X-ray generation by laser hole boring and channelling in dense plasma

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Introduction

We report on an experiment which aimed to investigate the sensitivity of X-ray radiation generation to the degree of laser channelling occurring in overdense plasma. Channelling is driven by the processes of relativistic self-induced transparency (RSIT) [1] and radiation pressure hole boring (HB) [2] and enables the laser to interact with the target plasma volumetrically. X-rays are produced by electron acceleration in the fields generated, or via Bremsstrahlung due to interaction with the fields of the target atoms, and provide a useful diagnostic due to their penetration through the dense target, enabling the channelling dynamics to be probed. Investigation of laser hole-boring and channelling physics in dense plasma at the upper limits of intensities achievable today (~10^{21} Wcm^{-2}) benchmarks models used to design future experiments at multi-petawatt lasers, for which radiation pressure driven effects will dominate the physics.

Experiment

The experiment was conducted using the PHELIX laser. This system is one of few capable of routinely achieving peak intensities up to mid-10^{20} Wcm^{-2}, which are required to probe radiation pressure-driven phenomena. This system can deliver 200 J pulses (~155 J on-target) with a duration of 700 fs (FWHM). The high temporal intensity contrast delivered (~10^{11} [3]) is also critical for experimentation using ultra-thin (nanometre scale) and low density foam type targets, to prevent significant target expansion prior to the arrival of the peak laser energy.

To investigate X-ray generation, a complementary suite of diagnostics were implemented to characterise both the spectral and spatial distributions, and source size. These included a crystal spectrometer operating in the range 17-200 keV, a scintillator-based array diagnostic, which provides low resolution spatial and spectral measurements extending to the hard X-ray range, and a high resolution (μm) penumbral imaging system to quantify the X-ray source size.

Additionally, a curved stacked detector [4], consisting of image plate and steel filters, was placed around the interaction region. This provides a high resolution angular and low resolution energy measurement of the distribution of electrons which 'escape' the target foil. Furthermore, the degree of laser light both reflected from and transmitted through the target was measured. This not only enables the plasma absorption dynamics to be probed, but additionally enables the conditions for the onset of transparency to be determined. Pictures of the experimental set-up in the PHELIX target chamber are shown in Fig. 1.

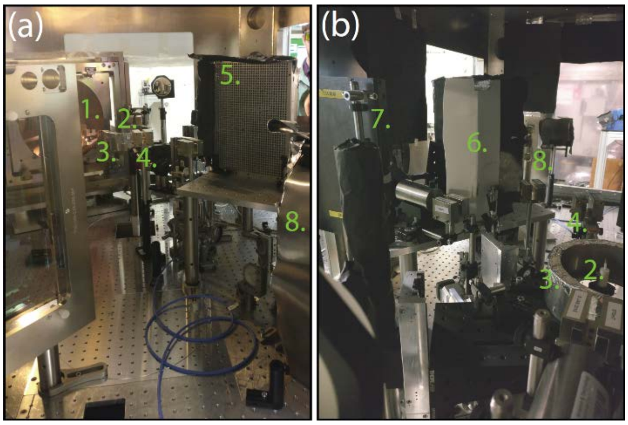

Figure 1: (a) and (b) Photographs of the experimental set-up, where the labels identify the main components as follows; 1. off-axis parabola, 2. target, 3. curved stacked detector, 4. penumbral imager, 5. scintillator array, 6. laser transmission screen, 7. electron spectrometer and 8. X-ray crystal spectrometer.

The targets selected for exploring X-ray generation were relatively thin (40-1000 nm) foils (Al, Au and CH) and low density plastic based foam targets (25-500 mg/cm^3), in order to investigate the transition from surface-dominated physics to volumetric interaction induced by HB and RSIT.

Analysis of the data measured on the experiment is currently underway, and results will be reported in future publications.

References

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Experiment beamline: none
Experiment collaboration: other: PHELIX
Experiment proposal: P124
Accelerator infrastructure: other: PHELIX
PSP codes: none
Grants: EP/J003832/1, EP/L001357/1 and EP/K022415/1
Strategic university co-operation with: none

DOI:10.15120/GR-2018-1