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High-Harmonic Generation of Terahertz Field-Driven Nonequilibrium Dynamics in Weyl and Dirac Semimetals

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Harmonic generation, a universal hallmark of driven nonlinear systems, provides a powerful tool for uncovering the fundamental principles that govern ultrafast nonlinear dynamics. In this presentation, I will show our investigation of terahertz (THz) field-driven nonlinearity in massless-fermion systems, drawing on our recent studies of the Weyl semimetal TaP [1] and the Dirac semimetal Cd_3As_2 [2]. We reveal how nonlinear carrier kinetics enable high harmonic generation and examine how optical pumping reshapes the nonlinear response through transient population inversion. Furthermore, we demonstrate all-optical tunability of high-harmonic yield and present a theoretical framework that captures the essential ultrafast dynamics in these topological semimetals under an intense THz drive.

- [1] P. Pilch et al., Terahertz third-harmonic generation of lightwave-driven Weyl fermions far from equilibrium, *Nano Lett.* **25**, 16637-16642 (2025).
- [2] C. Zhu et al., Population inversion and ultrafast terahertz nonlinearity of transient Dirac fermions in Cd_3As_2 , *Phys. Rev. B* **109**, L201111 (2024).