Development of a Microchannel Plate–Based Gated X-Ray Imager for Imaging and Spectroscopy Experiments on Z

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ABSTRACT

This paper describes a microchannel plate (MCP)–based, gated x-ray imager developed by National Security Technologies, LLC (NSTec), and Sandia National Laboratories (SNL) over the past several years. The camera consists of a 40 mm × 40 mm MCP, coated with eight 4 mm wide microstrips. The camera is gated by sending subnanosecond high-voltage pulses across the striplines. We have performed an extensive characterization of the camera, the results of which we present here. The camera has an optical gate profile width (time resolution) as narrow as 150 ps and detector uniformity of better than 30% along the length of a strip, far superior than what was achieved in previous designs. The spatial resolution is on the order of 40 microns for imaging applications and a dynamic range of between ~100 and ~1000. We also present results from a Monte Carlo simulation code developed by NSTec over the last several years. Agreement between the simulation results and the experimental measurements is very good.

Technical Specifications

Item	Description	Values
1	Recordable MCP Strip Size	4 mm × 37 mm
2	Impedance of MCP Strip	~ 19 Ω
3	Resistance of Each Channel	<2 Ω (1.75 Ω)
4	MCP Strip Bias Voltage (DC)	Operation ≤800 V Maximum ≤900 V
5	Peak Voltage on MCP Strip	~ 850 V
6	Available DC Bias Range	±500 V
7	DC Bias Voltage Between Strips	<400 V
8	Impedance of Input CB	21–22 Ω
9	Impedance of Output CB	50 Ω
10	Temporal Resolution	300 ps PFN/Z-cables: 150±6 ps 700 ps PFN/Z-cables: 274±10 ps
11	Pulsed Gain Variation	30% (150 ps) / 10% (274 ps)
12	Phosphor Bias	DC ≤3 kV; Pulsed ≤5 kV
13	Spatial Resolution	<50 μm
14	Dynamic Range	100–10,000 (depending on operating conditions)

Fielding Requirements

- Well-characterized, reliable, and reproducible
- Endure harsh environments at Z (mechanical shock wave and EMP)
- Compact and user-friendly operations

Performance Optimization: Design Assistance by Monte Carlo Simulation

A Monte Carlo simulation code developed at NSTec, Los Alamos Operations over the past several years was used to optimize the gated performance of the camera. Specifically, simulations were run to determine the temporal width of the gating voltage pulse that obtains a short optical gate while maximizing camera sensitivity. The voltage pulse from a Kentech pulser with a 300 ps flat-top pulse-forming network was used and the flat top was 'shortened' to study shorter pulse widths.

Electronic Characterizations: TDR and Pico-probe

Electronic characterization of the camera is done using time domain reflectometry (TDR). A picoprobe is used to measure the time dependence of the gating voltage pulse along the MCP striplines.

Performance Characterizations: Temporal and Spatial Resolution

A short pulse (<1 ps) UV laser was used to study the detector temporal resolution. By varying the delay between the voltage pulse and the laser, the detector optical gate was sampled as a function of position along the strips. A resolution mask was used to determine the spatial resolution of the camera. NSTec's MCP simulation code was used to simulate detector gate profiles and detector spatial resolutions. Results show that the detector optical gate is ~150 ps FWHM, and the spatial resolution is ~40 microns. Excellent agreement between experiment and simulations is demonstrated.

Performance Characterizations: Dynamic Range and Saturation

The short-pulse UV laser was also used to study the dynamic range and saturation behavior of the camera. The intensity of the laser was increased, thus increasing the number of photoelectrons beginning cascades in the MCP. The laser intensity was increased until the gain was nonlinear. The quantum efficiency of the MCP for photoelectron generation from the UV light was assumed to be ~0.1%, and simulations were performed for comparison. In Figure (A) below the plotted data and simulations show very good agreement. The plot shows onset of nonlinearity near 300 photoelectrons. Figure (B) shows the linear region only. Figure (C) shows a simulation study of the dynamic range of the detector for different DC offsets. Overall, the dynamic range of the detector is between ~100 and ~1000.

Performance Characterizations: Uniformity of Sensitivity

Using the position-dependent optical gate profile measurements made with the short-pulse UV laser, we were able to determine the position-dependent detection sensitivity. This was done by integrating the position dependent gate profiles. Using the position dependent voltage pulses measured with the picoprobe, the simulations code was used to simulate the position-dependent detector sensitivity. In Figure (A) below the experimentally determined position-dependent sensitivity for a 300 ps voltage pulse is shown in blue, while the simulations are shown in red. Agreement is clearly very good. In Figure (B) the experimental data for a 700 ps voltage pulse is shown (no simulations have been performed for this voltage pulse).

Summary

We have described the technical specifications and experimental characterization of a MCP-based gated x-ray imager for imaging and spectroscopy experiments on SNL's Z facility. The imager is gated with a subnanosecond high-voltage pulse. The characterization shows that the imager optical gate profile width is as narrow as 150 ps, the spatial resolution is ~40 microns, and the dynamic range is between ~100 and ~1000. Simulations using NSTec's MCP simulation code agree with the experimental results. The camera is currently being fielded on Z with great success.

References

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