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Diagnostics of pedestal intensity of intense and short fast-heating laser pulse with x-ray backlighting

X線バックライト法を用いた高速加熱用短パルス高強度レーザーのペデスタル計測

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Preformed plasma generated by a leakage pulse component from a high intensity laser pulse seriously influences on heating performance of a compressed fuel in fast ignition scheme. We measured temporally evolved plasma formation with x-ray radiography. It was found that plasma of 40-60μm in scalelength was formed just before arrival of the main pulse. Intensity of the leakage component was estimated by comparing the experimental result with hydrodynamic simulation.

1. Introduction

In fast ignition scheme [1], highly compressed fuel is heated by an extremely intense and short laser pulse (10^{19}W/cm^2/1ps) to cause ignition and burn. A gold cone attached to a fuel capsule is used for guiding the heating-laser energy and thus enables to transfer its energy efficiently to the fuel. The heating laser also includes pre-pulse and/or pedestal components, whose intensity ratio is usually around 10^{-6}~10^{-8} with respect to that of the main pulse. Here after we call these components leakage pulses. These pulses will preform a plasma inside the cone which is harmful for efficient heating of the fuel due to increase in density scalelength and thermo-magnetic filamentations [2-4].

We observed the pre-plasma formation for the case of LFEX (Laser for Fast ignition EXperiment) laser irradiation in order to estimate quantity of the leakage component by comparing the experiment with hydrodynamic simulation.

2. Experiment

In the experiment LFEX laser was used. It provided a laser pulse of 300 J in 1.5 ps at 1064 nm in wavelength. Pulse contrast ratio of 10^{-8} was expected, but characterization of the leakage component has not yet been experimentally verified.

Figure 1 shows the experimental setup.　Time-resolved 1-dimensional (1D) spatial distribution of preformed plasma was measured with x-ray backlight technique combined with an x-ray streak camera (XSC) and an imaging slit. The overall spatial resolution was 48 μm. A gold foil of 10 μm in thickness was irradiated by the LFEX laser. An aluminum foil of 10 μm was irradiated with a laser pulse from GEKKO-XII　(300　J　/　1　ns / 532　nm) to generate an x-ray backlight source of 1.59　keV　(Al^{+11} He_{α} line). Typical image from the x-ray steak camera is inset in Fig. 1.

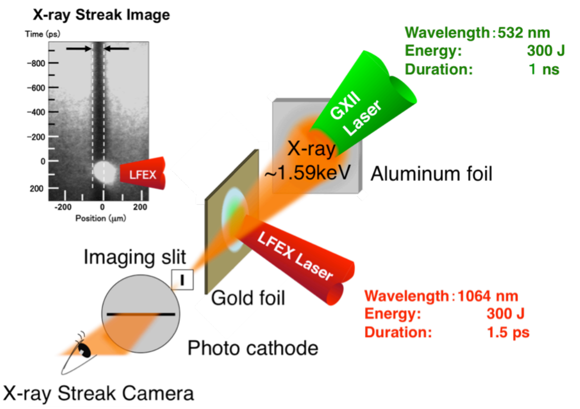

Fig. 1. Experimental setup for preformed plasma observation. The inset is a typical image from the x-ray streak camera

Abel inversion was used to drive the density profile of the preformed plasma. Assuming radially symmetric distribution, absorption of x-rays along the line of sight, in direction of *l*, is given by

$$T = \exp\left[-\int \mu\rho\, dl\right] , \qquad (1)$$

where T is the transmission of x-ray, μ the mass absorption coefficient in cm^2/g, and ρ the density in g/cm^3. Since the intensity of the leakage component was predicted to be 10^{12}~10^{13} W/cm^2, temperature of the preformed plasma is around several 10 eV. Therefore mass absorption coefficient of gold in cold state is still valid for 1.59 keV photons.

3. Analysis

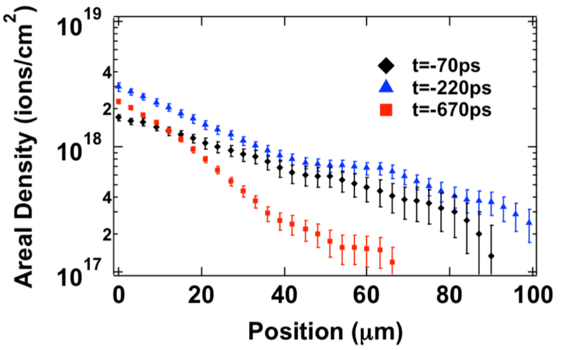

Fig. 2. Density profile of the preformed plasma estimated from the x-ray radiograph.

Figure 2 shows the observed 1D density distribution of the preformed plasma. The heating laser is incident from the right hand side and the origins of the spatial and temporal axes are defined to be the surface of the target and the onset of the main pulse, respectively. Preformed plasma became observable at approximately 700 ps before the main pulse arrival and the density scalelength at this time becomes 40-60 µm. Upon this result, the time duration of the leakage component is assumed to be 1 ns in the following simulations.

We estimated the intensity and spot size of the leakage pulse by comparing the experiment with simulations made with a 2D radiation hydrodynamic code (STAR2D) [5]. First we attempted to simulate the preplasma formation assuming that the spot size of the leakage pulse on the gold surface is the same as that of the LFEX main pulse (i.e., 40 µm in diameter). Other parameters of the leakage pulse were, respectively, 1 ns in duration and irradiance in the range of 10^{11}~10^{13} W/cm^2. However, under these conditions the simulated results could not replicate the experimental results in terms of the density profile, expansion velocity and the density scalelength. So, assuming that the leakage component is attributed to the amplified spontaneous emission, say, from the final amplifiers of LFEX system, thus having a much larger spot size on the gold foil than that of the main pulse, another simulation was made by using 1D radiation hydrodynamic code (STAR1D) [6].

Figure 3 shows comparison between the experiment and the 1D simulations. In this case a leakage pulse of 1 ns and 500 µm in spot diameter at 5×10^{12} W/cm^2 were assumed. The simulation reproduces the experiment fairly well.

In the presentation, these experimental results and analysis with simulations will be discussed.

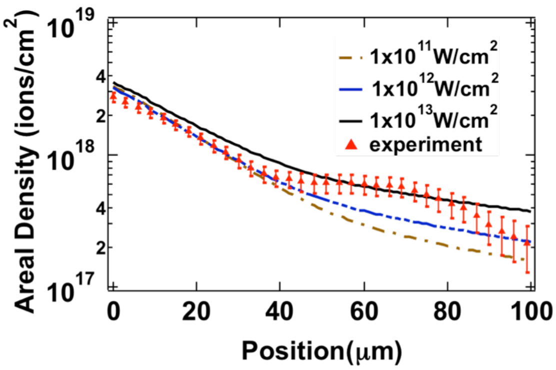

Fig. 3. Comparison of the density distribution between the experiment and 1D simulations

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