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Terahertz saturable absorption from relativistic high-temperature thermodynamics in black phosphorus

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Black phosphorus is a unique two-dimensional (2D) material (Figure 1) with a tunable infrared band gap and anisotropic conduction properties [1]. Black phosphorus also displays the occurrence of a pressure-induced topological Lifshitz transition turning the material from a narrow gap semiconductor to a massless Dirac metal due to a nonavoided band crossing [2]. We investigate the ambient pressure nonlinear terahertz (THz) electrodynamics of black phosphorus along the more conducting armchair direction and found that its THz saturable-absorption properties can be understood within a thermodynamic model by assuming a fast thermalization of the electron bath [3]. While black phosphorus does not display the presence of massless fermions at ambient pressure and temperature the material's anomalous THz nonlinear properties can be accounted for by a relativistic massive Dirac dispersion, provided that the Fermi temperature is low enough. This suggests that an optimal tuning of the Fermi level could be a strategy to engineer a strong THz nonlinear response in other massive Dirac materials, such as transition-metal dichalcogenides or high-temperature superconductors

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