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Hot Electron Measurement using Electron Spectrometer on FIREX in Gekko XII

激光12号高速点火実験における電子スペクトロメーターによる高速電子計測

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The high-energetic electron measurement is one of the most important issues to research the ignition mechanism. Hot electrons are generated by a strong electric field based on the interaction between the high intensity laser and the produced pre-plasma. The pre-formed plasma is found to be created by the imploding laser in addition to the pre-pulse of LFEX. It is important to suppress the pre-formed plasma in order to achieve the high coupling efficiency between the imploded core and the hot electron.

1. Introduction

It is important to deposit hot electrons to the imploded core in order to realize fast ignition. According to simulations of the integrated target with a gold (Au) cone of 7 μm-thickness and 500 μm diameter deuterium polystyrene (thickness of 6 μm) with the combination of LFEX (maximum energy 10 kJ, 1.06 μm, ω) and Gekko XII (20 kJ, 0.53 μm, 2ω) lasers, the suitable energy of the hot electron to obtain high coupling efficiency is less than 1 MeV. The energy of the hot electron depends on the scale length of the pre-formed plasma, which is created mainly by the pre-pulse. The hot electron penetrates the imploded core when the energy is too high. Therefore the suppression of the pre-pulse is essential to achieve fast ignition. Here we measure the hot electron energy spectra by using the electron spectrometer [1]. The effective temperatures (T_{eff}), which are induced from the slopes of the spectra are compared at various targets and conditions.

2. Relation between pre-formed plasma and T_{eff}

From the results of a PetaWatt laser [2] and the simulation, the absorption and heating efficiencies of the laser can be expected to improve at the short pulse and the high intensity. We compare the T_{eff} between 1.5 ps and 4 ps pulses. At the short pulse, T_{eff} is larger but it is larger than the expected value from the scaling. The relation between the scale length and T_{eff} can be modified from the Puhkov [3] scaling as,

$$T_{eff} \sim (\alpha/3.546)\ (I/I_{18})^{1/2} \times (2.465\ L^{1/4} - 2.223), \quad (1)$$

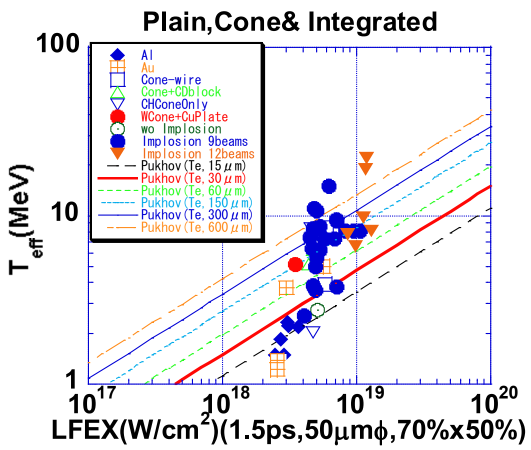

Fig. 1. T_{eff} vs LFEX power in various targets. T_{eff} depends on the target shape due to the pre-plasma formation.

where α, I, I_{18} and L are the coefficient factor of 1.5 MeV, the laser intensity in W/cm^2, the normalized factor of 10^{18} and the scale length in μm, respectively. T_{eff} increases over the scaling value by using the short pulse of LFEX. This suggests the effect of the strong pre-pulse in the short pulse duration (=high intensity).

To reduce the pre-pulse, a saturable absorber is installed in the LFEX laser oscillator. T_{eff} can slightly decrease due to one tenth of the pre-pulse reduction. However the higher T_{eff} is not only due to the pre-formed plasma by the pre-pulse because T_{eff} in the integrated target is higher than that in the plain target (see Fig. 1). The saturable absorber should be improved because the pre-plasma suppression becomes worse after many discharges of the LFEX.

In the integrated target, there is a possibility that the imploding lasers create the pre-formed plasma by irradiating the Au cone, in addition to the pre-plasma formed by the pre-pulse of the LFEX. Although the omega component of the GXII laser before the wavelength conversion has a different focal point, it may partially irradiate the inner part of the Au cone. The imploded core may collide with the cone tip and form the pre-plasma at the inner part of the cone.

We compare the T_{eff} in plain, cone and integrated targets. The T_{eff} in the cone is higher than the T_{eff} in the plain target. The scale length of the pre-plasma in the cone formed by the pre-pulse of the LFEX is longer than that in plain target because the pre-plasma jets from the cone surface make high dense pre-plasma on the axis of the cone. In the integrated target, the electron acceleration mechanism is complicated. The effects of pre-formed plasmas by the implosion and the imploding laser should be considered in addition to the pre-plasma formed by the pre-pulse. As shown in Fig. 1, the T_{eff} in the implosion is obviously higher than the T_{eff} in the cone.

Part of omega light irradiates the inner cone. In the standard integrated experiments, 9 beams of 12 beams of GXII are used in order to avoid direct irradiation to the cone. Omega lights from 3 beams around the cone partially irradiate the inner cone. The distance between the position irradiated by the omega light and LFEX laser is 250 μm. The clearance is only 200 μm because the focal point of the LFEX laser fluctuates around ±50 μm. The pulse width and the intensity of the imploding laser are 1 ns and 10^{12} W/cm^2, respectively. According to the simulation, the growth of the pre-formed plasma becomes 200 μm. Therefore the plasma pre-formed by the imploding laser affects the generation of the hot electron.

The imploded core may destroy the cone tip and may affect the hot electron spectrum. We also perform the integration experiment using full beams (12 beams) of the GXII laser in addition to 9 beam implosion. In the 12 beams case, the focal position is shifted in order to avoid the direct irradiation of the neighbouring 3 beams to the cone. The elongated cone is used in order to avoid the irradiation of omega component of the neighbouring 3 beams to the inner cone. According to 2-dimentional X-ray streak results, the imploded core at 12 beams irradiation does not move unlike at 9 beams. In the 9 beams case, the imploded core moves toward the cone tip. The pre-formed plasma may be created by collision of the imploded core with the tip at 9 beams. The T_{eff} at 9 beams should be higher than the T_{eff} at 12 beams. However both values of T_{eff} are not so different as shown in Fig.1. This means the collision of the imploded core with the cone tip is not essential in the current situation. The clearance between the LFEX and the irradiating position by the omega light is 200 μm. The clearance between the 2-omega light and the outer cone is only 3 μm. More X-rays at 12 beams are observed than at 9 beams by using a simple X-ray monitor [4]. In the 12 beams case, 2-omega light may directly irradiate the outer cone and create pre-plasma in the cone inner. This assumption can be verified by the results shown in Fig. 2. In Fig. 2, the T_{eff} is shown as a function of the difference between the implosion and the LFEX injection timing. In both the 9 beams and 12 beams cases, maximum T_{eff} can be obtained when the implosion corresponds to the LFEX injection. T_{eff} decreases because the super high dense plasma explodes toward the LFEX laser path after implosion. If the pre-formed plasma is created by the imploding laser, this result can be explained without contradiction.

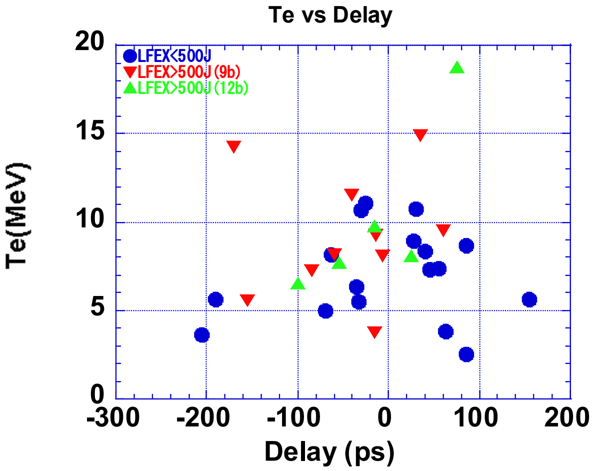

Fig. 2. T_{eff} vs LFEX injection timing. Maximum T_{eff} can be obtained when the implosion corresponds to the LFEX injection.

3. Summary

The high coupling efficiency between the imploded core and the hot electrons can be obtained at the short pulse duration of the LFEX. To achieve high coupling efficiency, it is important to suppress the pre-formed plasma. The pre-formed plasma is found to be created by the imploding laser in addition to the pre-pulse of LFEX by the comparison between the experiment and the scaling.

References

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