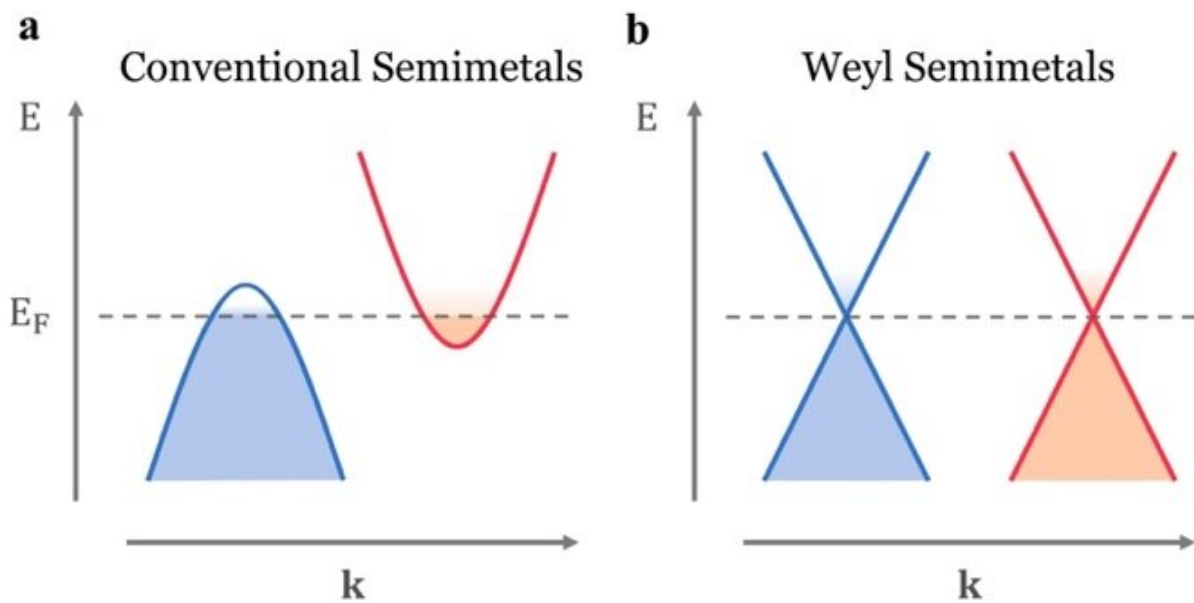


Review of photonics based on Weyl semimetals

January 5 2023



(a) Conventional semimetals, (b) Weyl semimetals. Credit: Cheng Guo, Viktor S. Asadchy, Bo Zhao and Shanhui Fan

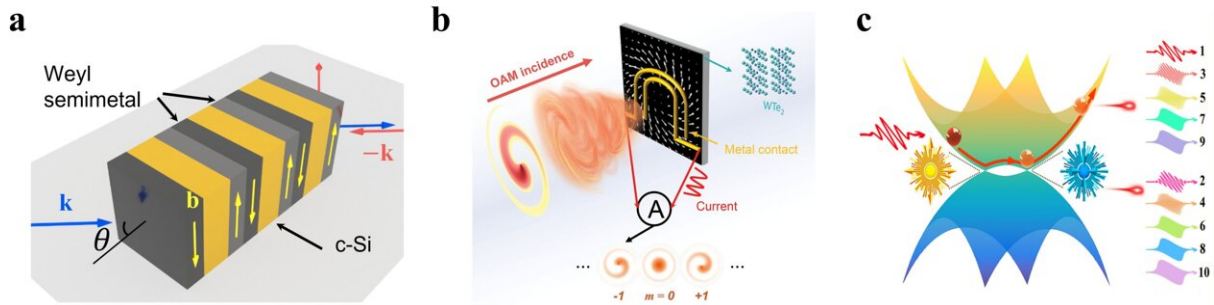
Weyl semimetals are topological materials whose low-energy excitations obey the Weyl equation. In a Weyl semimetal, the conduction and valence bands touch at discrete points in momentum space called Weyl nodes. Weyl nodes are monopoles of the Berry curvature and are robust under generic perturbations. The quasiparticles near the Weyl nodes are analogous to Weyl fermions in high-energy physics; they exhibit linear

dispersion and well-defined chirality.

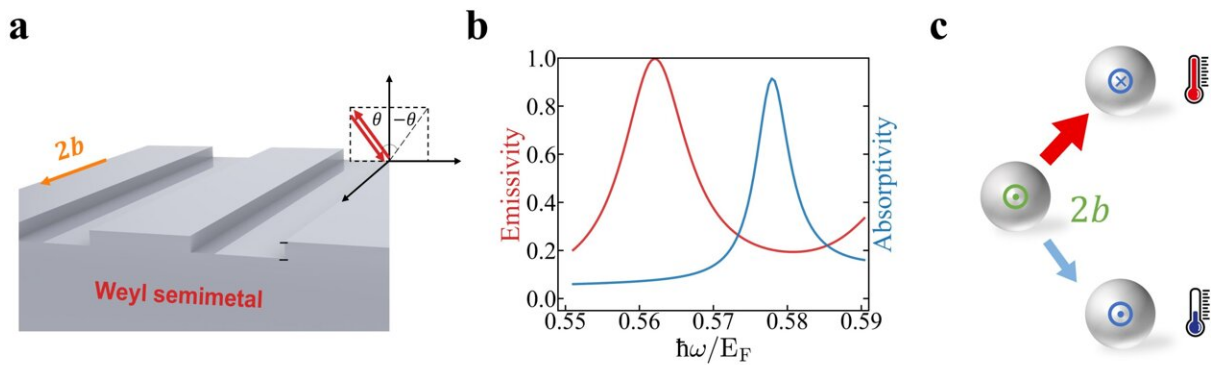
In a new paper published in *eLight*, a team of scientists led by Professor Shanhui Fan at Stanford University has reviewed the basic concepts and optical responses of Weyl semimetals.

The non-trivial topology of Weyl semimetals leads to many unusual electronic, magnetic, thermal, and [optical properties](#). These intriguing features have been extensively studied in the literature. Besides these fundamental interests, Weyl semimetals may also enable new opportunities in practical applications. For example, photonic applications include compact optical isolators and circulators, orbital angular momentum detectors, higher-order harmonic generation, and non-reciprocal thermal emitters. However, such an application-oriented exploration is still at an early stage, which requires more joint efforts from scientists and engineers.

Weyl semimetals are a special class of semimetals. They exhibit common properties of semimetals as well as some unique characteristics. According to band theory, solids can be classified as insulators, semiconductors, semimetals, and metals. An insulator or a semiconductor has a band gap between the valence and conduction bands; the [band gap](#) is more significant for an insulator than for a semiconductor. A semimetal has a minimal overlap between the conduction and valence bands and a negligible density of states at the Fermi level. A metal has a partially filled conduction band and an appreciable density of states at the Fermi level.



(a) Optical isolation. (b) Direct OAM detection. (c) High harmonic generation.
Credit: Cheng Guo, Viktor S. Asadchy, Bo Zhao and Shanhui Fan



(a) A nonreciprocal thermal emitter. (b) The absorptivity and emissivity spectra of the device in (a) at a given incident angle. (c) A radiative thermal router.
Credit: Cheng Guo, Viktor S. Asadchy, Bo Zhao and Shanhui Fan

The researchers provide their outlook on future works on the emerging topic of photonics based on Weyl semimetals. So far, most works on Weyl semimetals focus on novel physics. Engineers have tremendous challenges and opportunities to make these physical effects practically

useful.

There are many opportunities, including the synthesis of high-quality and large-area Weyl semimetals and the fabrication of photonic devices based on Weyl semimetal materials. Other options include the design of photonic structures to enhance the [light-matter interactions](#) in Weyl semimetals and photon management to enhance the light absorption and photocurrents in Weyl semimetals. Indeed, many efforts must be undertaken to construct practical devices from Weyl semimetals.

More information: Cheng Guo et al, Light control with Weyl semimetals, *eLight* (2023). [DOI: 10.1186/s43593-022-00036-w](https://doi.org/10.1186/s43593-022-00036-w)

Provided by Chinese Academy of Sciences

Citation: Review of photonics based on Weyl semimetals (2023, January 5) retrieved 7 May 2024 from <https://phys.org/news/2023-01-photonics-based-weyl-semimetals.html>

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