## §3. Hot Electron Measurement Using Electron Spectrometer on FIREX in Gekko XII

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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  $\mu m$ -thickness and 500  $\mu m$  diameter deuterium polystyrene (thickness of 6 µm) with the combination of LFEX (maximum energy 10 kJ, 1.06 µm, w) and Gekko XII (20 kJ, 0.53  $\mu$ m, 2 $\omega$ ) 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 of LFEX laser. The hot electron goes through 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 (Teff), which are induced from the slopes of the spectra are compared at various targets and conditions.

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 Puhkov scaling [3].  $T_{eff}$  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.  $T_{\rm eff}$  can slightly decrease due to one tenth of the pre-pulse reduction. However the higher  $T_{\rm eff}$  is not only due to the pre-formed plasma by the pre-pulse because  $T_{\rm eff}$  in the integrated target is higher than that in the plain target (see Fig. 1).

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  $\mu$ m. The clearance is only 200  $\mu$ m because the focal point of the LFEX laser fluctuates around ±50  $\mu$ m. The pulse width and

the intensity of the imploding laser are 1 ns and  $10^{12}$  W/cm<sup>2</sup>, respectively. According to the simulation, the growth of the pre-formed plasma becomes 200  $\mu$ m. 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<sub>eff</sub> at 12 beams. However both values of T<sub>eff</sub> 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. The T<sub>eff</sub> 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  $T_{\text{eff}}$  can be obtained when the implosion corresponds to the LFEX injection. Teff decreases because the super high dense plasma explodes toward the LFEX laser path after implosion. If the preformed plasma is created by the imploding laser, this result can be explained without contradiction.

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 preformed 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.

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