High Energy Density plasma generated with a short laser pulse at relativistic intensity

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Abstract

We present an experimental study of thin foils (with thickness between 10nm and 200nm) irradiated at relativistic intensity (10^{20} W/cm^2) by a short laser pulse (30fs). These experiments are motivated by the possibility to produce Ultra-Hot Dense Matter (UHDM).

The specific goal of our experiments is to study the energy deposition at near-solid density, the so-called target isochoric heating, and infer initial plasma conditions from target decompression following the heating.

The 200TW class laser system at the Advanced Laser Light Source (ALLS) facility is used in those experiments with a very high contrast ratio (10^{-12}) in order to produce hot near-solid density plasmas with steep electronic gradient. The laser pulse temporal contrast between the peak intensity and the ns pedestal is controlled in several ways. A saturable absorber is used before injection of the laser pulse into the regenerative amplifier. It allows reaching a contrast ratio close to 10^{10} up to 20 ps before the peak intensity. An XPW cleaning system is used inside the laser chain to bring the peak to ASE contrast ratio at 10^{12}. In order to further reduce them, a planar plasma mirror was placed at 7 mm distance before the target. The laser fluence is around 54 J.cm^{-2} on the plasma mirror surface. The measured plasma mirror reflectivity is 60 % using a laser pulse at nominal energy conditions, while less than 0.5 % in low intensity conditions. The plasma mirror is reducing the foot of the raising edge of the laser pulse and is shaping the rise time of the main pulse. Considering that the plasma mirror starts to become reflective at a fluence of 2×10^{14} W.cm^{-2}, we estimate that the rising edge of the laser pulse is thus reduce by 2 orders of magnitude up to less than 1 picosecond before the peak of the laser pulse.

Taking into account the plasma mirror reflectivity, the maximum laser energy on target is E_{laser} = 2 J. With routinely obtained laser pulse duration of 30 fs, the maximum laser intensity is close to 1×10^{20} W.cm^{-2} on target. In order to optimize laser-plasma absorption, the laser incidence angle on target was 45^{o} and a p polarization was used. The figure 1 shows the schema of the experimental set up used in these experiments.

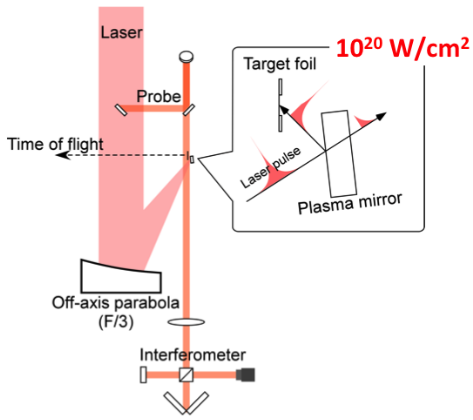

Figure 1: Experimental set up with the plasma mirror to improve the contrast

The plasma expansion following the heating phase is characterized with shadowgraph and Michelson interferometer diagnostics based on a 40fs laser probe beam. Other diagnostics include ion time of flight detectors and calorimeters.

We present and discuss for the first time our entire set of results obtained with ultrathin targets (10nm – 200nm). Plasma with an energy/unit mass in the 10^{7}MJ/kg and with a density of a fraction of the solid density (between 10% and 30%) has been generated.

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