TT 1: TR: Graphene 1

Time: Monday 10:15–13:00 Location: H18

TT 1.1 Mon 10:15 H18

Orbitally controlled Kondo effect of Co ad-atoms on graphene — •Tim Wehling[1], Alexander Balatsky[2], Mikhail Katsnelson[3], Alexander Lichtenstein[1], and Achim Rosch[4] — [1]I. Institut für Theoretische Physik, Universität Hamburg, Jungiusstrasse 9, 20355 Hamburg, Germany — [2]Theoretical Division, Los Alamos National Laboratory, Los Alamos, New Mexico 87545, USA — [3]Institute for Molecules and Materials, Radboud University of Nijmegen, Heijendaalseweg 135, 6525 AJ Nijmegen, The Netherlands — [4]Institute for Theoretical Physics, University of Cologne, 50937 Cologne, Germany

Based on ab-initio calculations we identify possible scenarios for the Kondo effect due to Co ad-atoms on graphene. For a Co atom absorbed on top of a carbon atom, the Kondo effect is quenched by spin-orbit coupling below an energy scale of $\sim$15 K. For Co with spin $S = 1/2$ located in the center of a hexagon, an SU(4) Kondo model describes the entanglement of orbital moment and spin at higher energies, while below $\sim$ 60 meV spin-orbit coupling leads to a more conventional SU(2) Kondo effect. The interplay of the orbital Co physics and the peculiar band-structure of graphene is directly accessible in Fourier transform tunneling spectroscopy or in the gate-voltage dependence of the Kondo temperature displaying a very strong, characteristic particle-hole asymmetry.

TT 1.2 Mon 10:30 H18

Revivals of quantum wave packets in graphene — •Viktor Krückl[1] and Tobias Kramer[1,2] — [1]Institut für Theoretische Physik, Universität Regensburg, 93040 Regensburg — [2]Department of Physics, Harvard University, Cambridge, MA 02138, USA

We investigate the propagation of wave-packets on graphene in a perpendicular magnetic field. The wave-packet evolution in graphene differs drastically from the one in an electron gas and shows a rich revival structure similar to the dynamics of highly excited Rydberg states [1]. We present a detailed analysis of the occurring collapses, revivals and fractional revivals analytically as well as numerically. In order to study the impact of disorder on the effect we apply our novel numerical scheme to solve the wave-packet propagation on the effective single-particle Dirac-Hamiltonian of graphene in the presence of random impurity potentials.

[1] Viktor Krueckl and Tobias Kramer, New J. Phys. **11** 093010 (2009)

TT 1.3 Mon 10:45 H18

Externally induced spin relaxation in graphene — •Jan Bundesmann[1], Michael Wimmer[1,2], and Klaus Richter[1] — [1]Institut für theoretische Physik, Universität Regensburg, 93040 Regensburg, Germany — [2]Instituut-Lorentz, Universiteit Leiden, 2300 RA Leiden, The Netherlands

In the fast growing research field of spintronics graphene seems to be a promising candidate. From theory weak spin-orbit interaction is expected in pure carbon-based materials. However, experimental results and theoretical predictions differ by several orders of magnitude: spin lifetimes in the experiment are much smaller than, e. g., the ones obtained from recent DFT calculations [1].

In our calculations we will include also externally induced spin-orbit interactions. Sources for this might be impurities in the substrate or adsorbed atoms. For this investigation we set up a tight-binding model for graphene including intrinsic and Rashba-type spin-orbit interactions. By local variation of the Rashba parameter we model systems with the above introduced sources of spin-orbit interaction and study spin-orbit effects on quantum transport.

[1] M. Gmitra, S. Konschuh, C. Ertler, C. Ambrosch-Draxl and J. Fabian; arxiv:0904.3315

TT 1.4 Mon 11:00 H18

Coulomb interaction in graphene: Relaxation rates and transport — •Michael Schütt[1], Pavel Ostrovsky[2], Igor Gornyi[2], and Alexander Mirlin[1,2] — [1]Institut für Theorie der Kondensierten Materie, Karlsruhe Institute of Technology (KIT), 76128 Karlsruhe, Germany — [2]Institut für Nanotechnologie, Karlsruhe Institute of Technology (KIT), 76021 Karlsruhe, Germany

We study electron transport in graphene with Coulomb interaction at finite temperatures by using Keldysh diagrammatics. In the case of clean graphene we obtain the total scattering rate, the transport scattering rate, and the energy relaxation rate at the Dirac point. Since the total scattering rate diverges graphene exhibits a non-Fermi-liquid behavior similar to disordered metals. Unlike metals clean graphene has a finite conductivity due to the Coulomb interaction. For conductivity we obtain the same analytic behavior as was found using the Boltzmann approach [1,2]. We analyze the plasmon spectrum of graphene and formulate quantum kinetic equations to describe transport in the crossover between the Coulomb interaction dominated regime and the disorder dominated regime.

[1] L. Fritz et al., Phys. Rev. B 78:085416 (2008).
[2] A. Kashuba, Phys. Rev. B 78:085415 (2008).

TT 1.5 Mon 11:15 H18

Is it possible to detect edge states in graphene quantum dots? — •Michael Wimmer[1], Anton R. Akhmerov[1], and Francisco Guinea[2] — [1]Instituut-Lorentz, Universiteit Leiden, The Netherlands — [2]Instituto de Ciencia de Materiales de Madrid, Spain

We analyze the single particle states at the edges of graphene quantum dots of arbitrary shapes. By combining analytical and numerical arguments, we show that localized edge states, distinct from extended ones, exist in dots of all dimensions. The number of these states is proportional to the circumference of the dot measured in lattice constants. Perturbations breaking electron-hole symmetry shift the edge states away from zero energy but do not change their total amount.

15 min. break

TT 1.6 Mon 11:45 H18

Graphene: Relativistic transport in a nearly perfect quantum liquid — •Lars Fritz[1], Markus Mueller[2], Joerg Schmalian[3], and Subir Sachdev[4] — [1]Universitaet zu Koeln, Institut fuer theoretische Physik, Zuelpicher Strasse 77, 50937 Koeln — [2]The Abdus Salam International Centre for Theoretical Physics, Strada Costiera 11, 34151 Trieste, Italy — [3]Department of Physics and Astronomy Iowa State University Ames, Iowa 50011, USA — [4]Harvard University, 17 Oxford Street, Cambridge, MA 02138, USA

Electrons and holes in clean, charge-neutral graphene behave like a strongly coupled relativistic liquid. The thermo-electric transport properties of the interacting Dirac quasiparticles are rather special, being constrained by an emergent Lorentz covariance at hydrodynamic frequency scales. At small carrier density and high temperatures, graphene exhibits signatures of a quantum critical system with an inelastic scattering rate set only by temperature, a conductivity with a nearly universal value, solely due to electron-hole friction, and a very low viscosity. In this regime one finds pronounced deviations from standard Fermi liquid behavior. These results, obtained by Boltzmann transport theory at weak electron-electron coupling, are fully consistent with the predictions of relativistic hydrodynamics.

TT 1.7 Mon 12:00 H18

Hyperfine interaction and electron-spin decoherence in graphene and carbon nanotube quantum dots — •Jan Fischer[1], Bjoern Trauzettel[2], and Daniel Loss[1] — [1]Department of Physics, University of Basel, Klingelbergstrasse 82, 4056 Basel, Switzerland — [2]Institute of Theoretical Physics and Astrophysics, University of Würzburg, D-97074 Würzburg, Germany

We analytically calculate the nuclear-spin interactions of a single electron confined to a carbon nanotube or graphene quantum dot [1]. While the conduction-band states in graphene are p-type, the accordant states in a carbon nanotube are sp-hybridized due to curvature. This leads to an interesting interplay between isotropic and anisotropic hyperfine interactions. By using only analytical methods, we are able to show how the interaction strength depends on important physical parameters, such as curvature and isotope abundances. We show that for the investigated carbon structures, the ^{13}C hyperfine coupling strength is less than 1 μeV, and that the associated electron-spin decoherence time can be expected to be several tens of microseconds or longer, depending on the abundance of spin-carrying ^{13}C nuclei. Furthermore, we find that the hyperfine-induced Knight shift is highly anisotropic, both in graphene and in nanotubes of arbitrary chirality.

[1] J. Fischer, B. Trauzettel, D. Loss, Phys. Rev. B 80, 155401

(2009)

TT 1.8 Mon 12:15 H18

Spin transport in graphene with inhomogeneous spin-orbit coupling — •Dario Bercioux[1] and Alessandro De Martino[2] — [1]Freiburg Institute for Advanced Studies, Albert-Ludwigs-Universität, D-79104 Freiburg, Germany — [2]Institut für Theoretische Physik, Universität zu Köln, Zülpicher Straße 77, D-50937 Köln, Germany

Recent theoretical [1] and experimental [2] works have shown that spin-orbit couplings in graphene can play a relevant role. Motivated by these results, we address the problem of spin transport in graphene through spin-orbit nanostructures, *i.e.* regions of inhomogeneous spin-orbit coupling on the nanometer scale. In analogy with the case of usual two-dimensional electron gases, we discuss the phenomenon of spin-double refraction [3,4] and its consequences on the spin polarization. In particular we study the transmission properties of a single- and a double-interface between a normal region and a region with finite spin-orbit coupling, and analyze the polarization properties of these systems. In addition, for the case of the single interface, we consider the formation of bound states localized at the interface, analogous to the states occuring at the edges of graphene in the weak topological insulator regime discussed by Kane and Mele [5].

[1] D. Huertas-Hernando, *et al.*, Phys. Rev. Lett. **103**, 146801 (2009).
[2] A. Varykhalov, *et al.*, Phys. Rev. Lett. **101**, 157601 (2008).
[3] V. M. Ramaglia, *et al.*, Eur. Phys. J. B **36**, 365 (2003).
[4] V. M. Ramaglia, *et al.*, J. Phys.: Condens. Matter **16**, 9143 (2004).
[5] C. L. Kane and E. J. Mele, Phys. Rev. Lett. **95**, 226801 (2005).

TT 1.9 Mon 12:30 H18

Edge effects in quantum transport and quasiparticle spectra of graphene nanostructures — •Jürgen Wurm[1,2], Klaus Richter[1], and Inanç Adagideli[2] — [1]Institut für Theoretische Physik, Universität Regensburg, 93040 Regensburg — [2]Faculty of Engineering and Natural Sciences, Sabancı University, Orhanlı - Tuzla, 34956, Turkey

In this work, we focus on the spectral and transport properties of graphene nanostructures. In recent work, we studied the effects of edges on the transport and spectral properties of graphene quantum dots, as well as on the conductance of graphene nanoribbons numerically [1,2]. Some edges can lead to effective time reversal symmetry breaking, others are effective intervalley scatterers. In this work, we develop a theory that is capable of handling such effects in graphene nanostructures. We do this in two steps. First, we derive an exact expression for the Green function of a graphene flake, where each term in this expansion corresponds to the specific number of times the quasiparticle hits the edge. Second, we use the Green function to calculate: (i) the spectra for closed systems and (ii) the conductance of open systems. In particular, we focus on phase coherent effects, such as the weak localization correction to the average conductance, and the universal conductance fluctuations. Moreover, we show how the size of these effects depends on the edges.

[1] J. Wurm et al., Phys. Rev. Lett. **102**, 056806 (2009)
[2] J. Wurm et al., New J. Phys. **11**, 095022 (2009)

TT 1.10 Mon 12:45 H18

Charge transport in disordered superconductor-graphene junctions — •Georgo Metalidis[1], Dmitry Golubev[2], and Gerd Schön[1] — [1]Institut für Theoretische Festkörperphysik, Karlsruher Institut für Technologie, D-76131 Karlsruhe, Germany — [2]Institut für Nanotechnologie, Karlsruher Institut für Technologie, D-76021 Karlsruhe, Germany

We consider the charge transport through superconductor-graphene tunnel junctions, including the effect of disorder. Coherent scattering on elastic impurities in the graphene layer can give rise to multiple reflections at the graphene-superconductor interface, and can thereby increase the probability of Andreev reflection, leading to an enhancement of the subgap conductance above its classical value. Although the phenomenon is known already from heterostructures involving normal metals, we have studied how graphenes peculiar dispersion relation influences the effect.