Optics and plasmonics of Dirac and Weyl fermions

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Relativistic Dirac and Weyl fermions were extensively studied in quantum field theory. Recently they emerged in the nonrelativistic condensed-matter setting as gapless quasiparticle states in some types of crystals. Notable examples of 2D systems include graphene and surface states in topological insulators such as Bi$_2$Se$_3$. Their 3D reincarnation is Dirac and Weyl semimetals that were recently discovered experimentally. Most of the research has been focused on their topological properties and electron transport. However, their optical and plasmonic properties are no less exciting. Optical phenomena can provide valuable insight into the fascinating physics of these materials. Moreover, their unique optical properties can be utilized in future optoelectronic devices. I will discuss a couple of examples illustrating these points. They include plasmons and polaritons in Dirac/Weyl semimetals and nonlinear optical response of graphene and topological insulators.

Fig. 1. Optical properties of Weyl semimetals in a magnetic field. Left: real part of refractive index as $\mu$ a function of frequency normalized to plasmon resonance for electromagnetic waves propagating at different angles $\theta$ to the magnetic field. The coupling to plasmon oscillations causes the formation of photonic stop bands where $\text{Re}[\mu]=0$. Right: the effect of chiral anomaly on the absorption spectra of right-hand and left-hand circularly polarized electromagnetic waves (RHC and LHC) propagating along the magnetic field.