Current and future capabilities of MCP detectors for UV-Vis instruments

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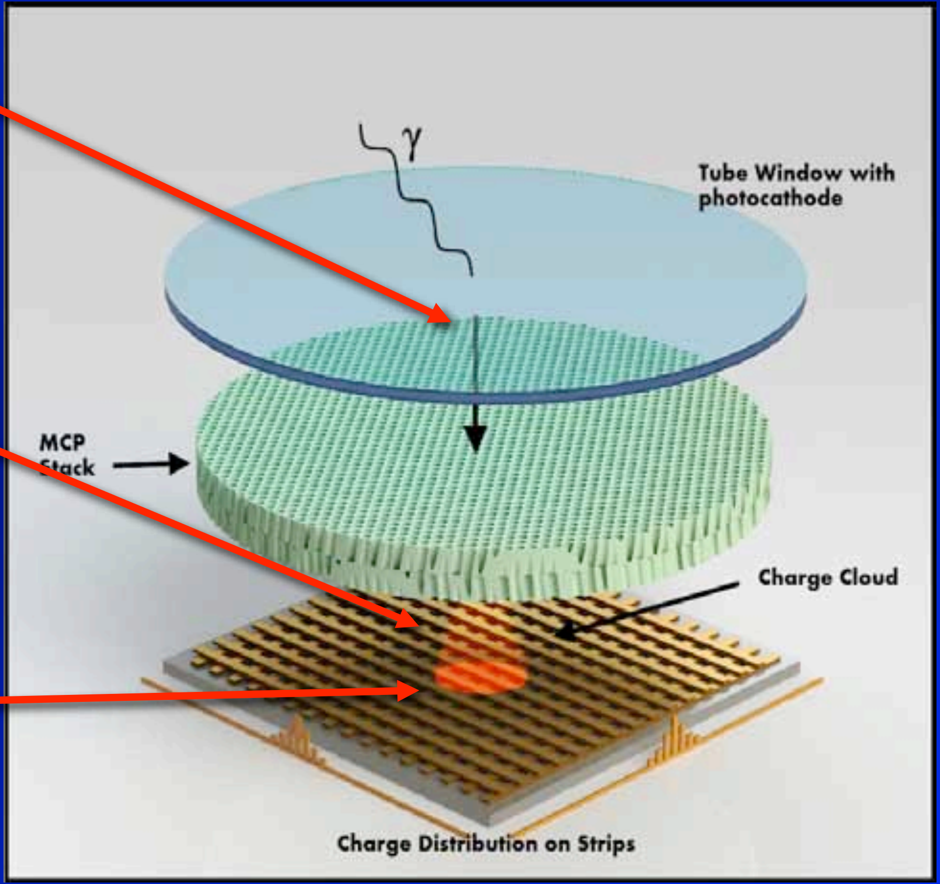
Microchannel Plate Detector

Photocathode converts photon to electron

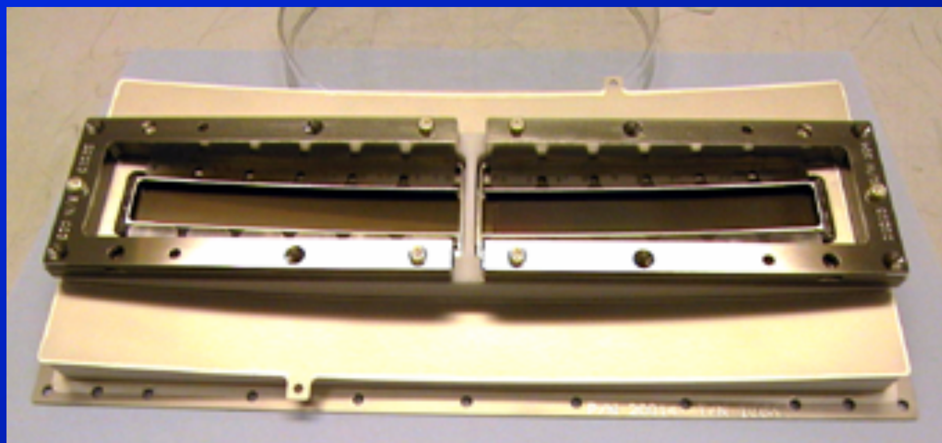
MCP(s) amplify electron by 10^4 to 10^7

Patterned anode measures charge centroid



MCP Detector Examples

COS FUV for Hubble (200 x 10 mm windowless)



18 mm Optical Tube

P-Alice on
New Horizons
(1.1Watt, 660 gms)

200+ "detector years" in space including mission to Pluto (estimated existence > 10^9 yrs)

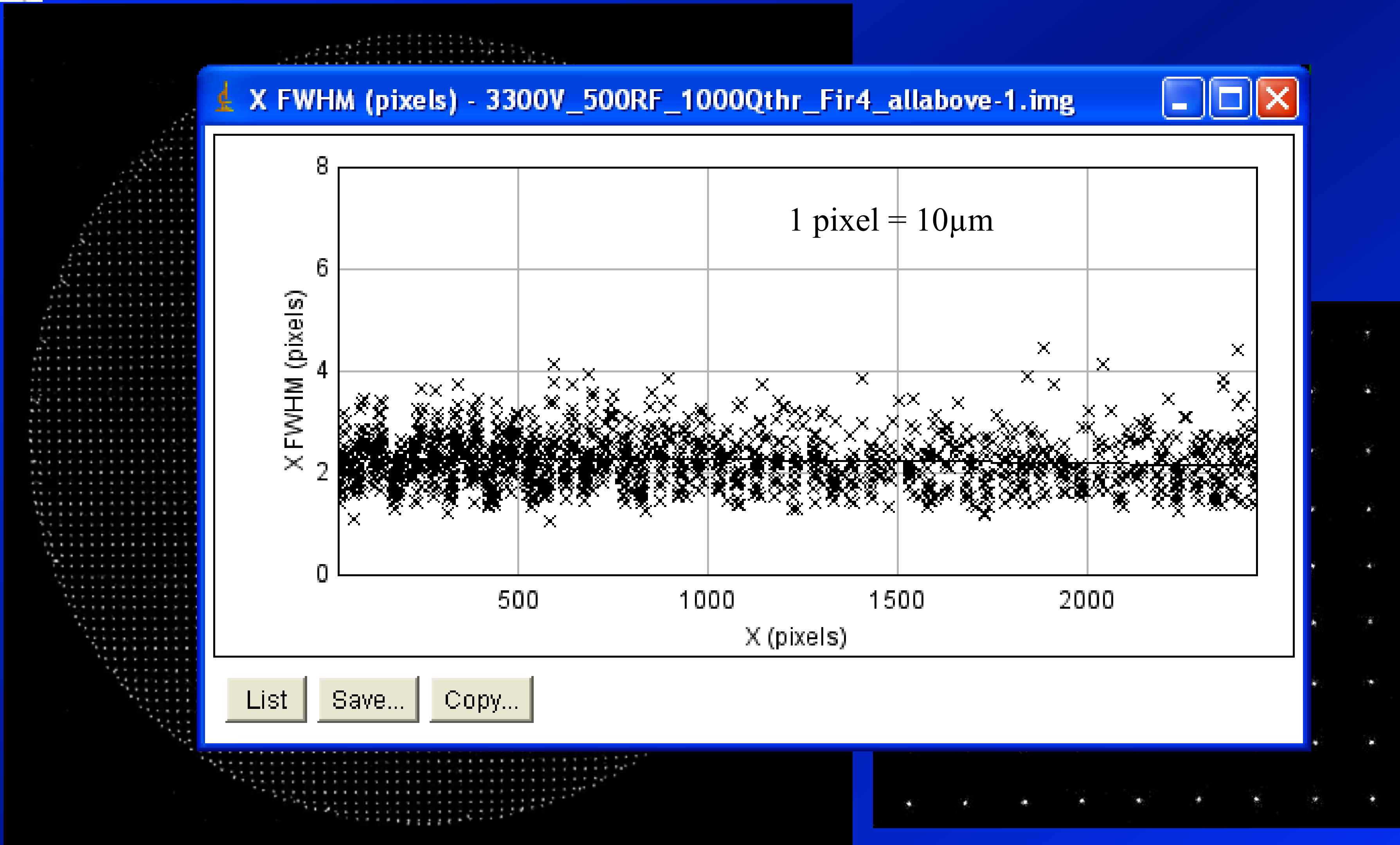
Advantages:

• *Photon counting*	*zero read noise*
• *Time tagged events*	*< 100 ps*
• *Large, flexible format*	*> 100 mm (0.1Gpxl)*
• *High dynamic range*	*10^8*
• *Spatial resolution*	*< 15 mm FWHM*
• *Low out of band response*	
• *Ability to smoothly curve focal plane*	
• *Room temperature operation*	
• *Robust and reliable*	
• *Radiation hard*	

Disadvantages: Solutions

Disadvantages	Solutions
QE dependent on photocathode	
Fixed pattern noise	*MCP fabrication*
Spatial non-linearity	*Better anode*
Low throughput	*Faster electronics*
Lifetime (~ 3 Coulombs cm^{-2})	*Lower gain (x10-100)*
High Voltage operation	*Lower gain – Lower HV*
Vacuum operation (pumps, doors, vacuum tubes)	

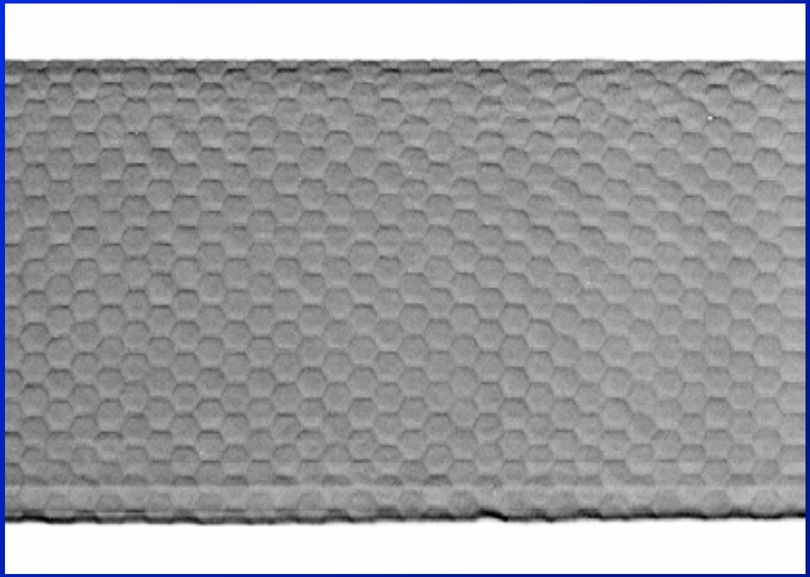
50 mm anode imaging tests - resolution



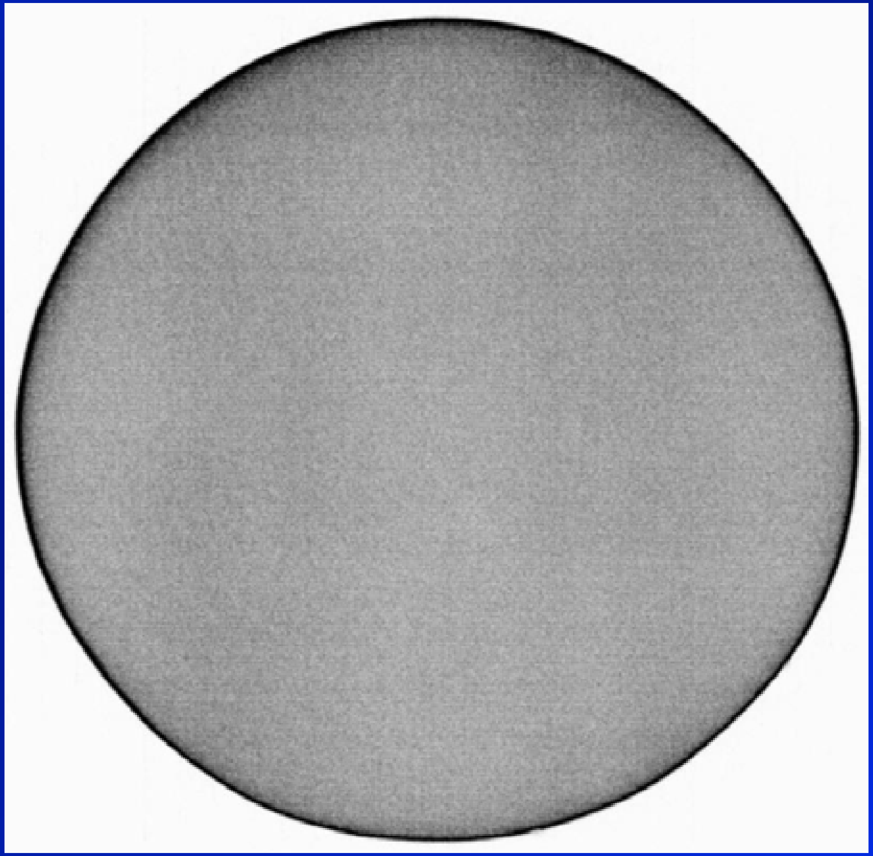
Zoomed - 20 um FWHM avg.

40 mm active area - 0.5 x 0.5 mm pinhole grid

MCP Fixed pattern noise



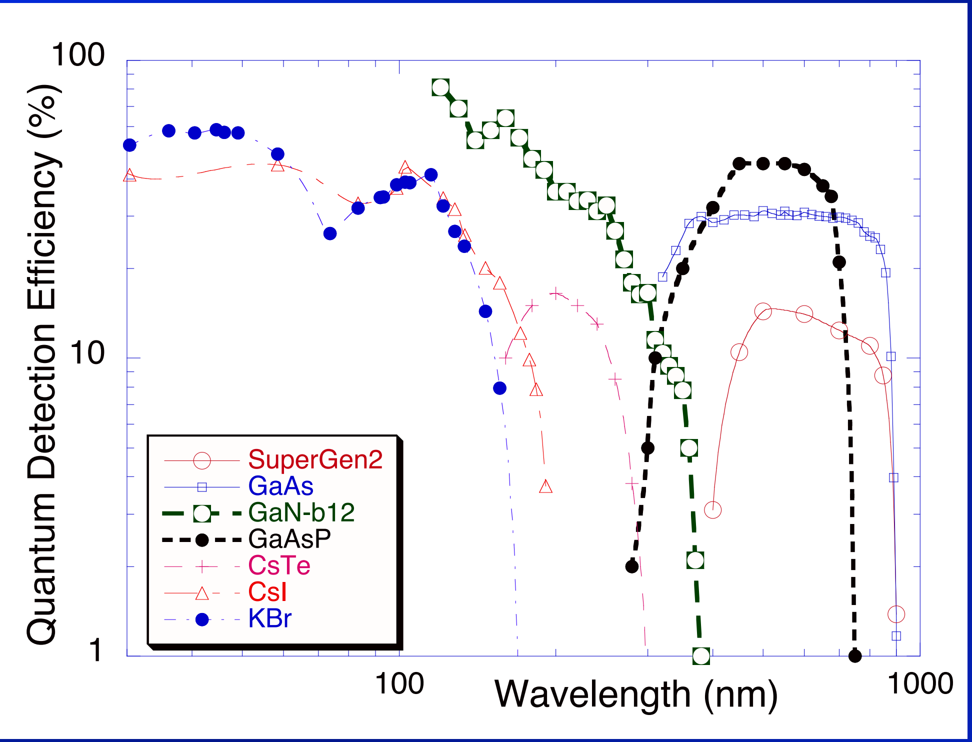
COS flat field
16 x 10 mm



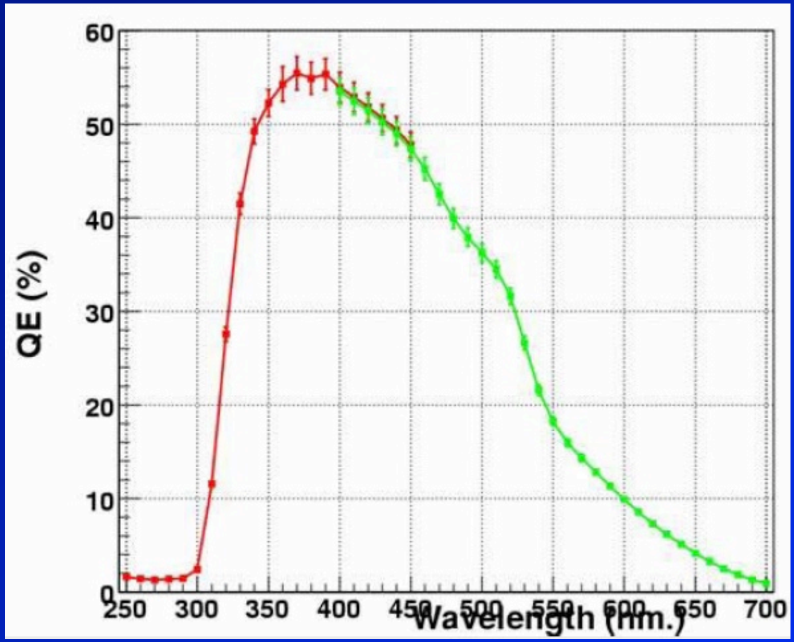
Optical tube flat field
25 mm

Photocathodes, 10nm - 900nm

GaN is a robust material with good handling properties.
Samples have been re-cleaned and reprocessed many times achieving same QE
GaN sample in a sealed tube has not changed in QE measurably in over 5.5 years.



General comparison of conventional and GaN photocathodes.



Recent improvements in bialkali cathodes, fills the gap between GaN and GaAsP.

PHOTONIS – Clermont-Ferrand workshop 2010

Borosilicate glass MCPs

Fabricated using hollow tube draw and stack technique

Glass is inexpensive, low Z (no lead), and has a higher softening temperature

- *Lower gamma background*
- *Deposition of high T opaque photocathodes like GaN*

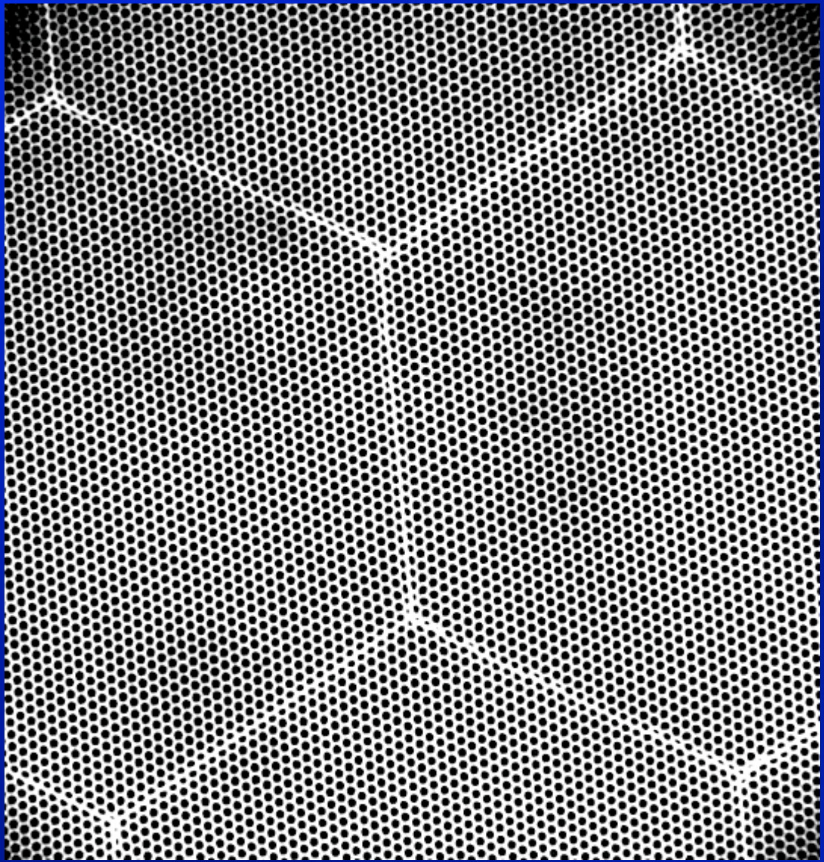
Functionalized using Atomic Layer Deposition (ALD)

- *Semiconductor Resistive layer, tunable over wide range*
- *Amplifying layer (Al_2O_3) with high secondary electron coeff.*
- *Better lattice match to GaN*

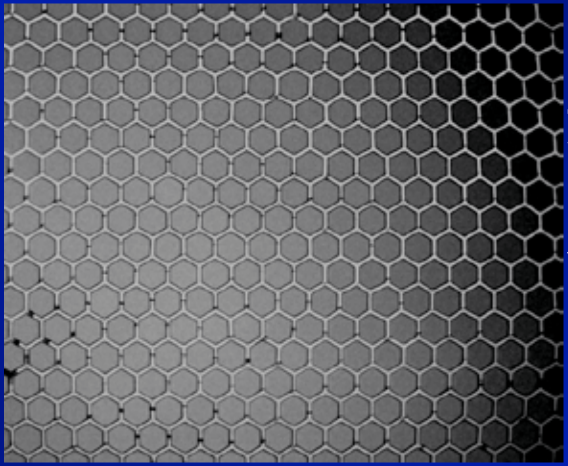
Separates surface optimization from substrate optimization!

Borosilicate Microchannel Plate Substrates

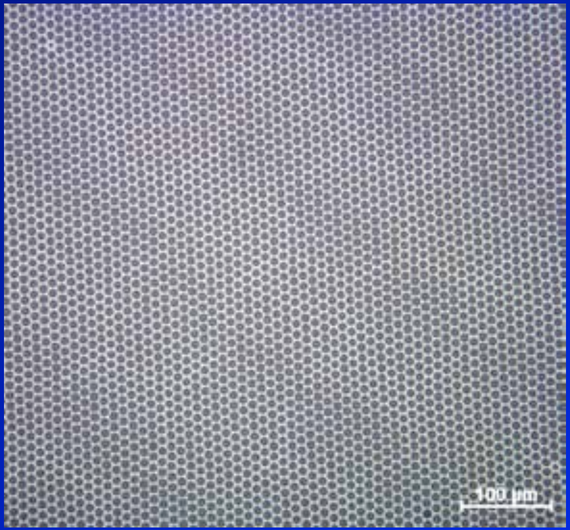
Micro-capillary arrays (Incom) with 20 µm or 40µm pores (8° bias) made with borosilicate glass. L/d typically 60:1 but can be much larger. Open area ratios from 60% to 83%. These are made with hollow tubes, no etching is needed.



20 µm pore borosilicate micro-capillary substrate. Pore distortions at multifiber boundaries, otherwise very uniform.



40 µm pore borosilicate micro-capillary substrate with 83% open area



Coming soon,

10 µm pore borosilicate micro-capillary substrate with 50% open area

Psec Timing Project
(P.I Henry Frisch, U. Chicago, Argonne)

Large area (8”x8”) MCP image tubes for Cherenkov arrays and PET detectors

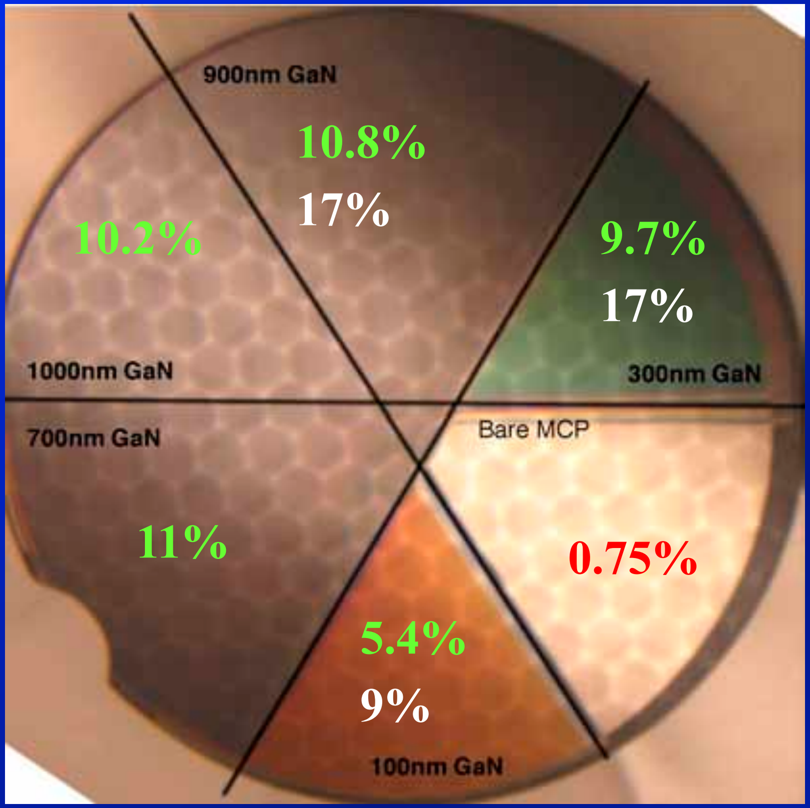
Stripline readout, specialized ASICs

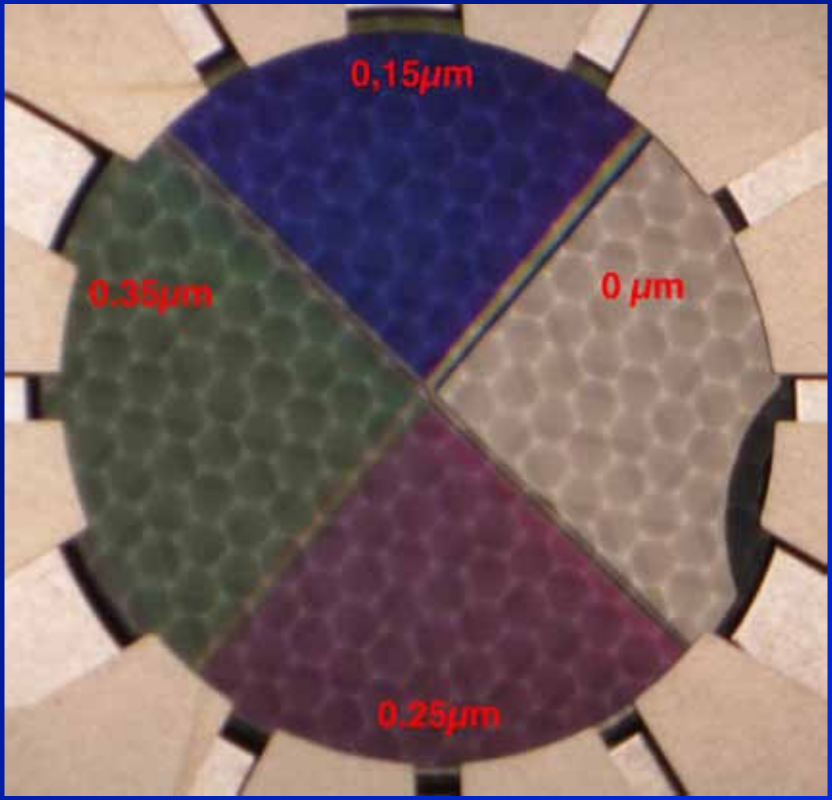
Pulse timing to 1 ps (multiple photon)

Thousands of tubes for large area

8” MCP has been made/ tested and shows normal gain behavior, also have 8” cross delay line detector for imaging studies.

GaN Cathode on ALD Borosilicate MCP
(NiCr substrate)





- QEs measured after CS (214nm, web)
- 10º (green) or 45º (white) graze angle
- Shows typical QE-thickness asymptote for opaque cathode

- Next sample to be tested
- More samples in fab with ALD sapphire on top of MCP as base layer for GaN(Mg) deposition.

MCP detector performance

	1985	2011	2020
Pixel Size (μm)	50	5	5
Format (mm)	100	100	200
Global Ct. rate (kHz)	5	4,000	40,000
Local Ct. rate (kHz)	1	40	40
Dark rate (cts cm^{-2} s^{-1})	0.5	.085	.085
Pixels (Mpixel)	0.7	64	1600

MCP Sensor Progress & Prospects

MCP Detectors have been the workhorse in UV imaging for decades

Most of the order-of-magnitude improvements (e.g. throughput, resolution) have been due to advances in microelectronics which are now being implemented for flight programs

New ALD coating technologies have resulted in a very rapid development of Borosilicate MCPs that can be larger, quieter, and survive higher temperatures that facilitate new photocathode deposition techniques (e.g. opaque GaN)

Clearly there is still work to do:

- *Improve QE in all bands*
- *Demonstrate stability and low background with each improvement*
- *Scaling readouts to the largest formats*
- *Raise TRL level of each new technology*

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