MA 25: Graphene: Transport (with DY/DS/O/TT)

Time: Wednesday 9:30–12:15 Location: POT 051

MA 25.1 Wed 9:30 POT 051

Ratchet effects in graphene with a lateral potential — •Josef Kamann[1], Leonid Golub[2], Matthias König[1], Jonathan Eroms[1], Felix Fromm[3], Thomas Seyller[3], Dieter Weiss[1], and Sergey Ganichev[1] — [1]University of Regensburg, Germany — [2]Ioffe Physical-Technical Institute of the RAS, St. Petersburg, Russia — [3]Technical University of Chemnitz, Germany

We report on the observation of terahertz radiation induced ratchet effects in graphene with a lateral periodic potential. These effects generate a dc electric current from an ac electric field. To probe ratchet effects, a metal grating has been deposited on top of epitaxially grown graphene. This lattice contains periodically deposited stripes with different widths and spaces and, therefore, has no inversion symmetry.

We demonstrate that the ratchet effect is generated only in the modulated area and does not arise in unpatterned graphene. This proves the symmetry breaking induced by the asymmetric lateral potential. Additional effects like edge currents or the circular ac Hall effect are excluded by the geometry of the samples and by illumination under normal incidence. The ratchet signal is studied with respect to the polarization and the wavelength of the radiation. We show that the ratchet effect is sensitive to both linear and circular polarization and conducted calculations for different elastic-scattering processes to compare them to our experimental findings.

MA 25.2 Wed 9:45 POT 051

Magnetic quantum ratchet effect in graphene — •Christoph Drexler[1], Sergey Tarasenko[2], Peter Olbrich[1], Johannes Karch[1], Marion Hirmer[1], Florian Müller[1], Martin Gmitra[1], Jaroslav Fabian[1], Rositza Yakimova[3], Samuel Lara-Avila[4], Sergey Kubatkin[4], Minjie Wang[5], Junichiro Kono[5], and Sergey Ganichev[5] — [1]THz Center, University of Regensburg, Germany — [2]Ioffe Physical-Technical Institute, St. Petersburg, Russia — [3]Linköping University, Sweden — [4]Chalmers University, Göteborg, Sweden — [5]Rice University, Houston, USA

We report on the experimental observation of the magnetic quantum ratchet effect in epitaxial- and CVD- grown graphene layers excited by pulsed terahertz (THz) - laser radiation [1]. Our experimental findings can be well understood in terms of asymmetric carrier scattering in graphene in presence of an in-plane magnetic field yielding strong structure inversion asymmetry (SIA) in graphene. The SIA stems from the fact that graphene is deposited on a substrate and/or is sensitive to chemical bonding of adatoms on the surface. Considering hydrogen atoms on top of carbon we calculated the magnitude of the photocurrent being in good agreement with the data obtained from the experiments. The amplitudes of the current differ significantly for the used material systems whereas its sign can be influenced by the post-groth treatment of the samples. The ratchet current can be calibrated to measure the strength of the SIA, which plays an important role in graphene ferromagnetism and spintronics.

[1] C. Drexler et al, Nat. Nano. 8 104-107, 2013.

MA 25.3 Wed 10:00 POT 051

Spin transport in arrays of graphene nanoribbons — Matthias Berl, Bastian Birkner, Andreas Sandner, Silvia Minke, Dieter Weiss, and •Jonathan Eroms — Institut für Experimentelle und Angewandte Physik, Universität Regensburg, Germany

We performed non-local spin valve and Hanle measurements in arrays of graphene nanoribbons in both single and bilayer graphene. Nanoribbons were patterned by electron beam lithography and oxygen-based reactive ion etching. By fabricating several sets of electrodes, we can compare spin transport data in bulk and nanoribbons on the same graphene flake. Due to band-gap opening in the nanoribbons at low temperatures, spin transport measurements were only possible at 200 Kelvin. For single layer graphene we observe that while nanopatterning decreases the electron mobility, the spin lifetime increases from 200 ps to 500 ps. This is consistent with a Dyakonov-Perel-like contribution to spin relaxation. In bilayer graphene, we observe a low electron mobility and high spin lifetimes of about 1 ns in both bulk and nanoribbons, again consistent with Dyakonov-Perel-like spin relaxation. Attempting to see an influence of possible magnetic moments at the sample edges, no clear signature was detected in the Hanle data at 200 Kelvin.

MA 25.4 Wed 10:15 POT 051

THz radiation interacting with epitaxial graphene — •Christian Sorger, Sascha Preu, and Heiko B. Weber — Lehrstuhl für Angewandte Physik, Universität Erlangen-Nürnberg, 91058 Erlangen, Germany

We investigate the interaction between terahertz (THz) radiation and periodically doped graphene ribbons. We find a remarkable polarization dependence. The Drude response of graphene can be probed with THz electric fields parallel to the ribbons. This results in a high-pass filter-like behavior with a 3dB-frequency in the THz range. The exact value depends on carrier mobility and carrier concentration. For THz electric field perpendicular to the ribbons we detect rather high transmission as the response is dominated by plasmonic effects. Utilizing the material system epitaxial graphene on silicon carbide (SiC) we show that no lithographic patterning is required to couple light into the two-dimensional electron gas (2DEG). As the interaction strength depends on the geometry of the 2DEG and its electronic properties, respectively, this strategy allows for a characterization of the AC conductivity in epitaxial graphene.

MA 25.5 Wed 10:30 POT 051

Numerically exact approach to transport properties of disordered two-dimensional materials — •Stefan Barthel[1,2], Malte Rösner[1,2], Fernando Gargiulo[3], Oleg V. Yazyev[3], and Tim O. Wehling[1,2] — [1]Institut für Theoretische Physik, Universität Bremen, Germany — [2]Bremen Center for Computational Materials Science, Universität Bremen, Germany — [3]Institute of Theoretical Physics, Ecole Polytechnique Fédérale de Lausanne (EPFL), Switzerland

We present a numerical method for modeling electron transport in disordered two-dimensional materials such as graphene with resonant impurities. Covalently bonded adatoms, such as hydrogen, modify the electronic structure and transport properties of graphene in the diffusive as well as localized regime in which quantum corrections become important. The electronic structure is described using a tight-binding model involving pz-orbitals on a honeycomb lattice, whereas the transport properties are evaluated in the linear response approximation (Kubo-Greenwood) using the kernel polynomial method as a solver. By combining these methods we gain access to large systems containing up to 10^6 atoms. These results are compared to the ones obtained using the Landauer-Büttiker approach in the above-mentioned transport regimes.

MA 25.6 Wed 10:45 POT 051

Quantum Hall Effect in Chemically Functionalized Graphene: Defect-Induced Critical States and Breakdown of Electron-Hole Symmetry — •Nicolas Leconte[1,2], Jean-Christophe Charlier[2], and Stephan Roche[1] — [1]ICN2 - Institut Catala de Nanociencia i Nanotecnologia, Campus UAB, 08193 Bellaterra (Barcelona), Spain — [2]Université catholique de Louvain (UCL), Institute of Condensed Matter and Nanoscience (IMCN), Chemin des étoiles 8, 1348 Louvain-la-Neuve, Belgium

Unconventional magneto-transport fingerprints in the quantum Hall regime (with applied magnetic field from one to several tens of Tesla) in chemically functionnalized graphene are reported. Upon chemical adsorption of monoatomic oxygen (from 0.5% to few percents), the electron-hole symmetry of Landau levels is broken, while a double-peaked conductivity develops at low-energy, resulting from the formation of critical states conveyed by the random network of defects-induced impurity states. Scaling analysis suggests an additional zero-energy quantized Hall conductance plateau, which is here not connected to degeneracy lifting of Landau levels by sublattice symmetry breakage. This singularly contrasts with usual interpretation, and unveils a new playground for tailoring the fundamental characteristics of the quantum Hall effect. The study on oxygen is complemented with a study on a simplified divacancy model, confirming the percolation of impurity states leading to delocalized states.

Coffee break (15 min.)

MA 25.7 Wed 11:15 POT 051

Ultra long spin decoherence times in graphene quantum dots with a small number of nuclear spins — •Moritz Fuchs[1], John

Schliemann[2], and Björn Trauzettel[1] — [1]Institut für Theoretische Physik und Astrophysik, Universität Würzburg, 97074 Würzburg — [2]Institut für Theoretische Physik, Universität Regensburg, 93053 Regensburg

We study the dynamics of an electron spin in a graphene quantum dot, which is interacting with a bath of less than ten nuclear spins via the anisotropic hyperfine interaction. Due to substantial progress in the fabrication of graphene quantum dots, the consideration of such a small number of nuclear spins is experimentally relevant. This choice allows us to use exact diagonalization to calculate the longtime average of the electron spin as well as its decoherence time. We investigate the dependence of spin observables on the initial states of nuclear spins and on the position of nuclear spins in the quantum dot. Moreover, we analyze the effects of the anisotropy of the hyperfine interaction for different orientations of the spin quantization axis with respect to the graphene plane. Interestingly, we then predict remarkable long decoherence times of more than 10ms in the limit of few nuclear spins.

MA 25.8 Wed 11:30 POT 051

Carrier dynamics in graphene under Landau quantization — •Florian Wendler[1], Martin Mittendorff[2], Stephan Winnerl[2], Manfred Helm[2], Andreas Knorr[1], and Ermin Malic[1] — [1]Institut für Theoretische Physik, Nichtlineare Optik und Quantenelektronik, Technische Universität Berlin, Germany — [2]Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany

We investigate the ultrafast dynamics of low-energetic Dirac electrons in graphene under Landau quantization [1]. In a joint experiment-theory study, we provide calculations based on the density matrix formalism [2] as well as measurements of the relaxation dynamics via differential transmission spectroscopy.

As a consequence of the linear dispersion at the Dirac points, graphene exhibits a non-equidistant Landau level spectrum which allows to address specific transitions by optical pumping. Exploiting this to selectively excite the energetically lowest Landau levels, we employ pump-probe spectroscopy to explore the carrier dynamics in this regime. A surprising sign reversal in differential transmission spectra is observed both in experiment and theory and provides evidence for strong Auger scattering on a picosecond timescale. Our calculations even predict the occurrence of a substantial carrier multiplication in Landau quantized graphene [3].

[1] M. Mittendorff et al., (in preparation).

[2] E. Malic, A. Knorr, Graphene and Carbon Nanotubes: Ultrafast Optics and Relaxation Dynamics, (Wiley-VCH, Berlin, 2013).

[3] F. Wendler, A. Knorr, and E. Malic, (submitted).

MA 25.9 Wed 11:45 POT 051

Polarization dependence of optical carrier excitation in graphene — •Martin Mittendorff[1,2], Torben Winzer[3], Ermin Malic[3], Andreas Knorr[3], Harald Schneider[1], Manfred Helm[1,2], and Stephan Winnerl[1] — [1]Helmholtz-Zentrum Dresden-Rossendorf, P.O. Box 510119, 01314 Dresden, Germany — [2]Technische Universität Dresden, 01062 Dresden, Germany — [3]Technische Universität Berlin, Hardenbergstraße 36 10623 Berlin, Germany

We present near-infrared pump-probe measurements to investigate the polarization dependence of optical carrier excitation in graphene. Excitation with linearly polarized radiation leads to an anisotropic distribution of the nonequilibrium carriers in momentum space. This anisotropy can be revealed by the comparison of pump-probe signals for different polarization configurations. In parallel configuration the probe beam has the same polarization with respect to the pump beam, for the perpendicular configuration the polarization of the probe beam is rotated by 90°. The signal amplitude of the parallel configuration is about twice as large as compared to the perpendicular configuration. The initial relaxation process is faster for the parallel polarized probe beam, which leads to identical signals about 150 fs after excitation. At this time delay an isotropic carrier distribution is reached by electron-phonon scattering. These findings are confirmed by microscopic calculations.

MA 25.10 Wed 12:00 POT 051

Anisotropic photoinduced current injection in graphene — •Julien Rioux[1], John Sipe[2], and Guido Burkard[1] — [1]University of Konstanz — [2]University of Toronto

Quantum-mechanical interference effects are considered in carrier and charge current excitation in gapless semiconductors using coherent optical field components at frequencies ω and 2ω. Due to the absence of a bandgap, excitation scenarios outside of the typical operation regime are considered; we calculate the polarization and spectral dependence of these all-optical effects for single- and bilayer graphene. For linearly-polarized light and with one-photon absorption at ω interfering with 2ω absorption and ω emission, the resulting current injection is five times stronger for perpendicular polarization axes compared to parallel polarization axes. This additional process results in an anisotropic current as a function of the angle between polarization axes, in stark contrast with the isotropic current resulting from the typical interference term in graphene [Rioux et al., PRB 83, 195406 (2011)]. Varying the Fermi level allows to tune the disparity parameter $d = \eta_I^{xyyx}/\eta_I^{xxxx}$ closer to typical values in GaAs [$|d| \approx 0.2$, Rioux and Sipe, Physica E 45, 1 (2012)]: from -1, when the additional process is fully Pauli-blocked, to $-3/7$, when it is fully accessible, thus facilitating polarization sensitive applications.