<table>
<tr><td>ESRF</td><td>Experiment title:
Combining SAXS with radiography to measure shock steepening in laser-driven matter</td><td>Experiment number:
MI-1266</td></tr>
<tr><td>Beamline:
ID19</td><td>Date of experiment:
from: 10 Dec 2016 to: 15 Dec 2016
21 Mai 2017 22 Mai 2017</td><td rowspan="2">Date of report:
03.03.2018

Received at ESRF:</td></tr>
<tr><td>Shifts:
2 x 9</td><td>Local contact(s):
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Report:

The central aspect of this proposal was to combine small angle x-ray scattering (SAXS) with radiography during a laser-driven shocks that are frequently employed to produce high pressures. The conditions achieved in these experiments can vary from those achieved in static compression using diamond-anvil cells, due to the dynamic nature of the shock generation and of the temporal response of the material. This is particularly true at high strain rates.

The central aspect of this proposal was to combine small angle x-ray scattering (SAXS) with radiography exploiting the coherence properties of the X-ray beam.

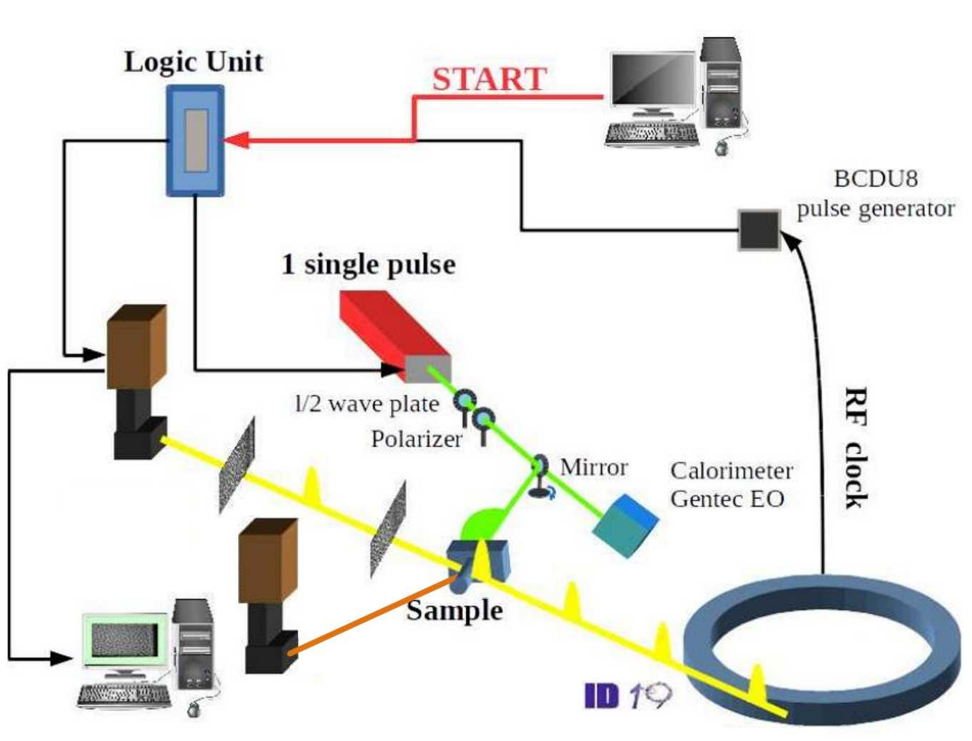

Figure 1: Schematic overview of the experimental set-up. The ESRF storage ring operated in 4- or 16-bunch filling mode, i.e. the source pulse repetition was approximately 1.42 MHz for the 4-bunch mode. The X-rays were generated by the means of two undulators. XPCI was per-formed 145 m from the source to achieve enhanced partial spatial coherence of the X-ray beam. Shock wave compression in the sample was generated using a 6J or ~1J, ~10 ns pulsed laser. The laser pulse and the image acqui-sition were synchronized with the X-ray pulses using the RF of storage ring as the master clock. XPCI images were recorded by a high-spatial resolution, ultra-high-speed indirect X-ray detector [1].

During the experiment in December a Gaia laser of 5 J-energy and 10 ns-pulse duration was provided by Thales to drive the shocks. Single bunch snapshots were recorded with a fast Shimadzu HPV-X2 camera, in 16 bunch mode (8 µm pixel size, 6.4 m propagation distance, around 30 keV photon energy, 170 ns exposure time, short enough to isolate the X-ray flash, about 100 ps-long, from one bunch of electrons in the storage ring). Unfortunately, a severe breakdown of the Gaia laser following an electrical problem at startup strongly limited the time of the experiments and usability of the laser. These problems could be partially compensated by a the use of a 10ns pulsed BrilliantB ~1J laser, operating either a fundamental wavelengths of 1064 nm or at second harmonics (532nm).

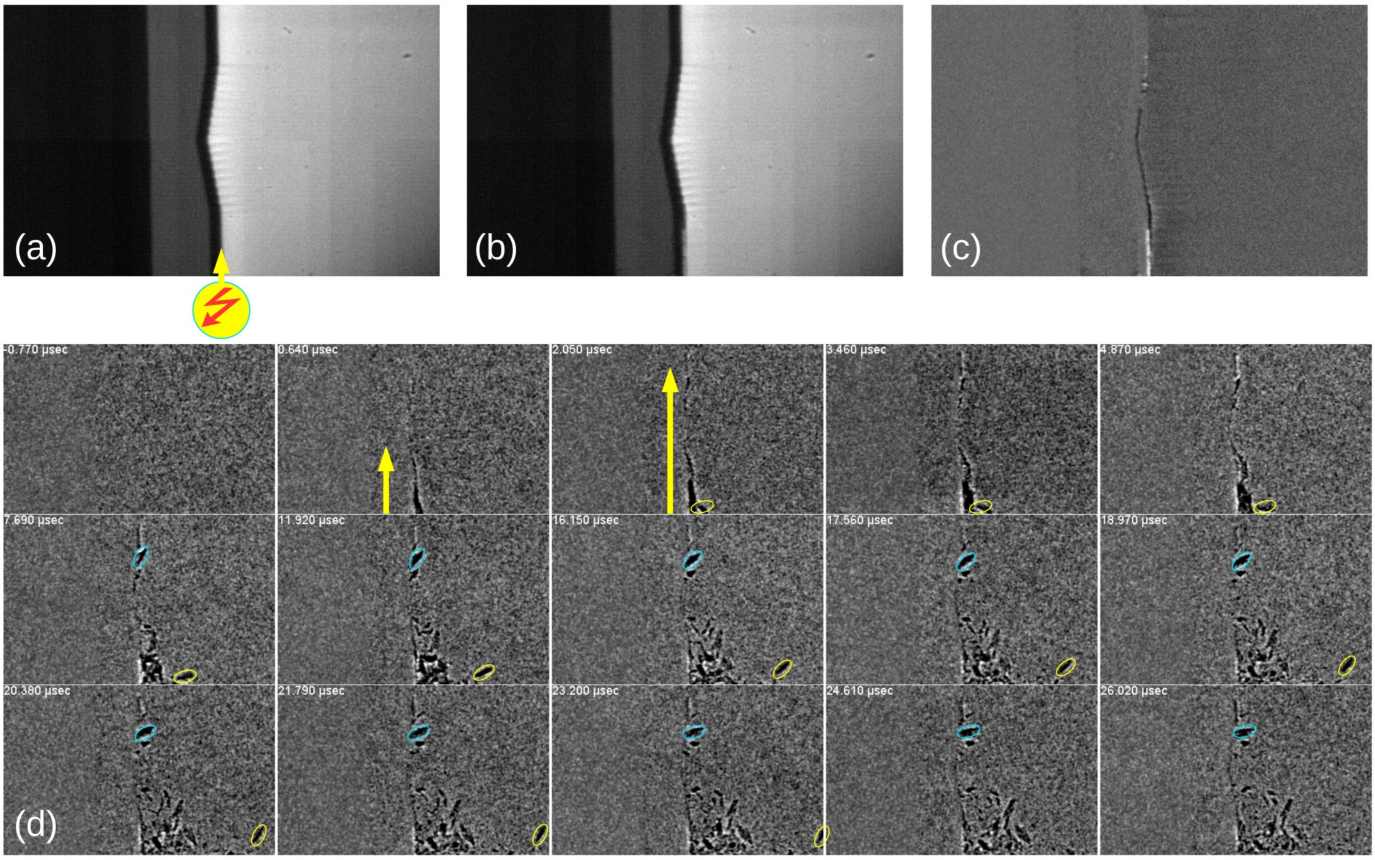

Figure 2: Time resolved radiograph's from a grooved Si wafer surface. The impact position of the laser is out side the observation window and marked by an arrow. The grooves are almost parallel to the X-ray beam, the incidence angle is just above zero (α_i ~0.1°). The signal of the grooves are before and after the laser impact visible. The difference image shows the formation of a crack and a corresponding change in the XASX-signal. Figure (d) shows a time series of the developing crack (arrows); the frame rate was 0.71MHz. Small particles break away with about 100m/s.

Figure 2 shows a radiograph a Si wafer surface with a grooved terrace like structure that produces additionally a strong scattering signal (horizontal stripes figure 1a,b,c). Laser impact arrived the sample surface just out side the grooved area (marked by and arrow in figure 1a). Figure 1c represents the numerical difference before (fig.1a) and after (fig.1b) the laser impact. Figure 1d shows the temporal evolution of a surface strain wave induced by the laser pulse, that develop with time and running trough the grooved area and producing a crack and showing the break away small particles. Taking into account an effective field of view of 3.2 × 2.0 mm^2 with an effective pixel size of 8.0 µm the particle marked with an yellow ellipse moved away from the surface by a speed of about 140m/s at about 2µs after the laser impact and slowing down to about 70m/at about 22µs. The blue marked particles moves much slower and detaches from the surface much later (~30ms after the impact) which may be connected with its strong rotational movement.

We would like to thank AXO Dresden, GmbH for the preparation of the samples.

References:

[1] M. P. Olbinado, V. Cantelli, O. Mathon, S. Pascarelli, J. Grenzer, A. Pelka, M. Roedel,I. Prencipe, A. Laso Garcia, U. Helbig, D. Kraus, U. Schramm , T. Cowan, M. Scheel, P. Pradel, T. De Resseguier and A. Rack, J. Phys. D: Appl. Phys. 51, 055601 (2018).