KFM 13: Topological Insulators and Semimetals (joint session TT/KFM)

Time: Friday 10:00–12:45 Location: H7

KFM 13.1 Fri 10:00 H7

Wave-particle duality of electrons with spin-momentum locking — •Dario Bercioux[1,2], Tineke van den Berg[1], Dario Ferrero[3,4,5], Jerome Rech[4], Thibaut Jonckheere[4], and Thierry Martin[4] — [1]Donostia International Physics Center (DIPC), Manuel de Lardizbal 4, E-20018 San Sebastián, Spain — [2]IKERBASQUE, Basque Foundation of Science, 48011 Bilbao, Basque Country, Spain — [3]Aix Marseille Univ, Université de Toulon, CNRS, CPT, Marseille, France — [4]Dipartimento di Fisica, Università di Genova, Via Dodecaneso 33, 16146, Genova, Italy — [5]SPIN-CNR, Via Dodecaneso 33, 16146 Genova, Italy

We investigate the effects of spin-momentum locking on the interference and diffraction pattern of electrons in a double- or single-slit Gedankenexperiment. We show that the inclusion of the spin degree-of-freedom when coupled to the carrier's motion direction — a typical situation occurring in systems with spin-orbit interaction — leads to modify the interference and diffraction patterns depending on the geometrical parameters system.

[1] Bercioux *et al.*, Eur. Phys. J. Plus **135**, 811 (2020)

KFM 13.2 Fri 10:15 H7

Volkov-Pankratov states in topological graphene nanoribbons — Tineke L. van den Berg[1], •Alessandro De Martino[2], M. Reyes Calvo[3], and Dario Bercioux[1,4] — [1]Donostia International Physics Center, Donostia-San Sebastián, Spain — [2]Department of Mathematics, City, University of London, London, United Kingdom — [3]Departamento de Fisica Aplicada, Universidad de Alicante, Alicante, Spain — [4]IKERBASQUE, Basque Foundation of Science, Bilbao, Spain

In topological systems a smooth modulation of the gap at the interfaces between topologically distinct phases can lead to the appearance of massive edge states, as first described by Volkov and Pankratov in 1985. In this contribution I will show that, in the presence of intrinsic spin-orbit coupling smoothly modulated near the edges, graphene nanoribbons host Volkov-Pankratov states in addition to the topologically protected helical states. This result is obtained by means of two complementary methods, one based on the effective low-energy Dirac equation description and the other on a fully numerical tight-binding approach, with excellent agreement between the two. I will then briefly discuss how transport measurements might reveal the presence of Volkov-Pankratov states, and possible graphene-like structures in which such states might be observed.

KFM 13.3 Fri 10:30 H7

Symmetry-enforced topological nodal planes — Marc A. Wilde[1,2], Matthias Dodenhöft[1], Arthur Niedermayr[1], Andreas Bauer[1,2], •Moritz M. Hirschmann[3], Kirill Alpin[3], Andreas P. Schnyder[3], and Christian Pfleiderer[1,2,4] — [1]Physik Department, Technische Universität München, Garching, Germany. — [2]Centre for QuantumEngineering (ZQE), Technische Universität München, Garching, Germany. — [3]Max Planck Institute for Solid State Research, Stuttgart, Germany. — [4]MCQST, Technische Universität München, Garching, Germany.

Topological semimetals and metals may contain nodal points or lines, i.e., zero- or one-dimensional crossings in the energy bands. In the present work we discuss an extension to two-dimensional nodal features. These nodal planes are enforced in crystals with certain non-symmorphic space groups. We specify the necessary conditions for the existence of nodal planes and consider in the process paramagnetic as well as magnetic space groups. Based on an analysis of symmetry eigenvalues we identify space groups that lead to nodal planes with a non-zero Chern number. Our arguments are supported by minimal models and explicit calculation of the topological invariants. Furthermore, we have identified a number of materials with topological nodal planes. Among them is the ferromagnetic phase of MnSi, for which we show that the symmetry-enforced topological nodal planes exist, using de Haas-van Alphen spectroscopy and density functional theory calculations.

[1] M.A. Wilde et al., Nature 594, 374-379 (2021)

KFM 13.4 Fri 10:45 H7

Network of topological nodal planes and point degeneracies in CoSi — •Nico Huber[1], Kirill Alpin[2], Grace L. Causer[1], Lukas Worch[1], Andreas Bauer[1], Georg Benka[1], Moritz M. Hirschmann[2], Andreas P. Schnyder[2], Christian Pfleiderer[1], and Marc A. Wilde[1] — [1]Physik Department, Technische Universität München, D-85748 Garching, Germany — [2]Max-Planck-Institute for Solid State Research, Heisenbergstrasse 1, D-70569 Stuttgart, Germany

We report the experimental identification of symmetry-enforced topological nodal planes in CoSi which together with multifold point degeneracies and Weyl points form a network of band crossings satisfying the fermion doubling theorem. For this, we have combined measurements of Shubnikov-de Haas oscillations in CoSi with material-specific electronic structure calculations and a symmetry analysis [1]. The observation of two nearly dispersionless Shubnikov-de Haas frequency branches is shown to provide clear evidence of four distinct Fermi surface sheets at the R point of the Brillouin zone and of the symmetry-enforced orthogonality of the wave functions at the intersections with the nodal planes. These results highlight that CoSi features six- and fourfold crossings at R and Γ and that a comprehensive account of all topological charges in the network going beyond point degeneracies is needed.

[1] Huber et al., arXiv:2107.02820

15 min. break.

KFM 13.5 Fri 11:15 H7

Twisted and chiral photon states scattered on chiral molecular liquids — Silvia Müllner[1], Florian Büscher[1], Dirk Wulferding[2], Yurii G. Pashkevich[1,3], Vladimir Gnezdilov[1,4], Anton A. Pechkov[5], Andrey Surzhykov[5], and •Peter Lemmens[1] — [1]IPKM, TU Braunschweig, Germany — [2]CCES, Inst. for Basic Science, Seoul, Republic of Korea — [3]O.O. Galkin Donetsk Inst. for PaE, NASU, Kyiv - Kharkiv, Ukraine — [4]B. Verkin Inst. for Low Temp. Phys and Eng., NASU, Kharkiv, Ukraine — [5]Inst. Math. Phys., TU Braunschweig and PTB, Braunschweig, Germany

Twisted or structured light [1] has been recognized as a novel probe of chiral states of matter. The respective light matter coupling is still discussed controversially. Using resonant light-matter coupling of twisted and chiral photon states [1] to chiral molecular liquids we study their inelastic response. For this instance, quasi-elastic Raman scattering (QES) is investigated in isotropic, nematic and chiral nematic phases of liquid crystals. The response is diffusive and dominated by a narrow distribution or single relaxation rate.

We acknowledge important discussions with G. Napoli (Univ. del Salento, Lecce). This research was funded by the DFG Excellence Cluster QuantumFrontiers, EXC 2123, DFG Le967/16-1, DFG-RTG 1952/1, and the Quantum- and Nano-Metrology (QUANOMET) initiative of Lower Saxony within project NL-4.

[1] H. Rubinsztein-Dunlop, et al., Journ. Opt. 19, 013001 (2017)

KFM 13.6 Fri 11:30 H7

Berry curvature-induced local spin polarisation in gated graphene/WTe_2 heterostructures — •Jonas Kiemle[1,2], Lukas Powalla[3,4], Elio J. König[3], Andreas P. Schnyder[3], Johannes Knolle[2,5], Klaus Kern[3,4], Alexander Holleitner[1,2], Christoph Kastl[1,2], and Marko Burghard[3] — [1]Walter Schottky Institut and Physics Department, Technical University of Munich, Am Coulombwall 4a, Garching — [2]MCQST, Schellingstrasse 4, München — [3]Max-Planck-Institut für Festkörperforschung, Heisenbergstrasse 1, Stuttgart — [4]Institut de Physique, Ecole Polytechnique Fédérale de Lausanne, Lausanne — [5]Department of Physics TQM, Technical University of Munich, James-Frank-Strasse 1, Garching

Experimental control of local spin-charge interconversion is of primary interest for spintronics. Van der Waals heterostructures combining graphene with a strongly spin-orbit coupled two-dimensional (2D) material enable such functionality by design. Here, we probe the gate-tunable local spin polarisation in current-driven graphene/WTe_2 heterostructures through magneto-optical Kerr microscopy. We observe, that even for a nominal in-plane transport, substantial out-of-plane spin accumulation is induced by a corresponding out-of-plane current flow [1]. Our findings unravel the potential of 2D heterostructure engineering for harnessing topological phenomena for spintronics, and constitute an important step toward nanoscale, electrical spin control.

[1] L. Powalla, J. Kiemle et al., arXiv:2106.15509 (2021)

KFM 13.7 Fri 11:45 H7

Impact of domain disorder on optoelectronic properties of semimetal $MoTe_2$ — •Maanwinder Partap Singh[1,2], Jonas Kiemle[1,2], Philipp Zimmermann[1,2], Marko Burghard[3], Christoph Kastl[1,2], and Alexander Holleitner[1,2] — [1]Walter Schottky Institut and Physics Department, Technical University of Munich, Am Coulombwall 4a, 85748 Garching, Germany. — [2]Munich Center of Quantum Science and Technology (MCQST), Schellingstr. 4, 80799 Munich, Germany. — [3]Max-Planck-Institut für Festkörperforschung, Heisenbergstrasse 1, D-70569 Stuttgart, Germany.

$MoTe_2$, one of the candidates to realize the topological type-II Weyl semimetal, crystallizes in several structures. At room temperature, $Mote_2$ can have either a semiconducting (2H) or a metallic phase (1T'). Upon cooling, the monoclinic phase undergoes a transition at $\sim$ 240 K into an orthorhombic phase (T_d), which breaks the inversion symmetry. We investigate the optoelectronic properties of $MoTe_2$ as a function of temperature using photocurrent spectroscopy in combination with Raman and transient reflection spectroscopy. We elucidate the impact of phase disorder on the generation of local photocurrents especially with respect to ultrafast photogalvanic currents [1].

[1] Singh et al. (submitted)(2021)

KFM 13.8 Fri 12:00 H7

2D-Berry-curvature-driven large anomalous Hall effect in layered topological nodal-line MnAlGe — •Satya N. Guin and Claudia Felser — Max Planck Institute for Chemical Physics of Solids, 01187 Dresden, Germany

Topological magnets comprising two-dimensional (2D) magnetic layers with Curie temperatures (TC) exceeding room temperature are key for dissipationless quantum transport devices. However, the identification of a material with 2D ferromagnetic planes that exhibits an out-of-plane-magnetization remains a challenge. We report a ferromagnetic, topological, nodal-line, and semimetal MnAlGe composed of square-net Mn layers that are separated by nonmagnetic Al-Ge spacers. The 2D ferromagnetic Mn-layers exhibit an out-of-plane magnetization below TC 503 K. Density functional calculations demonstrate that 2D arrays of Mn atoms control the electrical, magnetic, and therefore topological properties in MnAlGe. The unique 2D distribution of the Berry curvature resembles the 2D Fermi surface of the bands that formed the topological nodal line near the Fermi energy. A large anomalous Hall conductivity (AHC) of 700 S/cm is obtained at 2 K and related to this nodal line-induced 2D Berry curvature distribution. The high transition temperature, large anisotropic out-of-plane magnetism, and natural hetero-structure-type atomic arrangements consisting of magnetic Mn and non-magnetic Al/Ge elements render nodal-line MnAlGe one of the few, unique, and layered topological ferromagnets that have ever been observed.

[1] S. N. Guin et al., Adv. Mater. 2021, 33 (21), 2006301

KFM 13.9 Fri 12:15 H7

A quantum oscillation study in the Dirac nodal-line semimetal HfSiS — •Claudius Müller[1], Jasper Linnartz[1], Leslie Schoop[2], Nigel Hussey[1,3], and Steffen Wiedmann[1] — [1]High Field Magnet Laboratory (HFML-EMFL), IMM, Radboud University, Nijmegen, the Netherlands — [2]Department of Chemistry, Princeton University, Princeton, New Jersey, USA — [3]H. H. Wills Physics Laboratory, University of Bristol, Bristol, UK

We have performed a de Haas - van Alphen (dHvA) quantum oscillation study of HfSiS in high magnetic fields up to 31 T. For parallel alignment of the magnetic field and the c-axis, we observe quantum oscillations originating from individual electron and hole pockets, as well as oscillations caused by magnetic breakdown (MB) between these pockets. The MB orbits come in a wide variety, ranging from a so-called 'figure-of-eight' orbit to orbits enclosing large areas in the Brillouin zone (BZ). These MB orbits can be seen as a manifestation of Klein tunneling in momentum space [1], although in a regime of partial transmission due to the finite separation between adjacent pockets. Our experimental observation, the strong dependence of the oscillation amplitude on the field angle and the cyclotron masses of the MB orbits, is in good agreement with the theoretical predictions for this novel tunneling phenomenon.

[1] M. van Delft et al., Phys. Rev. Lett. 121, 256602 (2018)

KFM 13.10 Fri 12:30 H7

Magnetic breakdown and open orbits in $LaIn_3$ — •Jasper Linnartz[1], Davide Pizzirani[1], Claudius Müller[1], Sam Teicher[2], Ratnadwip Singha[3], Sebastiaan Klemenz[3], Leslie Schoop[3], and Steffen Wiedmann[1] — [1]High Field Magnet Laboratory (HFML-EMFL), IMM, Radboud University, Nijmegen, the Netherlands — [2]Materials Department and California Nanosystems Institute, University of California Santa Barbara, Santa Barbara, USA — [3]Department of Chemistry, Princeton University, Princeton, USA

$LaIn_3$ which crystalizes in the $AuCu_3$ structure provides is a highly tunable system for emergent phenomena in condensed matter such as a monotonic increase of its critical temperature upon Sn doping. It is also considered as a model system for the heavy fermion systems $CeIn_3$ and $PrIn_3$.

We present a systematic de Haas-van Alphen quantum oscillations study on $LaIn_3$ up to 30 T. By measuring the temperature and angle dependence, the Fermi surface and the charge carrier properties such as the effective cyclotron masses are determined. While the finding of some pockets of the complex Fermi surface is in agreement with theoretical predictions, the observation of various high-frequency oscillations at specific angles points towards field-induced magnetic breakdown that can be described in a two-dimensional network of open orbits.