PROTON GENERATION DRIVEN BY A HIGH INTENSITY LASER USING A THIN-FOIL TARGET

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Abstract

We measured the proton signals produced by laser interaction with thin-foil target. The maximum proton energy increases when the size of preformed plasma is reduced. We obtained the maximum proton energy of ~3.4 MeV with 2.5 μm thick stainless-steel target.

INTRODUCTION

During the high-intensity laser-plasma interaction relativistic electrons and high-energy ions are accelerated, and the electromagnetic waves in a range from the x-ray to terahertz radiation are emitted [1-5]. A preformed plasma made by a prepulse is one of the important parameters in optimizing the generation of high-energy charged particles and electromagnetic wave radiation. In particular, the preformed plasma plays an important role in the absorption of the main pulse energy [3]. In addition, its presence affects the ion acceleration, x-ray emission, and fast electron generation [6-11]. Kaluza et al. paid attention to a dependence of the proton generation from the laser irradiated thin-foil target on the duration of the ASE [9]. That is why, controlling the size of the preformed plasma by changing the ASE duration is important for the ion acceleration optimization.

In this paper, we observed the proton signal. The maximum proton energy increases when we have reduced the size of preformed plasma. We observed the maximum proton energy of ~3.4 MeV with 2.5 μm thick stainless-steel target.

EXPERIMENTAL SETUP

We use a Ti:sapphire laser system (J-KAREN) at JAEA[12,13]. The laser pulse duration is ~40 fs [full width at half maximum (FWHM)]. The ASE level is greatly suppressed by using an OPCPA preamplifier in a double CPA Ti:sapphire laser system[13]. The contrast level of ASE is controlled by inserting a saturable absorber (SA) in the laser system [13,14]. The contrast level of ASE is less than 10^{-10}. Figure 1 shows the schematic view of the experimental setup. The p-polarized laser beam is focused by the off-axis parabolic mirror with an incidence angle of 45°. The spot size of the focused laser beam is 8 μm (FWHM) x 4 μm (FWHM). It contains ~55 % of energy within $1/e^2$ from the profile of the focusing pattern. The estimated peak intensity is ~2×10^{19} W/cm^2 with the energy of ~700 mJ. The probe beam passes through the optical delay line. A linear translation stage is used to vary the delay between the pump and probe beams. The plasma image is magnified by a factor of ~10 and detected by the CCD camera. The intensity of the probe beam is attenuated by neutral density filters so as to fall within the dynamic range of the camera. A narrow-band interference filter is placed in front of the CCD cameras to reject unwanted emission from the plasma. The band pass width is 10 nm for central wavelength of 800 nm. The interferogram is obtained from a Fresnel biprism using a hundred femtosecond probe pulse at the time of ~50 ps before the pump beam [15].

For detection of the protons generated during the main laser pulse interactions with the target, we use the time of flight (TOF) ion analyzer [16,17]. The TOF measurement gives an on-line real-time information about the proton energy distribution. The protons produced in the intense laser-target interaction are measured in the direction normal to the target.

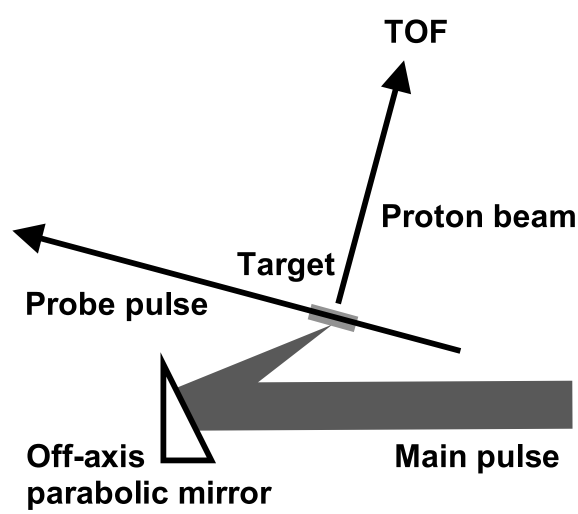

Figure 1: Schematic diagram of the experimental setup: TOF stands for the time of flight ion analyzer.

EXPERIMENTAL RESULTS

Figure 2 shows the ion spectra at the target normal direction with 2.5 µm thick stainless-steel target. Fig. 2(a) shows the ion spectrum without with fast pockels cell voltage off in the laser system. The maximum proton energy is ~2.8 MeV. The ASE duration is longer than 1 ns before the main pulse and the preformed plasma at the front side is generated. Fig. 2(b) shows the ion spectrum with fast pockels cell voltage on. The ASE duration is ~740 ps before the main pulse by controlling a fast pockels cell timing in the laser system [18]. In this case the preformed plasma is not detectable. This means it is smaller than approximately ~30 µm. The higher laser pulse contrast is confirmed with the on-target contrast diagnostic [19] based on the target reflectivity measurement. The maximum proton energy increases up to ~3.4 MeV by reducing the preformed plasma.

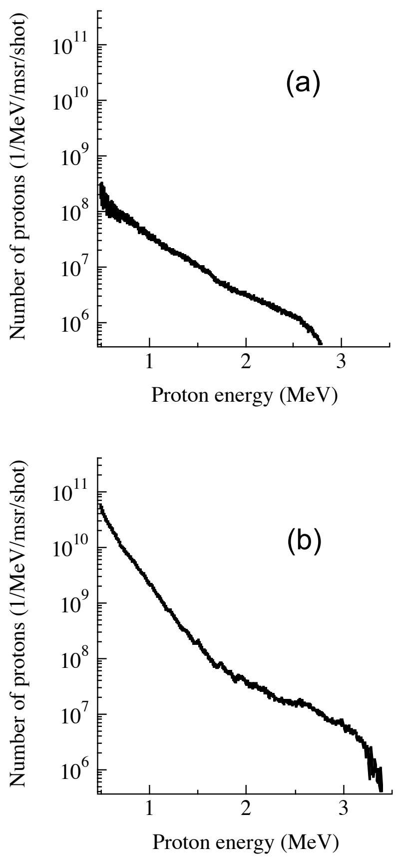

Figure 2: Energy distributions of protons measured by TOF spectrometer with fast pockels cell voltage off (a) and on (b).

SUMMARY

The maximum proton energy increase by reducing the size of preformed plasma with fast pockels cell voltage on. We observed the maximum proton energy of ~3.4 MeV with 2.5 µm thick stainless-steel target.

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