Measurement of PW laser injection time to imploded core plasma by using X-ray framing camera

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Abstract. Measurement of PW laser injection time relative to the imploded core plasma by using X-ray framing camera was successfully achieved. The core plasma radii estimated from the X-ray framing camera are consistent with those estimated from X-ray streak camera and well agree with the results of 1D hydrodynamic simulation (ILESTA-1D). This means that the spatial resolution of X-ray framing camera is high enough and reliable to monitor implosion processes. PW laser injection time was observed as the bright zone on the stripline of X-ray framing camera. The measured X-ray intensity peak is consistent with that observed with X-ray streak camera. It is concluded that one can estimate PW laser injection time with a few tens of ps resolution from the peak position of X-ray intensity recorded by X-ray framing camera.

1. Introduction

Fast ignition scheme is one of proposed ways to generate laser fusion plasma. This scheme separates the laser into two systems: one for implosion and the other for heating the imploded fuel core. Fast ignition scheme is considered to be a powerful method because the laser energy required for implosion in fast ignition scheme is expected to be much smaller than that in central ignition scheme.

For effective heating of the imploded core, it is necessarily to control an injection time of heating laser synchronized with imploded core. However, it is difficult to measure the imploded core and heating laser injection at the same time because of the large spectral difference between thermal X-ray from the imploded core plasma and high energy X-ray from the hot electron heated by heating laser. In this paper, we propose a simultaneous measurement of imploded core plasma and injection time of ultra-intense PW laser by using an X-ray framing camera.

2. Experiments

The experiments were operated by using GEKKO 12 laser system. The targets were CD shells (491 \(\mu\) m in diameter and 6.12 \(\mu\) m in thickness for shot number '29984', 504 \(\mu\) m in diameter and 6.42 \(\mu\) m in thickness for shot number '29986') with Au cones, which had a 30° opening angle. The tip of the cone was placed 50 \(\mu\) m away from the target center. 9 beams (400 J/beam) of GEKKO 12 irradiated the shell to create the imploded core plasma and after that an ultra-intense PW laser (200 J) were injected to heat the cone.

X-ray emission from the imploded core plasma was measured with a time- and space-resolving X-ray framing camera (XFC). Observation was made in the direction perpendicular to the Au cone and

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the images were recorded with a CCD camera. As shown in Fig. 1, there were four striplines on the microchannel plate (MCP) of XFC. Four electric pulses propagate through each four striplines with arbitrary delay. Striplines become sensitive only when an electric pulse exist, therefore time evolution of 2D X-ray images of core plasma were made on the striplines. An X-ray streak camera (XSC) coupled to a slit camera was simultaneously used to measure the imploded core plasma.

![Figure 1. The schematic diagram of X-ray framing camera (XFC).](image)

### 3. Results and discussion

Figure 2 shows the time-, space-resolved images obtained with XFC (shot number 29984). Three 2D core images were recorded in each striplines. The time intervals between the three images are 80 ps. The time intervals between neighbouring striplines are 500 ps. As shown in Fig. 2, bright zone due to high energy X-ray was observed in the second and third stripline.

![Figure 2. The time- and space-resolved images obtained with X-ray framing camera. (shot number 29984).](image)

#### 3.1. Measurement of imploded core

Figure 3 shows the time evolution of the imploded core plasma radius estimated from XFC images and XSC images. The solid line shows the result of 1D hydrodynamic simulation (ILESTA-1D) [1]. As shown in Fig. 3, the core plasma radii estimated from XFC images are consistent with that estimated from XSC images and agree well with the result of 1D simulation. These results mean that the spatial resolution of XFC is high enough to observe implosion processes, although it is lower than that of XSC.
3.2. Measurement of laser injection time

Figure 4 shows X-ray image obtained with XSC. As shown in Fig. 4, the horizontal emission line due to high energy X-ray is also observed with XSC. Figure 5 shows these time evolution of X-ray intensity. The dot and square shows core radius data obtained with XFC and XSC, respectively. The solid line shows the shell trajectory simulated by ILESTA-1D. Although the X-ray intensity peak is not measured by XFC due to limited time range, that is estimated to be almost in agreement with that by XSC. The PW laser injection time in shot number 29986 was delayed 250 ps compared to that in shot number 29984. It is inferable that emission peak position obtained with XFC and XSC is certainly delayed about 250 ps compared with that in shot number 29984. Therefore, it is concluded that the emission observed with XFC and XSC is due to high energy X-ray caused by hot electrons generated by heating laser injection. It is considered that we can estimate PW laser injection time with a few tens of ps resolution from a peak position by using adequate model which is under study. Moreover, we are going to improve measurement system by using appropriate filters [2-3] to measure the energy distribution of high energy X-ray.

Figure 3. The time evolution of core plasma radius estimated from XFC images and XSC images (shot number 29984). The solid line shows the result of 1D simulation (ILESTA-1D).

Figure 4. X-ray image obtained with XSC (shot number 29984).
4. Summary

We succeeded in measuring PW laser injection time relative to the imploded core plasma by using XFC. By comparing with XSC data, it is confirmed that the spatial resolution of XFC is high enough and reliable to monitor implosion processes. PW laser injection time was observed as the bright zone on the stripline by XFC. It is considered that we can estimate PW laser injection time with a few tens of ps resolution from a peak position of X-ray intensity recorded by XFC. Thus, this method will be very important for study of imploded core heating mechanism in fast ignition. For higher energy laser experiments in near future, it is necessarily to suppress a high energy X-ray signal by filters. Furthermore, we will be able to measure the energy distribution of high energy X-ray by using appropriate filters.

5. References

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Figure 5. The time evolution of X-ray intensity measured by XFC and XSC. The solid line shows the shell trajectory calculated by ILESTA-1D. The left figure shows the result in shot number 29984 and the right figure shows that in shot number 29986.