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Advances in Performance of Microchannel Plate Detectors for HEDP Diagnostics

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In recent years, a team from NSTec and SNL has built a unique capability to develop microchannel plate (MCP)-based framing x-ray cameras for HEDP diagnostics. At the SNL Z facility, multistrip MCP detectors to record up to eight channels are employed in 2-D, sub-nanosecond time-resolved imaging and time- and space-resolved spectroscopy diagnostics.

Progressively more stringent technical temporal resolution and response uniformity requirements have necessitated a systematic design approach based on iterative modeling of the MCP using inputs from electrical circuit characterization. An inherently large exponential dependence in MCP gain, $V^{11.5}$, has mandated a firm understanding of the applied voltage pulse shape propagating across the strip. We pioneered direct measurements of the propagating waveform using a Picoprobe® and developed a Monte Carlo code to simulate MCP response to compare against test measurements. This scheme is shown in Figure 1.

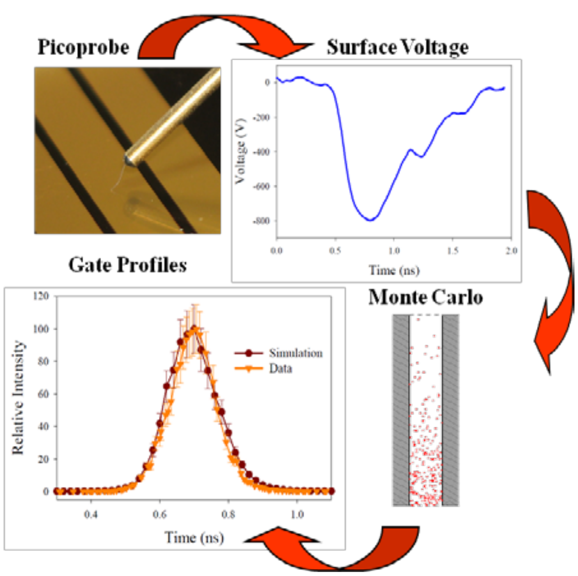

Figure 1: A systematic approach for developing an advanced MCP detector

The simulation detailed a physical model of the cascade and amplification process of the MCP[i,ii] that includes energy conservation for the secondary electrons, the effects of elastic scattering of low-energy electrons from the channel wall, and gain saturation mechanisms from wall charging and space charge. Our model can simulate MCP response for both static and pulsed voltage waveforms.

Using this design approach, we began to characterize the newly developed second-generation detector (H-CA-65) by using a Manson x-ray source to evaluate the following DC characteristics: MCP sensitivity as a function of bias voltage, flat-field uniformity and spatial resolution, and variation of spatial resolution and sensitivity as a function of phosphor bias voltage. Dynamic performance and temporal response were obtained by using an NSTec short-pulse laser to measure optical gate profiles, saturation, and dynamic range. These data were processed and combined to obtain the gain variation and gate profiles for any position along an MCP strip. Typical position-sensitive gate profiles of the detector are shown in Figure 2.

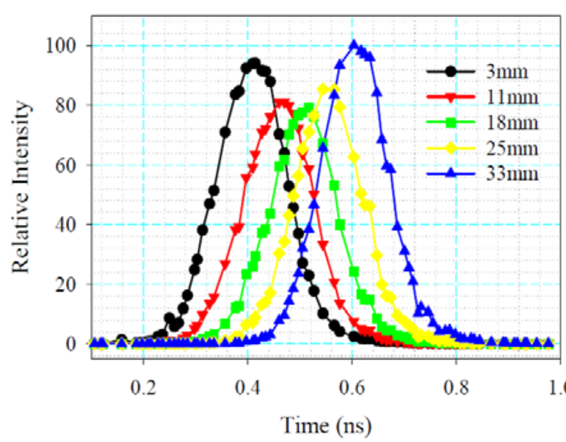

Figure 2. Typical position-sensitive gate profiles of NSTec H-CA-65 MCP detector with a 300 ps FWHM PFN and Z-fielding cables

The measured gate profiles for the latest design have shown excellent agreement with Monte Carlo simulations.[iii] This modeling success provides us with a powerful tool for designing and optimizing MCP detectors that will meet

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specified requirements. For example, the pulse-forming network (PFN) pulse width can be chosen based on Monte Carlo simulation to achieve the shortest gate profiles without loss of significant gain. In Figure 2, a 150-ps FWHM gate profile was determined to be the inherent response time of our detector, This is close to the transit time of the electrons inside the MCP. The difference between design and measured performance of the H-CA-65 is within experimental errors. The most exciting outcome from the characterize/model process is that MCP gain uniformity can be achieved by adjusting output circuit impedance and judiciously selecting an appropriately wide voltage pulse waveform to drive the MCP strip. The combination of impedance, reflection ratio, and pulse shape/width can be optimized to provide a uniform pulse to propagate across a strip.

Figure 3 shows the sensitivity measured across an MCP strip for an old-style SNL detector and the H-CA-65. The H-CA-65's uniformity is 30% or better for a strip driven by a 300-ps FWHM PFN (yielding a 150-ps FWHM optical gate profile), compared to a factor of five or less for the old detector. For the time-resolved spectroscopy diagnostic at Z, gain uniformity across the strip is a much more critical criterion than a narrow optical gate. A gain uniformity of 10% along the MCP strip was achieved when driven by a 700-ps FWHM PFN (yielding a 250-ps FWHM optical gate), a two order of magnitude improvement. The developments that produced the H-CA-65, which are now part of our MCP design process, have reduced product cost and the time it takes to develop and characterize the new MCP detectors.

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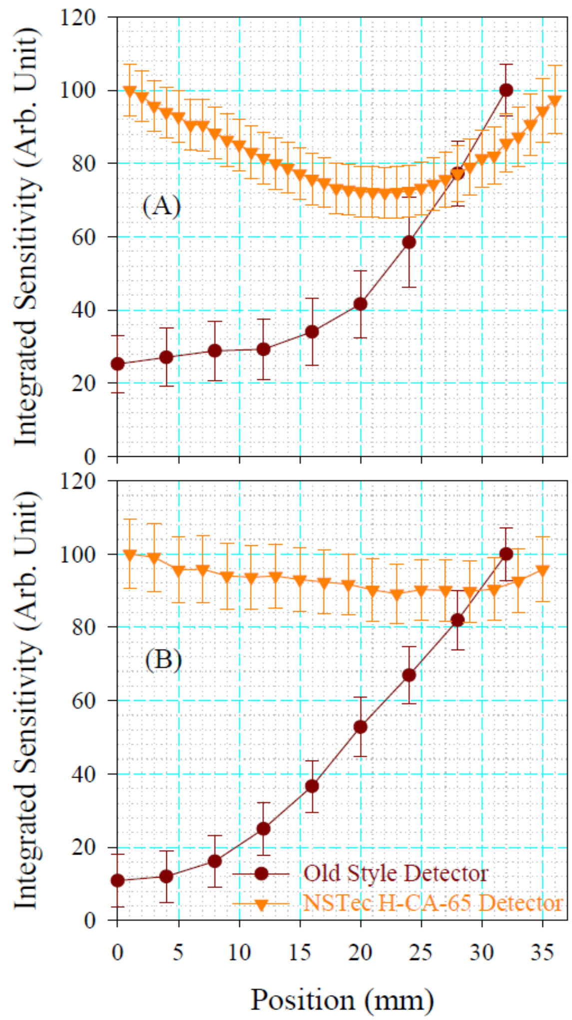

Figure 3. Comparisons of sensitivity variations along MCP strips between NSTec H-CA-65 and old-style SNL detectors using (A) a 300-ps FWHM PFN and (B) a 700-ps FWHM PFN with Z-fielding cables

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