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Fast Electron Energy Transport in Solid Target Generated by High Contrast High Intense Laser Pulse

高コントラスト，超短パルスレーザーによって生成した高速電子の固体中でのエネルギー輸送

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The fast electron spectrum was measured simultaneously with the proton energy in the interaction between the solid and the high intense laser. There were two components in the electron spectrum. The higher electron temperature component was almost explained by the ponderomotive formula. The total electron spectrum including the lower temperature component was also explained by a simple model. The detected maximum proton energy was 23 MeV with SUS thin foil target.

1. Introduction

The generation of high energetic ion in high intense laser pulse with solid target is a rapidly growing research area. In the generation mechanism, the target normal sheath acceleration is usually assumed [1-3]. Then, for the solid target, the increase of laser intensity is important to generate higher ion, which means increasing the electron temperature as high as possible. Actually, the maximum energy of ion grows in proportion to the electron temperature, and the electron temperature increases in proportion to the square root of the laser intensity. In this experiment, the fast electron and the high energetic ion were measured simultaneously.

2. Experimental and Discussion

The experiment was performed using J-KAREN (JAEA-Kansai Advanced Relativistic Engineering) laser system. J-KAREN has a measured intensity contrast ratio of 10^{-10} [4]. The pulse duration was 80 fs. The laser pulses with up to 8 J were delivered on target. The peak laser intensity of the normal incidence was 4.0×10^{20} $\mathrm{Wcm^{-2}}$. The center wavelength was 800 nm. The incident angle was 45 degree to the target normal.

The target materials were Stainless (SUS) and Polyimide. These thicknesses were 2.5 μm and 7.5 μm, respectively.

The electron spectrometer (ESM) was placed behind the target in the direction of laser axis, while CR-39 stack was in the direction of target normal.

CR-39 stack was used for the detection of the ion. The detected ions were almost protons. The obtained maximum proton energy was evaluated to be 23 MeV in the SUS target with taking the stopping range of CR-39 stack into account.

Figures 1(a) and 1(b) show the measured electron spectra. These were obtained with SUS and Polyimide, respectively. The vertical axis is the electron number and the horizontal axis is the electron energy. The dots were obtained in the experiment. Both spectra clearly have two components. The higher energy component of the measured energy spectra was fitted with an approximation of Maxwellian distribution, which is shown by the broken line. The electron temperatures of SUS and Polyimide targets were 5.1 and 4.8 MeV, respectively. These values are almost same each other in spite of the different materials. The ponderomotive formula,

$$T_e[MeV] = 0.511\left(\sqrt{1 + I_{18}\lambda_{\mu m}^2/1.37} - 1\right) \qquad (1)$$

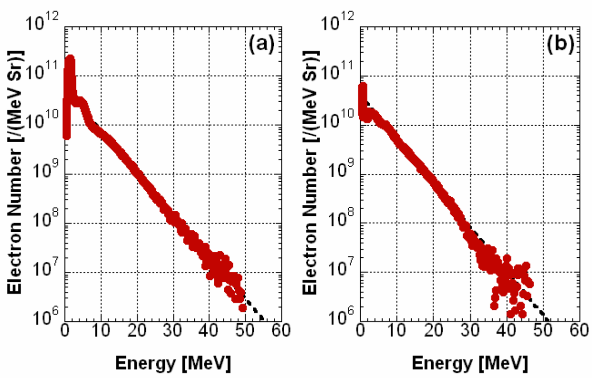

Fig. 1. The electron spectrum for (a) the SUS and (b) the Polyimide targets. The dot and dot-line show the experimental point and the slope temperature fitting.

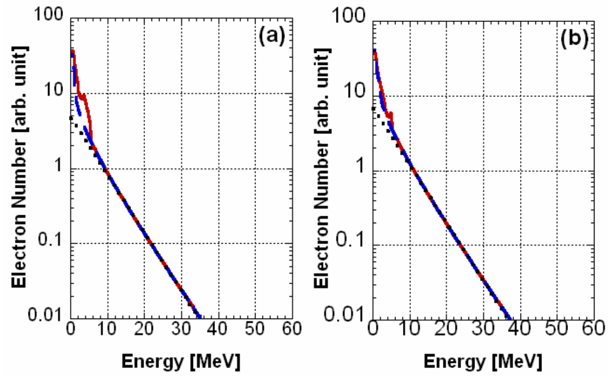

Fig. 2. The electron spectrum for (a) the SUS and (b) the Polyimide targets. The solid line, the broken line and the dot line become with effect of the re-acceleration, without effect of the re-acceleration case and the slope temperature fitting, respectively.

where T_e, I_{18}, and $\lambda_{\mu m}$ are the electron temperature, the laser intensity in units of 10^{18} Wcm^{-2}, and the wavelength in microns, respectively, is used for estimating the average energy of electrons accelerated by the ponderomotive force in the transverse field of the incident light wave [5]. It corresponds to be the fast electron temperature of 6.5 MeV. Then it is almost the same as those which experimentally obtained. Under 7 MeV region (low energy region), the electron spectrum was observed to be different in the different target condition.

To understand this result, a simple model was assumed. We have estimated the distribution of energetic electrons to the rear side of the solid target.

Figures 2(a) and 2(b) show the evaluated electron spectra of SUS (a) and Polyimide (b), respectively. The vertical axis is the electron number and the horizontal axis is the electron energy. The solid line and the broken line are obtained with and without considering the effect of the re-acceleration. The dot line was obtained by the slope temperature fitting. In both targets, the electron temperature became 5.6 MeV by the fitting of Maxwell distribution.

For higher energy component, there is almost no difference between two targets. This means that re-acceleration of the front side plays almost no effect to higher energy component.

When we compare the electron number under 7 MeV, the solid line is found to be almost 2 times higher than the broken line in SUS target, while it is almost the same level in Polyimide. These results suggest that the re-acceleration plays an important role in SUS target. It could be caused by the thin thickness of SUS in this experiment. This tendency can be seen in the experimentally obtained spectrum. Actually, Polyimide target was 3 times thicker than SUS. The experimentally obtained electron number in SUS target was 3 times larger than the Polyimide. It can be explained by the larger number of electron generation in SUS with assuming the barrier suppression ionization [6]. In the laser intensity of 4.0×10^{20} Wcm^{-2}, the electron number in SUS can be estimated to be 4 times larger than Polyimide.

3. Summary

The electron distribution to the rear side of the target has been detected and analyzed with a simple model. The higher temperature component is explained by the ponderomotive formula, but the lower component was proved to be affected by the re-acceleration at the front side.

In this experiment, the maximum proton energy was measured to be 23 MeV in SUS target with the irradiating intensity of 4.0×10^{20} Wcm^{-2}.

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References

[1] P. Mora, *Phys. Rev. Lett.* **90**, 185002 (2003).
[2] A. J. Mackinnon, et. al., *Phys. Rev. Lett.* **86**, 1769 (2001)., A. J. Mackinnon, et. al., *Phys. Rev. Lett.* **88**, 215006 (2002).
[3] S. C. Wilks, et. al., *Phys. Plasmas* **8**, 542 (2001).
[4] H. Kiriyama, et. al., *Opt. Lett.* **35**, 1497 (2010).
[5] S. C. Wilks, et. al., *Phys. Rev. Lett.* **69**, 1383 (1992).
[6] S. Augst, et. al., *Phys. Rev. Lett.* **63**, 2212 (1989).