Bulk and surface polaritons in Weyl semimetals

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Weyl semimetals (WSMs) have attracted a lot of interest as a new class of gapless three-dimensional topological materials. Their Brillouin zone contains an even number of band-touching points, or Weyl nodes, that can be described by topological invariants defined as integrals over the two-dimensional Fermi surface. For each pair of Weyl nodes, these invariants can be viewed as topological chiral charges of opposite sign of chirality. The separation of Weyl nodes in momentum space leads to their topological protection and gives rise to surface states with so-called Fermi arcs. This separation also gives rise to strongly anisotropic and gyrotropic optical response. We determine the peculiar properties of both bulk and surface electromagnetic eigenmodes, or polaritons, in WSMs. We show how the information about electronic structure of WSMs, such as position and separation of Weyl nodes, Fermi energy, surface states, Fermi arcs, etc. can be extracted from the transmission, dispersion, reflection, and polarization of electromagnetic modes. We identify the most sensitive optical signatures of the electronic properties of WSMs and discuss the potential of WSM thin films for optoelectronic applications, such as giant Faraday rotation without an external magnetic field.

Fig. 1. **Left:** Energy dispersion of bulk electron states in Weyl semimetals in the $k_z = 0$ plane. The Weyl nodes are separated by $2b$ along the $k_x$ axis. **Center:** Faraday rotation. Spectra of real (a) and imaginary (b) parts of the polarization coefficient $K_x = E_x/E_y$ for an incident wave linearly polarized in y-direction after traversing a 1-µm film in x-direction. **Right:** Anomalous surface plasmon dispersion due to Fermi arc states. Real part of the surface plasmon frequency as a function of the plasmon wavenumber in y-direction for two values of the electron Fermi momentum $k_F = 0.5b$ (a) and $0.8b$ (b). The surface plasmon frequency for bulk metals neglecting surface states contribution is shown as a dashed line. All plots are for $\hbar\nu_F b = 100$ meV.