Supplemental Material: Photocurrents in Weyl semimetals

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I. ROOM TEMPERATURE DETECTION OF BLACKBODY INFRARED RADIATION

We demonstrate the use of noncentrosymmetric Weyl semimetals as room temperature IR detectors for radiations coming from a blackbody object at an equilibrium temperature $\mathrm{T_b}$. We consider the same setup used in Fig. 3 in the main text, that is two pairs of Weyl nodes in the presence of TR symmetry.

A blackbody object held at an equilibrium temperature $\mathrm{T_B}$ has a continuous radiation intensity spectrum $I(\omega, T_B) = \hbar\omega^3(4\pi^2c^2)^{-1}(e^{\hbar\omega/k_BT} - 1)^{-1}$, which is peaked at $\hbar\omega \sim 2.8\ \mathrm{k_BT_b}$. Generalizing Eq. (3) and (4) in the main text to take into account the continuous blackbody spectrum, each Weyl node brings about a photocurrent density:

$$\begin{aligned} J_i^b(T,\mu) &= \left(\frac{-e^3\tau k_B^4 T_b^4}{128\pi^4\hbar^5\epsilon_0 c^3}\right)\bar{J}_i^b \\ &= \left(\frac{-e^3\tau k_B^4 T_b^4}{128\pi^4\hbar^5\epsilon_0 c^3}\right)\int_0^\infty dx \frac{x^3\bar{J}_i(\omega = \frac{xk_BT_b}{\hbar})}{e^x - 1}. \end{aligned} \tag{1}$$

The prefactor gives the strength of the photocurrent density, while the dimensionless integral, defined by $\mathrm{\bar{J}_i^b}$ above, corresponds to the dimensionless photocurrent response due to a blackbody radiation.

The IR detection performance is presented in Fig. 1 as a function of temperature for various chemical potential values. At $\mu = 0$, the photocurrent vanishes at $\mathrm{T} = 0$ and steadily increases with T until $\mathrm{T} \approx 0.5\ \mathrm{T_b}$, in consistent with Fig. 3(d) in the main text. For finite $\mu \approx \mathrm{k_BT_b}$, the photocurrent drops monotonically with temperature with up to 35% of $\mathrm{\bar{J}^b}$ survives at $\mathrm{T} = \mathrm{T_b}$. This reduction value is comparable to that due to the monochromatic drive shown in Fig. 3(d) of the main text. Note that even for room temperature, the conditions $\mathrm{k_BT} \approx \mathrm{k_BT_b} \approx \mu \approx 26$ meV can be easily achieved in realistic Weyl semimetal materials. Our estimation gives a magnitude of $\mathrm{J^b} \sim 100\ \mathrm{Am^{-2}}$ at room temperature. All these results illustrate that Weyl semimetals are excellent candidates for IR detectors.

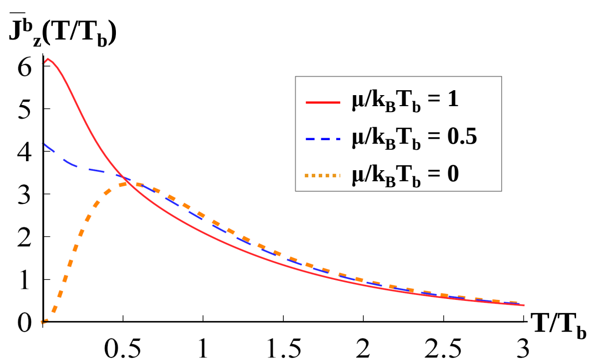

FIG. 1. Dimensionless photocurrent response $\mathrm{\bar{J}_z^b}$ due to a blackbody radiation with room temperature $\mathrm{T_b}$. We take $\mathrm{v_t/v_F} = 0.8$ and $\theta_\mathrm{A} = 0$. At $\mu = 0$, the photocurrent vanishes at $\mathrm{T} = 0$ because of symmetric excitations and requires finite temperature to have a non-zero response. When $\mu \sim k_BT_b$, $\mathrm{\bar{J}_z^b}$ just decays with temperature, with 35% remaining at $\mathrm{T} = \mathrm{T_b}$.