Performance Characterization Of A Simultaneous Positive and Negative Ion Detector For Mass Spectrometry Applications

(2145P)

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Introduction

- Microchannel Plates (Figures 1) are parallel arrays of millions of independent electron multipliers. Originally developed for use in night vision systems, these compact electron multipliers are being used in a wide variety of analytical instruments as electron and ion detectors.

  The unmatched temporal response, high gain and low noise characteristics of a microchannel plate based detector have made them the preferred detector in many analytical instrument applications.

Typical Microchannel Plate Configurations

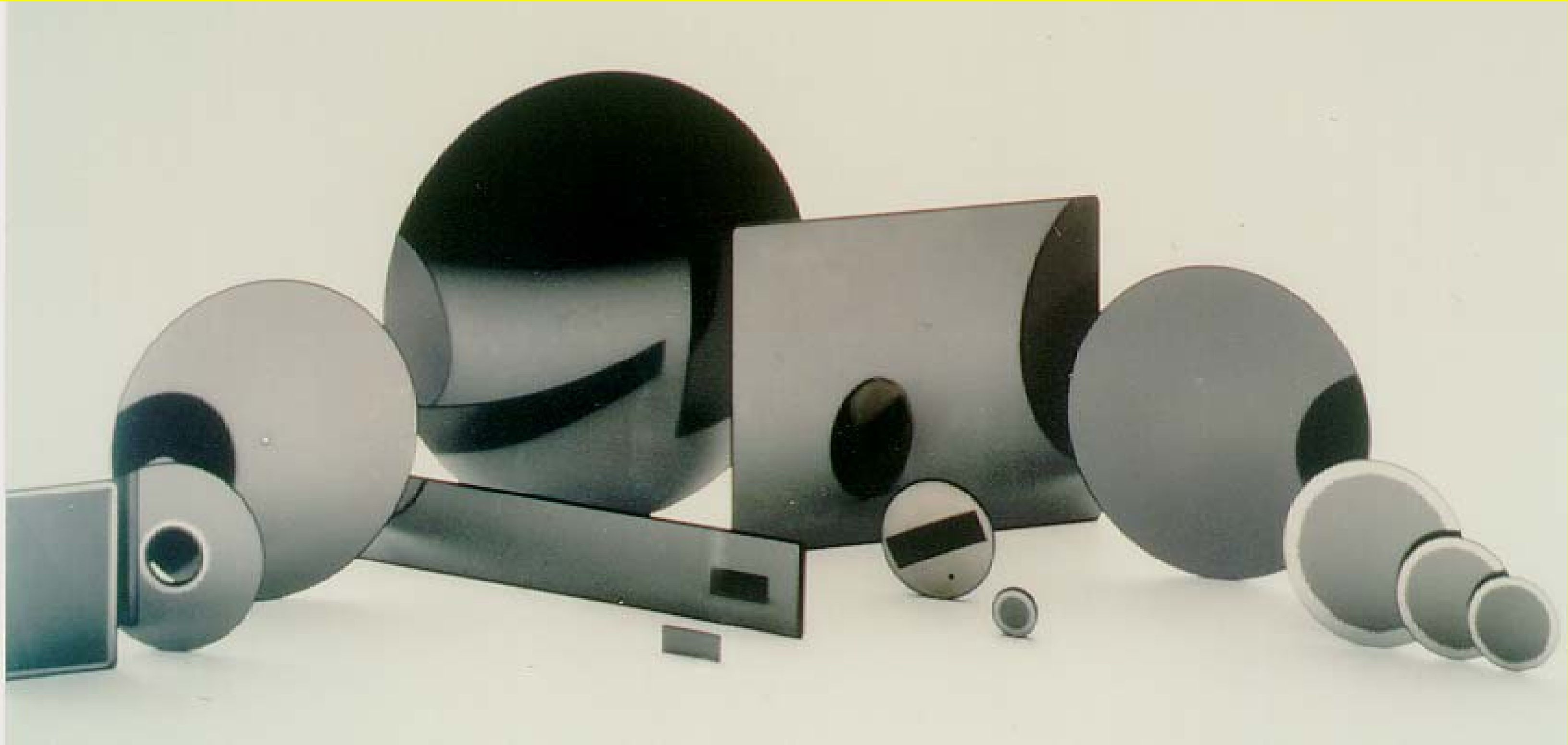

Figure 1

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Introduction Cont.

- In operation, (Figure 2) charged particles or electromagnetic radiation impinge upon the input side of the microchannel plate. Secondary electrons will be generated as a result of collision with the channel wall. The resultant secondaries will be accelerated down the channel, resulting in still further collisions and secondary electron emission. This process is repeated until the total charge exits the MCP output side and is collected by the readout device.

  The resultant net charge increase (Io/In) is called the gain. Figure 3 illustrates a typical gain response as a function of applied voltage.

The Operation Of A Microchannel Plate

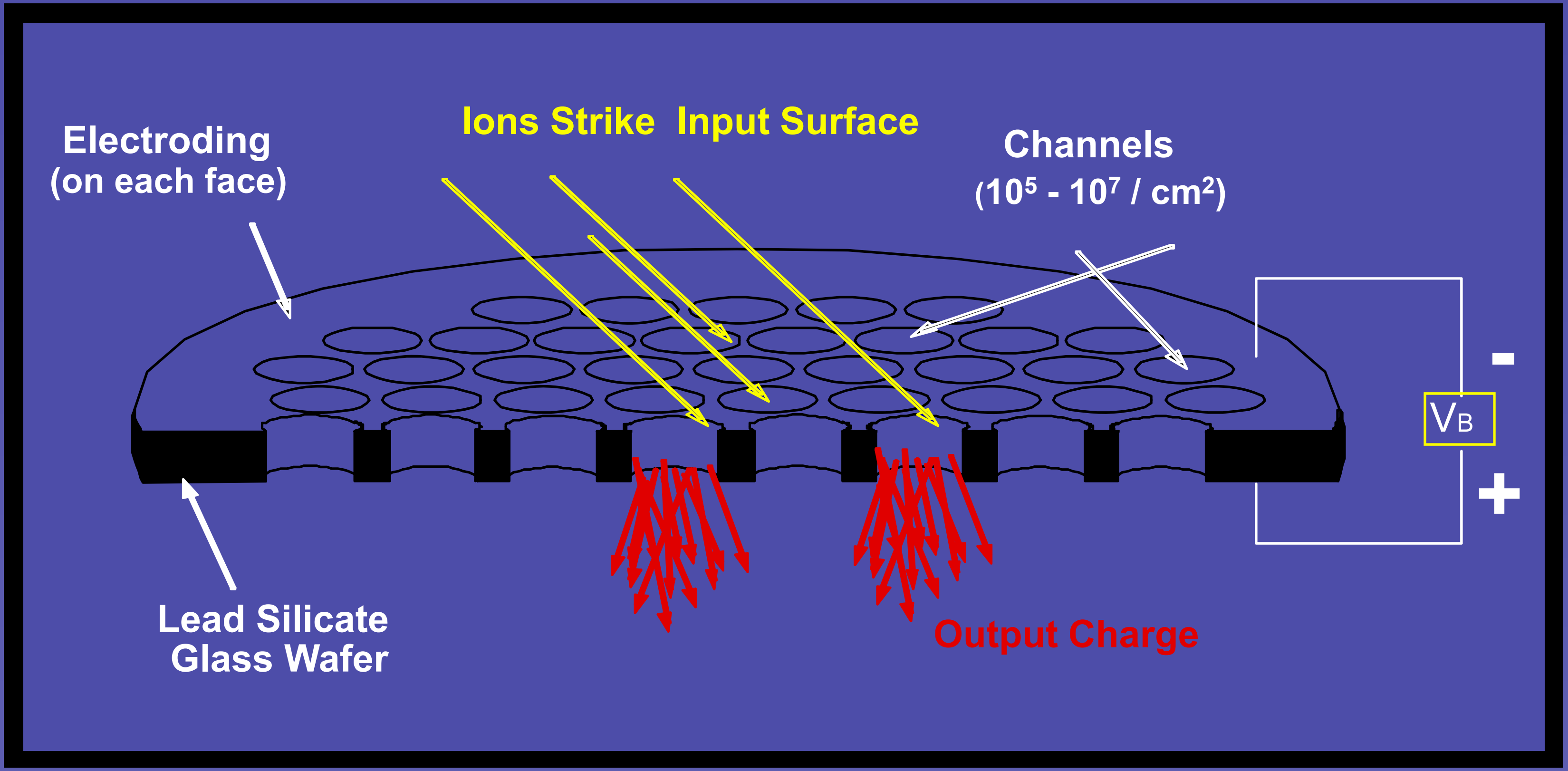

Figure 2

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Gain Response Curve:

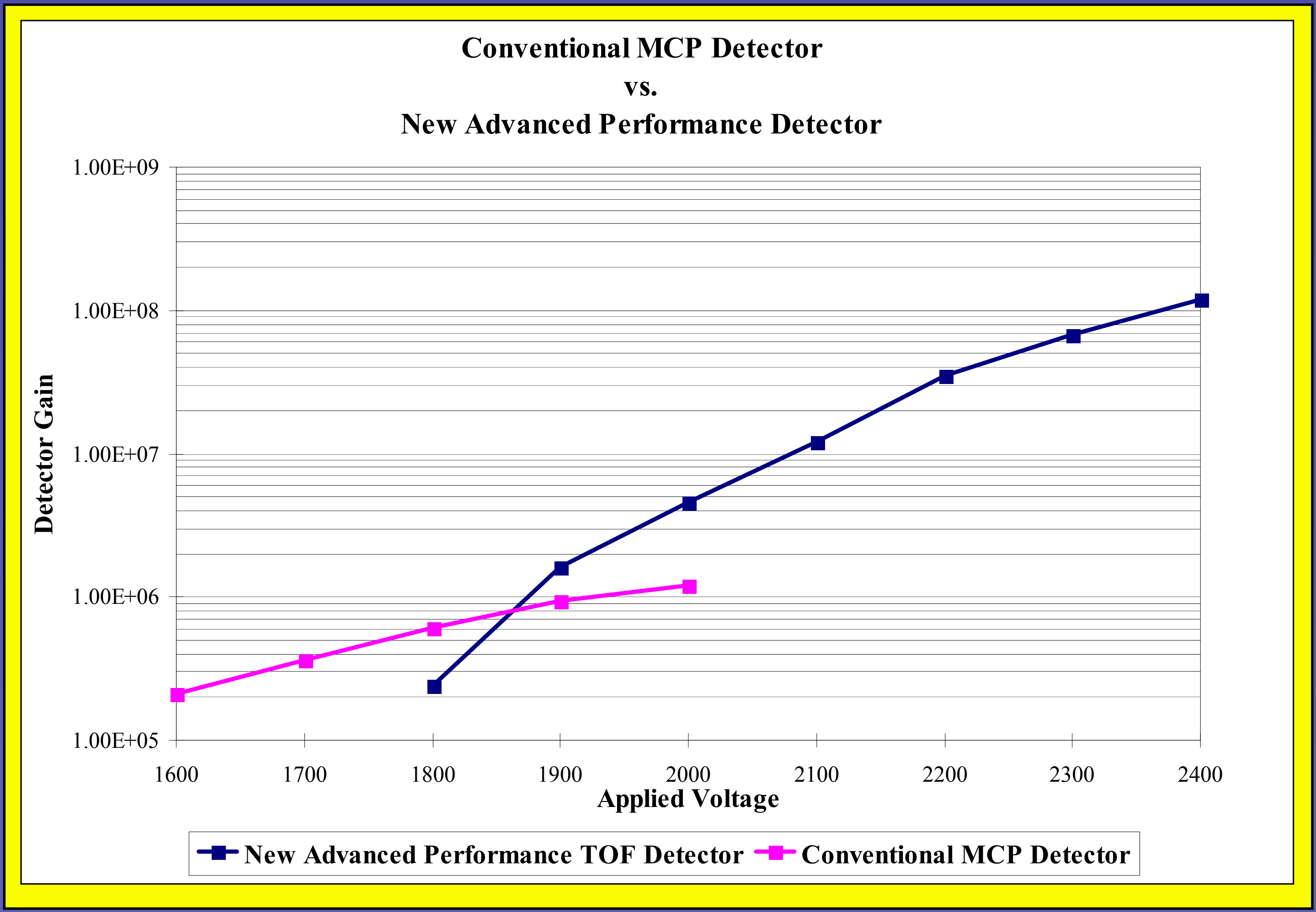

Figure 3

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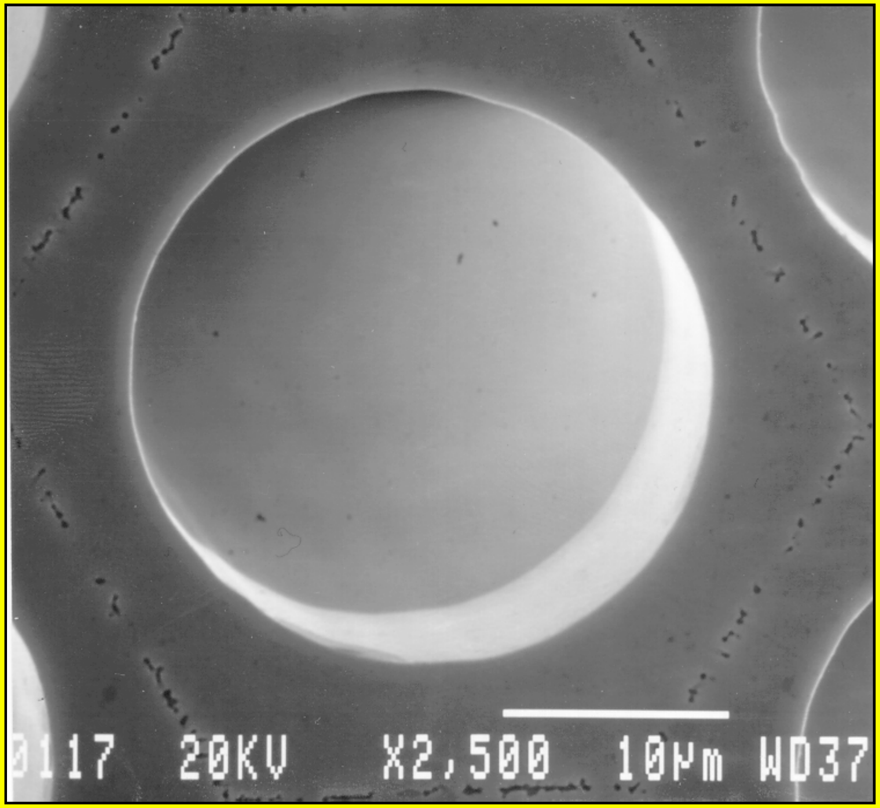
Discussion

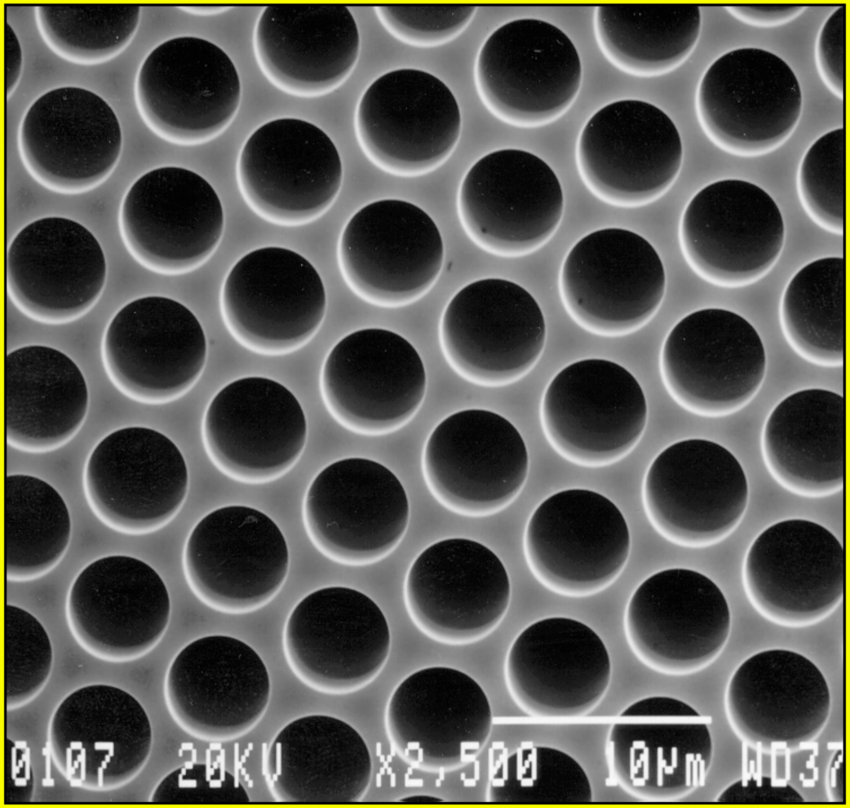
- The independent nature of each microchannel (illustrated in figure 4) in an MCP presents some intriguing possibilities for segmentation. In normal applications, a continuos, thin metalization (typically nichrome or inconnel) is applied to both the input and output surfaces of the microchannel plate.

  The purpose of this film is to electrically connect each channel in parallel so that when a potential is applied, each channel will produce the same gain.

Microchannel Density Micrographs:



25 µm pore MCP



5 µm pore MCP

Figure 4

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Discussion Cont.

- Recent advances in shadow mask and laser ablation technology have opened up new possibilities for making compact segmented detectors.

  The active area of the microchannel plate can now be effectively partitioned into multiple areas offering specific performance capabilities.

  Separate areas could be effectively biased to preferentially detect either positively or negatively charged particles. Various sections could be operated at various gain levels by modulating the voltage across each section. Operation at various gain levels would be useful in enhancing the dynamic range of a detector or provide a monitor or feedback signal for the instrument.

  Large segmented, rectangular microchannel plates could now be used in place of arrays of single channel electron multipliers

Objective

- The objective of this development program was to determine if a microchannel plate could be segmented and operated as two individual detectors which can be simultaneously biased to detect either positive and negative ions.

Experimental Approach

- Twenty Five Millimeter Active Diameter Microchannel Plates were prepared with a 3 millimeter gap in the metalization on the input and output sides. (Figure 5)

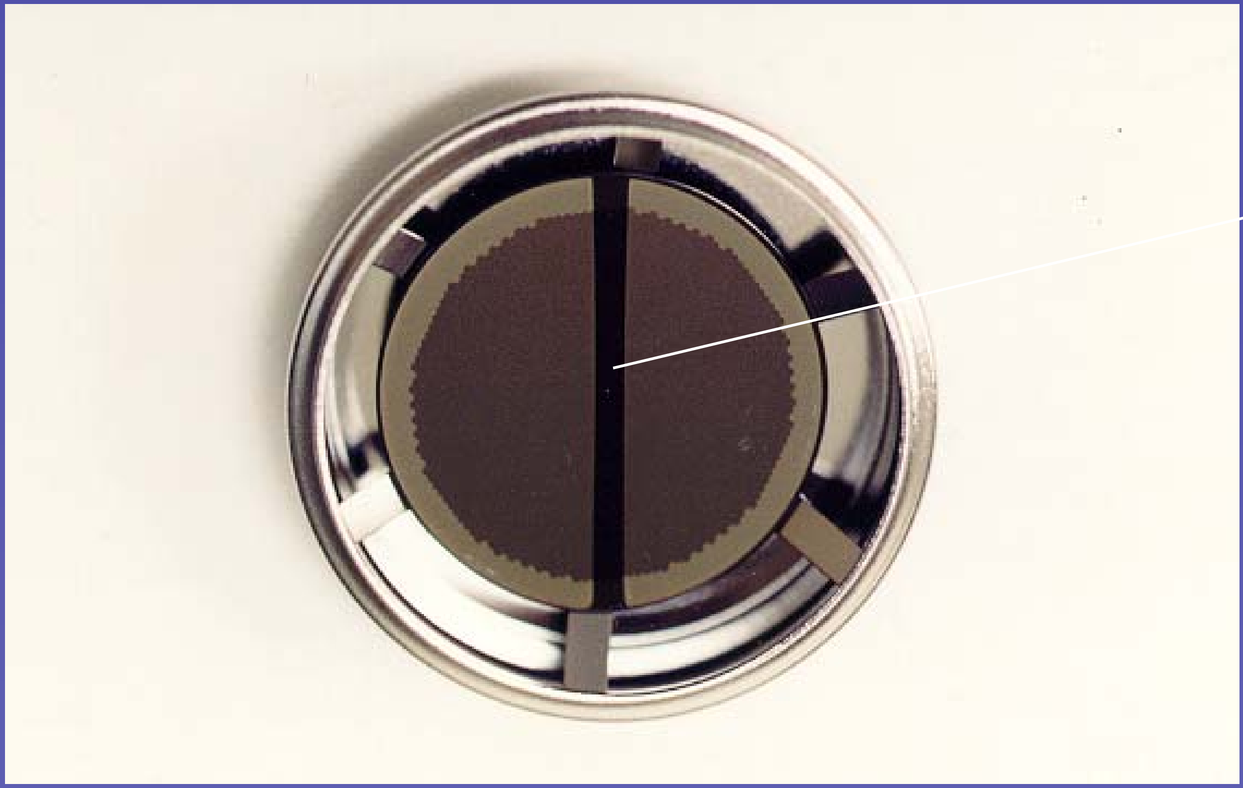
- Additional Microchannel plates were prepared using laser ablation to prepare the gap in the metalization.

- Sets of microchannel plates were subsequently subjected to gap resistance measurements and assembled (Figure 6) into Chevron configurations as ion detectors.

- The detectors were next loaded into a demountable (Figure 7) vacuum test stand and stimulated with positive and negatively charged particles.

- The prototype detector was fitted with a fiber optic phosphor screen in order to quickly visualize the positive and negative ion detection. The phosphor screen could also be used to collect signal current.

Segmented Microchannel Plate



Non Conductive Region

Figure 5

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Simultaneous Positive and Negative Detector

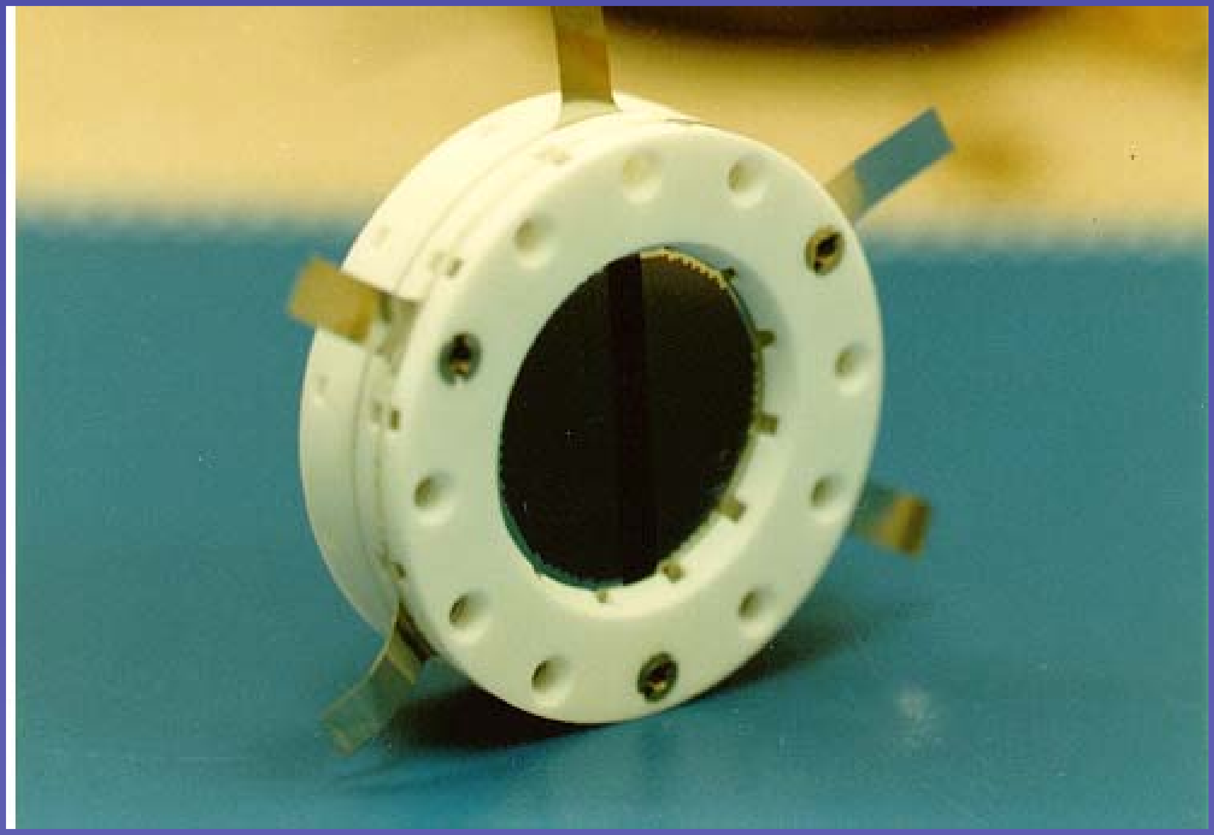

Figure 6

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Simultaneous Positive and Negative Detector Collecting Positive Ions.

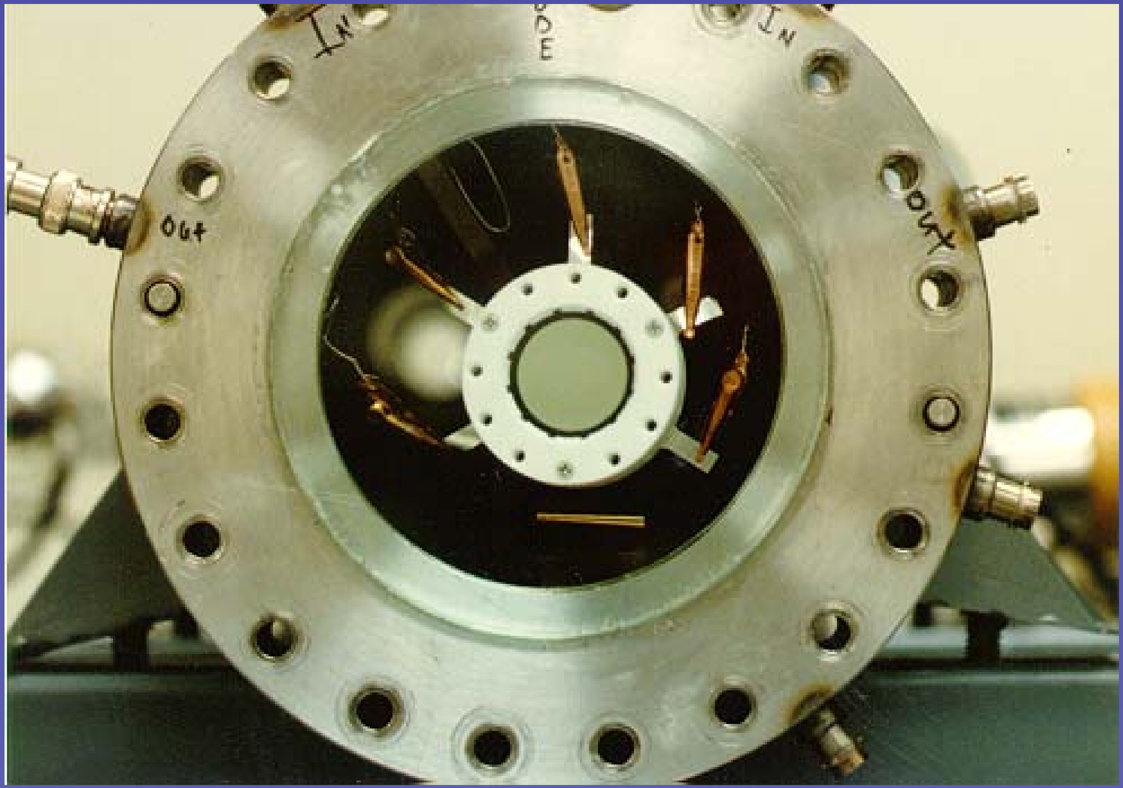

Figure 7

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Detector Biasing Schemes for Analog and Pulse Counting Modes of Operation

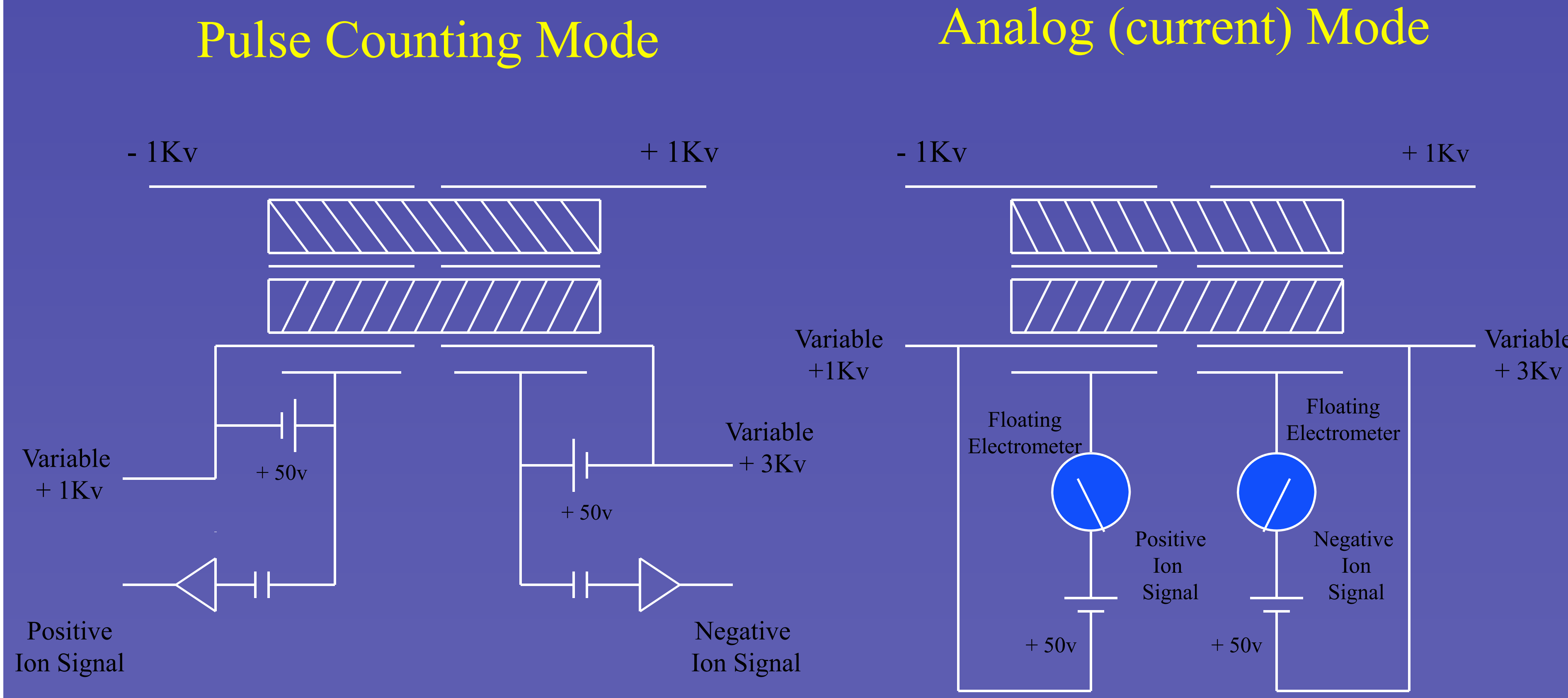

Figure 8

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Results:

- The shadow mask segmentation approach produced gap resistances on the order of 6E12 ohms/mm.
- The ablation segmentation approach yielded gap resistances on the order of 2E16 ohms/mm.
- The detector was successfully operated with the full operating voltages listed in figure 8.
- Positive ions from an electron impact source were next directed to the detector. The left side of the detector responded as evidenced by the light emission (figure 9) from the left portion of the phosphor screen. Current measurements, using a split anode, indicated that the anode current increased from 5E-12 amps to 2.3E-7 amps when the positive ions were directed to the detector. The signal current from the negative ion segment of the detector increased from 4.1e-12 amps to 8E-12 amps as the positive ion source was activated. This small increase over the dark current was most likely due to stray electrons from the ionization source impinging on the negative ion segment.
- An electron source was subsequently activated and the negative ion segment produced a proportional increase in signal current while the positive ion segment showed little increase over the dark current.
- The signal current could be varied by independently varying the gain on each segment.
- The ceramic housing was ultimately replaced by a metal one to eliminate the possibility of charging from stray charged particles.

Simultaneous Positive and Negative Detector Collecting Positive Ions.

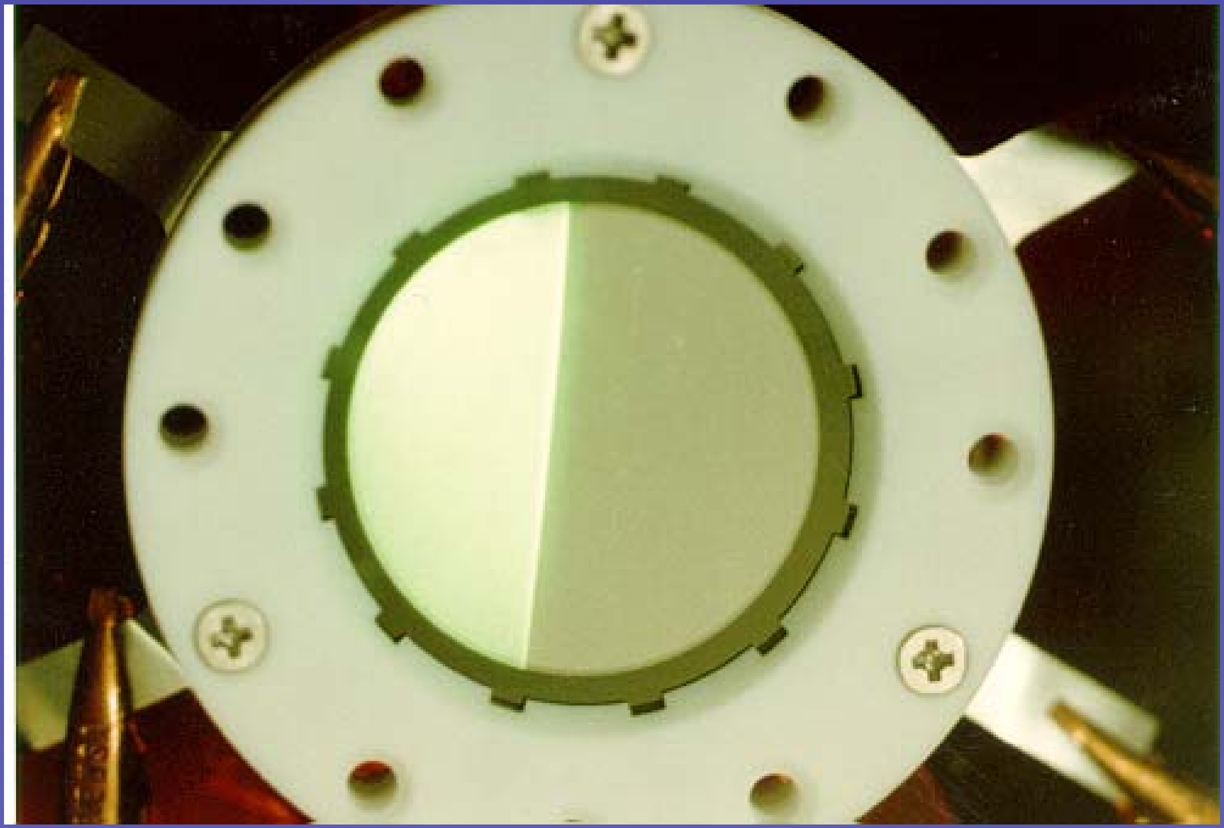

Figure 9

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Conclusions

- A segmented microchannel plate has been successfully demonstrated to detect both positively and negatively charged particles.
- Independent gain modulation of each segment was demonstrated.
- The detector could be operated in both the analog (current) and ion counting modes.
- Conversion to a metal housing eliminated charging from misdirected charged particles.
- Microchannel Plate segmentation can be used in array applications in place of multiple point detectors.
- US Patent #4988867 has been granted to this technology.

Future Work

- The detector performance will be characterized with an ion source which produces both positive and negative ions.