MA 33: Focus Session: Topology in 3D Reciprocal Space: Beyond Dirac and Weyl Quasiparticles (joint session TT/MA)

Topological Dirac and Weyl semimetals are currently in focus of condensed-matter research. The ultra-relativistic electrons in these systems manifest themselves in experimental probes in many very unusual ways, such as chiral currents, hydrodynamic electron flows, and chiral optical response. Theory and experiment go further and offer even more exotic topological phases, which have no analogies in high-energy physics. Among the recent discoveries are Lorentz-invariance breaking quasiparticles, multi-Weyl semimetals, and topological phases in non-electronic systems.

Organized by: Artem Pronin (Universität Stuttgart), Claudia Felser (MPI-CPfS Dresden), Martin Dressel (Universität Stuttgart)

Time: Wednesday 15:00–18:15 Location: H2

Invited Talk MA 33.1 Wed 15:00 H2

Novel optical and electrical responses in topological semimetals — •Joel Moore — University of California, Berkeley, USA — Lawrence Berkeley National Laboratory, Berkeley, USA

Several new classes of topological materials have been confirmed to exist in experiments over the past decade. Many of these materials support unique electromagnetic properties that affect transport and optical responses in potentially useful ways. For example, topological insulators support a particular electromagnetic coupling known as "axion electrodynamics", and understanding this leads to an improved understanding of magnetoelectricity in all materials. The main focus of this talk is on how topological Weyl and Dirac semimetals can show unique electromagnetic responses; we argue that in linear response the main observable property solves an old problem about optical rotation via the orbital moment of Bloch electrons. Nonlinear responses such as magnetoconductivity can reveal more surprising behavior. Nonlinear optical response (second-harmonic generation) is already known to be remarkably strong in existing Weyl materials, and may show an unexpected strength and quantization in Weyl materials without mirror symmetries.

Talk includes results obtained with Fernando de Juan, Adolfo Grushin, Takahiro Morimoto, Joseph Orenstein, Daniel Parker, Ivo Souza, and Shudan Zhong.

Invited Talk MA 33.2 Wed 15:30 H2

Beyond the elementary particles and the 10-fold classification of non-interacting topological phases — •Alexey Soluyanov — Physics Institute, University of Zurich, Zurich, Switzerland

One of the research directions in string theory is the separation of important theoretical problems into distinct classes based on their similarities. Electronic structure problem is usually not considered to be important in the string theory community. In this talk I will show that the electronic structure theory in fact allows not only for theoretical analysis of problems in quantum field theory and general relativity, but also for their cheap (on the LHC scale) experimental tests, and also provides many hints to other problems in physics, often considered to be of bigger importance than the study of material properties. In particular, I will show that even weakly-interacting crystalline materials realize a collection of topologically-protected quasiparticle excitations that can either be direct analogs of relativistic elementary particles, or due to the absence of Lorentz-symmetry constraint realize completely novel quasiparticles not present in the high-energy standard model. Materials that host such quasiparticles exhibit special transport properties. I will give a detailed description of several families of such materials. Finally, I will show that even the simplest elemental compounds hide physical phenomena that provide very accessible analogies to complicated theoretical physics theories, and illustrate that the current understanding of even the simplest non-correlated crystalline materials is far from complete.

Invited Talk MA 33.3 Wed 16:00 H2

Direct optical detection of Weyl fermion chirality in a topological semimetal — •Nuh Gedik — Department of Physics, Massachusetts Institute of Technology, Cambridge, MA USA

A Weyl semimetal is a novel topological phase of matter, in which Weyl fermions arise as pseudo-magnetic monopoles in its momentum space. The chirality of the Weyl fermions, given by the sign of the monopole charge, is central to the Weyl physics, since it serves as the sign of the topological number and gives rise to exotic properties such as Fermi arcs and the chiral anomaly. In this talk, I will present our recent measurements in which we directly detect the chirality of the Weyl fermions by measuring the photocurrent in response to circularly polarized mid-infrared light. The resulting photocurrent is determined by both the chirality of Weyl fermions and that of the photons. Beyond Weyl semimetals, these experiments establish nonlinear photocurrent spectroscopy as a powerful tool for studying the geometrical properties of the electronic wavefunction in quantum materials. To this end, I will also discuss how we used this method to reveal electrically switchable Berry curvature dipole in the monolayer topological insulator WTe2.

15 min. break.

Invited Talk MA 33.4 Wed 16:45 H2

Evidence for an axionic charge density wave in the Weyl semimetal $(TaSe_4)_2I$ — •Johannes Gooth — Max Planck Institut für Chemische Physik fester Stoffe

An axion insulator is a correlated topological phase, predicted to arise from the formation of a charge density wave in Weyl semimetals. The accompanying sliding mode in the charge density wave phase, the phason, is an axion. It is expected to cause anomalous magneto-electric transport effects. However, this axionic charge density wave has so far eluded experimental detection. In this paper, we report for the first time the observation of a large, positive contribution to the magneto-conductance in the sliding mode of the charge density wave Weyl semimetal $(TaSe_4)_2I$ for collinear electric and magnetic fields (E||B). The positive contribution to the magneto-conductance originates from the anomalous axionic contribution of the chiral anomaly to the phason current, and is locked to the parallel alignment of E and B. By rotating B, we show that the angular dependence of the magneto-conductance is consistent with the anomalous transport of an axionic charge density wave.

Invited Talk MA 33.5 Wed 17:15 H2

Investigations of Dirac/Weyl semimetals under external stimuli — •Ece Uykur — 1. Physikalisches Institut, Universität Stuttgart, Stuttgart, Germany

Dirac/Weyl semimetals acquire 3D linearly dispersive electronic bands, as opposed to the parabolic bands, with band crossings near the Fermi energy, where the low energy excitations are described by the relativistic Weyl or Dirac equations. Optical spectroscopy is one of the strongest methods to probe these low energy responses. Moreover, it can be coupled to an external tuning mechanism such as magnetic fields, pressure, etc. Additional tuning parameters can be used to create a Dirac/Weyl state and/or to provide valuable information about the nature of the observed topological state. A peculiar magnetic field dependence of the Landau-level transitions, for instance, would hint the existence of the massless Dirac/Weyl fermions in the studied system. In this talk, I will summarize our efforts on different Weyl/Dirac semimetals and their optical responses under an external tuning parameter.

MA 33.6 Wed 17:45 H2

Optical conductivity studies of topological nodal semimetals — •Artem V. Pronin[1], David Neubauer[1], Micha B. Schilling[1], Felix Hütt[1], Martin Dressel[1], Alexander Yaresko[2], Leslie M. Schoop[3], Chandra Shekhar[4], and Claudia Felser[4] — [1]1. Physikalisches Institut, Universität, Stuttgart, 70569 Stuttgart, Germany — [2]MPI für Festkörperforschung, 70569 Stuttgart, Germany — [3]Princeton University, Princeton, NJ 08544, USA — [4]MPI für Chemische Physik fester Stoffe, 01187 Dresden, Germany

We have studied a large number of different topological nodal semimetals (TNSMs) by means of optical spectroscopy [1]. Theory predicts that the optical conductivity of TNSMs is not only distinct from the response of "ordinary" semiconductors and metals, but also very sensitive to the TNSM's band structure and band dimensionality [2]. In real TNSMs, free-electron absorption and contributions from topologically trivial parabolic bands are essential. Both effects may mask the predicted behavior. Some of the studied materials are indeed affected by the aforementioned effects quite substantially. In the others, the low-energy optical response, related to the linear electronic bands, is clearly observed. In the course of the presentation, optical conductivity of the studied TNSMs will be discussed alongside the theory predictions.

[1] PRB **93**, 121202 (2016); PRL **119**, 187401 (2017); PRL **121**, 176601 (2018); PRB **98**, 195203 (2018); JPCM **30**, 485403 (2018).
[2] PRL **108**, 046602 (2012).

MA 33.7 Wed 18:00 H2

Thin-film investigations of 3D Dirac fermions in antiperovskite compounds — •Dennis Huang[1], Hiroyuki Nakamura[1], Eslam Khalaf[1,2], Pavel Ostrovsky[1,3], Kathrin Müller[1], Ulrich Starke[1], Alexander Yaresko[1], and Hidenori Takagi[1,4,5] — [1]Max Planck Institute for Solid State Research, 70569 Stuttgart, Germany — [2]Department of Physics, Harvard University, Cambridge MA 02138, USA — [3]L. D. Landau Institute for Theoretical Physics RAS, 119334 Moscow, Russia — [4]Department of Physics, University of Tokyo, 113-0033 Tokyo, Japan — [5]Institute for Functional Matter and Quantum Technologies, University of Stuttgart, 70569 Stuttgart, Germany

Topological semimetals hosting Dirac or Weyl fermions lie at the forefront of research in condensed matter physics. Recently, a class of antiperovskite compounds (A_3BO: A = Ca, Sr, Ba; B = Sn, Pb) have been predicted to possess both massive 3D Dirac fermions and topological surface states protected by crystal symmetry. Using molecular beam epitaxy, we grow thin films of the antiperovskite compounds Sr_3PbO and Sr_3SnO. We report ongoing efforts to elucidate the exotic electronic properties of these compounds using transport and spectroscopic probes.