Control of topological phase transitions by symmetry-selective coherent phonons

Jigang Wang[1,2]

1. Ames Laboratory – USDOE, Ames, Iowa 50011, USA
2. Department of Physics and Astronomy, Iowa State University, Ames, Iowa 50011 U.S.A.

jgwang@iastate.edu

A new light-induced symmetry switch, that works by twisting the crystal lattice of a Dirac material with selective mode symmetry (center, Figure 1), coherently splits Dirac points to two pairs of Weyl points (left, Figure 1) and photogenerates giant low dissipation current with an exceptional ballistic transport protected by induced Weyl band topology. Such light-driven topological control principles are demonstrated using a few-cycle optical [1] and terahertz [2] pulses to driven coherent phonons of IR and Raman symmetries. We use these schemes to induce a topological phase transition from Dirac to Weyl semimetal states or a topological insulator to semimetal transition in $ZrTe_5$. Experimental results combined with first-principles modeling shows that two pairs of Weyl points dynamically created by light-induced mode-selective phonon pumping of broken inversion symmetry. Such phononic terahertz light control breaks ground for coherent manipulation of Weyl nodes and robust quantum transport without application of static electric or magnetic fields. The discovery holds great promise for spintronics, topological effect transistors, and quantum computing. The methodology demonstrated can be extended to characterize a broad range of complex materials, such as topological semimetals at THz-nm limit [3], topological insulators [4] and superconductors [5], key for developing superconducting quantum circuits and topological transistors.

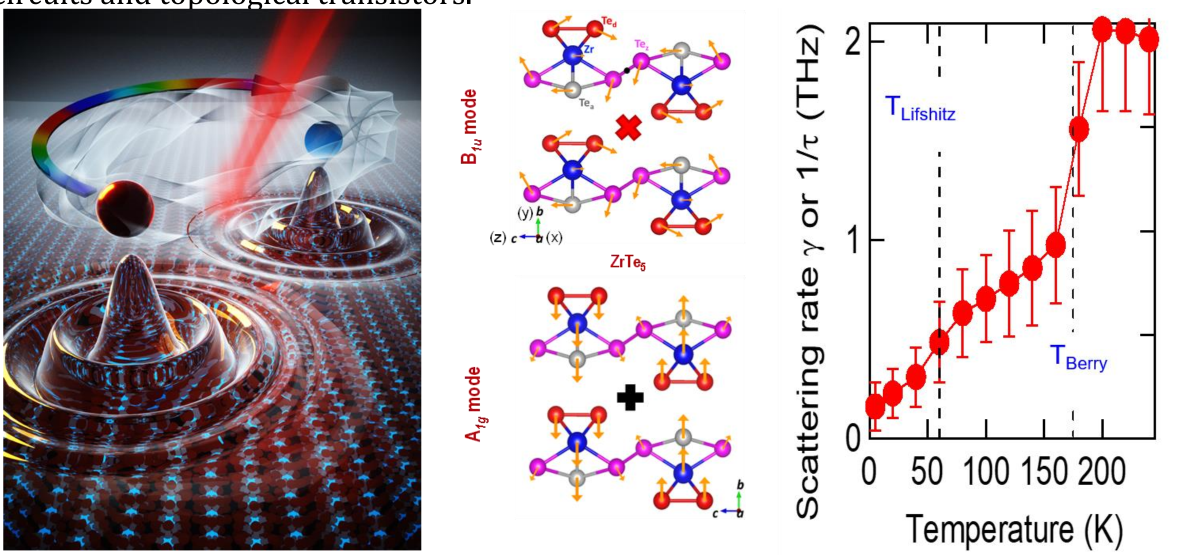

Figure 1: Light-induced of Weyl points (left) in a Dirac material of $ZrTe_5$ [1]. Coherently twisted lattice motion of selective modes (center) by laser pulses, i.e., a light phononic switch, can control the chirality and symmetry, and photogenerate giant low dissipation topological photocurrents with an exceptional ballistic transport protected by induced Weyl nodes topology [right].

References:

[1] L. Luo, et al., **Nature Materials,** 20, 329–334 (2021)

[2] C. Vaswani, et al., **Physical Review X** 10, 021013 (2020).

[3] R. H. J. Kim, et al., **ACS Photonics,** 8, 7, 1873–1880 (2021) (Cover)

[4] X. Yang et al., **npj Quantum Materials** 5, 13 (2020).

[5] C. Vaswani, et al., **Nature Communications, 12,** 258 (2021).