Time- and angle-resolved photoemission for Material Science

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Time- and angle-resolved photoemission spectroscopy (trARPES) provides insight into time resolved band structures and unoccupied states. We will show two applications of this technique: (1) We use optical pulses to excite coherent phonons in the $Bi_2Sr_2CaCu_2O_8$ (Bi2212) lattice, and measure the resulting oscillations in electronic energy levels. Higher momentum electrons exhibit stronger electron-phonon coupling, consistent with an A_{1g} phonon mode. Such measurements have the potential to help determine the relationship between superconductivity and electron-phonon coupling in cuprates. (2) We use trARPES to measure unoccupied electronic states in the topological insulator Bi_2Se_3. Circularly-polarized optical pump pulses are shown to result in a net current in the unoccupied states. These currents are strongest at energies where a direct transition between occupied and unoccupied states is possible.