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Ultrafast Probing of Dynamical Spin-Charge Coupling in Topological Insulators

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The three-dimensional topological insulator (TI) is a new quantum phase of matter that exhibits quantum-Hall-like properties, even in the absence of an external magnetic field. Charge carriers on the surface of a TI behave like a two-dimensional gas of massless helical Dirac fermions for which the spin is ideally locked perpendicular to the momentum. In this talk, I will discuss recent experiments in which we used the angular momentum of circularly polarized ultrafast laser pulses to directly visualize and manipulate the spin-charge coupling in TIs. By using laser pulses in the UV region, we performed novel time of flight based angle-resolved photoemission spectroscopy that enabled simultaneously mapping all three components of spin over the entire Dirac cone of a TI. We find that an idealized description of helical Dirac fermions only applies within a small energy window about the Dirac point, beyond which strong textural deformations occur. Utilizing the pump-probe technique, we selectively obtained time-resolved dynamics of surface and bulk excitations. By using circularly polarized laser pulses in the optical region, we achieved preferential excitation of spin species on one side of the surface Dirac cone, resulting in a charge imbalance in momentum space and thus causing a current flow with a direction dependent on photon helicity.

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