TOPOLOGICAL INSULATORS PROBED BY ULTRAFAST LASER PULSES

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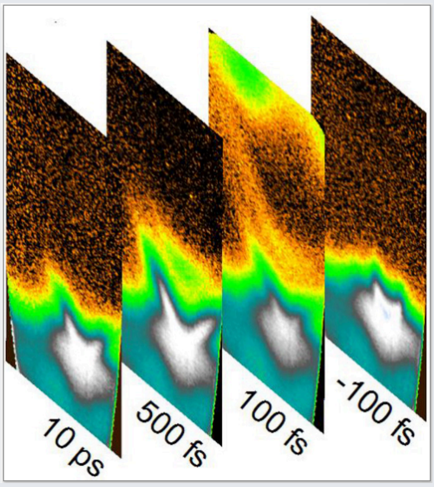
Topological insulators are a new state of quantum matter: they are characterized by conducting surface states, while their bulk is insulating. The electrons at the surface have an exceptional mobility and are remarkably immune to the presence of defects. These properties reveal new opportunities for the transmission of current and information with unprecedented speed.

To turn these opportunities into reality, it is nevertheless necessary to be able to control surface electrons over very short time scales, which can be possible for instance with ultrashort light pulses. A team of scientists from the Laboratoire de Physique des Solides, the Laboratoire des Solides Irradiés, the SOLEIL synchrotron and the Universities of Purdue and Princeton have used a new and powerful experimental method —angle resolved photoemission with a femtosecond laser source— which makes it possible to observe in real time the dynamics of electronic bands. This technique is particularly well adapted for the direct observation of the evolution of surface electrons, which in topological insulators are organized in particular bands — Dirac cones— as shown in a work recently published in Nature Communications.

Following the excitation with a laser pulse, electrons are driven into normally empty states, and their relaxation can be followed in real time with a sequence of images (see movie), which allow the direct measurement of the excitation lifetime. These measurements, performed on several topological insulators of the Bi_2Te_3 and Bi_2Te_2Se family, have demonstrated that an asymmetry can be created between electrons and holes in the surface conducting states. Thanks to the unique properties of Dirac fermions, this makes it possible to create with light strongly out of equilibrium electronic states, with an exceptionally long lifetime of several tens of picoseconds (see Figure), which cannot be obtained with a normal metallic state.



Temporal evolution of the Dirac cone and of electronic bands in the topological insulator Bi_2Te_3 following excitation with ultrafast laser pulses

The transient shift of the chemical potential of Dirac fermions corresponds to a sizeable change in the energy barrier between bulk electronic bands and surface electronic states. This discontinuity corresponds to a Schottky barrier, the basic physical parameter controlling the behavior of devices like semiconducting diodes: consequently, the possibility of modifying and controlling this barrier with ultrafast light pulses is extremely interesting in the perspective of using topological insulators for a new generation of photoconducting devices.

M. Hajlaoui, E. Papalazarou, J. Mauchain, L. Perfetti, A. Taleb-Ibrahimi, F. Navarin, M. Monteverde, P. Auban-Senzier, C.R. Pasquier, N. Moisan, D. Boschetto, M. Neupane, M.Z. Hasan, T. Durakiewicz, Z. Jiang, Y. Xu, I. Miotkowski, Y.P. Chen, S. Jia, H.W. Ji, R.J. Cava and M. Marsi, *Tuning a Schottky barrier in a photoexcited topological insulator with transient Dirac cone electron-hole asymmetry*, Nature Communications, 5, 3003, (2014)

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