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High-precision measurement of the K-edge shift in heavy-ion heated aluminum

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The HHT experiment area at GSI offers the unique capability to heat matter by intense bunches of high-energy heavy-ions from the SIS-18 heavy-ion synchrotron and to probe the generated short-lived states with X-rays created by the PHELIX laser facility. Focusing ~300-ns-long bunches of up to 4×10^9 U^{73+} ions down to sub-millimeter spot-sizes, aluminum samples were heated to around 1700 K. We detected X-ray absorption spectra around the K-edge (1560 eV) under these conditions.

High-precision measurements of the K-edge shift were achieved using characteristic emission lines of the X-ray backlighter for on-shot spectral calibration of the X-ray absorption near edge structure. The extracted red shifts, on the order of 0.2 eV at 1700 K, are compared with predictions from density-functional-theory molecular dynamics (DFT-MD) simulations. The hydrodynamic evolution of the target was investigated by 2D simulations with the code BIG2, to account for the thermal expansion during the heating phase. The DFT-MD results reveal a competition between the reduction of the Fermi energy in the conduction band and the lowering of the 1s binding energy (indicating stronger binding) upon heating.

In this contribution, we present the experimental setup combining heavy-ion heating with laser-driven X-ray diagnostics, discuss the measured K-edge shifts in aluminum, and compare the results with DFT-MD predictions. Finally, we give an outlook on future absorption spectroscopy studies on heavy-ion heated iron which will provide complementary diagnostics to previous X-ray diffraction studies on the phase transition and melting dynamics. The demonstrated techniques are directly applicable to experiments at the future FAIR facility, where unprecedented ion beam intensities will enable studies of continuum lowering at warm-dense-matter conditions.

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