TT 10: Nanotubes and Nanoribbons

Time: Monday 11:30–13:00 Location: HSZ 204

TT 10.1 Mon 11:30 HSZ 204

Correlated or coherent - Kondo-like features in carbon nanotubes with transparent contacts — •Magdalena Margańska[1], Wei Yang[2], Carles Urgell[2], Sergio Lucio de Bonis[2], Milena Grifoni[1], and Adrian Bachtold[2] — [1]Institute for Theoretical Physics, University of Regensburg, 93053 Regensburg, Germany — [2]ICFO - Institut De Ciencies Fotoniques, The Barcelona Institute of Science and Technology, 08860 Castelldefels (Barcelona), Spain

We report on electron transport measurements in high-quality carbon nanotube devices with a total transmission of about 1.5 e^2/h. At high temperatures the linear conductance exhibits moderate oscillations as a function of the gate voltage around an average value of the order the quantum of conductance. Upon decreasing temperature, we observe an intriguing fourfold increase in the period of the oscillations accompanied by an enhancement in their amplitude. This temperature dependence is rather unusual. On the one hand, the high temperature oscillations are suggestive of charging effects in an open carbon nanotube quantum dot. On the other hand the low temperature transport characteristics is reminiscent of single-particle Fabry-Pérot interference in a carbon nanotube waveguide. We reconcile these observations by attributing the four-fold increase to the interplay of resonant tunneling, interaction and quantum fluctuations, leading to an SU(4) Kondo-like enhancement in open quantum dots systems. Our work provides a comprehensive phenomenology of transport in nanotubes when both interference and interaction are involved.

TT 10.2 Mon 11:45 HSZ 204

Transport properties and Thermoelectric figure of Merit of CNT peapods — •Alvaro Rodriguez[1,2], Arezoo Dianat[1], Rafael Gutierrez[1], Leonardo Medrano[3], and Gianaurelio Cuniberti[1] — [1]Institute for Materials Science and Max Bergmann Center of Biomaterials, Tu Dresden, 01062 Dresden, Germany. — [2]Max Planck Institute for Complex Systems, 01187 Dresden, Germany. — [3]Physics and Materials Science Research Unit, University of Luxembourg, L-1511 Luxembourg.

The ability to control the electrical and thermal response in nanoscale systems represents a fundamental challenge towards the optimization of the thermoelectric figure of merit. Recent experimental studies have addressed the electrical and thermal conductivity of so called carbon nanotube (CNT) peapods, where C_{60} or larger fullerenes are encapsulated in carbon nanotubes. The reported results showed some discrepancies regarding the transport properties, suggesting either a positive or a negative effect of the fullerenes. In our computational study, we address this issue by combining electronic and vibrational structure calculations with quantum transport methods based on Green's functions to investigate the electrical, thermal and thermoelectric response of C_{60}@(8,8) CNT peapod system. We were able to calibrate the contribution of local structural deformations of the CNT surface due to the fullerene insertion; especially, we found a considerable suppression of thermal transport at low frequencies, similar to the effect found using silicon nanopillars in other nanostructures. We discuss the changes in the thermoelectric figure of merit when comparing to a pure CNT.

TT 10.3 Mon 12:00 HSZ 204

Transport spectroscopy of MoS_2 nanotubes — •Wolfgang Möckel[1], Simon Reinhardt[1], Luka Pirker[2], Christian Bäuml[1], Maja Remškar[2], and Andreas K. Hüttel[1] — [1]Institute for Experimental and Applied Physics, University of Regensburg, 93040 Regensburg, Germany — [2]Solid State Physics Department, Institut Jožef Stefan, Ljubljana, Slovenia

While synthesis procedures for nanotubes based on layered materials other than graphene are well-known, their transport properties are so far largely unexplored. Here, we introduce transition metal dichalcogenide (TMDC) nanotubes as a new material platform for quantum dots. We present results on optimized nanotube synthesis and device fabrication, and demonstrate low-temperature transport spectroscopy measurements on quantum dots lithographically defined in multiwall MoS_2 nanotubes. First results show clear Coulomb blockade, with charging energies of $\sim 1\,\text{meV}$ and discrete conductance resonances in single electron tunneling.[1] Ongoing work targets improvement of the contact properties, the reduction of charge noise, as well as spectroscopy in magnetic fields. — [1]S. Reinhardt *et al.*, Phys. Stat. Sol. RRL **13**, 1900251 (2019).

TT 10.4 Mon 12:15 HSZ 204

Spin-Orbit Coupling modulations near edges: emergence of massive edge states — •Tineke L. van den Berg[1], M. Reyes Calvo[2], Alessandro De Martino[3], and Dario Bercioux[1,4] — [1]Donostia International Physics Center (DIPC), Paseo Manuel de Lardizabal 4, E-20018 San Sebastián, Spain — [2]Departamento de Fisica Aplicada, Universidad de Alicante, 03690 Alicante, Spain — [3]Department of Mathematics, City, University of London, London EC1V 0HB, United Kingdom — [4]IKERBASQUE, Basque Foundation of Science, E-48011 Bilbao, Spain

In topological two-dimensional systems, gap modification near system edges, can lead to the appearance of massive edge states, as we have shown in earlier work [1]. In graphene, it is the Kane-Mele Spin-Orbit Coupling (SOC) that leads to the opening of a topological gap [2]. Here we will deal with systems subject to inhomogeneous SOC. In zigzag nanoribbons, smooth spatial modification of SOC near the edges results in in-gap massive edge states at the K and K' points. In armchair nanoribbons, such massive states appear at the Γ point. We analyse the properties of these states, and propose how to measure and tune them [3].

[1] C. L. Kane and E. J. Mele, PRL. 95, 226801 (2005).
[2] T. L. van den Berg, M. R. Calvo and D. Bercioux, arXiv:1911.09363.
[3] T. L. van den Berg *et al. in preparation*

TT 10.5 Mon 12:30 HSZ 204

Correlated Topological States in Graphene Nanoribbon Heterostructures — •Jan-Philip Joost[1], Antti-Pekka Jauho[2], and Michael Bonitz[1] — [1]CAU Kiel, Germany — [2]CNG, DTU Physics, Kongens Lyngby, Denmark

Finite graphene nanoribbon (GNR) heterostructures host intriguing topological in-gap states [1]. These states may be localized either at the bulk edges or at the ends of the structure. Here we show that correlation effects (not included in previous density functional simulations) play a key role in these systems: they result in increased magnetic moments at the ribbon edges accompanied by a significant energy renormalization of the topological end states, even in the presence of a metallic substrate [2]. We present simulations of 7-9-AGNRs based on a Green functions method with GW self-energy applied to an effective Hubbard model. Our computed results for the differential conductance are in excellent agreement with experimental observations [3]. Furthermore, we discover a striking, novel mechanism that causes an energy splitting of the nonzero-energy topological end states for a weakly screened system. We predict that similar effects should be observable in other GNR heterostructures as well.

[1] T. Cao et al., Phys. Rev. Lett. 119, 076401 (2017)
[2] J.-P. Joost, A.-P. Jauho, M. Bonitz, Nano Letters (2019), DOI:10.1021/acs.nanolett.9b04075
[3] D. J. Rizzo et al., Nature 560, 204-208 (2018)

TT 10.6 Mon 12:45 HSZ 204

Four-terminal graphene-based nanostructures for electron quantum optical stups — Sofia Sanz[1], Pedro Brandimarte[1], Daniel Sánchez-Portal[2], •Géza Giedke[1,3], and Thomas Frederiksen[1,3] — [1]Donostia International Physics Center (DIPC), 20018 San Sebastián, Spain — [2]Centro de Física de Materiales (CFM), CSIC-UPV/EHU, 20018 San Sebastián, Spain — [3]IKERBASQUE, Basque Foundation for Science, 48011 Bilbao, Spain

Graphene nanoribbons (GNRs) an attractive basis for coherent electron transport. We study configurations that provide functionalities for simple "electron quantum optics" setups.

A central building block of such setups is the four-terminal device formed by two GNRs crossing each other at 60 degrees.

Using a tight-binding approximation and the Green's function formalism we analyze the transmission amplitudes between the four arms for low-energy electrons. Studying different widths, stackings and GNR edge topologies, we identify promising settings with suppressed back-scattering and those realizing functionalities such a 50:50 beam splitting or full transfer between the stacked ribbons. Applications for GNR-based interferometers are discussed.