

Observation of the Interband Berry Phase in Light-Driven Solids – Above and Below the Tunneling Barrier

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Since its introduction, the concept of Berry phase [1] has become a unifying principle across quantum physics, underlying phenomena ranging from the quantum Hall effect and electric polarization to the topology of Bloch bands in solids. In crystalline materials, geometric phases naturally arise as electronic wavefunctions evolve in momentum space under external fields, reflecting the topology of the underlying band structure.

In this talk, I will present a new perspective on Berry phases in strong-field driven solids, where geometric phases emerge not only from adiabatic motion within a band, but also from coherent interband dynamics. When driven by an intense laser field, electrons tunnel from the valence to the conduction band, launching electron-hole wavepackets that evolve in momentum space and recombine to emit high harmonics [2]. This interband high-harmonic generation (HHG) process provides direct access to quantum trajectories and their accumulated phases.

First, as a case study, I will show how the interband Berry phase is resolved experimentally in α -quartz using polarization-controlled interferometry [3], enabling direct mapping of geometric phases along light-driven trajectories in k -space. I will then extend this framework to the tunneling step itself, where we uncover a *complex* geometric phase [4], whose imaginary component originates from evolution under the tunneling barrier [5]. This phase is experimentally accessed via a two-color interferometric scheme that modulates the barrier and reveals its geometric contribution.

Finally, I will demonstrate how light can dynamically induce topology: using a terahertz-infrared pump-probe scheme, we transiently generate Berry curvature in an otherwise trivial material (MgO) and track the emergence of a dynamical Berry phase with sub-cycle resolution [6].

Together, these results establish strong-field and attosecond spectroscopy as a powerful platform for probing, and even engineering, geometric phases in solids, opening new routes toward ultrafast control of topological quantum matter.

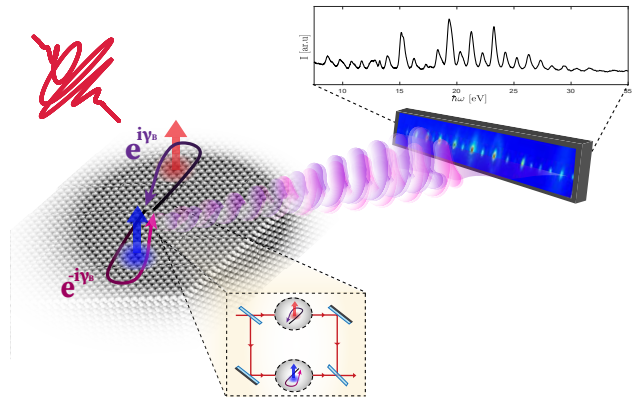


Figure 1: Observation of the interband Berry phase in light-driven solids

References

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