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Laser-driven X-ray diagnostics for heavy-ion-heated warm-dense-matter studies

The study of matter at high-energy-density (HED) conditions is relevant to the understanding of compact astrophysical objects, and crucial for applications such as inertial confinement fusion. For producing such extreme states of matter in the laboratory, volumetric heating by intense pulses of heavy ions offers a novel approach (compared to more established drivers such as high-energy lasers), allowing to heat large sample volumes on the mm^3 scale, with small gradients, on comparably long time scales, and near thermal equilibrium. The future FAIR facility in Darmstadt will provide powerful pulses of heavy ions with unprecedented intensity, allowing to reach eV temperatures and Mbar pressures. The plasma physics collaboration HED@FAIR will exploit these unique capabilities for its HED science program.

In order to probe the heavy-ion-beam-generated short-lived dense samples, X-ray pulses generated by the interaction of high-energy lasers with matter represent a powerful diagnostic. We have recently exploited the available infrastructure at GSI, which allows to use the ion bunches from the SIS18 heavy-ion synchrotron in combination with the ns-pulse of the high-energy laser facility PHELIX at the HHT (high-energy high-temperature) experiment area, in order to demonstrate the feasibility of laser-driven X-ray diagnostics of heavy-ion-heated matter within the FAIR Phase-0 research program. We have commissioned and applied laser-driven X-rays for investigating heavy-ion-heated matter through X-ray diffraction, X-ray Thomson scattering and X-ray absorption spectroscopy. We report on first findings using this platform, in terms of observing phase changes in iron and diamond, as well as volumetric temperature measurements of a heated aluminium sample.

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