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Diagnostics of imploded core and the heating laser injection time using a X-ray streak camera in fast ignition experiment
高速点火統合実験におけるX線ストリークカメラを用いた爆縮コア及び加熱時刻計測

Takehiro Sogo, Yoshinori Ishii, Mayuko Koga, Shinsuke Fujioka, Hiroyuki Shiraga and Hiroshi Azechi
十河 雄大, 石井 圭憲, 古賀 麻由子, 藤岡 慎介, 白神 宏之, 疇地 宏

Institute of Laser Engineering, Osaka University
2-6, Yamadaoka, suita,Osaka 565-0871, Japan
大阪大学レーザーエネルギー学研究センター　〒565-0871　大阪府吹田市山田丘2－6

We have coupled a multi-imaging x-ray streak camera technique with an x-ray shielding made by tungsten to measure time-resolved 2D images, and applied it to fast ignition experiments. We have successfully measured the imploded core dynamics with temporal and spatial resolution of 10.5 ps and 22 μm, respectively, and the heating laser injection time with the accuracy of ±8 ps.

1. Introduction

In fast ignition experiment, it's very important to understand the heating process of imploded core plasma. In measuring imploded core plasma dynamics, because it's necessary to observe very short time duration transition (~100 ps) of very small core plasma (~50μm), measuring instruments are required high temporal and spatial resolutions of 10 ps and 15 μm, respectively. The multi-imaging x-ray streak camera (MIXS) technique meets the requirements [1]. This is the one of the methods of the ultra-fast 2D x-ray imaging is based on the concept of 1D image sampling. Furthermore, there are the multi-channel MIXS(McMIXS) can measure the 2D electron temperature distribution or the 1D+McMIXS combines the ordinary 1D streak camera with the McMIXS [2][3].In fast ignition experiment, there is a serious problem of the high energy x-ray caused by the heating laser injection.

In this study, we measured the imploded core plasma dynamics and the heating laser injection timing by combing the 1D+McMIXS with x-ray shields.

2. Shield from the high energy x-ray

In 2009's experiment, we confirm that the high energy x-ray generated electrons from the photoelectric surface of a photocathode and caused discharge or background noise (Fig. 1). In this study we shield cathode disk with the tungsten be 3 mm thick except for that slit to protect the photoelectric surface from the high energy x-ray (Fig. 2). We estimated that energy of the high energy x-ray is about 200 keV and the background noise can be reduced to approximately 20% with this shield. Fig. 3 shows the typical image measured by MIXS. The discharge has disappeared and the background noise has been reduced to 20%. This agrees with an estimate.

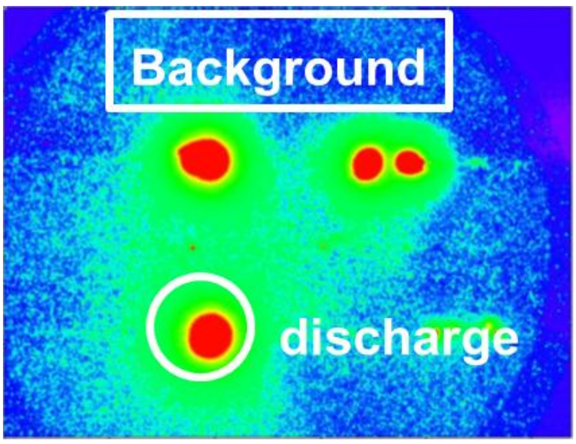

Fig.1. The typical image without the shield

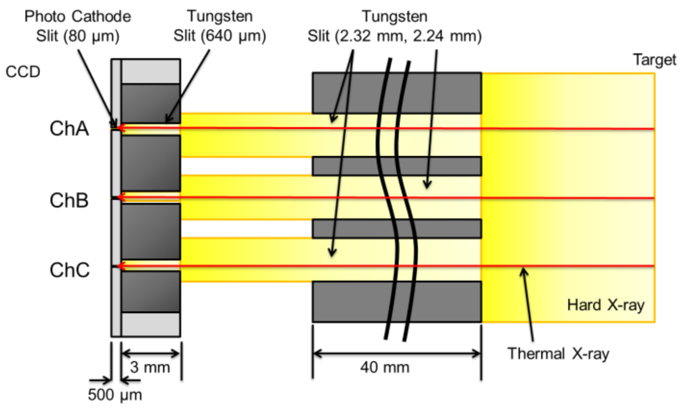

Fig.2. Tungsten shield

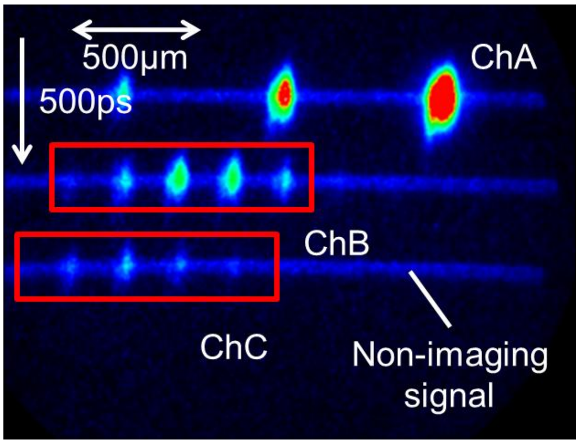

Fig.3. The typical image with the shield

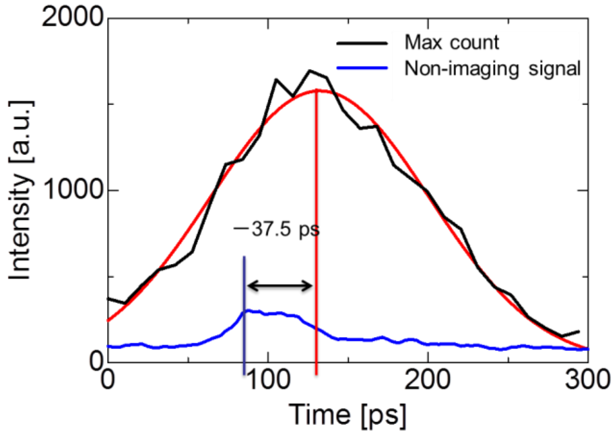

Fig.4. The time waveform of the x-ray emission from imploded core plasma (black), gaussian curve fitting (red) and the heating laser (blue).

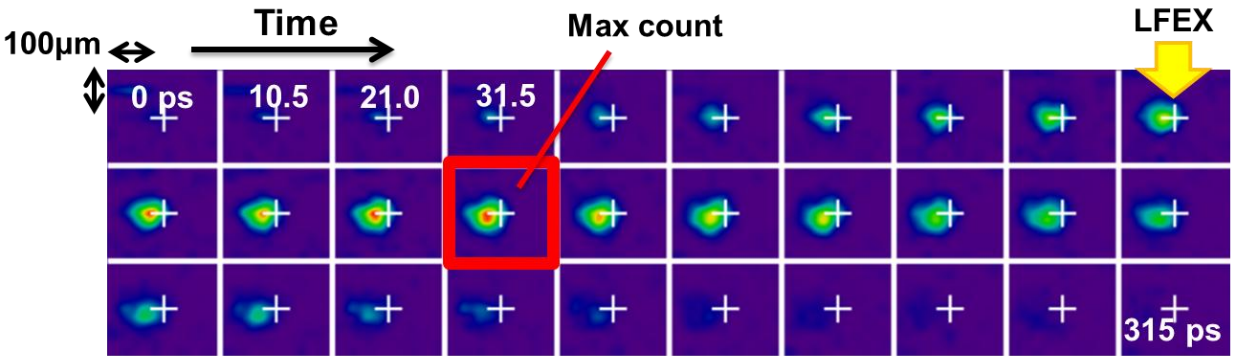

Fig.5. Reconstructed time-resolved 2D image. The inter-frame time is 10.5ps. The arrow shows the heating laser injection time. The highlighted framework shows the x-ray emission from the core plasma is maximum.

3. The heating laser injection time

In this experiment, we observed the belt-shaped non-imaging signal (Fig. 3) when the target is irradiated by the heating laser. This is caused by the high energy x-ray. Because this becomes noises and prevents an accurate estimate, when we reconstruct time-resolved 2D images, we must make subtract this signal. On the other hand we can utilize this to decide the heating laser injection timing. The timing of the heating laser injection is

$$T = t_{\mathrm{LFEX}} - t_{\mathrm{max}}, \qquad (1)$$

where t_{LFEX} is the time when the non-imaging signal is observed and t_{max} is the time when the x-ray emission from the imploded core plasma is maximum. The accuracy of T was $\pm$8ps. Fig. 4 shows the typical time waveform in fast ignition experiment. This timing T was used for feedback control of the laser condition and considerations of the neutron yield, the x-ray emission and the electron temperature. Fig. 5 shows time-dependent change of reconstructed 2D x-ray image. The arrow. By combing the 1D+McMIXS with x-ray shields we obtained time-resolved x-ray images of imploded core plasma and the heating laser injection timing and we were able to discuss the relationship between the heating laser injection timing and imploded core plasma dynamics.

References

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