TT 26: Nanotubes and Nanoribbons

Time: Tuesday 9:30–11:30 Location: H 3007

TT 26.1 Tue 9:30 H 3007

Electronic transport in bent carbon nanotubes — Eric Kleinherbers[1,2], Thomas Stegmann[3], and •Nikodem Szpak[1] — [1]Faculty of Physics and CENIDE, University of Duisburg-Essen, 47057 Duisburg, Germany — [2]Department of Physics and Astronomy, University of California, Los Angeles, California 90095, USA — [3]Instituto de Ciencias Físicas, Universidad Nacional Autónoma de México, 62210 Cuernavaca, Mexico

We study the electronic transport through uniformly bent carbon nanotubes. For this purpose, we describe the nanotube with the tight-binding model and calculate the local current flow by employing nonequilibrium Green's functions (NEGF) in the Keldysh formalism. In addition, we describe the low-energy excitations using an effective Dirac equation in curved space with a strain-induced pseudomagnetic field, which can be solved analytically for the torus geometry in terms of the Mathieu functions. We obtain a perfect quantitative agreement with the NEGF results. For nanotubes with an armchair edge, already a weak bending of 1

[1] E. Kleinherbers, T. Stegmann, N. Szpak, Phys. Rev. B 107 (2023) 195424

TT 26.2 Tue 9:45 H 3007

Microwave generation and vortex jets in superconductor nanotubes — •Vladimir M. Fomin[1,2], Oleksandr V. Dobrovolskiy[3], and Igor Bogush[1,2] — [1]Leibniz IFW Dresden, IET, 01069 Dresden, Germany — [2]Moldova State University, 2009 Chişinău, Republic of Moldova — [3]University of Vienna, Nanomagnetism and Magnonics, Superconductivity and Spintronics Laboratory, 1090 Vienna, Austria

The dynamics of superconducting (Abrikosov) vortices determine the resistive response of superconductors. In pinning-free planar thin films, the penetration and motion of vortices are controlled by edge defects, leading to such arrangements as vortex chains, vortex jets, and phase-slip regimes. Relying upon the time-dependent Ginzburg-Landau equation, we predict that these vortex patterns should appear in superconductor open nanotubes even without edge defects, due to the inhomogeneity of the normal magnetic induction component. Distinct from planar thin films, the vortex jets are constrained within the half-tubes and correlate strongly between them. Due to a stronger confinement of single vortex chains in tubes of small radii, we reveal jumps in the average voltage and frequency of microwave generation, which occur when the number of fluxons moving in the half-tubes increases by one. We also realize non-symmetric vortex jets and chains by tilting the magnetic field in the plane perpendicular to the nanotube axis, with a jet-to-chain transition unseen for planar constrictions. In all, our findings are essential for novel 3D superconductor devices, which can operate in few- and multi-fluxon regimes.

TT 26.3 Tue 10:00 H 3007

Superconducting vortex diode effect in open nanotubes — Rodrigo H. de Bragança[1,2], Igor Bogush[2,3], and •Vladimir M. Fomin[2,3] — [1]Universidade Federal de Pernambuco, Departamento de Física, Centro de Ciências Exatas e da Natureza, 50740-560 Recife, Brasil — [2]Leibniz IFW Dresden, IET, 01069 Dresden, Germany — [3]Moldova State University, 2009 Chişinău, Republic of Moldova

Due to advances in high-tech roll-up technology and direct-write nanoprinting using focused electron and ion beams, novel complex-geometry 3D nanoarchitectures have been fabricated that provide new tools for controlling vortex motion. We focus on the vortex ratchet effect due to periodic asymmetric pinning potentials, which bias or rectify the vortex motion, in a rolled-up open Nb nanotube of a small thickness with a paraxial slit. It is demonstrated that the nontrivial topology of the screening currents in the open nanotube together with asymmetric pinning centers give rise to a superconducting vortex diode effect. Numerical simulations have provided the current–voltage characteristics and the efficiency of the superconducting diode effect. Vortices move over paths along two narrow channels, where the normal component of the magnetic field is close to maximal. We attribute the high efficiency of the diode effect in the system to the asymmetric pinning centers placed in the narrow channels, where the vortices move. In the system under analysis, we obtain a twice higher resistance for the transport current in one direction than in another one. These results shed light on the perspectives of application of 3D superconducting nanoarchitectures by virtue of the superconducting diode effect.

TT 26.4 Tue 10:15 H 3007

Superfluidity without superfluid: frictionless He-transport through a carbon nanotube — •Alberto Ambrosetti, Pier Luigi Silvestrelli, and Luca Salasnich — Università degli Studi di Padova (Italy)

In a conventional superfluid, such as ^{4}He or dilute atomic-gases at very low temperatures, a mesoscopic particle can freely move, experiencing no friction. According to Landau's superfluidity criterion, the quasi-linear collective excitation spectrum of the superfluid forbids quantum scattering between the superfluid and the moving mesoscopic particle, below a critical velocity. Here we predict frictionless-motion also in the absence of conventional superfluids, namely when a He atom flows inside a narrow carbon nanotube (CNT). Due to the quasi-linear spectrum of its collective plasmon and phonon modes, the CNT represents a solid analog of the superfluid medium, and admits extension of Landau's criterion of superfluidity. The superfluidity mechanism accordingly acquires broader generality, and is shown to persist up to much higher temperatures.

TT 26.5 Tue 10:30 H 3007

Magnetotransport in iron-filled nanotubes: learning about the properties of iron nanoparticle chains — Subhadeep Datta[1], •Magdalena Marganska[2], Luca Magazzu[2], and Milena Grifoni[2] — [1]School of Physical Sciences, Indian Association for the Cultivation of Science, Kolkata, India — [2]Institute for Theoretical Physics, University of Regensburg, 93053 Regensburg, Germany

Carbon nanotubes, with their hollow cores, are often used to encapsulate smaller molecules and nanoparticles. The properties of the smaller system can then be studied through their influence on the carbon nanotube behaviour. We present the results of an experiment measuring magnetotransport in quantum dots created from carbon nanotubes filled with iron/iron oxide nanoparticles. We observe the signatures of the magneto-Coulomb effect and hybridization between the electronic states of iron and of the nanotube dependent on the gate voltage. From the hysteretic behaviour of the conductance we extract the possible magnetization curves of the iron nanoparticles, identifying the ferromagnetic nature of their interactions.

TT 26.6 Tue 10:45 H 3007

Ultrafast Dynamics of Laser-Excited Topological Edge States in Graphene Nanoribbon Heterostructures — •Jan-Philip Joost and Michael Bonitz — Kiel University, Institute for Theoretical Physics and Astrophysics, 24098 Kiel, Germany

The electromagnetic properties of finite graphene nanoribbon (GNR) heterostructures are strongly affected by localized topological edge states [1].Recently, we showed for 7-9-armchair-GNRs that the increased electronic correlations of these states results 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]. Here, we improve the description of the system by including long-range Coulomb interactions within the Pariser–Parr–Pople Model. We study the ultrafast electron response in a freestanding unit cell of the 7-9-armchair-GNR following a laser excitation by employing our newly developed dynamically screened ladder (DSL) approximation within the G1–G2 scheme [3], which goes well beyond the *GW* description by including strong coupling effects. We find that the localized edge states play a major role in the ultrafast electron dynamics within the first 30fs after the laser interaction.

[1] J.-P. Joost et al., Nano Lett. **19** (2019) 9045
[2] D. J. Rizzo et al., Nature **560** (2018) 204
[3] J.-P. Joost et al., Phys. Rev. B **105** (2022) 165155

TT 26.7 Tue 11:00 H 3007

Ionic liquid gating of MoS_2 nanotubes and ribbons — •Konstantin D. Schneider[1], Robin T. K. Schock[1], Stefan Obloh[1], Matthias Kronseder[1], Matjaž Malok[2], 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, Institute Jožef Stefan, 1000 Ljubljana, Slovenia

Due to its intrinsic layered, quasi-two dimensional nature the semiconductor MoS_2 is at the center of many research efforts. While its optical parameters and semiconducting characteristics are the main focus of research, previous work has also shown that MoS_2 exhibits superconductivity when increasing its charge density by heavily doping the MoS_2 surface using an ionic liquid gate [1]. Here we present our efforts to reach superconductivity in MoS_2 nanotubes and -ribbons, the intrinsically one-dimensional variants of this material. Our nanotubes are grown via a chemical transport reaction, yielding diameters down to 7 nm and lengths up to several millimeters. For device definition, we utilize fabrication methods previously developed to create MoS_2 quantum dots [2]. To maximise the contact area of MoS_2 and the ionic dopant, the nanotubes are suspended by transferring them onto predefined contacts. DEME-TFSI is then applied to the chip prior to cooldown.

[1] T. Ye *et al.*, Science **338** (2012) 1193
[2] R. T. K. Schock *et al.*, Adv. Mater. **35** (2023) 2209333

TT 26.8 Tue 11:15 H 3007

Ab-initio study of electromigration forces on atoms on graphene nanoribbons — •Susanne Leitherer[1], Mads Brandbyge[2], and Gemma C. Solomon[1,3] — [1]Nano-Science Center and Department of Chemistry, Copenhagen University,Denmark — [2]Department of Physics, Technical University of Denmark,Denmark — [3]NNF Quantum Computing Programme, Niels Bohr Institute, University of Copenhagen, Denmark

In this contribution, we study the electromigration of atoms on 2D armchair graphene nanoribbons, as investigated in recent scanning probe experiments [1], employing first principles electronic structure and transport calculations [2]. Our findings show that the electromigration forces on the adatoms are related to the induced charges in the adsorbate-surface bonds rather than only to the induced atomic charges [3]. A left/right effective bond order can be used to predict the force direction. Focusing in particular on 3d transition metal atoms, we show how a simple model of a metal atom on benzene can explain the forces in an inorganic chemistry picture. Our study demonstrates that models including the ligand field of the atoms might provide a better understanding of adsorbate migration on 2D surfaces under non-equilibrium conditions.

[1] T. Preis et al., Nano Lett. 21 (2021) 8794
[2] N. Papior et al., Comput. Phys. Commun. 212 (2017) 8
[3] S.Leitherer et al., JACS-Au (2023, accepted)