**Controlling strong-field optical response of massless Dirac fermions in graphene**

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Under strong laser fields, electrons in solids radiate high-harmonic fields by travelling through quantum pathways in Bloch bands in the sub-laser-cycle timescales. Understanding these pathways in the momentum space through the high-harmonic radiation can enable an all-optical ultrafast probe to observe coherent lightwave-driven processes and measure electronic structures as recently demonstrated for semiconductors. However, such demonstration has been largely limited for semimetals because the absence of the bandgap hinders an experimental characterization of the exact pathways. In this study, by combining electrostatic control of chemical potentials with HHG measurement, we resolve quantum pathways of massless Dirac fermions in graphene under strong laser fields. Electrical modulation of HHG reveals quantum interference between the multi-photon interband excitation channels. As the light-matter interaction deviates beyond the perturbative regime, elliptically polarized laser fields efficiently drive massless Dirac fermions via an intricate coupling between the interband and intraband transitions, which is corroborated by our theoretical calculations. Our findings pave the way for strong-laser-field tomography of Dirac electrons in various quantum semimetals and their ultrafast electronics with a gate control.

[1] S.Y. Cha, et. al., “Gate-tunable quantum pathways of high harmonic generation in graphene”, Nature Communications 13, 6630 (2022).

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