

DS 33: Transport: Topological Semimetals 2 (jointly with MA/TT)

Time: Wednesday 15:00–17:45

Location: HSZ 204

DS 33.1 Wed 15:00 HSZ 204

Topological properties of magnetic semi-metals with non-symmorphic symmetries — ●ANDREAS P. SCHNYDER — Max Planck Institute of Solid State Research, Heisenbergstrasse 1, 70569 Stuttgart

Topological semi-metals exhibit band crossings near the Fermi energy, which are protected by the non-trivial topological character of the wave functions. In many cases, these topological band degeneracies give rise to exotic surface states and unusual magneto-transport properties. In this talk, I will discuss this physics in the context of *magnetic* semi-metals with non-symmorphic symmetries. In particular, I will show that non-symmorphic symmetries of cubic magnetic space groups lead to protected four-fold degenerate Dirac points and Dirac lines. As a concrete example, I will examine the topological properties of the antiferromagnet CuBi_2O_4 in terms of a low-energy tight-binding model, derived from ab-initio DFT calculations. I will discuss the monopole charges and the associated surface states of this system.

DS 33.2 Wed 15:15 HSZ 204

Density wave instabilities and surface state evolution in interacting Weyl semimetals — MANUEL LAUBACH¹, CHRISTIAN PLATT², RONNY THOMALE³, TITUS NEUPERT⁴, and ●STEPHAN RACHEL¹ — ¹TU Dresden — ²Stanford University — ³University of Würzburg — ⁴University of Zürich

We investigate the interplay of many-body and band structure effects of interacting Weyl semimetals (WSM). Attractive and repulsive Hubbard interactions are studied within a model for a time-reversal-breaking WSM with tetragonal symmetry, where we can approach the limit of weakly coupled planes and coupled chains by varying the hopping amplitudes. Using a slab geometry, we employ the variational cluster approach to describe the evolution of WSM Fermi arc surface states as a function of interaction strength. We find spin and charge density wave instabilities which can gap out Weyl nodes. We identify scenarios where the bulk Weyl nodes are gapped while the Fermi arcs still persist, hence realizing a quantum anomalous Hall state.

DS 33.3 Wed 15:30 HSZ 204

Experimental observation of type-II Weyl states in TaIrTe_4 — ●ERIK HAUBOLD¹, KLAUS KOEPERNIK¹, DMITRIY EFREMOV¹, SEUNGHYUN KHMIM², ALEXANDER FEDOROV^{1,3}, YEVHEN KUSHNIRENKO¹, JEROEN VAN DEN BRINK^{1,4}, SABINE WURMEHL^{1,4}, BERND BÜCHNER^{1,4}, TIMUR KIM⁵, MORITZ HOESCH⁵, KAZUKI SUMIDA⁶, KAZUAKI TAGUCHI⁶, TOMOKI YOSHIKAWA⁶, AKIO KIMURA⁶, TAICHI OKUDA⁷, and SERGEY BORISENKO¹ — ¹IFW Dresden, P.O. Box 270116, 01171 Dresden, Germany — ²MPI CPFS, 01187 Dresden, Germany — ³II. Physikalisches Institut, Universität zu Köln, 50937 Köln, Germany — ⁴Department of Physics, TU Dresden, 01062 Dresden, Germany — ⁵Diamond Light Source, Didcot OX11 0DE, United Kingdom — ⁶Graduate School of Science, Hiroshima University, Higashi-Hiroshima 739-8526, Japan — ⁷Hiroshima Synchrotron Radiation Center, Hiroshima University, Higashi-Hiroshima 739-0046, Japan

Weyl semimetals have raised a lot of interest lately due to their interesting exotic surface states. TaIrTe_4 , belonging to the recently introduced class of type-II Weyl semimetals, hosts 4 Weyl points. These are well separated in the Brillouin zone and connected by rather long and parallel Fermi Arcs, making the material especially interesting for further research and future applications. In this work we find direct correspondence between theoretical predictions and ARPES results for both bulk and the surface states. Remarkably, these surface states are spin polarized, highlighting the potential for novel applications.

DS 33.4 Wed 15:45 HSZ 204

Magneto-optical infrared studies of the Weyl semimetals TaAs, TaP and NbP — D. NEUBAUER¹, R. KEMMLER¹, W. LI¹, R. HÜBNER², A. LÖHLE¹, M. SCHILLING¹, M. SCHMIDT³, C. SHEKHAR³, C. FELSER³, M. DRESSEL¹, and ●A. V. PRONIN¹ — ¹Physikalisches Institut, Universität Stuttgart, Germany — ²FMQ, Universität Stuttgart, Germany — ³MPI CPFS, Dresden, Germany

We have investigated the infrared response of TaAs, TaP, and NbP in zero magnetic field and in fields of up to 30 T. Additionally, magneto-transport measurements have been conducted on the same samples. In all compounds, we can reliably trace the transitions between different

Landau levels. The transition frequencies demonstrate a square-root field dependence, typical for the linearly dispersed bands. In TaP, we can also see a sizeable shifting of the plasma edge in magnetic field and an interplay between this plasma-edge shift and the Landau-level transitions. We compare the optical spectra of the three compounds, describe the spectra by the recent models for the (magneto)-optical response of Weyl semimetals, and extract such parameters as the Fermi velocities of the carriers in the Weyl bands and the positions of the Fermi levels relative to the Weyl points.

DS 33.5 Wed 16:00 HSZ 204

Emergent Weyl fermion bulk excitations in TaP evidenced from ^{181}Ta quadrupole resonance — H. YASUOKA^{1,2}, T. KUBO^{1,3}, Y. KISHIMOTO^{1,3}, D. KASINATHAN¹, M. SCHMIDT¹, B. YAN¹, Y. ZHANG⁴, H. TOU³, C. FELSER¹, A.P. MACKENZIE^{1,5}, and ●M. BAENITZ¹ — ¹MPI for Chemical Physics of Solids, 01187 Dresden, Germany — ²Advanced Science Research Center, Japan Atomic Energy Agency, Tokai, Japan — ³Department of Physics, Graduate school of Science, Kobe University, Kobe, Japan — ⁴IFW Dresden, P.O. Box 270116, 01171 Dresden, Germany — ⁵SUPA, School of Physics & Astronomy, University of St. Andrews, UK

The monophosphite TaP has a non centrosymmetric structure and sizeable spin orbit coupling and belongs the class of Weyl semimetals. A crossing of linear dispersive ($E \propto k$) topologically protected polarized bands in a single point in reciprocal space defines the Weyl node where the fermion mass vanishes theoretically and a giant orbital hyperfine coupling is expected [1]. ^{181}Ta quadrupole resonance (NQR) resolves three NQR lines associated to the split level transitions for $I=7/2$ Ta. The spin lattice relaxation was measured for the $\pm 5/2 \leftrightarrow \pm 3/2$ transition. Above 30 K, a pronounced $(1/T_1T) \propto T^2$ is found. We attributed this to the magnetic excitations of Weyl fermions ($N(E) \propto E^2$) with temperature dependent orbital hyperfine coupling in agreement with the prediction from theory [1].

[1] Z. Okvatovity et al., arXiv:1609.3370v1

15 min. break.

DS 33.6 Wed 16:30 HSZ 204

Magnetic Properties of Dirac Fermions in a Family of Anti-perovskites — ●MORITZ MANDES HIRSCHMANN and ANDREAS PHILIPP SCHNYDER — Max Planck Institute for Solid State Research, Stuttgart, Germany

We study the magnetic properties of the anti-perovskite materials A_3EO , where A denotes an alkaline earth metal, while E stands for Pb or Sn. The low-energy electronic properties of this family of anti-perovskites is described by three-dimensional Dirac fermions, which are gapped out by spin-orbit coupling [1-3]. We discuss the magnetic response of this Dirac electron system, considering both orbital and spin Zeeman effects. Interestingly, a strong Zeeman field splits the gapped Dirac cones into ungapped Weyl points, which are protected by a quantized Chern number. The compound Eu_3PbO breaks in its ferromagnetic phase intrinsically the time-reversal symmetry by exhibiting a magnetization that corresponds to a large Zeeman splitting at the Europium atoms. Again we observe Weyl points in the band structure. Using a tight-binding description we calculate these Chern numbers and demonstrate that the Weyl points are connected by Fermi arcs in the surface Brillouin zone. Furthermore, we determine the Landau level structure of the gapped Dirac electrons.

[1] T. H. Hsieh, J. Liu, and L. Fu. *Phys. Rev. B*, 90:081112, Aug 2014[2] J. Nuss, C. Mühle, K. Hayama, V. Abdolazimi, and H. Takagi. *Acta Crystallographica Section B*, 71(3):300-312, Jun 2015.[3] D. Samal, H. Nakamura, and H. Takagi. *APL Mater.*, 4(7), 2016.

DS 33.7 Wed 16:45 HSZ 204

Emergent Weyl points from Floquet Weyl semimetals in the resonant limit — ●LEDA BUCCIANINI¹, STITHADI ROY¹, SOTA KITAMURA², and TAKASHI OKA¹ — ¹Max Planck Institute for Physics of Complex Systems, Germany — ²Tokyo University, Japan

We investigate the formation of Weyl points from a Dirac semimetal after shining it with circularly polarized light, focusing on the resonant frequency limit. Within a Floquet formalism, we describe the phase

diagram as a function of the intensity and frequency of the laser. A couple of Weyl points split both from the original Dirac point and from the Floquet side bands. Increasing the value of the laser intensity, the Weyl points emerging from the original Dirac point and the side band merge, annihilate and then gap out. We also compute the monopole charge for each of the emergent Weyl points.

DS 33.8 Wed 17:00 HSZ 204

Self-forming superconducting microstructures from Weyl semi-metals — ●MAJA D. BACHMANN¹, NITYAN NAIR³, FELIX FLICKER³, RONI ILAN³, NIRMAL J. GHIMIRE², ERIC D. BAUER², FILIP RONNING², JAMES G. ANALYTIS³, and PHILIP J.W. MOLL¹ — ¹Max-Planck-Institute for Chemical Physics of Solids, 01187 Dresden, Germany — ²Los Alamos National Laboratory, Los Alamos, NM, USA — ³Department of Physics, University of California Berkeley, CA, USA

The non-trivial topology of the bulk bands in topological semi-metals protects new electronic states at the surface, such as the famous Fermi arc states. If a superconducting gap is induced in these materials, exotic electronic states are expected to appear at the interface such as zero-energy Majorana modes. These novel states provide insights into the topological aspects of electronic matter and are of interest for quantum coherent applications. Here we will present a new route to reliably fabricating superconducting microstructures from the intrinsically non-superconducting Weyl semi-metals NbAs and TaAs under ion irradiation. The large difference in the surface binding energy of Nb/Ta and As leads to a natural enrichment of Nb/Ta at the surface during ion milling, forming a superconducting surface layer ($T_c \sim 3.5\text{K}$). Being formed from the target crystal itself, the ideal contact between the superconductor and the bulk enables an effective gapping of the nodes due to the proximity effect. Simple low energy ion irradiation may thus serve as a powerful tool to fabricate topological quantum devices from mono-arsenides, even on an industrial scale.

DS 33.9 Wed 17:15 HSZ 204

Angle-dependent magnetoresistance in Weyl semimetals with long-range disorder — ●JAN BEHREND¹ and JENS H

BARDARSON^{1,2} — ¹Max-Planck-Institut für Physik komplexer Systeme, 01187 Dresden, Germany — ²Department of Theoretical Physics, KTH Royal Institute of Technology, Stockholm, SE-106 91 Sweden

The chiral anomaly is one of the most intriguing features of Weyl semimetals. It states that left- and right-handed fermions are not conserved individually, while their sum is. One of its experimental consequences is the negative magnetoresistance predicted in Weyl semimetals. Recent experiments show strong indications for such an anomalous conductivity response, while some outstanding issues remain. Most prominently, the anomalous response is much more sharply peaked for parallel magnetic and electric fields than expected from simple theoretical considerations. Here, we investigate scattering in Weyl semimetals in presence of magnetic fields for a correlated disorder potential. We find a decrease of the internode relaxation time when the magnetic field is tilted away from the separation of the Weyl nodes. Since the internode relaxation time is proportional to the anomaly-related conductivity, this feature may explain the narrow current plume seen experimentally.

DS 33.10 Wed 17:30 HSZ 204

Surface states in holographic Weyl semimetals — ●MARKUS HEINRICH, AMADEO JIMENEZ-ALBA, SEBASTIAN MÖCKEL, and MARTIN AMMON — Theoretisch-Physikalisches Institut, Friedrich-Schiller-Universität Jena

Weyl semimetals (WSMs) are a class of gapless topological materials with low-energy excitations behaving as Weyl fermions. Their most prominent feature are topologically protected surface states, so-called Fermi arcs, which were recently tied to an effective axial magnetic field arising at a surface due to lattice deformations. As in the chiral magnetic effect, this field gives rise to an anomalous current at finite chemical potential which is localised at the surface. We performed its subtle computation in the strong coupling limit by using a holographic model. We found a non-trivial universality of the current, allowing us to interpret it in a simple Fermi arc-like picture. In the end, I will discuss the limits of this universality.