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Multi-Frame X-Ray Imaging with a Large Area 40ps Camera

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ABSTRACT

We have developed a large area short pulse framing camera that is capable of sixteen frames and shutter times of 40ps per frame. This is accomplished with a high fidelity electrical circuit and a $L/D=20$ microchannel plate, driven by a short pulse (80ps) high amplitude electrical driver. We will show results of this work we have done to support this type of shutter time and the difficulties associated with large area high speed shuttering.

1. INTRODUCTION

The study of laser produced plasmas¹ sometimes requires the use of large area two dimensional imaging. Previous work with a single $L/D=40$ (L/D being the length to the diameter ratio of the pores in the MCP) Microchannel Plate (MCP) has readily produced shutter times as short as 80-100 psec.^{1,2} However, for higher spatial resolution imaging, shorter shutter times will be required to reduce the effect of motional blurring. For 5 micron resolution, and with plasma velocities of about 10^7 cm/s, exposure times of less than 50 psec will be required. We have developed a large area short pulse framing camera that is capable of 16 frames and shutter times of <40ps per frame. The ability to generate shutter times of less than 40ps relies on the ability to propagate a short (<80ps) electrical pulse onto the active area of a thin MCP of thickness $L=2$ mm with sufficient amplitude to generate gain. Modeling¹ has shown that shutter times of <40ps can be obtained if the electrical input can be tailored by using an appropriate combination of pulsed and reverse bias voltages to produce the desired pulse shape onto the active area of the microchannel plate.

2. ELECTRICAL PULSE GENERATION

In order to achieve the desired shuttering characteristics, a system employing a driver and shaper, along with DC bias is used, followed by an impedance matching transformer. The driver is an avalanche transistor based step generator with an amplitude of -3000V and a rise time of 200ps. This is accomplished using a stack of (26) voltage biased transistors. The step generator drives a two diode shunt shaper, the output of which (Fig. 1) is a 2700V, into 50 ohm impulse with a full width half maximum of 80ps. The shaper functions are as (Fig. 2) follows: the -3000V step is first inverted using a six inch length of semi-rigid coax. The resulting +3000V step is then applied through a 5 nH current limiting inductor to two series diodes shunted to ground. As the voltage increases towards +3000V across the diodes, they eventually break down resulting in a fast -2800 edge. The signal at the junction of the inductor and the diodes is then fed through a series 2nf capacitor to the output. Also connected to the output is a 2 nH inductor to ground through a 100pf capacitor. This high-pass network serves two purposes: first it minimizes the precursor, and second it sharpens the trailing edge of the gate pulse. One advantage of this shaper configuration is that any resulting precursor will be the opposite polarity of the gating pulse, and therefore will lessen the effect on the shutter time of the microchannel plate. In addition, a reverse dc bias is applied onto the gate pulse to narrow the effective shutter time of the framing camera.

3. ELECTRICAL PULSE PROPAGATION

The electrical pulse must be propagated and impedance transformed from 50 Ohm to 6 Ohm onto the active area of the microchannel plate (Fig. 3) with as little distortion as possible. We use a stripline (which consists of a center conductor and two outer ground planes) 50 ohm to 6.25 ohm tapered impedance transformer circuit which is an exponential taper with a characteristic length of 7.5mm. A 50 ohm semi-rigid cable is used to launch the pulse onto the tapered circuit. Each tapered circuit has a 9.5% voltage loss due to the impedance transformation. However, at the end of the taper, a transition from stripline to microstrip has to be made as the microchannel plate is microstrip format. At this point, all the currents on the top side of the stripline must flow through vias to the bottom side of the microstrip. The pulse is then propagated onto the microchannel plate through a gold foil. As the gating pulse exits the microchannel plate, it propagates back to 50 ohms in the same manner and is terminated to avoid reflections onto the microchannel plate. Presently we are attempting to resolve a problem concerning the grounding vias that ultimately results in gating pulse distortion. The leading edge of the gating pulse is degraded from a 38 psec fall time to a 47 psec fall time. This results in a 3.7% loss in voltage at the microchannel plate. We estimate at this point, all losses included, we are putting approximately 750-800V onto the MCP. The microchannel plate also has losses associated with it.

4. FIDELITY OF MICROCHANNEL PLATE

In previous papers³ we have reported on short pulse gating using a $L/D=20$ MCP with a 1.75mm wide, 15 Ohm strip. The active area of the circuit that we use for the present large area framing camera is 5.8mm wide, making it a 6.25 ohm strip on a $L/D=20$ MCP, with a thickness of 0.2mm. The coating is as reported previously⁴ except that the ohmic losses of the microstrip are reduced to 2.2 Ohms because of the larger area of coating. The ohmic loss causes a reduction in the gate pulse amplitude. A 5% reduction in electrical pulse amplitude results in a 23% reduction in gain as the gain is proportional to $V^{4.6}$. The frequency spectrum of the MCP has been measured with a Wiltron network analyzer. The MCP, as coated, is 1 db down at 20 GHz, for a 20mm section of microchannel plate material as measured. The current length of microchannel plate we are using is 40 mm, making the frequency response 1db down at 10 GHz. With the pulse width that we are currently using, the microchannel plate is a factor of 2.2 better than needed in the frequency response, but still suffers from the ohmic losses. We estimate the loss from one end of the MCP to the other end to be 12% as measured with TDR throughput measurements.

5. MEASUREMENT OF SHUTTER TIME

To measure the shutter time of the framing camera, a 3 micro Joule, 3ps, 1.2Hz frequency tripled laser was used to excite the primary photo-electrons from the gold coated input surface of the microchannel plate. This is similar to past experiments except that we are now using 202nm, the third harmonic of the laser. This increased the primary photo-electron production by approximately 250 times, allowing more flexibility in the use of the laser. In past experiments we used the second harmonic of the laser.³ In this technique we produce a uniformly illuminated line focus onto the front surface of the MCP. This produces a short burst of primary photo-electrons uniformly across the input face of the MCP. The primary photo-electrons receive gain from the electrical pulse that is traversing across the microchannel plate. The secondary electrons emitted by the microchannel plate are then accelerated with a 3Kv potential onto a P-11 phosphor screen. This in turn is recorded by a Photometrics CCD camera used in its linear regime.

6. PROBLEMS WITH CURRENT DETECTOR DESIGN

We have built this detector within the housing of our old max module framing camera design. This has proven to be a challenging effort. We have found that the vacuum interface is one area that needs improvement. Also, as previously stated, the transition from stripline to microstrip is a very poor junction, but was required for the vacuum feed though. This will be the major area of improvement in the

next detector design. We have found that the use of round microchannel plates is not the best configuration to use in the 40ps framing camera. We are currently working with vendors to purchase plates that are square or rectangular in shape with $L/D=20$.

7. WORK CURRENTLY IN PROGRESS

We currently have a working detector on the Omega target chamber at the Laboratory For Laser Energetics. This detector has produced several pieces of data on implosion experiments (Fig. 4). We are also working on a new detector housing design that will accommodate the microchannel plate configuration much better. The pulser amplitude that the current detector is using is only just adequate for the current work. We are currently in contact with vendors to purchase a pulser of higher amplitude and a pulse width equivalent to what we are using now.

8. CONCLUSIONS

We have been able to consistently demonstrate sub 40ps gating with the current large area framing camera in laboratory experiments, and on implosion experiments at Omega. Currently, the limitations we are facing are to produce a large amplitude narrow gate pulse (4kv, 80ps fwhm), and the ability to adequately propagate the electrical pulse onto the active area of the microchannel plate. We are also looking into ways to reduce the ohmic losses associated with the coatings that make up the microstrip on the microchannel plate.

9. REFERENCES

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FIGURE CAPTIONS

- (Fig. 1) Output of two diode shunt shapers
- (Fig. 2) Schematic of two diode shunt shapers
- (Fig. 3) Mechanical layout of MCP with TDR showing discontinuities
- (Fig. 4) Images from 40ps framing camera at Omega

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Fig. 1

Fig. 2

Fig. 3

3.7 μm wall 250 μm dia. glass microballoon 300 J in 6 beams

Fig. 4

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