IPM

Institute for Research in Fundamental Sciences

School of Physics

Ph.D. Defense Session

Title:

Anomalous transport signatures of strained Weyl semimetals

Candidate:

Shiva Heidari, IPM

Virtual Room:

www.skyroom.online/ch/schoolofphysics/defense

Time/ Date:

15:30 / 13 October 2020

۱۵:۳۰ /۲۲ مهر ۱۳۹۹

Abstract:

The Bloch theory of electronic states can predict the nontrivial topological structures. As long as the topological invariants remain well-defined in a periodic cycle, the gaps never close and the crossing points never open gaps. Berry phase or Zak's phase is an intrinsic phase acquired by the Bloch wave function of electronic states which is nonzero for topologically nontrivial systems. Weyl semimetal is a topological phase of matter whose band crossing points are topologically protected and never open gaps. Weyl nodes in bulk are the source of the Berry curvature in momentum space with opposite signs at different points. The topological nature of bulk sates leads to the unique and unusual Fermi arc surface states. In contrast to the topological insulators that surface states are thoroughly separated from the bulk bands, Fermi-arc in Weyl semimetals connect to the bulk states. The unique and unprecedented surface states in Weyl semimetals are mainly used as an experimental smoking gun to confirm the Weyl phase. One of the most interesting aspects of the physics of Weyl semimetals is the chiral anomaly in the presence of the electromagnetic field. Chiral anomaly supplies many exotic and interesting transport phenomena in Weyl semimetals including exotic electromagnetic response, anomalous Hall effect, negative magnetoresistance and the chiral magnetic effect. In recent years, it has been shown that the elastic deformation in Weyl semimetals can couple to the electronic excitation in the form of elastic gauge fields. The electron-phonon coupling due to strain leads to the pseudomagnetic and pseudoelectric fields in the Weyl semimetals which may lead to novel physical properties. In this thesis, we will focus on three novel physical consequences of a lattice distortion in Weyl semimetals. At first, we will discuss the chiral Hall effect in the strained Weyl semimetals without any external magnetic field. The chiral Hall effect is interpreted as the spatial chirality and charge separation in a deformed Weyl semimetal. The planar Hall effect as another signatures of the electron-phonon coupling will also be introduced. Subsequently, we will show that Hall viscosity can indeed modify the phonon dynamics. To this end, we first consider a model Hamiltonian and then determine the elastic gauge fields associated to both acoustic and optical phonons. It will be shown that the topological Hall viscosity for optical phonons may conduct a measurable shift in the optical branch of phonon dynamics which can be confirmed by Raman experiment. Finally, we will introduce the topological Fermi liquid theory to describe the anomaly-induced collective excitations in Weyl semimetals. The novel anomalous plasmon mode is proposed in strained Weyl semimetals which unidirectionally propagates along the pseudomagnetic field and vanishes instantly in the absence of lattice distortion. The origin of this gaped vi mode is the oscillation of charge density between the bulk and the boundaries triggered by the strain-induced anomalous non-conservation of local charge. The unusual thermal transport associated to the anomalous plasmons is proposed along the pseudomagnetic field. Such unprecedented thermal conductivity which does not satisfy the WiedemannFranz law can be considered as an experimental smoking gun to confirm the presence of the anomalous plasmon mode.

Address: School of Physics, Institute for Research in Fundamental Sciences (IPM), No. 70, Lavasani St., Tehran, Iran

Tel: +98 (21) 22 28 06 92, 22 29 09 34