Time resolved soft x-ray photoelectron spectroscopy as metal melting diagnostic.

A. Lévy, S. Macé, S. Cervera, E. Lamour, C. Prigent, J.P. Rozet,
S. Steydli, M. Trassinelli, D. Vernhet
Institut des NanoSciences de Paris, Sorbonne Universités UPMC Paris 6, 75252 Paris Cedex 05, France
J. Gaudin, B. Chimier, N. Fedorov, Y. Mairesse, I. Papagiannouli, P. Martin,
CELIA - Université de Bordeaux, CEA, CNRS, CELIA, 33400 Talence, France
R . Grisenti
Institut für Kernphysik, J. W. Goethe Universität Max-von-Laue-Str. 1, 60438 Frankfurt (M), Germnay
K. Ueda, Y. Ito
Tohoku University, Sendai 980-8577, Japan
P. Combis, V. Recoules, L. Soulard, L. Videau
CEA, DAM, DIF, 91297 Arpajon, France

We aim to understand phase transitions dynamics of metallic materials irradiated by femtosecond laser pulses. This peculiar interaction is characterized by the specific energy deposition mechanism. In fact, in these conditions, the laser pulse energy is absorbed by the electronic population which temperature can reach several eV while the atomic lattice remains cold. This leads to the creation of the so-called out-of-equilibrium regime of matter in between the solid and the plasma state. This highly excited solid state remains difficult to model as well as extremely challenging to study experimentally.

On the experimental side, one way to tackle this issue is to use soft x-ray Photoelectron emission spectroscopy (PES). This technic has been shown to be a powerful method routinely used in a static mode to explore the electronic structure of solids. The electronic structure is determined by the atomic ordering, as a results for a given element different lattice, or phase, will have different electronic structure. This will be reflected by the characteristic features observable in the photoelectron spectrum. Our research program currently under development aims to perform time-resolved PES focusing on the understanding of solid to liquid phase transition dynamics. As a first proof of principle we choose to explore gold melting, which in spite of having being intensively investigated remains a puzzling example.

We will present the results of the first experiments have been performed at the CELIA laboratory using the usual pump and probe scheme (see fig. 1). The 800 nm, 2 ps beam was used as pump to heat up the 1 µm thick gold layer deposited on Si. The soft x-ray light source was made of high-harmonic generation delivering probe pulse of 41 eV photon energy. The sample was irradiated at two different fluences: 230 and 395 mJ/cm². Photoelectron emission spectra of the valence band were recorded at different delays up to 300 ps. The results show a clear evolution of the spectrum as a function of time. The experimental results will be discussed with respect to state of the art electronic structure calculations using ab-initio method.

These first demonstrate the potential of time-resolved PES to investigate dynamics of phase transition. We will present the foreplaned up-graded experimental set-up will allow us to explore the dynamics on the sub-ps timescale.

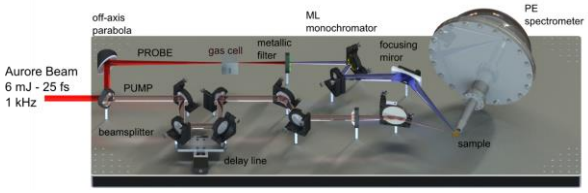

Fig. 1: Scheme of the foreplaned experimental set-up.