Measuring position in 2-dimensions using induced signals in a microchannel plate detector
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- Good spatial information is essential for quality imaging.
- Whether detecting photons, ions, or neutrons inevitably one is concerned with detecting electrons.
- Goal: Development of a detector with (a) single-electron sensitivity, (b) sub-millimeter spatial resolution, (c) sub-nanosecond time resolution, and (d) the capability of resolving two spatially separated, simultaneous electrons.

Courtesy of Paul Scherrer Institut
Microchannel Plate (MCP) Motivation

- An MCP is composed of millions of leaded glass tubes (2-10 μm in diameter) where each channel acts as an independent secondary electron emitter.
- An applied voltage across the plate causes the initial electron to be cascaded with an amplification of ~10^3-10^4.
- Individual plates can be stacked to achieve a gain of 10^6–10^8.

### MCP Motivation:
1. Sensitivity to a broad range of particles including charged particles and neutrons
2. High gain
3. Fast temporal response
4. Compact size
5. Stable operation even in high magnetic fields

<table>
<thead>
<tr>
<th>Type of radiation</th>
<th>Detection efficiency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Electrons</strong></td>
<td>50-85</td>
</tr>
<tr>
<td>0.2 - 2 keV</td>
<td></td>
</tr>
<tr>
<td>2 - 50 keV</td>
<td>10-60</td>
</tr>
<tr>
<td><strong>Positive ions</strong></td>
<td></td>
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<tr>
<td>(H+, He+, A+)</td>
<td>5-85</td>
</tr>
<tr>
<td>0.5 - 2 keV</td>
<td></td>
</tr>
<tr>
<td>2 - 50 keV</td>
<td>60-85</td>
</tr>
<tr>
<td>50 -200 keV</td>
<td>4-60</td>
</tr>
<tr>
<td><strong>U.V. radiation</strong></td>
<td>1-5</td>
</tr>
<tr>
<td>300 - 1100 Å</td>
<td></td>
</tr>
<tr>
<td>1100-1500 Å</td>
<td></td>
</tr>
<tr>
<td><strong>Soft X-rays</strong></td>
<td>5-15</td>
</tr>
<tr>
<td>2 - .50 Å</td>
<td></td>
</tr>
<tr>
<td><strong>Diagnostic X-rays</strong></td>
<td>~1</td>
</tr>
<tr>
<td>0.12 - 0.2 Å</td>
<td></td>
</tr>
<tr>
<td><strong>Thermal Neutrons</strong></td>
<td>14-25</td>
</tr>
<tr>
<td>0 - 25 meV</td>
<td></td>
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</tbody>
</table>


A single electron is amplified to a cloud of $10^7$-$10^8$ electrons, which is sensed by a wire plane (2 orthogonal planes can provide 2D).

Wires in a sense wire plane have a 1 mm pitch and are connected to taps on a delay line.

Position is related to the time difference between the signals arriving at the ends of the delay line.

Resolution = 466 $\mu$m FWHM

Improving the Spatial Resolution

- Minimized the distance between the MCP and the sense wire plane.
- Optimized the electric field of the system.
- Optimized the grounding of the signals.

Resolution = 466 μm FWHM

With optimizations, resolution = 240 μm FWHM
Improving the Spatial Resolution

With digital signal processing, resolution = 115 μm FWHM

With digital signal processing and use of a 10 GS/s Digitizer (Tektronix DPO5204B), resolution = 95 μm FWHM
Slow Neutron Radiography

Slow neutron radiography was performed at the LENS facility at Indiana University.

Characteristics of LENS:
- 13 MeV proton linac driver
- $^9$Be(p,n) reaction to produce neutrons
- Thermalization (polyethylene, solid CH$_4$ at 6.5K)
- 100 n/(ms.cm$^2$) neutron flux

10$^B + n$(25 meV) → $^7$Li + $^4$He

$\sigma = 3840$ b

* 2mm Wide Slits, Horiz. Oriented, 5mm Pitch
(Thermal capture $\sigma$ for $^{113}$Cd = 19,820 b)
In the first 2D neutron image (using sense wires):

- Can clearly distinguish the MCP-B (25mm diameter), and the MCP-Z (40mm diameter), and the 3 slits in the mask.
- Measured expected slit width (2mm) and pitch (5mm) with resolution = 861 μm FWHM.
- There is a non-uniform intensity fluctuation in X (offline analysis is underway).
- Our Peak/Bkgd is only ~2.
- S/B = 0.7 and S+B = 170 cps, and are currently rate limited by our DAQ.
Summary:
I. Demonstrated proof-of-principle of the induced signal method.
II. Using only the zero-crossing point of the induced signal, resolution = 95 μm FWHM.
III. Acquired first 2D image for slow neutrons, resolution = 861 μm FWHM.

Outlook:
I. Improve Signal Processing
   i. Utilize the entire induced signal shape.
   ii. Implement a differential readout method.

II. Neutron Radiography – Improvement to S/N
   i. Assemble a faster waveform digitizer DAQ.
   ii. Incorporate a TDC for a coincidence (MCP & proton beam) measurement.
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LENS Staff

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Mechanical Instrument Services and Electronic Instrument Services

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