TT 26: Transport: Graphene and Carbon Nanotubes

Time: Wednesday 14:00–19:00 Location: HSZ 03

Invited Talk TT 26.1 Wed 14:00 HSZ 03
Nanotube and Graphene ElectroMechanics — •Adrian Bachtold — CIN2 (CSIC-ICN) Barcelona, Campus UAB, Spain

Carbon nanotubes and graphene have attracted a lot of attentions as high-frequency mechanical resonators. For instance, nanotube resonator devices hold promise for ultralow mass detection or quantum electromechanical experiments. However, the detection of the mechanical vibrations remains very challenging. In this talk, I will present a novel detection method of the vibrations of nanotubes and graphene, which is based on atomic force microscopy. This method enables the detection of the resonances up to 3.1 GHz with subnanometer resolution in vibration amplitude. Importantly, it allows the imaging of the mode-shape for the first eigenmodes. I will also report on a new artificial nanofabricated motor in which one short nanotube moves relative to another coaxial nanotube. The motion is shown to be controlled by how the atoms are arranged within the two nanotubes. The motion is actuated by imposing a thermal gradient along the device, allowing for sub-nanometer displacements. This is, to our knowledge, the first experimental demonstration of displacive actuation at the nanoscale by means of a thermal gradient.

TT 26.2 Wed 14:30 HSZ 03
Quantum spin Hall state in gapless graphene? — •Martina Hentschel and Grigory Tkachov — MPI für Physik komplexer Systeme, Dresden

We demonstrate the possibility of a quantum spin Hall state in a two-dimensional gas of massless Dirac fermions as is realized in graphene [1]. To this end we use a generalized zigzag-confinement model that admits a spin-orbit interaction. At a certain critical strength the spin-orbit coupling induces a phase transition of the quantum-spin-Hall type. It is characterized by the existence of a novel type of edge states consisting of a Kramers pair of counter propagating modes with opposite spin orientations (i.e. exhibiting spontaneous quantum Hall effects of opposite signs). These edge states are capable of accumulating an integer spin. They exist without any excitation gap in the bulk, due to which our system stands out among other quantum spin Hall systems studied earlier [2-4]. We show that the local density of states is discontinuous at the transition and its energy dependence reflects the phase diagram of the system.

[1] G. Tkachov and M. Hentschel, arXiv: 0803.0713.
[2] C. L. Kane and E. J. Mele, Phys. Rev. Lett. **95**, 226801 (2005).
[3] B. A. Bernevig and S. C. Zhang, Phys. Rev. Lett. **96**, 106802 (2006).
[4] M. König, S. Wiedmann, C. Brüne, A. Roth, H. Buhmann, L. W. Molenkamp, X.-L. Qi, and S.-C. Zhang Science **318**, 766-770 (2007).

TT 26.3 Wed 14:45 HSZ 03
Transport properties of the graphene edge state — •Michael Wimmer, Inanc Adagideli, and Klaus Richter — Institut für Theoretische Physik, Universität Regensburg, 93040 Regensburg

A graphene edge in zigzag configuration supports a localized state, the graphene edge state. Despite being localized at the graphene boundary, recent numerical studies within the nearest-neighbor tight-binding model found that transport in the graphene edge state is influenced little by edge defects [1].

We investigate systematically the transport properties of the graphene edge state for corrections to the nearest-neighbor tight-binding model. In particular we find that the nearest-neighbor tight-binding model—the paradigm model of graphene—is not suitable for describing edge state transport, as exponentially small corrections (such as next-nearest neighbor hopping, see also Ref. [2]) alter the transport properties of the edge state fundamentally.

[1] F. Muñoz Rojas *et al.*, Phys. Rev. B **74**, 195417 (2006), L. Zârbo *et al.*, Europhys. Lett. 80, 47001 (2007).
[2] M. Wimmer *et al.*, Phys. Rev. Lett. **100**, 177207 (2008).

TT 26.4 Wed 15:00 HSZ 03
Exchange phenomena in transport across graphene armchair nanoribbon quantum dots — •Sonja Koller[1], Leonhard Mayrhofer[1,2], and Milena Grifoni[1] — [1]Universität Regensburg — [2]Fraunhofer IWM Freiburg

Taking into account interaction effects, we have investigated spectrum and transport properties of finite size graphene armchair nanoribbons (ACNRs). In wide ribbons, the long-ranged part of the Coulomb interaction dominates, yielding charging and spin-charge separation effects. For narrow ribbons, short-ranged processes become relevant. Those can involve not only two bulk electrons, but also one bulk electron and one electron localized in an edge state, which arises at both zig-zag ends of the stripe. In particular, this edge-bulk interaction strongly influences spectrum and transport properties of the system. In transport, the most prominent feature is the occurrence of a pronounced negative differential conductance for a completely symmetric, unpolarized setup. Further, we discuss the transport characteristics of ACNRs in magnetic field and with collinearly polarized contacts.

TT 26.5 Wed 15:15 HSZ 03
Time dependent transport in graphene nanosystems — •Viktor Krückl[1], Christoph Kreisbeck[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

In recent experiments the Quantum Hall Effect in graphene is measured for high magnetic fields leading to numerous different filling factors. In order to characterise these effects, we investigate the local density of states for the massless Dirac Hamiltonian in crossed electric and magnetic fields. We predict a unique substructure for each Landau level and present analytical expressions to describe their composition. For more complex setups we present an algorithm which solves the time dependent problem. The numerical data corresponds up to a very high accuracy to the aforementioned analytically solvable problem. Within this computational scheme also other phenomena like the Zitterbewegung can be studied.

15 min. break

TT 26.6 Wed 15:45 HSZ 03
Functional RG on graphene nanodisks — •Michael Kinza, Jutta Ortloff, and Carsten Honerkamp — Universität Würzburg, Institut für Theoretische Physik und Astrophysik

Graphene-nanodisks are nanometer-sized graphene structures with a closed edge. They are promising candidates for future nanoelectronic devices. In a tight-binding approximation trigonal zigzag nanodisks with size N (which is proportional to the number of edge atoms) have 2N-fold degenerated zero-energy-states. By using the functional renormalization group an effective Hamiltonian for these zero-energy-states is derived and used to explore spin-resolved transport through the nanodisks coupled to metallic electrodes in the coulomb blockade regime.

TT 26.7 Wed 16:00 HSZ 03
A theory of ballistic transport in disordered graphene — •Alexander Schuessler[1], Pavel Ostrovsky[1], Igor Gornyi[1], and Alexander Mirlin[1,2] — [1]Institut für Nanotechnologie, Forschungszentrum Karlsruhe, 76021 Karlsruhe, Germany — [2]Institut für Theorie der Kondensierten Materie, Universität Karlsruhe, 76128 Karlsruhe, Germany

We develop an analytic theory of ballistic electron transport in disordered graphene in a "short-and-wide"geometry [1]. Considering a sample of a large width W, we analyze the evolution of the conductance, the shot noise, and the full statistics of the charge transfer with increasing length L, both at the Dirac point and at a finite gate voltage. The transfer matrix approach combined with the disorder perturbation theory and the renormalization group is used. We also discuss the crossover to the diffusive regime and construct a "phase diagram" of various transport regimes in graphene. Our analytical results are in agreement with experimental observations [2,3].

[1] A. Schuessler et al., arXiv: 0809.3782.
[2] R. Danneau et al., Phys. Rev. Lett. **100**, 196802 (2008).
[3] L. DiCarlo et al., Phys. Rev. Lett. **100**, 156801 (2008).

TT 26.8 Wed 16:15 HSZ 03
Tomonaga-Luttinger liquid parameters of magnetic waveguides in graphene — •W. Häusler[1,2], A. De Martino[1,3], T. K. Ghosh[1,4], and R. Egger[1] — [1]Institut für Theoretis-