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Evaluation of laser-driven electron energy spectrum with High Energy X-ray Spectrometer under suppressed preplasma condition

低プレプラズマ条件での高エネルギーX線分光による レーザー生成電子スペクトルの評価

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In fast ignition (FI) research, a dense fuel is heated directly by MeV-energy electrons generated by a relativistic-intensity laser pulse. However, a preformed plasma produced by the laser prepulse can increase the high-energy part of electrons, which have lower energy deposition on the fuel. Efficient fuel heating requires the reduction of laser energy conversion into the high-energy electrons. In this work, we experimentally investigate the effect of preplasma suppression on the electron temperature. The relativistic electrons are characterized by bremsstrahlung x rays emitted from a foil target using High Energy X-ray Spectrometer (HEXS) combined with Monte-Carlo transport code: Geant4. The hot electron temperature obtained in low prepulse case is significantly lower than that obtained in high prepulse case.

1. Introduction

Fast ignition (FI) is a way to directly heat a dense fuel with a relativistic-intensity laser pulse. In this scheme, laser energy is converted to MeV-energy electrons beam at the laser-plasma interaction region, and the electrons heat the fuel at its maximum compression. Efficient heating highly demands controlling energy distribution function and divergence angle of electron beams.

High energy x-ray spectrometer (HEXS) was therefore developed to characterize energetic electrons inside the target via bremsstrahlung x rays emitted from targets.

In FI experiment, it was found by HEXS that excessively high temperature of hot electrons for FI heating was generated. This is because a preformed plasma produced by the laser prepulse can increase the high-energy electrons, which have lower energy deposition on the fuel. We investigated the effect of suppressed preplasma condition with plasma mirror to reduce the high-energy electrons.

2. Spectrometer

A schematic diagram of HEXS is shown in Fig.1. Twelve pairs of x-ray filter and imaging plate (IP) are stacked in a plastic cylinder [1]. X-ray absorption filters are arranged in an order of lower Z (Al) to higher Z (Pb) materials. Thicknesses of them are also adjusted so as to cover the energy range from 10 keV to 700 keV. Fuji BAS-MS imaging plates are used as an x-ray detector.

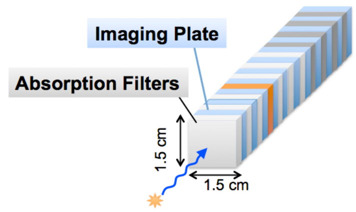

Fig.1 Schematic diagram of High energy x-ray spectrometer (HEXS). HEXS is composed of twelve pairs of x-ray absorption filters and imaging plates (IP).

Monte Carlo code Geant4 [2], calculating energy transport and deposition of energetic particles and photons through a matter, is used to obtain x-ray spectrum from signals recorded in IPs. Figure 2 shows calculated sensitivity of each filter-IP combination for various filters with Geant4. The sensitivity is given, as a function of photon energy, in units of energy deposited in each IP for a single x-ray photon incidence.

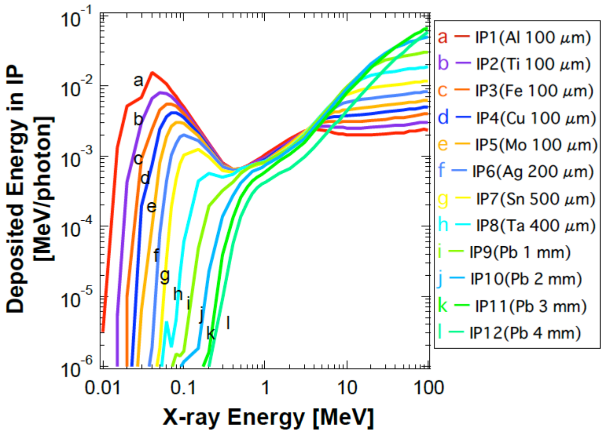

Fig.2 Sensitivity of each filter-IP pair calculated with Geant4 code. X-ray attenuation by the pairs set between the source and corresponding pair is taken into considerations.

3. Fast Ignition Experiment

HEXS was introduced to FI experiment with Gekko XII and LFEX lasers at Institute of Laser Engineering. The target was a block of a tantalum cube and a tin plate attached with a gold cone and a CD hemi-sphere. The CD hemi-sphere was driven with Gekko XII of 1.2 ns, 715 J and 1.9×10^{15} W/cm^2. The LFEX laser of 1.5 ps, 796 J, 2.6×10^{19} W/cm^2 irradiated the inside of the gold cone at the maximum compression of the sphere.

In this experiment, it was found by HEXS measurement that excessively high temperature of hot electrons for FI heating was generated. This is because a preformed plasma produced by the laser prepulse can increase the high-energy electrons [3], which have lower energy deposition on the fuel. It is necessary to reduce the high-energy electrons to reach the efficient FI heating because most of laser energy is converted to the high-energy electrons that don't contribute to heating.

4. Experiment under Suppressed Preplasma Condition

To suppress hot electron generation in high energy component, we investigated preplasma mitigation with the use of plasma mirror and HEXS. Plasma mirror system is a technique that a laser prepulse transmits an anti-reflection coated SiO_2 and a preplasma generated by the prepulse reflects main pulse. This system is operated at Institute of Chemical Research, Kyoto university.

The setup of this experiment is shown in Fig.3. The target was Au or Al 10 μm^t attached to Pb 1 mm^t. T^6 laser of 40 fs, 220 mJ/shot, 2.3×10^{18} W/cm^2 was incident at 45 degree from target normal. Two HEXSs measured x ray emission at rear target normal and laser axis. It was confirmed that hot electron temperature decreases with the use of plasma mirror.

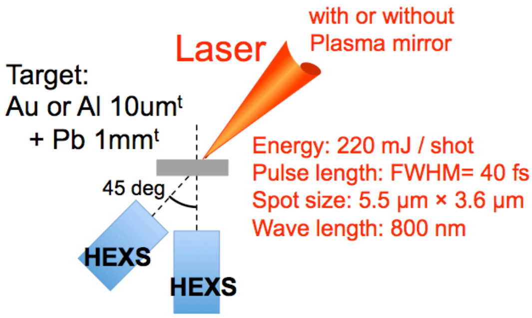

Fig.3 Setup of low preplasma experiment.

Acknowledgments

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