# TT 8: Postersession Transport: Graphene and Carbon Nanotubes

Time: Monday 13:00–16:45 Location: P1B

TT 8.1 Mon 13:00 P1B

**Dirac fermion quantization on graphene edges: Isospin-orbit coupling, zero modes and spontaneous valley polarization** — •Grigory Tkachov — Max Planck Institute for the Physics of Complex Systems, Dresden

The talk addresses boundary electronic properties of graphene with a complex edge structure of the armchair/zigzag/armchair type. It is shown that the finite zigzag region supports edge bound states with discrete equidistant spectrum obtained from the Green's function of the continuum Dirac equation [1]. The energy levels exhibit the coupling between the valley degree of freedom and the orbital quantum number, analogous to a spin-orbit interaction. The characteristic feature of the spectrum is the presence of a zero mode, the bound state of vanishing energy. It resides only in one of the graphene valleys, breaking spontaneously Kramers' symmetry of the edge states. This implies the spontaneous valley polarization characterized by the valley isospin $\pm 1/2$. The polarization is manifested by a zero-magnetic field anomaly in the local tunneling density of states, and is directly related to the local electric Hall conductivity.

[1] G. Tkachov, arXiv: 0811.2698.

TT 8.2 Mon 13:00 P1B

**Time dependent charge and spin transport in graphene nanoribbons** — •Claudia Gomes da Rocha, Lakshmi Sankaran, Jens Kunstmann, Luis E.F. Foa Torres, and Gianaurelio Cuniberti — Institute for Materials Science and Max Bergmann Center of Biomaterials, Dresden University of Technology, D-01062 Dresden, Germany

Interesting quantum phenomena can be revealed when low dimensional materials are subject to external fields. In our work we theoretically investigate how external fields influence the transport properties of graphene nanoribbons. We demonstrate that armchair-edge nanoribbons subject to a time-periodic gate potential show the so called quantum wagon-wheel effect, in which Fabry-Perot oscillations can be periodically suppressed or recovered as a function of the AC parameters[1]. For zigzag-edge nanoribbons, more intriguing phenomena take place due to the existence of edge states. Essentially, Fabry-Perot oscillations manifest in a limited range of bias and gate voltages and they cannot be totally recovered by tuning the AC gate. Furthermore, zigzag nanoribbons having a Klein edge are expected to yield spin-polarized bands when described by mean-field Hubbard Hamiltonian. Here we also show that the presence of a DC external gate in zigzag-edge systems suppresses the characteristic edge states. This leads to a transition from a completely spin-polarized semiconducting system to one which is non-magnetic and metallic.

[1] L. E. F. Foa Torres, and G. Cuniberti, cond-mat arXiv. 0807.4953

TT 8.3 Mon 13:00 P1B

**Ab-Initio Studies of Electronic and Transport Properties of Graphene Nanoribbons** — Uwe Treske[1,2], Frank Ortmann[1,2], •Björn Oetzel[1,2], Karsten Hannewald[1,2], and Friedhelm Bechstedt[1,2] — [1]Institut für Festkörpertheorie und -optik, Friedrich-Schiller-Universität Jena, Max-Wien-Platz 1, 07743 Jena, Germany — [2]European Theoretical Spectroscopy Facility, Friedrich-Schiller-Universität Jena, Max-Wien-Platz 1, 07743 Jena, Germany

We present ab-initio DFT calculations for Graphene Nanoribbons (GNRs). We focus our attention on the band structures and gap behavior versus ribbon widths for armchair and zigzag GNRs. Furthermore we study the influence of spin polarization and spin ordering on the band structure and the magnetic behavior of zigzag GNRs. The transmission functions are calculated in the Landauer-Büttiker formalism using the number-of-states approach similarities and differences of quantum transport are discussed for several groups of armchair and zigzag GNRs.

TT 8.4 Mon 13:00 P1B

**Microwave graphene nano-transistors** — Andreas Betz, •Emiliano Pallecchi, Julien Chaste, Takis Kontos, Gwendal Fève, Jean-Marc Berroir, and Bernard Plaçais — Laboratoire Pierre Aigrain, Ecole Normale Supérieure, 24 rue Lhomond, 75005 Paris, France.

We report on microwave characterization of graphene nano-transistors. The samples consist of top-gated graphene flakes connected to source and drain electrodes. We performed room temperature transmission measurements using an RF probe station from which we can access both the transconductance and the gate capacitance. We observed mobility as large as 7800 $cm^2/Vs$, while the maximum transconductance was 2.5 mS/$\mu$m at DC and 0.5 mS/$\mu$m at gigahertz frequency. The gate capacitance at the gate voltage corresponding to the maximum transconductance is about 0.9 fF (100 nm gate length). Our measurements show that graphene nano-transistors are characterized by a large transit frequency $f_T = g_m/2\pi C_g$ on the order of 1 THz for a gate length of 100 nm (best device measured). We finally discuss their possible sensitivity as fast charge detectors.

TT 8.5 Mon 13:00 P1B

**Trans-conductance of back-gated and top-gated multi-walled carbon nanotube field-effect transistors** — •asaf avnon[1] and jaako leppäniemi[2] — [1]Freie universität Berlin,Berlin,Germany — [2]University of Jyväskylä, Jyväskylä, Finland

In this study we have mapped the gate response of thin multi-walled carbon nanotubes (MWNT)-based field-effect transistors (FET). We observe advancing hysteresis in gate-response of back-gated MWCNT FETs and retarding hysteresis in top- gated MWCNT FETs. The hysteresis could be a result of mobile charge carriers trapped in the insulator as it diminishes at low temperatures both in devices with a top-gate and a back-gate. The hysteresis in the gate response could be utilized in future memory applications.

TT 8.6 Mon 13:00 P1B

**Scattering dynamics in intra-nanotube quantum dots** — •Dario Bercioux[1], Gilles Buchs[2,3], Pascal Ruffieux[3], Pierangelo Gröning[3], Hermann Grabert[1], and Oliver Gröning[3] — [1]Physikalisches Institut and Freiburg Institute for Advanced Studies, Albert-Ludwigs-Universität, D-79104 Freiburg, Germany — [2]Kavli Institute of Nanoscience, Delft University of Technology, P.O. Box 5046, 2600 GA Delft, The Netherlands — [3]EMPA Swiss Federal Laboratories for Materials, Testing and Research, nanotech@surfaces, Feuerwerkerstrasse 39, CH-3602 Thun, Switzerland

Room temperature active intratube quantum dots in metallic single-walled carbon nanotubes are realized by means of low dose medium energy $Ar^+$ irradiation. With this low invasive method defect-induced confinement regions of the order of, or shorter than, 10 nm are produced which are demonstrated to lead to particle-in-a-box-like states with energy separations up to 200 meV, hardly achievable with nowadays' lithography processes. Fourier-transform scanning tunneling spectroscopy compared to results of a Fabry-Pérot electron resonator model yields clear signatures for inter- and intra-valley scattering of electrons confined between consecutive defects. [1] G. Buchs *et al.* arXiv:0812.3883v1 [cond-mat.mes-hall]

TT 8.7 Mon 13:00 P1B

**Disorder effects in graphene: A local distribution approach** — •Jens Schleede, Gerald Schubert, and Holger Fehske — Institute for Physics, Ernst-Moritz-Arndt Universität Greifswald, Germany

We present a study of different models of local disorder in mono- and bilayer graphene and graphene nanoribbons. In particular, we investigate the Anderson model on a two-dimensional honeycomb lattice and determine the probability distribution of the local density of states using a highly efficient kernel polynomial method. Supplemented by a careful finite-size scaling analysis, this quantity allows for distinguishing extended from localised states. Our findings are corroborated by the evaluation of the time evolution of an initially localised wave packet, which is based on Chebyshev expansion technique. While our results for the 2D infinite systems indicate complete localisation for arbitrary weak Anderson disorder, the finite system sizes of graphene strips (nanoribbons) induce another length scale to the problem. So despite the localisation on large length scales, finite 2D devices may show metallic behaviour for weak disorder. Moreover we show that the ground state properties of graphene are largely affected by the geometric pattern and disorder at their edges.

TT 8.8 Mon 13:00 P1B

**Towards entanglement in carbon nanotube based double quantum dots** — •Lorenz Herrmann[1,2], Fabien Portier[3], Patrice Roche[3], Christian Glattli[2,3], Takis Kontos[2], and Christoph Strunk[1] — [1]Inst. for Exp. and Appl. Physics, Univ. Regensburg, Germany — [2]Lab. Pierre Aigrain, ENS Paris, France — [3]SPEC, CEA Saclay, France

We investigate carbon nanotube-based double quantum dots with two normal (Ti/Au) and one central superconducting (Al) contact. The characterization of the devices via the normal contacts reveals that the superconducting electrode splits the carbon nanotube into two coupled quantum dots. As an additional feature compared to ordinary double dot systems, we can use our middle electrode (Al) not only to split the nanotube into two dots, but also to inject Cooper pairs into our double dot system. By sending a current from the superconducting to the normal contacts it is possible to divide the current into the two output branches. Since Coulomb charging energy prevents double occupation of one dot, the splitting of a pair into the two different normal contacts is favoured if the gate configuration is such that Coulomb interaction between the dots is strong. That is the case at the so called triple points of the initial stability diagram of the double dot. The splitting of the Cooper pairs thus occurs via a co-tunneling process. We find an enhanced subgap conductance at the triple points, which possibly reflects correlated Andreev processes.