Photocurrents in Weyl semimetals of gyrotropic classes

E.L. Ivchenko
Ioffe Institute of RAS, 26 Politekhnicheskaya, 194021 Saint-Petersburg, Russia
ivchenko@coherent.ioffe.ru

In the past decade, the discoveries of topological insulators and Weyl semimetals (WSMs) have taken center stage in condensed matter science. After neutrinos were found to possess a small mass, the electrons near accidental band touching points, or Weyl nodes, in the Brillouin zone of WSMs remain the only particles with a massless linear energy dispersion and a definite chirality. Unlike the original elementary Weyl fermions, in solids the dispersion cones can be tilted or even overtilted which is realized, respectively, in type I and type II WSMs. The topological properties of WSMs manifest themselves in the chiral anomaly in the presence of parallel electric and magnetic fields, topological surface states (Fermi arcs) and topological charges (monopoles) in the reciprocal $\boldsymbol{k}$-space.

The discovery of WSMs has been followed by both theoretical and experimental studies of their transport and optical properties, linear and nonlinear. In particular, it has been shown that the interaction of circularly-polarized light with chiral fermions is governed by the Berry curvature of the Weyl node. This allows a new look at the Circular PhotoGalvanic Effect (CPGE), an appearance of a helicity-dependent electric photocurrent upon shining circularly-polarized light on the sample [1]. This effect is allowed by the symmetry of gyrotropic (or optically active) media, and many WSMs belong to the family of gyrotropic crystals. It has been demonstrated that, in each Weyl valley, the CPGE reveals universal features independent of details of the material. However, in the Weyl node of opposite chirality the CPGE current has the opposite polarity. As a result, the net current induced within two Weyl nodes of opposite chirality becomes nonvanishing only in tilted WSMs where it, however, loses its universality and depends on the tilt parameter.

In Refs. [2,3] we have developed a theory of the circular photogalvanic effect in Weyl semimetals with the point groups containing improper symmetry operations, mirror-reflection planes and rotoinversion axes, and proposed minimal models which allow for the CPGE. In semimetals of the C_{2v} symmetry with the linear energy dispersion, the net CPGE photocurrent becomes nonzero taking into account a spin-independent tilt term in the electron effective Hamiltonian. However, this is insufficient for the crystal class C_{4v}, like the TaAs Weyl semimetal. In this case one needs to add to the Hamiltonian not only the tilt but also spin-dependent terms of the second or third order in the electron quasi-momentum referred to the Weyl node.

We have complementarily investigated the magneto-gyrotropic photogalvanic effect, i.e. the generation of a photocurrent under unpolarized excitation in a magnetic field. In quantized magnetic fields, the photocurrent is caused by optical transitions between the one-dimensional magnetic subbands. A value of the photocurrent is particularly high if one of the photocarriers, an electron or a hole, is excited to the chiral subband with the energy below the cyclotron energy.

[1] E. L. Ivchenko, *Optical Spectroscopy of Semiconductor Nanostructures* (Alpha Science Int., Harrow, UK, 2005)
[2] L. E. Golub, E. L. Ivchenko and B. Z. Spivak, JETP Lett. **105**, 782 (2017).
[3] L. E. Golub and E. L. Ivchenko, arXiv:1803.02850.