Quantitative Electron-Phonon and Phonon-Phonon Coupling in Bismuth Telluride

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Bismuth Telluride (Bi_2Te_3) is a high-performance thermoelectric material due to its unusually low thermal conductivity. This has been attributed to the nature of the bonding in bismuth telluride, with highly anharmonic bonds. Upon visible laser excitation, presence of hot carriers drives a change in the bond lengths along the c-axis, driving a pair of A_{1g} optic phonon modes. We can then observe the modulation of the band structure and phonon modes due to electron-phonon and phonon-phonon coupling driven by the A_{1g} modes. We combine time-resolved ARPES and time-resolved diffraction to measure the deformation potential and excited state band structure in Bi_2Te_3. The deformation potential is approximately -1600 meV/A and 5800 meV/A for the two modes. In addition, using x-ray diffuse scattering we can measure the anharmonic coupling of the A_{1g} mode to acoustic phonons and the acoustic phonon dispersion relation.

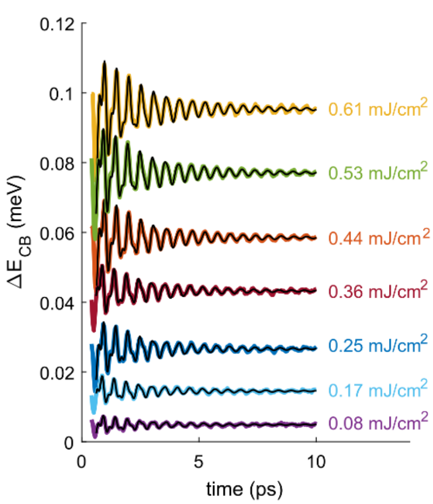

Figure 1: time-resolved ARPES spectroscopy of Bi_2Te_3. The conduction band is modulated by the coherent motion of two A_{1g} optic phonon modes.

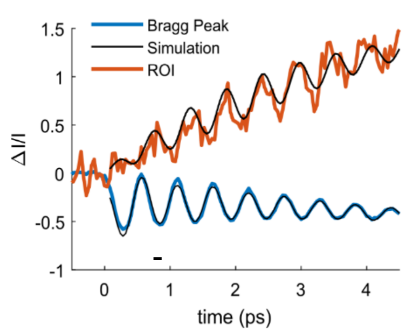

Figure 2: Time-resolved Bragg and diffuse scattering in Bi_2Te_3. The blue curve shows the modulation of the (4 4 5) peak due to an A_{1g} optic phonon. The orange curve shows changes in the diffuse scatter generated due to anharmonic coupling of an LA acoustic branch to the A_{1g} phonon.