Development of a 2-inch Square, Position Sensing, Photomultiplier Tube (PMT) For Medical Applications

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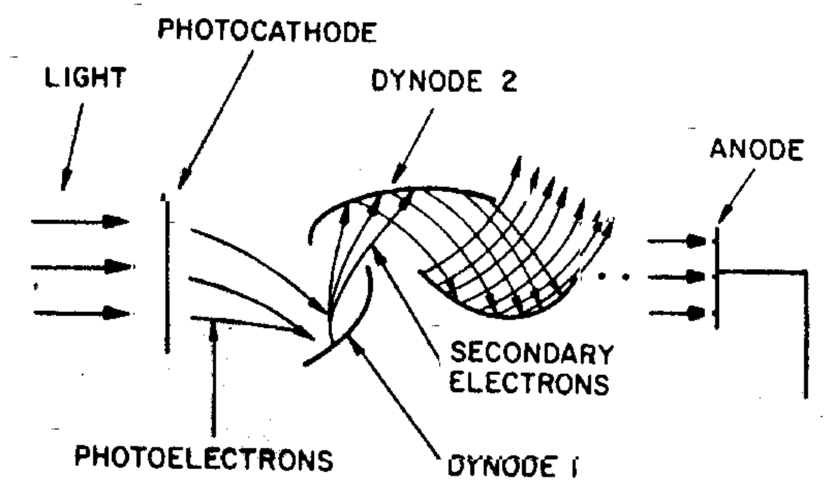
Introduction

- Photomultiplier Tubes are very sensitive detectors of radiant energy in the ultra-violet, visible and near infra-red regions of the electromagnetic spectrum.
- A photomultiplier tube (PMT) typically consists of an evacuated envelope, a dynode chain, and a photocathode.
- PMTs are manufactured in a wide variety of active diameters ranging from 25 - 120 mms, and are almost always made of glass envelops.

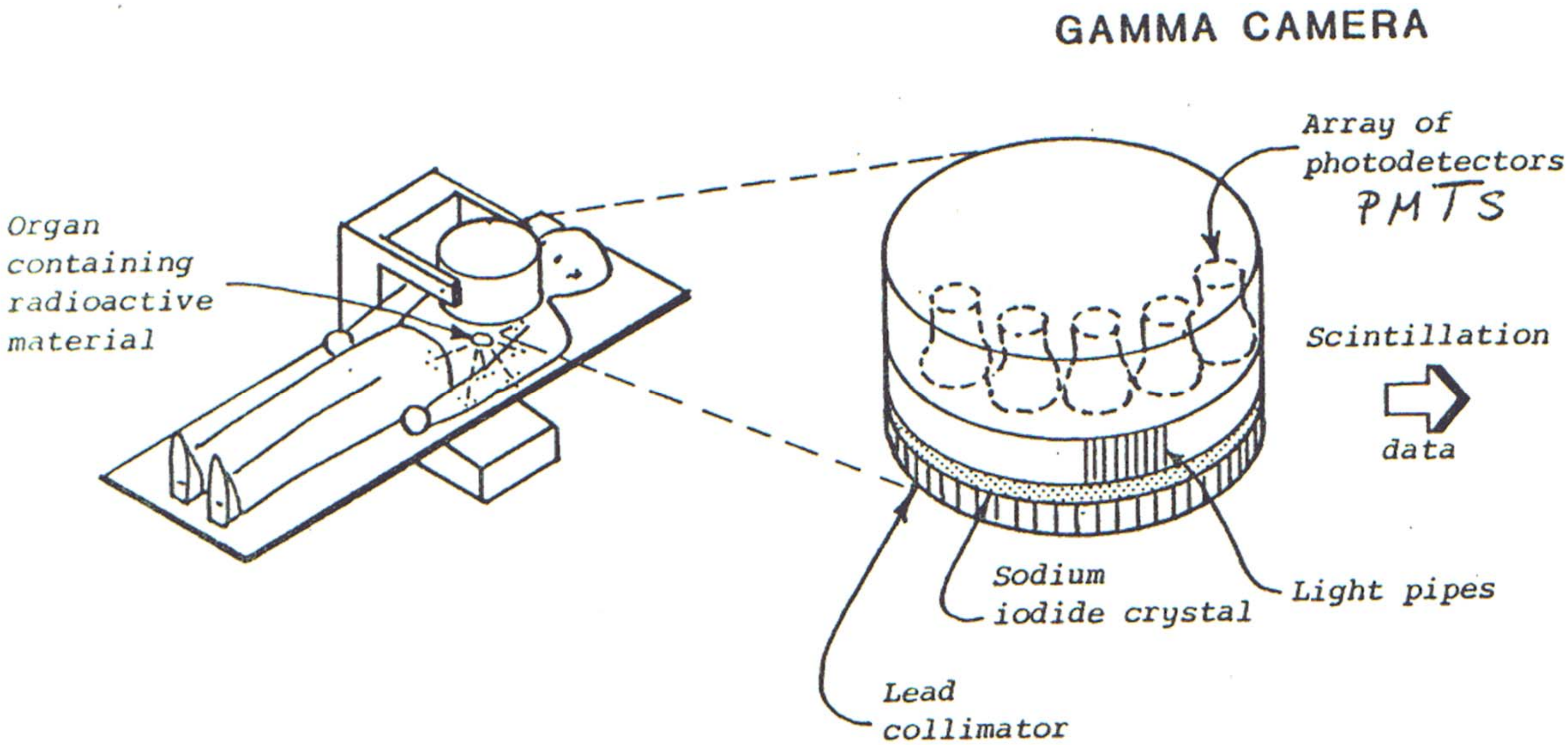
Operation



•In operation, the weak optical signal presented to the photocathode caused photoelectrons to be generated. The photoelectrons are next accelerated to the first dynode where, upon collision with the surface, liberate secondary electrons. The resultant secondary electrons are subsequently accelerated to the next dynode, and upon collision, generate additional secondary electrons. The sum charge of all the secondary electrons is collected by a metal anode.

Laprade Finger Taken With Direct X-Ray Conversion On MCP

Gamma Camera Application



In this application, the patient is administered (injection, inhalation or ingestion) radioactive material (most often technetium, thallium, gallium or iodine) which is drawn to the organ of interest. Weak gamma ray emissions produce scintillations in the sodium iodide crystal, which are then detected by the photomultiplier tubes. A computer then creates an image from the position and intensity information from the PMTs.

* Illustration from Drew Consultants, Inc

Positron Emission Tomography

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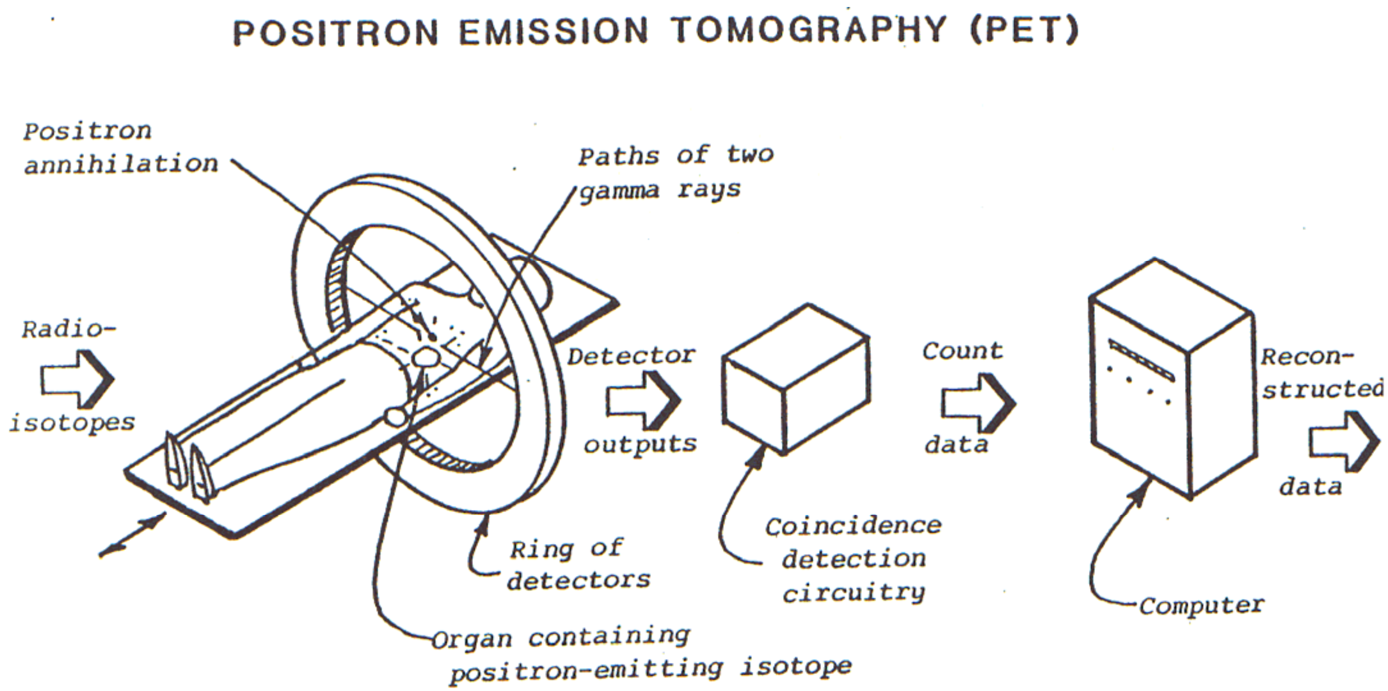

Radionuclides (carbon, oxygen, nitrogen, and fluorine) that emit positrons are administered to the patient. When an emitted positron encounters an electron, two gamma rays are generated traveling away from each other at 180 degrees. When two PMTs detect an event simultaneously (in coincidence) the path can be traced back to the point of origin. Only events which occur in coincidence are considered true events. Producing events with only true events, produced higher quality images.

* Illustration from Drew Consultants, Inc

Objectives

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•Develop a large active area, photomultiplier tube with position sensing capability.

•The device should be of a configuration suitable for assembly into large arrays with a high fill factor.

•The device needs to have single photon sensitivity.

•The detector must have high gain (> 1 million) and a narrow Pulse Height Distribution (PHD).

•The photomultiplier must be contained in a low profile, light weight package.

Experimental Approach

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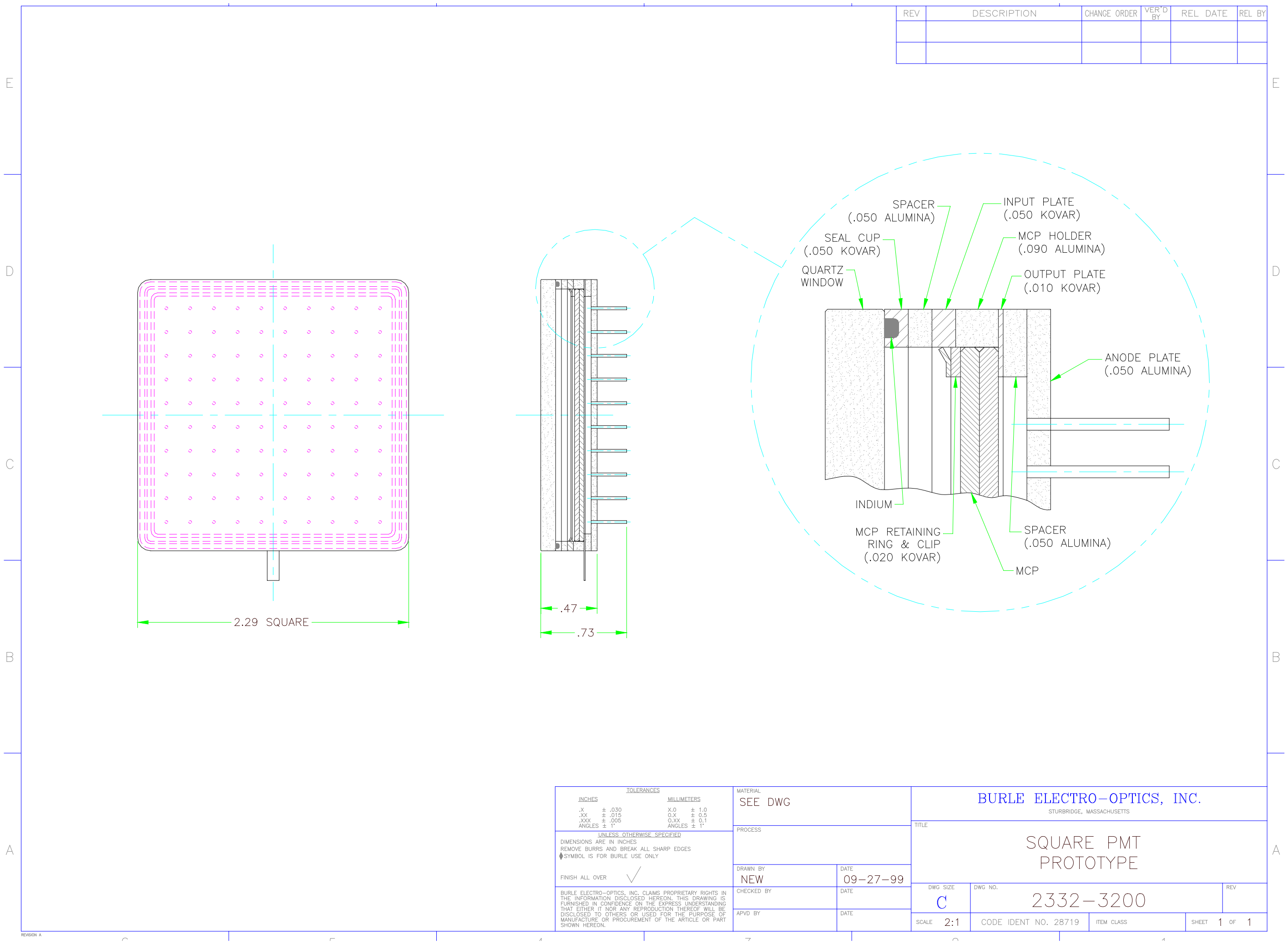
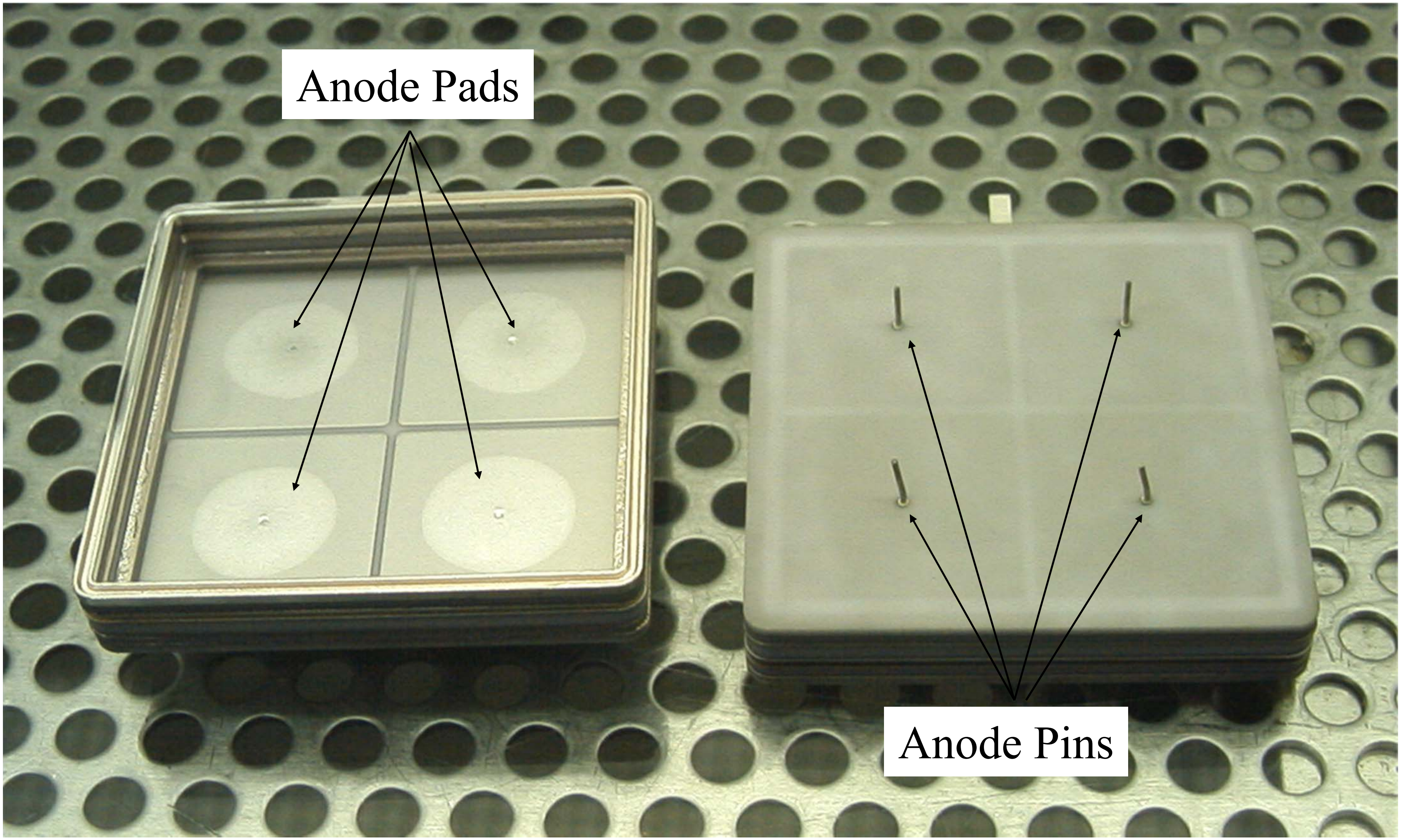
- **Configuration:** Two inch square active area.
- **Tube Body:** Brazed ceramic/Kovar flange design
- **Readout:** Metal Multi Anode 2 X 2
- **Electron Multiplier:** 2.1” square Long Life, Extended Dynamic Range (EDR) microchannel Plate Chevron
- **Cathode Substrate:** Quartz
- **Window Seal:** Indium following internal transfer.

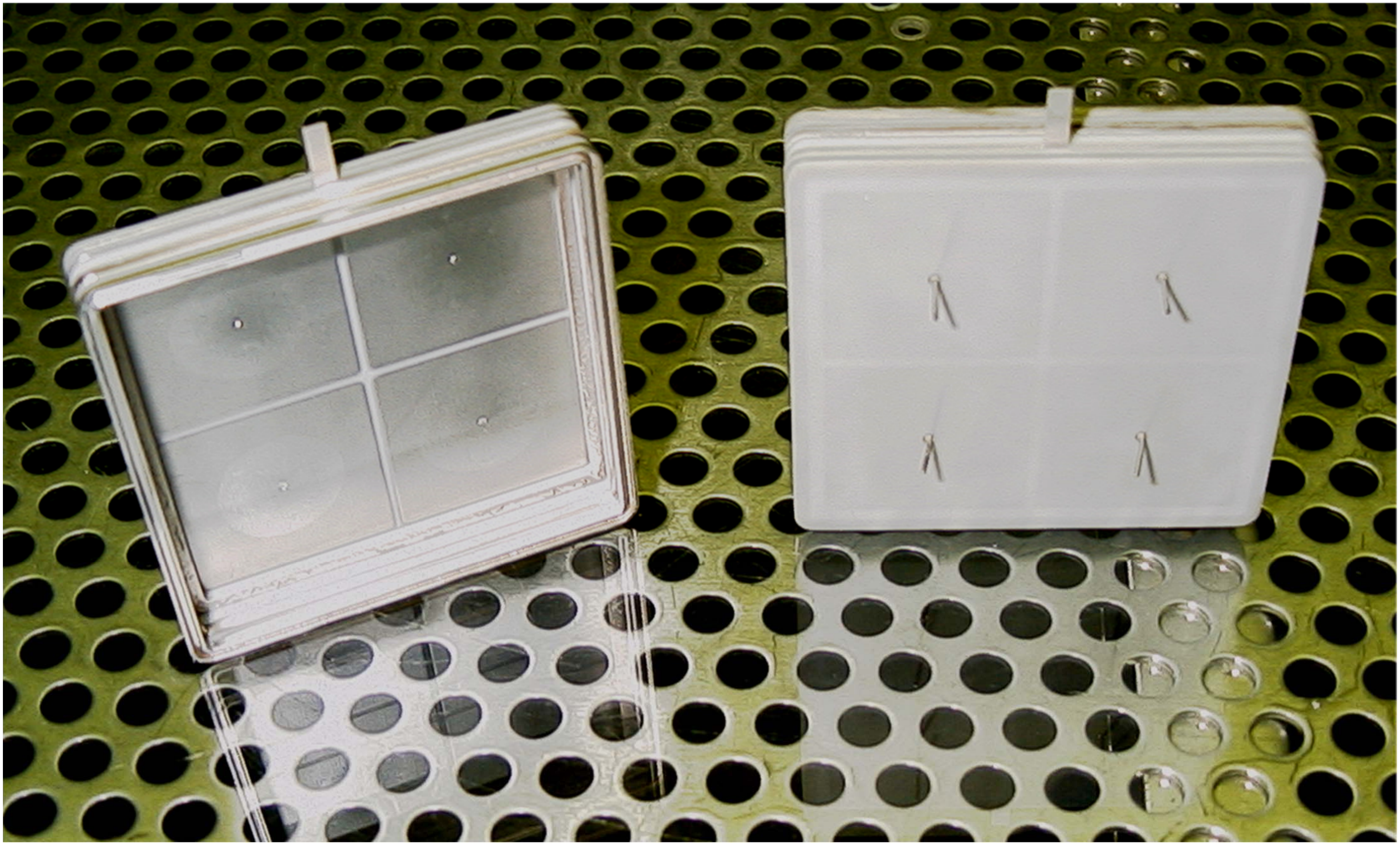
Proposed 2 Inch Square, Position Sensing PMT



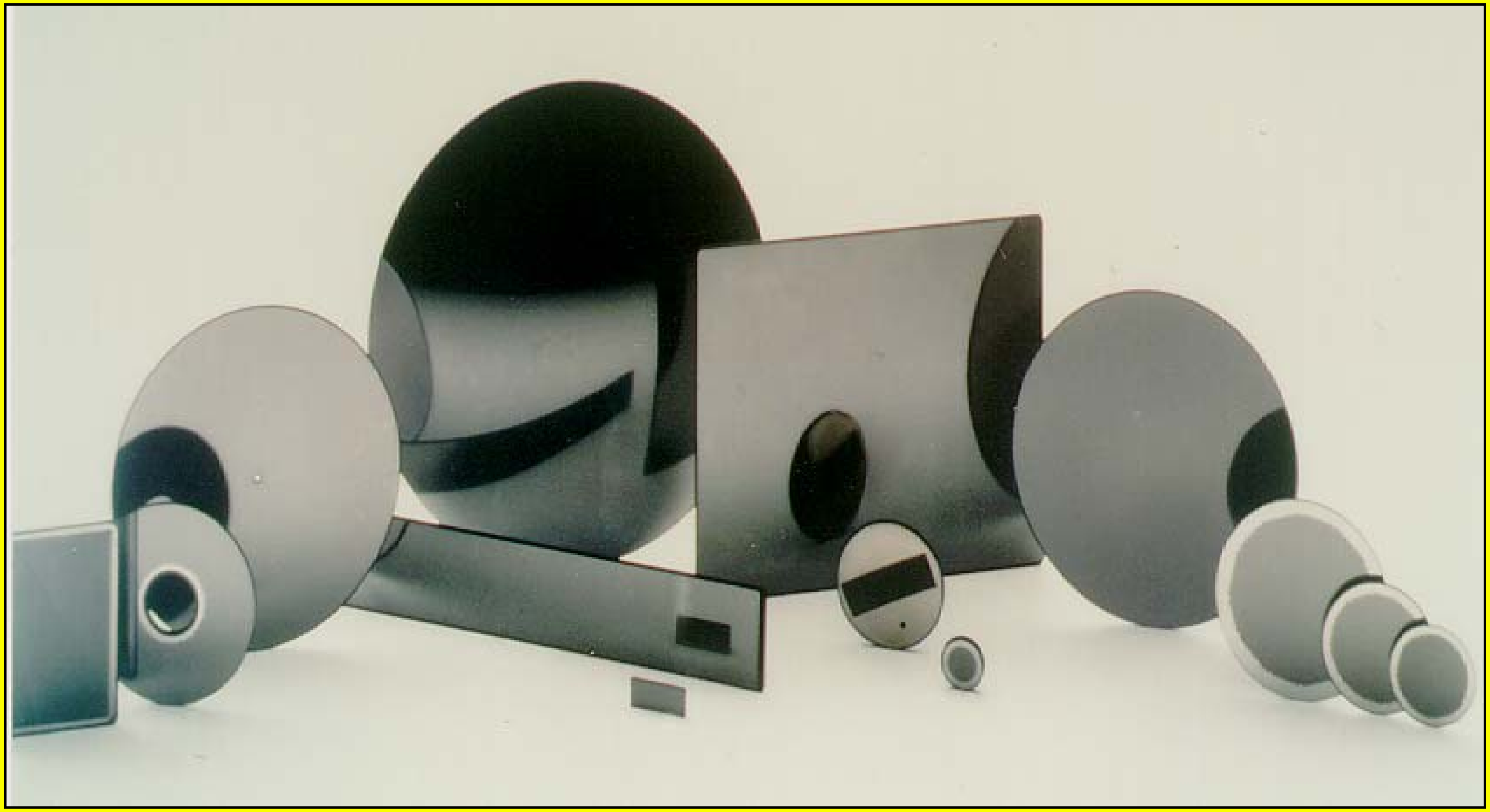
Tube Body



Tube Body



Burle Currently Produces MCPs in Sizes Ranging from 5 to 150mm



Microchannel Plate Factors

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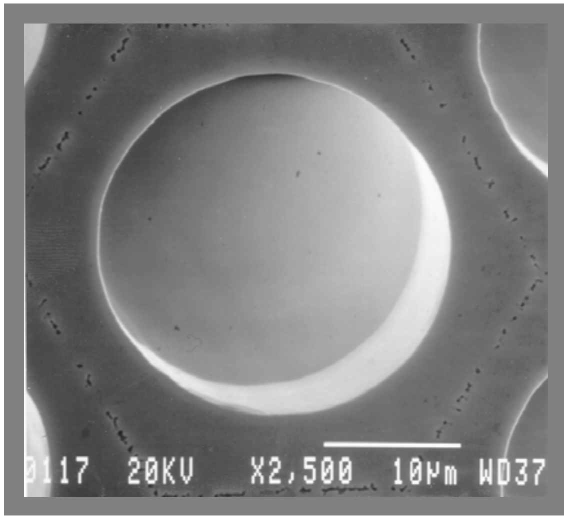
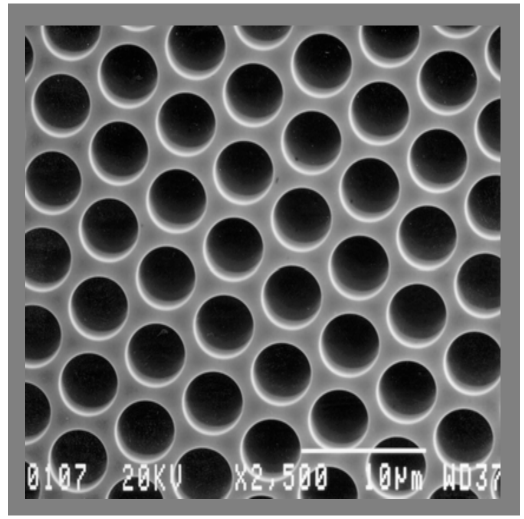
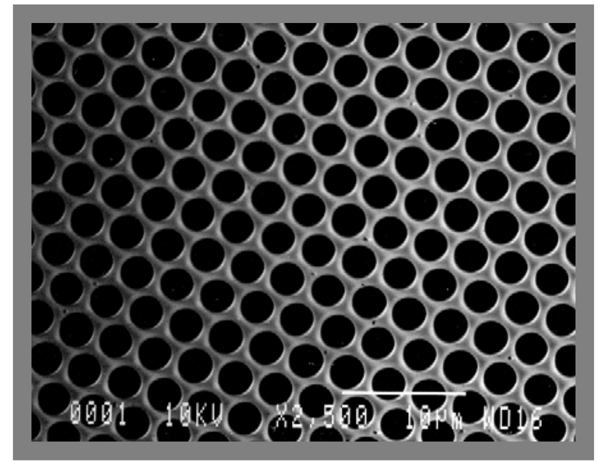


25 micron pore



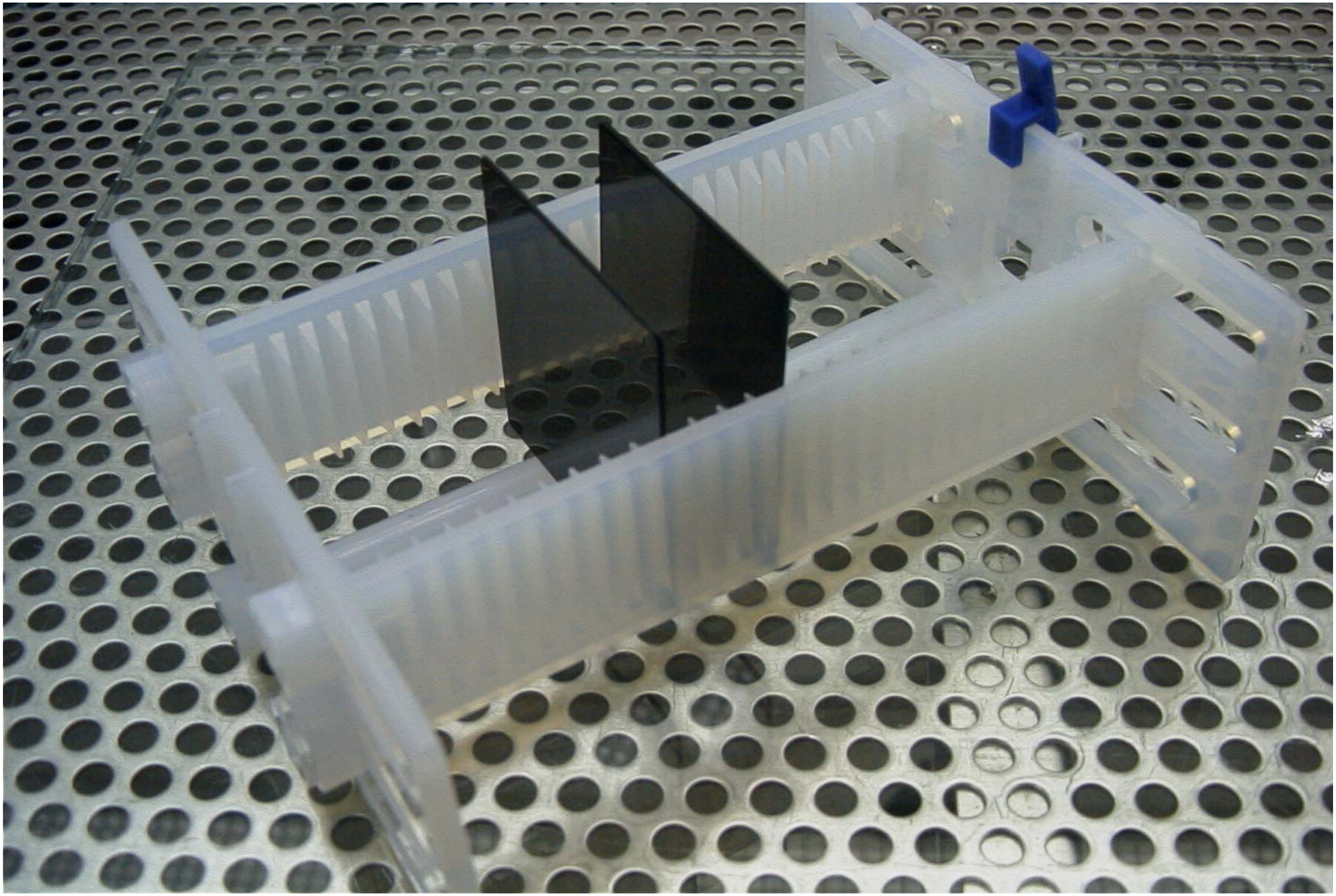
5 micron pore



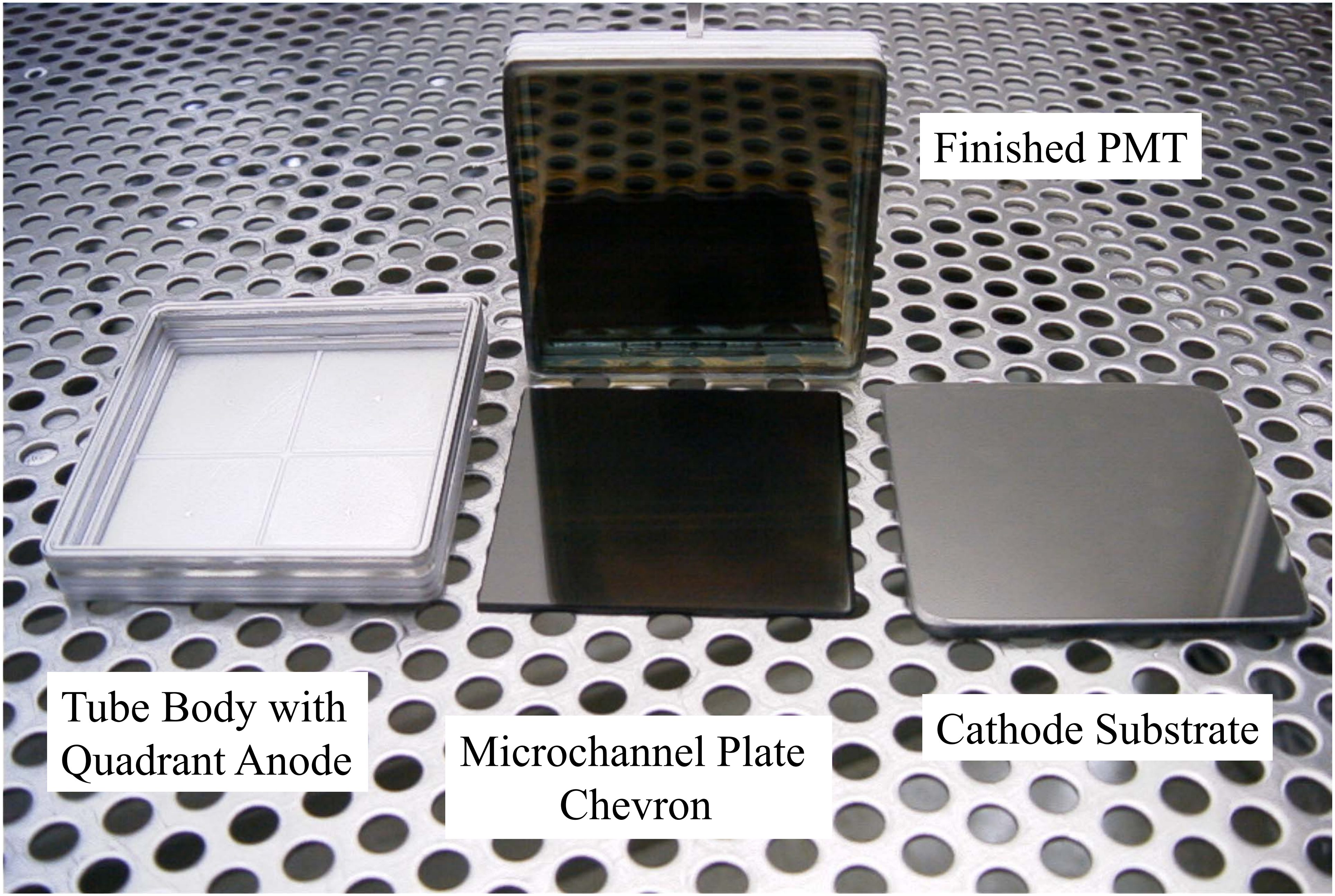
2 micron pore

Factor	25 micron pore	5 micron pore	2 micron pore
Pulse Width	10 ns	650 ps	250 ps
Gain	10 million	5 million	2 million
Max. Ct. Rate	5 million/cm2	50 million/cm2	100 million/cm2
Noise	5 cts./cm2	5 cts./cm2	5cts./cm2
Robustness	High	Medium	Medium
Cost	Low	Medium	High

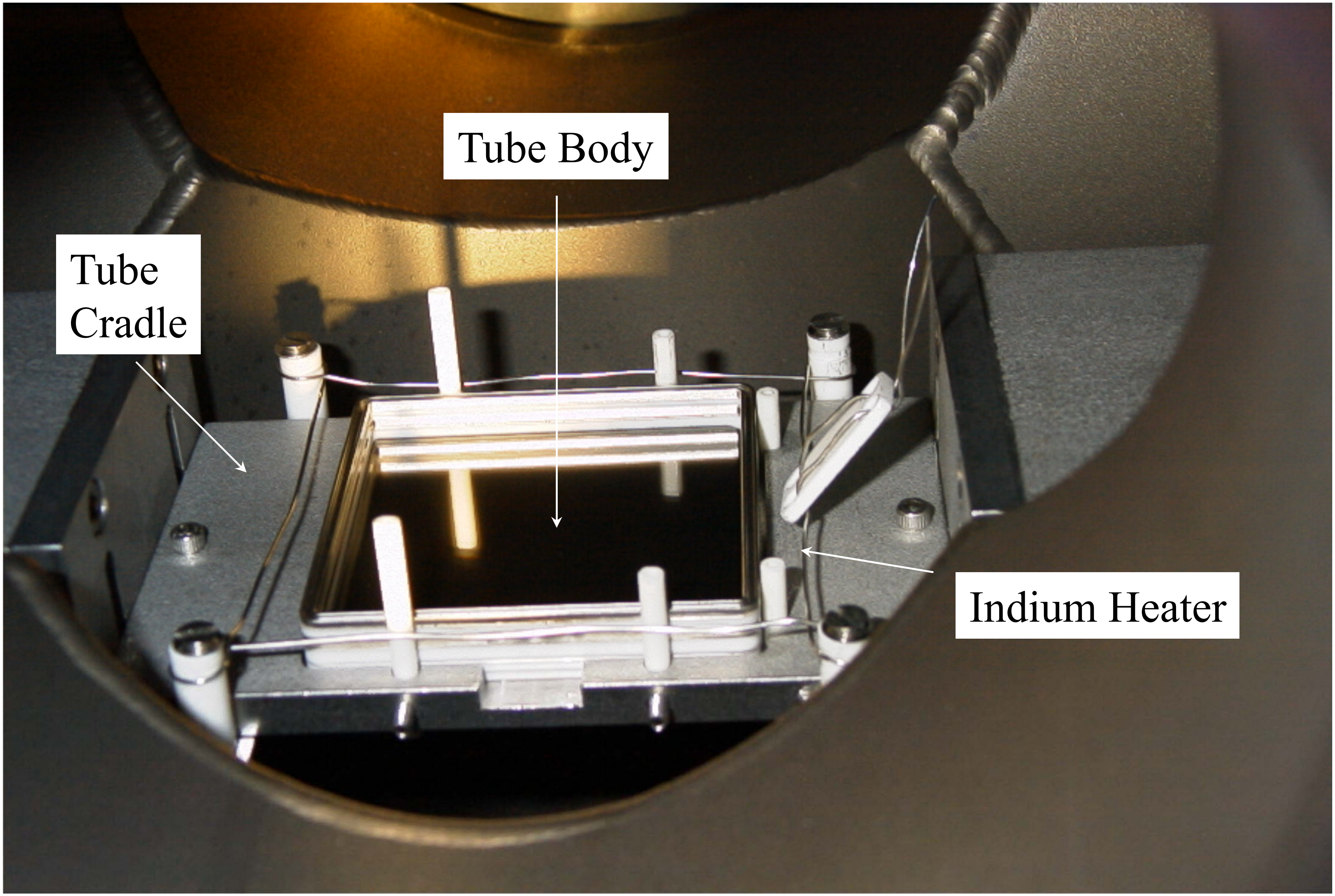
Microchannel Plates



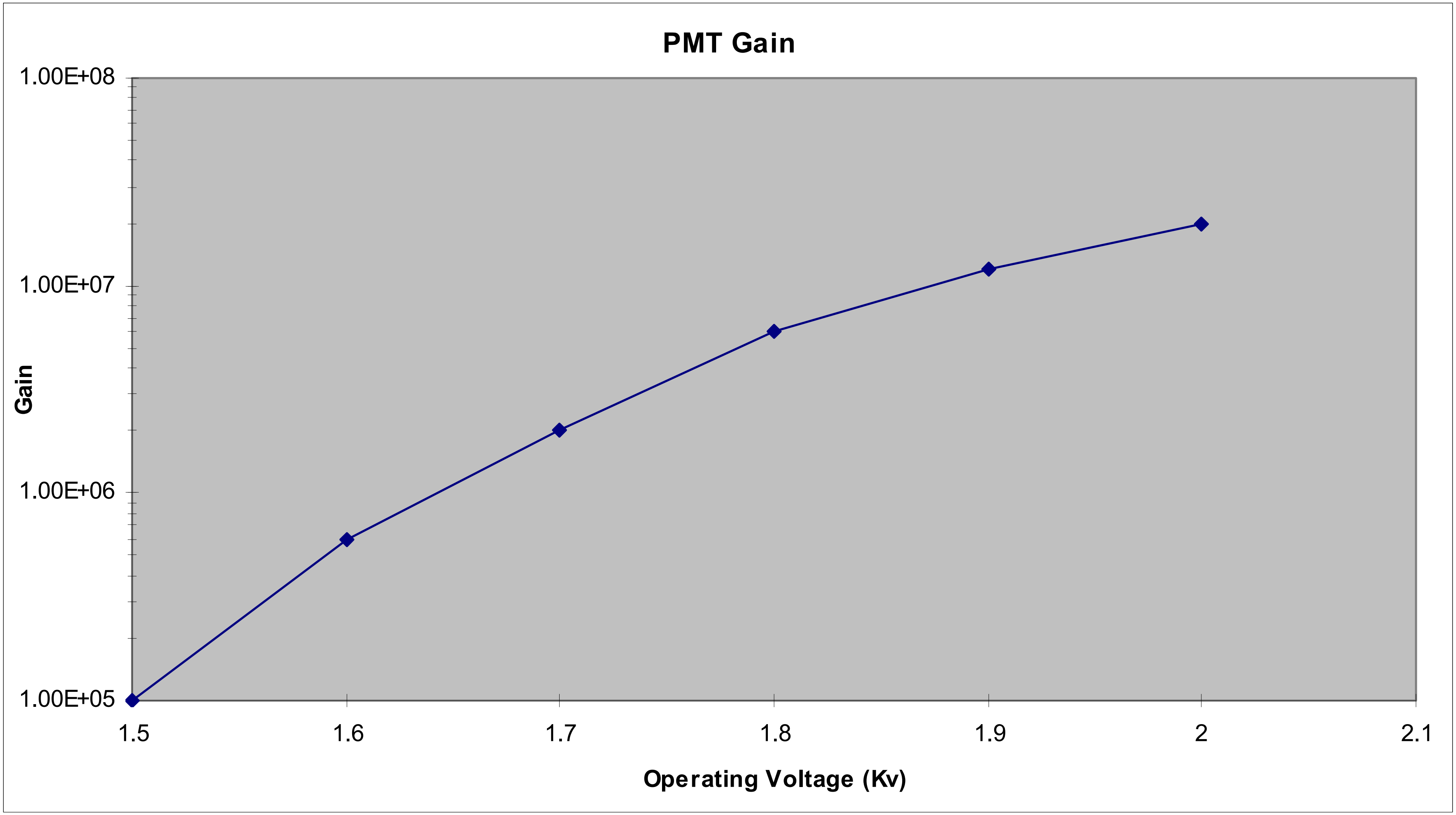
2 Inch Square MCP PMT



Tube Assembly in Process Station



Results - Gain



Results - Pulse Height Resolution

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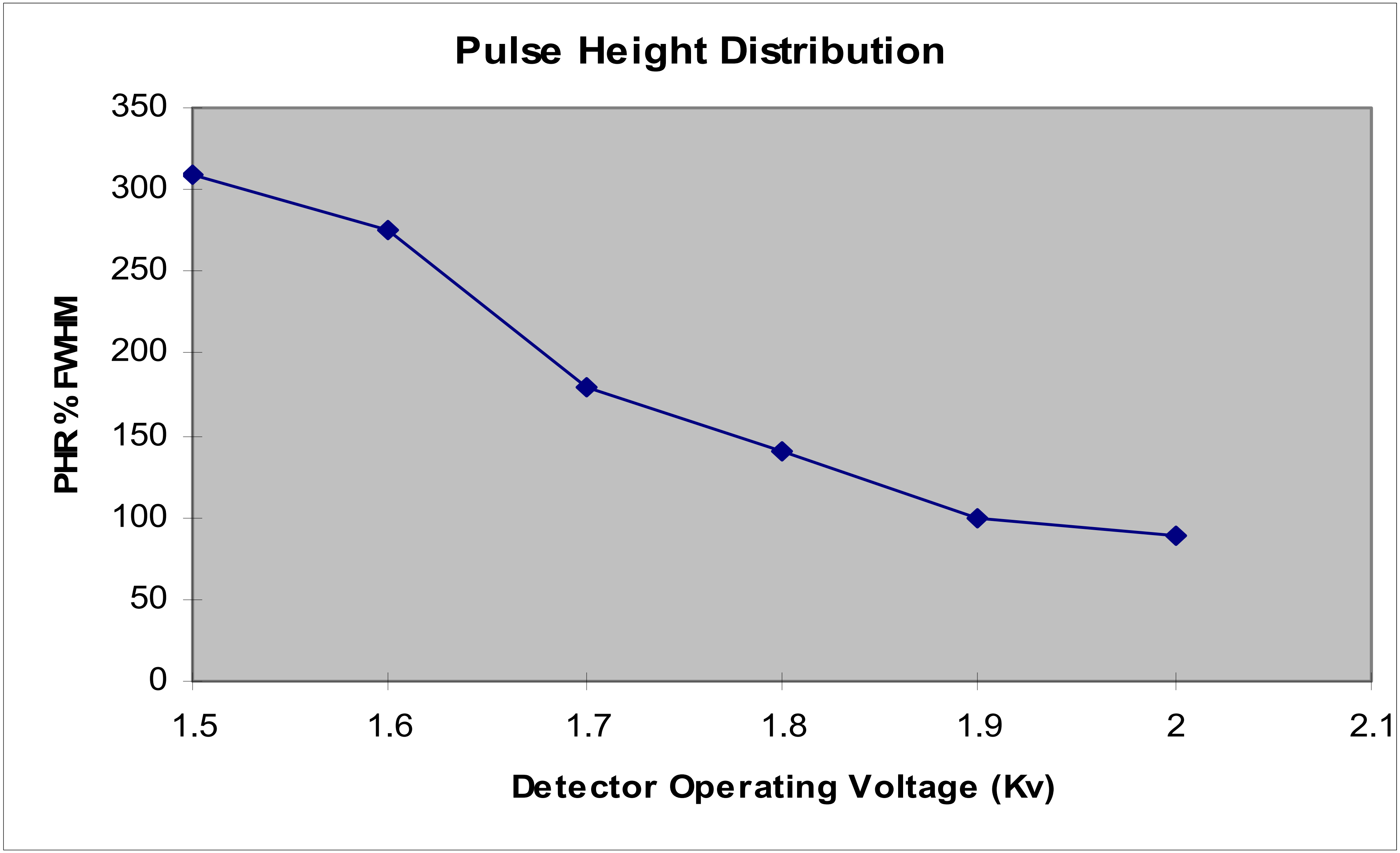

Results - Noise

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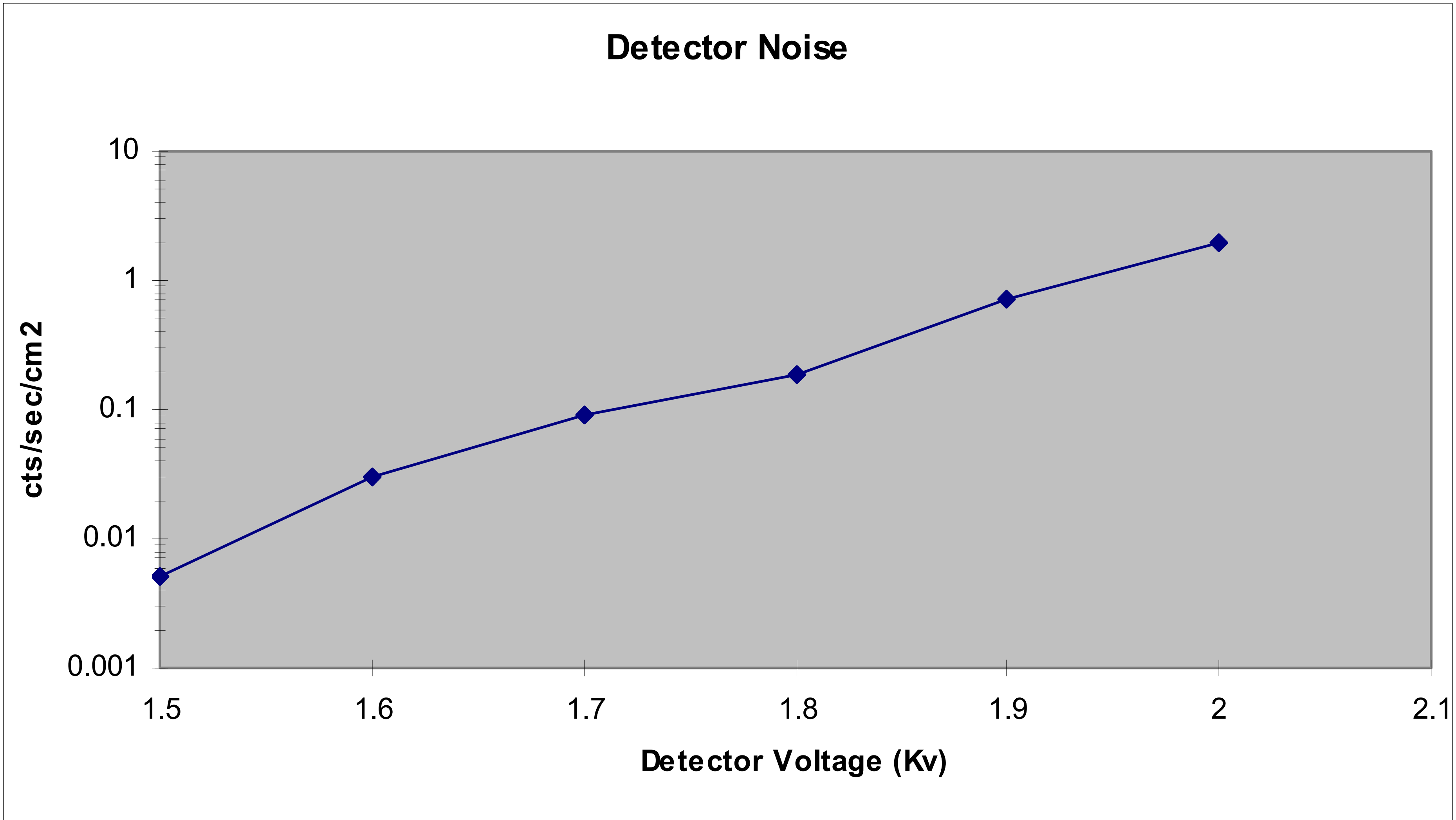

Summary

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Mechanical

- Overall Height - less than 0.5”
- Active dimensions 2” X 2”
- Mechanical Envelop - 2.3” X 2.3”
- Weight - 2.5 oz.

Electro-Optical

- Single Photon Sensitivity
- Large collection area
- Position sensing (Quadrant)
- Gain - up to 20 Million
- PHR - less than 100% FWHM
- Noise - Less than 5 cts/sec/cm2

Future Work

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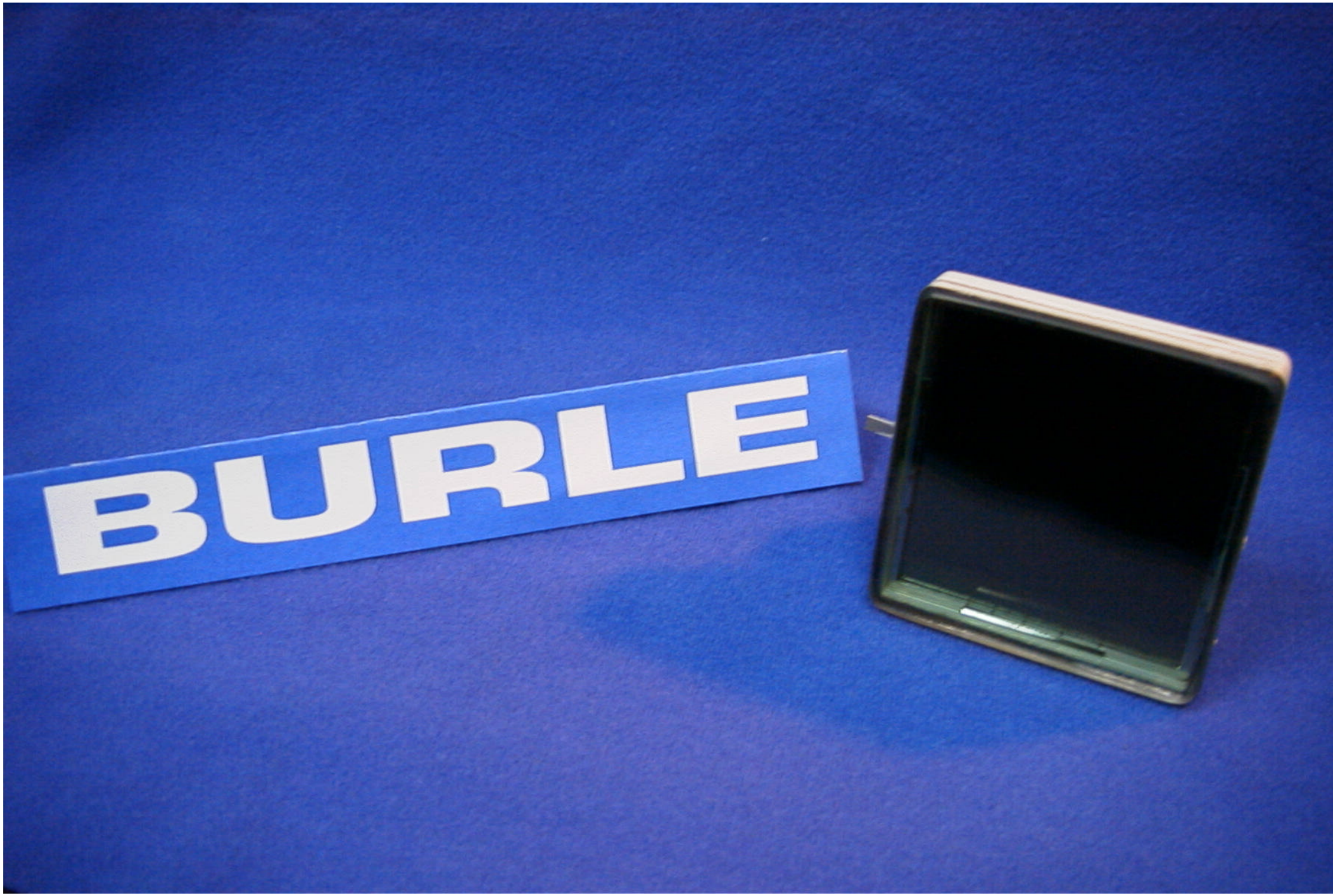
- Develop a bi-alkalie cathode model for visible light applications.
- Develop an all axial lead model
- Introduce additional anode pixel models 4 X 4, …10 X 10.
- Mass production - low cost manufacturing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