PHYSIK

THEORETISCH PHYSIKALISCHES KOLLOQUIUM

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Quantum kinetic theory of magneto-transport in topological materials

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Topological materials, such as topological insulators, Weyl semimetals, and strongly spin-orbit coupled semiconductors, have attracted considerable attention due to their potential in spin electronics and quantum computation. Their strong spin-orbit coupling gives rise to a host of observable inter-band coherence effects such as the spin- and anomalous Hall effects, spin-orbit torques, a minimum conductivity and chiral anomalies in magneto-transport. I will first discuss a general quantum kinetic theory of linear response to an electric field which can be applied to solids with arbitrarily complicated band structures and includes the inter-band coherence response and the Bloch-state repopulation response on an equal footing [1]. One of the principal aims of our work is to enable extensive transport theory applications using computational packages constructed in terms of maximally localized Wannier functions. I will demonstrate that the inter-band response in conductors consists primarily of two terms: an intrinsic contribution due to the entire Fermi sea that captures, among other effects, the Berry curvature contribution to wave-packet dynamics, and an anomalous contribution caused by scattering that is sensitive to the presence of the Fermi surface. The Berry phase correction to the density of states in a magnetic field in semiclassical wavepacket dynamics appears as an intrinsic contribution to the density matrix in linear response to a magnetic field. I will subsequently discuss the magneto-transport of Weyl metals that results from chiral anomalies, i.e., positive magneto-conductances quadratic in magnetic field associated with the presence of separate Fermi surface pockets surrounding distinct Weyl points. Our theory explicitly accounts for the dependence of chiral anomalies on weak inter-pocket scattering, and demonstrates that the chiral anomaly only partially survives disorder scattering even in the limit of extremely weak inter-pocket scattering [2]. Finally I will focus on the charge conductivity of 2D hole systems, which displays strong signatures of the spin-orbit interaction. The Hall coefficient in a weak perpendicular magnetic field contains a contribution of second order in the spin-orbit interaction and non-linear in the carrier number density, which at high densities represents as much as 20% of the total signal. An appropriate experimental setup with top and back gates can lead to a direct electrical measurement of the spin-orbit constant [3]. I will end with a summary of potential future applications of our approach.

References:

1. Dimitrie Culcer, Akihiko Sekine, and A. H. MacDonald, Phys. Rev. B **96**, 035106 (2017).
2. Akihiko Sekine, Dimitrie Culcer, and A. H. MacDonald, arXiv:1706.01200, to appear in Phys. Rev. B.
3. Hong Liu, Elizabeth Marcellina, A. R. Hamilton, and Dimitrie Culcer, arXiv:1708.07247.

Gäste sind herzlich willkommen.

TECHNISCHE UNIVERSITÄT KAISERSLAUTERN

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