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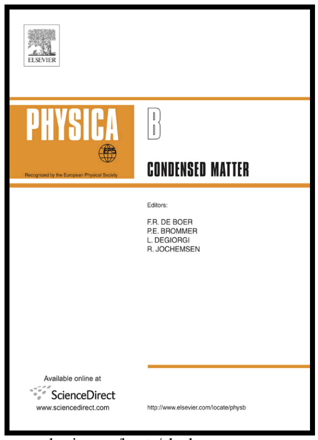


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# Optical properties of $YbMnBi_2$: a type II Weyl semimetal candidate



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We discuss our recent optical investigation of $YbMnBi_2$, a representative type II Weyl semimetal, by considering a simple scheme for the electronic structure, which can be embedded within a recent theoretical approach for the calculation of the excitation spectrum. Our study allows us disentangling the generic optical fingerprints of Weyl fermions, which are in broad agreement with the theoretical predictions but also challenge the present understanding of their electrodynamic response.

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Weyl fermions play a major role in quantum field theory but have been quite elusive as fundamental particles. The prerequisite for the realization of Weyl fermions is either the presence of broken space inversion symmetry at a single Dirac cone, which leads to two Weyl nodes hallmarked by the same momentum but shifted by the same amount in opposite directions along the energy axis relatively to each other, or broken time-reversal symmetry, which results in Weyl nodes at the same energy but separated in momentum space [1]. Evidences for Weyl fermions with broken space inversion symmetry have been reported in so-called non-centrosymmetric, transition metal monopnictide crystals, like TaAs and TaP [2, 3]. Moreover, the proposal for the existence of two types of Weyl semimetal was recently made; the standard type I with point-like Fermi surface and the previously overlooked type II arising at the contact of the Fermi level along the line boundaries of electron and hole pockets [4, 5]. A type II Weyl semimetallic state has been predicted [6] and observed in $MoTe_2$ [7].

The quasi two-dimensional bismuth layers $AMnBi_2$ ($A$ = alkaline as well as rare earth atom) lately advanced as a suitable playground for the investigation of such emergent low-energy quasiparticle excitations [8–11]. These non-centrosymmetric and magnetic materials host strong spin-orbital interaction and their two-dimensional network of Bi atoms guarantees Dirac massless dispersions. Furthermore, the broken time-reversal symmetry, induced by the magnetic order, may lift the degeneracy at the Dirac cones [12]. $EuMnBi_2$ and $YbMnBi_2$ were thoroughly scrutinized with respect to the electronic properties of Weyl fermions. High precision ARPES investigations show that $YbMnBi_2$ (but not $EuMnBi_2$) is a genuine Weyl semimetal of type II [13].

Recently, we were triggered by the opportunity to exploit $YbMnBi_2$ and $EuMnBi_2$ as an arena in order to explore the optical response and chase the related fingerprints of a type II Weyl semimetal (i.e., in the Yb-based material) in contrast to its semimetal counterpart (i.e., the Eu compound) [14]. Here, we wish to further elaborate on the comparison between the optical response of the Yb-compound with the available theoretical predictions, also emphasizing future challenges towards a comprehensive understanding of the charge dynamics in Weyl semimetals.

We collect reflectivity spectra ($R(\omega)$) on well characterized single crystals [11, 15] as a function of temperature from the far-infrared up to the ultraviolet. This allows performing reliable Kramers-Kronig transformation, giving access to the optical conductivity. We refer to the literature for additional details on the experimental technique [16] and collected data [14].

The real part $\sigma_1(\omega)$ of the optical conductivity in $YbMnBi_2$ is shown in the inset of Fig. 1 for the whole investigated spectral range. By first inspecting the spectra at low frequencies, we recognize a metallic contribution merging into a Drude-like resonance well below 100 $cm^{-1}$ at all temperatures, in broad agreement with the *dc* transport properties [15]. This bears testimony to a rather small scattering rate (i.e., width of the Drude resonance), so that the metallic component is quite narrow, falling into the spectral range dominated by the Hagen-Rubens extrapolation of the measured $R(\omega)$ [14]. The overall metallic contribution is however rather weak, which suggests small Drude weight and moderate-to-low concentration of itinerant charge carriers. This is consistent with the rather fuzzy signature of the Fermi surface, as measured with ARPES technique [13]. Three broad peaks at $\sim 100$, 500 and 6000 $cm^{-1}$ dominate $\sigma_1(\omega)$ in the Yb compound (see plain arrows in inset of Fig. 1). We