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Nanosecond Gating of Microstripline Microchannel Plate Framing Cameras: Characterization and Simulation

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ABSTRACT

The soft x-ray microstripline microchannel plate (MCP) framing camera has become one of the workhorses of ICF diagnostics. Much progress has been made in making these diagnostics work well with gate times of 100 ps and below. Often weak input signal or source timing uncertainties dictate a requirement for longer gate times, preferably in the same instrument that also has fast gating capability. The large power-law dependence of MCP gain on applied voltage is useful in shortening the gating time of the microstripline camera. However, this sensitivity leads to tight constraints on the shape of the long duration electrical pulses that are needed to drive the MCP to produce experimentally desirable optical gating profiles. Simple modeling and measurements are used to better understand the character of the voltage pulses needed to achieve optical gate widths between 500 ps and ~2 ns.

Keywords: MCP Gated Camera, Framing Camera, soft x-ray diagnostics

1.Introduction

The development and principles of the microstripline microchannel plate (MCP) framing camera are well described the in the review by Kilkenney[1]. This work introduces nothing fundamentally new; it serves to reintroduce the same ideas from a different perspective. The overriding goal of most of the development of this type of framing camera has been to produce to shorter gating times. In this mode of operation the electron transit time is the limiting factor effective use of the camera, i.e. a fast gate but no signal. Here the optical gating shape is less sensitive to the shorter time scale details of electrical gate's pulse shape. In this paper, we look at the problems of driving a framing camera system that has been principally for short time gating with longer pulses.

There are two motives for long (1-2ns) pulse desire for long pulse operations in the same high speed instrument. The first is to gather more photons when the incoming rate is limited. In this first case the details of the top of the pulse can be ignored if each photon saturates a channel plate pore - a binary image. If multiple photons need to be detected per pore with some kind of linearity the gating function needs to be well understood and preferably smooth. This work does not take into consideration pore gain depletion in the intermediate case. The second reason for long pulse operation is to perform experiments where some timing uncer tainty or jitter needs be tolerated. In the case of trying to compensate for timing uncertainty, a smooth and as flat as possible gating function is indicated.

The Lawrence Livermore National Laboratory Flexible X-ray Imager (FXI) [2,3] uses pulse forming modules to provide variable length electrical gates. The FXI's pulser and pulse forming modules were manufactured by Kentech Instruments [4]. The fast leading edge of the gating voltage is generated using avalanche transistor technology. To turn the voltage pulse off quickly, the voltage pulse is applied to a pulse forming module. In this module about half the propagated out to down a delay line where it is inverted by reflecting off of a short at the end delay line, when the reflection arrives back at the original pulse it sums with the original pulse to produce a low level, so the output width of the electrical pulse is the double transit time of the delay line. Modules with different cable lengths are used to provide different electrical gates. Since the out put 50 ohm line and the 50 ohm clipping line represent a 25 ohm load to the pulser a matching network is used to minimize reflections to (and back from) the pulser. In the original Kentech modules a pair of 68 resistors parallel is suspended between brass ground planes, forming a stripline structure that feeds the clipping cable junction.

A single pulser and pulse forming modules former is used to drive a single 12.5 ohm microstrip on the MCP. The FXI PFM modules output into 50 ohm cables. This 50 ohm signal is sent into a mismatch circuit where the 50 ohm environment is coupled to a 12.5 ohm environment consisting of two parallel 25 ohm cables. At this match point a 3.3

nF capacitor is used to isolate any DC bias applied to the MCP strip. This separate bias is used to vary effective gain. The mismatch circuit's 25 ohm outputs use 25 ohm SMA connectors and cables to connect to gold bridging foils that connect to the microstrip on the MCP. On the MCP there will also be microstrip dispersion, loss in the micro-stripline end of strip mismatches, proximity effects and other phenomena.

In the FXI framing camera, the microchannel plate is coated with conducting gold strips and with the back of the channel plate continuously coated with gold as to form micro-strip transmission lines. These front strips function both to transmit negative voltage pulses across the channel plate and to act as the principle photocathode for soft x-ray detection. When both voltage and x-rays are present, the liberated photoelectrons are multiplied by collisions in the channels of the channel plate, and provided the voltage was on long enough, a stream of electrons is launched out of the back of the plate and accelerated to a phosphor screen, where the electrons are converted to photons, a fraction of which are then collected by a CCD camera or by a piece of film. The gain of MCP with voltage follows a power-law with an exponent (for the L/D=40 plates used in this work) having a value nominally between 9 and 12. With this power law effect the "optical" gate of the instrument is shorted relative to the electrical gate, up to the point where the electrons, with their finite mass, do not have time to transit from the front of the channel plate to the exit of the channel plate. The overriding goal of most of the development of these framing cameras has been to go to shorter and shorter gating times, operating close to the close to where the electron transit time compromises the effective gain of the camera, i.e. a fast gate but no signal. In this mode of operation the optical gating shape is dominated by the electron transit time, smoothing out the many of the details of electrical gate's pulse shape. For longer electrical pulses the micro-channel plate still responds to details of the pulse on this transit time scale.

For operation at the National Ignition Facility (NIF) for NIF Early Light (NEL) experiments the FXI-1 was upgraded and repackaged. This repackaging included mounting the system in an airbox to mount in a NIF Diagnostic Instrument Manipulator (DIM) [5]. In the course of these testing this upgrade the effective optical gates for some of the long pulse forming modules were found to be shorter than the optical gates for some of the shorter pulse forming modules. As described below this was, in hindsight, consistent with the details of the electrical pulse. To fix this problem, Kentech Instruments Ltd.. provided a modified 2 ns pulse forming module and the parts to assemble more modules. This upgraded module and our attempts to make improved copies of this module are discussed. Several optical and electrical measurements have been made since, but the nature of this upgrade and the demands on the instrument make this work fragmentary and by no means complete. Some simple modeling of the MCP and the electrical system have been done in an attempt to understand the parameters for operating these 60 ps optical gate (with 200ps electrical gate) framing cameras with nanosecond optical gates.

Ideally we would characterize the gating function of the framing camera with a high repletion rate short pulse x-ray source. For regular calibration and testing of the optical gating function a short pulse UV laser can be used. The Bechtel Nevada Livermore Operations Short Pulse Laboratory has an amplified and frequency quadrupled Ti:Sapphire femto-second laser that is used for FXI calibration[]. The intensity of the UV laser light hitting the MCP is adjusted such that the peak value of the centered gating pulse gives a CCD count value well in the linear range of operation of the system. The triggering of the FXI relative to the laser is scanned. For each delay the average of a region of interest of the CCD readout is recorded. The laser power is sampled to correct (linearly) for laser energy fluctuations. The sub-picosecond time scale of this laser makes for an ideal match to the transit time version of the Eberhart Model[] describe in Kilkenney[]

To use this model to best effect the voltage pulse on the channel plate micro-strip structure 12.5 ohm (or lower for other cameras) needs to be measured – typically with 50 ohm attenuators and a 50 ohm oscilloscope. We have used the 50 ohm voltage out of the PFM and assumed the properties of the mismatch circuit. A moderately successful technique that gives representative pulses is to connect to the outputs of the mismatch circuit two cables- one relatively long 25 ohm "get lost cable" and a 50 ohm cable that connects to an though high speed high energy attenuators to a fast oscilloscope. The 25 ohm to 50 ohm mismatch and the effect of the second 25 ohm cable is used in an ideal way to calculate what would appear on the MCP. Additional corrections can be applied to this technique, but it appears to produce fairly representative voltage waveforms without them. The output voltage of a micro-stripline MCP could be similarly measured but time, availability and risk to a MCP module have not allowed these additional tests.

Since the production of the FXI's original pulser , the manufacturer, Kentech electronics had noted some of this problems and had posted on their web site a model of an improved pulse forming model. The original PFM scheme is shown in Figure 1. They sent us an example of this improved model that tested well in the short pulse laser lab. To replicate this PFM for the other channels Kentech sent us the materials to assemble more pulse formers. A sampling oscilloscope with a Time Domain Reflectormeter module was used in Time Domain Transmission mode – so that the oscilloscopes TDR unit made an idealized (though much lower voltage) pulser substitute. The component layouts of the modified circuit is shown if Figure 2. The smoothness of the responses was determined in detail by the proximity of the wire coil to the high frequency MELF packaged resistors used indicating that cross coupling capacitance is important. Figure 3 show a TDT plots for an old style PFM. Figure 4 shows the TDT plots of the new PFMs. Figure 5 shows the optical gating function results showing that we now have nanosecond gating.

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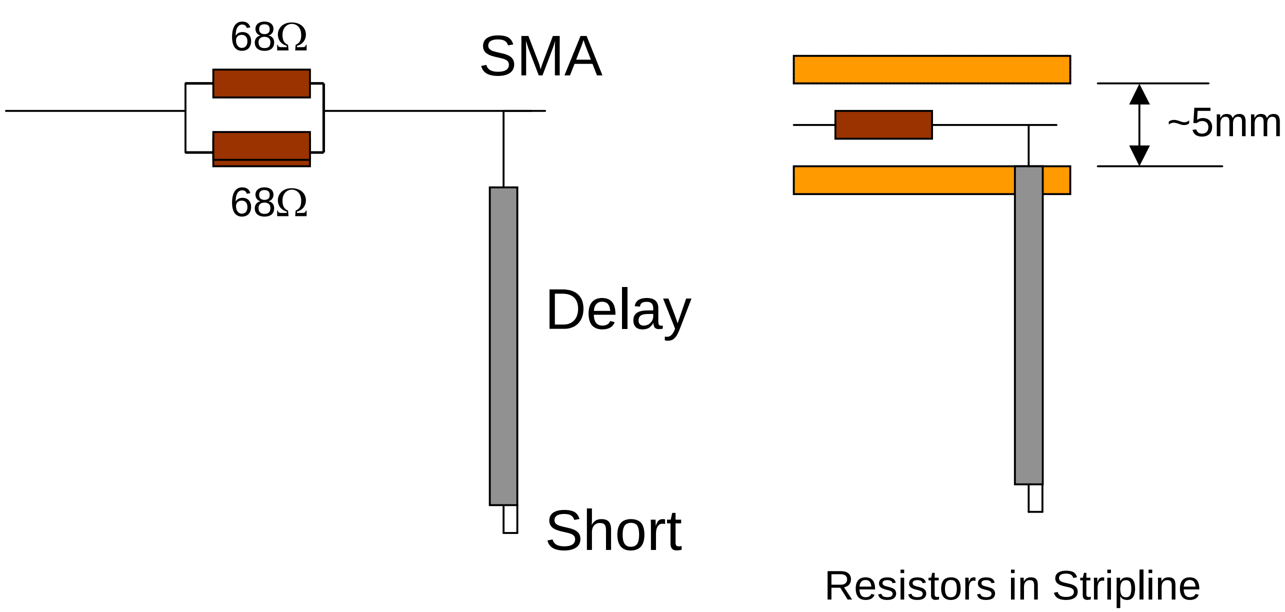

Figure1 Old PFM

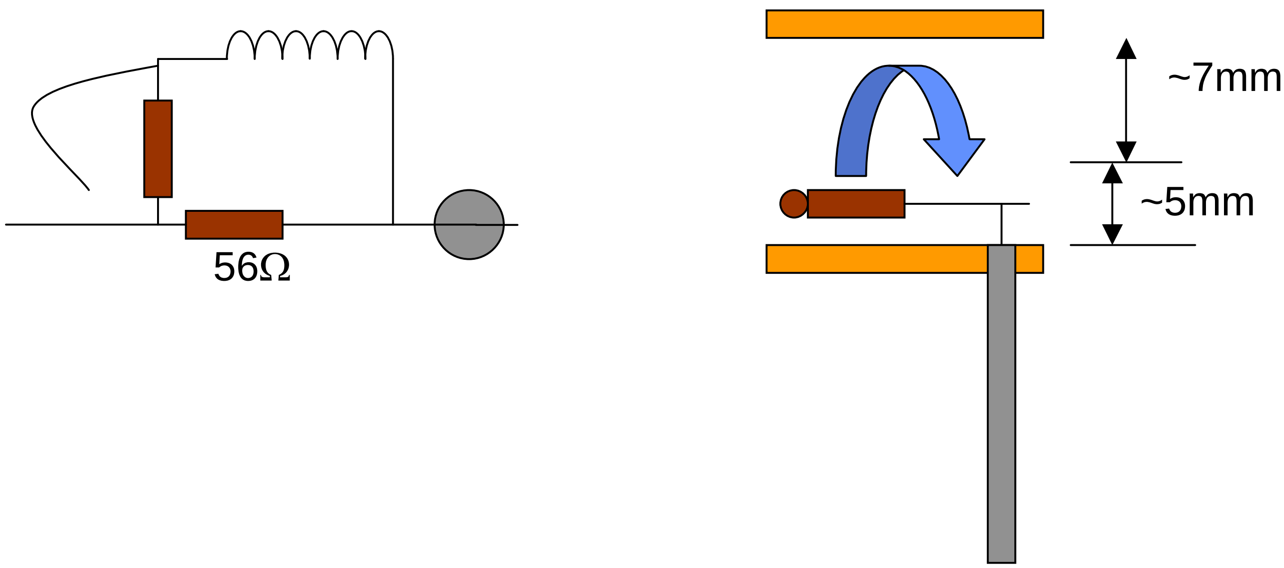

Figure 2 New PFM

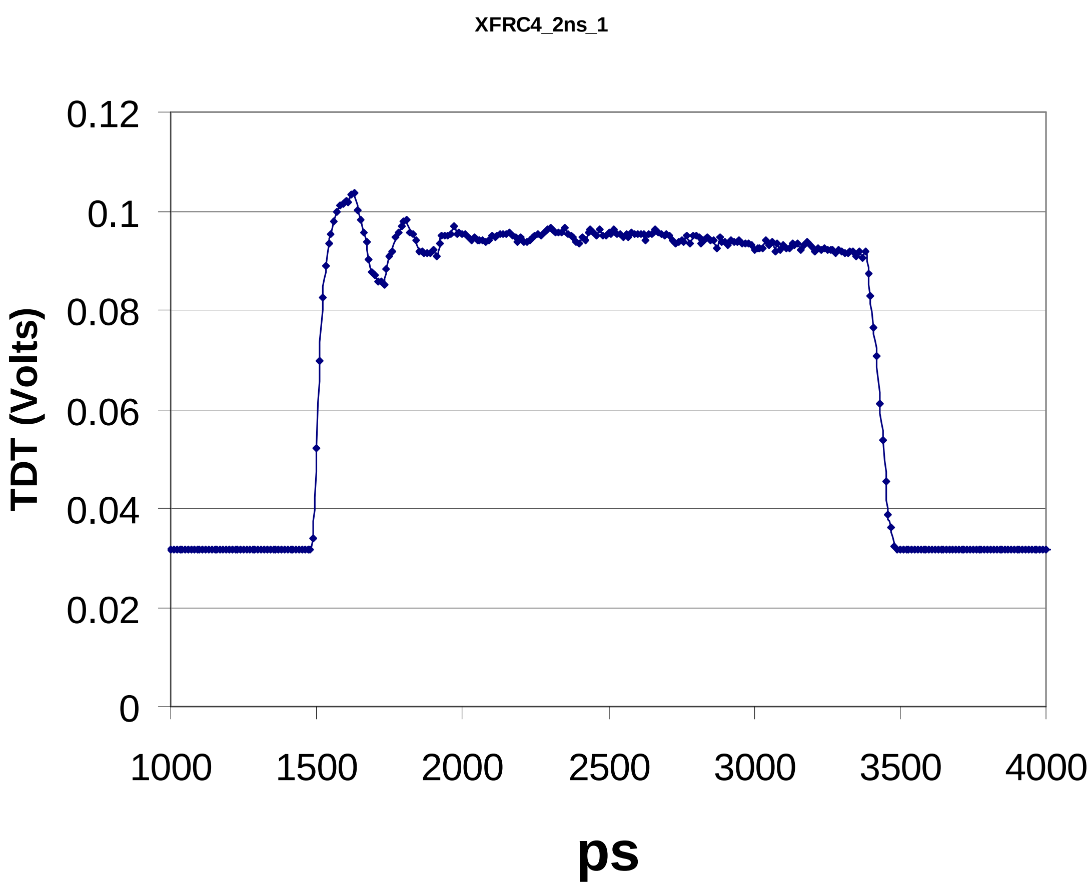

Figure 3

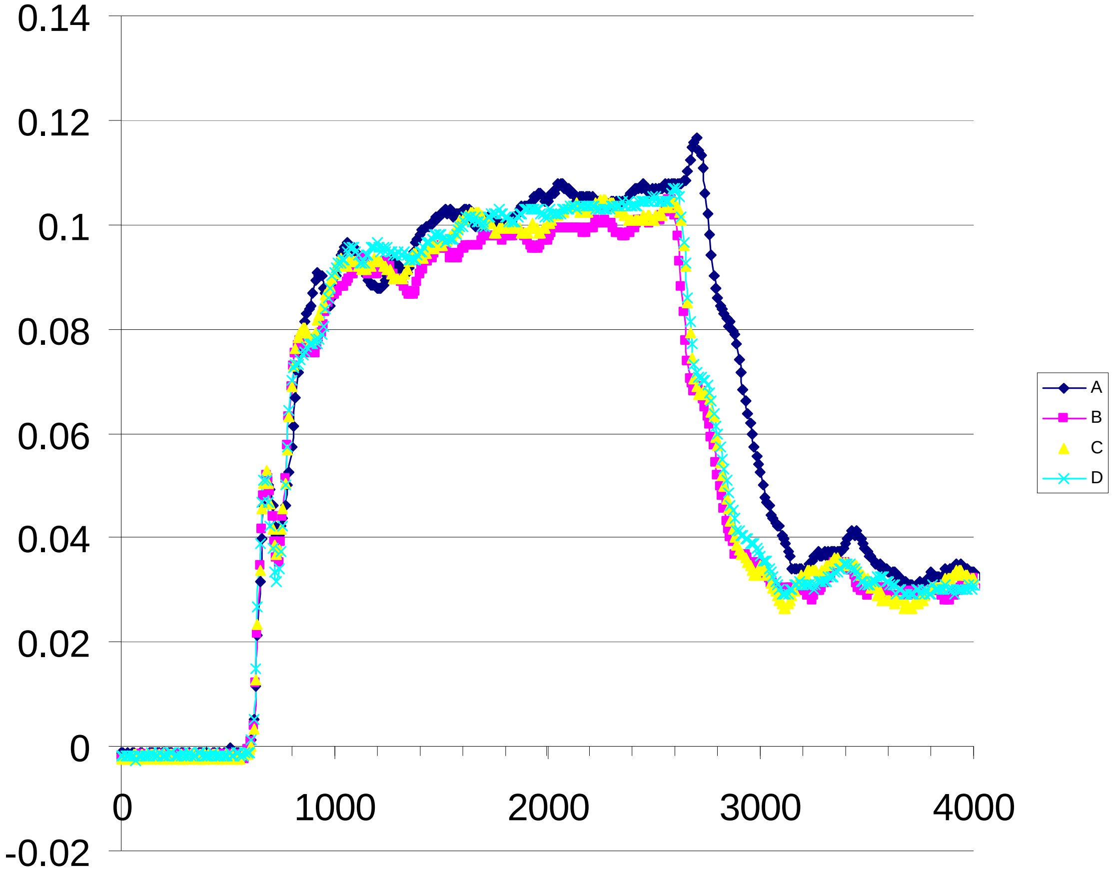

Figure4 TDT of new 2ns PFMs.

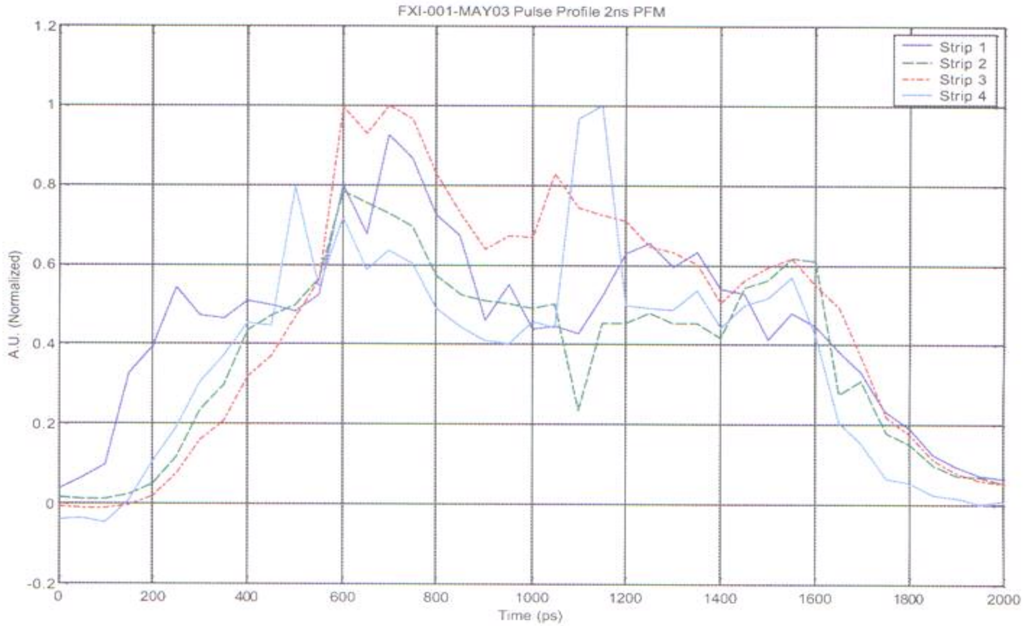

Figure 5 Optical gating functions for new 2ns PFMs.