Interband Berry Phase in Laser-Driven Crystals

HHG as an internal interferometer in solids

Eren Erberk Erkul

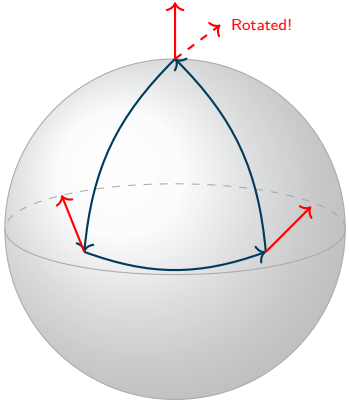
nature.com/articles/s41586-023-06828-5

The Origin: Curvature

Carl Friedrich Gauss

Geometric Phase Intuition

Parallel Transport on a Sphere



$$\gamma = \oint \boldsymbol{\mathcal{A}}(\boldsymbol{R}) \cdot d\boldsymbol{R}$$

Phase from path geometry

The Quantum Connection

Sir Michael Berry (1984)

Berry phase

$$\gamma = \oint \boldsymbol{\mathcal{A}}(\boldsymbol{R}) \cdot d\boldsymbol{R}$$

phase from the path geometry

The Core Concept

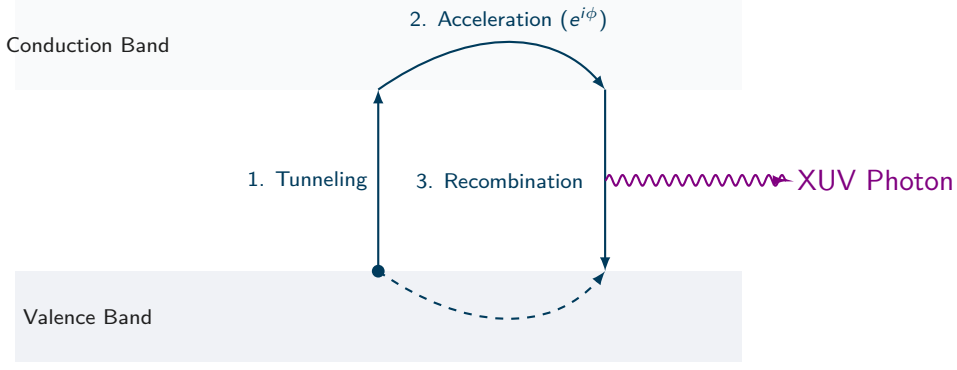
- HHG $\rightarrow$ **Internal Interferometer**

- Target: **Interband Geometric Phase**

  - Phase $\rightarrow$ Interference Spectrum

Mechanism

Time = Loop Size in Reciprocal Space

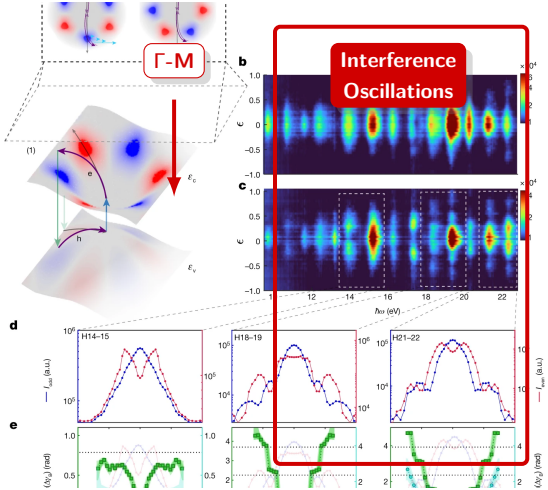


The Measured Phase

$$\gamma_{\mathrm{int}} = \int (\boldsymbol{\mathcal{A}}_c - \boldsymbol{\mathcal{A}}_v) \cdot d\boldsymbol{k} \; - \; \Delta\phi_d$$

intraband connection + dipole-phase jump

Ellipticity bends the loop

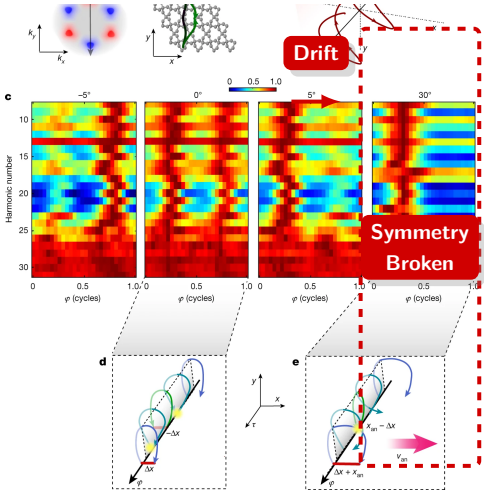


Curvature $\rightarrow$ Drift

$$\dot{\boldsymbol{r}} = \nabla_{\boldsymbol{k}} \varepsilon_n(\boldsymbol{k}) - \dot{\boldsymbol{k}} \times \boldsymbol{\Omega}_n(\boldsymbol{k})$$

anomalous velocity controls recombination overlap

Control field reveals curvature

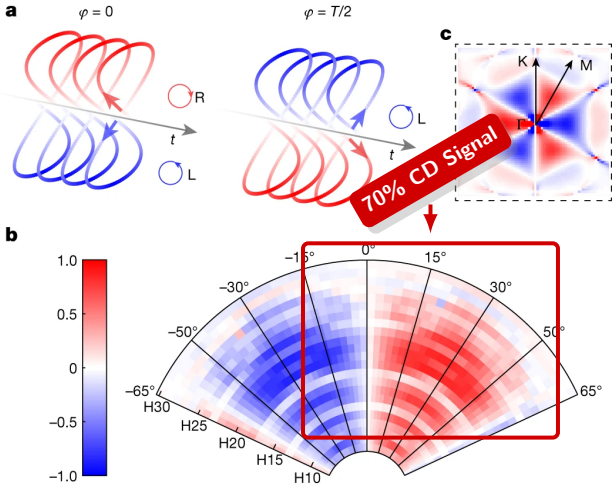


Circular dichroism

$$\mathrm{CD}(\omega) = \frac{I_+(\omega) - I_-(\omega)}{I_+(\omega) + I_-(\omega)}$$

helicity dependence as a geometric fingerprint

Chiral response in HHG



Take-home

- HHG as sub-cycle interferometer
- Resolves interband geometric phase
- Curvature $\rightarrow$ Drift & Dichroism

Questions