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Tracking phase transitions at extreme conditions of pressures and temperatures using high-energy lasers and XFELs

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Studying matter under extreme conditions is critically important for a wide range of science application including, for example planetary science, astrophysical high-velocity impacts as well as industrial applications. While laser compression is playing a major role in exploring phase diagrams at extreme condition of pressures and temperatures, the associated physical processes and phase transitions mechanism are barely understood. The arrival of XFELs, in complement with synchrotron sources are providing unique new measurements and deeply modifying our understanding of dense matter.
In that context, we present a short overview of recent studies devoted to investigate the solid-solid and solid-liquid transition in laser-shocked iron alloys [1] and iron oxides using X-ray diffraction, X-ray diffuse scattering and X-ray absorption spectroscopy. Experiment were performed at the MEC end-station of the LCLS facility at SLAC (USA), at the EH5 end-station of the SACLA facility (Japan) and at ID24-ESRF (France). Our results show dynamic high-pressure phases that are not identical to those revealed by static diamond anvil cell compression, questioning transition paths, and especially the spin transition mechanism in the case of Fe2O3. Finally, we have also possibly highlighted the reduction of iron in Fe2O3 upon release after a shock at 120 GPa. This observation highlights the rapidity of the redox mechanism under high-velocity impact as suggested by recovered samples from meteorite impacts.
[1] A. Krygier, Physical Review B, 2022

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