

High harmonic spectroscopy of a topological phase transition

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The topological state of matter is intimately linked with dynamics, as manifested via the chiral edge currents in topological insulators. Yet, the ultrafast dynamics of non-equilibrium electronic response to intense light fields in these materials has remained virtually unexplored. Understanding these dynamics is not only fundamentally interesting, but also important for developing light-wave electronics in topological materials. We study these dynamics using high harmonic generation spectroscopy, a key tool of attosecond spectroscopy in solids.

Attosecond spectroscopy has made major progress in understanding ultrafast electron dynamics in solids [1,2]. Yet, so far it has mostly focused on the role of the band structure. The impact of the topological properties, such as the Berry curvature and the topological invariants of condensed matter systems, on the attosecond dynamics of electronic response has hardly been explored. Does the highly non-equilibrium electron dynamics in the bulk, driven by a strong laser field, encode the topological properties on the sub-laser cycle time-scale? How do the Berry curvature and the Chern number affect the first step in the nonlinear response – the field-driven injection of electrons across the bandgap?

We address these questions using the paradigmatic example of the topological insulator, the Haldane system [3]. We show how the topological state of the system controls its attosecond, highly non-equilibrium electronic response to strong low-frequency laser fields, in bulk. We identify the topological effects on the directionality and the attosecond timing of electron currents injected into the conduction band by the driving laser field. We also show that the highly nonlinear optical response to strong fields, the high harmonic emission, displays topologically-dependent attosecond delays, and that the helicities of the emitted harmonics can record the phase diagram of the system and its topological invariants.

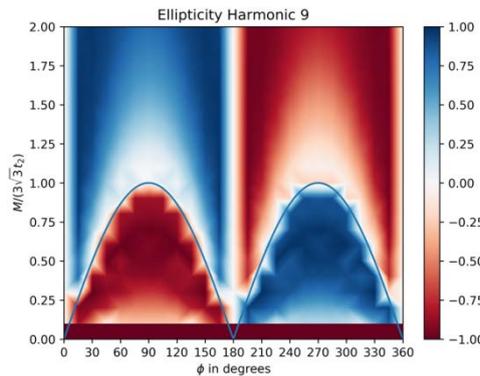


Figure 1: Signed ellipticity of high harmonics of a linearly polarized driver maps the phase diagram of the Haldane system. The blue line separates trivial (above) and topological (below) phases.

[1] Vampa G *et al* 2015 *Nature* **522** 462

[2] Kruchinin SY *et al* 2018 *Rev. Mod. Phys.* **90** 021002

[3] Haldane F D M 1988 *Phys. Rev. Lett.* **61** 2015