ADVANCES IN MICROCHANNEL PLATES AND PHOTOCATHODES FOR ULTRAVIOLET PHOTON COUNTING DETECTORS

O.H.W. Siegmund[a], K. Fujiwara[a], R. Hemphill[a], S.R. Jelinsky[a], J.B. McPhate[a], A.S. Tremsin[a], J.V. Vallerga[a], H.J. Frisch[b], J. Elam[c], A. Mane[c], D.C. Bennis[d], C.A. Craven[d], M.A. Deterando[d], J.R. Escolas[d], M.J. Minot[d], J.M. Renaud[d],

[a]Experimental Astrophysics Group, Space Sciences Laboratory, 7 Gauss Way, University of California, Berkeley, CA 94720

[b]Enrico Fermi Institute, 5640 S. Ellis Ave. University of Chicago, Chicago, Il 60637

[c] Argonne National Laboratory, 9700 S. Cass Ave. Argonne, Il 60439

[d]Incom, Inc. 294 Southbridge Road, Charlton, MA 01507

Atomic Layer Deposition – Borosilicate Glass Microchannel plate Development Efforts

Concept

Use borosilicate microcapillary array as a substrate and coat with an atomic layer deposited resistive layer and secondary electron emissive to functionalize the microchannel plate.

Large Area Picosecond Photodetector Program

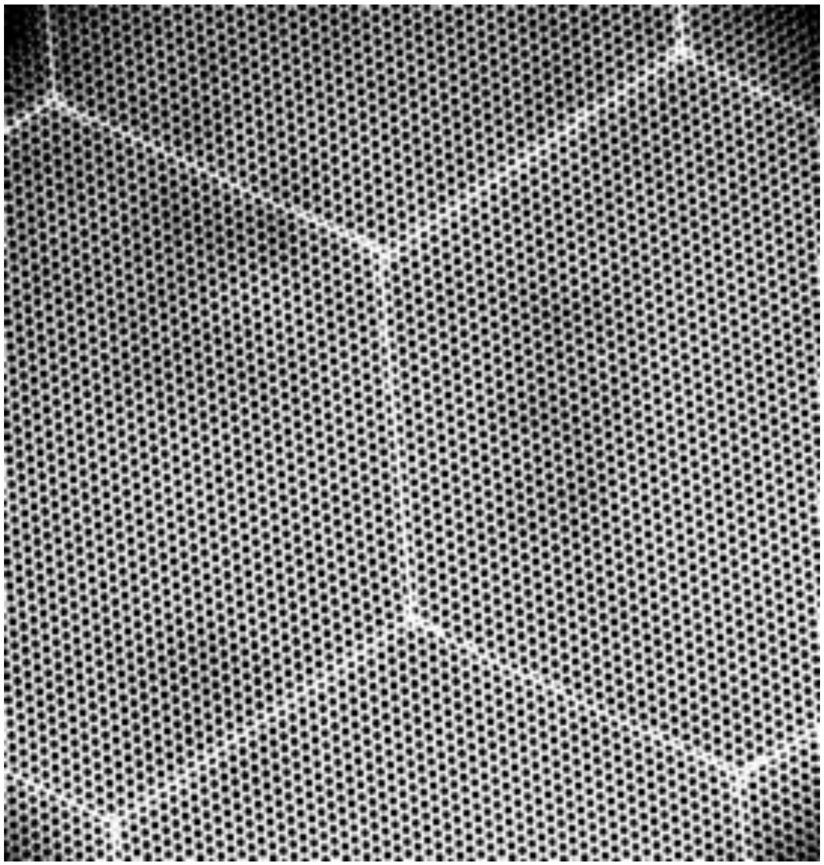
Major effort at Argonne National Lab., U. Chicago, UC Berkeley and several other National Labs, Universities and Industry to develop large area (8") microchannel plates and employ them in sealed tube sensors with optical photocathodes for high speed timing/imaging applications in High Energy Physics, Astronomy, etc.

NASA APRA – Nanoengineered MCPs for Astrophysics

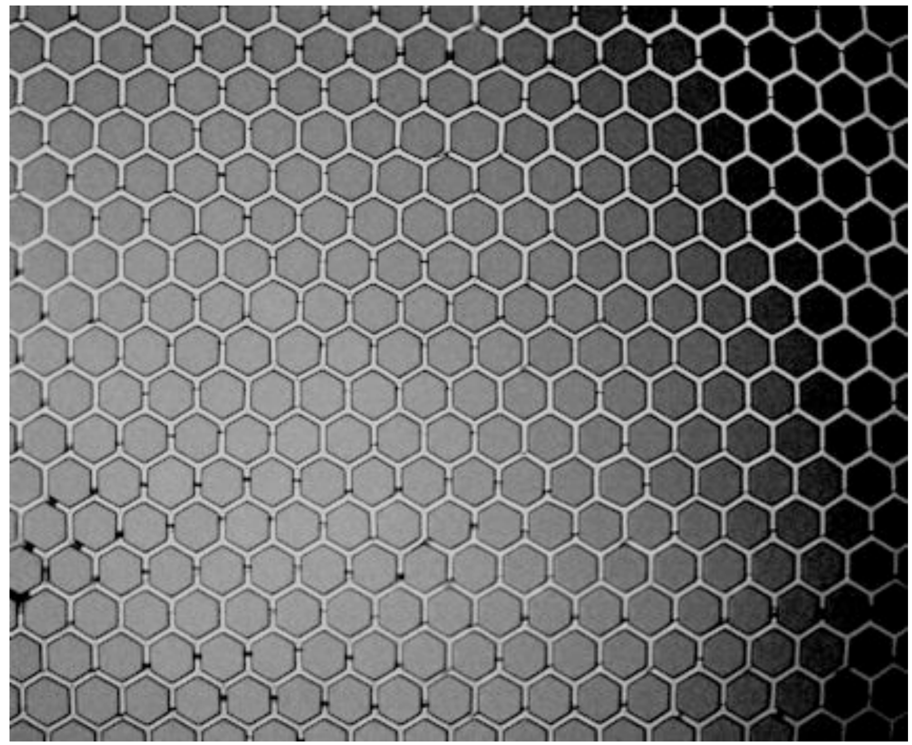
Development study to produce small pore, large area MCPs with borosilicate glass substrates and ALD, with high quality imaging, high spatial resolution, low background and high QDE (compatibility with high temperature photocathode depositions).

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

Borosilicate Substrate Atomic Layer Deposited Microchannel Plates

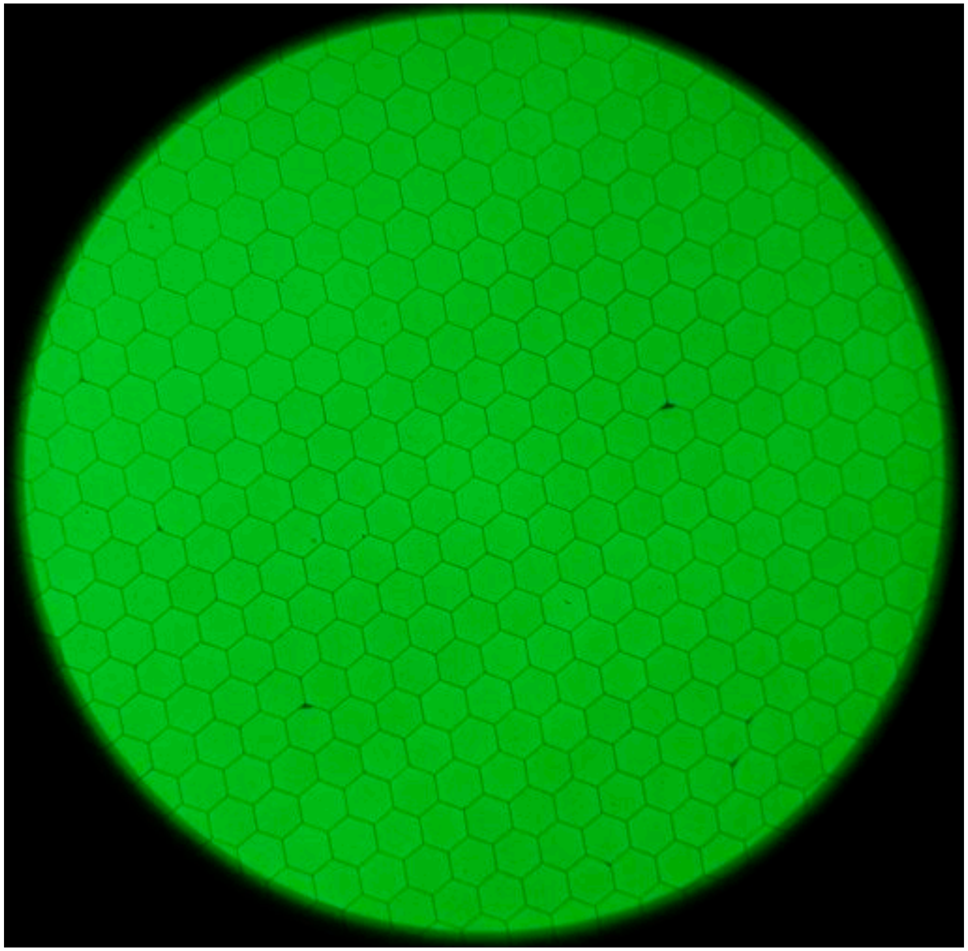
Micro-capillary arrays (Incom) with 20 µm or 40µm pores (8° bias) made with borosilicate glass. Resistive and secondary emissive layers are applied (Argonne Lab, Arradiance) to allow these to function as MCP electron multipliers. Each step is separately engineered/optimized.

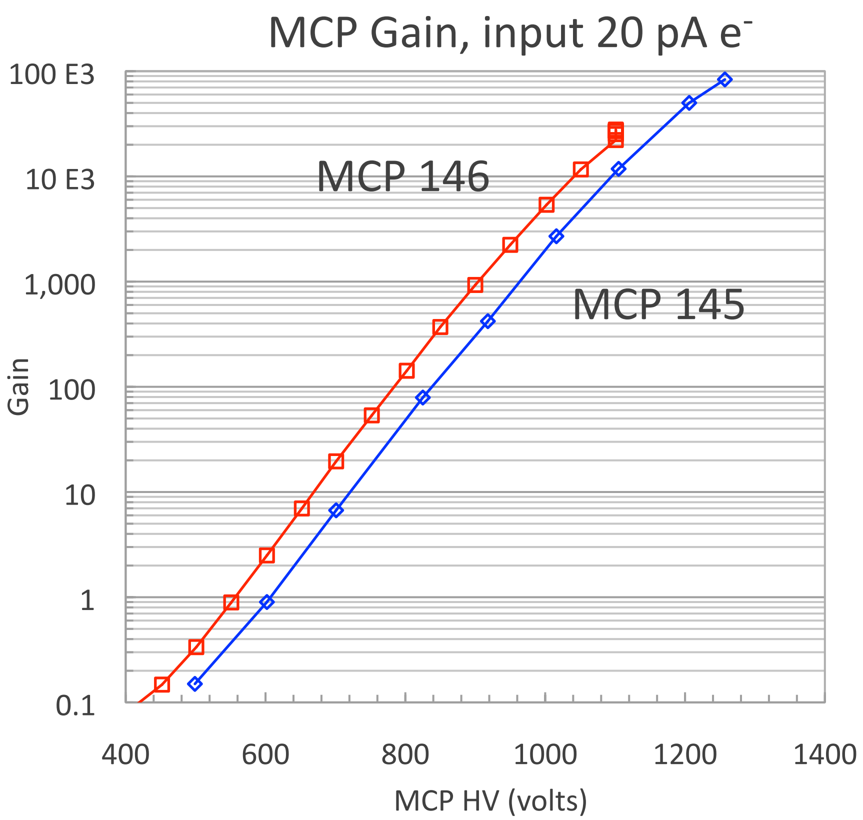
Visible light transmission for a 20 µm pore borosilicate micro-capillary ALD MCP .

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.

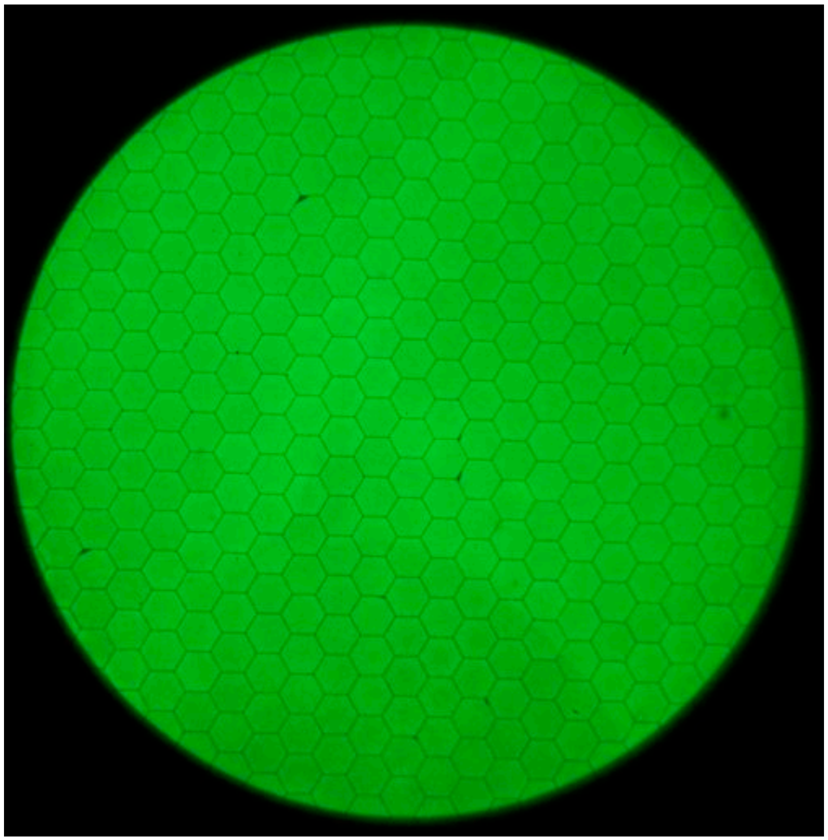




Single MCP tests in DC amplification mode show imaging and gain very similar to conventional MCPs. Sample imaging performance has improved dramatically over the last 12 months due to process improvements.

Robustness of ALD MCPs, 33mm

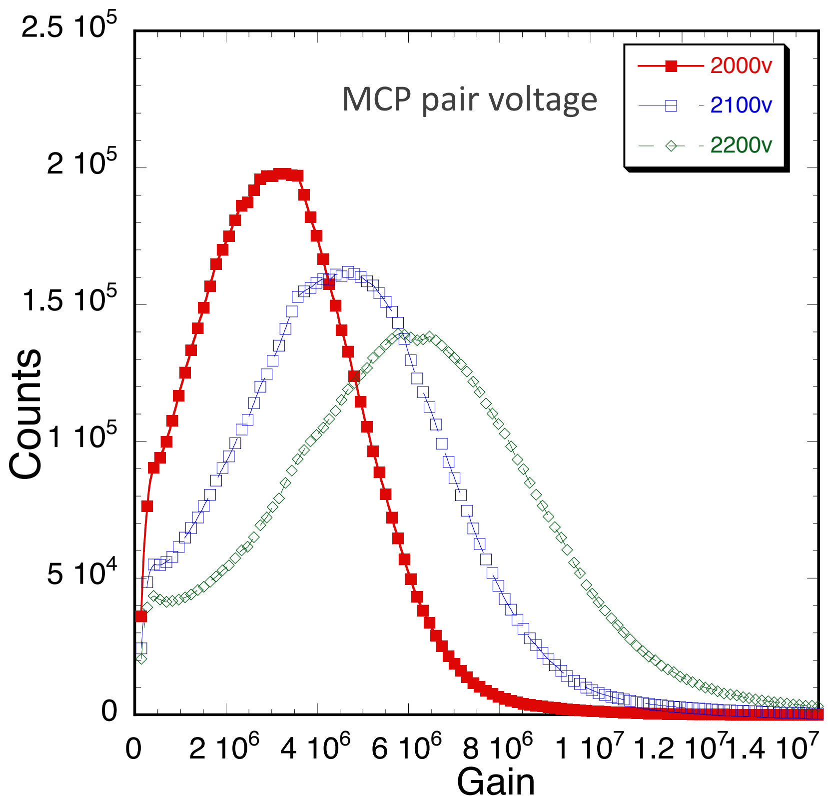
Conventional MCPs are highly likely to be physically damaged by high voltage breakdown events. We had a phosphor screen failure that damaged an ALD functionalized borosilicate glass MCP. Inspection showed no melting of the pores!



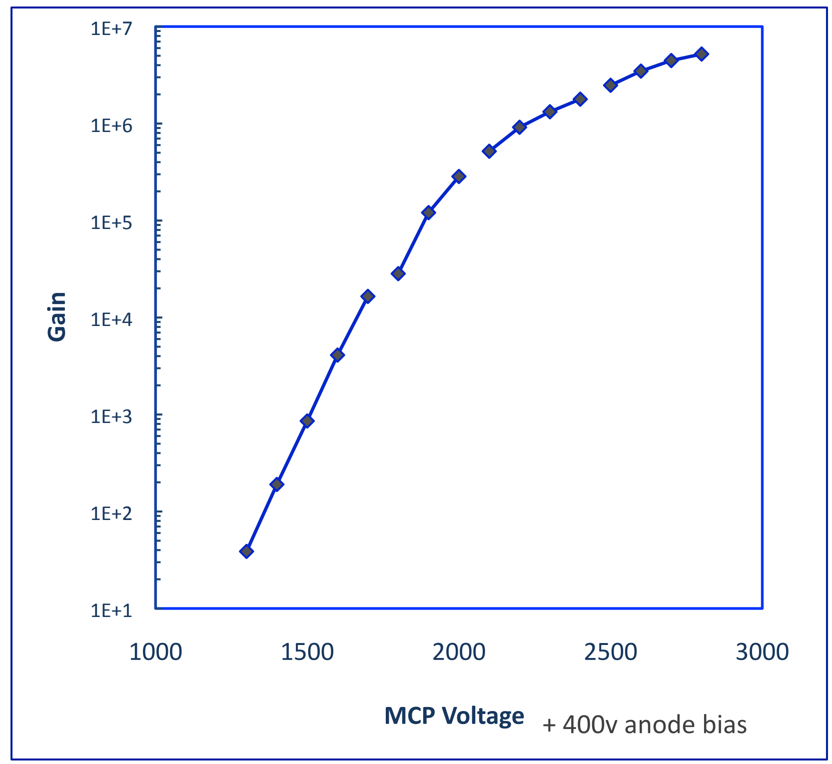
An additional electrode layer was applied on top of the damaged face and then tested in our phosphor detector – no sign of any damage in the image!!!

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.

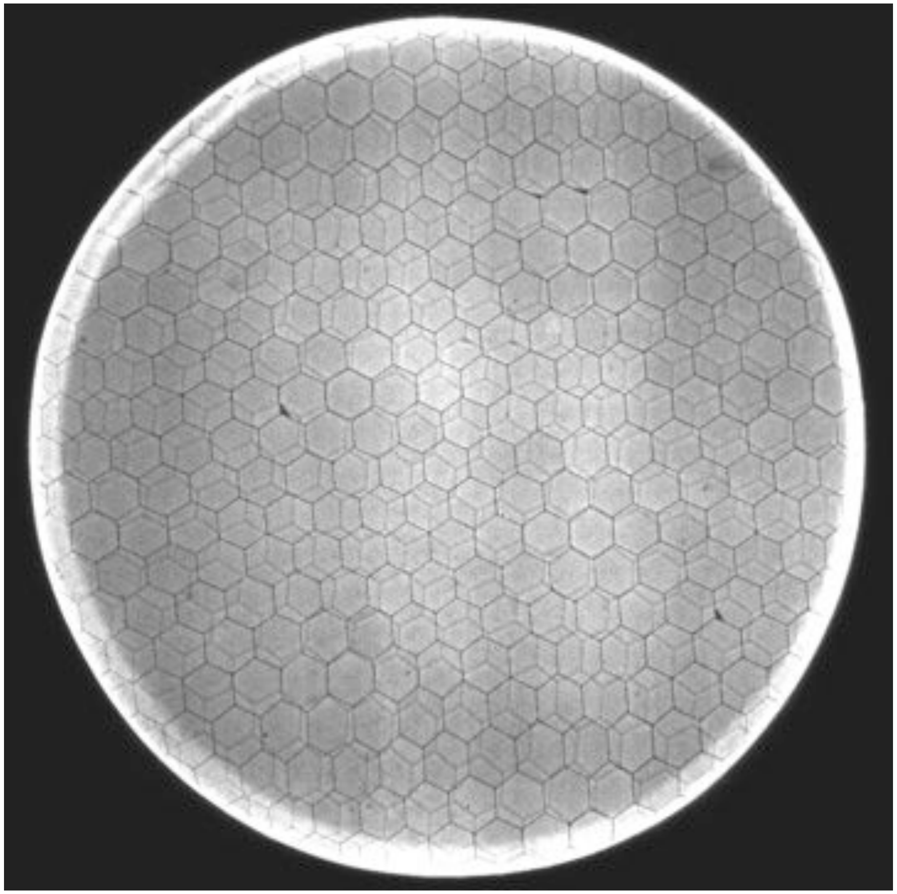
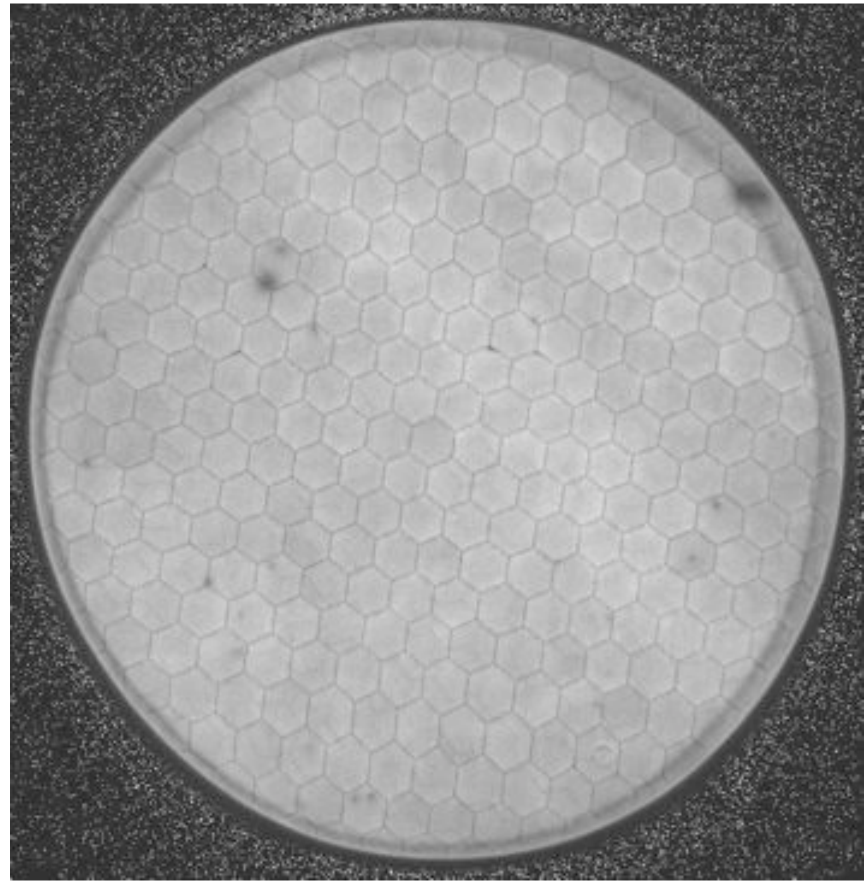


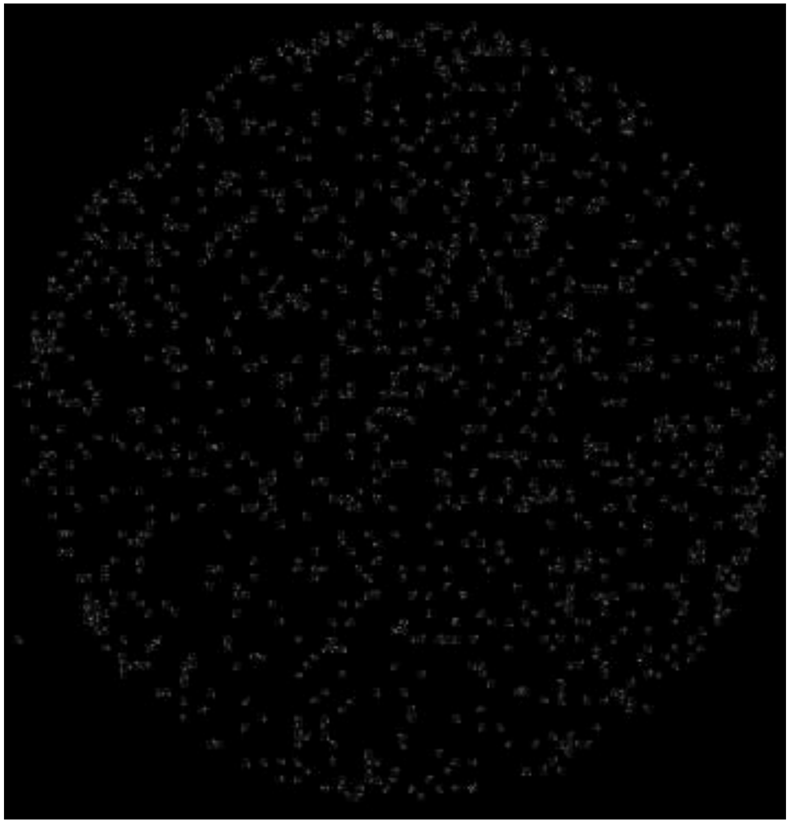
Image of 185nm UV light, shows top MCP hex modulation (sharp) and faint MCP hexagonal modulation from bottom MCP. A few defects, but generally very good. Edge effects are field fringing due to the MCP support flange.

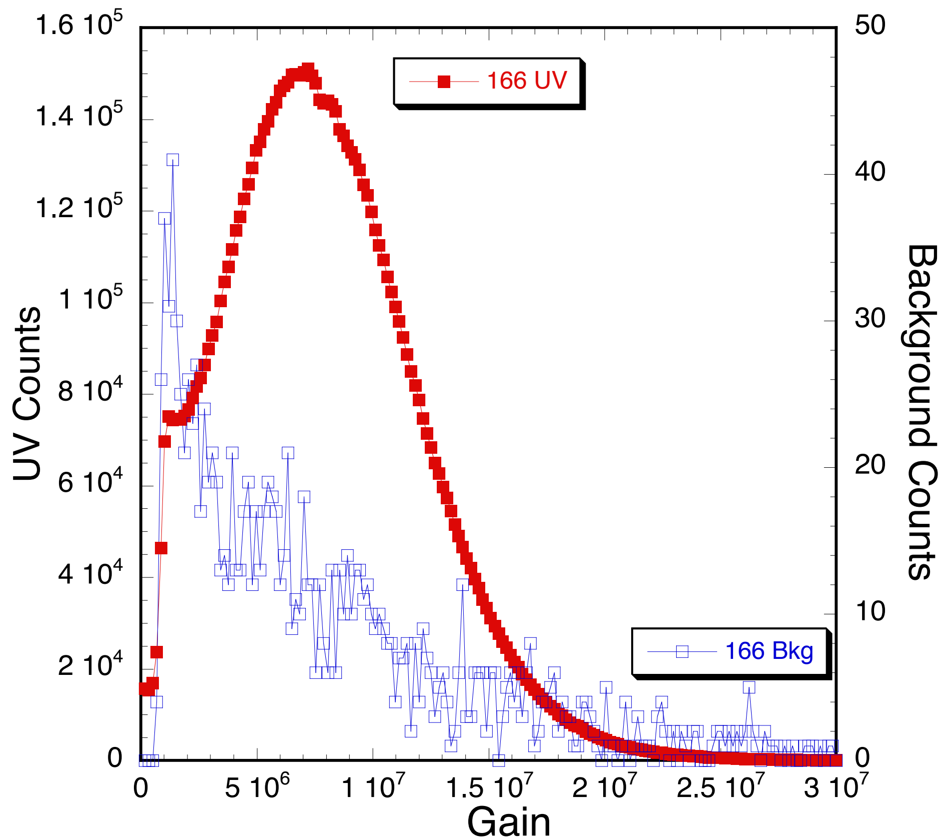


Gain map (average gain), shows top MCP hex modulation (sharp) and a few spots where the gain is low.

ALD-MCP Background Rate

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





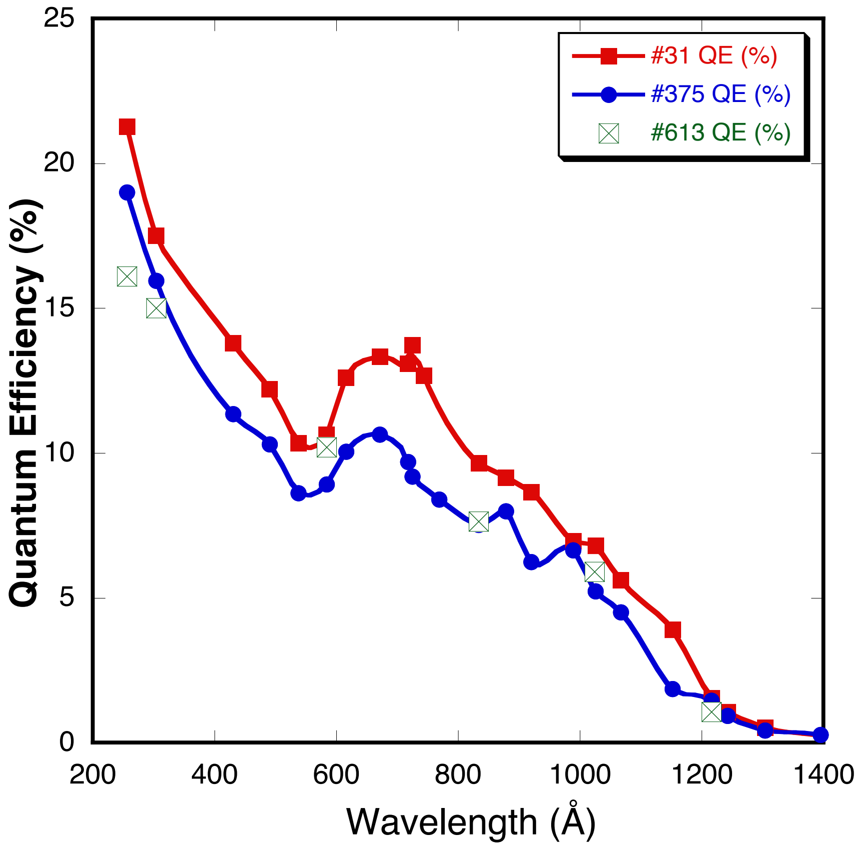
3000 sec background, 0.0845 events cm^{-2} sec^{-1}. at 7 x 10^6 gain, 1050v bias on each MCP. Get same behavior for all of the current 20µm MCPs

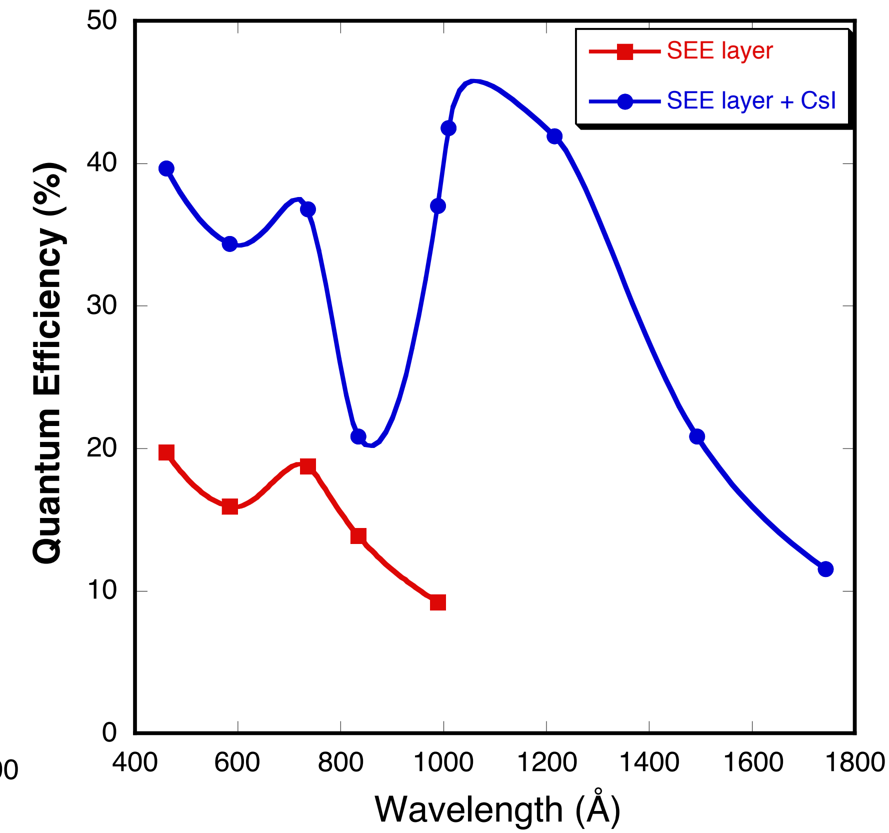
Pulse amplitude distributions for UV 185nm, and for background events.

ALD-MCP Quantum Efficiency

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

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



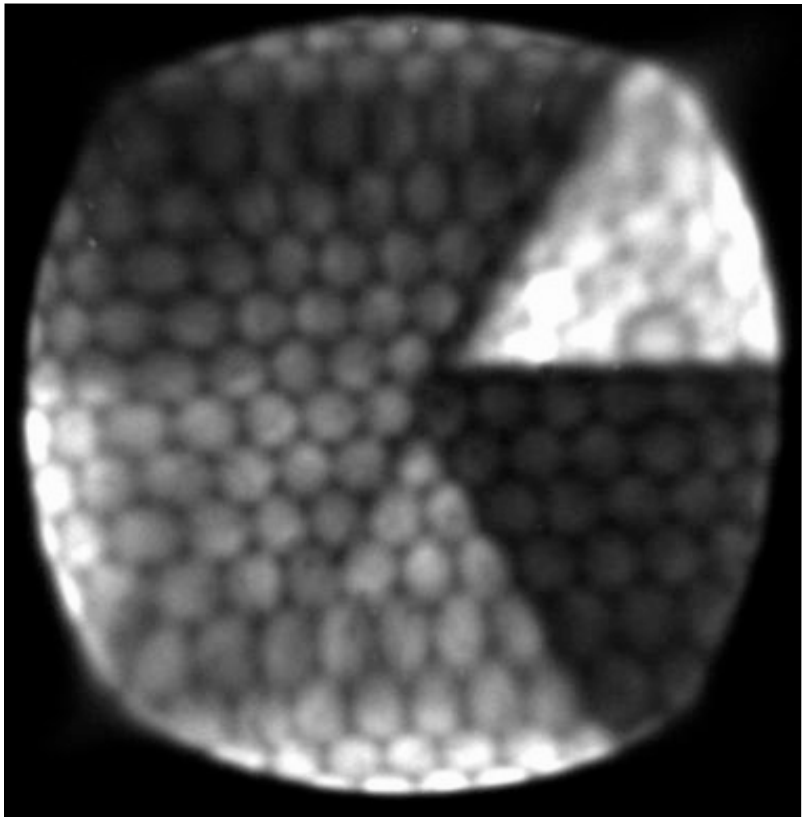


#375 & #613 MCP pairs, 20µm pores, 8° bias, 60:1 L/d, 60% OAR. #31 MCP pair, 40µm pores 8° bias, 60:1 L/d, 83% OAR, shows higher QDE.

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

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.

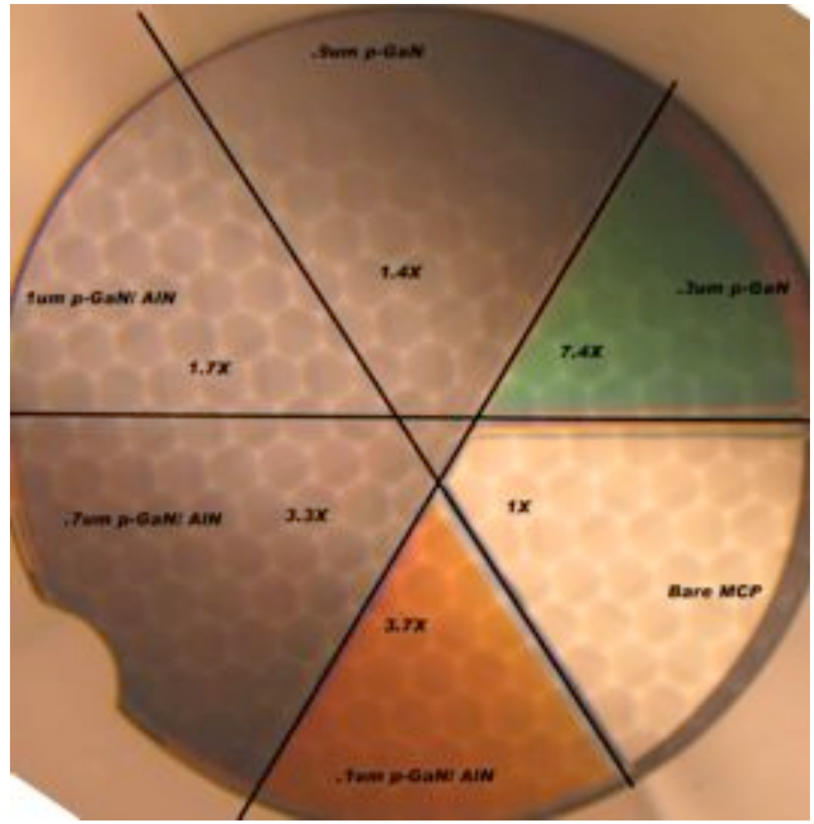
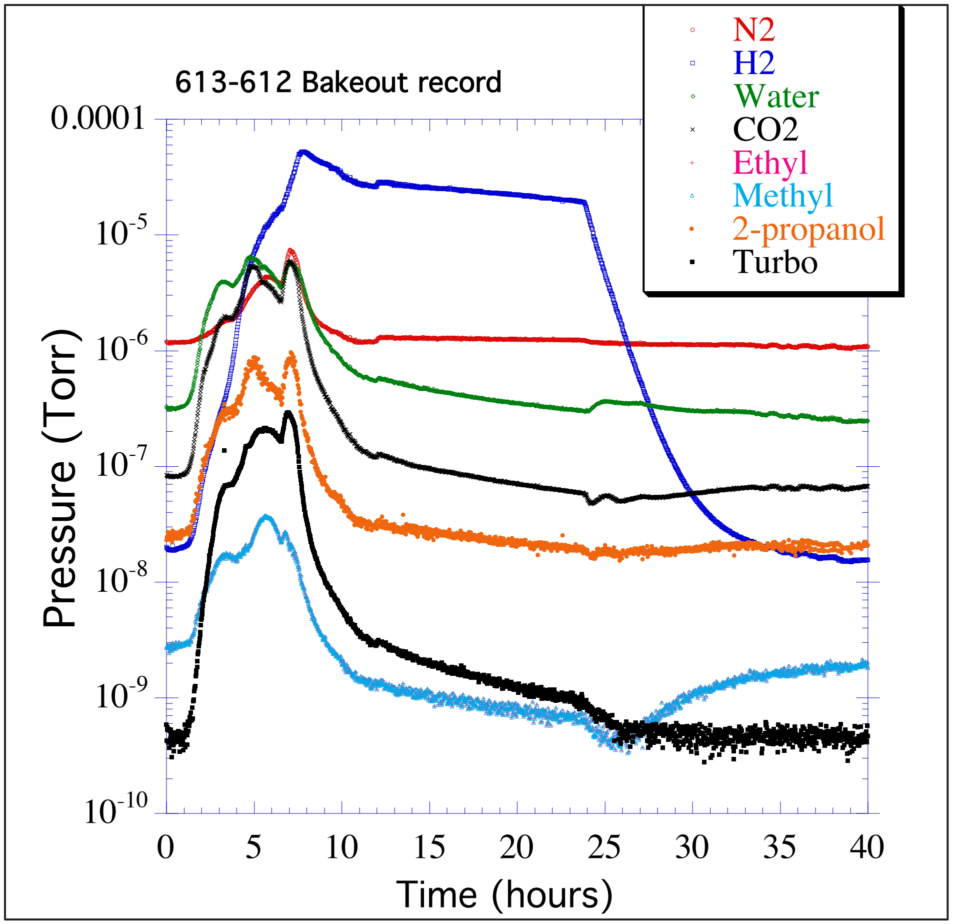


Photo of 20µm pore MCP with zones of different GaN thickness and structure, Deposited by SVT associates (A. Dabiran).

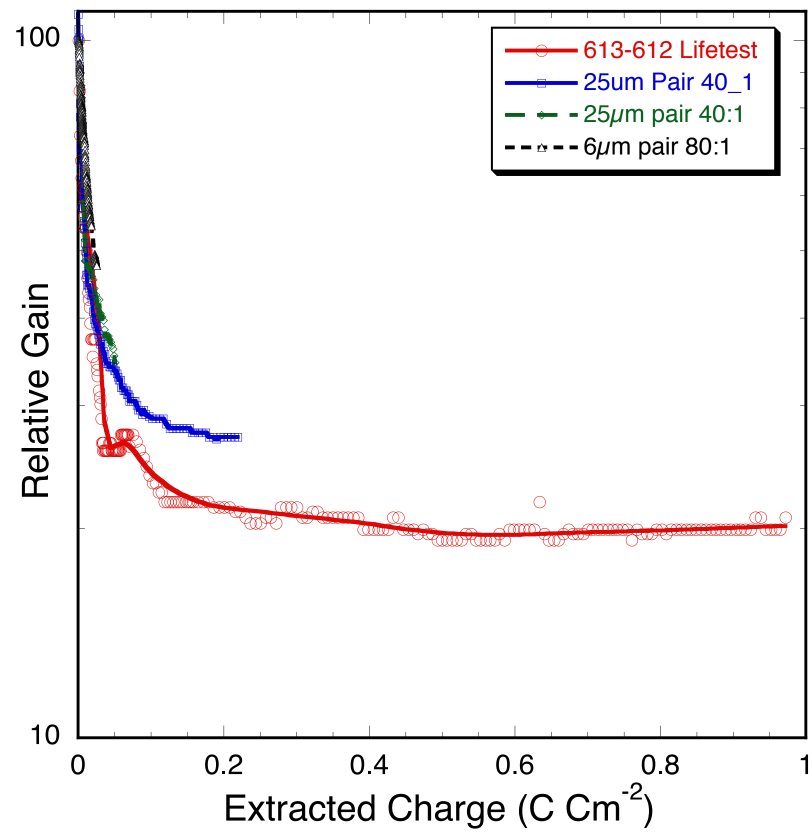
33mm ALD-MCP Preconditioning Tests

350°C bakeout with RGA monitoring



RGA monitoring of MCP pair (20µm pore, 60:1 L/d, 8° bias) 350°C bakeout.

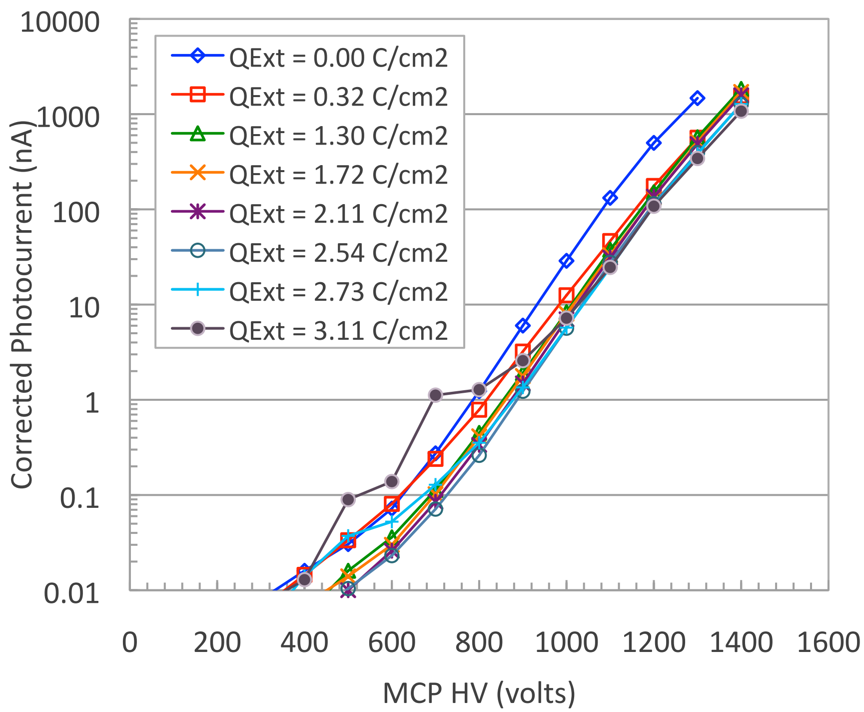
Scrubbing with UV after 350°C bake



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

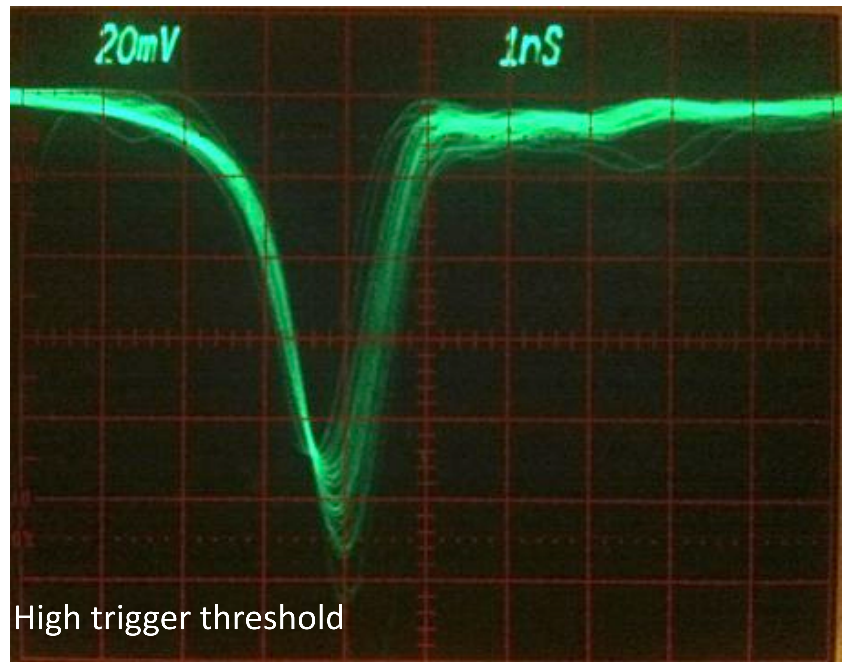
33mm ALD-MCP Scrubbing & Timing Tests

Ageing test after 150°C bake



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

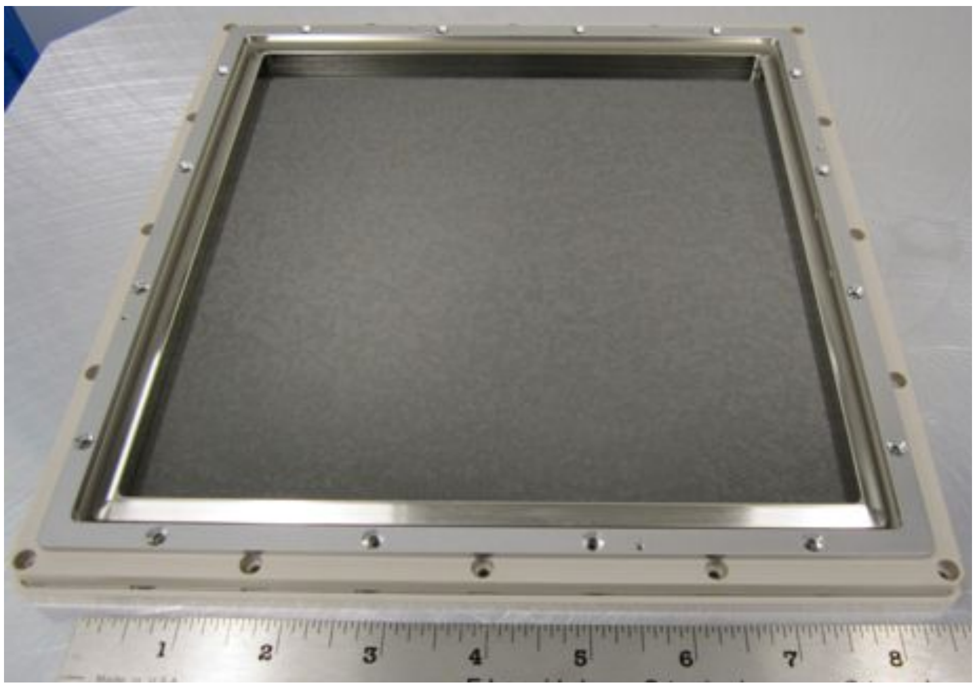
Anode Pulse Shape



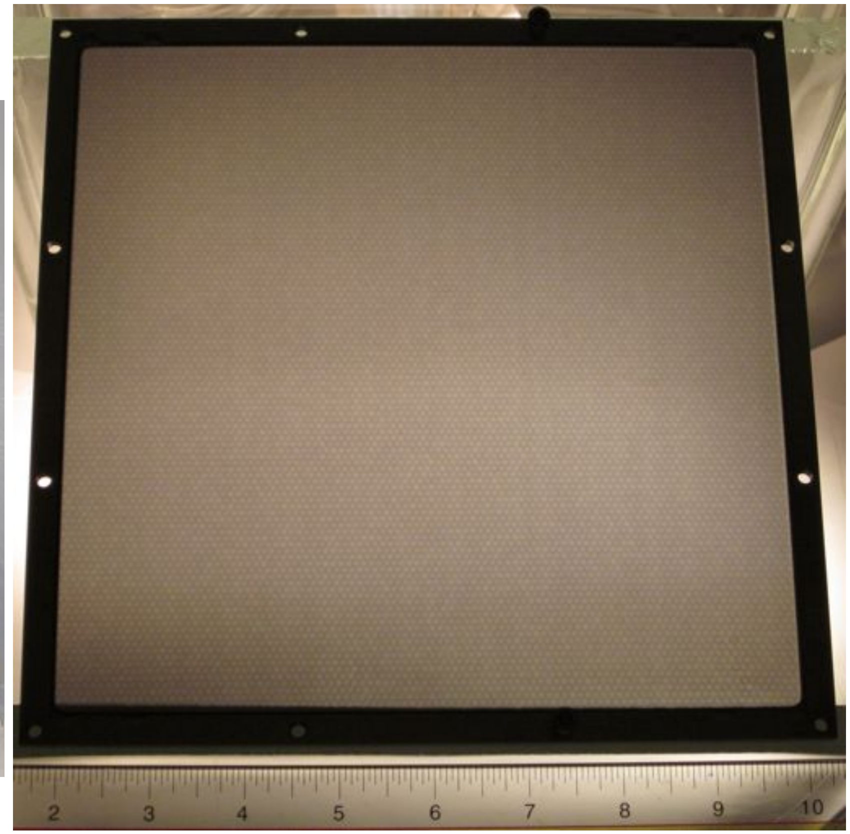
ALD borosilicate MCP pair, 20µm pore, 60:1 L/d, 8° bias, 0.7mm/1000v MCP gap. Single event pulses are ~1ns wide, limited by scope bandwidth (1GHz).

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.

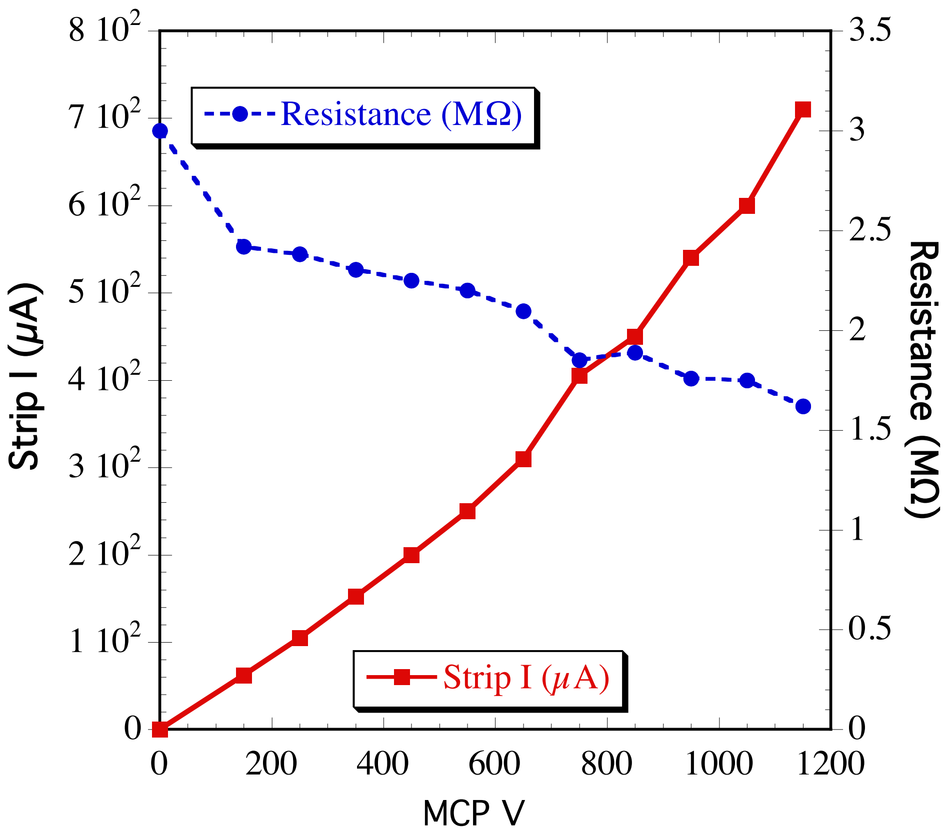


20cm electroded ALD 20µm pore MCP in detector assembly with a cross delay line imaging readout

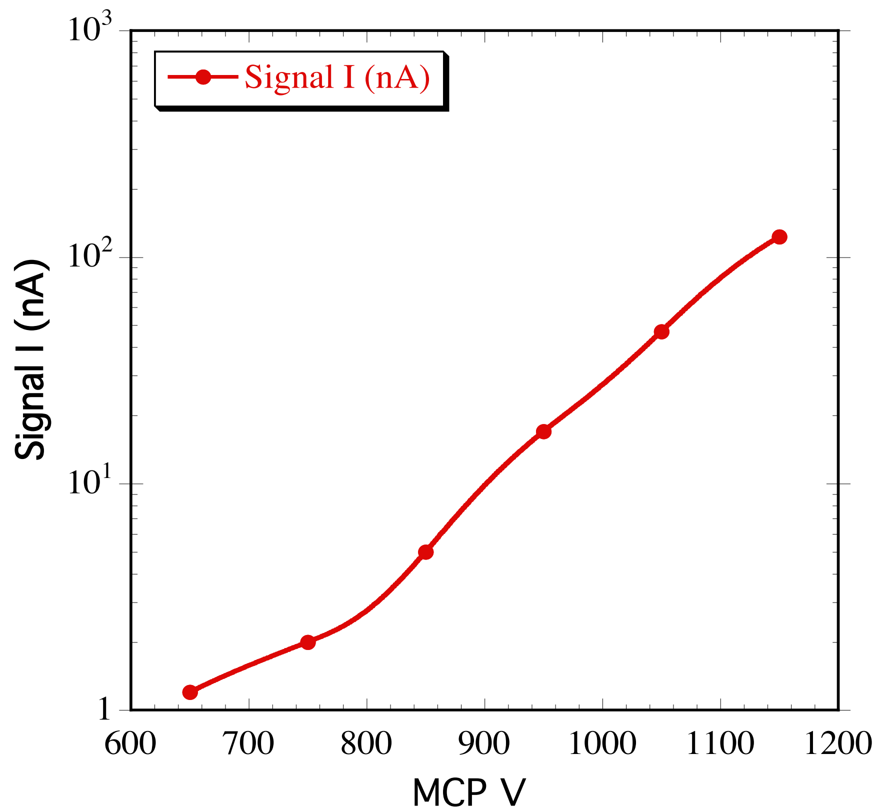


20cm MCP showing the multifiber stacking arrangement, 40µm pore, 8° bias.

Testing of 20cm, 20µm pore ALD-MCPs



20cm MCP strip current and resistance

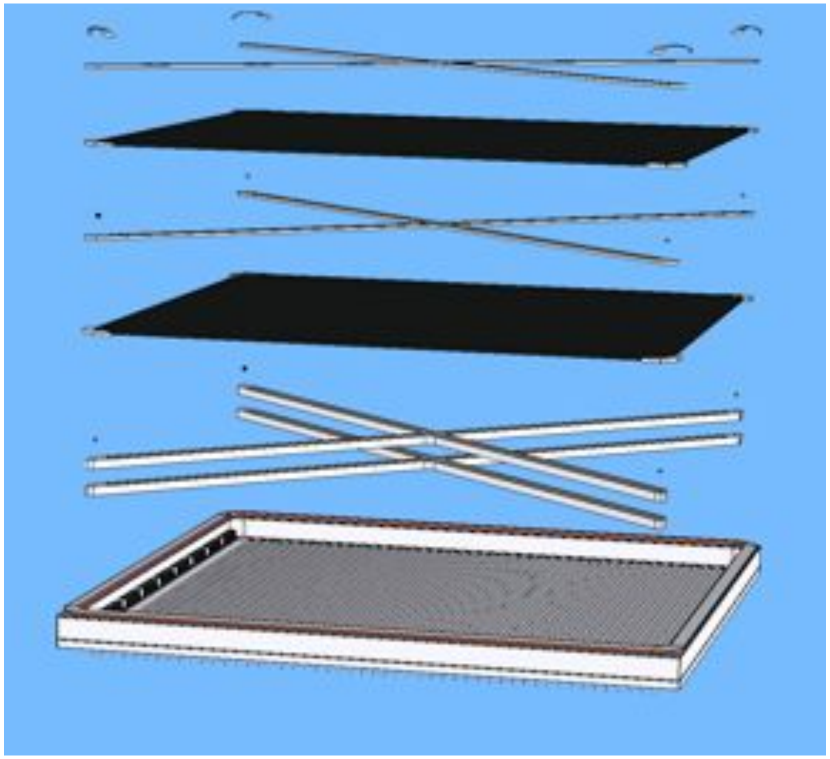


20cm MCP output signal v.s. V for UV input

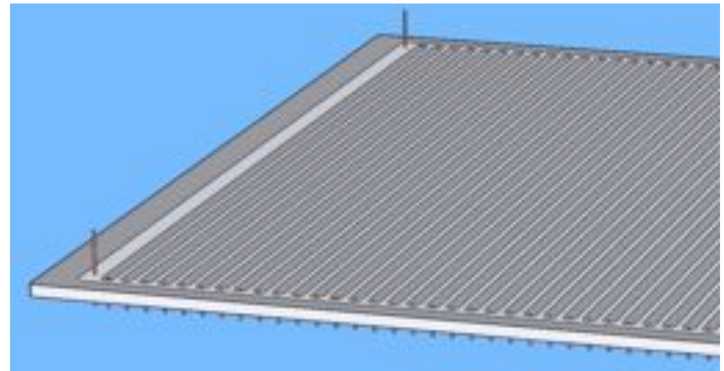
An initial test with one 20cm, 20µm pore, 60:1 L/d ALD-MCP shows a normal MCP gain curve.The cross delay line detector accepts 2 MCPs and spacers. It will allow <200µm spatial resolution for MCP pairs, and permit full evaluation of 20cm MCPs.

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.

ALD-Borosilicate Microchannel Plate Summary

- ALD functionalized MCPs using borosilicate glass microcapillary arrays have been successfully made in 33mm and 20cm formats with 20µm and 40µm pores and 8° bias.
- Tests indicate that many of the performance characteristics are similar to standard commercial MCPs both in analog and photon counting modes, and can accommodate opaque GaN cathodes.
- MCP preconditioning shows good stability.
- Initial 20cm, 20µm pore MCPs show normal gain behavior.
- Background rates are low, <0.1 events cm^{-2} sec^{-1}.
- Design and fabrication of 20cm sealed tube is well advanced and we have made semitransparent Bialkali (25%) cathodes.

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