scattering to be the phase breaking process.

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Polarization resolved magneto-Raman scattering of graphene on natural graphite

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It was recently demonstrated that purely electronic Raman scattering can be measured in graphene flakes on bulk natural graphite subject to a quantizing magnetic field [1]. We investigate a similar graphene flake by micro-Raman scattering at 4.2K and in magnetic fields up to 29T. Different types of electronic excitations are observed and identified in circular polarization resolved experiments. The magnetic field evolution of these excitations reveals details of the graphene band structure, such as the electron-hole asymmetry, as well as possible signs of an interaction with the underlying substrate. The latter is further suggested by an unusually rich coupling between the zone-center E_{2g}-phonon and the electronic excitations.

[1] C. Faugeras et al., Phys. Rev. Lett. 107, 036807 (2011)

HL 81.7 Thu 16:30 ER 270

Relaxation dynamics in Landau-quantized graphene probed in the mid-infrared range — •Martin Mittendorff[1], Stephan Winnerl[1], Harald Schneider[1], Manfred Helm[1], Milan Orlita[2], Marek Potemski[2], Mike Sprinkle[3], Claire Berger[3], and Walter A. de Heer[3] — [1]Helmholtz-Zentrum Dresden-Rossendorf, Institute of Ionebeamphysics and material research, Germany — [2]Grenoble High Magnetic Field Laboratory, France — [3]Georgia Institute of Technology, Atlanta, USA

In contrast to conventional semiconductors the Landau levels (LLs) in graphene are not equidistant. This feature allows us to investigate a single LL transition selectively. By applying magnetic fields of up to 7 T we could investigate three different transitions at a fixed wavelength of 16.5 μm via pump-probe measurements. By varying the magnetic field the photon energies were brought into resonance with the different transitions. For the transition $LL_{0(-1)} - > LL_{1(0)}$ we could not only observe an increase of the pump-probe signal by a factor of 2.5 but also a decrease of the relaxation time from 20 ps to 5 ps. Interestingly, the reduced relaxation time is observed in a wider range of magnetic fields than the increase of the signal amplitude. Additionally the minimum of the relaxation time is shifted in respect to the maximum signal. For the transitions $LL_{-1(-2)} - > LL_{2(1)}$ and $LL_{-2(-3)} - > LL_{3(2)}$ we could only observe an slight increase of the pump-probe signal.