Ultrafast structural dynamics of metallic materials studied by photoelectron spectroscopy

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Synopsis Time-resolved photoelectron spectroscopy is proposed to investigate the structural dynamics of metallic samples on an ultrafast timescale upon femtosecond laser excitation.

This work aims to study phase transitions in metallic materials upon excitation by femtosecond laser pulses [1] using time-resolved photoelectron spectroscopy (PES). When irradiated by short infrared laser pulses, the outermost electrons of a metallic material heat rapidly (~100 fs) creating a very strong out-of-equilibrium state of matter. Next, the energy is transferred to the lattice through electron-phonon interactions in a timescale of a few picoseconds, modifying the atomic structure [2] (phase transition, disorder, rearrangements). Then, the solid cools down on a longer timescale of few hundred of picoseconds leading also to lattice modifications. The difficulties in modeling this specific regime of matter and the associated phase transitions arise from its intrinsic out-of-equilibrium character: indeed, matter properties such as electron-phonon coupling, electronic, ionic thermal conductivity and heat capacity remain poorly known [3].

In this context, pump/probe time-resolved experiments with sub-picosecond resolution may help to improve our description of the aforementioned processes and material properties in these extreme density and temperature conditions. Additionally, the comparison between theory and experimental data will allow testing the validity of the actual models and data interpretation. The relaxation of matter can be observed in time by monitoring the PES spectra of the metal's valence band (VB) at different time after excitation. Figure 1 presents the results using a 2 ps IR pump pulse and the High Harmonic Generation 40 eV beamline of the CELIA laboratory as a probe [4]. The duration of the pump pulse is restricted by the probe pulse energy.

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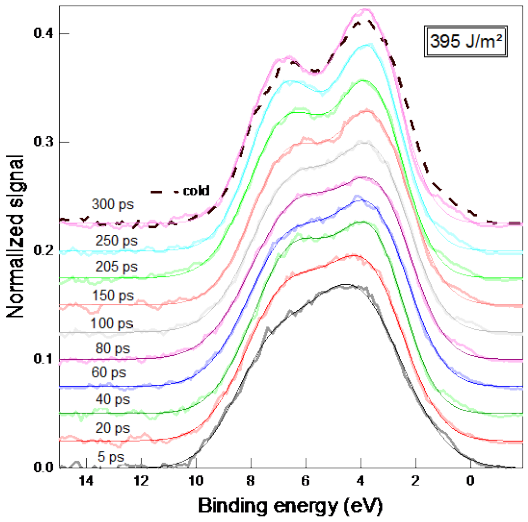

Figure 1. Temporal evolution of the VB spectrum for a 1 µm thick layer of gold using a probe pulse of 40 eV.

In order to reach femtosecond timescales, we have developed and characterized a new beamline that delivers femtosecond pulses up to 100 eV. The associated results on the ultrafast dynamics of thin gold layers will be presented at the conference. Further improvements to the experiment, which will open perspectives in studying different materials at different excitation intensities, will be also detailed.

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References

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