Twelve-frame camera for soft X-ray

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THE procedure of inertial confinement fusion (ICF) takes place in sub-nanosecond period. In order to investigate the hydrodynamic instability and asymmetry during the implosion, we need to measure the two-dimensional distribution of plasmas temperature and density as well as its relationship with time. For this purpose, an X-ray picosecond multiframe technique has been developed.

Traditionally, there are two techniques for gating images, i.e. swept framing and gated microchannel-plate (MCP) framing. Because the former has spatial loss in short exposure time and little dynamic range, the latter is recently in routine use[1—5].

1 Construction and principle of the camera

A schematic diagram of this type of camera is shown in fig. 1. It consists of a twelve-pinhole array, a picosecond high voltage pulse generator, a gated MCP with microstrips and contact camera. The pinhole array as an imager is fixed on a detachable conetube. The length of the conetube and the object distance decide the image magnification. A high voltage pulse is used as the MCP shutter. Four gold microstrips on the MCP are used as the electric pole and the light cathode of the strobe tube. A photoelectron signal produced at the front surface of the MCP is amplified only when the high voltage passes pulse across a given point on the microstrips. By using twelve pinholes to project the same X-ray source onto the microstrips, twelve different X-ray images are recorded sequentially by film. Spatial resolution of an image

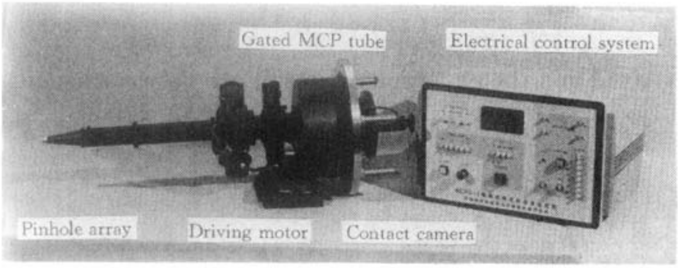

Fig. 1. Schematic diagram of the camera.

is determined by the diameter of pinhole, wavelength of measured X-ray, image magnification and the channel diameter of the MCP. Temporal resolution of an image is determined by the width of gating pulse. The time interval between images on a microstrip depends on the distance between pinhole and the image magnification.

2 Camera feature

We developed a soft X-ray gated MCP twelve-frame camera with temporal resolution of about 60 ps and two-dimensional spatial resolution of 25 lp/mm. The camera has a large dynamic range and a good interference resistance. It has four microstrips arranged parallel, which can be gated independently. As a result, it can avoid an intensity distortion on imaging plate caused by a drop of gain in the MCP with a meander microstrip that is too long for the gating pulse transit. The measurable time range is extended by adjusting the time delay between microstrips and it is easily combined with a pinhole transmission grating or filter to perform synchronous measurement of time-space-energy. Besides, by using a gating circuit to turn on the four microstrips, the time uncertainty between microstrips is obviously reduced because of the effective control of the triggering jitter. The gating mode is shown in figure 2.

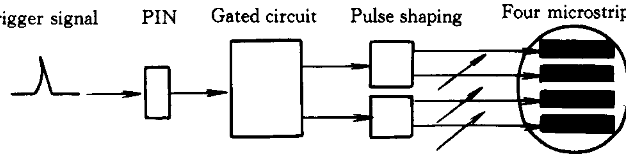

Fig. 2. Gating mode.

3 Critical technique

The design and fabrication of gating pulse circuitry are the key to camera, for the amplitude of pulse determines the system's gain and the width determines the exposure time. Using a special transistor circuit, a step internal pulse with 10 kV/ns rise-rate is produced on a 50 Ω resistance. Furthermore, the leading edge of the pulse is steepened further by an avalanche diode. Finally, a high voltage on 50 Ω resistance, with FWHM 210 ps and amplitude 220 V, is obtained after shaping, which corresponds to 58 ps exposure time of the camera.

On the other hand, the design, mounting and adjustment of the gating tube are also important. The tube consists of a high field-intensity phosphor screen and an MCP coated with gold microstrip transmission lines. The lines are separated, acting as the photo cathode of the MCP. The fabrication technology, uniformity, total resistivity of the microstrips as well as their property coupling with the input and output of gated pulses affect directly the transmitting character and imaging quality of the gating pulse in the microstrips. The total ohms resistance of 6 mm-wide, 200 mm-long meandrous Au microstripe has been reduced to 0.5 Ω with special processing techniques. The transmitting charactersistics such as propagation velocity, loss, and reflection have been measured. Based on this work, a gated imaging module with four independent microstrips has been designed, manufactured, mounted and adjusted.

4 Manufacture

In Oct. 1993, a gated MCP soft X-ray multiframe is developed by Institute of Nuclear Physics and Chemistry, Chinese Academy of Engineering Physics and Xi'an Institute of Optics and Precision Mechanics, Chinese Academy of Sciences. After two-year effort, the critical technological issues have been solved. Now we have already accomplished the adjustment of the gated pulse circuit, the manufacturing of the microstrips and the mounting of the gating module as well as the machining and assembling of the camera system. The camera has been tested by laser-shot solid target again and again. The testing experiments show that the gated circuity and electronic control are stable at work and the camera has a good property of resisting electric-magnetic interference. The problem of the trigger synchronism have been solved basically . It is capable of capturing a dynamic image in a short time. Also the parameters of the camera have been measured, as shown in table 1.

Table 1

No.	Parameter	Results achieved
1	temporal resolution	$\leqslant 58$ ps
2	spatial resolution	20—251 p/mm
3	frames	12—16
4	microstrip size	6×33 mm^2
5	photo response	0.1—10 keV
6	trigger jitter	$\leqslant \pm 50$ ps
7	measuring time range	5 ns

At the present, the camera has essentially been completed. The principal technical parameters, such as time and space resolution, have come to the advanced international level. It had successfully been used in experiments of laser-produced plasma (see figure 3).

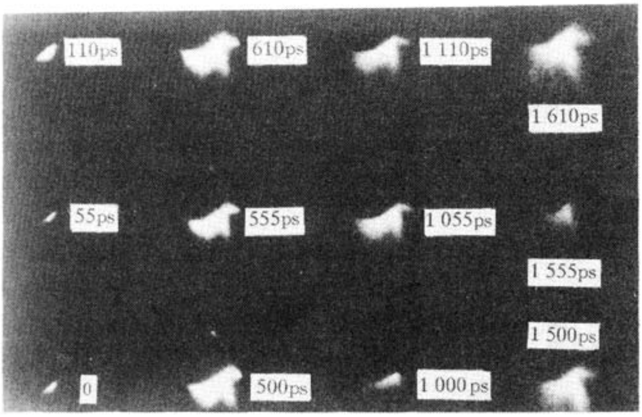

Fig. 3. Twelve-frame images on laser-produced plasma.

The camera is at the moment a critical device to study the moving rule of critical surface, hydrodynamic instability of interface as well as the uniformity of radiation field. Moreover, it will also play an important part in the investigation on the opacity, imbalance and implosion hydrodynamics.

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References

1 Bell, P. M., Kilkenny, J. D., Implementation of 40 ps high-speed gated-microchannel-plate based X-ray framing cameras on reentrant SIM's for nova, *UCRL-JC*-117193 DE94 018597.

2 Landen, O. L., Bell, P. M., Oertel, J. A. *et al.*, Gain uniformity, linearity, saturation and depletion of gated microchannel-plate X-ray framing cameras, *UCRL-JC*-112384.

3 Kilkenny, J. D., High speed proximity focused X-ray cameras, *Laser and Particle Beams*, 1991, 9(1): 49.

4 Ze, F., Kauffman, R. L., Kilkenny, J. *et al.*, New multichannel soft X-ray framing camera for fusion experiments. *UCRL-UC*-11094 *DE*93 009302.

5 Failor, B. H., Gorzen, D. F., Armentrout, C. J. *et al.*, Characterization of two-gated microchannel-plate framing cameras, *Rev. Sci. Istrum*, 1991, 62(12): 2 862.

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