QMA Fall School

Topological Quantum Matter 2021

October 13 - 15, 2021
Radisson Blu Hotel in Erfurt

ct.qmat
Complexity and Topology in Quantum Matter

Wednesday, October 13	
12:00 - 14:00	Lunch
14:00 - 14:10	Welcome note from organisers
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14:30 - 16:00	**Maxim Chernodub** "*Transport Effects due to Scale Anomaly* "
16:00 - 16:30	Coffee Break
16:30 - 18:00	**Fabrizio Nichele** "*Majorana Modes in Hybrid Devices: Status and Prospects*"
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10:30 - 12.00	**Titus Neupert** "*Novel Concepts in Topological Band Theory*"
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Maxim Chernodub

Researcher at CNRS, Institut Denis Poisson, Tours, France

Maxim obtained his PhD in Physics in 1999 at the ITEP in Moscow. After working there subsequently for two years, he moved to the Kanazawa university in Japan. In 2003, he moved back to ITEP for three years until in 2006 he got a position at Hiroshima university in Japan. After one year, in 2007 he again moved back to ITEP. Since 2008, he is a permanent researcher at the CNRS in France. Maxims research areas include lattice gauge theory and Quantum Chromodynamics as well as heavy-ion collisions, strong magnetic fields and CP violation. Furthermore he studies topological objects and nonperturbative effects in field theories.

"Transport Effects due to Scale Anomaly"

14:30 - 16:00 Wednesday, October 13

We overview transport phenomena generated by the scale anomaly in interacting quantum field theories of massless (chiral) particles, making an emphasis on Dirac and Weyl semimetals at the charge neutrality point. We discuss anomaly-induced thermoelectric effects in the background of the magnetic field in the presence of a temperature gradient. We also consider systems with boundaries, where the scale anomaly produces non-quantized edge current. The magnitude of all these phenomena is proportional to the beta function associated with the renormalization of electric charge.

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Fabrizio Nichele

Research Staff Member at IBM Zürich Research Laboratory,
Zürich, Switzerland

Fabrizio received his Ph.D. in Physics in 2014, from the Swiss Federal Institute of Technology (ETH) in Zürich. He was awarded the ETH medal for his doctoral work on transport experiments in nanoscrutcures characterized by a strong spin-orbit interaction. Subsequently, he held a postdoctoral appointment and Assistant Professor position at the Center for Quantum Devices and Station Q Copenhagen of the University of Copenhagen, Denmark, where he worked on topological superconductivity. In 2018 he was awarded an ERC Starting Grant for carrying out a project on topological states in two-dimensional electron gases and he is now working at IBM Research Zürich.

"Majorana Modes in Hybrid Devices: Status and Prospects"
16:30 - 18:00 Wednesday, October 13

Non-Abelian anyons are unlike any other particle type we know of: exchanging the position of two of them does not simply multiply the total wave function by a phase factor, but performs a complex operation that can change the quantum mechanical state of the entire system. With the theoretical advancements achieved in the last decades, forming and controlling non-Abelian anyons in a solid-state physics laboratory appears to be within reach. In the nextyears, this possibility might open the door to technological applications where quantum information is stored non-locally in distant particles and processed via braiding operations. In condensed matter physics, particles which follow this exchange statistics are expected to appear at the edges of certain topological superconductors and take the name of Majorana modes. Majorana modes are currently attracting an incredible interest both due to their anticipated unusual physical properties, but also because they might be employed for faster calculation in future quantum computers. As a main advantage compared to other routes to quantum computing, Majorana modes promise topological protection towards local perturbations, making computations inherently robust. My lecture will present the key ideas of topological quantum computing and focus on recent experimental developments in realizing topological states of matter, in particular using superconductor/semiconductor hybrid devices.

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Steve Winters

**Assistant Professor of Physics at Wake Forest University,
North Carolina, USA**

Steve received his PhD in Chemistry from the University of Waterloo, Canada in 2014 for work on strongly correlated organic materials. Subsequently, he held a postdoctoral appointment and junior research position at the Institute for Theoretical Physics in Frankfurt, Germany, where his work focused on quantum magnetism with strong spin-orbit coupling. He joined the faculty of Wake Forest University in Fall 2020. His current work focuses on quantum magnetism and the interplay of correlations and topology.

"Spin Liquids and Quantum Magnetism"

08:30 - 10:00 Thursday, October 14

In this tutorial, I will introduce the basics of quantum magnetism in the context of quantum spin liquids (QSLs). Topics covered will include: (i) A brief survey of materials, (ii) Microscopic origins of different magnetic Hamiltonians, (iii) Mean-field approaches for QSLs, and associated classifications, (iv) An introduction to exactly solved models, (v) Experimental considerations (what to measure?), and finally (vi) Challenges for the field.

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Tomasz Klimczuk

Professor of Solid State Physics at Gdańsk University, Poland

Prof. Tomasz Klimczuk graduated in physics at the Faculty of Applied Physics and Mathematics, Gdansk University of Technology. A breakthrough in his academic career was receiving the Columbus Scholarship from Foundation for Polish Science (FNP), which gave him the opportunity to work at the University of Princeton (Chemistry Department). The cooperation with Prof. Robert Cava started in 2003 continues to this day. In 2006, Dr. Klimczuk began his internship as Director's Funded post-doctoral fellow in Los Alamos National Laboratory (LANL) and three years later he started research at the Institute of Transuranium Elements (Joint Research Centre, European Commission) - in Karlsruhe. Despite working in Germany, he accepted an invitation to participate in the Young Scientists Council at the Ministry of Science and Higher Education. In 2012, he returns to Poland and has been developing a research group at Gdansk University of Technology. He promoted four PhD students and the next two will graduate soon. His research activities are focused mainly on synthesis and physical properties of new materials. He reported several new compounds including 15 actinide based materials, and more than 20 superconductors that remain his scientific obsession. Five of them belong to a very unique class of noncentrosymmetric superconductors. Prof. Tomasz Klimczuk is the co-author of more than 200 papers indexed in ISI Master Journal List.

"Searching for New Superconducting Compounds"

10:30 - 12:00 Thursday, October 14

In this lecture various strategies in the search for new superconducting compounds will be discussed. First, I will briefly introduce the three most important techniques that are used to determine superconducting parameters, such as critical temperature, lower and upper critical fields, electron-phonon coupling coefficient, etc. Then I will present the way we discovered superconductivity in $CaBi_2$, $LiPd_2Ge$, $LiGa_2Ir$ and

Nb/$TaRh_2B_2$ and Nb/$TaIr_2B_2$. A special attention will be given to the boride family in which compounds there is lack of centrosymmetry, and hence interesting physics is expected. Finally, I will try to convince you that the cooperation of physicists, crystallographers and chemists is necessary and sometimes brings excellent results.

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Kai Rossnagel

Professor of Physics at Christian-Albrechts-University, Kiel, Germany

Kai Rossnagel is a Lead Scientist at DESY and a Professor of Physics at Kiel University, where he received his Dr. rer. nat. and habilitation in physics in 2001 and 2009, respectively. From 2002 to 2003, he was a Feodor Lynen Research Fellow of the Alexander von Humboldt Foundation at the Advanced Light Source in Berkeley. In the mid 2010's, he was a visiting scientist at the RIKEN SPring-8 Center in Japan. Currently, he serves as the spokesperson of the priority research area Kiel, Nano, Surface and Interface Science (KiNSIS) at Kiel University.
Being a surface and condensed matter physicist by training, Kai Rossnagel is deeply fascinated by the unbelievable variety of spectacular structures, physical properties, and cooperative phenomena emerging from the pocket universes of condensed matter. His primary research drive is to understand the function of quantum materials and their interfaces at the atomic level on the basis of electronic structure and ultrafast dynamics. To film the dances of the electrons, his delocalized group at Kiel and DESY develops novel photoelectron spectroscopy techniques and instrumentation and exploits the most brilliant soft x-ray radiation produced by storage rings as well as high-repetition-rate free-electron lasers.

"TMDC-tronics"

14:00 - 15:30 Thursday, October 14

Transition-metal dichalcogenides (TMDCs) provide a fruitful and inexhaustible resource for exploring novel forms of nano and quantum electronics based on electronic phenomena in layered structures down to the 2D limit. Here, I will give an overview on "TMDC-tronics", including valleytronics, supertronics, Mottronics, orbitronics, twistronics etc., and I will present experimental studies of TMDC-tronic materials and devices where the focus is on correlated and charge-density-wave systems. The experimental method of choice is angle-resolved photoemission spectroscopy (ARPES) in its modalities with highest spectral, spatial, and temporal resolution.

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Audrey Grockowiak

Scientific Staff Brazilian Center for Research in Energy and Materials (CNPEM), São Paulo, Brazil

High pressure dudette. Diamond breaker, ruby lover, extreme conditions enthusiast. After getting her PhD in 2012 in Grenoble, France, both for investigating the superconducting properties of silicon and looking at asteroid collisions in microgravity, she joined the Tozer high pressure group at the National High Magnetic Field Laboratory in Tallahassee, Florida. There, she painfully learned to use her tears as a pressure medium for her pressure cells, in order to investigate unconventional superconductors looking at the Fermi Surface of their normal state via Quantum Oscillation measurements, and more recently 'hot' superhydride superconductors. Hard core experimentalist, she joined in 2021 the Extreme Conditions Beamline EMA of the brand-new 4th generation Brazilian Synchrotron Sirius, where she is part of the development and commissioning team.

"Exploring high pressure"

16:00 - 17:30 Thursday, October 14

From the depth of the Earth to exoplanets, most materials exist at high pressures. To quote high pressure pioneer Ho-Kwang Mao: "high pressure should not be viewed as an extreme condition, but as an unexplored dimension. Consequently our "ordinary" P word should be regarded as a special condition in the P dimension". In this talk, I will introduce high pressure techniques used in various environments such as high magnetic fields, ultra low or high temperatures, or x-ray. Using current examples of extreme conditions research, I will show how high pressure can be used to tune ground states of materials to look at for example insulator to metal transitions, inducing exotic superconductivity or playing with frustrating magnetism.

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Koenraad Schalm

Professor for Theoretical Physics at the University of Leiden, Netherlands

Koenraad received his PhD in Physics in 1999 at the Yang Institute for Theoretical Physics from the Stony Brook University in New York. Afterwards he worked for two years as a postdoctoral fellow at the NIKHEF in Amsterdam, followed by being a research fellow at the ISCAP Columbia University until 2005. He then moved to the University of Amsterdam where he held a position as research assistant professor for two years. From 2007 to 2014, he was an associate professor at the university of Leiden, while in 2013 also being a visiting scientist at Harvard university for one year. From 2014 until today, he holds the position of professor for theoretical physics at the university of Leiden. Koenraad studies string theory and its connections to models of particle physics and cosmology in particular. His current research is focused on the remarkable possibilities that near-future cosmological observations as well as upcoming particle-collider or condensed matter experiments can contain signatures of string theory.

"Computing Transport Coefficients of Strongly Correlated Quantum Matter from Holography"

08:30 - 10:00 Friday, October 14

The anti-de Sitter/Conformal Field theory correspondence provides a unique novel perspective on critical phenomena at second order quantum phase transitions in systems with spatial dimensions $d > 1$. The finite temperature state near the quantum critical point is a prototype of strongly correlated quantum matter. These lectures will give an introduction technical background to apply so called "holographic" techniques of the correspondence to compute the transport properties of such systems.

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Titus Neupert

Associate Professor at the Department of Physics at the University of Zürich, Switzerland

Titus completed his Ph.D. studies in 2013 at the ETH Zurich. His thesis on electron fractionalization in two-dimensional quantum systems was awarded the ETH medal and Dissertation Prize of the Swiss Physical Society. He then moved to Princeton as a postdoctoral researcher. After three years, he moved back to Zürich, where he became Assistant Professor (2016) and eventually Associate Professor (2018) at the Department of Physics at the University of Zürich. He is currently working on three main areas of condensed matter theory: topological systems, open systems, and quantum computing. In 2020 he was awarded the Clarivate Highly Cited Researcher prize.

"Novel concepts in topological band theory"

10:30 - 12:00 Friday, October 15

In this lecture I will introduce a range of phenomena in topological band theory, that go beyond the 10-fold way classification of topological phases. These include (i) higher-order topological insulators, in which topological boundary states appear on corners and hinges instead of surfaces and edges, (ii) a differentiation between band topologies as stable, fragile and delicate as well as (iii) topological notions in non-Hermitian systems. I will focus on providing an intuition starting from concrete model examples and keep the presentation mathematically light.

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List of Poster Abstracts

Characterization of Tunable THz Rectification by Excitonic Insulator Candidate Diode

P1

Lukas Arnold, Universität Stuttgart, Germany

Schottky diodes can detect ultrafast pulses in the THz regime, which has widespread applications in both science and commercial applications. We form a tunable diode by approaching the tip of a scanning tunneling microscope (STM) onto the surface of Ta_2NiSe_5 [1], a material in which the electronic structure around the Fermi surface are defined by correlation of electrons, namely the spontaneous condensation of excitons [2]. We characterize the diode by guiding ultrafast THz pulses into the STM junction [3] and investigate its efficiency and bandwidth. Our results also assist in further understanding of the excitonic nature of Ta_2NiSe_5.

[1] Y. F. Lu, et al. Nature Communications 8, 14408 (2017).
[2] D. Jérome, T. M. Rice, and W. Kohn Phys. Rev. 158, 462 (1967).
[3] M. Abdo, et al. ACS Photonics 8, 702-708 (2021).

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Single-Particle Properties and Critical Behavior of a 3d Metal Coupled to Critical 2d Spin-Density Waves

P2

Bernhard Frank, TU Dresden, Germany

We study three-dimensional conduction electrons metal that interact with the fluctuations of an antiferromagnetic order parameter that characterizes the collective behavior of localized magnetic moments located within a single layer of the bulk. Based on a field theoretic model that incorporates the violation of momentum conservation perpendicular to the plane we identify hot and superhot electrons with anomalous, non-Fermi liquid damping rates. In addition, we determine the critical behavior of the spin sector and give an outlook on electronic transport properties.

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Comparative Growth Study of Ultrathin Bi Films on Clean and Oxygen-Reconstructed Nb(110)

P3

Robin Boshius, JMU Würzburg, Germany

We present a detailed study of the growth of Bi films on superconducting Nb(110) substrates in dependence on the Bi coverages and the Nb surface quality. We find that Bi grows in a (110) orientation at low coverage equivalent to about five pseudomorphic monolayers (ML) on clean Nb(110), but then undergoes a structural transition to Bi(111) below about 8 ML. Comparison with two oxygen-reconstructed Nb(110) surfaces, the NbO_x phases I and II, reveals that the film thickness at which the (110)-to-(111) transition takes place depends on the surface quality. Whereas it is observed at lower coverage for the NbO_x phase I, our results indicate that Bi(110) remains stable on NbO_x phase II up to the largest film thickness studied here, i.e., 18 ML. The quality and smoothness of the thin Bi films considerably depends on the cleanliness of the Nb substrate, revealing the most flat and defect-free Bi films grown on the oxygen-free clean Nb(110) surface. The proximity-effect-induced superconducting gap on the Bi surfaces will further be discussed.

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Discovery, Crystal Growth and Crystal Structure of the Topological Insulator Candidate $Bi_{12}Rh_3Ag_6I_9$

P4

Eduardo Carrillo Aravena, TU Dresden, Germany

A stacking of $[Bi_{12}Rh_3I]^{2+}$ layers, a 2D topological insulator (TI), can be achieved by electrostatic stabilization with an anionic spacer, potentially creating a weak 3D TI. This was first observed for $Bi_{14}Rh_3I_9 = [Bi_{12}Rh_3I]^{2+}[Bi_2I_9]^{2-}$. We are investigating ways to replace the $[Bi_2I_9]^{2-}$ spacer with other layers. By doing so, we hope to introduce new features (e.g., ferromagnetism), but also to learn more about the relationship between the chemical composition and structure on the one hand and the topological properties on the other. Here, we report the synthesis and crystal structure of $Bi_{12}Rh_3Ag_6I_9$, a new compound from the same structural family. It is a periodic stack consisting of the same 2D TI layers $[Bi_{12}Rh_3I]^{2+}$ but now alternating with $[Ag_6I_9]^{2-}$ spacer layers. The spatial separation between the TI layers should be large enough to ensure a (non-trivial) band gap. AgI is one of the most prominent ionic conductors. In a very similar way to AgI, the Ag^+ cations in the $[Ag_6I_9]^{2-}$ spacer layer are distributed over several positions. This unique combination of an ionic conductor and a potential TI material opens up the possibility of electrochemically adjusting the composition to correct for n- or p-doping of the material with high precision. Both single-phase polycrystalline powders and single-crystals are available for further measurements. Electronic structure calculations would also be welcome.

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Electronic Structure of Novel Crystalline Materials

P5

Johannes Heßdörfer, JMU Würzburg, Germany

The first synthesized and experimentally realized Weak Topological Insulator was $Bi_{14}Rh_3I_9$. It consists of 2D TI layers with a honeycomb lattice stacked with insulating spacer layers. The 2D TI is formed by rhodium centred bismuth cubes which form a Kagome lattice with iodine atoms in the middle of the lattice. A material with similar structure is $Bi_{13}Pt_3I_7$, it also consists of a 2D TI layer, composed of platinum centred bismuth cubes. Here the spacer layers lead to an alternating coupling and render the material topological trivial. By modifying the spacer layers in this materials the topological properties can be tuned. This led to the search of new compounds with similar structure, the first promising candidates are $Bi_{12}Rh_3Ag_6I_9$, $Bi_{12}Pt_3CuI_5$ and $Bi_{12}Pt_3AgI_5$. First investigations on the structural and electronic properties of this new materials were done by Angle Resolved Photoemission Spectroscopy, X-ray Photoelectron Spectroscopy, Low-Energy Electron Diffraction and Scanning Tunneling Microscopy. This poster will present the first results on the crystalline, atomic and electronic structure of these new compound. The results are promising and encourage further measurements to have a closer look at the electronic structure of the samples, which could confirm if the compound presents a non-trivial topology.

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Intrinsic Finite-Energy Cooper Pairing in j = 3/2 Superconductors

P6

Masoud Bahari, JMU Würzburg, Germany

In this poster, we demonstrate that Cooper pairing can occur intrinsically away from the Fermi surface in j = 3/2 superconductors with strong spin-orbit coupling and equally curved bands in the normal state. In contrast to conventional pairing between spin-1/2 electrons, we derive that pairing can happen between inter-band electrons having different total angular momenta, i.e., j = 1/2 with j = 3/2 electrons. Such superconducting correlations manifest themselves by a pair of indirect gap-like structures at finite excitation energies. An observable signature of this exotic pairing is the emergence of a pair of symmetric superconducting coherence peaks in the density of states at finite energies. We argue that finite-energy pairing is a generic feature of high-spin superconductors, both in the presence and absence of inversion symmetry.

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Adsorption of Small Molecules on the (110) surface of the Dirac Semimetal RuO_2

P7

Armando Consiglio, JMU Würzburg, Germany

A variety of catalytic oxidation and dehydrogenation reactions can be studied on the (110) surface of ruthenium dioxide (RuO_2), whose surface functionality are based on the interplay between Coulomb and kinetic energies, as well as on the interplay of lattice, spin-rotational and time-reversal symmetries. The catalytic qualities are directly related to the properties of its Fermi surface, with antiferromagnetic instabilities driven by a particularly large density of states. Indeed, besides of its outstanding performances and applications, this material gained attention because of its electronic and magnetic properties. The electronic structure induced by the crystal symmetry produces a complex Fermi surface composed of Dirac nodal lines and a consequent flat band surface state (FBSS), the latter having an active role in catalytic charge transfer processes at the oxygen bridge sites. Being tuned by surface doping and electrostatic environment, the FBSS presents an interesting playground for the study of surface chemistry. Also, the strong nesting of the Dirac nodal lines is prone to Fermi surface instabilities, a postulated driving force of the itinerant collinear antiferromagnetism. The proposed work shows the results of a combined theoretical and experimental effort; the aim is at the microscopic understanding of heterogeneous catalysis with a focus on the interplay of the catalyst's de-localized electronic band structure and the localized orbitals of its surface reactants, as well as on its thermodynamic properties.

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Observation of Dirac Fermions in a Triangular Topological Insulator

P8

Jonas Erhardt, JMU Würzburg, Germany

Topology in two-dimensional lattices is often connected to a honeycomb-like arrangement of atoms. Contrary to that, we demonstrate the topological non-trivial nature of indenene, a triangular monolayer of indium atoms that hosts massive Dirac fermions at the K/K'-points. As in the case of the large gap topological insulator bismuthene [1,2], the underlying silicon carbide substrate plays a pivotal role for the low-energy physics. Here its electric field along the surface normal causes hybridization between indium p_z and p_+/p_- orbitals, thereby opening a large hybridization gap in the otherwise metallic film. In addition, the substrate creates a competing term to the spin-orbit coupling (SOC) induced gap at K/K' by breaking the in-plane inversion symmetry (ISB). The ISB lifts the Kramers-degeneracy of the K/K' bands and promotes orbital angular momentum polarization in a distinct sequence that is unambiguously linked to a SOC vs. ISB induced gap, i.e., the topological character of indenene. In real space, this information is translated to the lateral charge distribution of the unit cell due to interference of adjacent indium wavefunctions, each contributing orbital as well as Bloch-phase. We make use of this remarkable property of the bulk wavefunction to verify the topological non-trivial nature of indenene by mapping the local density of states via scanning tunneling spectroscopy [3].

[1] F. Reis, G. Li, L. Dudy, M. Bauernfeind, S. Glass, W. Hanke, R. Thomale, J. Schäfer and R. Claessen, Science 357, 287 (2017).
[2] R. Stühler, F. Reis, T. Müller, T. Helbig, T. Schwemmer, R. Thomale, J. Schäfer and R. Claessen, Nat. Phys. 16, 47 (2020).
[3] M. Bauernfeind, J. Erhardt, P. Eck, P. K. Thakur, J. Gabel, Tien-Lin Lee, J. Schäfer, S. Moser, D. Di Sante, R. Claessen, and G. Sangiovanni (accepted for publication).

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Higher Order Auxiliary Field Quantum Monte Carlo Methods

P9

Florian Goth, JMU Würzburg, Germany

The auxiliary field quantum Monte Carlo (AFQMC) method has been a workhorse in the field of strongly correlated electrons for a long time and has found its most recent implementation in the ALF package (alf.physik.uni-wuerzburg.de). The utilization of the Trotter decomposition to decouple the interaction from the non-interacting Hamiltonian makes this method inherently second order in terms of the imaginary time slice. We show that due to the use of the Hubbard-Stratonovich transformation (HST) a semigroup structure on the time evolution is imposed that necessitates the introduction of a new family of complex-hermitian splitting methods for the purpose of reaching higher order. We will give examples of these new methods and study their efficiency, as well as perform comparisons with other established second and higher order methods in the realm of the AFQMC method.

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Magnetic Domain Structures on Gd(0001)/W(110) Films

P10

Patrick Härtl, JMU Würzburg, Germany

"Due their partially filled 4f shell which are coupled by the RKKY interaction, rare earth metals exhibit long-range magnetic order. Depending on the sign of the RKKY coupling and details of the sample geometry many different domain structures have been observed. For example, spin-resolved STM studies of Dy(0001) thin films on W(110) revealed a six-fold symmetric magnetic domain structure [1]. Here we report on similar experiments on Gadolinium (Gd) films epitaxially grown on W(110). Gd is a ferromagnetic metal with a Curie temperature of 293 K. Its half-filled 4f shell results in a spherical charge distribution and therefore a rather small magnetic anisotropy in comparison other rare earth metals [2].

Earlier spatially averaging experiments performed by Berger et. al. [2] suggest that Gd(0001) films on W(110) exhibit a thickness-dependent spin reorientation transition at around 40 nm from in-plane at thin films to out-of-plane for thicker. Our investigation on Gd(0001) films grown on W(110) indeed show a rather rich spin structure in STM/STS studies. We observe spin spiral-like magnetic domains with an in-plane as well as out-of-plane magnetized STM tips. We will discuss the transition of the magnetic structure in dependence of the Gd film thickness.

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Substitution Series in the $Bi_2[PtBi_6I_{12}]_3$ System **P11**

Maria Herz, TU Dresden, Germany

The reaction of Bi with Sn, Pt and BiI_3 above 300 °C yielded shiny, black, air insensitive crystals of the novel subiodide $Sn[PtBi_6I_{12}]$. Discovered during the search for novel topological insulators [1], the compound consists of alternating cuboctahedral $[PtBi_6I_{12}]^{2-}$ clusters and Sn^{2+} cations in an octahedral coordination between trigonal faces of two cuboctahedra, which concatenate them into linear chain, which makes it an analogue to the compound $Pb[PtBi_6I_{12}]$ [2]. Additionally, the crystals' cube-like morphology originates from six weaker Bi···I inter-cluster bridges per cluster connecting the chains. This, in combination with the composition of predominantly heavy elements, and hence a strong spin-orbit coupling within the compound, lead to the hope that the information obtained about the band gap could lead to this being fine-tuned and reduced in order to apply to other compounds and obtain topological properties.

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Hydrodynamic Transport and Optical Properties of Anomalous Hall Materials

P12

Eddwi Hesky Hasdeo, University of Luxembourg, Luxembourg

Internal structures of electrons encoded in wavefunctions (Berry curvature) can dramatically alter electron dynamics. One chief example is the anomalous Hall (AH) motion without magnetic field in a multiband system that break time reversal symmetry. In this poster, we elaborate such effects in hydrodynamic transport and optical properties of AH materials. Firstly, we will demonstrate anomalous cyclotron motion without magnetic field. Next, we will show polarization rotation of transmitted and reflected (Kerr and Faraday rotations) light due to AH effects in topological flat and dispersive bands. Finally, collective electrons in AH materials show peculiar hydrodynamic flows due to the Berry curvature.

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Accessing Surface Magnetic and Electronic Properties of $MnBi_2Te_4$ by X-Ray Spectroscopy and Thin-Film Growth

P13

Philipp Kagerer, JMU Würzburg

With its discovery as the first antiferromagnetic topological insulator, $MnBi_2Te_4$ has reopened the question of how the interaction between the time reversal symmetry breaking magnetic order and the topological properties can influence the surface electronic structure of a compound [1]. By now several reports on small gap-openings in the surface state of the compound have been published, where effects connected to the magnetic transition have turned out to be very peculiar [2,3]. In this regard a lot of questions are still unanswered experimentally. These include the differences between the magnetic properties of $MnBi_2Te_4$ at its surface vs. its bulk, the potential influence of interfaces up to the question, what role surface magnetism can play in lifting the topological protection of the surface state. Here we will present a study on MBE grown $MnBi_2Te_4$ heterostructures facilitating various soft x-ray and VUV spectroscopy techniques. In recent years we have built up two twin MBE setups in Würzburg and Hamburg for in-situ photoemission experiments and established a flexible growth platform for the growth of $MnBi_2Te_4$ heterostructures on BaF_2 [4]. Facilitating these possibilities we will present insights on the magnetic properties of these materials and try to work out their influence on the electronic structure of the thin films.

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Phase Escape Dynamics in InAs/Al Josephson Junctions: Optimal Control of Phase Diffusion

P14

Daniel Haxell, IBM Research, ETH Zurich, Switzerland

We study the phase escape mechanisms of highly transparent planar Josephson junctions (JJs) defined in a hybrid InAs/Al heterostructure. Such devices have many quantum computing applications: from gate-controlled transmons [1] and flux qubits [2], to potentially hosting topologically protected states in the presence of a Zeeman field [3]. We show that quantum fluctuations are the dominant mechanism of phase escape, with phase diffusion becoming significant for lower critical currents. Further, we control the phase dynamics using an electrostatic gate electrode and an in-plane field; both of these parameters can independently tune the transition temperature between phase escape regimes. In addition, we measure the phase dynamics in an asymmetric SQUID geometry, whereby two JJs with asymmetric critical currents form a loop. This geometry is typical for flux qubits and for measuring topological phases in hybrid JJs [2,3]. We demonstrate protection against phase escape for the small JJ in this geometry, due to the locking of the phase with the large JJ. We also observe a flux dependence of the SQUID transition temperature. An understanding of the phase dynamics of JJs in hybrid materials is crucial for harnessing the potential of the platform in quantum computing applications.

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Nesting Instability of Gapless U(1) Spin Liquids with Spinon Fermi Pockets in Two Dimensions

P15

Wilhelm Krüger, TU Dresden, Germany

Quantum spin liquids are exotic states of matter that may be realized in frustrated quantum magnets and feature fractionalized excitations and emergent gauge fields. Here, we consider a gapless U(1) spin liquid with spinon Fermi pockets in two spatial dimensions. Such a state appears to be the most promising candidate to describe the exotic field-induced behavior observed in numerical simulations of the antiferromagnetic Kitaev honeycomb model. A similar such state may also be responsible for the recently-reported quantum oscillations of the thermal conductivity in the field-induced quantum paramagnetic phase of α-$RuCl_3$. We consider the regime close to a Lifshitz transition, at which the spinon Fermi pockets shrink to small circles around high-symmetry points in the Brillouin zone. By employing renormalization group and mean-field arguments, we demonstrate that interactions lead to a gap opening in the spinon spectrum at low temperatures, which can be understood as a nesting instability of the spinon Fermi surface. This leads to proliferation of monopole operators of the emergent U(1) gauge field and confinement of spinons. While signatures of fractionalization may be observable at finite temperatures, the gapless U(1) spin liquid state with nested spinon Fermi pockets is ultimately unstable at low temperatures towards a conventional long-range-ordered ground state, such as a valence bond solid. Implications for Kitaev materials in external magnetic fields are discussed.

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FEL Based tr-ARPES of Ultrafast Electron Dynamics in Quantum Materials

P16

Michael Herber, DESY/University of Hamburg, Germany

We investigated the ultrafast electronic structure dynamics of various quantum materials by time- and angle-resolved photoelectron spectroscopy. To this end, a time-of-flight momentum microscope enabling the parallel detection of the photoelectrons two surface-parallel momentum components plus their kinetic energy was combined with the short-pulsed monochromatized XUV radiation from the PG2 beamline of FLASH at DESY. The use of XUV pulses specifically provides the possibility to study the combined temporal response of valence and core electrons. Here, the results of tow different experiments will be presented, focusing on the Dirac cone of graphene on Ir(111), the surface and bulk valence bands and core levels of Bi_2Se_3. Pump fluence and momentum-dependent dynamical effects will be discussed.

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Bose-Hubbard Realization of Fracton Defects

P17

Ruben Lier, MPI-PKS Dresden, Germany

Bose-Hubbard models are simple paradigmatic lattice models used to study dynamics and phases of quantum bosonic matter. We combine the extended Bose-Hubbard model in the hard-core regime with ring-exchange hoppings. By investigating the symmetries and low-energy properties of the Hamiltonian we argue that the model hosts fractonic defect excitations. We back up our claims with exact numerical simulations of defect dynamics exhibiting mobility constraints. Moreover, we confirm the robustness of our results against fracton symmetry breaking perturbations. Finally we argue that this model can be experimentally realized in recently proposed quantum simulator platforms with big time crystals, thus paving a way for the controlled study of many-body dynamics with mobility constraints.

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Exotic Quantum Criticality in Dirac Systems: Metallic and Deconfined

P18

Zihong Liu, JMU Würzburg, Germany

Motivated by the physics of spin-orbital liquids, we study a model of interacting Dirac fermions on a bilayer honeycomb lattice at half filling, featuring an explicit global SO(3)×U(1) symmetry. Using large-scale auxiliary-field quantum Monte Carlo (QMC) simulations, we locate two zero-temperature phase transitions as function of increasing interaction strength. First, we observe a continuous transition from the weakly-interacting semimetal to a different semimetallic phase in which the SO(3) symmetry is spontaneously broken and where two out of three Dirac cones acquire a mass gap. The associated quantum critical point can be understood in terms of a Gross-Neveu-SO(3) theory. Second, we subsequently observe a transition towards an insulating phase in which the SO(3) symmetry is restored and the U(1) symmetry is spontaneously broken. While strongly first order at the mean-field level, the QMC data is consistent with a direct and continuous transition. It is thus a candidate for a new type of deconfined quantum critical point that features gapless fermionic degrees of freedom.

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Bosonization of the Q = 0 Continuum of Dirac Fermions

P19

Sebastian Felipe Mantilla Serrano, MPI-PKS Dresden, Germany

We develop a bosonization formalism that captures non-perturbatively the interaction effects on the $Q = 0$ continuum of excitations of nodal fermions above one dimension. Our approach is a natural extension of the classic bosonization scheme for higher dimensional Fermi surfaces to include the $Q = 0$ neutral excitations that would be absent in a single-band system. The problem is reduced to solving a boson bilinear Hamiltonian. We establish a rigorous microscopic footing for this approach by showing that the solution of such boson bilinear Hamiltonian is exactly equivalent to performing the infinite sum of Feynman diagrams associated with the Kadanoff-Baym particle-hole propagator that arises from the self-consistent Hartree-Fock approximation to the single particle Green's function. We apply this machinery to compute the interaction corrections to the optical conductivity of 2D Dirac Fermions with Coulomb interactions reproducing the results of perturbative renormalization group at weak coupling and extending them to the strong coupling regime.

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Fluctuation-Induced Ferrimagnetism in Sublattice-Imbalanced Antiferromagnets with Application to $SrCu_2(BO_3)_2$ Under Pressure

P20

Pedro Monteiro Consoli, TU Dresden, Germany

We show that a collinear Heisenberg antiferromagnet, whose sublattice symmetry is broken at the Hamiltonian level, becomes a fluctuation-induced ferrimagnet at any finite temperature below the Néel temperature. We first demonstrate this in a layered variant of a square-lattice $J_1 - J_2$ model, in which spin-wave and Landau theories are used to determine the behavior of the uniform magnetization at low and elevated temperatures, respectively. We then consider a layered Shastry-Sutherland model, describing a frustrated arrangement of orthogonal dimers. This model displays an antiferromagnetic phase for large intra-dimer couplings. A lattice distortion that breaks the glide symmetry between the two types of dimers leads to broken sublattice symmetry and hence gives rise to ferrimagnetism. Given indications that such a distortion is present in the material $SrCu_2(BO_3)_2$ under high hydrostatic pressure, we suggest the existence of a fluctuation-induced ferrimagnetic phase in pressurized $SrCu_2(BO_3)_2$. We predict a nonmonotonic behavior of its uniform magnetization as a function of temperature.

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STM Functionalized Tips - One Step Beyond the Resolution Limits

P21

Artem Odobesko, JMU Würzburg, Germany

STM and STS is a powerful techniques for local probing of the topography on the atomic level and electron densities of states. Nonetheless, there are limitations on the spatial and energy resolution due to the irregular shape of the tip and the effect of thermal broadening. These limitations can be overcome by functionaling the STM tip apex with CO molecule to increase the spatial resolution of the tip or tunneling from a superconducting tip to exclude thermal broadening of the Fermi step of a normal metal tip. Here we try to combine both approaches to obtain an extra energy resolution with extra spatial resolution. With the help of such a ultra-functionalized STM tip, we are able to resolve rapidly decaying in space oscillations of Yu-Shiba-Rusinov bound states near magnetic Fe dimer on the bare Nb(110) surface. This allows us, for the first time, to determine the Fermi wavelength of Nb(110) surface. Such ultra-functionalized STM tips take the STM technique to the next level.

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Thermopower and Magnetotransport Properties of $Bi_{100-x}Sb_x$ Topological Insulator Thin Films Prepared by Rapid Quenching

P22

Ena Osmic, Helmholtz Zentrum Dresden Rossendorf, Germany

We have measured the temperature dependence of resistance $R(T)$, thermopower $S(T)$, magnetoresistance (MR) and the Hall effect (HE) of $Bi_{80}Sb_{20}$, $Bi_{85}Sb_{15}$ and $Bi_{90}Sb_{10}$ topological insulator thin films. Samples were prepared by sequential flash-evaporation at room temperature and annealing at $T = 350\,K$. The $R(T)$ of the three investigated samples shows metallic-like behavior for temperatures less than $T = 75\,K$, while for higher temperatures, $R(T)$ shows a semiconducting-like behavior. The thermopower $S(T)$ of the three investigated samples is negative in the entire temperature range measured in this work, with a linear behavior from 5 up to $\approx 100\,K$. The magnetoresistance of all samples is positive with a small temperature dependence. The highest MR ($B = 7\,T$) was observed in $Bi_{85}Sb_{15}$ with a $\approx 600\%$ and $\approx 125\%$ change at 5 and 300 K, respectively. Clear evidence of weak antilocalization contribution to the MR was observed only in sample $Bi_{85}Sb_{15}$ for temperatures $T < 75\,K$. Quantum oscillations in the MR originating from the Fermi surface, which has a clear two-dimensional character, were observed in sample $Bi_{85}Sb_{15}$ up to $\approx 21\,K$. Hall effect results indicate a p-type behavior for sample $Bi_{80}Sb_{20}$, while $Bi_{85}Sb_{15}$ and $Bi_{90}Sb_{10}$ display n-type behavior. Carrier mobility information of sample $Bi_{85}Sb_{15}$ was extracted from low field HE data, showing a remarkably high value of $\mu \approx 2.8 \times 10^4\,cm^2/Vs$ at 5 K, with a small decrease for increasing temperature.

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Modification of Magnetic Behavior in $La_xNd_{3-x}Fe_3Sb_7$

P23

Falk Pabst, TU Dresden, Germany

Unsubstituted $RE_3Fe_3Sb_7$ (RE = Nd, Pr) displays a very complex magnetic interaction of the Fe and rare earth sublattice resulting in magnetic compensation and sign reversal f the magnetization at low temperatures. Current investigations aim for a better understanding of this behavior in the parent compounds. Substituting Nd with non-magnetic La allows to modify the rare earth sublattice and subsequently quench the magnetic interaction.

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Jamming Dynamics in a Hardcore Spin System

P24

Benedikt Placke, MPI-PKS Dresden, Germany

We study the dynamics of hardcore spin model on the square and triangular lattice, obtained by analogy to hard spheres, where the translational degrees of freedom of the spheres are replaced by orientational degrees of freedom of spins on a lattice and the packing fraction as a control parameter is replaced by an exclusion angle. Analogously to the hard-sphere constraint, where no two sphere centers are allowed to be closer than the sum of their radii, in the hardcore spin model neighboring spins are forced to enclose an angle greater than their exclusion angle. In equilibrium, both models exhibit a Kosterlitz-Thouless transition at an exclusion angle Δ_{KT}. We study phase-ordering kinetics of states prepared using a quench protocol from the paramagnetic into the KT phase inspired by compression of hard spheres. We find a time scale of relaxation towards equilibrium that diverges with a power law with respect to both system size and the deviation from the critical angle $\Delta_J = \pi/2 > \Delta_{\mathrm{KT}}$. We show that this results from a combination of the diffusion-annihilation process describing the relevant phase ordering kinetics of a KT model, with a vanishing defect mobility setting the power law as $\Delta \to \Delta_J$.

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Gross-Neveu-SO(3) Quantum Criticality

P25

Shouryya Ray, TU Dresden, Germany

Two-dimensional spin-orbital magnets with strong exchange frustration have recently been predicted to realize a quantum critical point in the Gross-Neveu-SO(3) universality class. Unlike previously studied Gross-Neveu universality classes, this quantum critical point separates a Dirac semimetal from a long-range-ordered phase in which the fermion spectrum is only partially gapped out. Here, we characterize the quantum critical behavior of the Gross-Neveu-SO(3) universality class by employing three complementary field-theoretical techniques beyond their leading orders, and produce best-guess theoretical estimates for critical exponents by averaging over the results of the different techniques.

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Magnetic Order in the Triangular-Lattice Antiferromagnet $KCeS_2$

P26

Anton Kulbakov, TU Dresden, Germany

Yb- and Ce-based delafossites were recently identified as effective spin-1/2 antiferromagnets on the triangular lattice. Several Yb-based systems, such as $NaYbO_2$, $NaYbS_2$, and $NaYbSe_2$, exhibit no long-range order down to the lowest measured temperatures and therefore serve as promising candidates for the spin-liquid ground state. However, their isostructural Ce-based counterpart $KCeS_2$ exhibits magnetic order below $T_N = 400$ mK, which was so far identified only in thermodynamic measurements. Here we reveal the magnetic structure of this long-range ordered phase using magnetic neutron diffraction. We show that it represents the so-called "stripe-yz" type of antiferromagnetic order with spins lying approximately in the triangular-lattice planes orthogonal to the nearest-neighbor Ce–Ce bonds. No structural lattice distortions are revealed below TN, indicating that the triangular lattice of Ce^{3+} ions remains geometrically perfect down to the lowest temperatures

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Spectroscopic Signatures of Non-trivial Topology in Weyl Semimetals

P27

Jakub Schusser, JMU Würzburg, Germany

Dirac and Weyl semimetals have become a highly relevant topic in contemporary condensed matter physics. Despite the fact that several experimental approaches have been introduced, none allows for their unambiguous identification in photoemission. By performing angle-resolved photoemission spectroscopy (ARPES) on the bulk samples we show the spectroscopic manifestation of topologial features and Weyl physics beyond the simple photointensity over a broad range of excitation energies from the vacuum ultraviolet (VUV) to the soft X-Ray (SX) regime which allows us to compare the surface and the bulk band structure. Our experimental observations were complemented by state-of-the-art ab initio first principle photoemission calculations based on one-step model of photoemission and density functional theory (DFT). By utilizing the determinant criterion, we confirm the arc character of the spoon features in the constant energy contour close to Fermi level in non-centrosymmetric TaP and TaAs. We further show the drawbacks of the existing spectroscopic techniques used to determine whether given material has non-zero Chern number and discuss an improved approach for identifying Fermi arcs by the means of differential ARPES measurements. Our results represent an important step towards revealing topologically non-trivial materials as well as show the importance of proper final state description.

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Fermi Surface of the Chiral Topological Semimetal PtGa with Maximal Chern Number

P28

Valentin Schwarze, Helmholtz Zentrum Dresden Rossendorf, Germany

PtGa is a chiral topological semimetal with giant spin-split Fermi arcs with a maximal Chern number of four. We investigated the bulk Fermi surfaces of PtGa with angular-dependent de Haas-van Alphen (dHvA) measurements and band-structure calculations. Strong spin-orbit coupling leads to well separated spin-split bands. Eight bands cross the Fermi energy forming a multitude of Fermi surfaces resulting in intricate dHvA spectra. We were not able to assign all experimentally observed dHvA frequencies to the corresponding calculated extremal orbits, because of their considerable quantity and proximity. Yet, the experiment is in good agreement with the calculations confirming the topological character of PtGa.

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SP-STM Study of Magnetic Zig-Zag $2\sqrt{2} \times \sqrt{2}$ Structure on 3 AL Mn/W(001)

P29

Paula Weber, JMU Würzburg, Germany

Spin spirals and dead magnetic layers in the antiferromagnetic transition metal Mn on the heavy bcc(001) surface of W have recently attracted considerable interest [1,2]. In this poster, we present a spin-polarized STM investigation of 2-4 atomic layer (AL) thick Mn films on W(001). For 3 AL Mn on W(001) it has been theoretically proposed that this system grows pseudomorphically as islands while exhibiting an antiferromagnetic state [3]. Our topographic STM data confirm that pseudomorphic growth even prevails up to a Mn film thickness of 4 AL. Spin-resolved data were acquired by scanning with W tips which had been magnetized on Mn layers by in-situ treatment on Mn/W(001). This allowed us to collect topographic and spin-resolved data on the same scanning area. Applying this method, we found a magnetic zig-zag $2\sqrt{2} \times \sqrt{2}$ structure on 3 AL Mn and a strongly bias-dependent labyrinth overlay structure for 4 AL. The sensitivity of each tip was characterized by test measurements on the well-known 2 AL Mn on W(001) [2].

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Symmetry Resolved Entanglement in AdS/CFT

P30

Konstantin Weisenberger, JMU Würzburg, Germany

Quantum entanglement is a key resource in quantum computing, and an important quantity to characterize quantum phases of matter. It is however quite crude, depending only on the central charge of a quantum field theory. We introduce the concept of symmetry resolved entanglement entropy (SREE), which is a fine-grained version of the usual entanglement entropy, resolving the dependence of the entanglement entropy on a conserved charge. SREE can be calculated in a wide range of condensed matter systems like spin chains, free bosons, and free fermions. We calculate SREE in the context of the Anti-de Sitter/Conformal field theory (AdS/CFT) correspondence, for strongly interacting 2D CFTs with U(1) Kac-Moody symmetry. We find equipartition of entanglement between different charge sectors, and in general agreement between both sides of the AdS/CFT correspondence.

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Higher-Order Fabray-Perot Interferometer

Changan Li, JMU Würzburg, Germany

P31

We propose an intrinsic three-dimensional Fabry-Perot type interferometer, coined "higher-order interferometer", that is based on the chiral hinge states of second-order topological insulators and cannot be mapped to an equivalent two-dimensional setting because of higher-order topological obstructions. Quantum interference patterns in the two-terminal conductance of this interferometer are controllable not only by tuning the strength but also, particularly, by rotating the direction of the magnetic field applied perpendicularly to the transport direction. Remarkably, the conductance exhibits a characteristic beating pattern with multiple frequencies depending on the field strength and direction in a unique fashion. Our novel interferometer thus provides feasible and robust magnetotransport signatures for hinge states of higher-order topological insulators.

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Discovery of Axis-Dependent Conduction Polarity in $\mathbf{NaSnAs_{1-x}P_x}$ through Computationally-Guided Methods

P32

Andrew Ochs, MPI-CPfS Dresden, Germany

Most electronic materials exhibit a single dominant charge carrier type, either holes (p-type) or electrons (n-type), along all crystallographic directions. However, there are a small number of compounds, mostly metals, that exhibit simultaneous p-type and n-type conduction behavior along different crystallographic directions. We demonstrate the experimental discovery of semiconductors with this axis-dependent conduction polarity can be facilitated by identifying a large anisotropy of either the electron and hole effective masses (m^*), or both, providing the electron and hole masses dominate along different crystallographic directions. In this study, we calculated the layered semiconductors NaSnAs and NaSnP to have a lower electron m^* in-plane than cross-plane, and a very large hole m^* in-plane and small hole m^* cross-plane. We established the growth of large $NaSnAs_{1-x}P_x$ ($x = 0$, 0.1, 0.2, 0.3, 1) crystals via Sn flux, and measured band gaps ranging from 0.65 eV to 1.04 eV with increasing P content by diffuse reflectance experiments, in agreement with theory. NaSnAs, NaSnP, and their alloys all exhibit p-type thermopowers cross-plane and n-type thermopowers in-plane, confirming that the large anisotropy in the effective mass at the band edges is an excellent indicator for axis-dependent conduction polarity. Overall, this work shows that the discovery of semiconductors with such a phenomenon can be accelerated by computationally evaluating the anisotropic curvatures of the band edges, paving the way for their future discovery and application.

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The Pyrochlore S = 1/2 Heisenberg Antiferromagnet at Finite and Zero Temperature

P33

Robin Schäfer, MPI-PKS Dresden, Germany

We use cutting-edge computational methods to investigate the intricate frustrated three-dimensional quantum spin liquid candidate, the pyrochlore $S = 1/2$ antiferromagnet at finite and zero temperature.

Using a systematic cluster expansion based on tetrahedra, including clusters up to 25 lattice sites with nontrivial hexagonal and octagonal loops, we gain access to various thermodynamic properties in the thermodynamic limit at finite temperature. We found a pronounced maximum in the specific heat at $T = 0.57\,J$ that is stable across finite size clusters and converged in the series expansion. At $T \approx 0.25\,J$ (the limit of convergence of our method), the residual entropy per spin is $0.47\,k_{\mathrm{B}}\log(2)$, which is relatively large compared to other frustrated models at this temperature.

We applied SU(2) DMRG to periodic clusters with up to 128 sites to examine the zero temperature properties and determine the ground state energy, $E_0/N_{\mathrm{sites}} = -0.490\,J$. Our most striking finding is a robust spontaneous inversion symmetry breaking, reflected in an energy density difference between the two sublattices of tetrahedra, which is supported by different perturbative treatments. These findings suggest a scenario in which a finite-temperature spin liquid regime gives way to a symmetry-broken state at low temperatures. Furthermore, we study the magnetization process finding a pronounced and apparently robust 1/2-magnetization plateau where the groundstate breaks (real-space) rotational symmetry, exhibiting oppositely polarized spins on alternating kagome and triangular planes. Reminiscent of the kagome ice plateau of the pyrochlore Ising magnet known as spin ice, it arises via a much more subtle 'quantum order by disorder' mechanism.

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Signatures of Topological Skyrmion Phases of Matter

P34

Shuwei Liu, MPI-PKS Dresden, Germany

We study topological phases of matter defined by skyrmions in the ground state spin expectation value textures in the Brillouin zone. We present several elementary models to realize such phases that are protected by a generalized particle-hole symmetry. We demonstrate several essential features such as robust zero-energy modes and strongly localized states, and we develop an effective low-energy theory for these states.

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Photoelectron Spectroscopy of Topological Insulator/Ferromagnet Heterostructures

P35

Simon Marotzke, DESY/University of Hamburg, Germany

Topological insulators (TI) have sparked great interest in the last two decades due to the existence of spin-polarized, counter-propagating surface states. Possible applications include spintronics and topological quantum computing using Majorana fermions realized in topological hybrid systems [1-3].

Heterostructures consisting of a TI and a ferromagnet (FM) are hereby interesting hybrid systems as the perpendicular component of the magnetisation breaks time-reversal symmetry inside the TI. In consequence, a band gap in the TI opens. By manipulating the ferromagnetic state and the perpendicular component of magnetization, a topological phase transition can thus be induced. In a first step on the way to realise and observe a topological phase transition in TI/FM systems we fabricated Bi_2Se_3/Co/Pt heterostructures. A significantly reduced magnetic dead layer formation in comparison to a recent publication was observed, indicative of a good sample quality [4]. In order to analyse the electronic structure of the heterostructures (angle-resolved) photoemission spectroscopy (XPS) experiments were performed at P04@PETRA III using the ASPHERE III end station. Important insights were obtained regarding sensitivity to the buried topological insulator as well as chemical composition at the TI/FM interfaces by varying the photon energy in the range of E = 400 - 2800 eV as well as the thickness of the Co and Pt layers. The Bi 4f core levels provide a good indication for the sensitivity to the TI/FM interface and its chemical composition. A prominent result is the detection of two peaks for both spin-orbit split core levels for $E > 500$ eV, indicating two different chemical environments for Bi atoms. As the measurements with lower photon energies are highly surface-sensitive, the single peak visible for $E < 500$ eV can be attributed to the Co/Bi_2Se_3 interface, i.e., to the proximity of Bi to Co. The detected energy shift with respect to the unperturbed Bi_2Se_3 peak located at a higher binding energy can be quantitatively explained by the different electronegativity of Se and Co [5]. Importantly, an oxygen contamination at the interface would result in a peak shift to larger binding energies [5, 6]. Additionally, a first measurement on a Bi_2Se_3/B4C/Co/Pt sample exhibiting an interface between a topologically trivial and non-trivial insulator was conducted, showing the potential of such samples that will be further investigated in upcoming beamtimes at P04.

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Field Dependence of the Low-Energy Magnon Modes and a Possible Spin-Cholesteric Phase in $Sr_3Fe_2O_7$

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Nikolai Pavlovskii, TU Dresden, Germany

We systematically studied low-energy magnon excitations in the helimagnetically ordered bilayer perovskite $Sr_3Fe_2O_7$. The high temperature crystal structure of $Sr_3Fe_2O_7$ is centrosymmetric and tetragonal (I4/mmm). Below 330 K, a weak tetragonal distortion is observed, which presumably results from charge ordering. The helimagnetic order sets in below 115 K and is characterized by the propagation vector $(\xi\ \xi\ 1)$ with $\xi = 0.142$. The magnetic ground was previously believed to be characterized with a single-q magnetic order parameter that results from a frustration of exchange interactions, resulting in two types of equivalent helimagnetic domains. Our present results suggest that it could be instead a double-q state. Our elastic neutron-scattering measurements in a magnetic field applied along one of the (110) crystal directions further reveal an additional phase transition within the magnetic phase, associated with the destruction of long-range order along the direction orthogonal to the field, leading to an unusual spin-cholesteric magnetic phase that breaks both chiral symmetry and translational symmetry along only one of the crystal directions. In the orthogonal direction, we observe only short-range quasielastic spin dynamics. Across the transition from the magnetically ordered to the spin-cholesteric phase, these slow spin fluctuations fill in the spin gap in the spin-wave spectrum, as we can see in the high-resolution inelastic neutron-scattering spectra, and ultimately dominate the low-energy magnetic excitation spectrum after the long-range magnetic order is destroyed. We have also investigated domain selection and the relaxation of magnetic domains in $Sr_3Fe_2O_7$, which can be seen as slow time-dependent drift of the magnetic Bragg intensity at temperatures immediately below the magnetic phase transition.

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Suppression of the Radiation Squeezing in Interacting Quantum Hall Edge Channels

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We study the quantum fluctuations of the two quadratures of the emitted electromagnetic radiation generated by a quantum Hall device in a quantum point contact geometry. In particular, we focus our attention on the role played by the unavoidable electron-electron interactions between the two edge channels at filling factor two. We investigate quantum features of the emitted microwave radiation, such as squeezing, by studying the current fluctuations at finite frequency, accessible through a two-filters set-up placed just after the quantum point contact. We compare two different drives, respectively a cosine and a train of Lorentzian pulses, used for the injection of the excitations into the system. In both cases quantum features are reduced due to the interactions, however the Lorentzian drive is still characterized by a robust squeezing effect which can have important application on quantum information.

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Suppression of Superconductivity via Out-of-Equilibrium Electrons and Phonons

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Recent experiments with metallic nanowires devices suggest that superconductivity can be controlled by the application of electric fields [1,2]. In such experiments, critical currents are tuned and eventually suppressed by relatively small voltages applied to nearby gate electrodes, at odds with current understanding of electrostatic screening in metals. We demonstrate that this effect is linked to gate currents below 100 fA at the onset of critical current suppression in our devices [3]. Employing novel device geometries, we disentangle the roles of electric field and electron-current flow. Our results show that suppression of superconductivity does not depend on the presence or absence of an electric field at the surface of the nanowire but requires a current of high-energy electrons [4]. The suppression is most efficient when electrons are injected into the nanowire, but similar results are obtained also when electrons are passed between two remote electrodes at a distance d to the nanowire (with d in excess of 1 μm). In the latter case, high-energy electrons decay into phonons which propagate through the substrate and affect superconductivity in the nanowire by generating quasiparticles. We show that this process involves a non-thermal phonon distribution, with marked differences from the loss of superconductivity due to Joule heating near the nanowire or an increase in the bath temperature.

[1] De Simoni, G. et al. Nature Nanotechnology 13, 802–805 (2018).
[2] Paolucci, F. et al. Nano Letters 18, 7, 4195-4199 (2018).
[3] Ritter, M.F. et al. Nature Communications 12, 1266 (2021).
[4] Ritter, M.F. et al. arXiv:2106.01816 (2021).

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Topological Phases on Self-Similar Structures: Effect of Coordination

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Topologically nontrivial phases have recently been reported on self-similar structures. Here we investigate the effect of local structure, specifically the role of the coordination number, on the topological phases on self-similar structures embedded in two dimensions. We study a geometry dependent model on two self-similar structures having different coordination numbers, constructed from the Sierpinski gasket. For different non-spatial symmetries present in the system, we numerically study and compare the phases on both structures. We characterize these phases by the localization properties of the single-particle states, their robustness to disorder, and by using a real-space topological index. We find that both structures host topologically nontrivial phases and the phase diagrams are different on the two structures. This suggests that, in order to extend the present classification scheme of topological phases to non-periodic structures, one should use a framework which explicitly takes the coordination of sites into account.

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Frozen Deconfined Quantum Criticality

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There are a number of contradictory findings with regard to whether the theory describing easy-plane quantum antiferromagnets undergoes a second-order phase transition. The traditional Landau-Ginzburg-Wilson approach suggests a first-order phase transition, as there are two different competing order parameters. On the other hand, it is known that the theory has the property of self-duality which has been connected to the existence of a deconfined quantum critical point. The latter regime suggests that order parameters are not the elementary building blocks of the theory, but rather consist of fractionalized particles that are confined in both phases of the transition and only appear - deconfine - at the critical point. Nevertheless, numerical Monte Carlo simulations disagree with the claim of deconfined quantum criticality in the system, indicating instead a first-order phase transition. In our work, these contradictions are resolved by demonstrating via a duality transformation that a new critical regime exists analogous to the zero temperature limit of a certain classical statistical mechanics system. Because of this analogy, we dub this critical regime "frozen". A renormalization group analysis bolsters this claim, allowing us to go beyond it and align previous numerical predictions of the first-order phase transition with the deconfined criticality in a consistent framework.

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Magnon Spectrum of the Weyl Semimetal Half-Heusler Compound GdPtBi

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The compound GdPtBi is known as a material where the non-trivial topology of electronic bands interplays with an antiferromagnetic order, which leads to the emergence of many interesting magnetotransport phenomena. Although the magnetic structure of the compound has previously been reliably determined, the magnetic interactions responsible for this type of order remained controversial. In the present study, we employed time-of-flight inelastic neutron scattering to map out the low-temperature spectrum of spin excitations in single-crystalline GdPtBi. The observed spectra reveal two spectrally sharp dispersive spin-wave modes, which reflects the multi-domain state of the k = (1/2 1/2 1/2) face-centred cubic antiferromagnet in the absence of a symmetry-breaking magnetic field. The magnon dispersion reaches an energy of ≈ 1 .1 meV and features a gap of ≈ 0 .15 meV. Using linear spin-wave theory, we determined the main magnetic microscopic parameters of the compound that provide good agreement between the simulated spectra and the experimental data. We show that the magnetic structure of GdPtBi is dominated by second-neighbor interactions, thus featuring low frustration.

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Improving Topological Superconductivity in Two- and Three-dimensional Josephson Junctions

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As opposed to the numerous theoretical developments in the field of topological heterostructures hosting robust quasiparticles, difficulties are piling up for experimentalists on their way to building realistic and tunable setups with usable topological states. We address this widespread issue in a specific platform involving a planar Josephson junction made of semiconductor with strong spin-orbit coupling by proposing easy-to-reach regimes of parameters with enhanced stability of the Majorana end states. Moreover, the extension of those findings to a three-dimensional model provides henceforth a new flexible platform for realizing chiral Majorana edge states. Possible setups using Van der Waals heterostructures are suggested.

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Quantum Friction in the Hydrodynamic Model

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Kunmin Wu, University of Luxembourg, Luxembourg

We study the phenomenon of quantum friction in a system consisting of a polarizable atom moving at a constant speed parallel to a metallic plate. The plate is described using a charged hydrodynamic model for the electrons. This model featuring long-range, instantaneous interactions is appropriate for graphene or a clean metal in a temperature range where scattering due to Coulomb interactions dominates over the scattering of electron by impurities.

We find that a quantum friction force between the atom and the metal surface exists even in the absence of intrinsic damping in the plate, but that it only starts once the velocity of the atom exceeds the effective speed of sound in the plate. We argue that this condition can be fulfilled most easily in metals with nearly empty or nearly filled bands. We make quantitative predictions for the friction force to the second and fourth order in the atomic polarizability, and show that the threshold behavior persists to all orders of the perturbation theory.

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