ESRF	**Experiment title:** Time resolved XAS measurements of shocked Ta	**Experiment number**: HC2586
Beamline: ID24	**Date of experiment**: from: 25/04/2016 to: 23/05/2016	**Date of report**: 21/02/2018
Shifts:	**Local contact(s)**: Olivier Mathon	*Received at ESRF:*

Names and affiliations of applicants (* indicates experimentalists):

Florent Occelli*, CEA; Arnaud Sollier*, CEA; Paul Loubeyre*, CEA; Emilien Lescoutes, CEA; Raffaela Torchio*, ESRF ; Charles Pépin*, EPFL ; Richard Gaal, EPFL

Report:

Scientific background

Warm Dense Matter, WDM, the state in between condensed matter and classical plasma, is a new frontier in scientific research, where very little experimental data at the atomic level exist. XANES spectrum provide this access to the electronic structure. It has been demonstrated on ID24 that X-ray absorption spectroscopy using a single 100 ps X-ray pulse allows the succesful characterization of the electronic and structural properties of dynamically laser-shock compressed samples in the WDM state (Torchio et al., Sci. Reports 6, 26402). In the case of Ta, the measurements are performed at the L_3 edge (9.881 keV) associated to a direct electric-dipole transition, meaning that a strong peak appears just above the absorption edge. Measurements of the evolution of this L_3 edge on compression in terms of shift and shape could then reveal the change of the electronic density of states and be an ideal test for state of the art DFT calculations. Moreover, it should settle the controversy over the possible solid-solid phase transition (bcc to hex-w) in dynamically compressed Ta.

Experimental technique

A portable high-power laser had been installed on the ID24 beamline. This laser features an adjustable pulse length that can be tuned from 4 to 100 ns, for a maximum energy of 50 J. A 100 microns phase plate has been used to get a laser spot size on the target much larger than

the X-ray spot size. The target consisted a 10 microns Ta foil confined between two diamond windows of 25 microns thickness. Hydrodynamic simulations performed prior to the experiment showed that such target design allows to reach the confinement of a warm and dense state of few ns lifetime. A good reproducibility of the shock state has been observed experimentally.
A VISAR (Velocity Interferometer System for Any Reflector) had been installed on the beamline in order to measure the shock velocity at the back surface of the targets thus allowing us to deduce the maximum pressure induced in the sample.

Results

As seen in figure 1, the quality of a single bunch acquisition is good a clear shift of the white line in energy and in intensity is measured. Thermodynamical conditions are obtained from the hydrofdynamic simulations.

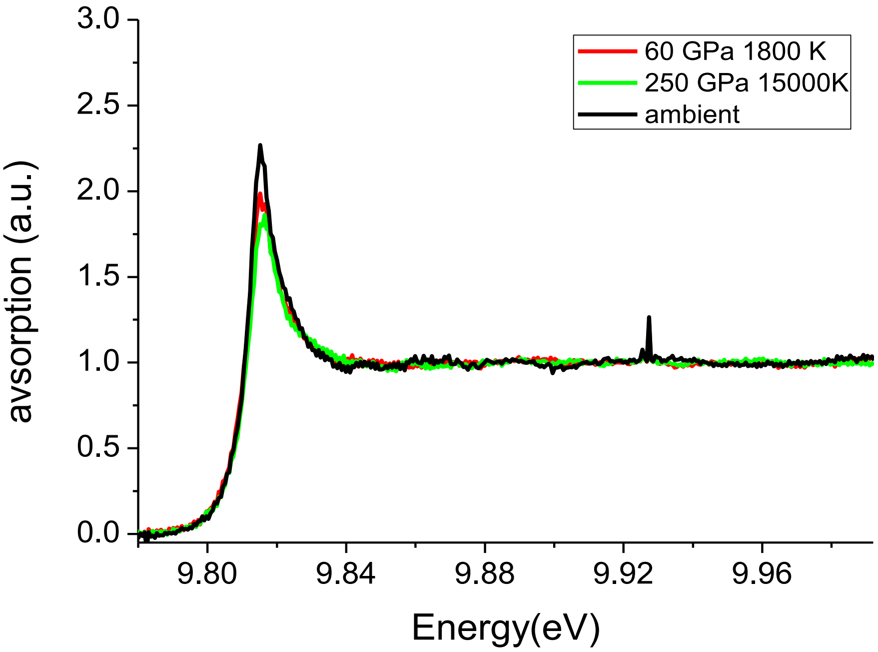

Figure 1: Effect of shocked stazte on the XANES spectra. Spectra were obtained with 1 x-ray bunch.

Four different runs were performed, as follow:

- Run 1: phase plate of 300 microns, targets: 40 µm diamond/10 µm Ta/50 µm diamond
- Run 2: phase plate of 100 microns, targets: 40 µm diamond/10 µm Ta/50 µm diamond
- Run 3: phase plate of 100 microns, targets: 25 µm diamond/10 µm Ta/25 µm diamond
- Run 4: no phase plate, targets: 25 µm diamond/10 µm Ta/25 µm diamond

For each run, around 30 targets were shot and the laser delay relatively to X-ray pulse was tuned by steps of 0.25 ns. A maximum pressure of ~250 GPa associated with a temperature of ~3000 K has been reached. The melting line was not crossed.
A very strong effect of the compression has been observed on the shift and intensity of the white line (Fig.2). No evidence for the bcc to hex-w has been observed.
Ab-initio DFT calculations of the electronic atomic changes for the same thermodynamic conditions are now being performed and will be compared to the measurements.

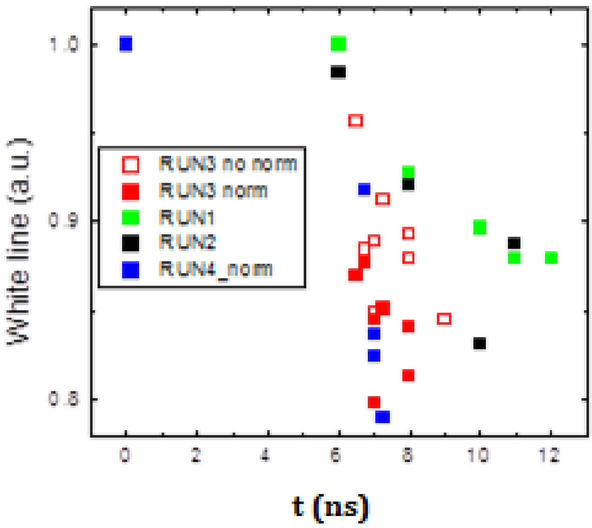

Figure 2: Evolution of the intensity of the white line at various delays for the four different runs.