High energy electron generation by the 15 mJ ultrashort pulse laser

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Abstract. We propose a small size high energy X-ray source utilizing ultrashort pulse lasers, and a new scheme for generating quasi-monoenergetic electrons. In this paper, we developed a compact laser electron generator and performed experiment that generated energetic electrons over 1 MeV electrons with only 15 mJ laser energy. The temperatures of emitted electrons were measured to be 0.2 MeV and 0.25 MeV without and with prepulse, respectively.

1. Introduction
X-ray radiography is utilized in non-destructive diagnosis of plants and facilities. Unfortunately, traditional X-ray sources except radioisotopes cannot be used in narrow spaces because of their sizes. Then, we propose a small-scale X-ray generator using ultrashort pulse lasers. The X-rays are generated via the bremsstrahlung of electrons which are generated by laser plasma interaction[1]. The advantage of this X-ray is that the reduction of device size should be possible because large container is not necessary.

In this paper, we developed a compact laser electron source for X-ray generation and performed experiment. In addition, we also demonstrated that the number of high energy electrons increase when the energy of the pre-pulse was increased [2].

2 High energy electron generation using a compact laser electron source
2.1 Experimental setup
First, we performed an electron generation experiment to verify a compact laser electron source. The outline of the source and an experimental setup is shown in Fig.1 and Fig.2, respectively.

The experiment was carried out using a Ti-Sapphire chirped pulse laser system(THALES ALPHA 10 US 20 TW). The wavelength of the system was 800 nm, the pulse width was 140 fs. The beam diameter was reduced from 50 mm to 10 mm by using a mask with a hole of 10 mm diameter, then, the output energy was reduced to 15 mJ.
As shown in Fig.1, the p-polarized laser beam was focused on a 30 µm thickness thin copper tape target with an 1/2 inch, f=25 mm Au coated off-axis parabolic mirror. A size of focus spot on the tape target was 2.3×2.1 µm (FWHM: Full Width Half Maximum). In addition, from the data of the profile, the length from the center of the spot to the first shade ring is about 2.3 µm. The theoretical value of the length is 2.4 µm. Therefore, the focus spot size is almost equal to the theoretical value.

2.2 Result of the experiment
The energy spectrum of generated electrons were measured by an electro-spectrometer shown in Fig.2[3].

As shown in Fig.3. Electrons with the energy over 1 MeV were observed. The distribution was close to the Boltzmann, and temperature of the electrons was ~200 keV. In addition, we observed that the number of high energy electrons increased when the energy of the pre-pulse was increased to 8 % of the main pulse. Then, the temperature of the electrons was increased to ~250 keV. It is considered that pre-pulses were effective owing to enhance the number of high energy of electrons.

3 Prepulse control experiment
3.1 Pre-pulse generator
When the pre-pulses become large, electron energy was enhanced by laser interaction with underdense plasma and quasi-monoenergetic electrons were generated [2]. In this work, we controlled the pre-
pulse energy to generate underdense plasma which should be adequate for a laser electron source.

An experimental setup is shown in Fig. 4. The beam from the laser was split to two beams by the aperture with two holes. The diameter of the holes and the two beams were 10 mm. One of the beams was used as a prepulse, and the other beam was used as a main pulse. The main pulse was delayed by the additional laser path on the moving stage. The delay time between the main pulse and the prepulse was from 5.1 ns to 3.5 ns. On the other hand, the polarization of prepulse was changed by a polarizing plate. The main pulse and the prepulse were superimposed by a polarization beam splitter and irradiated into the laser electron source. The maximum energy of the main pulse was 5 mJ. The intensity of the prepulse can be changed from 10 % to 75 % of the main pulse by changing the angle of the polarization beam splitter.

3.2 Result
In the result of the experiment, the spectrum of the electron energy was similar to the Boltzmann distribution when the intensity of the prepulse was 75 % of the main pulse. When the intensity of the prepulse was 10 %, the electron energy distribution has maximum at around 300 keV even though the width of the energy peak was not narrow. When only the main pulse was irradiated, we could not detect the spectrum because 5 mJ laser energy was too small. In this result, by using the prepulse, high energy electrons can generate with the small energy lasers.

It seems that changing the electronic spectrum caused by these three, self focusing, parametric resonance, and soliton acceleration [5]. It seems that increase of the electron numbers caused by self focusing, and generation of the quasi-monoenergetic electrons caused by soliton acceleration.

4. Conclusion
We developed the compact energetic electron source using an ultrashort pulse laser and this system generated energetic electrons with the energy over 1 MeV when the focusing spot size was ~2 µm and the pulse length was 140 fs. When we used the prepulse, energetic electrons can be generated with small laser energy. In addition, we observed that quasi-monoenergetic electrons when underdense plasmas was produced on the target by adjusting the intensity and the delay of the pre-pulses.

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