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Nanometer-scale characterization of laser-driven plasmas, compression, shocks and phase transitions, by coherent small angle x-ray scattering.

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Combining ultra-intense short-pulse and high-energy long-pulse lasers, with brilliant coherent hard X-ray FELs, such as the Helmholtz International Beamline for Extreme Fields (HIBEF) [1] under construction at the HED Instrument of European XFEL [2], or MEC at LCLS [3], holds the promise to revolutionize our understanding of many High Energy Density Physics phenomena. Examples include the relativistic electron generation, transport, and bulk plasma response [4], and ionization dynamics and heating [5] in relativistic laser-matter interactions, or the dynamics of laser-driven shocks, quasi-isentropic compression, and the kinetics of phase transitions at high pressure [3,6]. A particularly promising new technique is the use of coherent X-ray diffraction to characterize electron density correlations [4], and by resonant scattering to characterize the distribution of specific charge-state ions [5], either on the ultrafast time scale of the laser interaction, or associated with hydrodynamic motion. As well one can image slight density changes arising from phase transitions inside of shock-compressed high pressure matter. The feasibility of coherent diffraction techniques in laser-driven matter will be discussed. including recent results from demonstration experiments at MEC. Among other things, very sharp density changes from laser-driven compression are observed, having an effective step width of 10 nm or smaller. This compares to a resolution of several hundred nm achieved previously [6] with phase contrast imaging. [1] www.hibef.eu [2] www.xfel.eu/research/instruments/hed [3] B. Nagler et al., J. Synchrotron Rad. 22, 520 (2015). [4] T. Kluge et al, Phys. Plasmas 21, 033110 (2014). [5] T. Kluge et al., http://arxiv.org/abs/1508.03988 [6] A. Schropp et al., Sci. Rep. 3, 1633 (2013).

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