# The Current State of the Art in Large-Format Microchannel Plate Detectors for Ultraviolet Astronomy

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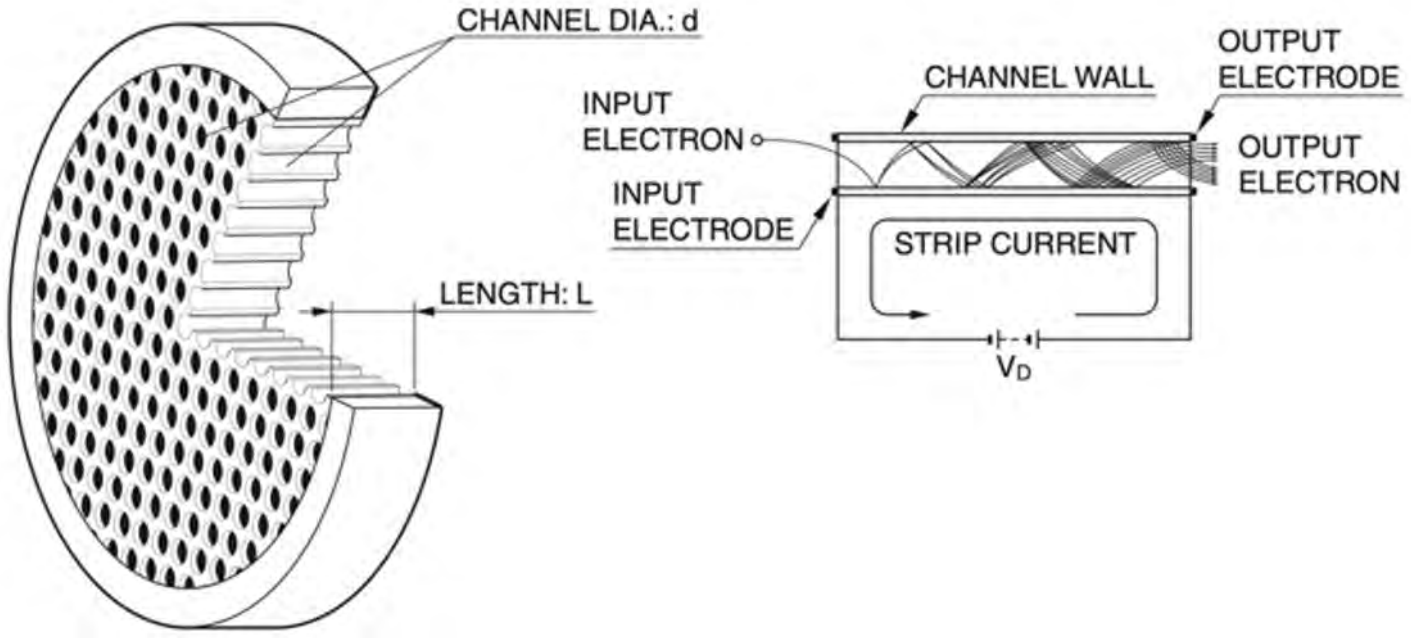
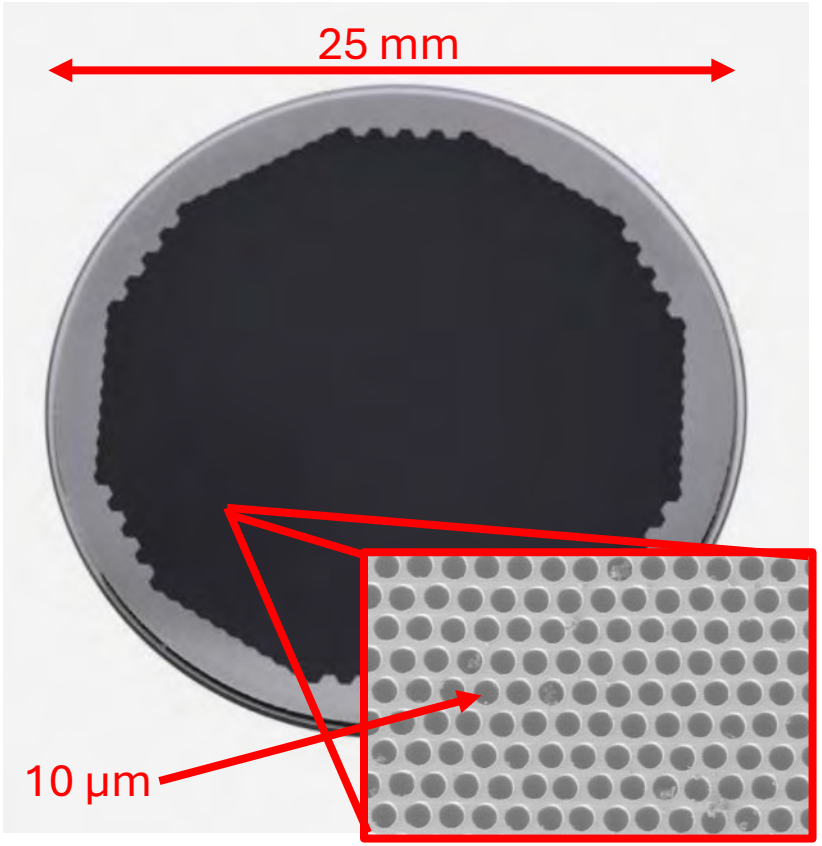
# Microchannel Plates




Hamamatsu Photonics K. K. Photomultiplier Tubes: Basics and Applications (2017)




In MCPs, the channels act as discrete electron multipliers, providing fine spatial resolution due to the smaller dimensions of the channels.

# Microchannel Plate Photodetector

Photocathode converts a photon to electron

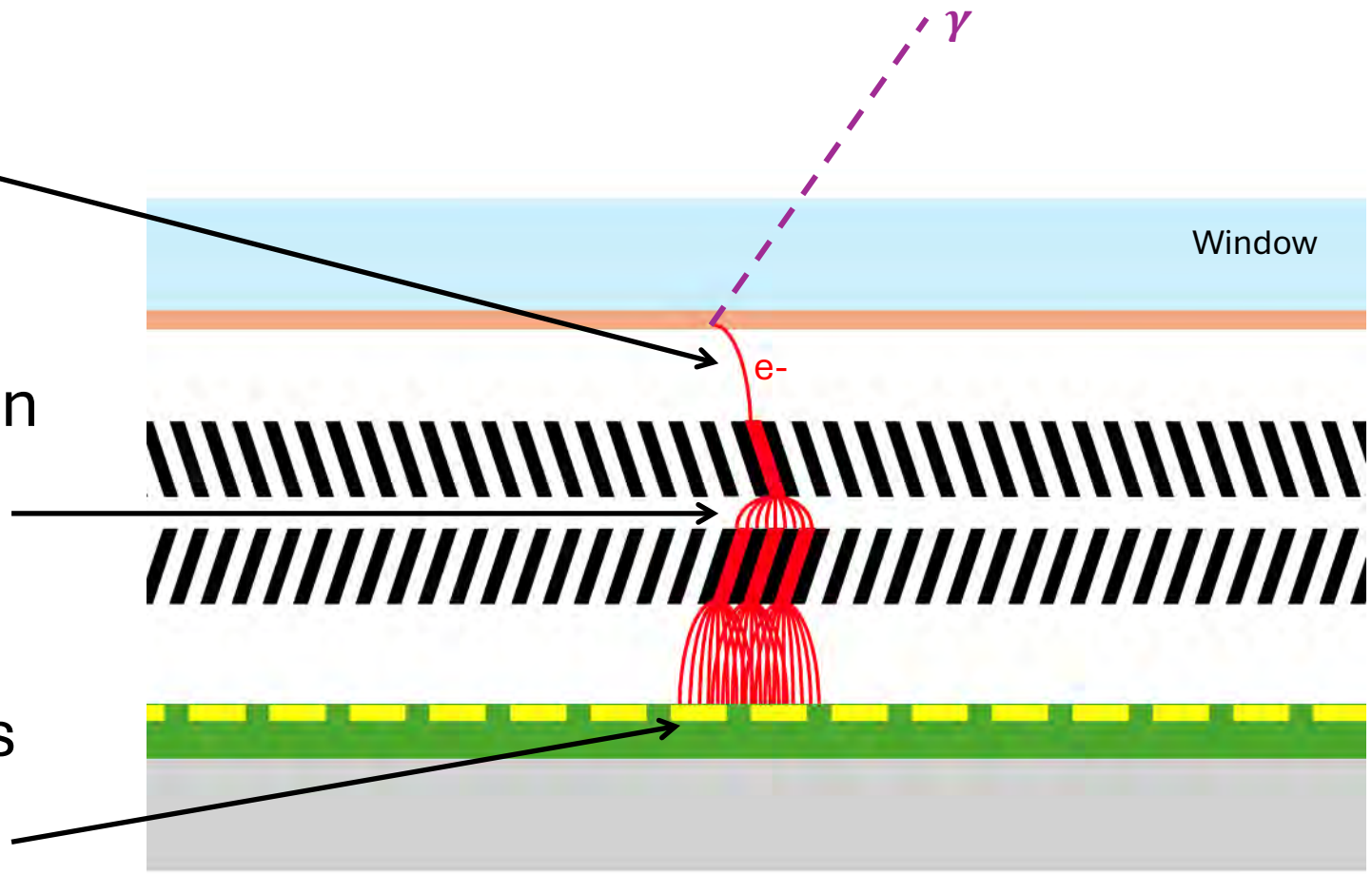
– Alkali halides, Multialkali, GaAs, GaN

MCP(s) amplify the electron by $10^4$ to $10^7$

– Conventional or nanofabricated MCP

Patterned anode measures charge centroid

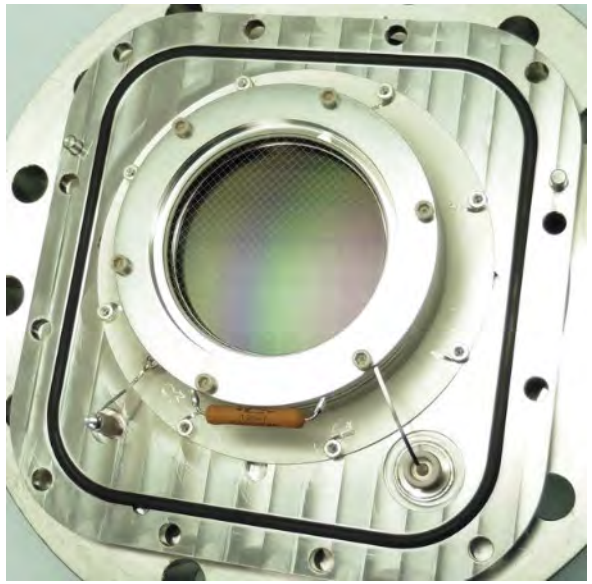
– Cross strip, Cross delayline, ASIC (Medipix or Timepix), Phosphor.



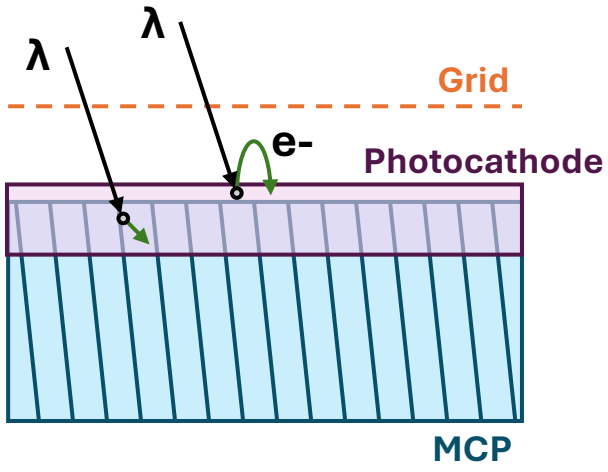
# Detector Configurations

## “Open Face” Detectors

Siegmund (2016)

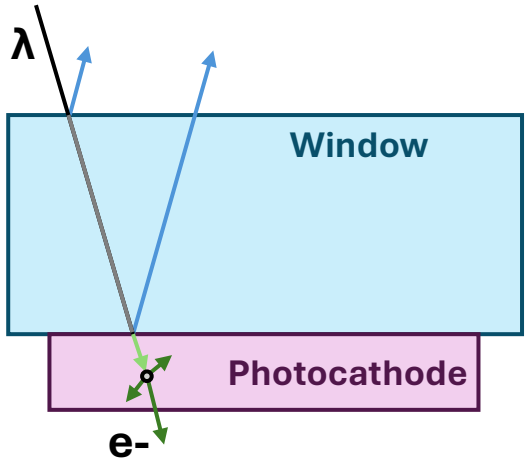


GOLD – 40 mm cross delay line detector with a CsI Photocathode




**Reflection (opaque mode)**

## Sealed Tube Detectors



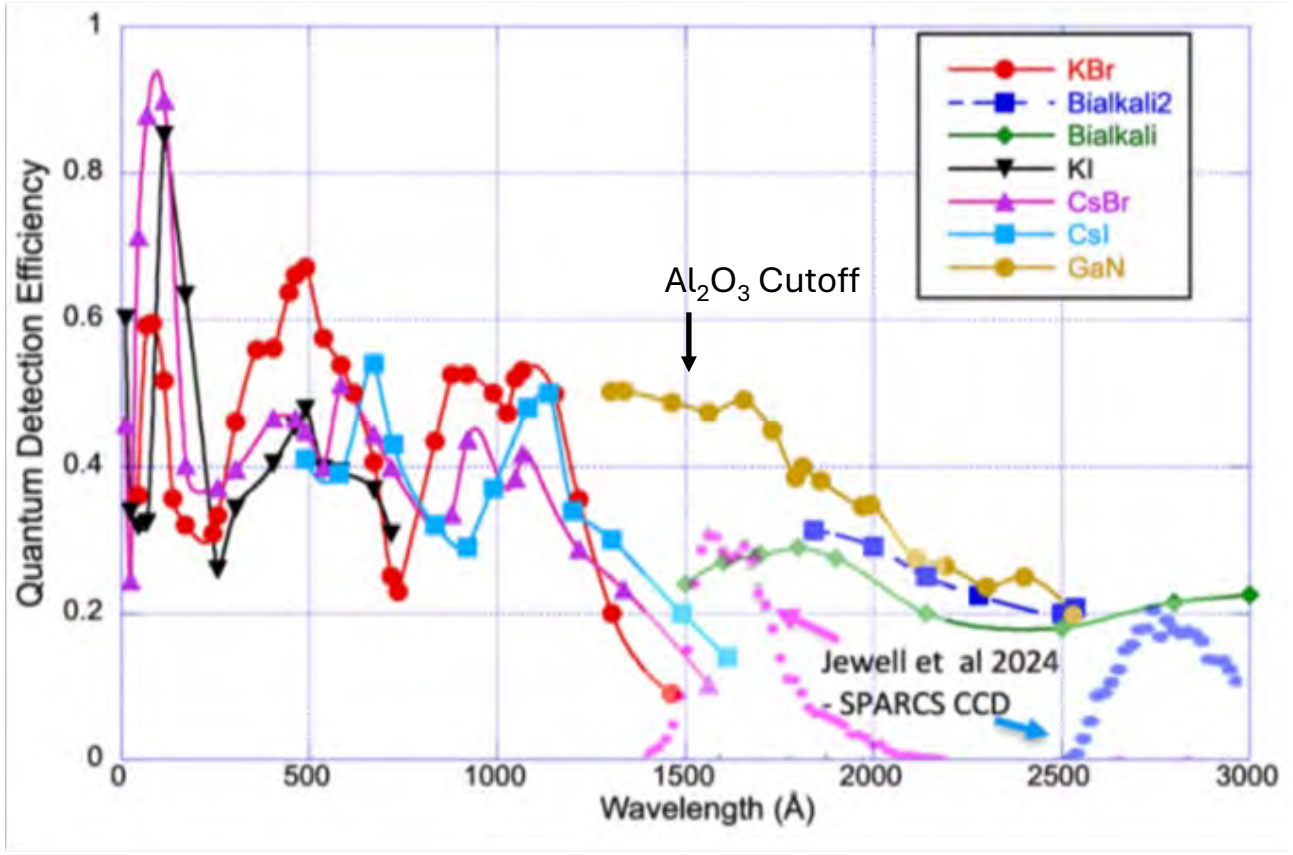

**Transmission (semitransparent mode)**

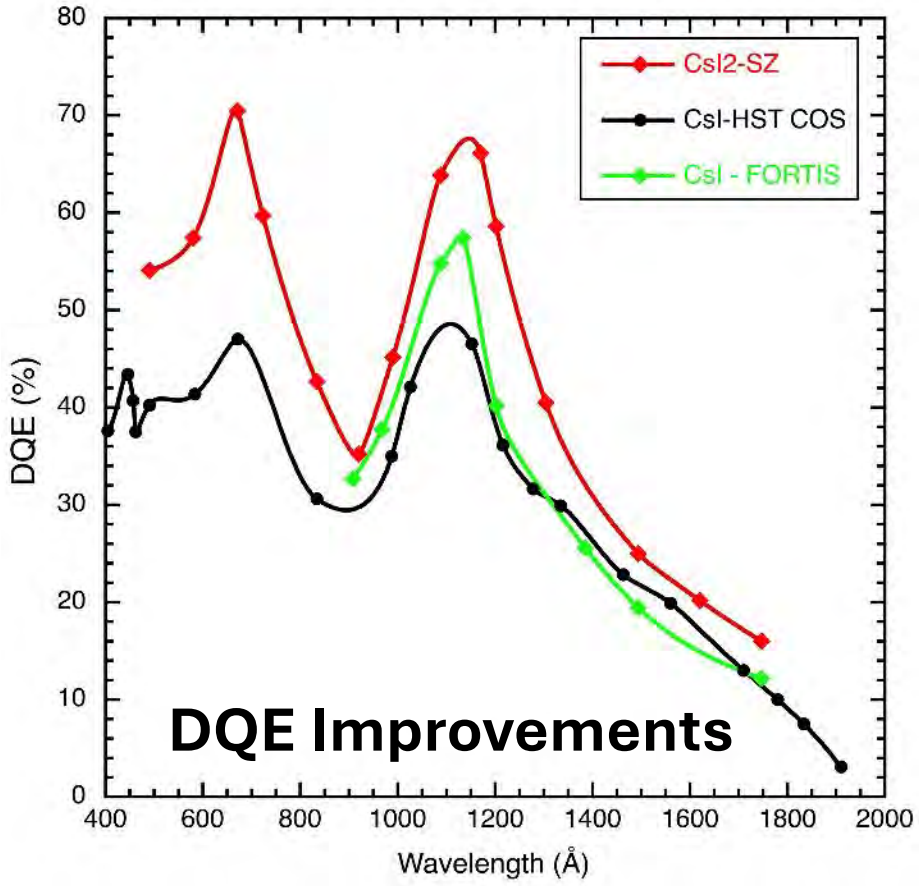
Jelinsky (2003)

GALEX – 65 mm cross delay line detector with $Cs_2Te$ on a $SiO_2$ window.

# Photocathode Materials

## Typical DQE Achievements




- HST COS is historical best case conventional MCP.
- FORTIS 20 µm borosilicate ALD 60:1.
- SZ is optimized for multiple performance parameters.

# Substrate Materials

## Borosilicate Glass

Best block with standard draw process

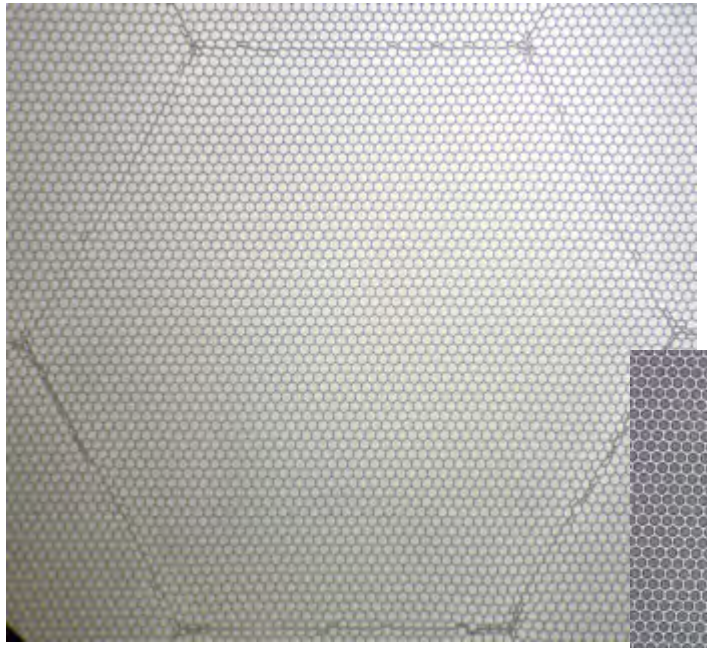


Photo of 20 µm pore, 73% open area, 60:1 L/d, C14 micro-capillary array.

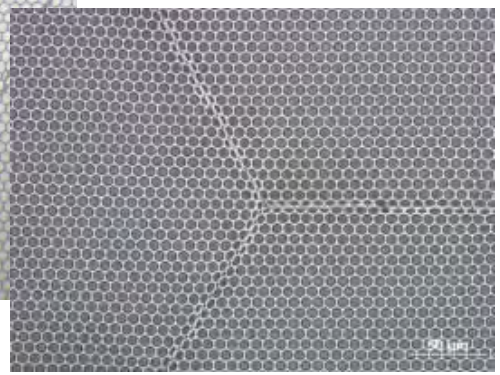
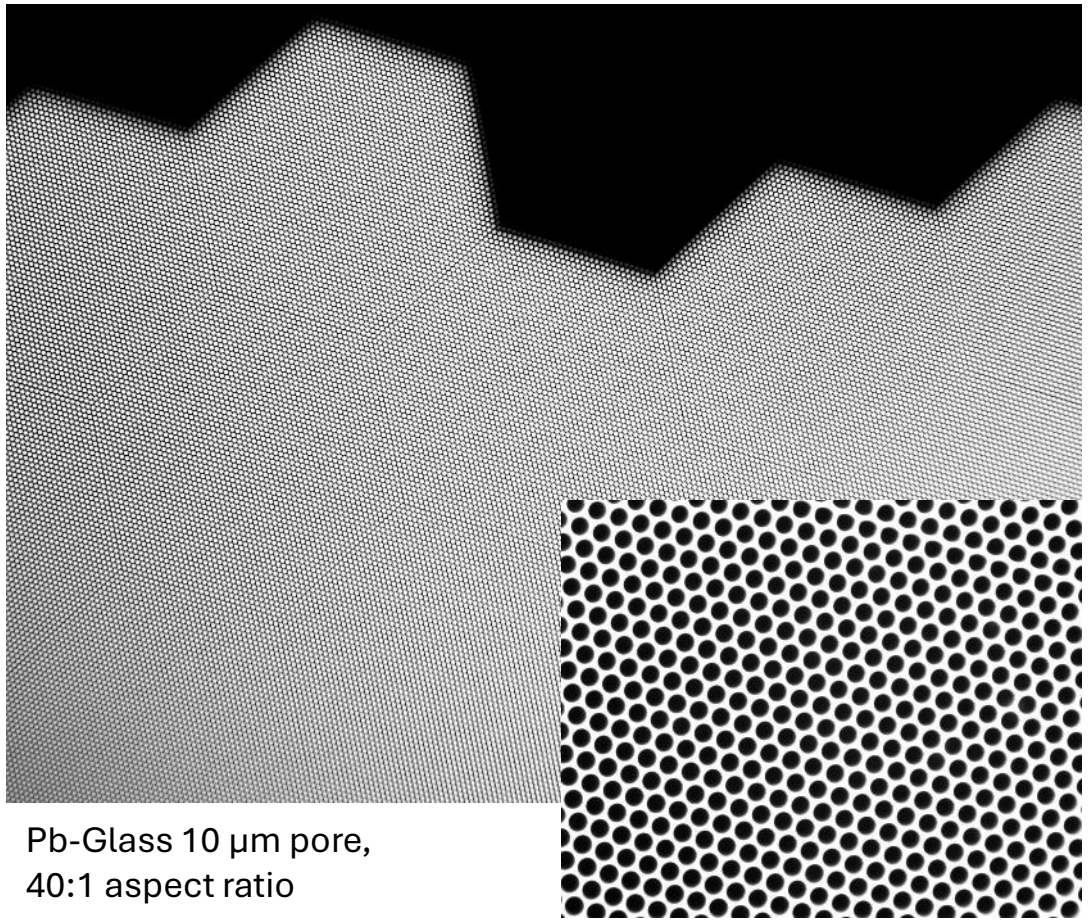


Photo of 6 µm pore, 63% open area, 60:1 L/d, C5 micro-capillary arrays.

## Pb-Silicate Glass

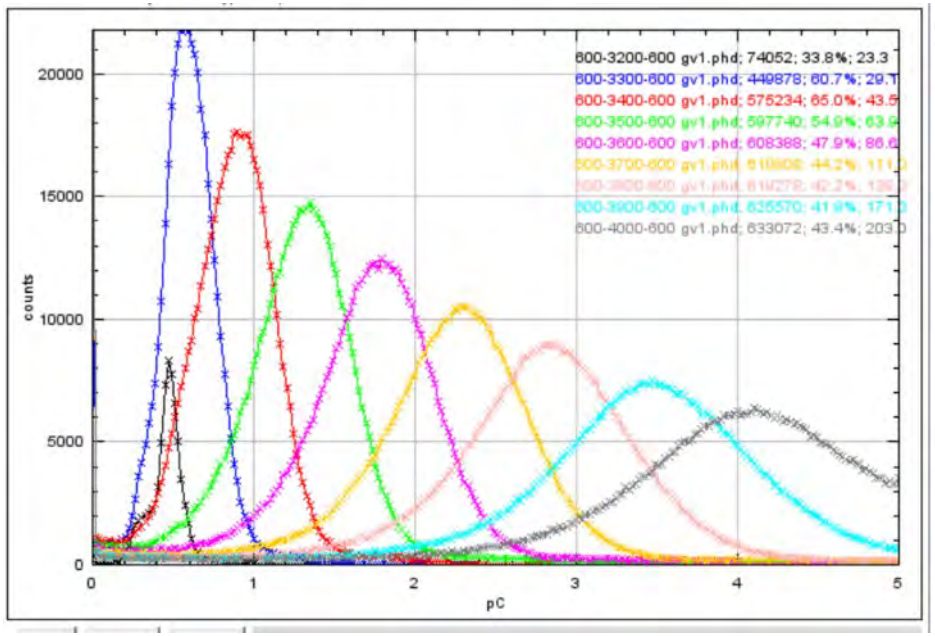


Pb-Glass 10 µm pore, 40:1 aspect ratio

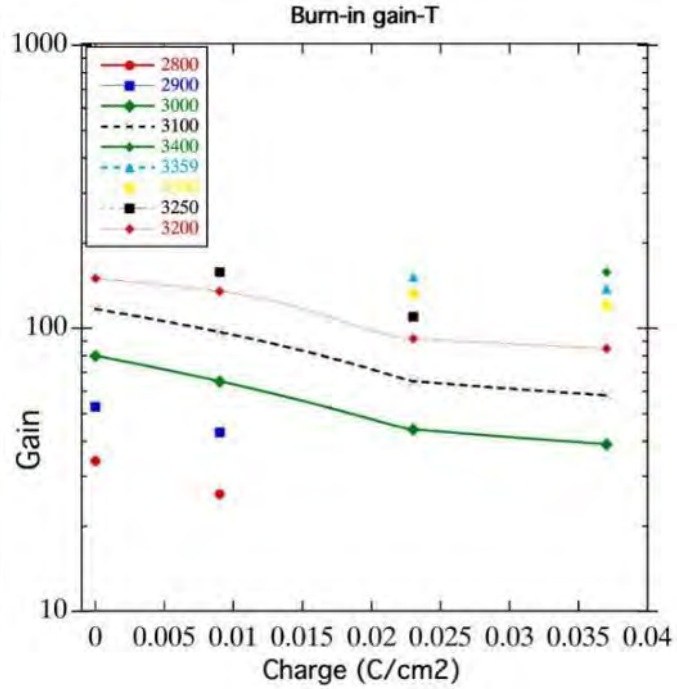
# Gain, PHD and Gain Stability

Pulse-height distributions measured under UV illumination for SZ 10µm, 40:1, 33mm x3 MCPs.

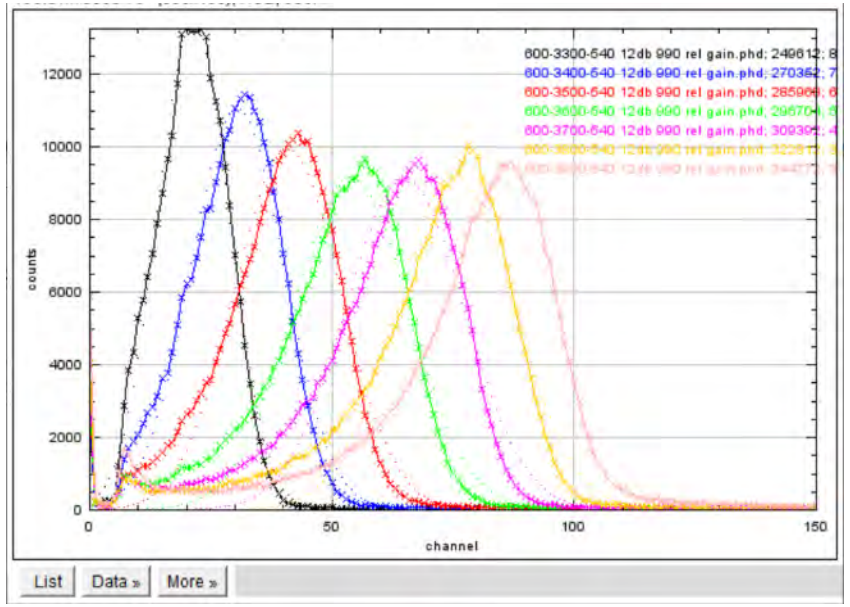
Narrow PHD ideal for photon counting and optimal resolution.




Gain versus extracted charge for multiple stack biases. The charge levels corresponding to the 24 hr, 48 hr, and 72 hr scrub intervals. For SZ 10µm, 40:1, 33mm x3 MCPs

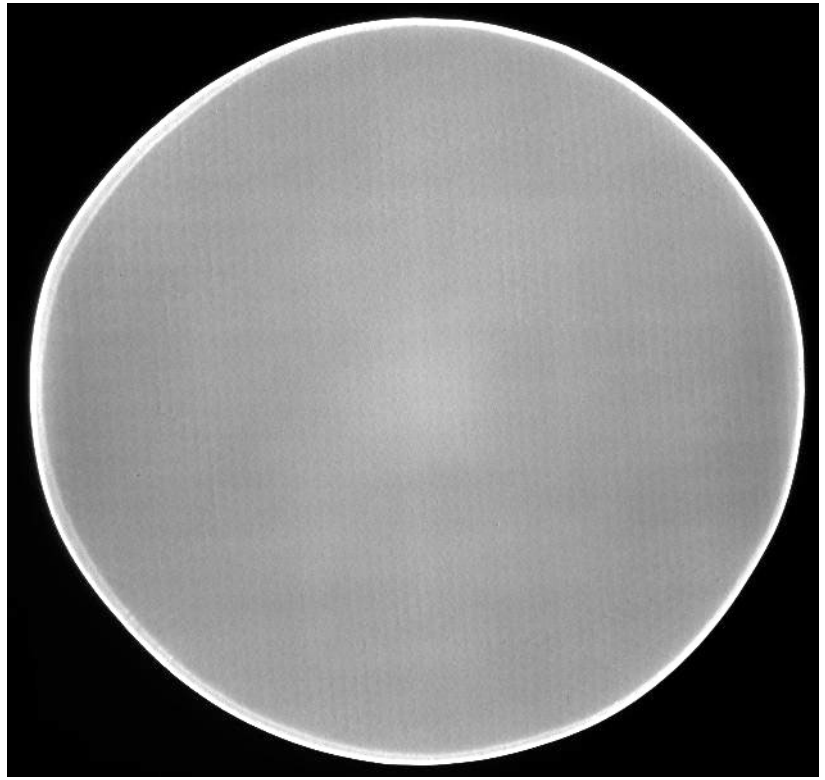



Pulse-height distributions measured under UV illumination for INCOM 10 µm, 60:1, 50 mm x3 MCPs.

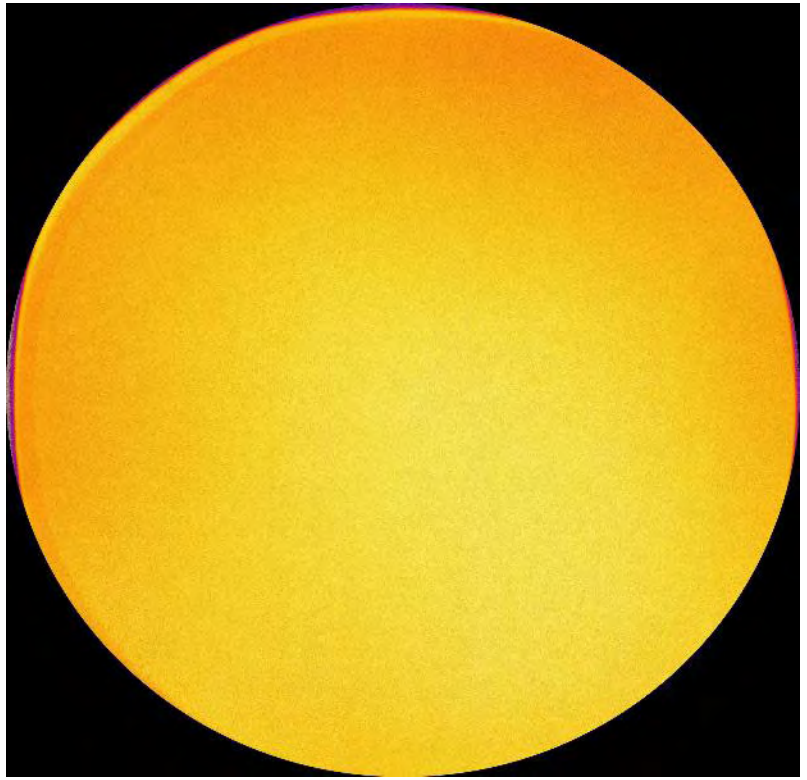


# Advanced Pb-Glass – Imaging Performance

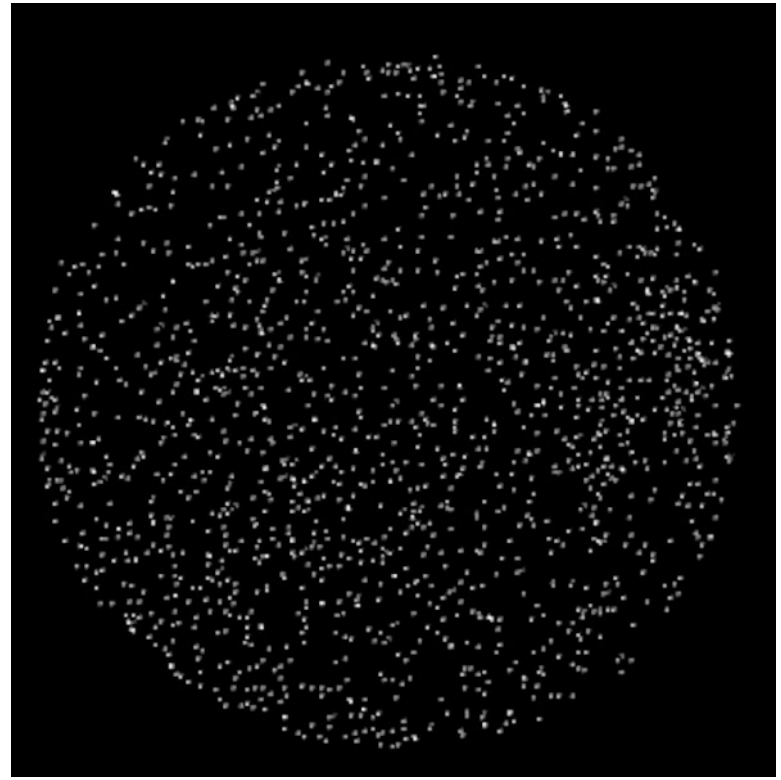
Accumulated single-photon event image. ~100 counts per pixel. Very low level fixed pattern noise.



Gain uniformity map obtained under flat-field illumination. Color scale indicates relative gain across the active area of the MCP.

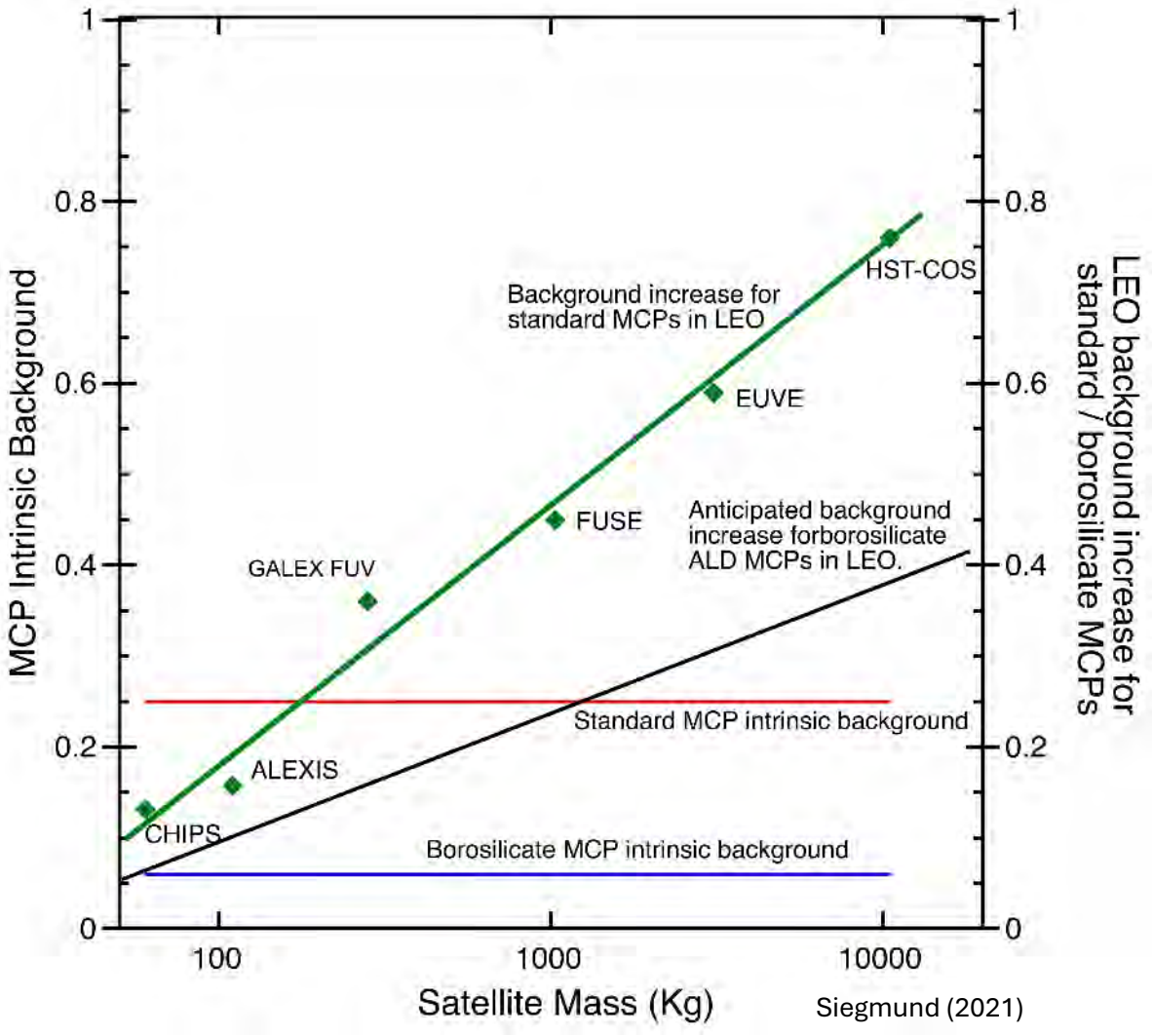


Background event rate map acquired under dark conditions. ~0.17 events $cm^{-2}$ $s^{-1}$.



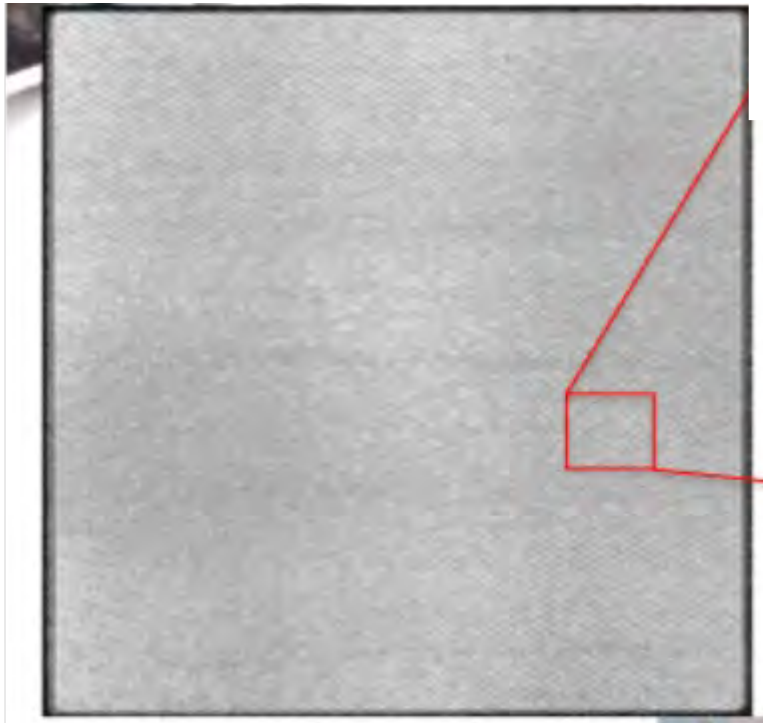
# Background vs Substrate Materials

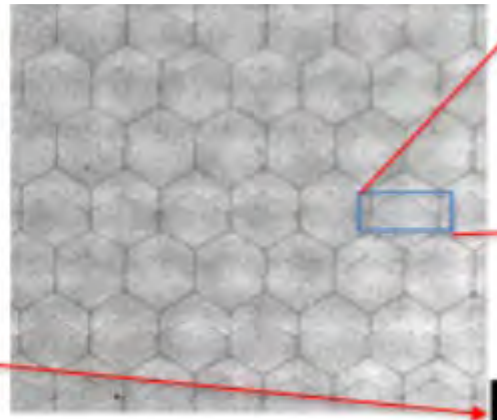
The in-orbit background is determined by the intrinsic radioactive background, $^{40}K$ for HST-COS and other missions. This is about 0.25 counts/cm$^2$/sec. In orbit the local radiation background is dominant. HST in LEO is a benign environment but the background is ~0.8 counts/cm$^2$/sec mainly Galactic cosmic ray and solar radiation. This is typically X and gamma rays from Bremsstrahlung stopping high energy charged particles. This can be reduced by a factor of 2.5 by using lead free glass. Sea level background with borosilicate ALD are as low as 0.02 counts/cm$^2$/sec, or 1 event per 25 μm resolution element every 2 months.

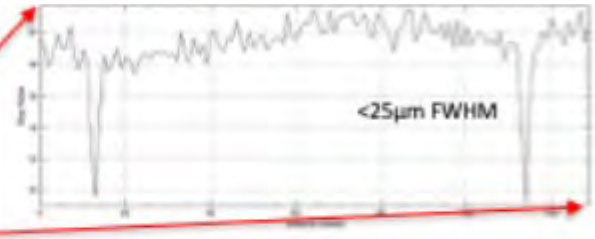



Siegmund (2021)

# Flat Field, Spatial Resolution and Background for Large Area Borosilicate/ALD Detectors



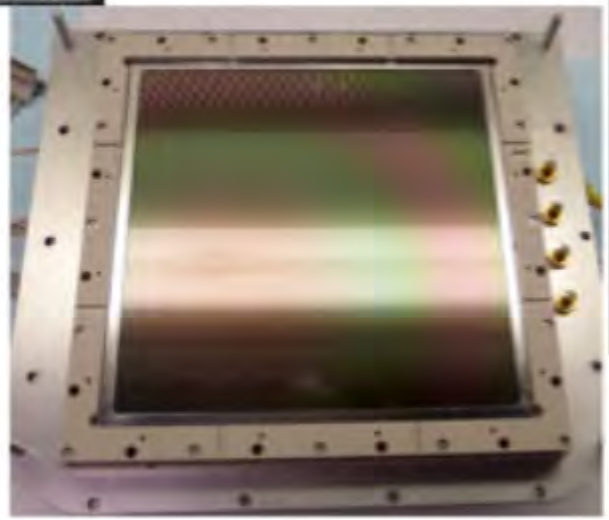





Incom 10 µm pore, 13° bias, L/D 60:1, MgO ALD pair.

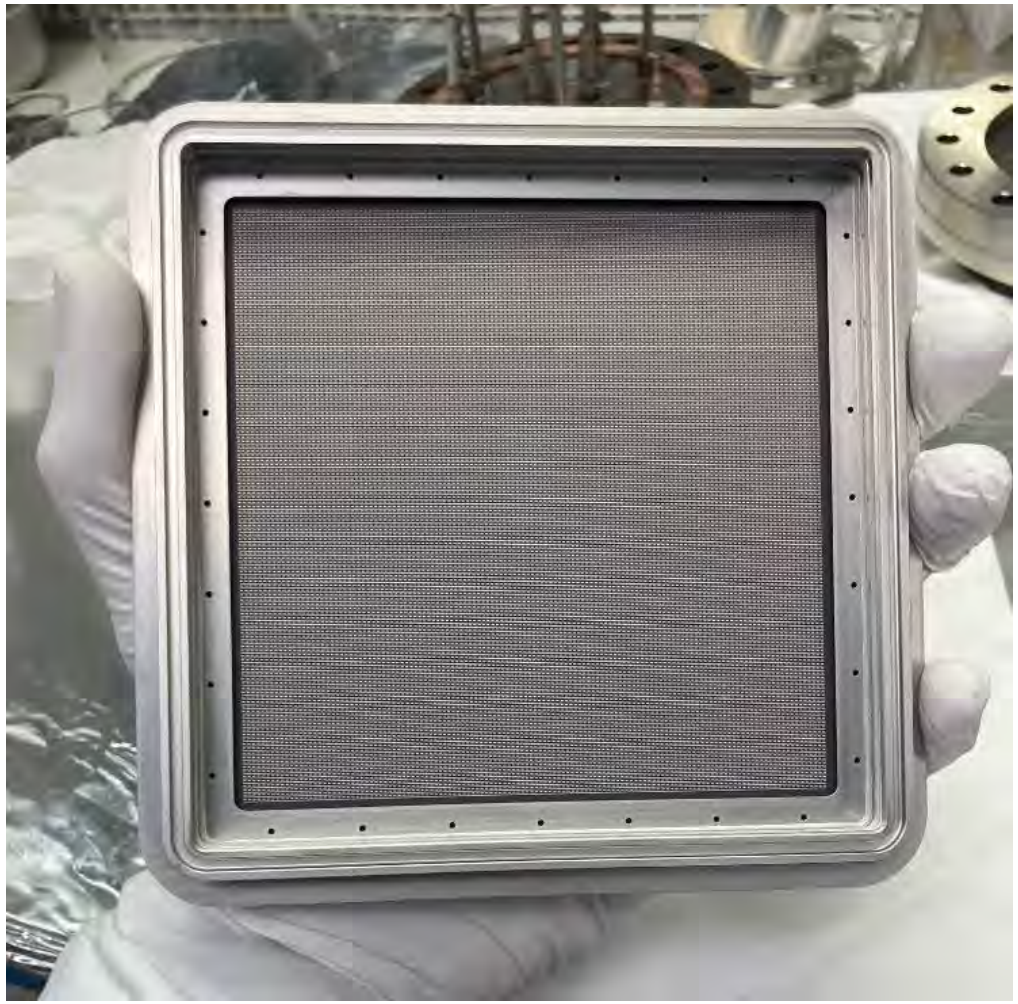
10cm x 10cm, 10µm, ALD MCP pair
Background 0.060 cts / sec / cm$^2$,
<2 events/resel/fortnight. 8

KBr cathode on 20 x 20 cm ALD, MCP XDL detector – flown 4x (Green et al).
**Flown from AU Northern Territory 2022.**

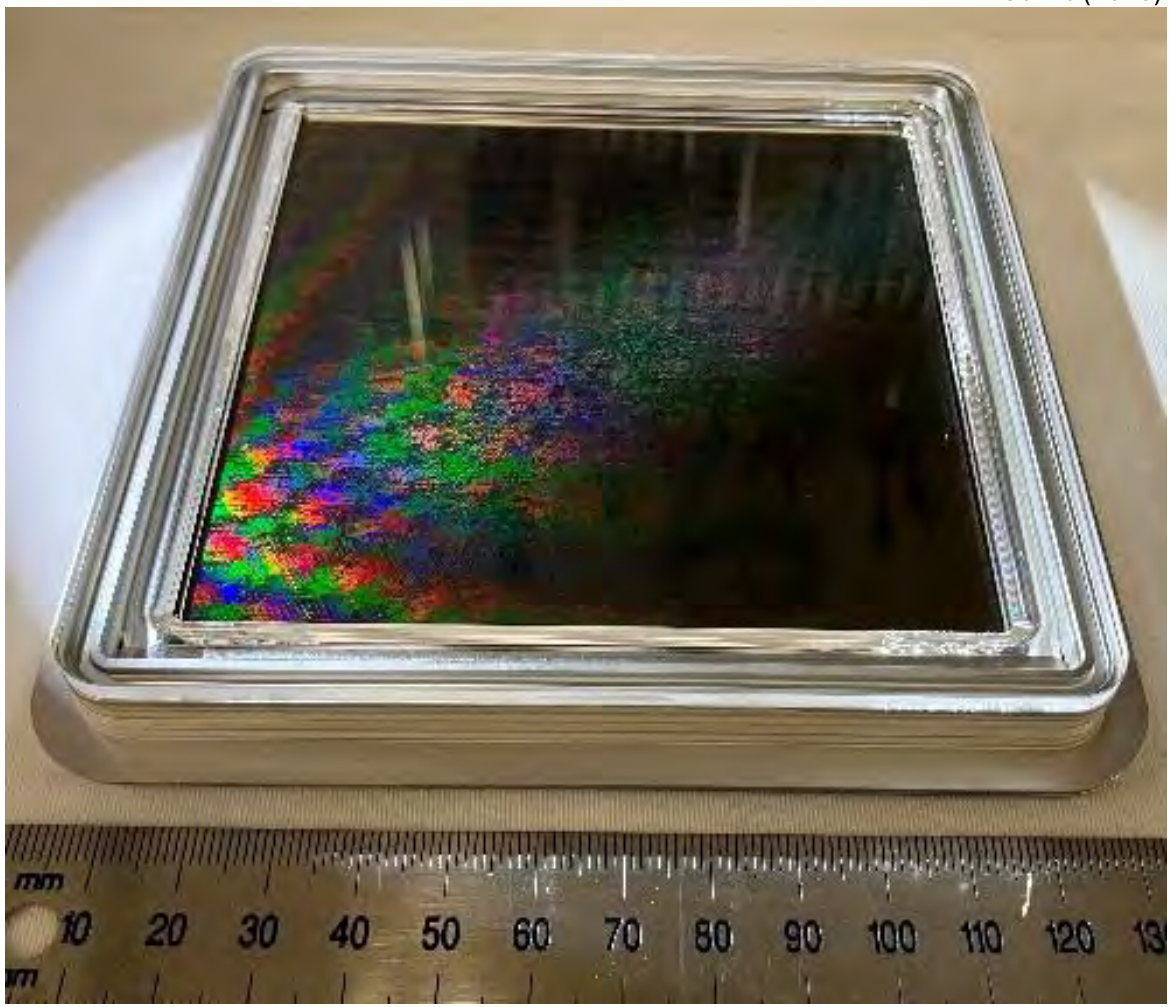


# 100 mm XS Anode Readout Sealed Tube Development at UCB

Curtis (2025)



The brazed anode assembly with 100mm HTCC XS anode and brazed body assembly are laser welded together, forming a hermetic detector assembly.

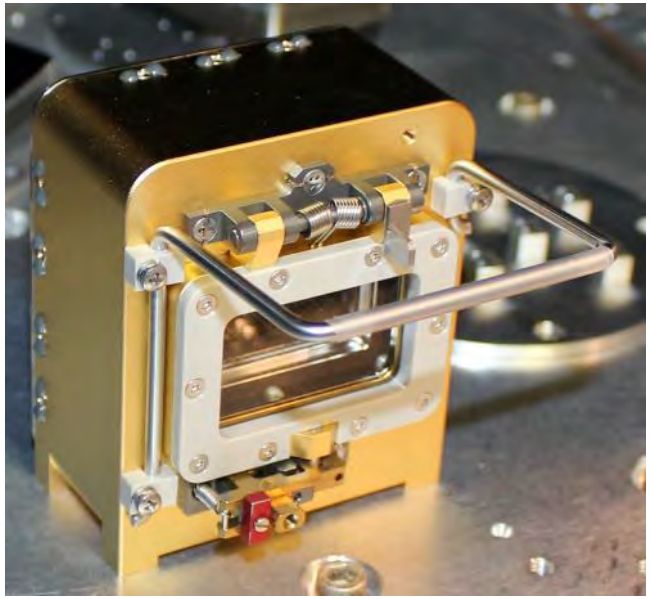



100mm 10μm MCPs installed within the detector assembly. Fused silica drop face window establishes the substrate for the semitransparent bialkali proximity photocathode.

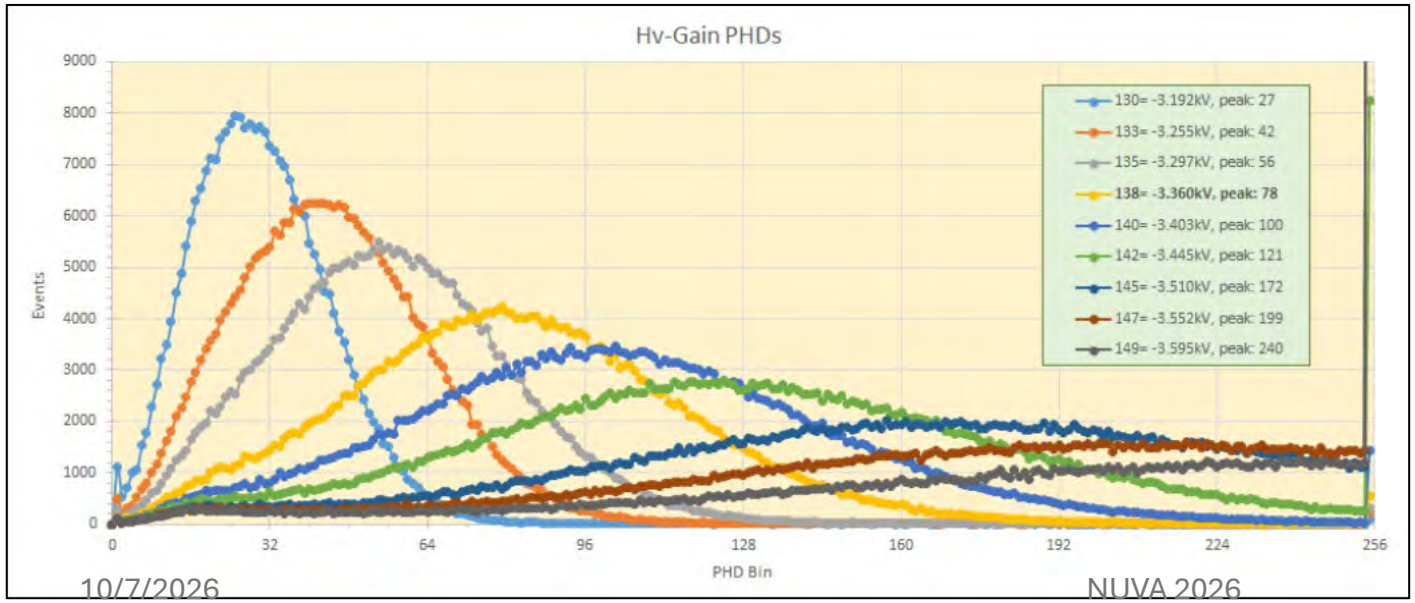
# ALD-MCP Flight Heritage

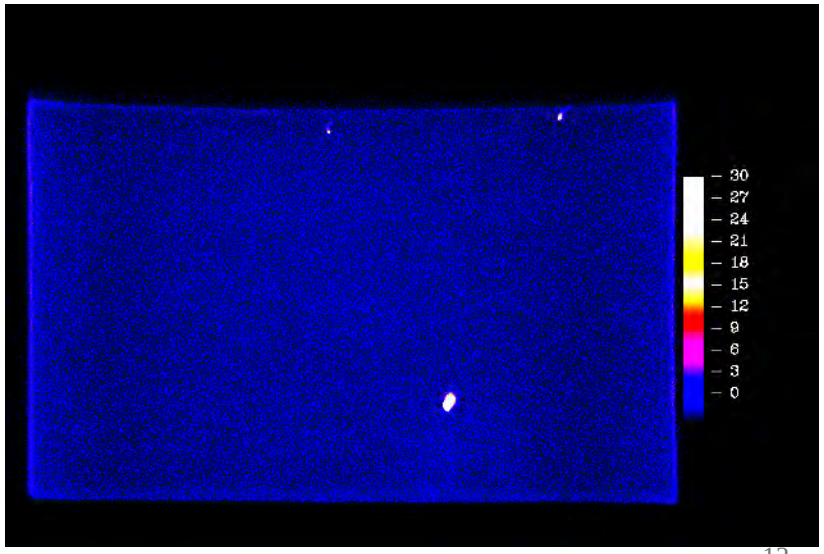
**Europa-UVS XDL Detector**

- 46 x 30 $mm^2$ MCP z-stack, 7.5 cm radius, 20 µm pore
- Cathode is opaque CsI deposited onto MCP, stable post launch.
- Added aperture mask between bottom-mid MCP to improve distortion
- Launched October 2024, HV commissioning May 2025
- In-flight dark rate (interplanetary space) 3.6 Hz/$cm^2$, 2.3 Hz/$cm^2$ excluding hot spots
- In-flight gain curve shows optimal performance at -3.36 kV



Davis (2026)

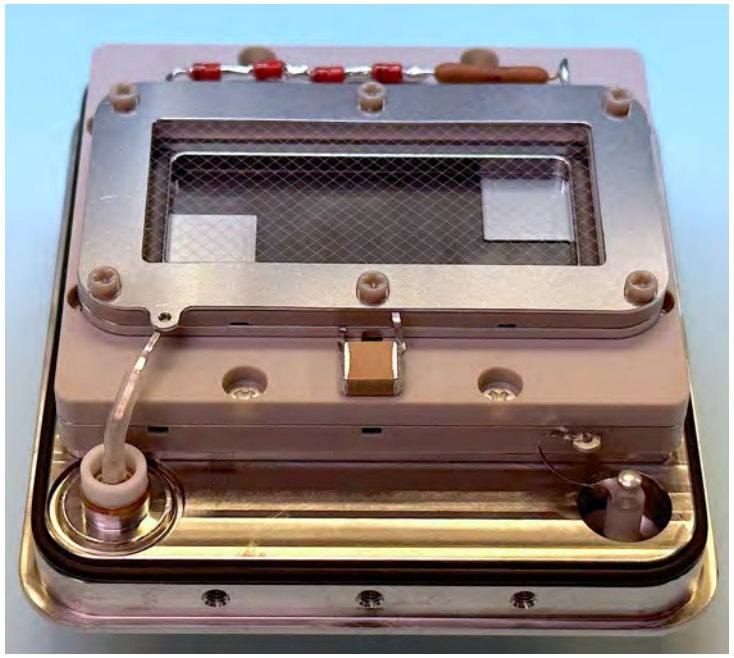


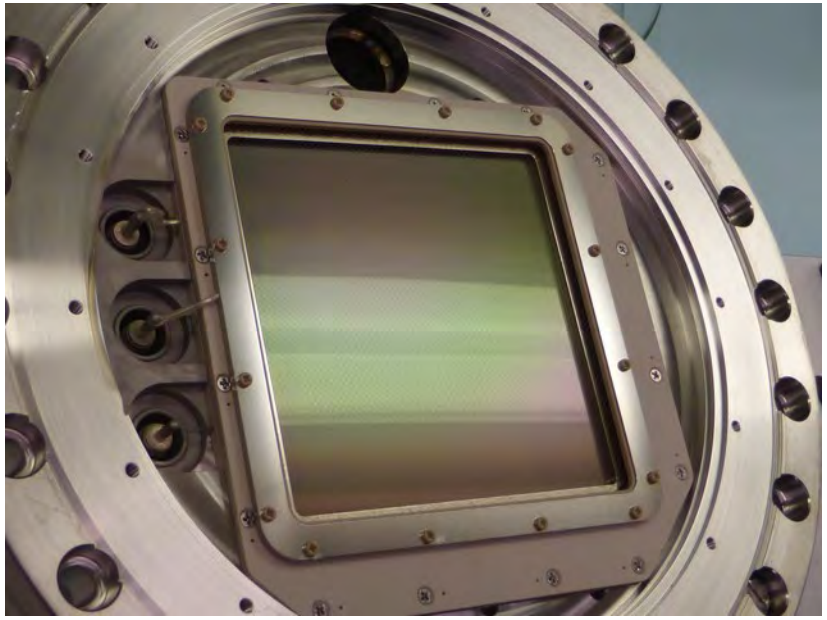



# Recent & Upcoming Instruments

ASPERA Pioneer (2027)
- Vargas, U. Arizona

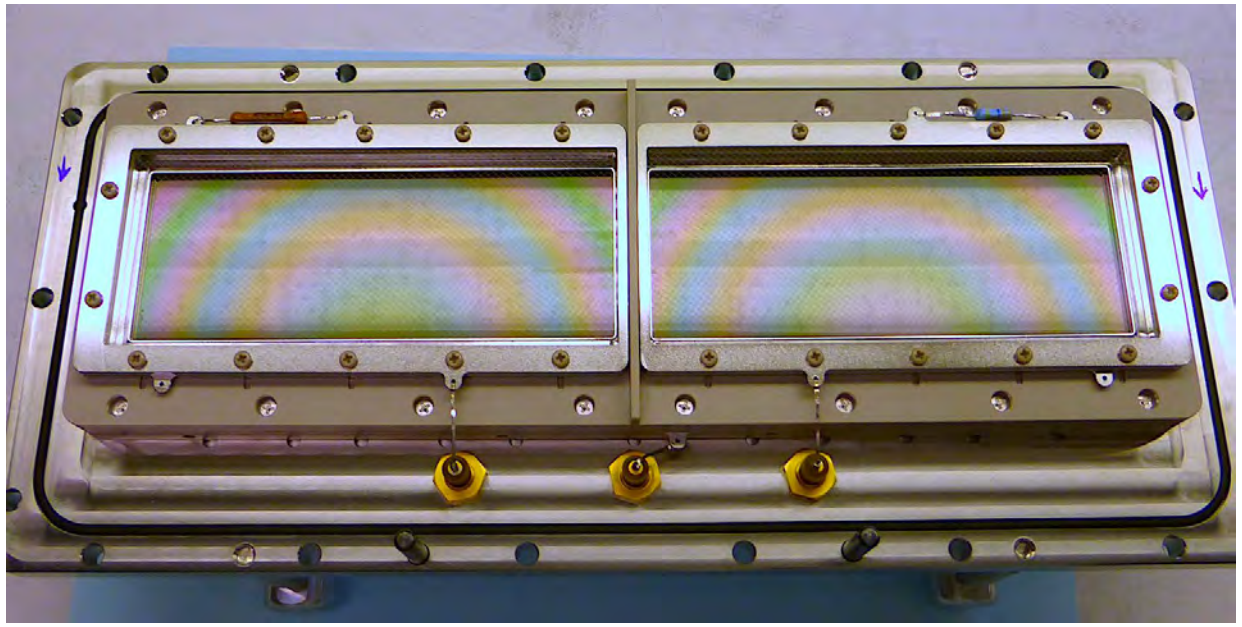
Two 1 x .3 cm zones for
100 to 110 nm spectra.





100 mm XS MCP detector with <25 μm resels

INFUSE (2023-26) 100mm XS Detector
MOBIUS (2028) 50 mm XS tube
FLUID 25mm XDL (2027).
SPRITE CubeSat (10/26)
MANTIS CubeSat (2028)
- France & Fleming U. Colorado



SISTINE, flown 3x, 2021-2022, 2 segment
115 mm x 40 mm with XDL readout.
- Nell U. Colorado

# Conclusions

- MCP detectors have been widely used and successful in space-base instruments for many applications.
- Over the years performance demands have increased, leading to advances in detector size, shape, event rate capability, spatial and timing resolution, mass and power consumption, and lifetime stability and robustness.
- Many of these advances have been incorporated into upcoming instruments/missions that will be flown over the next few years.
- Full realization of these new capabilities are fundamental to some of the longer-range goals in several NASA disciplines and are being tested through suborbital and Cubesat programs. In addition, there are ongoing proposal initiatives for infusion of these advances into programs at the SMEX and PROBE levels.