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Advanced x-ray imaging diagnostics for HEDP experiments

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The field of high energy density physics extensively benefits from the advent of ultra-intense optical and free-electron lasers both pumping and probing extreme states of matter. During the past decade, several physical fundamental problems have been pointed out in this field. Particular significance arises for shock compression of matter or plasma hydrodynamic instabilities, which are of prime importance for various domains such as astrophysics, inertial confinement fusion, planetology and technological and advanced material creation.

The x-ray imaging is a fundamental diagnostic in HEDP community as it enables to follow temporal evolution of fast evolving phenomena through the whole volume of investigated matter in the micrometer scales. Primary the precision of measurements is defined by the resolution of the applied imaging method.

Recently the novel phase-contrast imaging platform [1] based on coupling XFEL or laser-produced x-ray and XUV sources with photoluminescence (PL) LiF crystal detector [2] demonstrated the unique combination of sub-μm spatial resolution, large field of view (Fig. 1), and ultra-high dynamic range ~10^7 [3-5].

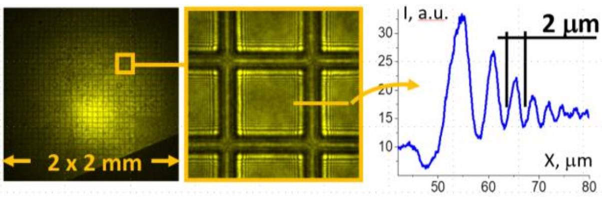

Fig. 1. PL image of 400 lpi grid recorded on a LiF crystal with spatial resolution of ~0.8 μm in the field of view FOV = 2 x 2 mm^2 at 7 keV photon energy of SACLA XFEL beam. High order diffraction fringes with period of ≤ 2 μm are observed with high contrast.

Due to a high degree of spatial coherence of XFEL beams the platform allows to perform phase contrast imaging (PCI) and significantly enhance the visibility of objects which are strongly opaque or have a very low absorption. That was demonstrated, for example, in [1] by the radiography of targets typically used for investigation Rayleigh-Taylor plasma instabilities (RTI) (Fig.2).

In Fig. 3 the different stages of RTI evolution (a) and shock compression in solid target (b) driven by optical high-power ns-laser pulses are shown. That is the first observation of μm-scale details in the whole volume where the process occurs and it is highly demand as the spatial resolution corresponds to the resolution of existing advanced models and computational methods.

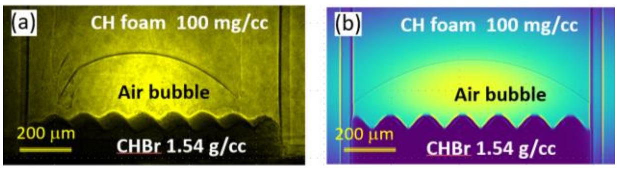

Fig.2. Phase contract radiography of RTI target with SACLA XFEL (10 keV) and LiF detector: comparison of experimental image (a) with modeling (b).

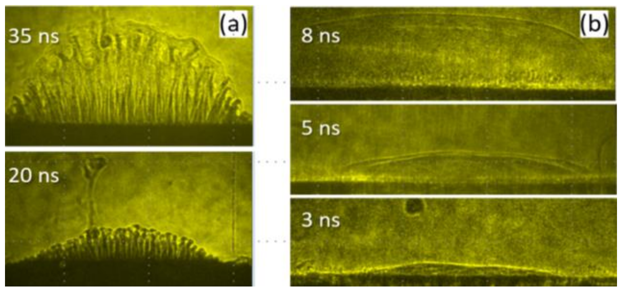

Fig. 3. PCI images of RTI (a) and shock waves in solid target (b) measured on LiF at different time delay after pumping laser pulse arrival (SACLA XFEL probe).

The LiF detector is efficient tool for characterization spatial and coherent properties of FEL beams and laser-produced sources [2,3,5]. In [7] the sub-μm size of high-order harmonics emitters created in laser plasma by newly discovered Burst Intensification Singularity Emitting Radiation (BISER) mechanism has been evaluated.

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