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Measurement of two dimensional x-ray imaging by total reflection framing camera in fast ignition fusion experiment

高速点火統合実験における全反射フレーミングカメラを用いた二次元Ｘ線画像計測

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In laser fusion experiments, a large number of photons incident to detectors. High-flux irradiation in a very short time (~ps) causes the saturation effect of microchannleplate (MCP) devices; photomultipliers in X-ray framing camera (XFC). And it is a serious problem for accurate measurement. Therefore, it is necessary to know the linearity of the detector. In fast ignition, the experimental data suggested the output saturation of the detector by high-flux x-ray irradiation. In this research, we developed a new MCP gain model for our XFC, which includes the saturation effect against intense input signals. The result shows better agreement with the experimental data than the conventional MCP gain model without the saturation effect.

1. Introduction

Pulse-gated X-ray framing cameras (XFC) have been deployed widely in laser-plasma experiments [1][2]. This type of camera has microchannel plate (MCP) devices as a photomultiplier, and Au microstriplines on its surface which work as photocathodes. The multiplication process of MCP is described by a simple, well-known model, called “dynode model” [3].

However, the gain of MCP is not infinite, thus if input photoelectrons increase extremely, output signal is heavily saturated. In fast ignition experiment, we also have to measure large number of photons in a very short time (~500ps). Then, the MCP output probably saturate and the experimental result is not consistent with the conventional MCP gain model which does not take into account of the saturation effect.

Therefore, in this research, we developed a new MCP gain model for our XFC which includes the saturation effect, and compared with the experimental data.

2. Experiment

Figure 1 shows the schematic diagram of our x-ray framing camera. Target images are projected on Au photocathodes on the MCP surface, and then changed into electrons. While voltage pulses propagate along photocathodes, the MCP becomes sensitive only when voltage pulses exist. Thus, our XFC has 80ps time resolution. We can get six images at 360ps full-scale, by using the six pinhole arrays and two voltage pulses which propagate with 200ps interval. After passing thorough the MCP, electrons hit a fluorescent plate, and finally recorded with a CCD camera. We use the XFC which has a pair of Pt total reflection mirrors to separate soft x-rays from imploded core plasma and hard x-rays from hot electrons generated by the injection of the heating laser.

Our XFC has two identical MCPs, one (MCP1) acts for gating, and another (MCP2) acts for electron multiplication. The Voltage pulse which propagates along the striplines on MCP1 is V=800V in a FWHM=200ps gaussian pulse. For MCP2, we can change DC voltage, 500~900V. In fast ignition experiment, we operated those at two voltages, 800V and 900V. We show one example of experimental data in Figure 2. Then, we calculated the average value of the intensity near the core centroid, and plotted the time variation for two voltages in Table I. Note that, even though we measure the same phenomenon, FWHM of two profiles have the difference by 50ps, and the ratio

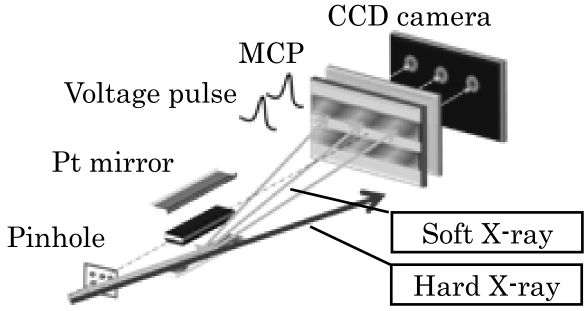

Figure 1 The schematic diagram of XFC

of maximum values is 1.21.

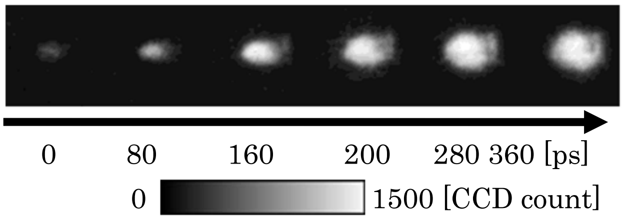

Figure 2 X-ray images of imploded core plasma (#34140)

3. MCP modeling

We describe the MCP gain model which includes the saturation effect by high flux irradiation. Some approaches are conducted about the MCP saturation effect [4][5]. We developed a new MCP gain model for our XFC, based on the conventional dynode model [6].

Input photoelectrons are accelerated by the electric field made by the voltage between the electrodes. Then, they collide with the channel wall of the MCP, and generate more secondly electrons. The gain of a MCP can be described by power law relation,

$$\delta_n = \left(\frac{V_Z}{V_C}\right)^k \qquad (1)$$

where δ_n is the effective gain per stage in a internal cascade multiplication process, V_z is the axial potential of electrons, V_c is the first crossover potential, and k is a constant coefficient. The total gain of MCP is,

$$G = \prod_n \delta_n = \delta_1 \delta_2 \delta_3 \cdots \delta_n \qquad (2)$$

The mechanism of the gain saturation is an increase of electrons stripped from channel walls. More input photons strip more electrons from channel walls, and leads to a decrease of the voltage between the electrodes. It is like an electric current between the electrodes of a capacitor.

4. Results & discussion

We show the result of the new gain model of our MCP in Table I, for two types of voltages; 800V & 900V. We note that the result of the new model shows better agreement with the experimental data than the conventional model without the saturation effect. Figure 3 shows the gain characteristic of input vs. output electrons for some applied voltages. At a high voltage, the saturation begins at the lower number of photons compare to at the low voltage. We estimate that the number of input photons is over 10^6 in fast ignition. We cannot evaluate the experimental data quantitatively in this state. Therefore, we have to adjust radiation intensity somehow with filters or pinholes.

Table I Comparison of the experimental data and the result of gain simulation

Voltage [V]	900	800	ratio
Core FWHM [ps]	445	391	-
Max intensity[a.u.]	1468	1215	1.21
Gain of conventional model	10920	3041	3.59
Gain of this research	63.7	33.7	1.89

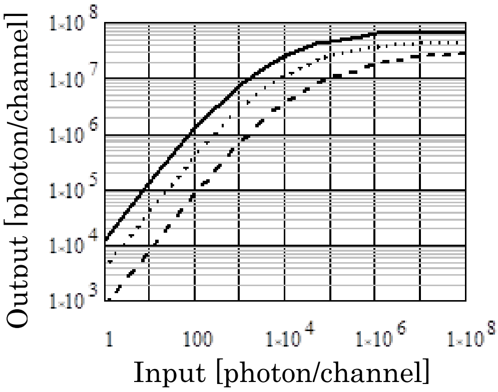

Figure 3 Input vs. Output gain curves of the MCP, at 900V (solid), 800V (dotted) and 700V (dashed)

5. Summary

In fast ignition experiment, we measured x-ray images of the imploded core plasma by using total reflection x-ray framing camera. The data suggested the output saturation of the MCP, therefore we developed a new MCP gain model which includes the saturation effect. The result showed better agreement with the experimental data than the conventional gain model without saturation. We also calculated the input-output gain characteristics and obtained the operational linearity range for our XFC.

6. References

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