Time Resolved Photoemission on Bismuth Surfaces

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The FEMTOARPES project (Angle Resolved Photoemission Spectroscopy with FEMTOsecond resolution) is dedicated to the study of out of equilibrium excited states in solids using time resolved photoemission spectroscopy. A new laboratory has been built, consisting of a 250 kHz femtosecond laser source at 800 nm, a femtosecond ultraviolet laser source at 6 eV (200 nm) and a photoelectron spectrometer.

We will present our first photoemission results obtained on a Bismuth 111 surface. We have performed “static” photoemission and have successfully measured the band structure of Bismuth using our femtosecond 6 eV laser source. Surface states and bulk states have been measured and the results compare well with recent photoemission data obtained recently with synchrotron sources [1-3], thus validating our experimental apparatus.

The time-resolved response of Bismuth following excitation by a femtosecond laser has been studied. Following femtosecond excitation, the Bismuth lattice undergoes macroscopic coherent oscillations, referred to as “coherent phonons”, due to the macroscopic population of a given phonon mode. Such oscillations have been observed in Bismuth in optical reflectometry experiments as well as in time-resolved diffraction experiments [4-6]. Using photoemission, we observe oscillations of the bulk bands which we interpret as another signature of the coherent phonon oscillations. Our photoemission set-up gives us access to new information regarding these oscillations: (i) surface bands do not oscillate, (ii) the amplitude of the oscillations are strongly k-dependent, (iii) the bands undergo a shift toward higher binding energies following laser excitation.

Understanding these trends is not trivial, in particular, unveiling the effects of laser excitation on the band structure is a challenge. With the support of Density Functional Theory calculations, we will present our current understanding of the physics at stake.