Opportunities of THz-ARPES for studies of solids and interfaces

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There is an increasing interest to control and manipulate the properties of solids with intense light fields. Prominent examples are photo-induced insulator-to-metal transitions, light-induced superconductivity, the observation of Floquet-Bloch states and light-wave driven electrical currents. Experiments along these lines benefit tremendously when the capability of angle-resolved photoelectron spectroscopy (ARPES) is exploited to probe the electronic structure of the material. Here, new opportunities arise in combination with THz excitation and moving beyond pump-probe schemes for time-resolution as demonstrated recently by our observation of THz-driven Dirac currents [1]

In the first subcycle time-resolved ARPES experiment, it has been revealed how the carrier wave of a THz pulse accelerates Dirac fermions in the topological surface state of Bi_2Te_3. While terahertz streaking of photo-emitted electrons traces the electromagnetic field at the surface, the acceleration of Dirac states leads to a strong redistribution of electrons in momentum space (Fig.1) The electrons carrying the current react inertia-less on the accelerating field and travel ballistically with the Fermi velocity of 410 nm/ps over distances of several hundreds of nanometres. This scenario opens up a realistic parameter space for dissipation-free lightwave-driven electronic devices at optical clock rates.

[1] J. Reimann, J., S. Schlauderer, C.P. Schmid, F. Langer, S. Baierl, K.A. Kokh, O.E. Tereshchenko, A. Kimura, C. Lange, J. Güdde, U. Höfer and R. Huber, *Nature* **562**, 396 (2018).

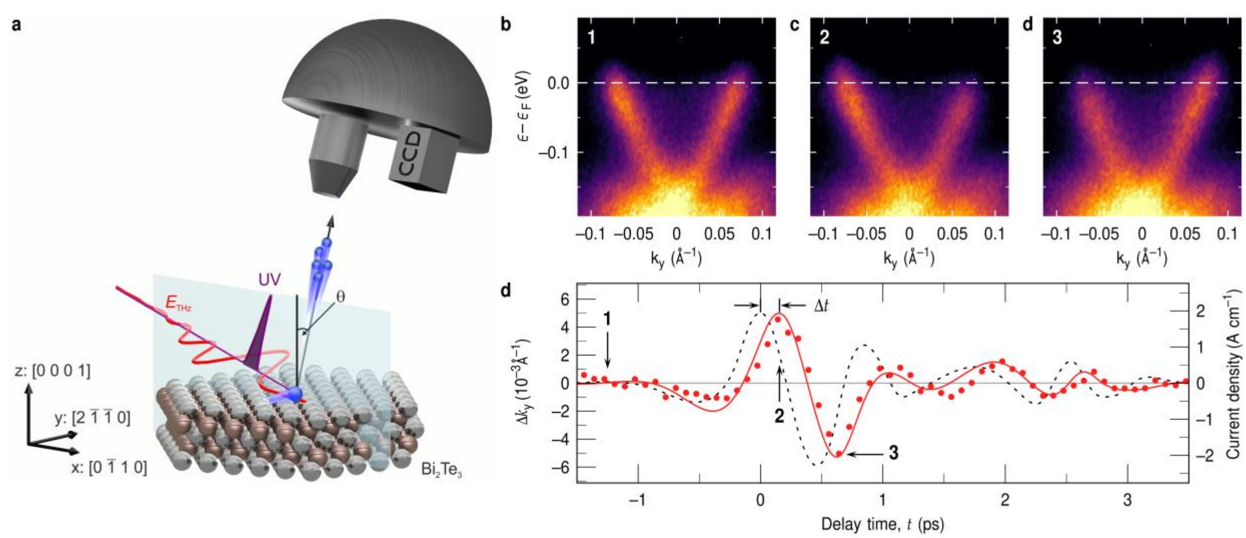

Fig. 1. (a) Electrons in the topological surface state of Bi_2Te_3 are accelerated by a linearly polarized THz field E_{THz} and are photoemitted by a time-delayed ultrashort UV pulse. The kinetic energy ϵ_{kin} and the photoemission angle θ of the electrons are measured to determine $\epsilon(\boldsymbol{k})$ in the topological surface band. (b), (c), (d) Photoemission maps before the arrival of the THz field (b), right after the positive field crest (c) and just after the negative field maximum (d). The electron distribution is accelerated away from the Fermi level (white-dashed line) and shifted along the V-shaped dispersion of the topological surface band. (e) Temporal evolution of the current density extracted from the photoemission maps (data points). Black dashed line: electric field of the THz waveform. Red solid curve: current dynamics simulated for scattering times of 1 ps.