Non-integer high-harmonic generation in a topological insulator

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Topologically non-trivial matter has been predicted to support a new quality of high-harmonic generation (HHG) [1-4]. Here, we present our results on HHG in the topological insulator bismuth telluride [5]. As shown in Fig. 1a, the frequency of the driving field sharply discriminates between HHG from the bulk and the topological surface, where long scattering times and the quasi-relativistic dispersion enable unusually efficient HHG. Intriguingly, all observed orders, generated in the surface state, can be continuously shifted to arbitrary non-integer multiples of the driving frequency by varying the carrier-envelope phase (CEP) of the driving field (see Fig 1b). The anomalous Berry curvature warranted by the non-trivial topology enforces meandering ballistic trajectories of the Dirac fermions, which were calculated in Fig 1c, causing a hallmark high-harmonic polarization pattern (see Fig. 1d). Our study provides a new platform to explore topology and relativistic strong-field quantum physics and sparks hope for non-dissipative topological electronics at infrared frequencies.

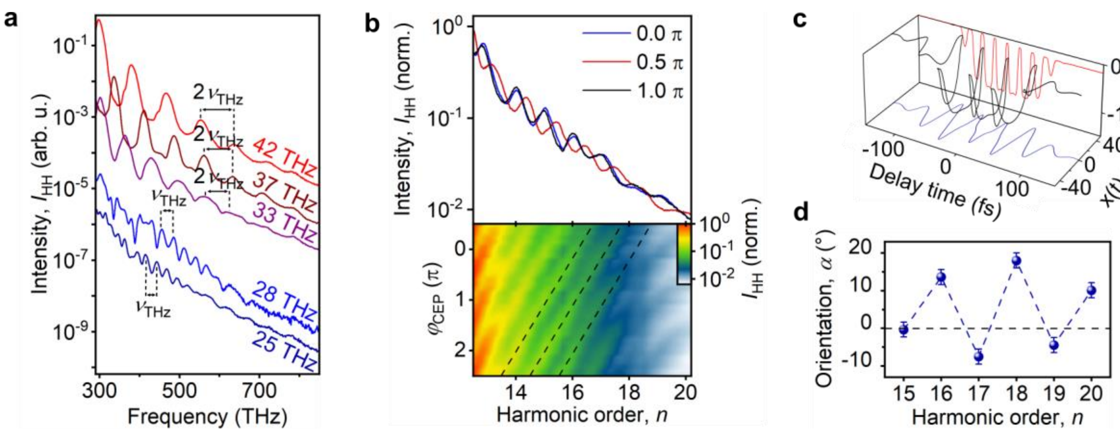

Figure 1: (a) HHG from Bi_2Te_3 for different driving frequencies, **(b)** Critical carrier-envelope phase dependence of the surface-generated harmonics allowing for non-integer HHG, **(c)** Real-space trajectory of Dirac fermions, **(d)** Hallmark high-harmonic polarization pattern due to Berry curvature

References:

[1] D. Bauer, K. K. Hansen, "High-harmonic generation in solids with and without topological edge states", Phys. Rev. Lett. **120**, 177401 (2018).
[2] R. E. F. Silva *et al.*, "Topological strong field physics on sub-laser cycle timescale", Nat. Photon. **13**, 849–854 (2019).
[3] D. Baykusheva *et al.*, "Strong-field physics in three-dimensional topological insulators", Phys. Rev. A **103**, 023101 (2021).
[4] J. Wilhelm *et al.*, „Semiconductor-Bloch formalism: derivation and application to high-harmonic generation from Dirac fermions", Phys. Rev. B **103**, 125419 (2021).
[5] C. P. Schmid *et al.*, "Tunable non-integer high-harmonic generation in a topological insulator", Nature **593**, 385-390 (2021).