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Measurements with a 35 psec gate time microchannelplate camera

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Abstract

Measurements of the x-ray gate time of 0.2 mm thick microchannel plates with an L/D aspect ratio of 20 as opposed to the more usual L/D=40, demonstrate that gate times of 35 ps can be achieved. Good agreement with time dependent modelling is demonstrated

I. Introduction

For the study of laser produced plasmas, there is a need for very fast gating of x-ray detectors. Laser produced plasmas emit in the spectral region of 0.1 - 1 keV, but have velocities that are typically in excess of 10^7 cm/sec and spatial scale structures less than 10 μ m (1,2). By x-ray imaging, the detailed structure and evolution of laser produced plasmas can be measured without velocity blurring if the shutter time is less than the spatial scalelength /velocity. Typically this is 100 ps or shorter. Furthermore, the advent of short pulse lasers from which the x-ray emission is short lived has stimulated further work on investigating the minimum x-ray gate times possible in x-ray detectors.

X-ray gating can most easily be achieved by gating microchannelplate (MCP) detectors(3). A microchannel plate x-ray camera consists of an MCP with a voltage applied across it to amplify the photo-electrons produced by incident photons, and a phosphor into which the output electrons from the MCP are accelerated by a positive voltage applied to it. The phosphors are coated onto fiber-optic faceplates and light is recorded by optical film or for the case of the tests in this paper by a CCD camera. These MCP detectors, which routinely use an MCP of thickness (L) 0.5 mm, have been extensively used to produce x-ray images on large laser systems.(2)

In previous years at this conference(2) we have reported how by reducing the thickness of the microchannelplate and therefore the electron transit time through the MCP the x ray gate time can be reduced from the typical value of 100 psec which is common for a 0.5 mm, L/D=40 MCP (4). Specifically we obtained 50 psec gating by reducing the thickness (L) of the microchannelplate to 0.25 mm

In this paper, we report further developments in the x ray gating of MCP s by using a thinner plate and by reducing the aspect ratio (L/D) of the MCP to also reduce the electron transit time.

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II. Modeling the response time of gated microchannel plates

Microchannel plates can produce x-ray gate times that are shorter than the duration of the applied voltage pulse because of the very non-linear dependence of the gain on the applied voltage V . Typically the gain G is

$$(1) \quad G = G_0 V^\gamma$$

For an $L/D=40$ MCP the gain exponent γ is ~ 9 . It is a reasonable assumption that the number of collisions with wall is independent of the accelerating field (5) and so for a $L/D=20$ MCP there are approximately half the number of collisions and therefore the gain exponent is halved. The actual published gain curves for the $L/D=20$ MCP used in this paper and the more common $L/D=41$ MCP's corroborate this assumption. If, for example, a Gaussian voltage pulse of FWHM $2t_{1/2}$ is applied, there is a narrowing of the gain profile from $2t_{1/2}$ for the voltage pulse to $2t_{1/2}/\gamma^{1/2}$. For $L/D=41$ MCP with $\gamma \sim 9$, a Gaussian pulse gives a threefold narrowing: an $L/D=20$ MCP with ~ 4 gives a twofold narrowing. The narrowing factor depends in detail on the shape of the voltage pulse.

However, Eq. (1) is not valid if the time a cloud of charge takes to transit the MCP t_{tr} becomes comparable to the rate of change of the voltage t_{el} . The average transit time in a MCP is

$$(2) \quad t_{tr} = \left(\frac{2m}{eV} \right)^{1/2} L n^{1/2}$$

where n is the number of collisions with the wall a typical electron makes, and typically $n \sim 0.5 (L/D)$ where D is the diameter of the micropore giving

$$t_{tr} = \left(\frac{2m}{eV} \right)^{1/2} \frac{L}{2^{1/2}} \left(\frac{L}{D} \right)^{1/2} \quad (3)$$

Detailed calculations show that the minimum gate time is approximately given by gain narrowing for the minimum electrical gate time which equals the transit time.

From Eq. (3), shorter transit times and, therefore, shorter gate times can be achieved by a reduction in L , and less easily, due to the weaker functional dependence by increasing V or decreasing L/D . Values for t_{tr} at $V=1\text{ kV}$ are shown in table 1.

Table 1

Typical Values of t_{tr} from eq³

L/D	L (mm)	t_{tr} (psec)
40	0.5	247
40	0.25	168
20	0.2	106

III. Measurements of the MCP gate widths

(i) Electrical Measurements

As the gate time of microchannelplates becomes shorter it is necessary to reduce the dispersion and losses of the electrical pulse as it is propagated along the microstrip that is coated onto the MCP. For these test experiments we used a 51 mm diameter MCP with $L/D=20$ and $L=0.2$ mm with no edge cladding (6). The coating was formed from 5000A of Cu and then overcoated with 400A of Au for the photocathode. The function of the Cu undercoating is to reduce the Ohmic resistance of the microstrip to 4.6 Ohms.

A time domain reflectometer trace of the this microstrip showed that the characteristic impedance of the microstrip was 15 Ohms and that the propagation velocity along the microstrip was 17.6 mm/100 psec. Fig 1 shows the degradation by the microstrip of a fast voltage edge to a rise time of 48 psec. This shows that the electrical characteristics of the microstrip are adequate for the electrical gate pulses used in this work, although for an improvement in the gate time the electrical characteristics would have to be improved. As well as the reduction in the rise time of the pulse there is also significant loss of amplitude resulting from the Ohmic loss and the mismatch from 25 Ohms feed cable to the 15 Ohm characteristic impedance of the microstrip.

(ii) Measurements of the Optical Gate FWHM:

To measure the response time of the gated MCP a 3 mJ, 2 ps, 1.2 Hz, frequency doubled dye laser was used to excite photo-electrons from the Au coated input surface of the MCP as shown schematically in Fig 2. Although uv light does not produce exactly the same electron energy distribution as x-rays, the gate width is dependent on many secondary processes and so is negligibly different for uv light. The output from the 0.53 μ m laser was used to trigger the Booth pulser and then optically delayed before being frequency doubled and spatially filtered. The second harmonic beam was expanded in one dimension with a cylindrical lens to uniformly illuminate the length of the microstrip on the MCP (Fig. 3).

In this technique, the gate FWHM time was measured from the spatial extent of the image along the active area of the microstrip and the propagation velocity of an electrical pulse along the microstrip as shown schematically in Fig 3. The illumination field uniformity was monitored by applying a DC voltage to the MCP. Synchronization of the electrical gate pulse was achieved by fine tuning the arrival time of the short UV optical pulse at the MCP strip. Because the electrical pulse was triggered from the optical pulse before a 20 nsec optical delay line, the jitter in the synchronization of the two pulses was 20 psec. The light output from the phosphor of the MCP camera was recorded by a Photometrics CCD camera used in its linear regime.

Electrical pulses of FWH 185 psec, 85 psec, 65 psec and 45 psec were used to produce optical gates under different conditions. The gate pulses were produced by reverse charging a diode over 1 nsec (with the Booth pulser of Fig. 2) and using the avalanche breakdown of reverse biased p-n diodes and then pulse formed to produce various pulse shapes(7). Various pulse shapers were used and were changed by varying the "shaper" in Fig 2. The voltage outputs of the pulsers varied as available as shown in table II.

Table II

$2^{1/2}$ Voltage FWHM psec	V peak into 15 Ohms	Measured Optical gate FWHM psec	Calculated FWHM psec
185	800	102 $\pm$ 2	95
85	560	36 $\pm$ 2	45
65	405	34 $\pm$ 2	40

The 45 psec electrical pulser was too short to produce significant output at the CCD camera.

The outputs from the CCD camera from two of the pulsers is shown in Fig 4. These are scans vs position on the output phosphor. From the propagation velocity along the microstrip these are converted to time. Fig 4 shows a gate width of 37 psec for one case and cases as short as 34 psec have been measured. The average FWHM of the optical gates for the three pulsers is shown in Table 2.

To model the expected response of the gated MCP a time dependent discrete dynode model was used. (3). The expected FWHM of the various cases is shown on table 2. In the calculation the effect of the various peak voltages is taken account of. Reasonable agreement is seen, although the measured values are lower than expected because of inaccurate knowledge of the MCP gain at the modest voltages used for gating.

IV. Conclusion

Good agreement between modeling and measurements has been demonstrated for 0.2 mm L/D=20 MCP. Faster gating yet would be possible subject to thinner MCP's being obtainable although the electrical pulse generation could then cause problems.

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Figure Captions

- Figure 1. The response of the microstrip on the MCP (lower solid line) to a 25 psec step function (upper solid line). The time delay in propagating along the microstrip is removed for the purpose of this display. The time base is 20 psec/division. The dots are the differential of the step.
- Figure 2 The experimental layout for displaying a uniform frequency double pulse from a dye laser onto the microchannel plate camera.
- Figure 3. The microstrip was coated across a diameter of the MCP. The complete diameter of the microstrip is illuminated by the laser, a short voltage pulse represented by the 65 psec case in this illustration was propagated across the microstrip. A short region of the microstrip amplifies the photoelectrons producing light from the phosphor over the gate width of the camera.
- Figure 4. The output light along the microstrip for a short pulse gate normalized by the film intensity from a DC gate. The results from two electrical gate widths are shown in this figure.

Fig. 1

Fig. 2

Fig. 3

$$t_{\text{volt}} = 185 \text{ psec}, 800 \text{v}$$

$$t_{\text{optical}} = 102 \text{ psec}$$

$$t_{\text{volt}} = 65 \text{ psec}, 400 \text{v}$$

$$t_{\text{optical}} = 37 \text{ psec}$$

$$t_{\text{optical}} = \text{Number of pixels} \times \text{velocity of propagation}$$

$$\text{Velocity of propagation} = \frac{5.6 \text{ psec} / \text{mm}}{13.6 \text{ pixels} / \text{mm}} = 0.41 \text{ psec} / \text{pixel}$$

Fig. 4

END

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