ADVANCES IN MICROCHANNEL PLATES AND PHOTOCATHODES FOR PHOTON COUNTING DETECTORS

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Microchannel Plate Development Efforts

Microchannel Plates – large (& small) area advanced technology

Development study to produce small pore, large area MCPs with borosilicate glass substrates and atomic layer deposited resistive layer and secondary electron emissive , with high quality imaging, high spatial resolution, low background and high QDE (compatibility with high temperature photocathode depositions).

Photocathodes

Lots of efforts in GaN opaque and semitransparent photocathodes

There are also other developments at different wavelength regimes

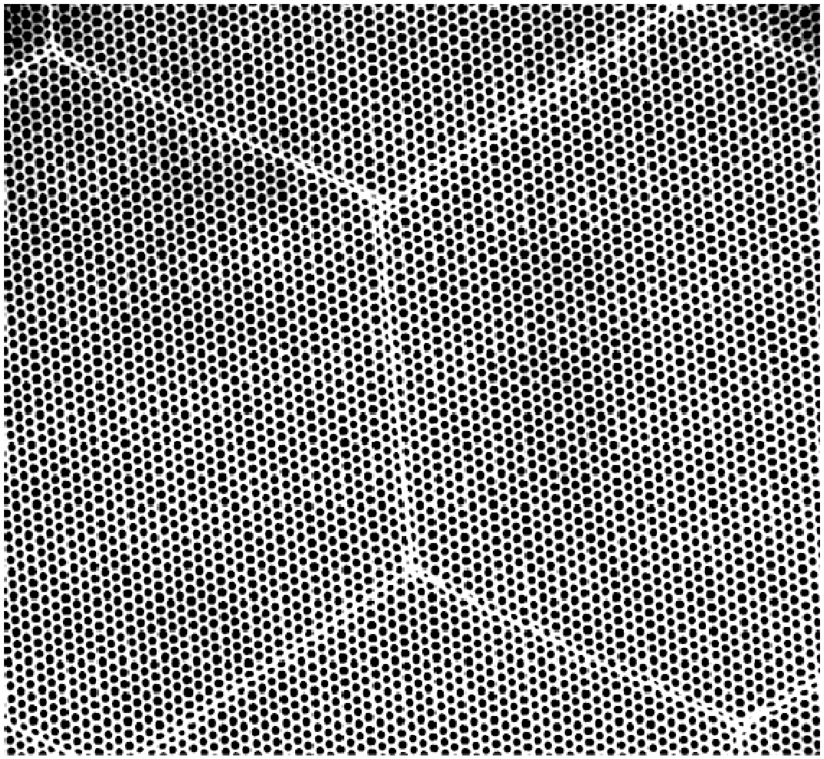
Readout and Electronics

Current readout work is focused on cross strip charge division anodes

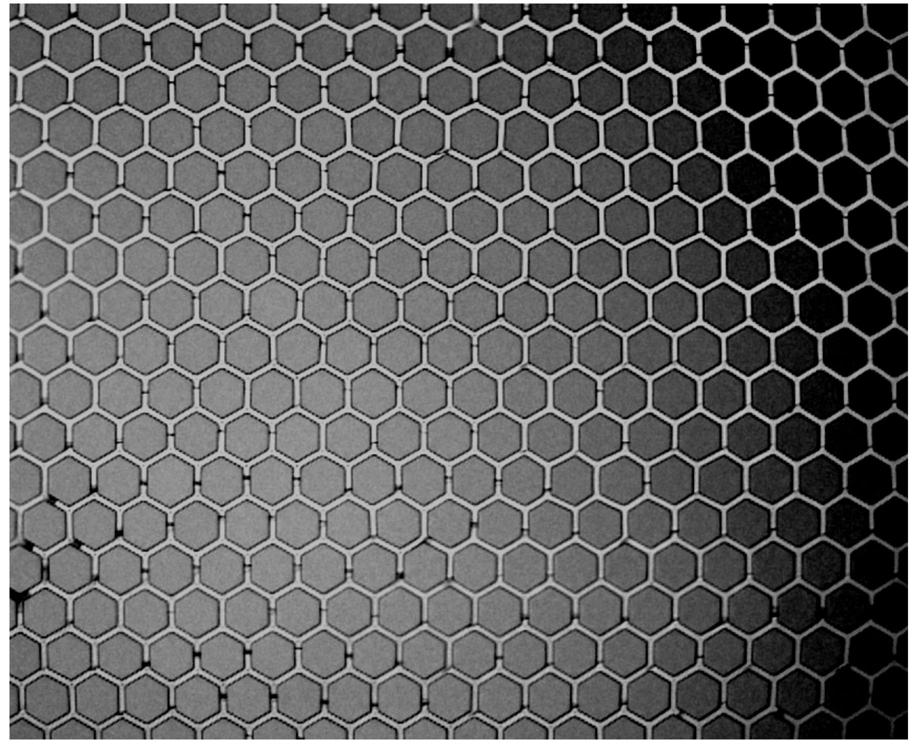
And high speed position and time encoding electronics.

Borosilicate Microchannel Plate Substrates

Micro-capillary arrays 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

DOE - Large Area Picosecond Photodetector Program
NASA APRA – Nanoengineered MCPs for Astrophysics

Borosilicate Substrate Atomic Layer Deposited Microchannel Plates

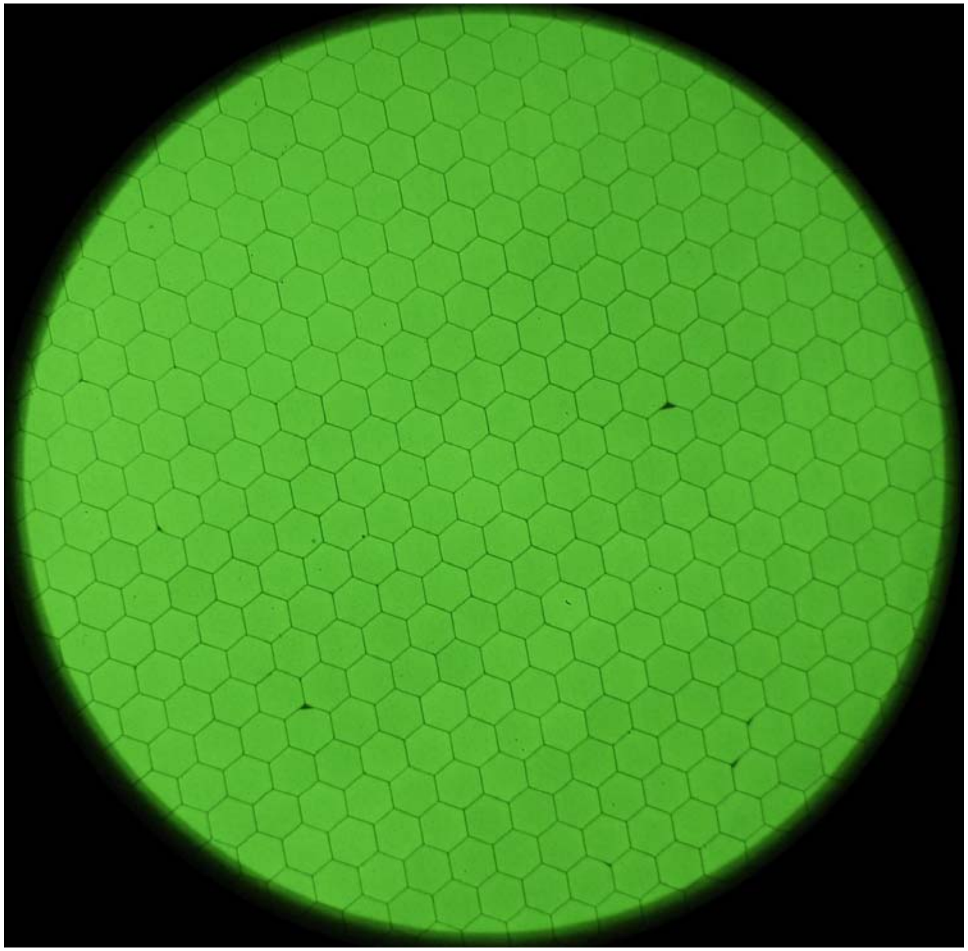
Micro-capillary arrays with 20 µm or 40µm pores (8° bias) made with borosilicate glass. Resistive and secondary emissive layers are applied (Argonne Lab, Arradiance) to allow these to function as MCP electron multipliers. Each step is separately engineered/optimized.

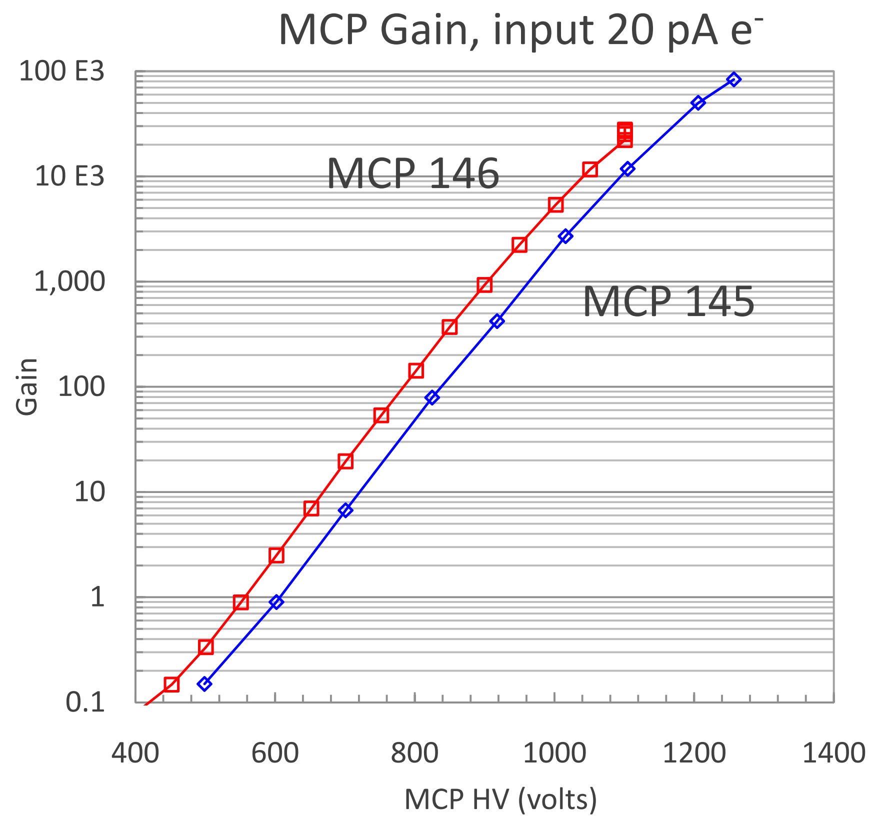
Visible light transmission for a 20 µm pore borosilicate micro-capillary ALD MCP .

Surface photo for a 20 µm pore borosilicate micro-capillary ALD MCP with NiCr electrode .

Single MCP - Phosphor Screen Tests

33mm, 20µm pore borosilicate MCP substrate, 60:1 L/d, 8 degree pore bias. 1100v MCP.

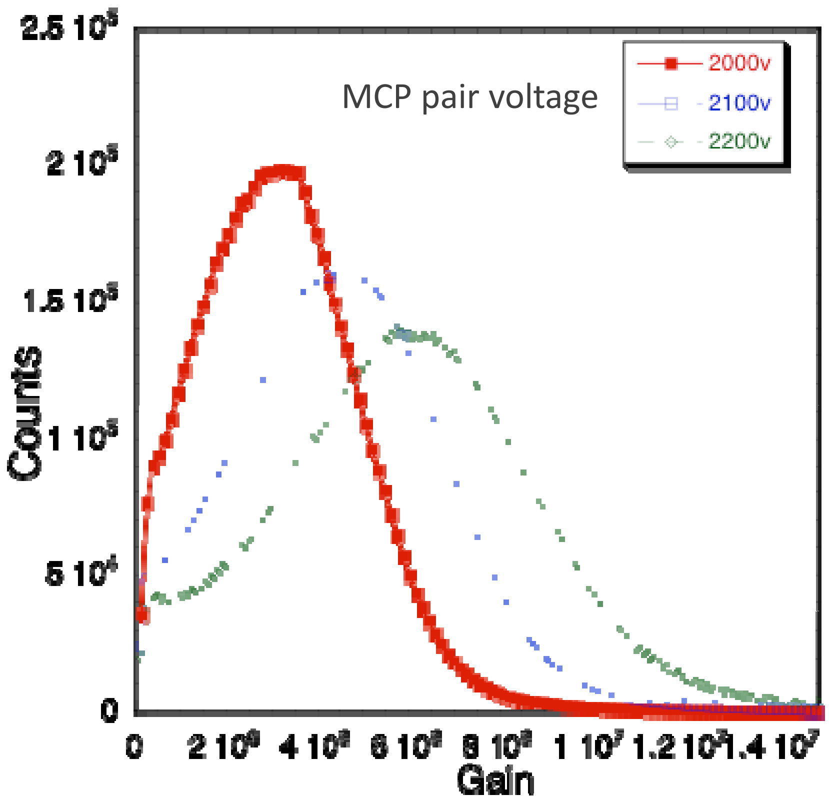




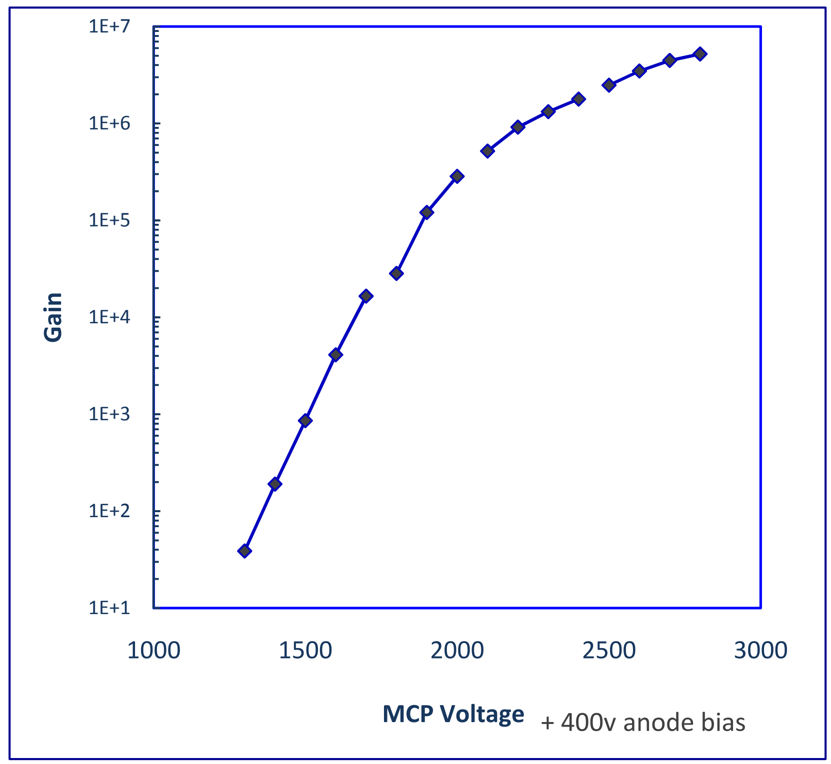
Single MCP tests in DC amplification mode show imaging and gain very similar to conventional MCPs. Sample imaging performance has improved dramatically over the last 12 months due to process improvements.

ALD-MCP Performance Tests, 33mm pairs

UV illuminated test results show similar gains to conventional MCPs, exponential gain dependence for low applied voltages, then saturation effects appear above gains of 10^6. Pulse heights are reasonably normal for 60:1 L/d pairs.



Pulse height amplitude distributions for a 33mm ALD MCP pair, 40µm pore, 60;1 L/d, 8 degree bias.



Gain for a pair of 20µm pore 33mm ALD MCP's, 60:1 L/d, 8 degree bias.

Photon Counting Imaging with MCP Pairs

MCP pair, 20µm pores, 8° bias, 60:1 L/d, 0.7mm pair gap with 300V bias.

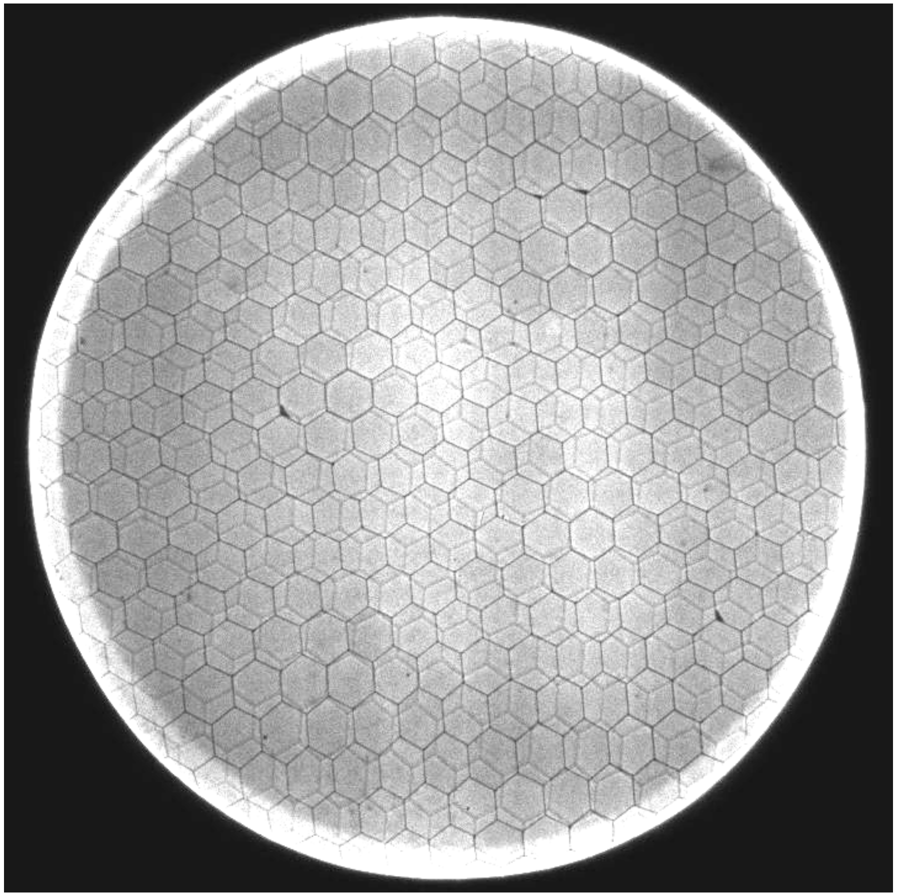
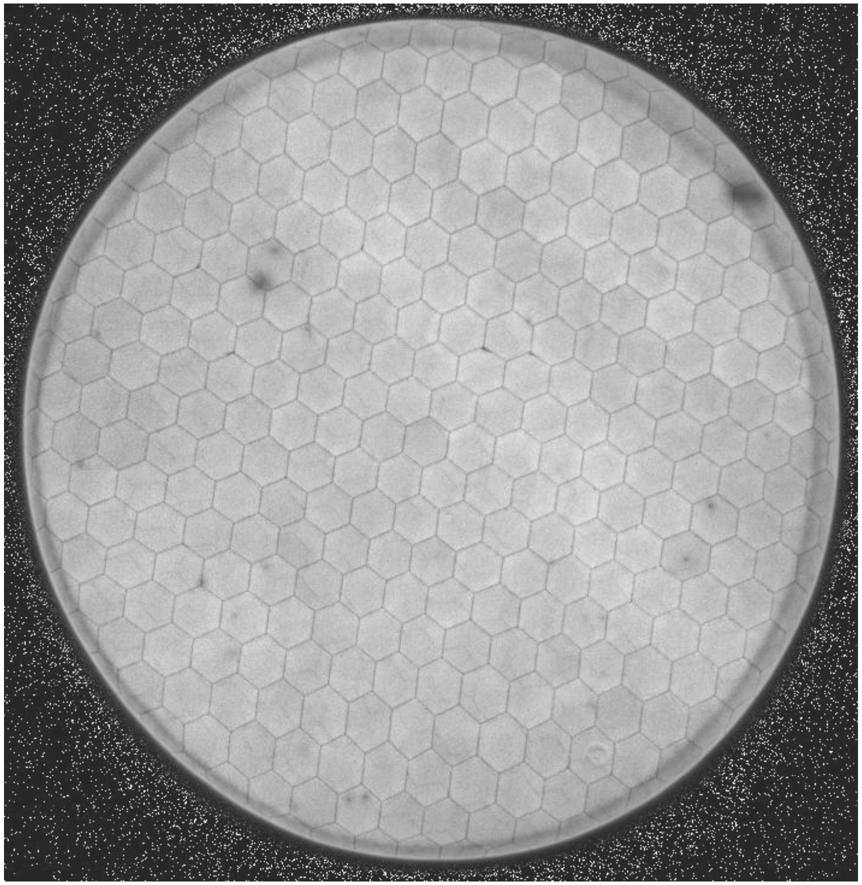


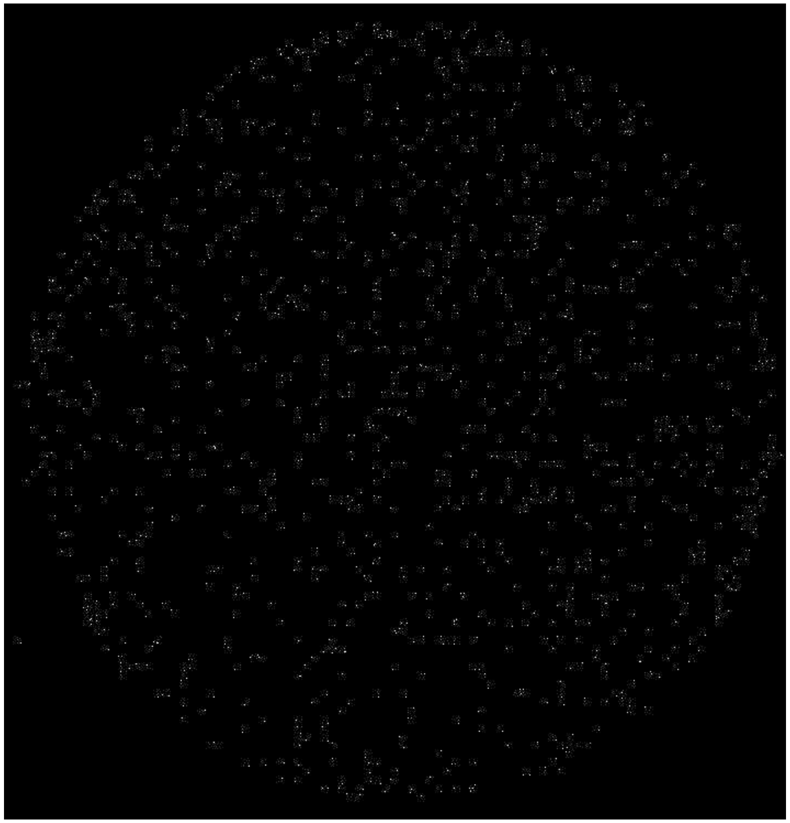
Image of 185nm UV light, shows top MCP hex modulation (sharp) and faint MCP hexagonal modulation from bottom MCP. A few defects, but generally very good. Edge effects are field fringing due to the MCP support flange.



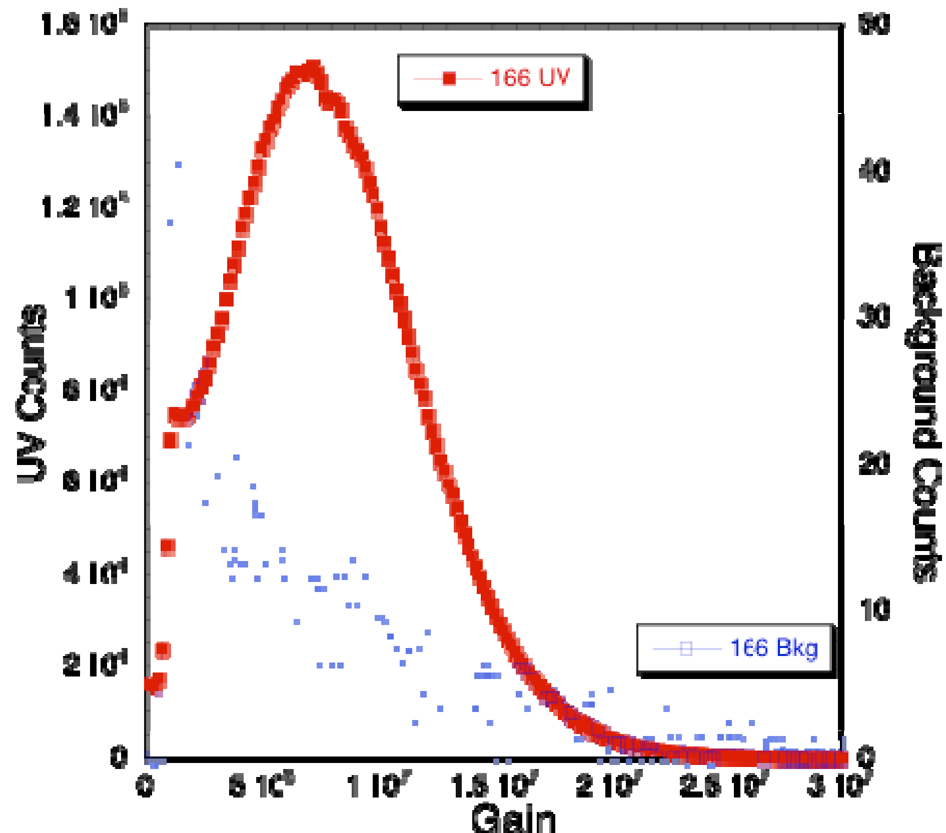
Gain map (average gain), shows top MCP hex modulation (sharp) and a few spots where the gain is low.

ALD-MCP Background Rate

MCP pair, 20μm pores, 8° bias, 60:1 L/d, 0.7mm pair gap with 300V bias.



3000 sec background, 0.0845 events cm^{-2} sec^{-1}. at 7 x 10^{6} gain, 1050v bias on each MCP. Get same behavior for all of the current 20μm MCPs

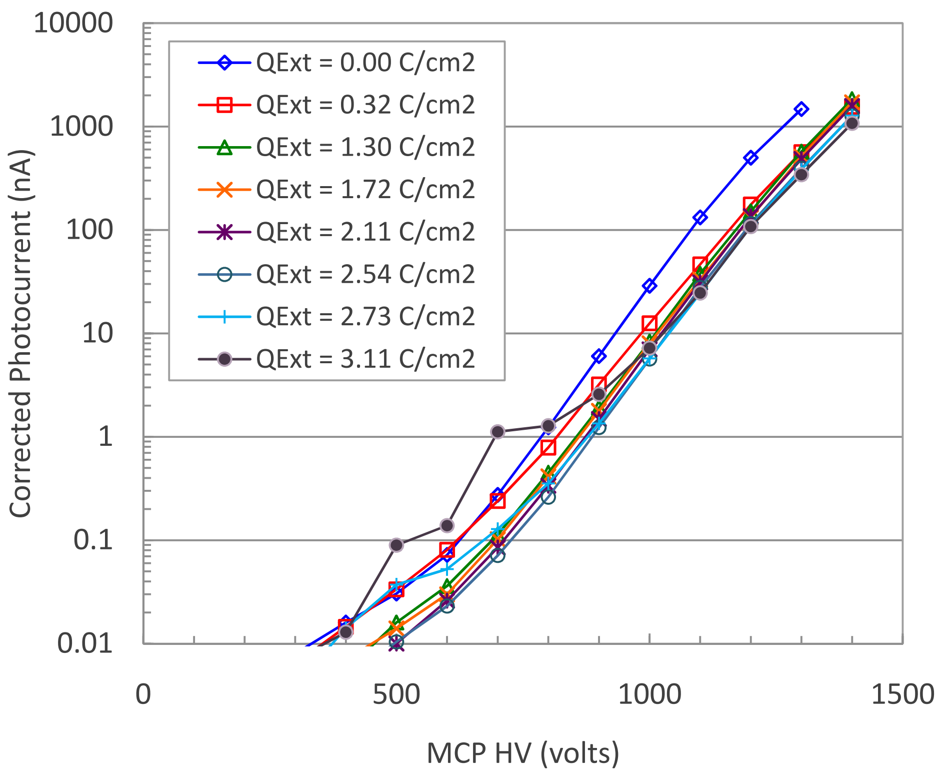


Pulse amplitude distributions for UV 185nm, and for background events.

MCPs rad hard, low radioactivity, low cross section (no lead)

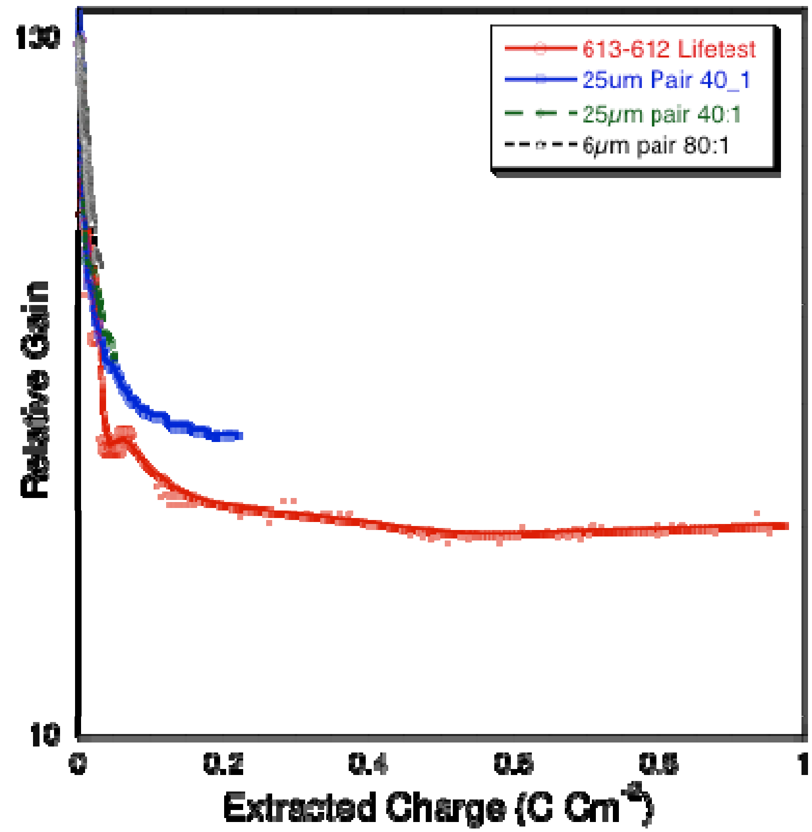
33mm ALD-MCP Preconditioning Tests

Ageing test after 150°C bake



Scrub of single ALD MCP (20µm pore, 60:1 L/d, 8° bias) after 150 °C bakeout.

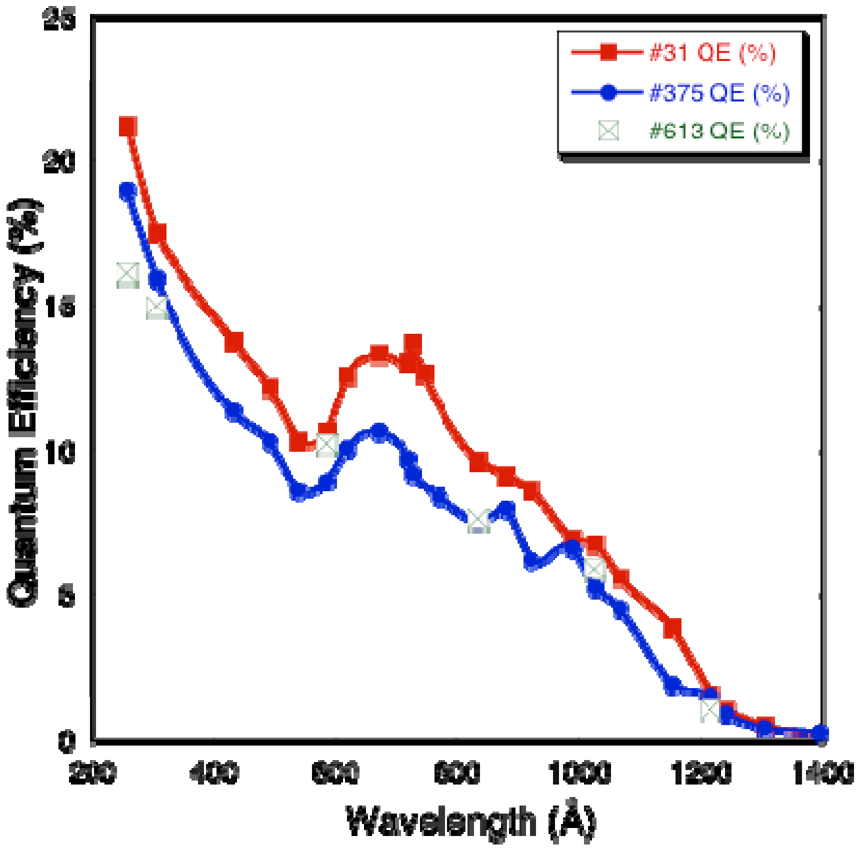
Scrubbing with UV after 350°C bake



Scrub of ALD MCP pair (20µm pore, 60:1 L/d, 8° bias) compared with conventional MCPs. UV input.

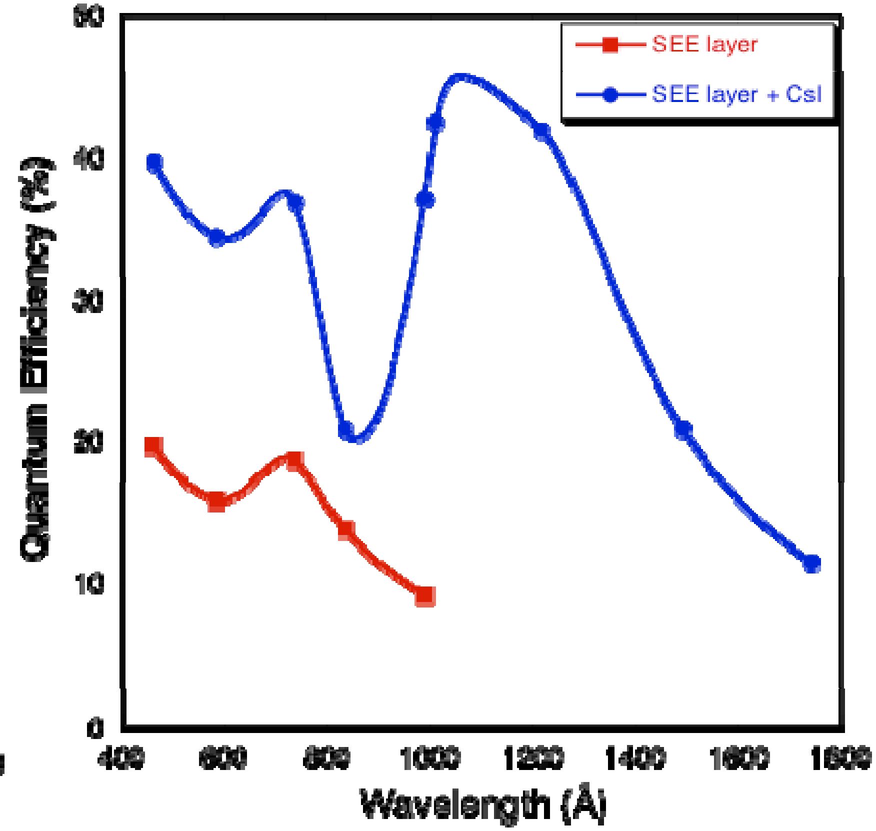
ALD-MCP Quantum Efficiency

ALD – borosilicate MCP photon counting quantum detection efficiency, normal NiCr electrode coating gives normal bare MCP QE.



#375 & #613 MCP pairs, 20µm pores, 8° bias, 60:1 L/d, 60% OAR. #31 MCP pair, 40µm pores 8° bias, 60:1 L/d, 83% OAR, shows higher QDE.

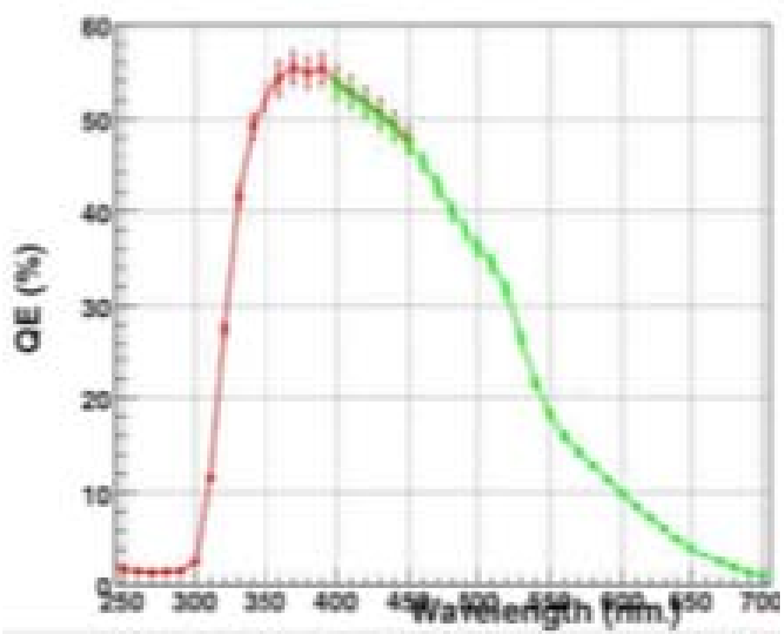
ALD – secondary emissive layer on normal MCP gives good "bare" QDE. CsI deposited on this gives a good "standard" CsI QDE.



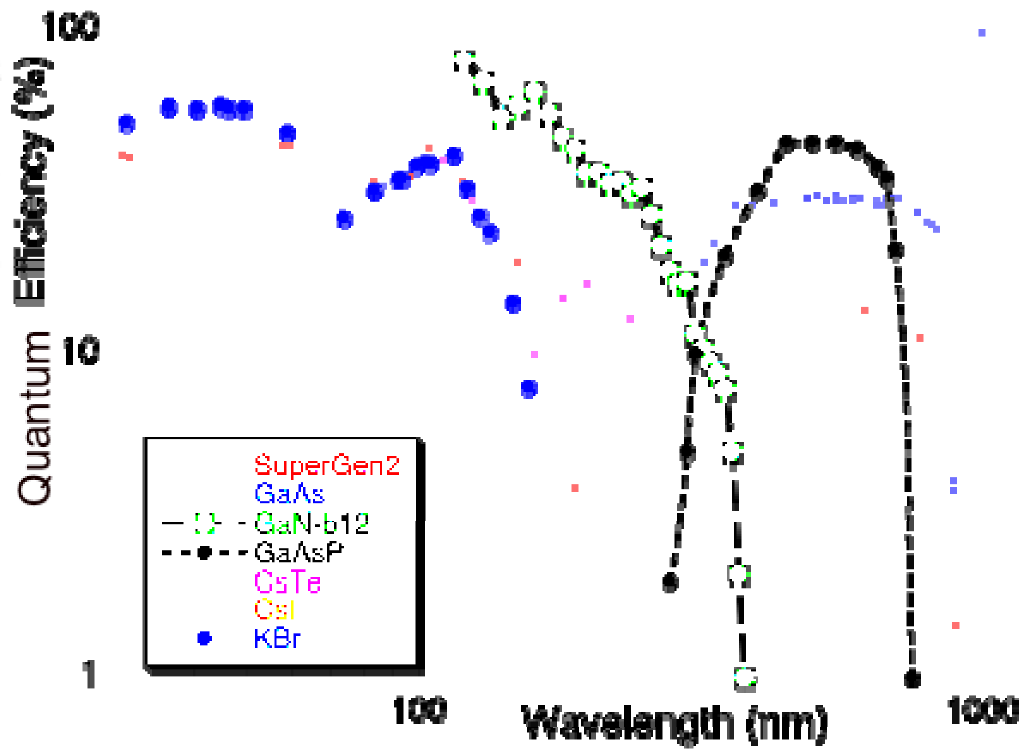
QDE for bare MCP with ALD secondary emissive layer, and with CsI deposited on top of this.

Photocathode Quantum Efficiency

QE for various photocathode materials, some opaque some semitransparent

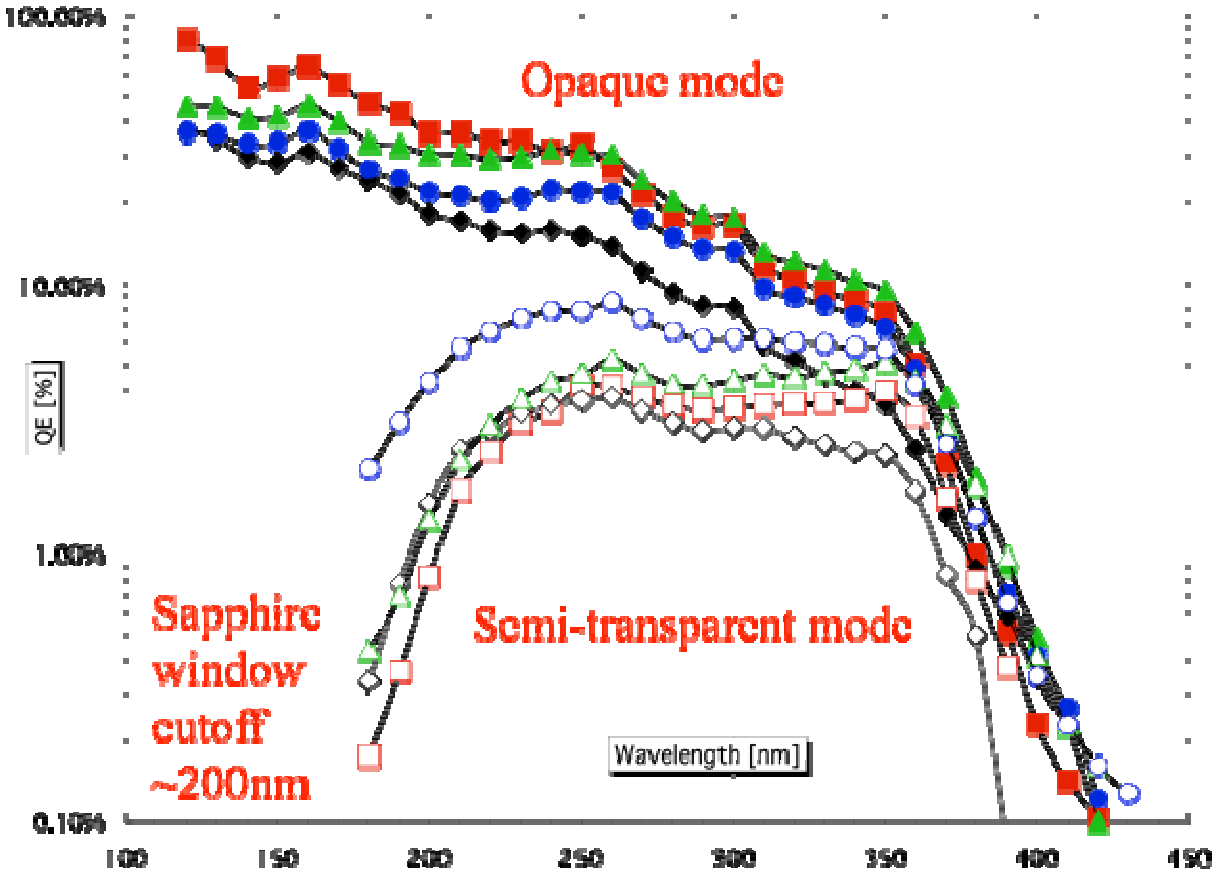


Recent improvements in bialkali cathodes, fills
The gap between GaN and GaAsP.
PHOTONIS – Clermont-Ferrand workshop 2010



Wide range of available materials with different long wavelength cutoffs. Considerable work in progress on GaN.

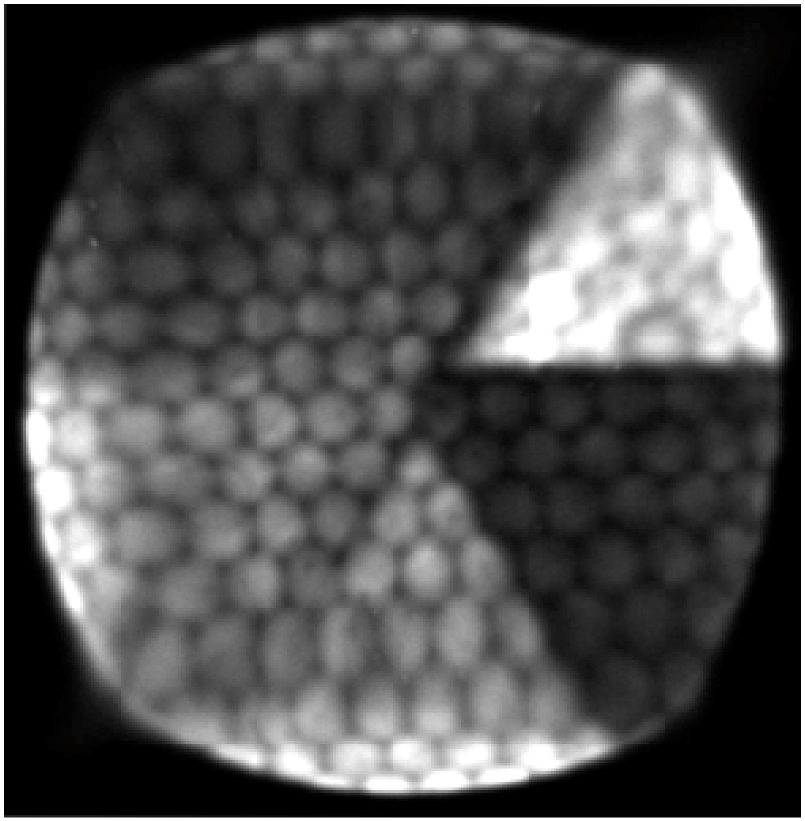
Opaque GaN Deposited on Sapphire



GaN semitransparent and opaque photocathode quantum efficiencies. The GaN is 150nm to 100nm thick with depth graded Mg concentration. The best semitransparent QE is for a substrate with only 50% GaN coverage - hence the achievable efficiency is probably closer to twice the measured values.

Opaque GaN Deposited on ALD MCPs

Borosilicate/ALD MCP coated by MBE with P-doped GaN/AlN of various thicknesses (amorphous/polycrystalline) and tested in a photon counting imaging detector



Integrated photon counting image using 184 nm UV shows unprocessed GaN layer response vs bare MCP.

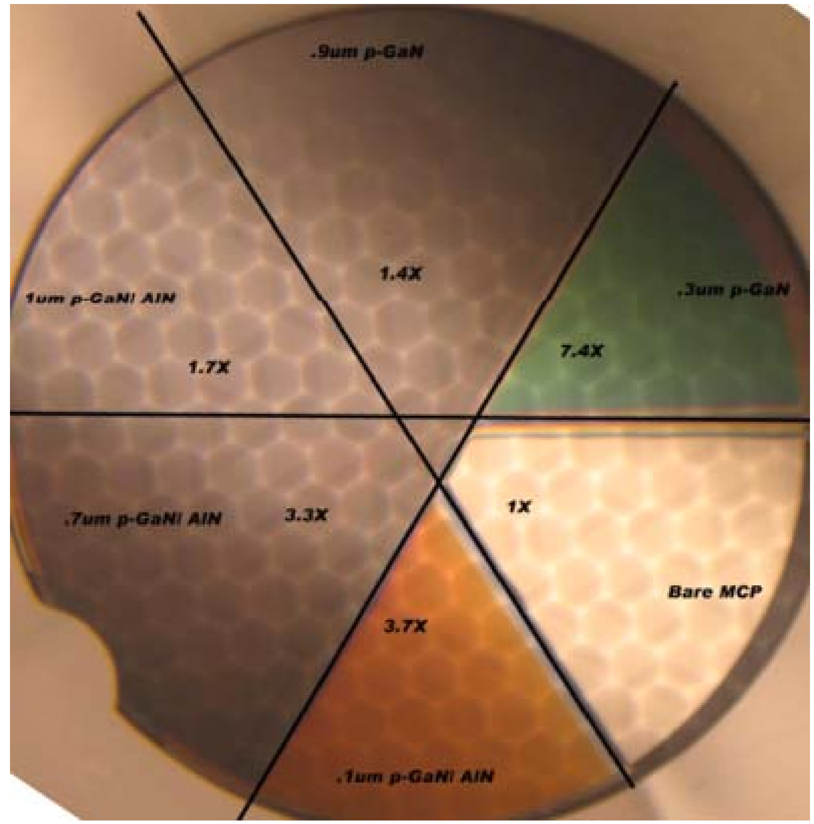
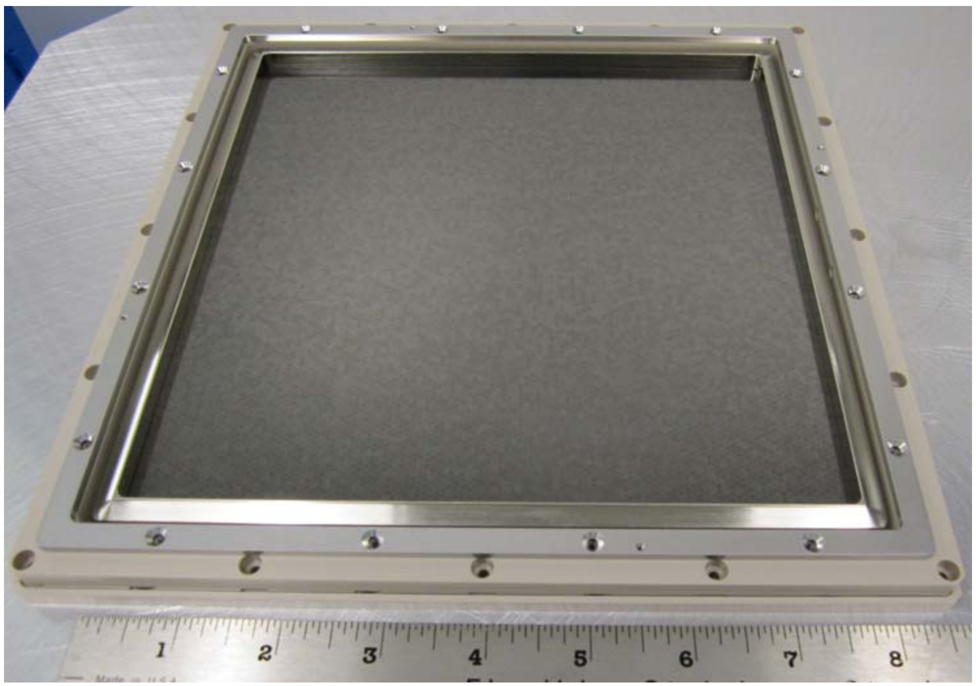


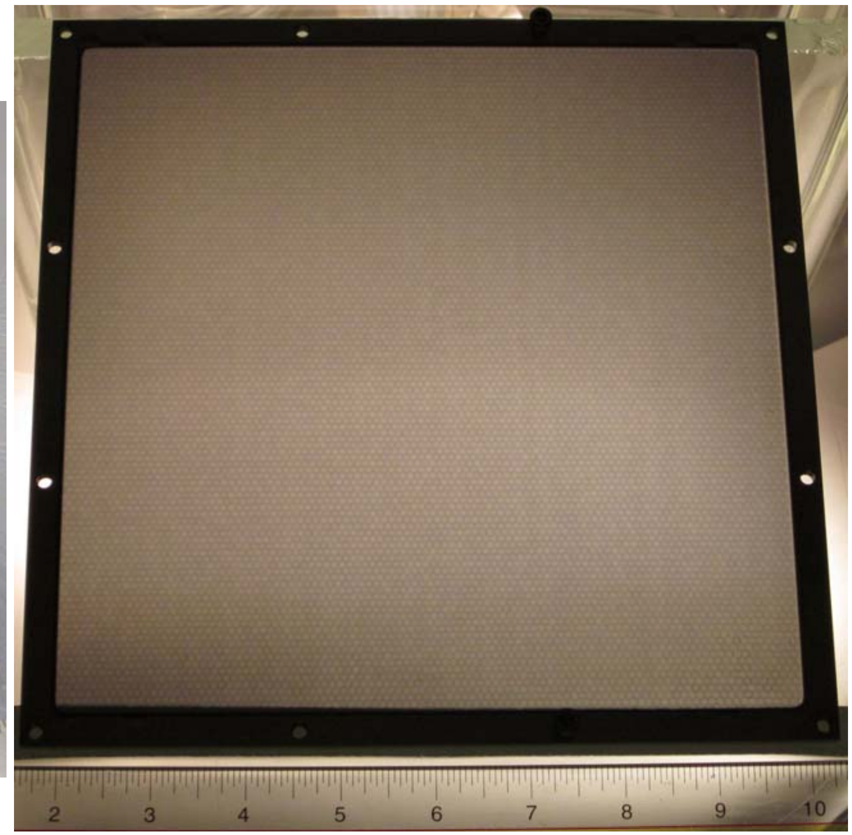
Photo of 20µm pore MCP with zones of different GaN thickness and structure, Deposited by SVT associates (A. Dabiran).

Progress with 20cm MCP Development

A small number of 20cm MCP substrates (20µm pore) have been functionalized by ALD at ANL and electroded at UCB-SSL. One has been tested in a detector specifically built to allow single MCPs, or pairs, to be evaluated.

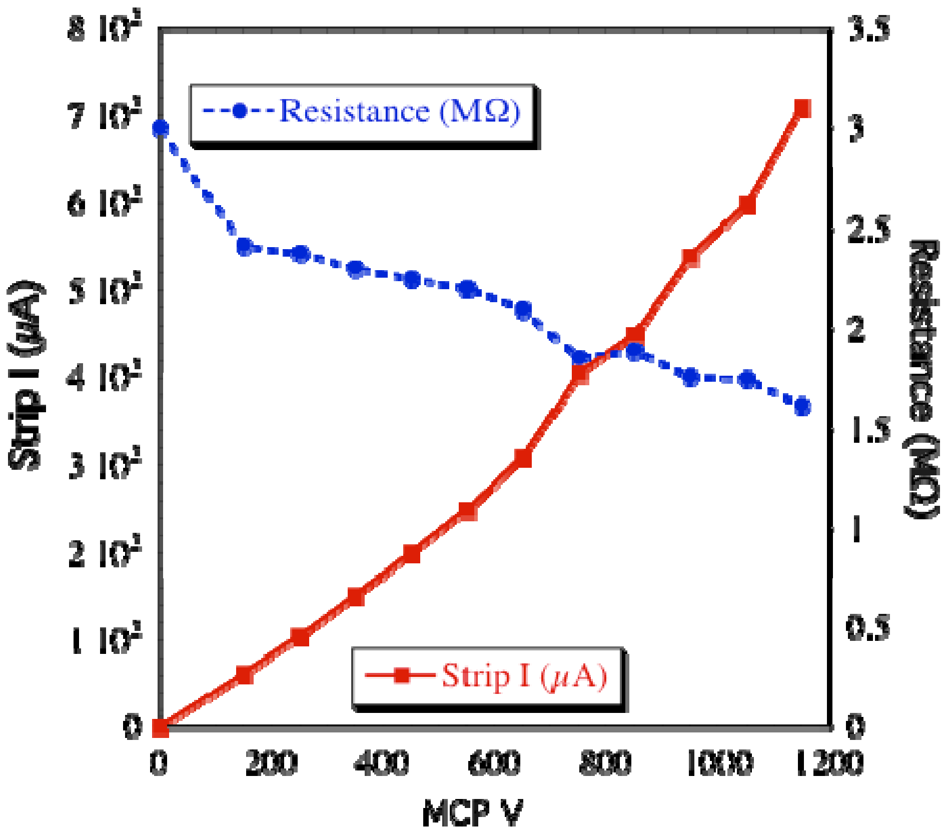


20cm electroded ALD 20µm pore MCP in detector assembly with a cross delay line imaging readout

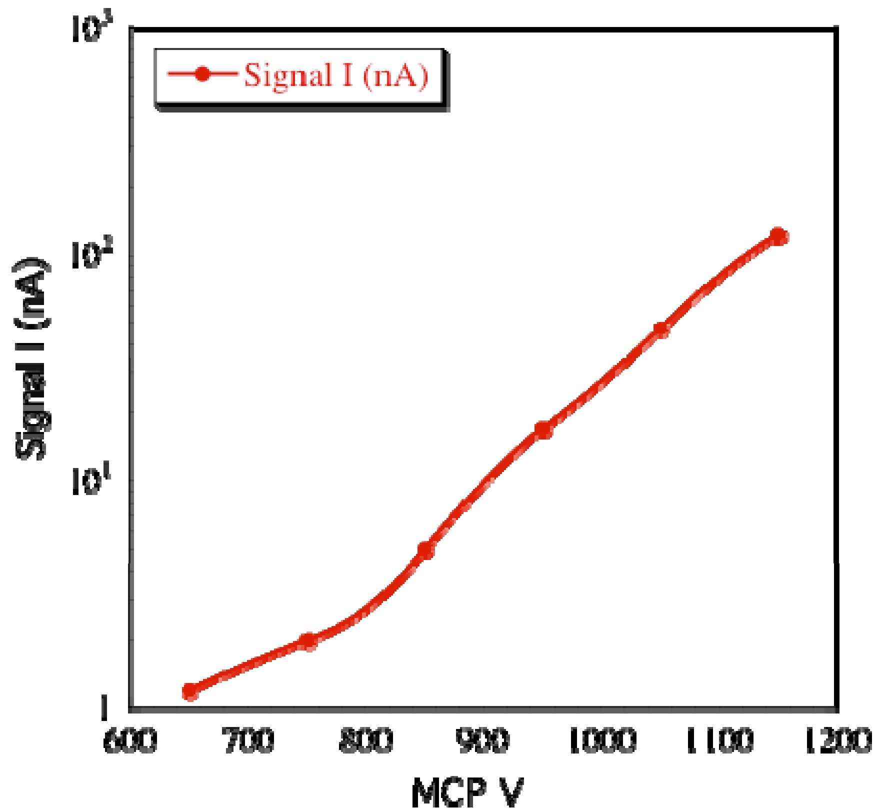


20cm MCP showing the multifiber stacking arrangement, 40µm pore, 8° bias.

Testing of 20cm, 20µm pore ALD-MCPs



20cm MCP strip current and resistance



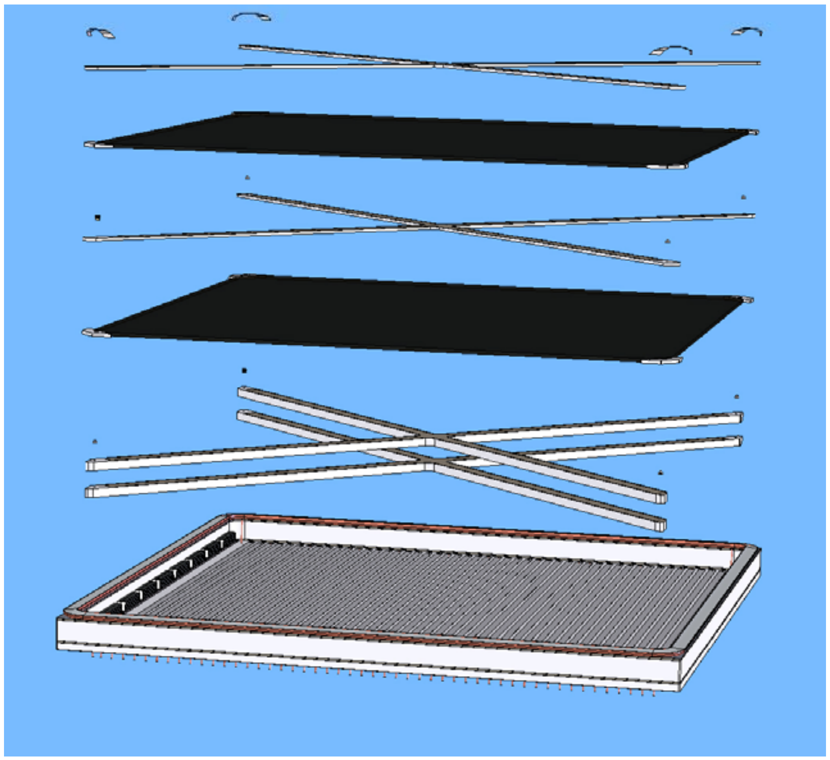
20cm MCP output signal v.s. V for UV input

An initial test with one 20cm, 20µm pore, 60:1 L/d ALD-MCP shows a normal MCP gain curve.The cross delay line detector accepts 2 MCPs and spacers. It will allow <200µm spatial resolution for MCP pairs, and permit full evaluation of 20cm MCPs.

Large Area Picosecond Photodetector

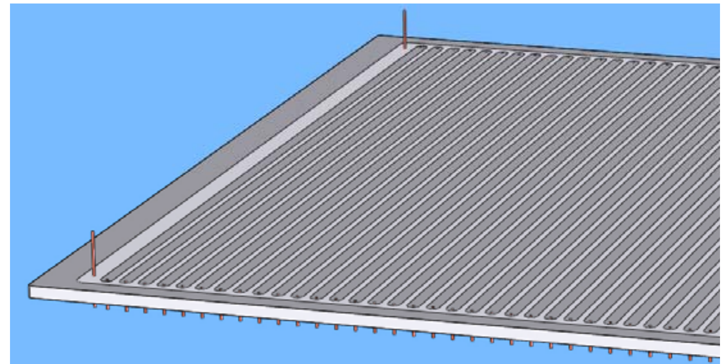
Brazed Body Assembly

The alumina/Kovar piece parts are brazed to form the hermetic package



Brazed Body Internal Parts Assembly

Into the body, we stack up getters and X-grid spacers and MCPs. X-grids register on HV pins, hold down MCPs, and distribute HV (via metallization contacts).



Anode

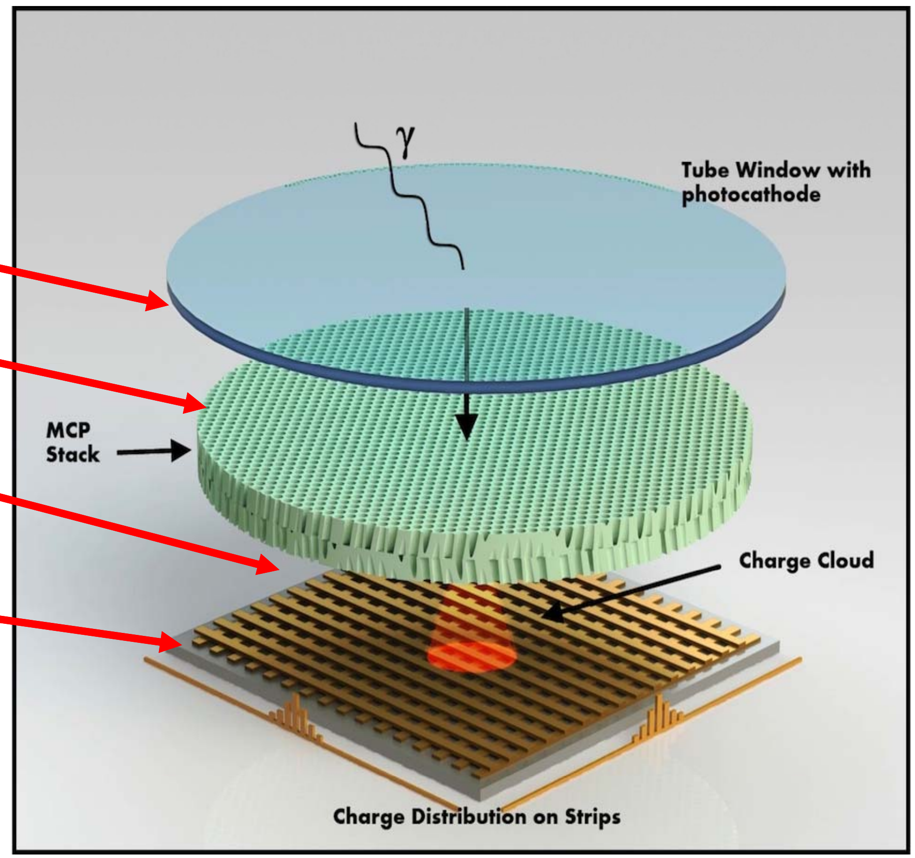
Alumina substrate with vias for signal/HV pins. 48 signal strips inside, complete GND plane outside. Signal & HV pins brazed in.

Ceramic body with Cu Indium well, 5mm thick B33 window and "blank" anode.

Cross Strip Anode MCP Detectors

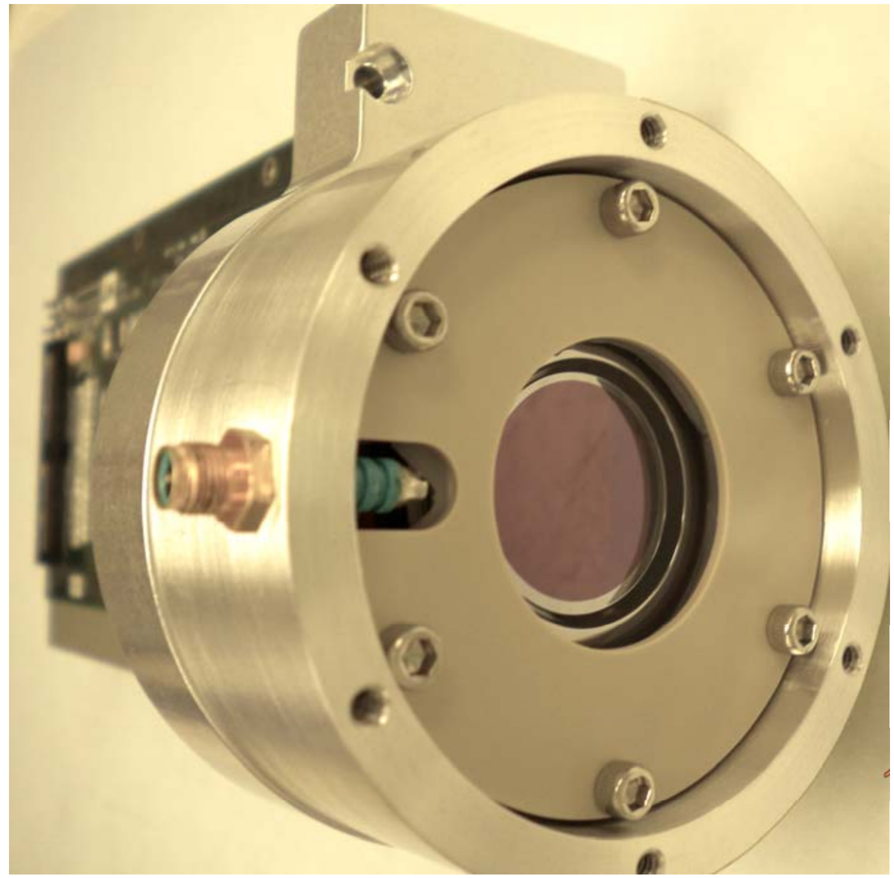
Charge divides between the two strip sets to give event centroids in X and Y
Uses lower gain (~5×10^5), works open face or in sealed tube configurations
< 15 µm FWHM spatial resolution, current formats from 22mm to 50mm, and 100mm
Current SMT electronics allows ~5 MHz event rates, ASIC electronics under development

- Photocathode converts photon to electron
- MCP(s) amplify electron by 10^4 to 10^5
- Rear field accelerates electrons to anode
- Strip anode encodes charge cloud



Cross Strip Anode MCP Detectors

50 mm Cross Strip anode open face detector, MCPs not installed.



22mm Cross Strip anode sealed tube in housing with front end amplifier