ESRF	**Experiment title:** X-ray spectrosccpy of iron in the Warm Dense Matter (WDM) regime.	**Experiment number**: HD 314
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Report:

By now, the laser heating technique permits to perform accurate structural measurements of solid and molten materials at pressures in the 200GPa range and at temperatures in the 0.5 eV range[1]. But only dynamical measurements could probe the properties of dense matter at higher temperatures, in the so-called Warm Dense Matter (WDM) regime. The WDM (a.k.a. Non-Ideal Plasmas, see [2]) is defined as a state where the coupling and degeneracy parameters of the electronic density are of order 1, i.e the interaction and kinetic energies are almost equal and the Fermi and thermodynamical temperatures are of the same order. For most systems, and in particular Fe, that corresponds roughly to densities in between ρ_0 and $10\rho_0$ and temperatures in the range 1 to 10eV (ρ_0 being the solid density at ambient conditions).

The aim of this proposal was to perform the first WDM experiment in front of a 3rd generation synchrotron source. This plasmas were generated in a modified diamond anvils cell by an electric discharge through a conducting wire. We first focused on the case of iron since i) measurements of the iron EoS and opacities in the WDM regime have already been performed by coupling a laser-driven shock with a laser driven x-ray source [3], ii) many calculations of dense iron plasmas opacities could be confronted to the experimental data[4], and iii)the ID24 beamline setup is well suited to work around the iron k-edge. For this, we were allocated 15 shifts of beamtime on ID 24 in July 2009 to perform time-resolved DEXAFS measurements on fast heated sample. Since coupling this type of experiment with a synchrotron beamline is very uncommon, especially because it needs the use of a brand new type of fast-reading detector (the Xh detector, consisting of a Fine Pitch Silicon Microstrip Detector developed for Energy Dispersive EXAFS [5]), most of the beamtime dedicated to this project was used for setting up the time-resolved control scheme of the ID24 beamline (SPEC macros triggering the electric power supply and the detector with an appropriate delay, data collection and process).

During this first attempt, we didn’t focus on the pressure/temperature performance of the system, but on the possibility to perform accurate and reproducible measurement of the sample properties in a warm and dense state while testing various plasma confinement methods. This means that instead of performing μs measurement at several 100kbar and at several eV, we settled for performing millisecond measurement in the 1 kbar/1eV range. But we successfully ended up performing the first DEXAFS measurements in iron at WDM P-T conditions. Here are the most interesting raw results obtained during this run over the 20 successful tests we performed.

Figure 1 shows a post-mortem picture of a confined plasma. Figure 2 shows the most notable corresponding spectra recorded during this run. A first look at these curves without any detailed analyze allow several qualitative remarks. 1-The confinment time is of the order of 1 ms, which is way enough to collect many usable DEXAFS spectra by steps of 0.1ms. 2-The spectra obtained here are of better quality than those obtained by the

laser shock technique[5]. In particular, the XANES signal raise is observed. 3-These measurements show qualitatively the expected physical results : i) observation of phase transformations from the observed changes in the XANES spectra features, which implies the transition kinetics is fast enough for the pupose of these measurements ; ii) in the 1st fluid phase spectrum, oscillations show a strucutre that continuously vanishes until the last spectrum, suggesting a correlation loss. 4-A significant edge red-shift is seen in the fluid phase as well as a strong increase in aborption. Recent ab-initio calculations on Al [6] infer such a behavior: the edge red-shift is interpreted as coming from a decrease in the Fermi energy in T as well as from a change in population around the Fermi energy, while the absorption raise should be due to a change in the excitonic state lifetime. This type of measurements is therefore a direct test to the most recent DFT calculations approximations in the high T/ρ_0 range where up to now, their validity couldn't really be checked. Other samples show the reproducibility of these measurements.

Using Kapton permits a fair contaiment without disturbing the x-ray probe (diffusion), but doesn't permit optical pyrometry measurement (strong light absorption in the visible range). The exact pressure/temperature couldn't be measured. But we are expecting to be able to estimate them by a thermodynamical model using the available data (lifetime, current increase rate, time to reach the known phase transitions, estimated or measured iron thermodynamical and transport properties). The next improvement of our experiment setup will consist of using optically transparent confinement materials (polycarbonate or solidified Ne are good candidates). Working with different confinement media should also permit to test the sample chemical pollution along the warming process. We are going to submit a new proposal in September 2009 in order to continue this project.

Fig. 1: Post-mortem picture of an iron sample pressed between two 100 µm-thick Kapton platelets as a containement. The dark leak path on the right shows the sample reached a high pressure/high temperature state. The DEXAFS spectra recorded during this run showed this state lifetime was of 1ms.

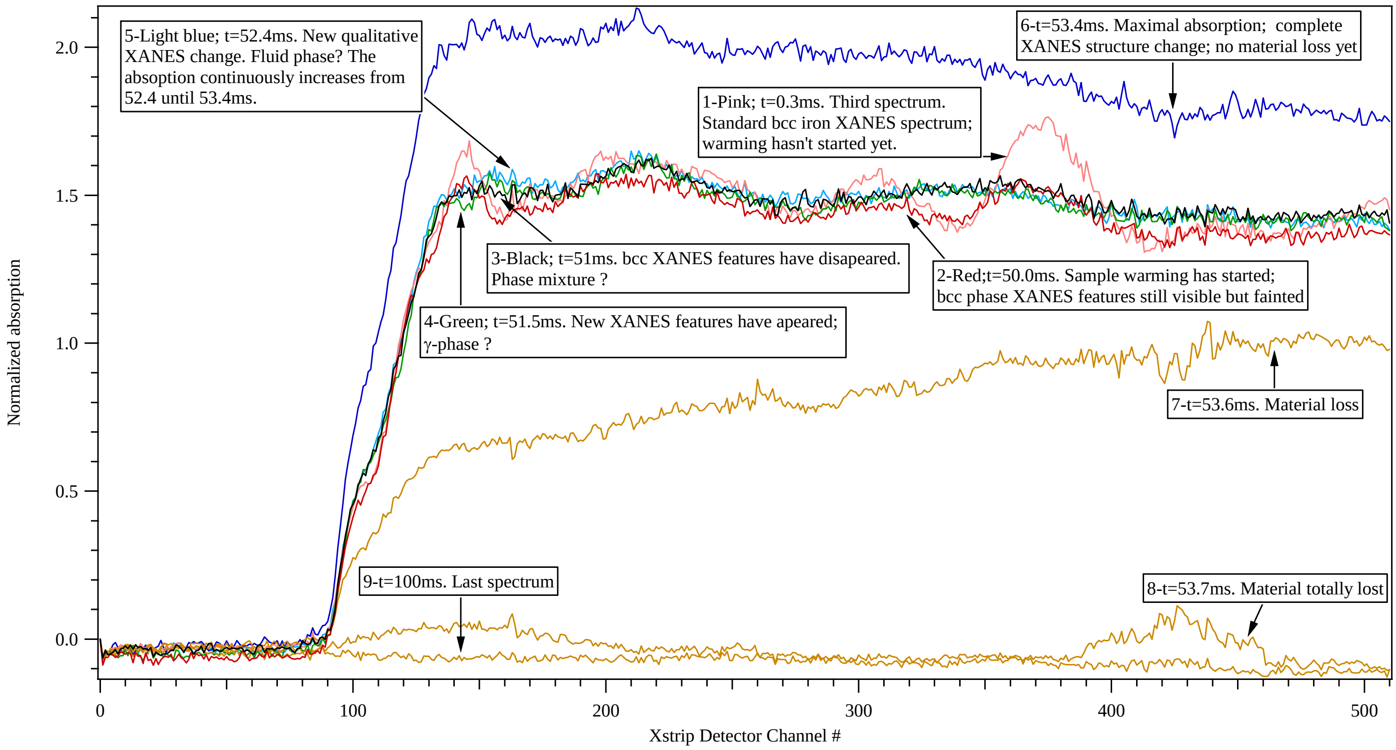

Figure 2: Most notable spectra recorded on the sample shown Fig. 1. 1000 spectra were recorded by 100µs steps. To prevent any data loss, we started counting ~50ms before triggering the current ramp.

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