Empty electronic surface states of topological insulators studied by two-photon photoemission

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Photoemission experiments provide one of the most powerful techniques to study electronic properties of surfaces. Their energy and momentum resolution allows direct measurements of surface band structures. In particular, in two-photon photoelectron spectroscopy (2PPE) an optical excitation by a femtosecond laser pulse pumps electrons into states which are unoccupied under equilibrium conditions. These states are then probed by photoemission through a second laser pulse. The method grants access to the energetics and also to the dynamics of excited states by introducing a variable pump-probe delay.

Topological insulators exhibit a new class of surface states in which spin and momentum are coupled. They are characterized by a simple helical spin structure and a linear dispersion crossing a band gap of a bulk insulator.

Topological insulator materials under study are Bismuth chalcogenides. In addition to their well-studied n-doped topological surface state (TSS) close to the Fermi level, additional TSSs are found 1.32 eV (1.12 eV) above the Fermi level in Bi_2Se_3 (Bi_2Te_2Se), while this feature is absent in Bi_2Te_3. These results are in agreement with theoretical calculations indicating a symmetry-inversion of the corresponding local band gap in the presence of the central Se atom.

The possibility of optical pumping between occupied and unoccupied TSSs opens a route for future studies of charge- and spin-dynamics in a TSS.