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Characteristics of the electron beam generated by irradiation of foil target with femtosecond laser plasma

フェムト秒レーザープラズマを背面にもつ薄膜ターゲットを用いたレーザー加速電子ビームの特性

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Enhancement of the intensity of the fast electrons emitted from a foil target irradiated by an intense laser pulse is observed by irradiation of the second femtosecond laser pulse in advance on the other surface of the target. It is found that the intensity of the fast electrons varies in accordance with the time interval between two laser pulses and the intensity of the second laser pulse. It is suggested that the fast electrons can be controlled by femtosecond laser produced plasma.

1. Introduction

Fast electrons accelerated by irradiating solid target with intense femtosecond laser can play an important role for various applications, such as ultra-fast electron diffraction [1], fast ignition for inertial confinement fusion [2], and femtosecond electron deflectometry [3], because they have advantages of high intensity and a short pulse. For developments of these applications, it is important to control the directivity or the intensity of the fast electrons. In this study, we show that electrons emitted from a foil target irradiated by an intense laser pulse are collimated by irradiation of the second femtosecond laser pulse in advance on the other surface of the target. It is observed that the intensity of the fast electrons varies in accordance with the time interval between two laser pulses and the intensity of the second laser pulse. It is suggested that the fast electrons can be controlled by femtosecond laser produced plasma.

2. Experimental Apparatus

The experiments are carried out with a Ti:Sapphire chirped pulse amplified laser system at Kyoto University, which delivers 450-mJ 40-fs pulses at a center wavelength of 810nm. The experimental setup is shown in Fig. 1. Laser pulses are split into two beams and focused on a foil target. One beam (CPA1) passing through a delay line is used for generation and acceleration of the fast electrons. The other beam (CPA2) is irradiated on the opposite surface before/after the arrival of the acceleration laser pulse. The intensities of the two laser pulses are variable independently by using irises, and the time delay between two laser pulses is varied from -540 to 250 ps. The time delay > 0 means that the CPA1 reaches on the target surface earlier. It is essential to determine the zero delay time for such experimental setup. However, this is difficult when using ultrashort pulses. In this experiment, we determined the zero delay time through a cross-correlation measurement using two electron pulses [4] by slightly shifting the positions of the two focal points. Based on the cross correlation, the zero delay time was determined to within ±600 fs.

In order to measure the intensity of the laser accelerated electrons, we use an electron imaging system composed of an electron lens, a fluorescent screen, and an electron-multiplying CCD camera [5]. The laser accelerated electrons emitted inthe

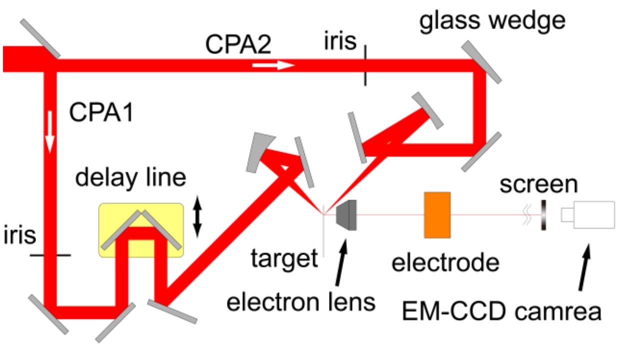

Fig.1. A schematic of experimental setup

target-normal direction are collected, and images of the electron sources are obtained. The energy of electrons reaching the screen is selected to be 120 keV using the electron lens.

3. Results and Discussions

Figure 2 shows that the images of the electrons sources at the time delay of -280, -150, -12, 120, and 250ps. The intensity of the CPA1 and the CPA2 is 2 × 10^{17} W/cm^2 and 4 × 10^{16} W/cm^2, respectively. Each image is obtained by double laser shots (the CPA1 and the CPA2). The color scale is linear and same for each image. The intensity of the electron beam is enhanced while the spot size is kept constant, when the optical delay < -100ps. Figure 3 shows that the dependence of the peak intensity of the electron beams on the time delay. Each point is obtained by averaging over 20 laser shots. It is observed that the intensity increases as the time delay is smaller and the enhancement appears only when the time delay is smaller than zero. At the time delay of -280ps, the intensity of the electron beam is 10 times higher than that obtained by irradiating with the CPA1 only.

This enhancement of the intensity of the fast electrons is caused by the CPA2, which irradiated the target before the CPA1. The intensity of the CPA2 is high enough to provide laser plasmas. This plasmas may influence on the characteristics of the electron beam, and this plasma may be able to control the electron beam. For obtaining more intense electron beam, we change the intensity of the CPA2. Figure 4 shows the dependence of the electron beam profiles on the intensity of the CPA2, at the time delay of -540ps. The intensity of the electron beam increases with increasing the intensity of CPA2. The intensity is 16 times higher than the case of single pulse (CPA1) irradiation.

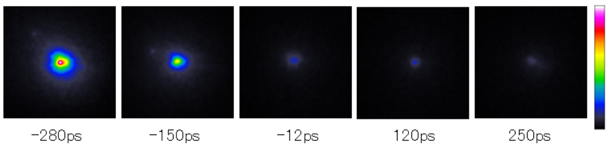

Fig.2. Images of the electron sources at the time delay of -280, -150, -12, 120, and 250ps.

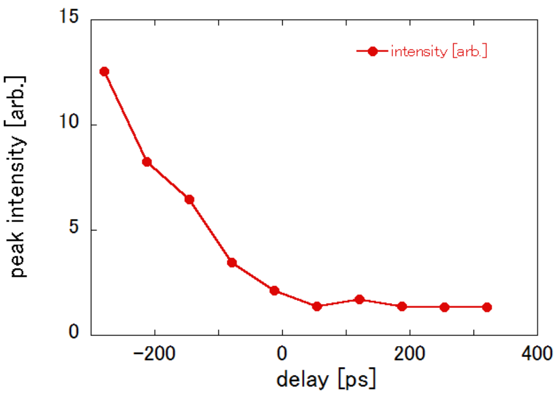

Fig.3. Dependence of the intensity of the electron beams on the time delay.

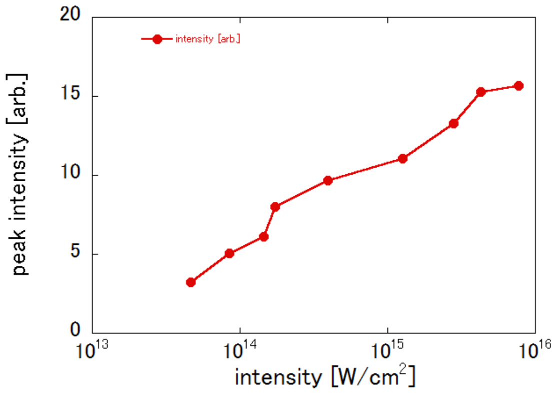

Fig.3. Dependence of the intensity of the electron beams on the intensity of CPA2.

4. Summary

The intensity of the fast electrons emitted from a foil target irradiated by an intense laser pulse are enhanced by irradiation of the second femtosecond laser pulse in advance on the other surface of the foil target. We found that the time interval between two laser pulses and the intensity of the second laser pulse influence the intensity of the fast electrons. By adjusting the delay and the intensity of laser pulses, intense electron beam is obtained. This suggests the fast electrons can be controlled by femtosecond laser produced plasma.

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References

[1] S. Tokita, M. Hashida, S. Inoue, T. Nishoji, K. Otani, and S. Sakabe: Phys. Rev. Lett. **105**, 215004 (2010).

[2] M. Tabak, J. Hammer, M. E. Glinsky, W. L. Kruer, S. C. Wilks, J. Woodworth, E. M. Campbell, M. D. Perry, and R. J. Mason: Phys. Plasmas **1**, 1626 (1994).

[3] Shunsuke Inoue, Shigeki Tokita, Kazuto Otani, Masaki Hashida, and Shuji Sakabe: Appl. Phys. Lett. **99**, 031501 (2011).

[4] Shunsuke Inoue, Shigeki Tokita, Kazuto Otani, Masaki Hashida, Masayasu Hata, Hitoshi Sakagami, Toshihiro Taguchi, and Shuji Sakabe, Phys. Rev. Lett. **109**, 185001 (2012).

[5] Shunsuke Inoue, Shigeki Tokita, Toshihiko Nishoji, Shinichiro Masuno, Kazuto Otani, Masaki Hashida, and Shuji Sakabe, Rev. Sci. Instrum. **81**, 123302 (2010).