

# Non-equilibrium Surface Dirac Fermion Dynamics of Topological Insulators

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Three-dimensional topological insulators (3D TIs) with surface Dirac fermions in a bulk energy gap induced by a strong spin-orbit coupling have attracted much attention as key materials to revolutionize current electronic devices. A spin helical texture of surface Dirac fermions, where the electron's spin is locked to its momentum, is a manifestation of a 3D TI. To unveil its Dirac fermion dynamics is crucial for the future development of (opto-)spintronic devices incorporating topological insulators. Angle-resolved photoemission spectroscopy implemented by a pump-and-probe method is powerful tool to study both occupied/unoccupied states as well as hot carrier dynamics [1]. Here, the surface Dirac fermion dynamics in the “carrier tuned” topological insulator  $(\text{Sb}_{1-x}\text{Bi}_x)_2\text{Te}_3$  have been explored.  $\text{Sb}_2\text{Te}_3$  ( $x=0$ ) has a Dirac node completely located above the Fermi energy [Fig.1(*left*)]. The excited electrons in the upper Dirac cone are found to stay longer than those below the Dirac node to form an inverted population. This is attributed to a reduced density of states near the Dirac node [2]. Once the Fermi energy gets into the bulk energy gap by an appropriate Bi doping ( $x=0.43$ ), the duration of the nonequilibrium surface electronic state exceeds  $>400$  ps. The keys for the prolonged nonequilibrium are the bulk insulation and further tuning of the Fermi level to the Dirac point of the topological surface state. These findings expand the pathways to high-mobility opto-spintronic applications.

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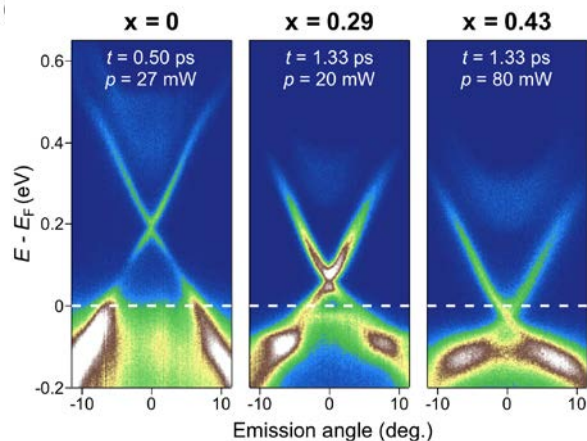


Fig. 1. Band dispersions of  $(\text{Sb}_{1-x}\text{Bi}_x)_2\text{Te}_3$  ( $x = 0, 0.29, 0.43$ ) acquired at certain pump-and-probe delay times.

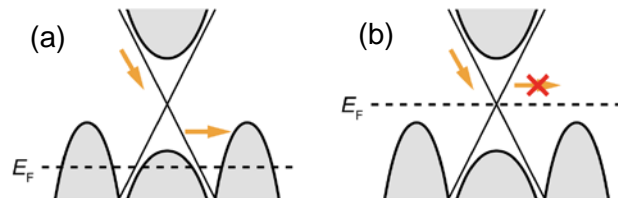


Fig. 1. Schematics of the relaxation processes in bulk metallic (a) and bulk insulating (b) TIs.

**Keywords:** Topological insulators; Nonequilibrium surface Dirac fermion dynamics

## References

- [1] Y. Ishida et al., Rev. Sci. Instrum. **85** (2014) 123904.
- [2] S. Zhu et al., Sci. Rep. **5** (2015) 13213.