TT 7: Fluctuations, Noise, Magnetotransport, and Related Topics

Time: Monday 15:00–18:00 Location: H23

TT 7.1 Mon 15:00 H23

Large Hall and Nernst effect from chiral spin fluctuations — Kamil K. Kolincio[1], Max Hirschberger[2,3], and •Jan Masell[3,4] — [1]Gdansk Tech, Gdansk, Poland — [2]University of Tokyo, Tokyo, Japan — [3]RIKEN CEMS, Wako, Japan — [4]Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany

Magnetic materials with tilted electron spins exhibit conducting behaviour that is explained by the geometrical Berry phase, driven by a chiral (left- or right-handed) spin-habit. Dynamical and nearly random spin fluctuations, with a slight trent towards left- or right-handed chirality, represent a promising route to realizing Berry-phase phenomena at elevated temperatures. [1] Here, we report thermoelectric and electric transport experiments on a triangular and on a slightly distorted kagomé lattice material, respectively. We show that the impact of chiral spin fluctuations is strongly enhanced for the kagomé lattice. Our modelling shows that the geometry of the kagomé lattice plays a crucial role as it helps to avoid cancellation of Berry-phase contributions already in the disordered (paramagnetic) state. Hence, the observations for the kagomé material contrast with theoretical models treating magnetization as a continuous field, and emphasize the role of lattice geometry on emergent electrodynamic phenomena.

[1] K. K. Kolincio, M. Hirschberger, J. Masell, S. Gao, A. Kikkawa, Y. Taguchi, T.-h. Arima, N. Nagaosa, Y. Tokura, PNAS 118, e2023588118 (2021)
[2] K. K. Kolincio et al., submitted

TT 7.2 Mon 15:15 H23

Revealing channel polarization of atomic contacts of ferromagnets and strong paramagnets by shot-noise measurements — Martin Prestel, •Marcel Strohmeier, Wolfgang Belzig, and Elke Scheer — University of Konstanz, 78457 Konstanz, Germany

We report measurements of the shot noise of atomic contacts using the mechanically controllable break junction (MCBJ) technique at low temperatures. In accordance with theoretical predictions [1, 2] single-atom contacts of the ferromagnets Co and Gd with conductance smaller than the conductance quantum show reduced noise compared to the expectation for the spin-degenerate single-channel transport. Additionally we focus on the strong paramagnets Pt [3], Pd [4], and Ir [5], where a nonmonotonic magnetoresistance has been reported for atomic contacts, interpreted as emerging magnetic ordering in small dimension, which is triggered by the vicinity of the respective bulk metals to a Stoner instability. Our recent measurements on Pd, Pt, and Ir reveal noise levels which are above, but close to the threshold to the spin-degenerate single-channel situation [6]. An anticorrelation between the minimum noise and the bulk Stoner parameter of these elements is observed. We discuss by how far this might indicate that spin polarization is reflected in the noise signal.

[1] Olivera et al., PRB 95, 075409 (2017)
[2] Häfner et al., PRB 77, 104409 (2008)
[3] Strigl et al., Nature Comm. 6, 6172 (2015)
[4] Strigl et al., PRB 94, 144431 (2016)
[5] Prestel et al., PRB 100, 214439 (2019)
[6] Prestel et al., PRB 104, 115434 (2021)

TT 7.3 Mon 15:30 H23

Synchronization in Josephson photonics devices with shot noise — •Florian Höhe[1], Lukas Danner[1,2], Brecht Donvil[1], Ciprian Padurariu[1], Björn Kubala[1,2], and Joachim Ankerhold[1] — [1]ICQ and IQST, Ulm University, Ulm, Germany — [2]Institute of Quantum Technologies, German Aerospace Center (DLR), Ulm, Germany

Phase stability is an important characteristic of radiation sources. For quantum sources exploitation and characterization of many quantum properties, such as entanglement and squeezing, may be hampered by phase instability. Josephson photonics devices, where microwave radiation is created by inelastic Cooper pair tunneling across a *dc-biased* Josephson junction connected in-series with a microwave resonator are particularly vulnerable lacking the reference phase provided by an ac-drive. To counter this issue, sophisticated measurement schemes have been used in [1] to prove entanglement, while in [2] a weak ac-signal was put in to lock phase and frequency of the emission.

The intrinsic shot noise of the Josephson-photonics device inevitably diffuses the oscillators phase and requires an extension of the classical theory [3] describing locking and synchronization to the quantum regime. Here, the shot noise, which is linked to the Full Counting Statistics, induces phase slips. Injection locking and synchronization lead to a strong narrowing of the photon emission statistics.

[1] A. Peugeot et al., Phys. Rev. X 11, 031008 (2021).
[2] M. C. Cassidy et al., Science 355, 939 (2017).
[3] L. Danner et al., Phys. Rev. B 104, 054517 (2021).

TT 7.4 Mon 15:45 H23

Theory of difference frequency quantum oscillations — •Valentin Leeb[1] and Johannes Knolle[1,2,3] — [1]Department of Physics TQM, Technische Universität München, James-Franck-Straße 1, D-85748 Garching, Germany — [2]Munich Center for Quantum Science and Technology (MCQST), 80799 Munich, Germany — [3]Blackett Laboratory, Imperial College London, London SW7 2AZ, United Kingdom

Quantum oscillations (QO) describe the periodic variation of physical observables as a function of inverse magnetic field in metals. The Onsager relation connects the basic QO frequencies with the extremal areas of closed Fermi surface pockets, and the theory of magnetic breakdown explains the observation of sums of QO frequencies at high magnetic fields. Here we develop a quantitative theory of *difference frequency* QOs in metals with multiple Fermi pockets with parabolic or linearly dispersing excitations. We show that a non-linear interband coupling, e.g. in the form of interband impurity scattering, can give rise to otherwise forbidden QO frequencies which can persist to much higher temperatures compared to the basis frequencies. We discuss the experimental implications of our findings, for example, for materials with multifold fermion excitations.

TT 7.5 Mon 16:00 H23

General bounds of electronic shot noise in the absence of currents — Jakob Eriksson[1], •Matteo Acciai[1,2], Ludovico Tesser[1], and Janine Splettstoesser[1] — [1]Department of Microtechnology and Nanoscience (MC2), Chalmers University of Technology, S-412 96 Göteborg, Sweden — [2]University of Gothenburg, S-412 96 Göteborg, Sweden

We investigate the charge and heat electronic noise in a generic two-terminal mesoscopic conductor in the absence of the corresponding charge and heat currents. Despite these currents being zero, shot noise is generated in the system. We show that, irrespective of the conductor's details and the specific nonequilibrium conditions, the charge shot noise never exceeds its thermal counterpart, thus establishing a general bound [1]. Such a bound does not exist in the case of heat noise, which reveals a fundamental difference between charge and heat transport under zero-current conditions.

[1] Eriksson et al., Phys. Rev. Lett. 127, 136801 (2021)

15 min. break

TT 7.6 Mon 16:30 H23

Direct observation of vortices in an electron fluid — •Tobias Völkl[1], Amit Aharon-Steinberg[1], Arkady Kaplan[1], Arnab Pariari[1], Indranil Roy[1], Tobias Holder[1], Yotam Wolf[1], Alexander Meltzer[1], Yuri Myasoedov[1], Martin Huber[2], Binghai Yan[1], Gregory Falkovich[3], Leonid Levitov[4], Markus Hücker[1], and Eli Zeldov[1] — [1]Department of Condensed Matter Physics, Weizmann Institute of Science, Rehovot, Israel — [2]Departments of Physics and Electrical Engineering, University of Colorado Denver, Denver, USA — [3]Department of Physics of Complex Systems, Weizmann Institute of Science, Rehovot, Israel — [4]Department of Physics, Massachusetts Institute of Technology, Cambridge, USA

Strongly-interacting electrons in ultrapure conductors have been shown to display signatures of hydrodynamic behavior including negative nonlocal resistance and Poiseuille flow in narrow channels. Here we provide the first visualization of current vortices in an electron fluid. By utilizing a nanoscale scanning superconducting quantum interference device on a tip we image the current distribution in a circular chamber connected through a small aperture to a current-carrying strip in the high-purity type-II Weyl semimetal WTe_2. We find that vortices are present only for small apertures, whereas the flow is laminar (non-vortical) for larger apertures. Our findings suggest a novel mechanism of hydrodynamic flow in thin pure crystals: the spatial diffusion of electrons' momenta is enabled by small-angle scattering at the surfaces, instead of the routinely invoked electron-electron scattering.

TT 7.7 Mon 16:45 H23

Optical dipole orientation of interlayer excitons in $MoSe_2$-WSe_2 heterostacks — •Mirco Troue[1], Lukas Sigl[1], Manuel Katzer[2], Malte Selig[2], Florian Sigger[1], Jonas Kiemle[1], Johannes Figueiredo[1], Mauro Brotons-Gisbert[3], Brian Gerardot[3], Andreas Knorr[2], Ursula Wurstbauer[4], and Alexander Holleitner[1] — [1]TU Munich — [2]Technical University Berlin — [3]Heriot-Watt University — [4]University of Münster

Transition metal dichalcogenide monolayers exhibit strong light-matter interactions, which promotes them as ideal candidates for novel 2D optoelectronic applications. A vertical stacking into van der Waals heterostacks leads to the formation of long-lived interlayer excitons in adjacent layers. We present the far-field photoluminescence intensity distribution of interlayer excitons in $MoSe_2$-WSe_2 heterostacks as measured by back focal plane imaging in the temperature range between 1.7K and 20K. An analytical model describing the emission pattern from a dielectric heterostructure is used to obtain the relative contributions of the in- and out-of-plane transition dipole moments associated with the interlayer exciton photon emission. We determine the transition dipole moments for all observed interlayer exciton transitions to be $(99 \pm 1)\%$ in-plane for R- and H-type stacking, independent of the excitation power and therefore the density of the exciton ensemble in the experimentally examined range. Moreover, we discuss the limitations of the presented measurement technique to observe correlation effects for many-body states in dense ensembles of interlayer excitons.

TT 7.8 Mon 17:00 H23

Magnetic and transport behaviour of quasi 2D NiS_2 flakes — •Roman Hartmann[1], Mario Amado Montero[2], Elke Scheer[1], and Angelo Di Bernardo[1] — [1]Fachbereich Physik, Universität Konstanz, Germany — [2]Department of Physics, University of Salamanca, Spain

Spintronics with 2D materials is emerging as a new field which enables development of devices with novel functionality compared to their three-dimensional counterparts.

We have recently managed to cleave single crystal NiS_2 down to the quasi 2D limit despite it not being a layered material. Bulk NiS_2 is a Mott insulator that has an interesting magnetic structure with an antiferromagnetic phase below 39 K and weak ferromagnetic ordering with a Curie temperature of 29 K. [1]

In transport measurements of thin flakes we see an increase in conductivity compared to the bulk, presumably due to the presence of metallic surface states. The ferromagnetic transition is clearly visible as kinks in the R-T curves and R-H curves . With magnetic field applied there is a complex hysteretic behaviour in the resistance with a strong asymmetry with respect to the direction of the applied field.

As a next step we are also looking into coupling the NiS_2 flakes to 2D superconductors to create two-dimensional superconducting spintronic devices.

[1] T. Thio et al., Phys. Rev. B 52, 5 (1995)

TT 7.9 Mon 17:15 H23

Spectral properties of the herringbone lattice — •Miguel Angel Jiménez Herrera[1,2] and Dario Bercioux[2,3] — [1]Centro de Física de Materiales (CFM-MPC) Centro Mixto CSIC-UPV/EHU, 20018 Donostia-San Sebastian, Basque Country, Spain — [2]Donostia International Physics Center, 20018 San Sebastián, Spain — [3]IKERBASQUE, Basque Foundation for Science, Euskadi Plaza, 5, 48009 Bilbao, Spain

We investigate the spectral properties of a two-dimensional electronic lattice that belongs to a non-symmorphic space group. More specifically, we look at the herringbone lattice that is characterised by two sets of glide symmetries applied in two orthogonal directions. We describe the system using a tight-binding model with nearest neighbors divided into horizontal and vertical hopping terms. We find two non-equivalent Dirac cones inside the first Brillouin zone along a high-symmetry paths, among other features, which react to different perturbations applied to the Hamiltonian. These perturbations break the symmetries of the lattice: we begin by placing different onsite potentials in the lattice sites. We observe annihilation of Dirac cones into semi-Dirac cones and nodal lines along high symmetry paths. Finally, we perturb the system by applying a dimerization on the hoppings. We report a flow of Dirac cones inside the first Brillouin zone describing quasi-hyperbolic curves

TT 7.10 Mon 17:30 H23

Hierarchical equations of motions approach to the study of thermodynamic uncertainty relations — Salvatore Gatto and •Michael Thoss — Institute of Physics, Albert-Ludwigs-Universität Freiburg

Thermodynamic uncertainty relations (TUR) are cost-precision trade-off relations in transport systems, relating the fluctuations in the heat and particle currents to the reversibility of the operation regime. While some violations have been reported for the TUR in classical systems, it has been found out that the geometry of quantum non-equilibrium steady-states alone directly implies the existence of a general quantum TUR. In this contribution, we investigate the relationship between quantum effects and current fluctuations in quantum systems. The hierarchical equation of motion approach is employed, which allows a numerically exact simulation of nonequilibrium transport in general open quantum systems involving multiple bosonic and fermionic environments.

TT 7.11 Mon 17:45 H23

Bosonization for $\mathbf{Q = 0}$ particle-hole excitations of 2D gapless fermions — •Sebastian Mantilla[1] and Inti Sodemann[1,2] — [1]Max Planck Institute for the Physics of Complex Systems, 01187 Dresden, Germany — [2]Institut für Theoretische Physik, Universität Leipzig, 04103 Leipzig, Germany

Understanding the non-perturbative effects of strong interactions on gapless phases of fermions in two-spatial dimensions is one of the major challenges in quantum condensed matter physics. Bosonization in one- and higher-dimensional systems has successfully captured such effects, where the picture of excitations in higher dimensions consists of small deformations of the Fermi surface. We discuss an extension for gapless phases in fermionic systems (e.g., nodal semimetals, Dirac fermions), not describable by the previous formalism since the Fermi surface shrinks to a point and the deformation picture breaks down. The new picture consists of a collection of excitons that considers non-perturbative effects in the weak- and strong-coupling regimes. We apply the formalism in two cases involving interacting electrons in graphene: the corrections to the optical response of 2D free fermions in monolayer graphene, and the weak coupling instability due to electron-hole attractive interactions in bilayer graphene. Our results contribute to understanding the effects of strong interactions in gapless fermions and extend bosonization beyond the picture of Fermi surface deformations.