TT 21: Topological Semimetals 1

Time: Tuesday 9:30–13:00 Location: HSZ 103

TT 21.1 Tue 9:30 HSZ 103

Optical conductivity of generalized Weyl semimetals — •Lucky Z. Maulana[1], Ece Uykur[1], Seulki Roh[1], Yohei Saito[1], Motoharu Imai[2], Kaustuv Manna[3], Claudia Felser[3], Martin Dressel[1], and Artem V. Pronin[1] — [1]1. Physikalisches Institut, Universität Stuttgart, 70569 Stuttgart, Germany — [2]National Institute for Materials Science (NIMS), Tsukuba, Ibaraki 305-0047, Japan — [3]MPI für Chemische Physik fester Stoffe, 01187 Dresden, Germany

Generalizations of Weyl semimetals are realized in materials, where more than two non-degenerate electronic bands touch at a given point of Brillouin zone. We have optically studied two groups of such materials: the multifold semimetals RhSi, CoSi, and PdGa, where the higher-spin generalizations of Weyl points have been confirmed, and $SrSi_2$ – a material, where quadratic double-Weyl fermions are supposed to be realized. In the presentation, we report our results on broadband complex optical conductivity for all these materials, comparer their optical spectra, and conclude on the peculiarities of their low-energy band structure based on our experiments.

TT 21.2 Tue 9:45 HSZ 103

The chiral anomaly in Weyl semimetals as seen by optics — Ece Uykur[1], Lucky Z. Maulana[1], Shekhar Chandra[2], Claudia Felser[2], Martin Dressel[1], and •Artem V. Pronin[1] — [1]1. Physikalisches Institut, Universität Stuttgart, 70569 Stuttgart, Germany — [2]MPI für Chemische Physik fester Stoffe, 01187 Dresden, Germany

The density imbalance between the electronic excitations with different chiralities in simultaneously applied parallel electric and magnetic fields, the chiral anomaly, is perhaps the most fascinating phenomenon occurring in Weyl semimetals. The existing experimental results reported on the chiral anomaly are mostly based on electrical-transport measurements using direct current, for example, on observations of the negative longitudinal magnetoresistance. However, it has been argued that dc transport may suffer from other effects, such as current jetting. Reports on detecting the chiral anomaly by other experimental methods are therefore of paramount importance. Here, we report on optical observations of the chiral anomaly in the Weyl semimetals TaAs and NbAs and also in GdPtPi, a triple-point semimetal, which becomes a Weyl semimetal upon application of a magnetic field.

TT 21.3 Tue 10:00 HSZ 103

Optical fingerprinting of magnetic reorientation in Weyl semimetals — •Ananya Biswas[1], Hechang Lei[2], Martin Dressel[1], and Ece Uykur[1] — [1]1. Physikalisches Institut, Universität Stuttgart, Germany — [2]Department of Physics and Beijing Key Laboratory of Opto-electronic Functional Materials & Micro-nano Devices, Renmin University of China, Beijing, China

Three dimensional magnetic Weyl semimetals are relatively new members of this topological realm, where the electron correlations are intertwined with flat bands and heavy fermions. They have been investigated extensively via transport and magneto-transport studies, while the optical investigations on these systems are scarce. Here, we focus on the optical characterization of the Fe_3Sn_2 single crystals that has shown to be one of the magnetic Weyl semimetal candidates. This material is a soft ferromagnet with distinguished flat bands and Weyl nodes, where the T_c=640 K and a spin reorientation takes place at $\sim$ 150 K. Our optical results demonstrate the typical signatures of the electron correlations together with the optical anomalies at the spin reorientation temperature indicating the close relation of the electronic and underlying magnetic structure in these new class of materials.

TT 21.4 Tue 10:15 HSZ 103

Resonance Raman scattering and magnetic-field tuning of the electronic band structure in the topological semimetal PdGa — Vladimir Gnezdilov[1,2,3], Dirk Wulferding[1,2], •Peter Lemmens[1,2], Florian Büscher[1], Yurii Pashkevich[4], Tanya Shevtsova[4], Claudia Felser[5], and Kaustuv Manna[5] — [1]IPKM, TU-BS, Braunschweig, Germany — [2]LENA, TU-BS, Braunschweig, Germany — [3]ILTPE Kharkov, Ukraine — [4]Galkin DonFTI, Kyiv, Ukraine — [5]MPI Dresden, Germany

The novel chiral topological semimetal PdGa is the first known compound where electronic bands acquire a maximal Chern number of $C = \pm 4$ [1]. Using Raman spectroscopy, we uncover a strong and sharp electronic resonance around $E = 2.35$ eV that allow us to follow changes of electronic Raman scattering occurring in moderate magnetic fields as well as phonon anomalies. Both observations point to a possible modification of the electronic band structure in PdGa in magnetic fields.

Work supported by DFG LE967/16-1 and QUANOMET NL-4.

[1] Schröter et al., arXiv:1907.08723 (2019)

TT 21.5 Tue 10:30 HSZ 103

Semi-Dirac state revealed in black phosphorus via high-pressure studies — •D. Rodriguez[1], Q. Yan[2], M. Dressel[1], and E. Uykur[1] — [1]1. Physikalisches Institut, Universität Stuttgart, 70569, Stuttgart, Germany — [2]Department of Chemistry, Tsinghua University, Beijing 100084, China

Semi-Dirac materials are a class of Dirac/Weyl semimetals that display a two-feature energy dispersion: linear (relativistic) along one momentum direction and quadratic (non-relativistic) in the other direction. The realization of this unique state in real materials is still pending. One promising system is the black phosphorus (BP). It has been theoretically predicted that hydrostatic pressure can close the band gap, driving the system through several electronic transitions from a gapped insulator with inverted bands to a Dirac semimetal state. An intermediate phase exists though, the semi-Dirac state characterized by a gapless anisotropic spectrum dispersing linearly along its armchair direction and parabolically along the zigzag. Here, we report high-pressure infrared measurements of BP tuned successfully through the insulator-to-metal transition. Our optical conductivity results present a highly anisotropic behavior for different light polarization in the low energy range consistent with the theoretical predictions of a semi-Dirac state. Moreover, results indicate that Dirac state in BP has a 3D character rather than 2D.

TT 21.6 Tue 10:45 HSZ 103

Surface Berry curvature dipole of Weyl semimetals — •Dennis Wawrzik[1], Jihh-Shih You[1], Inti Sodemann[2], and Jeroen van den Brink[1,3] — [1]Institute for Theoretical Solid State Physics, IFW Dresden, Germany — [2]Max Planck Institute for the Physics of Complex Systems, Dresden, Germany — [3]Department of Physics, TU Dresden, Germany

In the absence of magnetic field, the Hall effect in the linear response regime vanishes due to time-reversal symmetry. However, a transverse charge current can still occur in second-order response to an external electric field, as a result of the Berry curvature dipole (BCD) in momentum space. While there has been much effort to understand nonlinear transport due to a BCD in bulk, here we show that for Weyl semimetals the surface Fermi arcs of a proper chosen surface give rise to a giant BCD. In particular, the surface BCD scales with the sample size. In our study, we employ a general k-dot-p model which covers a wide class of type-I Weyl materials.

TT 21.7 Tue 11:00 HSZ 103

$e/2$ and $e/4$ quantization of the boundary charge in one-dimensional Weyl semimetals — •Mikhail Pletyukhov[1], Dante Kennes[1], Jelena Klinovaja[2], Daniel Loss[2], and Herbert Schoeller[1] — [1]RWTH Aachen University, Germany — [2]University of Basel, Switzerland

Universal properties of the boundary charge Q_B for one-dimensional and one-channel insulators have been studied in the recent papers [1]. At half-filling, the gap can close under certain conditions, and in this talk we discuss the associated Weyl semimetal physics extending our previous study of the boundary charge. We find quantization of Q_B in two generic classes of charge $e/2$ or $e/4$ in the presence of nonlocal inversion/chiral symmetries. We make a generalization to the Weyl case of both the Diophantine equation [2] , which includes numbers of edge modes connecting adjacent Weyl points, and the universal phase-dependence of the boundary charge [1]. Its fluctuations are shown to be very small in the quantized regions and featuring a remarkable power-law behaviour close to the phase points where the boundary charge makes a jump.

[1] M. Pletyukhov et al, arXiv: 1911.06886; 1911.06890
[2] I. Dana et al, J. Phys. C 18, L679 (1985); M. Kohmoto, Phys. Rev.

B 39, 11943 (1989); Y. Hatsugai, Phys. Rev. B 48, 11851 (1993)

15 min. break.

TT 21.8 Tue 11:30 HSZ 103

Non-Abelian anomalies in multi-Weyl semimetals — •Renato Miguel Alves Dantas, Francisco Peña-Benitez, Bitan Roy, and Piotr Surówka — Max-Planck-Institut für Physik komplexer Systeme, Nöthnitzer Str. 38, 01187 Dresden, Germany

We construct the effective field theory for time-reversal symmetry breaking multi-Weyl semimetals (mWSMs), composed of a single pair of Weyl nodes of (anti-)monopole charge n, with $n = 1, 2, 3$ in crystalline environment. From both the continuum and lattice models, we show that a mWSM with $n > 1$ can be constructed by placing n flavors of linearly dispersing simple Weyl fermions (with $n = 1$) in a bath of an $SU(2)$ non-Abelian static background gauge field. Such an $SU(2)$ field preserves certain crystalline symmetry (four-fold rotational or C_4 in our construction), but breaks the Lorentz symmetry, resulting in nonlinear band spectra (namely, $E \sim (p_x^2 + p_y^2)^{n/2}$, but $E \sim |p_z|$, for example, where momenta $\mathbf{p}$ is measured from the Weyl nodes). Consequently, the effective field theory displays $U(1) \times SU(2)$ non-Abelian anomaly, yielding anomalous Hall effect, its non-Abelian generalization, and various chiral conductivities. The anomalous violation of conservation laws is determined by the monopole charge n and a specific algebraic property of the $SU(2)$ Lie group, which we further substantiate by numerically computing the regular and "isospin" densities from the lattice models of mWSMs. These predictions are also supported from a strongly coupled (holographic) description of mWSMs.

TT 21.9 Tue 11:45 HSZ 103

Spin and valley wave collective modes in metals with population imbalance — •Alexander Zyuzin — Aalto University, Finland

The effect of electron-electron exchange interaction in metals with non-equilibrium spin orientation will be first reviewed. It will be shown, that as a result of the interaction, there exists a spin wave mode, describing the spin precession in the absence of applied magnetic field. The dispersion relation of the mode is gapless, proportional to the square of the wave vector at small frequencies, and inversely proportional to the electron-electron exchange interaction energy. The valley wave analog will be then discussed for the case of metals with valley population imbalance. Doped graphene and three-dimensional Weyl-Dirac semimetals will be considered as particular material candidates. The spin and valley waves serve as the energy gain sources for the external field, that generates the spin or inter-valley transitions.

TT 21.10 Tue 12:00 HSZ 103

Temperature effects on the conductivity of strongly-correlated Dirac semimetals — •Niklas Wagner[1], Sergio Ciuchi[2], Björn Trauzettel[1], and Giorgio Sangiovanni[1] — [1]Institut für Theoretische Physik und Astrophysik and Würzburg-Dresden Cluster of Excellence ct.qmat, Universität Würzburg, 97074 Würzburg, Germany — [2]Department of Physical and Chemical Sciences, University of L'Aquila, Italy

Dirac semimetals can be seen as the three-dimensional generalization of graphene, hosting linearly dispersing bands in the vicinity of a degeneracy point of the bandstructure. We investigate the effects of strong electronic correlations on various Dirac semimetal models by applying Dynamical Mean Field Theory (DMFT), focusing in particular on the finite-temperature crossover regions. By applying Iterated Perturbation Theory (IPT) we have the resolution on the real axis to calculate accurate transport properties. We calculate the conductivity as a function of the temperature and interaction strength and discuss the physical differences with respect to conventional metals.

TT 21.11 Tue 12:15 HSZ 103

Correlated phases from a three-dimensional pseudo-Landau flat band in a nodal-line semimetal — •Alexander Lau[1], Dmitry Pikulin[2], and Timo Hyart[1] — [1]International Research Centre MagTop, Warsaw, Poland — [2]Microsoft Station Q, Santa Barbara, USA

Nodal-line semimetals are a class of three-dimensional topological semimetals featuring two-fold degenerate band-crossing points that form closed loops in the Brillouin zone of the material. Based on an effective low-energy theory, we show how strain can be used to induce a set of three-dimensional pseudo-Landau levels in nodal-line semimetals. In particular, the zeroth Landau level realizes a three-dimensional flat band which gives rise to strong electron-electron interactions. We study magnetic and superconducting phases arising in this setup and discuss differences to similar phases in two dimensions.

TT 21.12 Tue 12:30 HSZ 103

Photoinduced Anomalous Hall Current in Nodal-Line Semimetals — •Andreas Leonhardt and Andreas P. Schnyder — Max Planck Institute for Solid State Research

Symmetry-protected nodal lines in three dimensions fall into the same topological category as graphene in two dimensions. The Berry curvature vanishes everywhere except for the nodal line, where it is divergent. This implies that the nodal line gives rise to an anomalous Hall conductivity. Like in the graphene case however, there are two valley currents from opposite sides of the nodal line that cancel exactly due to additional spatial symmetries. In candidate materials with a nodal line, spin-orbit coupling is non-negligible. Coupling the spin sub-spaces allows for the nodal line to gap out, turning the material into a topological insulator with a vanishing Berry curvature.

Driving the systems coherently with circular polarized light creates an imbalance between the two valley contributions. Using Floquet theory, we show that a net anomalous Hall current arises in the periodically driven nodal-loop semimetal. Depending on the polarization, the sign of the current can be switched, which is the distinguishing feature of this effect. We further investigate its stability upon gapping the nodal line via spin-orbit coupling or small symmetry breaking terms.

TT 21.13 Tue 12:45 HSZ 103

Strain engineered higher order topological phases for spin-3/2 Luttinger fermions — •Andras Szabo — MPIPKS Dresden

Higher order topological phases attracted a lot of attention in the recent years, and apart from elemental Bi have so far evaded experimental realization in electronic systems. I will present a potential path to use a Luttinger semimetal (LSM) in order to strain engineer a higher order topological Dirac semimetal (HOTDSM).

A Luttinger semimetal is constituted by effective spin-3/2 fermions and describes a bi-quadratic touching of Kramers degenerate valence and conduction bands. Several materials are believed to be sufficiently described by such model, including 227 pyrochlore iridates, half-Heuslers, HgTe and gray-Sn. Moreover, advances in experimental technology (piezoelectric-based apparatus, and growing samples on suitable substrates) present an infrastructure promising for the strain-engineering of such HOT phases.

I will show that certain nematic phases of a LSM, that can be induced by the application of external strain, describe a HOTDSM with topological hinge states along the strain direction. I will also argue that these phases are stable in the presence of sufficiently weak disorder, an inherent feature of real world material samples.