HL 7: (Quantum) Transport Properties

Time: Monday 15:00–18:00 Location: H31

HL 7.1 Mon 15:00 H31

A new Time-Domain Approach for Linear Responses and Electrical Conductivity — •Michel Panhans[1,2] and Frank Ortmann[1,2] — [1]Department of Chemistry, TU München — [2]Center for Advancing Electronics Dresden, TU Dresden

Linear-response theory is a powerful theoretical framework to investigate, e.g., electrical and magnetic transport and to compare theory with experiments. Many intriguing quantum-transport phenomena such as quantum Hall effects, spin Hall effects, and quantum spin Hall effects have been derived within this framework. Beyond the general theory, strong efforts have been spent in the last decade to develop efficient and accurate computational methods to calculate charge transport in condensed matter. [1] In our recent work, we present a new time-domain approach to calculate arbitrary linear responses, which is based on a decomposition of the general Kubo formula into time-symmetric and time-antisymmetric parts. [2] The new algorithm is at least 1000 times faster compared to former time evolution schemes. [3] As a showcase, we have investigated the quantum anomalous Hall effect of the disordered Haldane model, where the quantum dynamics of the topological state have been analyzed. The proposed theory and the computational method provide a promising route to access transport phemomena in complpex and topological systems.

[1] Z. Fan et al., Physics Reports, 903, 1-69 (2021)

[2] M. Panhans and F. Ortmann, Phys. Rev. Lett. 127, 016601 (2021)

[3] F. Ortmann et al., Phys. Rev. B 91, 165117 (2015)

HL 7.2 Mon 15:15 H31

Anomalous photo-Nernst currents in $HfTe_5$ — •Waldemar Schmunk, Maanwinder Singh, Alexander Holleitner, and Christoph Kastl — Walter Schottky Institut

Recently, strong evidence of a quasi-quantized 3D quantum Hall effect in non-magnetic semimetals $HfTe_5$ and $ZrTe_5$ has been reported by various groups. Plateau-like features in the Hall conductivity of $HfTe_5$ and $ZrTe_5$ point towards unconventional Hall physics in these 3D semimetals. Additionally, in high-density $HfTe_5$ crystals, an anomalous, but non-hysteretic, Hall conductivity has been reported as well, which points to a non-zero Berry curvature. Here, we present photocurrent measurements of thin $HfTe_5$ films in an external magnetic field. We find a localized edge photo response with opposite polarity at opposite edges. We interpret these edge photocurrents in terms of an anomalous Nernst current arising from the local excitation, the symmetry breaking at the edges, and the anomalous Hall conductivity. Such local photocurrents open the possibility to image anomalous Hall responses and possible related edge state physics in layered quantum materials.

HL 7.3 Mon 15:30 H31

Aharonov-Bohm oscillations and phase-coherence analysis in selectivly grown topological-insulator rings — •Gerrit Behner, Dennis Heffels, Jonas Kölzer, Kristoff Moors, Abdur Rehman Jalil, Erik Zimmermann, Gregor Mussler, Detlev Grützmacher, Hans Lüth, and Thomas Schäpers — Peter Grünberg Institut (PGI-9), Forschungszentrum Jülich, 52425 Jülich, Germany

The study of quantum-interference effects in 3D topological insulators is crucial for understanding their transport properties. We present low-temperature magneto-transport measurements on selectively-grown Sb_2Te_3 ring structures. Pronounced Aharonov-Bohm oscillations in the conductance are observed with a major contribution of surface-state transport. The surface contributions are determined from magnetotransport under the application of an in-plane magnetic field. Furthermore we determine the phase-coherence length by analysing universal conductance fluctuations. Finally, we perform quantum transport simulations based on tight-binding calculations using KWANT. The simulations allow us to reproduce the predominant features of the experimental data and further deepen the understanding of the underlying physical effects.

HL 7.4 Mon 15:45 H31

Tunneling spectroscopy simulations of topological insulator (TI) nanoribbons — •Dennis Heffels[1], Declan Burke[2], Malcolm R. Connolly[2], Peter Schüffelgen[1], Kristof Moors[1], and Detlev Grützmacher[1] — [1]PGI-9, FZ Jülich — [2]IC London

TI nanoribbons with proximity-induced superconductivity have been proposed as a possible platform for the realization of Majorana bound states (MBS). Attempts to detect these MBS have received much attention in solid-state physics in recent years. A major goal is to exploit their unusual non-Abelian statistics for topologically protected quantum computing. A very common method for the detection of MBS is tunneling spectroscopy. Implementing this experimental scheme with TI nanoribbons is very challenging, due to stringent requirements on the interfaces of the required heterostructure. Similar experiments on semiconductor nanowires have shown that careful interpretation of the measured data is of prime importance. Here, we present simulations that are tailored to support such tunneling spectroscopy experiments on TI nanoribbons that are proximitized via the top surface with a superconductor. We show that a 3D simulation of the TI-based tunnel junction device is essential to properly describe the proximity effect and disorder, which plays a crucial role. Interestingly, the absence or presence of a zero-bias conductance peak does not always reveal whether the system is in the trivial or the topological regime. We obtain a phase diagram of subgap features in the tunneling conductance as a function of magnetic field and Fermi level.

HL 7.5 Mon 16:00 H31

Transport in high mobility HgTe heterostructures — •Michael Kick, Lena Fürst, Johannes Kleinlein, Saquib Shamim, Hartmut Buhmann, and Laurens W. Mohlenkamp — Experimentelle Physik III, Physikalisches Institut, Universität Würzburg, Am Hubland, 97074

The Fractional Quantum Hall Effect (FQHE) has not yet been observed in the material system of HgTe. Due to recent progress in MBE growth, routinely charge carrier mobilities of HgTe heterostructures of over $\mu > 1 \cdot 10^6\,\mathrm{cm}^2/\mathrm{Vs}$ are obtained which is in the same order of magnitude as in the first reported experimental observation of the FQHE in GaAs/GaAlAs heterostructures. This opens up new prospects for transport investigations into the long time still open question of fractional states in this material system.

In 2-dimensional HgTe quantum wells, transport measurements show well pronounced quantum Hall plateaus for all filling factors, but no indication of any fractional state. High magnetic field measurements show a prolonged $\nu = 1$ plateau and a transition to an insulating state. Intriguingly, the $\nu = 1$ plateau exhibits a transition to an insulating state for filling factor $\nu = 1/2$.

Another possibility to observe the FQHE in HgTe is provided by the 2D surface states of a 3D topological insulator. High mobility layers, $\mu > 2 \cdot 10^6\,\mathrm{cm}^2/\mathrm{Vs}$, of tensil strained HgTe are subject of extensive magneto-transport investigations. First results reveal so far unresolved features predicted by recent band structure calculations, while the search for FQHE states is still on.

30 min. break

HL 7.6 Mon 16:45 H31

Structure-imposed electronic topology in cove-edged graphene nanoribbons — •Florian Arnold[1], Tsai-Jung Liu[1], Agnieszka Kuc[2], and Thomas Heine[1,2,3] — [1]Technische Universität Dresden, Dresden, Germany — [2]HZDR, Leipzig, Germany — [3]Yonsei University, Seoul, Republic of Korea

Cove-edged zigzag graphene nanoribbons (ZGNR-C) take their name from a regular pattern of coves which is formed by removing one terminal CH group per length unit on each zigzag edge. Based on three structural parameters that unambiguously characterize the atomistic structure of ZGNR-C, we present a scheme that classifies their electronic state, i.e., if they are metallic, topological insulators or trivial semiconductors, for all possible widths N, unit lengths a and cove position offsets at both edges b, thus showing the direct structure-electronic structure relation. We further present an empirical formula to estimate the band gap of the semiconducting ribbons from N, a, and b. Finally, we show possible ribbon terminations, which should give guidance for future synthetic efforts to realize new topological ZGNR-C with large band gap and to realize topologically protected edge states in these systems.

HL 7.7 Mon 17:00 H31

Temperature and magnetic field-dependent noise measurements in GaAs/AlGaAs quantum rings — •Birkan Düzel[1], Olivio Chiatti[1], Sven S. Buchholz[1], Andreas D. Wieck[2], Dirk Reuter[3], and Saskia F. Fischer[1] — [1]Novel Materials Group, Humboldt-Universität zu Berlin, 10099 Berlin, Germany — [2]Angewandte Festkörperphysik, Ruhr-Universität Bochum, 44780 Bochum, Germany — [3]Optoelektronische Materialien und Bauelemente, Universität Paderborn, 33098 Paderborn, Germany

Nanostructured materials offer a way to investigate phase-coherent transport of electrons and the resulting interference effects in systems. Measurements of the white noise have been used to determine system properties such as the elctron temperature T_e. Recently noise measurements in quantum ring structures have revealed white noise exceeding the expected thermal noise [1].

This work investigates the dependence of the excess noise in quantum rings on the bath temperature and applied magnetic field. Noise measurements in Al_xGa_xAs/GaAs-based etched quantum rings are performed in equlibrium with bath temperatures ranging from 15 mK to 4.2 K and magnetic fields ranging from -50 mT to 50 mT. Additionally, magnetotransport measurements are performed at 1 K with magnetic fields ranging from 0 T to 12 T.

[1] C. Riha *et al.*, Appl. Phys. Lett. **117**, 063102 (2020).

HL 7.8 Mon 17:15 H31

Coplanar waveguides for electronic measurements at terahertz frequencies — •Sergey Lavrentyev[1], Johannes Gröbmeyer[1], Gerhard Huber[2], and Alexander Holleitner[1] — [1]Walter Schottky Institut and Physics Department, TU Munich — [2]Walther-Meißner-Institut and Physics Department, TU Munich

We explore the usability of gold coplanar waveguides on a sapphire substrate as contacts for electronic transport measurements on 2D and topological materials in the terahertz regime. Our simulations reveal different modes with low attenuation. For the coplanar waveguide, we find the lowest attenuation in even modes compared to the predominance of odd modes in coplanar strip geometries. Moreover, our results show a frequency dependent behavior of the complex refractive index of the modes at sub-millimeter wavelengths. We find that gold coplanar waveguides are well suited for electronic measurements at terahertz frequencies.

HL 7.9 Mon 17:30 H31

Influence of fixed scatterers of various sizes and densities on the giant negative magnetoresistance in two dimensional electron gases. — •Janus Lammert[1], Beate Horn-Cosfeld[1], Jakob Schluck[1], Mihai Cerchez[1], Thomas Heinzel[1], Klaus Pierz[2], Hans Werner Schumacher[2], and Dominique Mailly[3] — [1]Institut für Experimentelle Physik der kondensierten Materie, Heinrich-Heine-Universität, Universitätsstraße 1, 40225 Düsseldorf, Germany — [2]Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig, Germany — [3]CNRS, Univ. Paris-Sud, Université Paris-Saclay, C2N Marcoussis, 91460 Marcoussis, France

The giant negative magnetoresistance (GNMR) in a 2DEG is studied through the effects produced by artificial scatterers (Lorentz arrays [1]) with varying scatterer density. The influence of the different types and ratios of scattering mechanisms shed light on both the temperature independent and the temperature dependent parts of the GNMR [2]. The effect of scattering on the shape and amplitude of the GNMR will be discussed. [1] H. A. Lorentz, Proc. R. Acad. Sci. Amsterdam 7, 438, 1905, [2] B. Horn-Cosfeld et al. Phys. Rev. B 104, 045306, 2021

HL 7.10 Mon 17:45 H31

First-principles calculations of temperature-dependent transport in semiconductors — Dan Han, Andreas Held, •Masako Ogura, and Hubert Ebert — Ludwig-Maximilians-University Munich, Munich, Germany

The carrier mobility is one of the central properties of semiconductors. So far, most first-principles calculations of carrier mobilities for bulk semiconductors are based on the Boltzmann transport equation. In this contribution, we present an alternative scheme to evaluate temperature dependent carrier mobilities.

As a starting point, we calculate the electronic structures using the Korringa-Kohn-Rostoker (KKR) Green's function method in combination with the coherent potential approximation (CPA) alloy theory allowing for chemical as well as temperature induced disorder in the material. Dealing with undoped elemental or compound systems, we account this way for lattice vibrations, i.e. atom displacements depending on temperature, which affect the electronic structure and also cause a finite electric resistivity. The corresponding electric conductivity is calculated by means of the Kubo-Greenwood formula implemented on the basis of the KKR-CPA. The carrier mobility is evaluated from the resulting temperature-dependent conductivity and carrier concentration. Results for the intrinsic transport properties of undoped elemental and compound semiconductors will be presented.