Advances in Microchannel Plates for Sealed Tube Detectors

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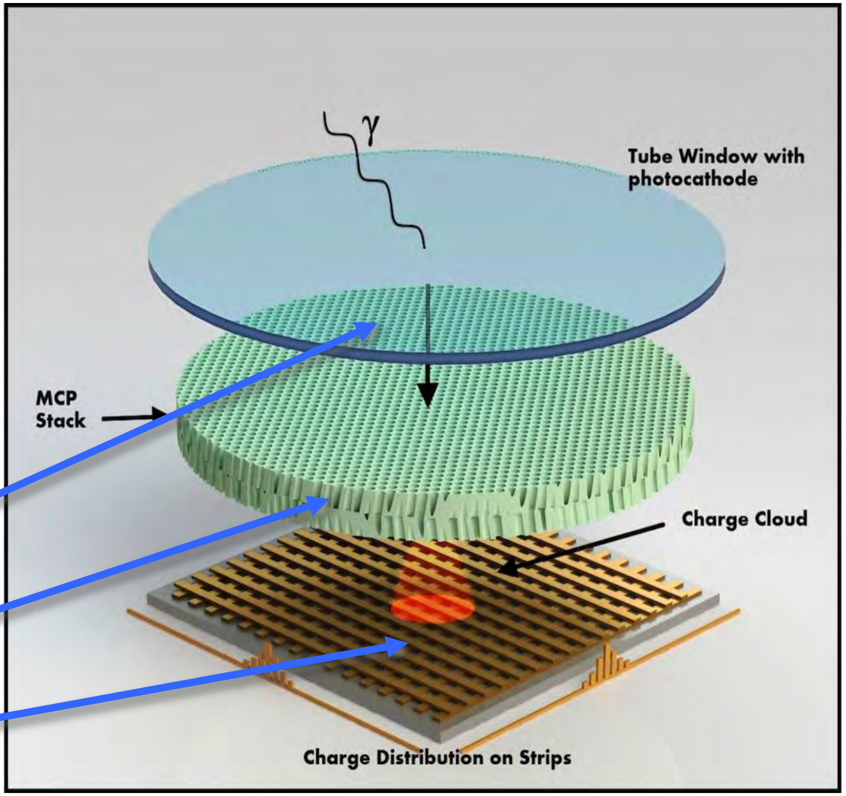
Sealed Tube MCP Photon Counters

Large Area Picosecond Photodetector Program (DOE)

Major effort at Argonne National Lab., U. Chicago, UC Berkeley and several other National Labs, Universities and Industry to develop large area (20cm) sealed tube sensors with optical photo-cathodes and novel microchannel plates and employ them for high speed timing/imaging applications in High Energy Physics, RICH, Astronomy, etc.

Concept

Proximity focused bialkali cathode, borosilicate microcapillary array with atomic layer deposited resistive layer and secondary electron emissive layer to make a microchannel plate, strip-line anode with ASIC amp/disc for picosecond resolution.



Photocathode on window or MCP converts photon to electron

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

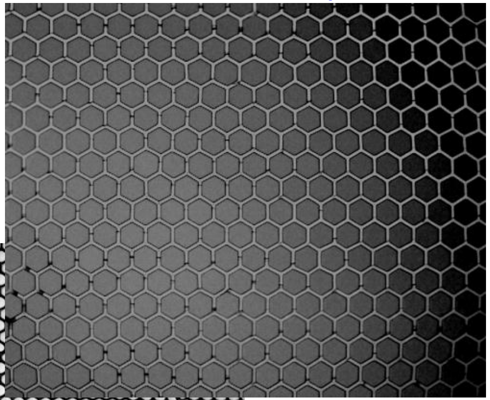
Strip-line anode measures charge position

Borosilicate Substrate Atomic Layer Deposited Microchannel Plates

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. Resistive and secondary emissive layers are applied (Argonne Lab, Arradiance) to allow these to function as MCP electron multipliers.

Visible light transmission for a 20 µm pore borosilicate micro-capillary ALD 33mm MCP. Pore distortions at multifiber boundaries, otherwise very uniform.

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



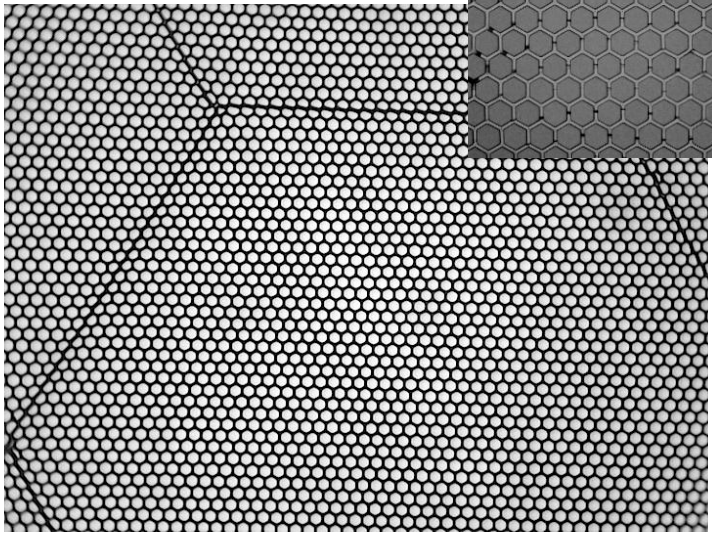


Photo of a 20 µm pore, 65% open area borosilicate micro-capillary ALD MCP (20cm).

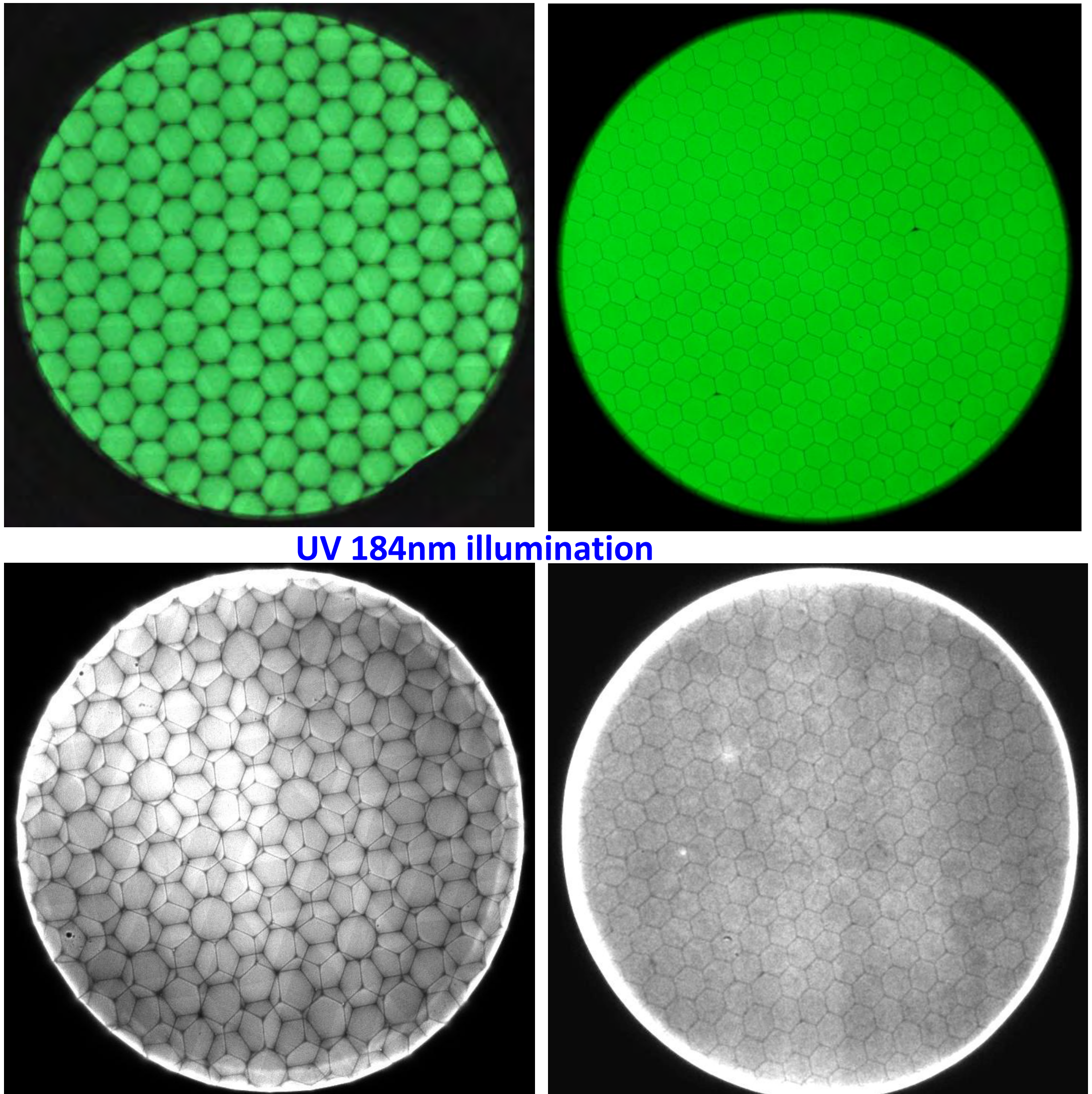
Imaging Performance of ALD MCPs, 33mm

Early 2010 | Early 2011

1 MCP, Phosphor readout

UV 184nm illumination

2 MCPs, Photon counting



20µm borosilicate MCP substrates, 60:1 L/d, 8 degree pore bias. ~1000v applied to each MCP.

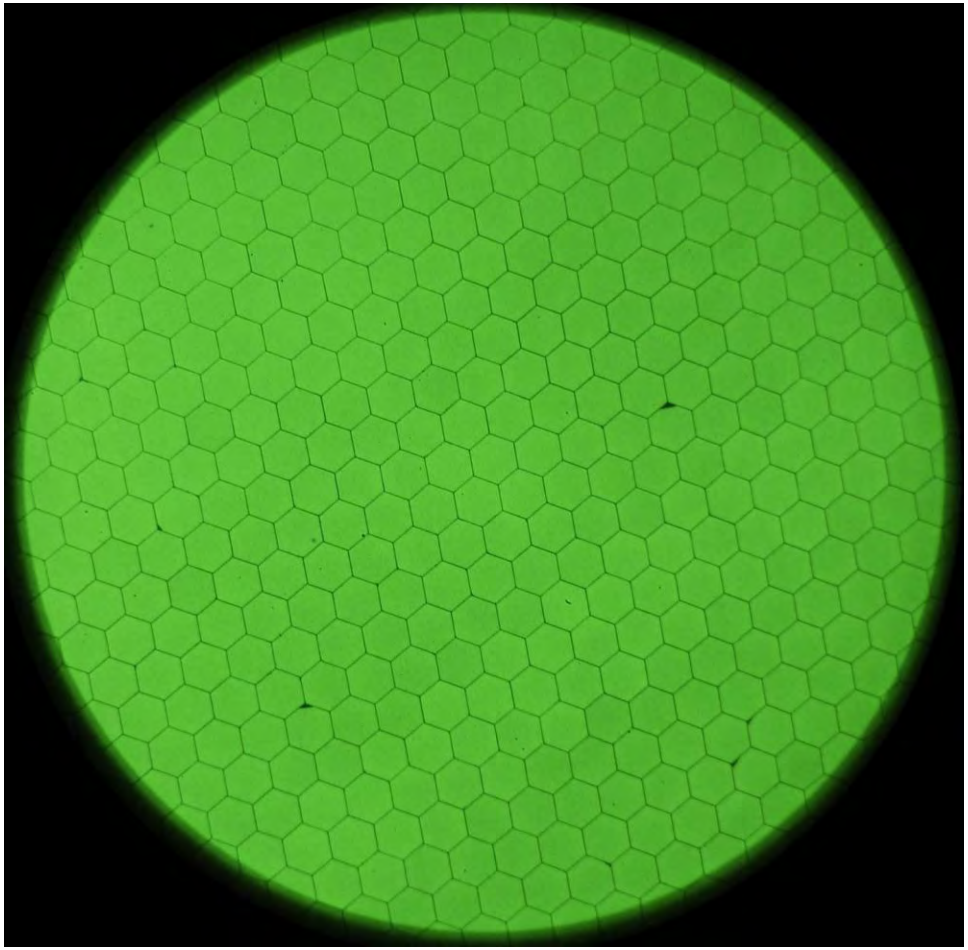
Single MCP tests in DC amplification mode show imaging and gain very similar to conventional MCPs.

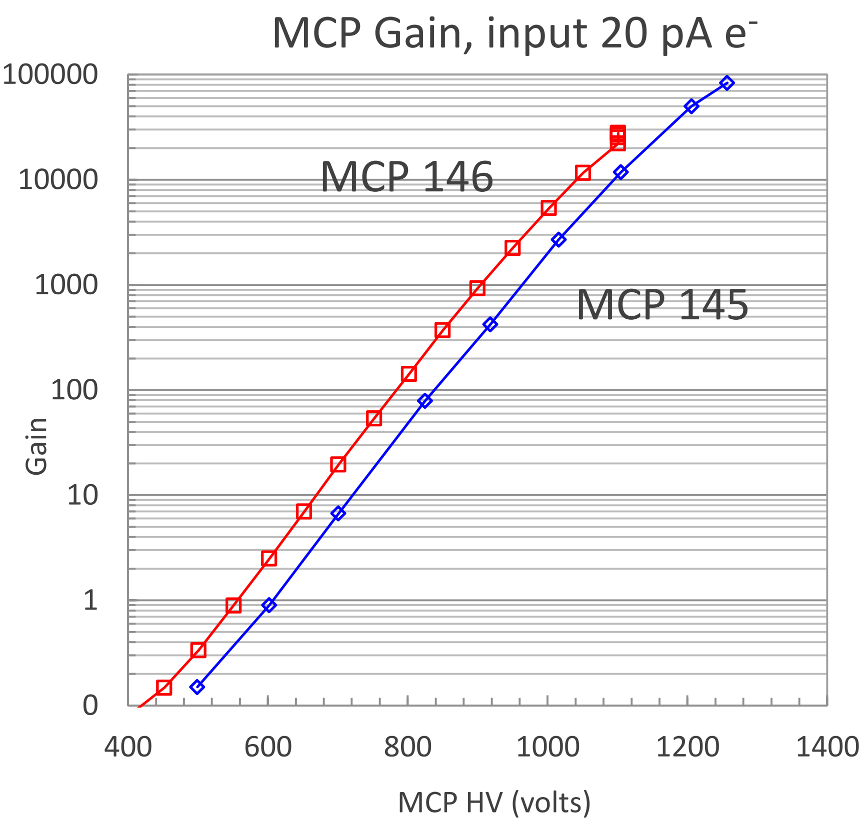
MCP pairs operated in photon counting mode also show imaging and gain very similar to conventional MCPs.

Sample performance has improved dramatically over the last 12 months due to process improvements.

Single MCP - Phosphor Screen Tests

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

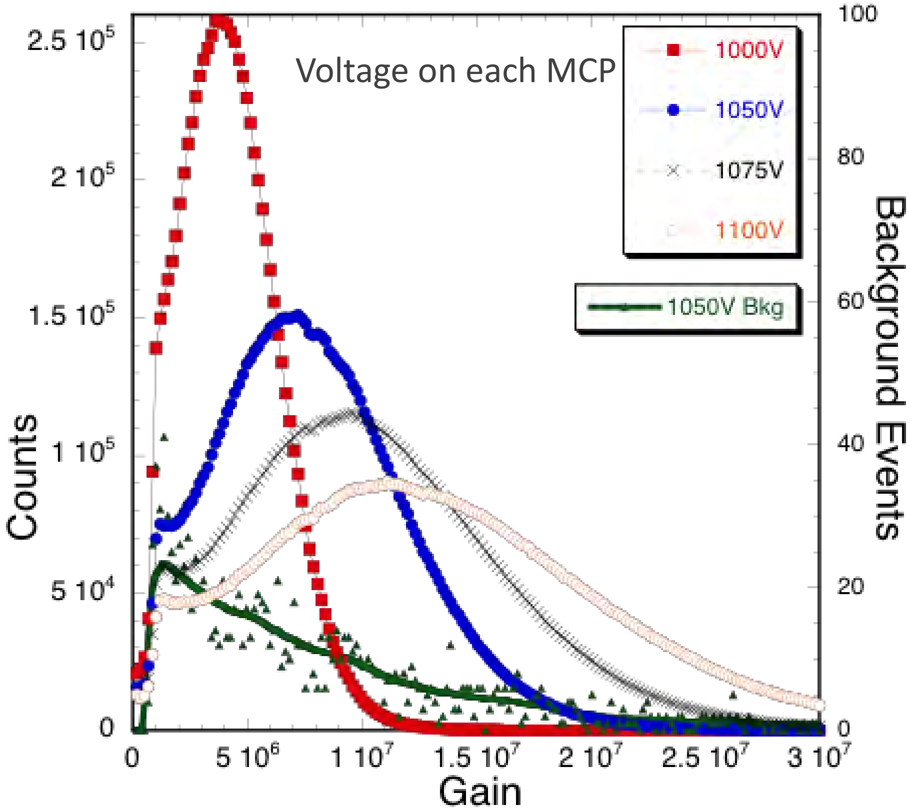




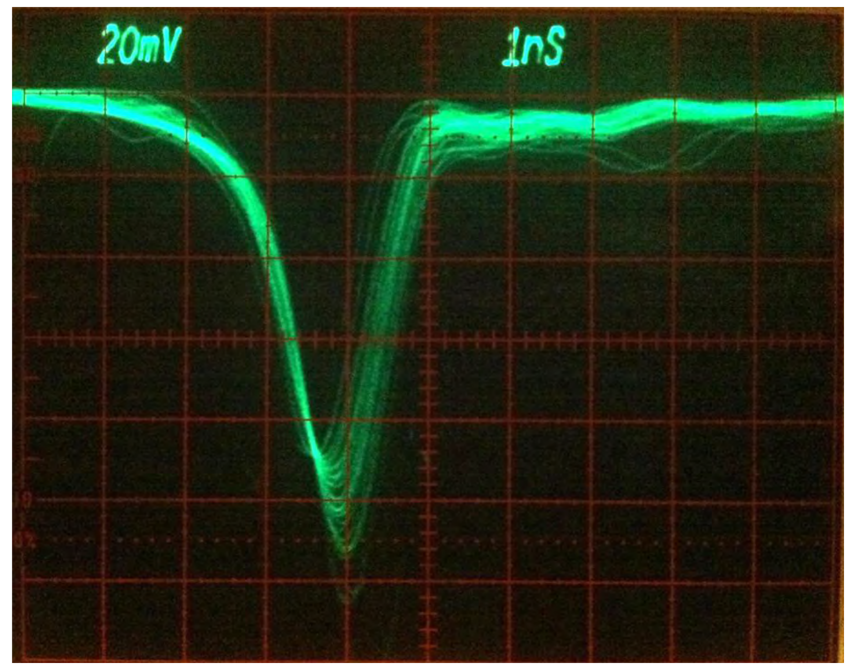
Single MCP tests in DC amplification mode show imaging and gain very similar to conventional MCPs. MCPs very robust, borosilicate softens at >700°C, even high voltage arcing to a phosphor screen did not destroy a test MCP!

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. MCP pair, 20µm pores, 8° bias, 60:1 L/d, 0.7mm pair gap with 300V bias. 3000 sec background.



ALD borosilicate MCP pair, 20µm pore, 60:1 L/d, 8° bias, 0.7mm/1000v MCP gap. Single event pulses are ~1ns wide. ~Typical response for 20µm pore MCPs.

O. Siegmund, LIGHT Workshop, Nov 1, 2011

Photon Counting Imaging with MCP Pairs

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

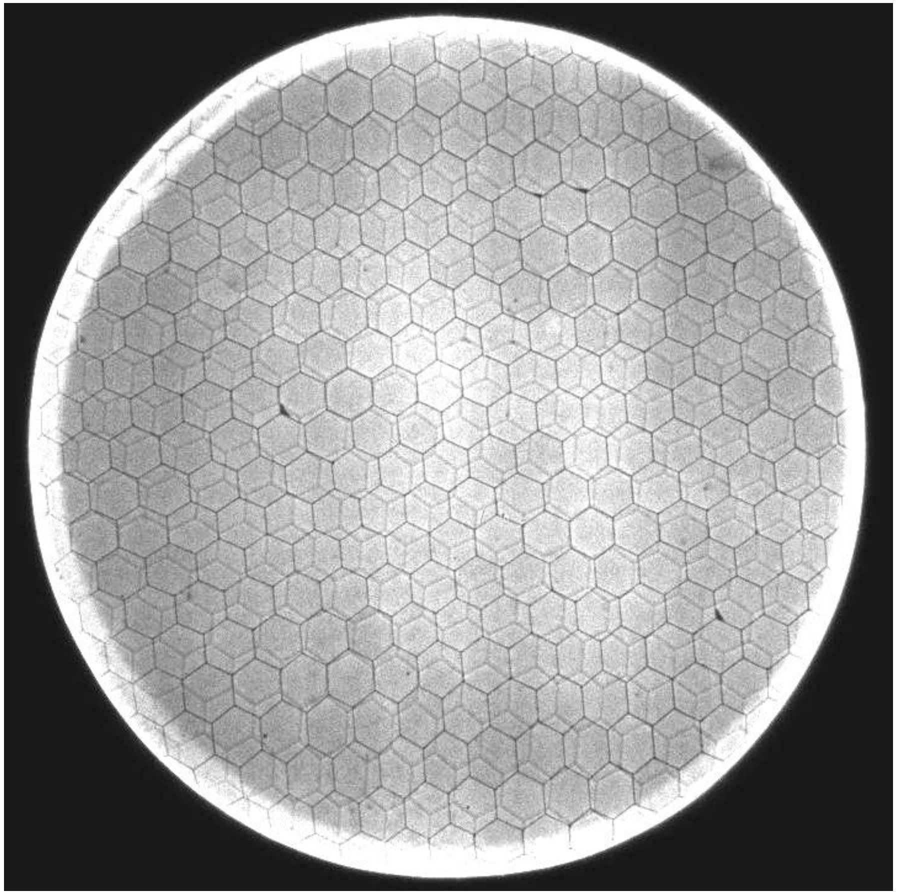
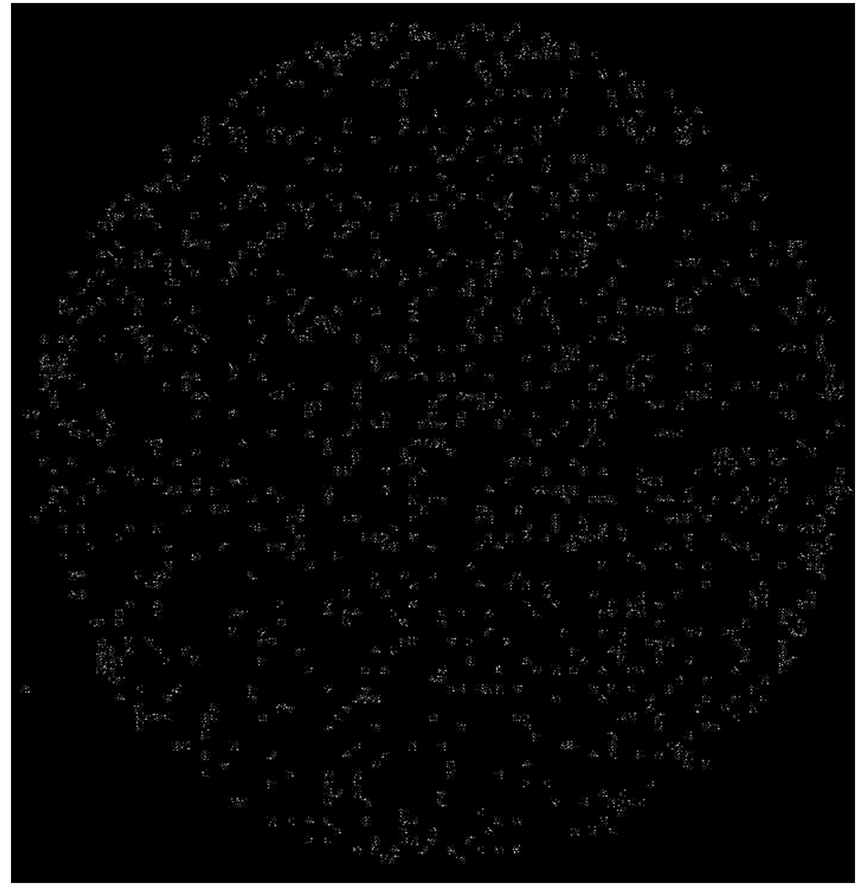


Image of 185nm UV light, shows top MCP hex modulation (sharp) and faint MCP hexagonal modulation from bottom MCP. A few defects, but generally very good. Edge effects are field fringing due to the MCP support flange.

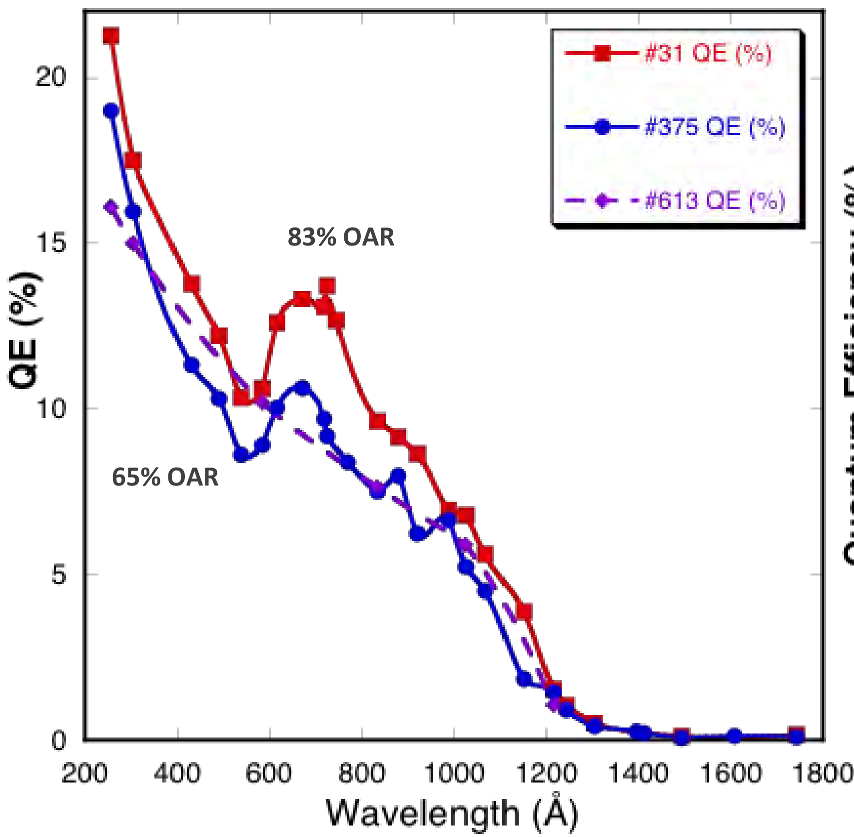


3000 sec background, 0.0845 events cm^{-2} sec^{-1} at 7×10^6 gain, 1050v bias on each MCP. Get same behavior for most of the current 20µm MCPs

O. Siegmund, LIGHT Workshop, Nov 1, 2011

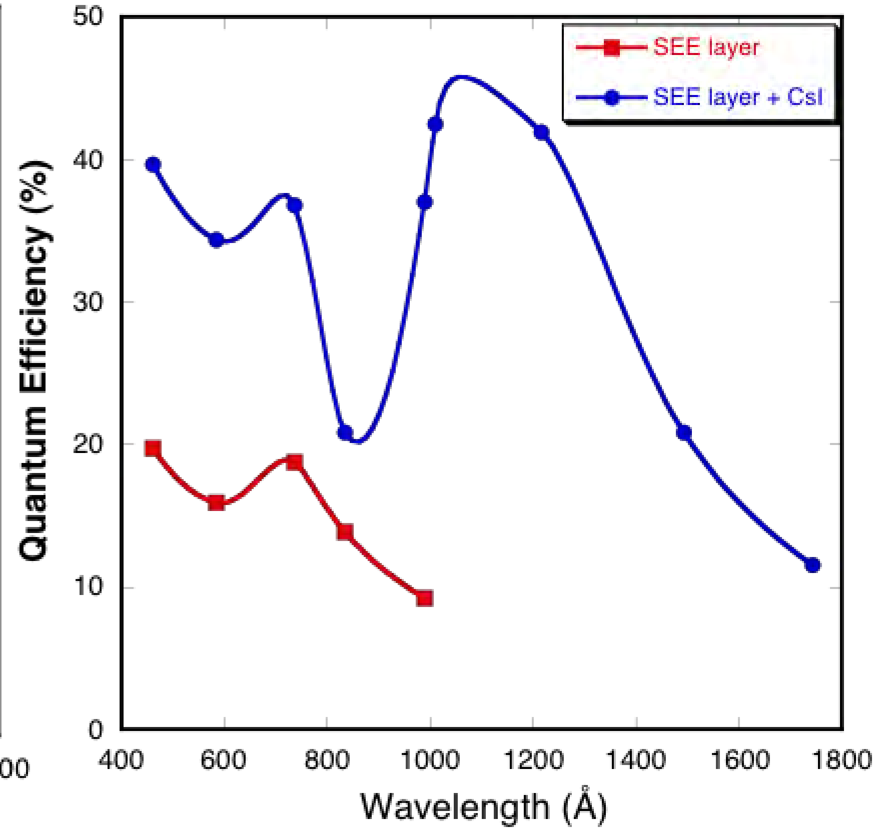
ALD-MCP Quantum Efficiency

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.

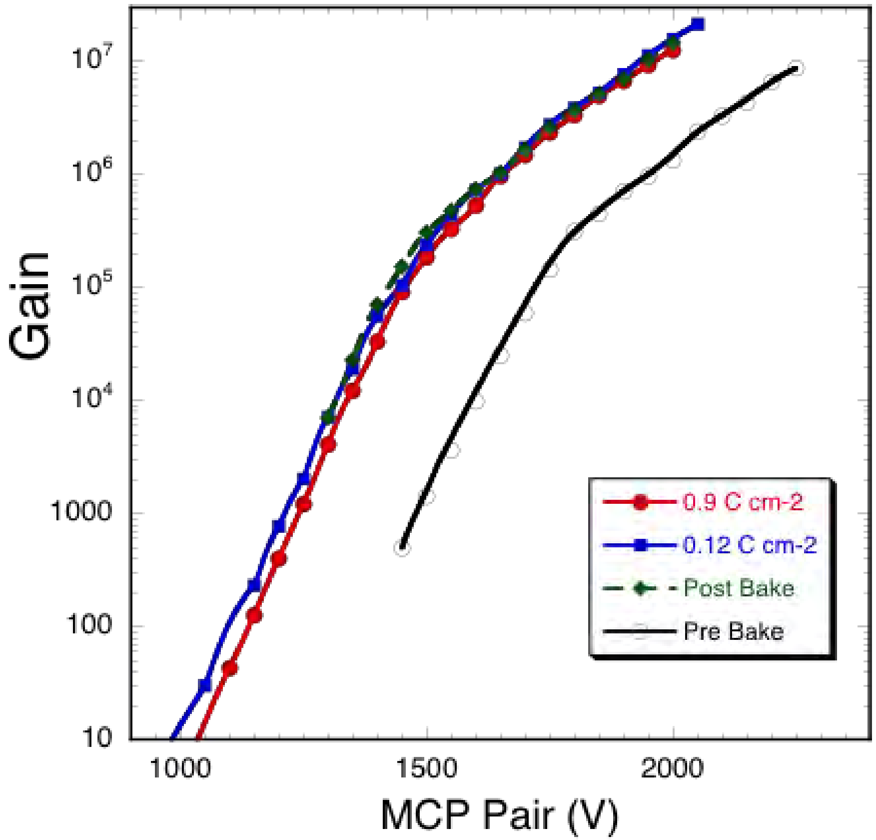
ALD – secondary emissive layer on normal MCP gives good "bare" QDE. CsI deposited on this gives a good "standard" CsI QDE.



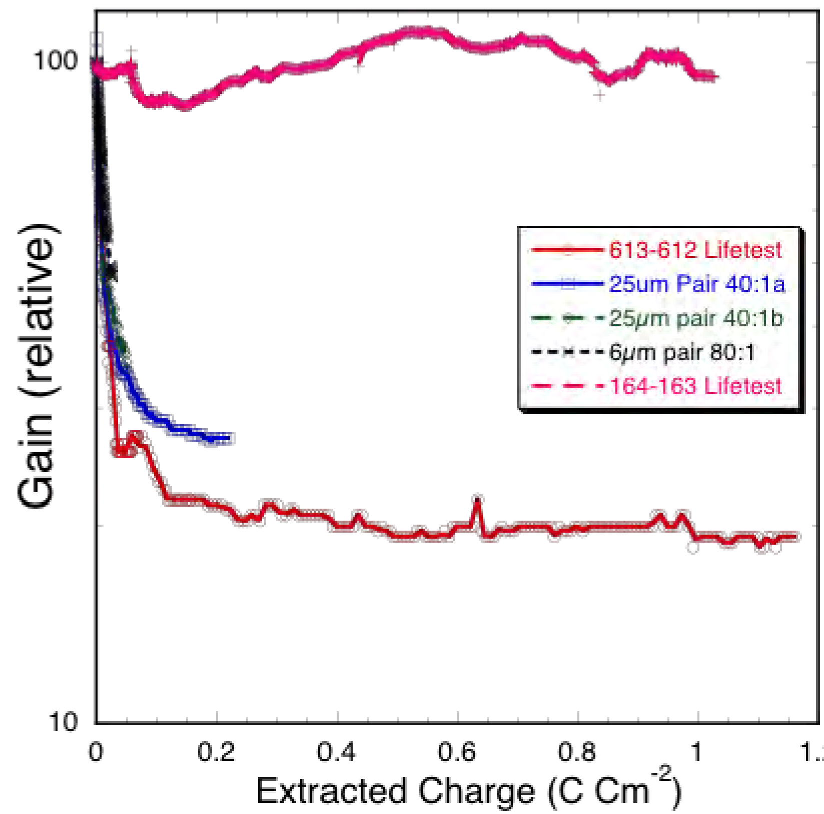
QDE for bare MCP with ALD secondary emissive layer, and with CsI deposited on top of this.

33mm ALD-MCP Preconditioning Tests

Vacuum 350°C bakeout with RGA monitoring first, then UV flood low gain, then high current extraction "burn in" (1 – 3µA). Most recent ALD formulation:-
Gain increases by x10 during bake, after 1 C cm^{-2} only few % gain change!



Gain curves of MCP pair (20µm pore, 60:1 L/d, 8° bias) at stages during preconditioning. Outgas during burn-in < 4 x 10^{-10} torr H_2.



UV scrub of ALD MCP pairs 613-613 & 164-163, (20µm pore, 60:1 L/d, 8° bias) compared with conventional MCPs.

Large Area Picosecond Photodetector Structure

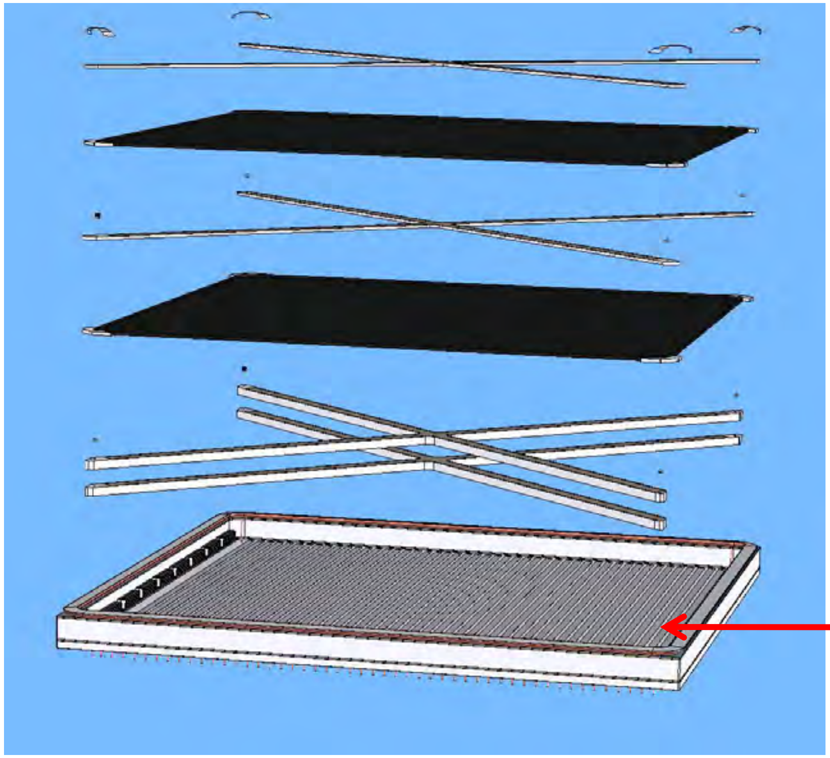
Window

Borofloat 33, 5mm thick input window using Indium seal, and semitransparent bialkali photocathode

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

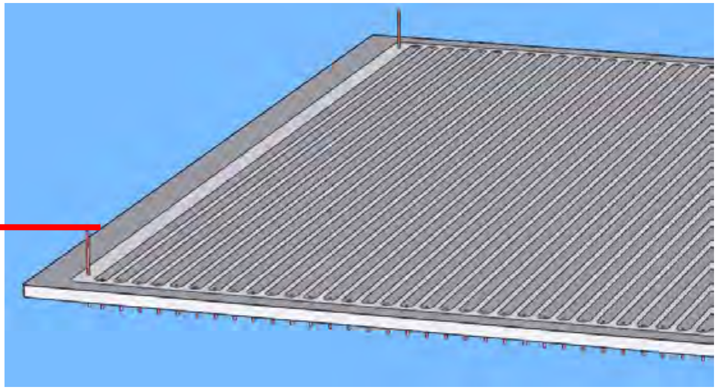
Brazed Body Assembly

Alumina/Kovar parts 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).

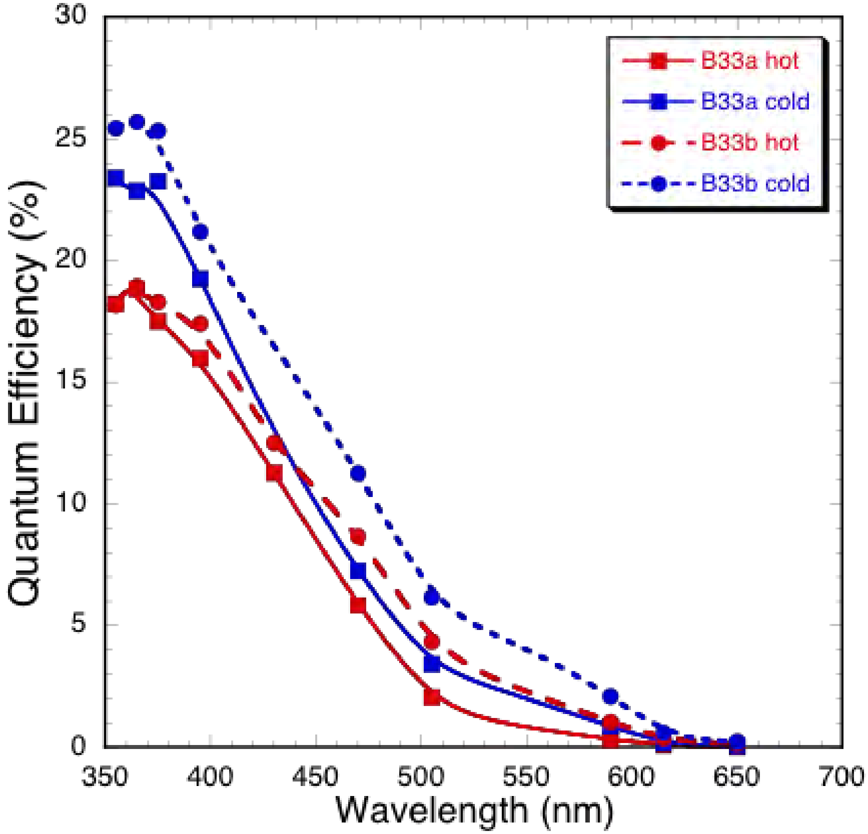


Anode

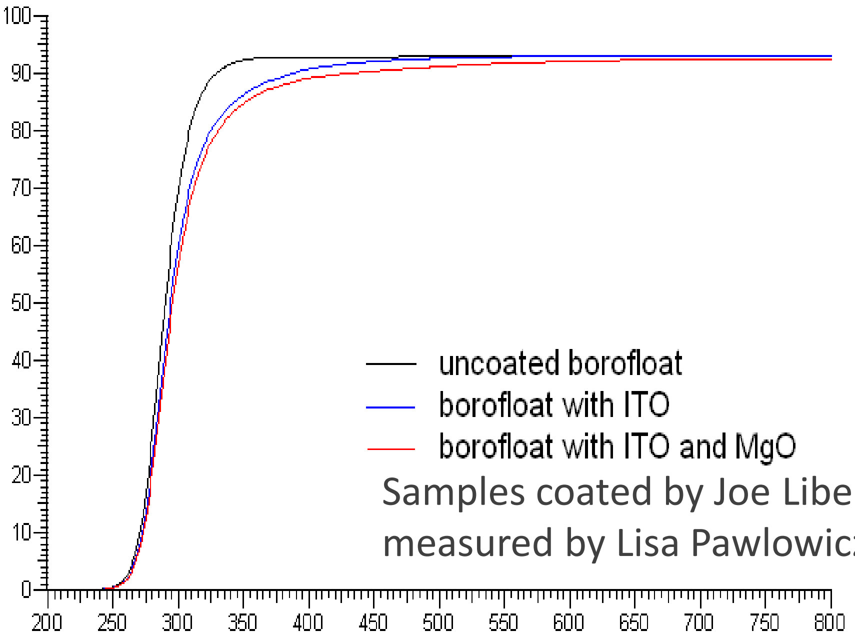
Alumina substrate with vias for signal/HV pins. 48 signal strips inside, complete GND plane outside. Signal & HV pins brazed in.

Bialkali Photocathode Sample Tests

Cathode test runs with Na_2KSb cathodes on borofloat-33 windows >20% QE achieved, QE uniformity better than ± 15%.



Bialkali test cathodes made on 31mm B33 windows. Can take 4 samples per run.
Purpose: - Quantum efficiency optimizations, substrate material and window coating tests.



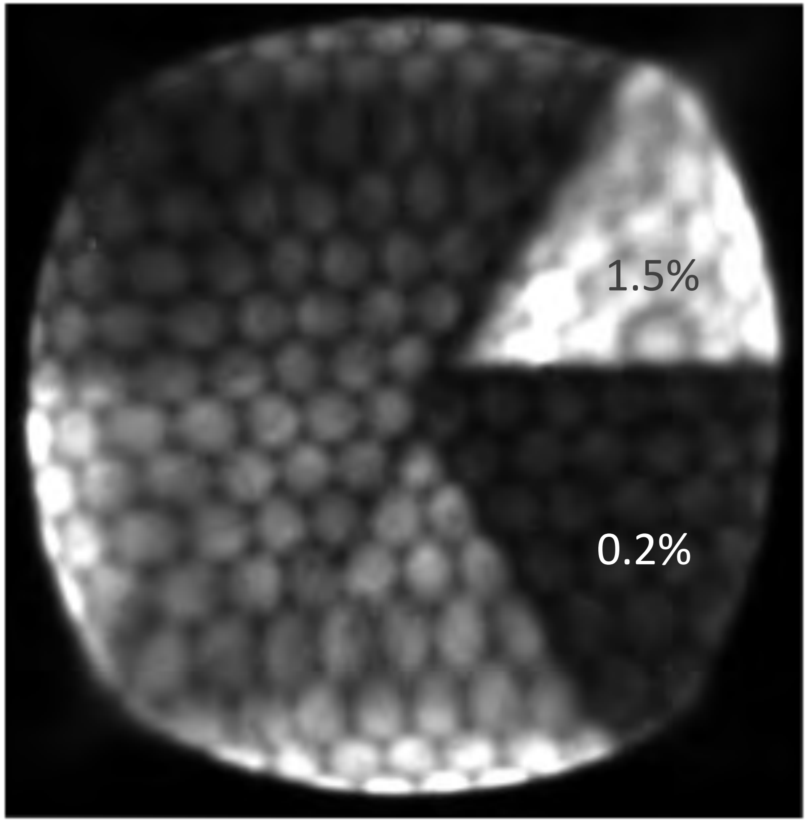
Samples coated by Joe Libera, measured by Lisa Pawlowicz

B33 Transmittance is typical of borosilicate glasses

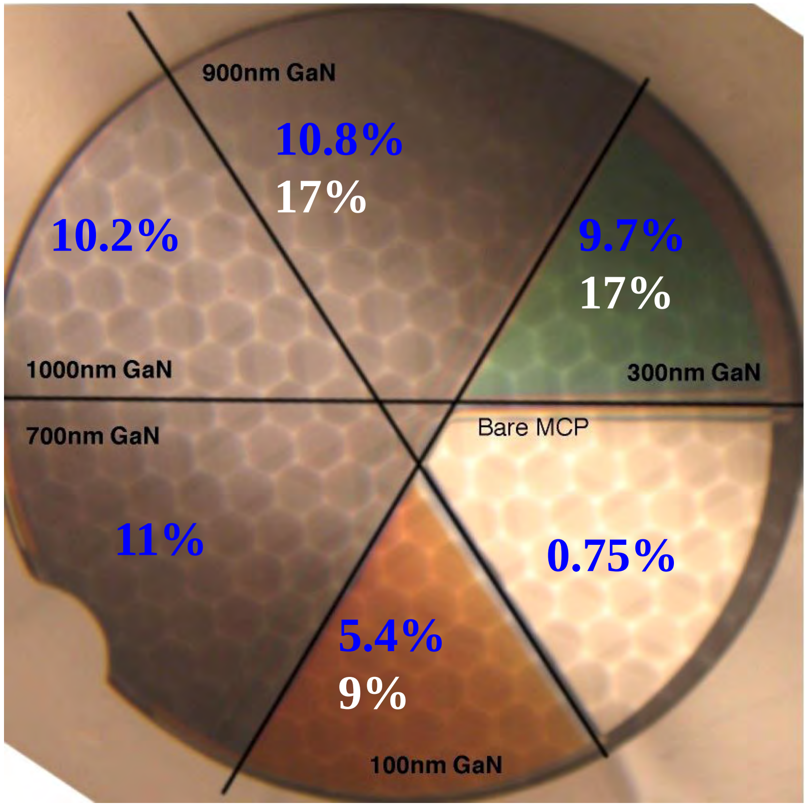
B33 transmission is adequate for the LAPPD wavelength bandpass. NiCr electrodes will be evaporated on the window borders for contacts.

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.

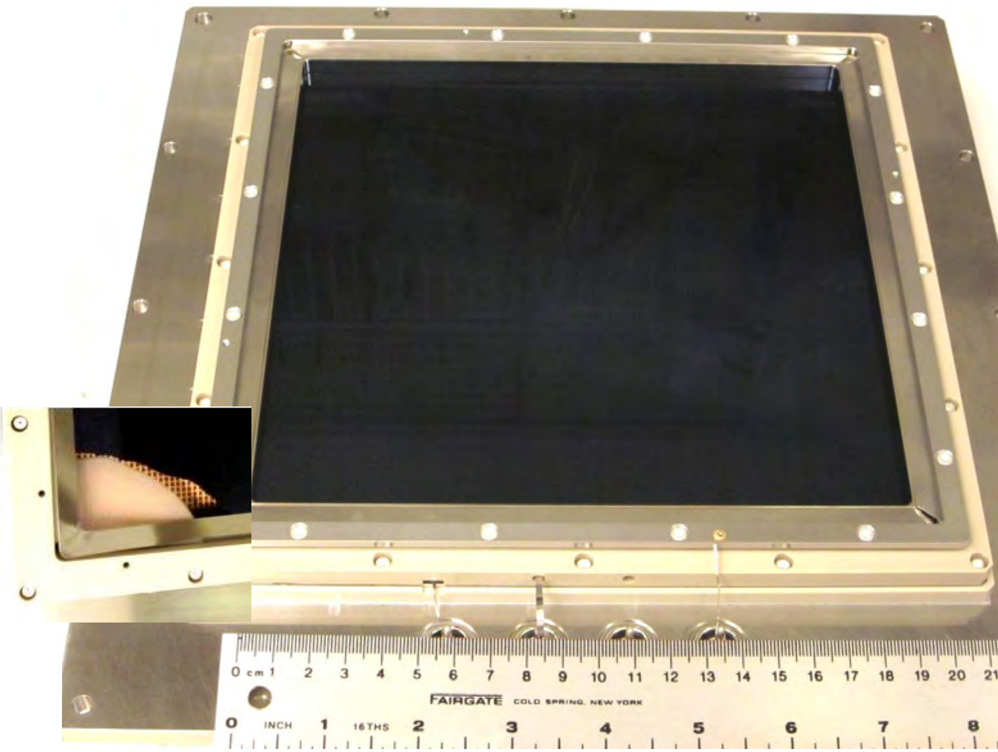


QEs (@214nm UV) measured after Cs. 10º (blue) or 45º (white) graze angle. Typical QE- thickness asymptote for opaque cathode.

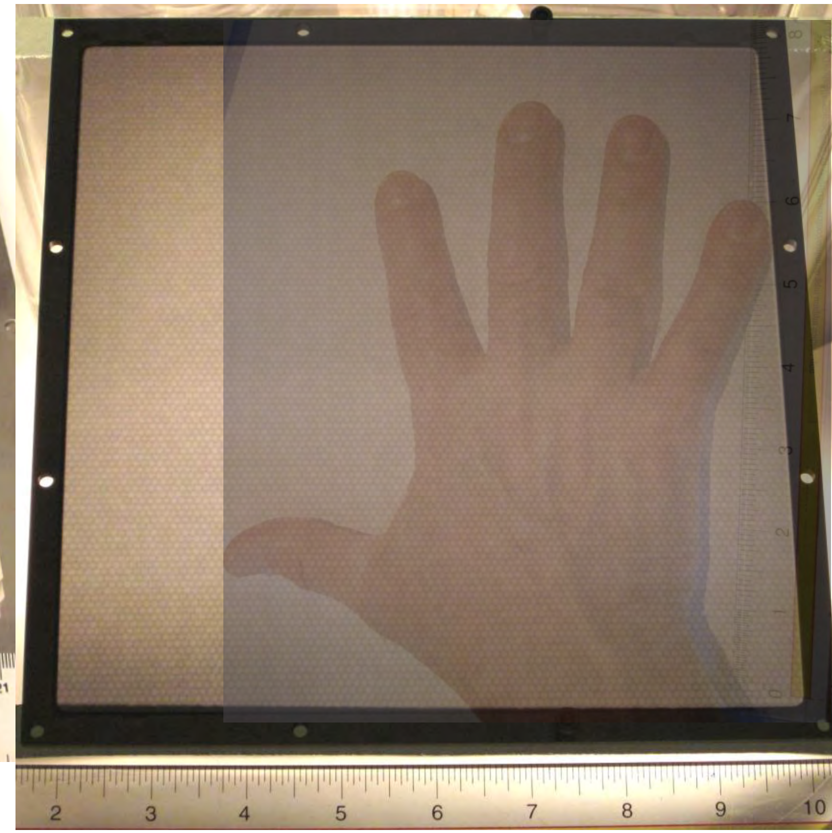
Deposited by SVT associates (A. Dabiran).

Progress with 20cm MCP Development

A small number of 20cm MCP substrates have been functionalized by ALD at ANL and electroded at UCB-SSL. **One pair** has been tested in a detector specifically built for evaluation of their performance. Mechanical quality not the best, due to much handling.

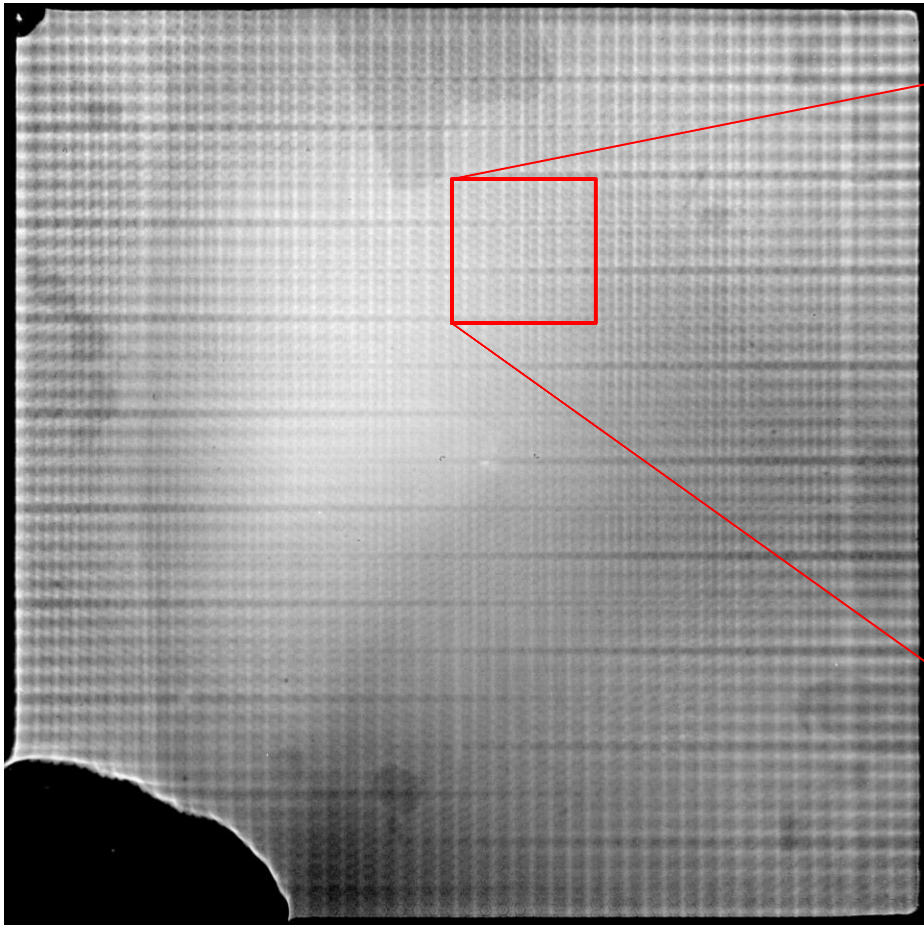


20cm electroded ALD 40µm pore MCP pair in detector assembly with a cross delay line imaging readout. Bottom MCP corner broken off!



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

Photon Imaging 20cm, 40μm pore ALD-MCP Pair



20cm MCP pair image with 185nm UV illumination

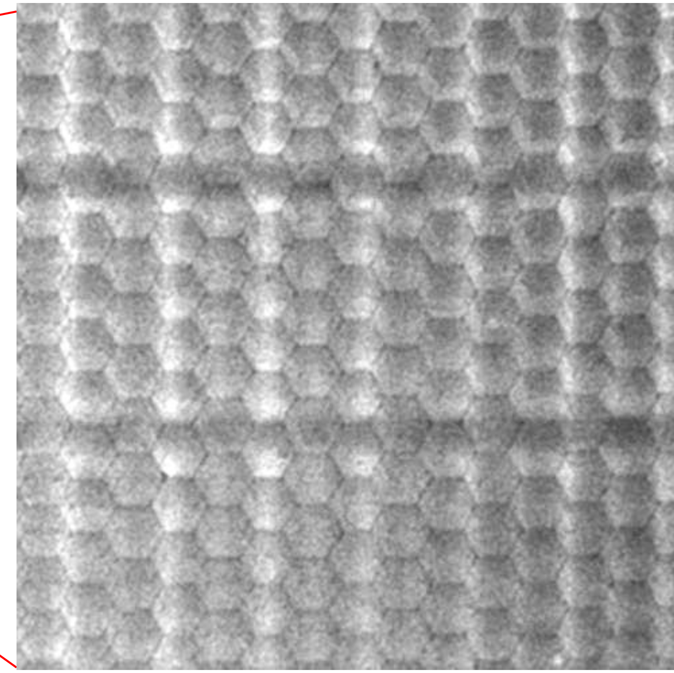
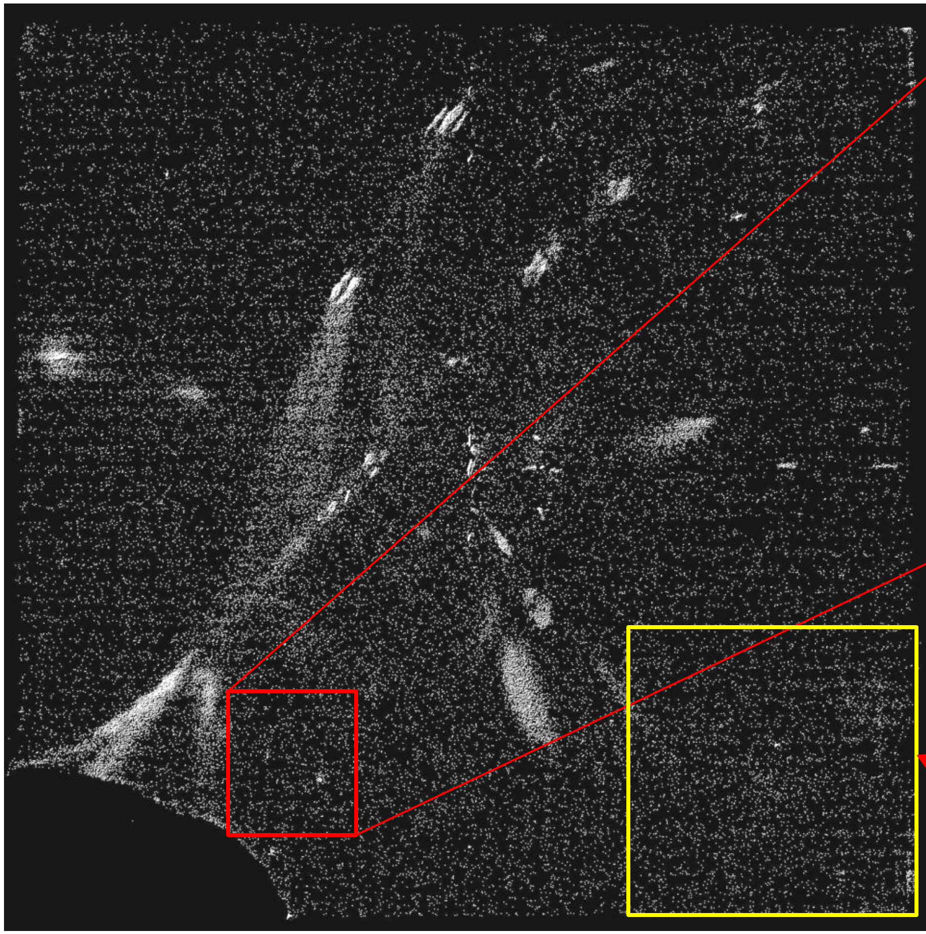


Image section showing the MCP multifibers

First data – taken last week

40μm pore, 40:1 L/d ALD-MCP pair, 0.7mm gap/400v. Striping is due to the anode period modulation as the charge cloud sizes are too small. However, this is the **FIRST** attempt at 20cm MCP ALD imaging without any opportunity for optimization.

Background, 20cm, 40μm pore ALD-MCP Pair



20cm MCP pair background, 2000 sec, 0.24 cnts sec^{-1} cm^{-2}

Area, 0.075 cnts sec^{-1} cm^{-2}

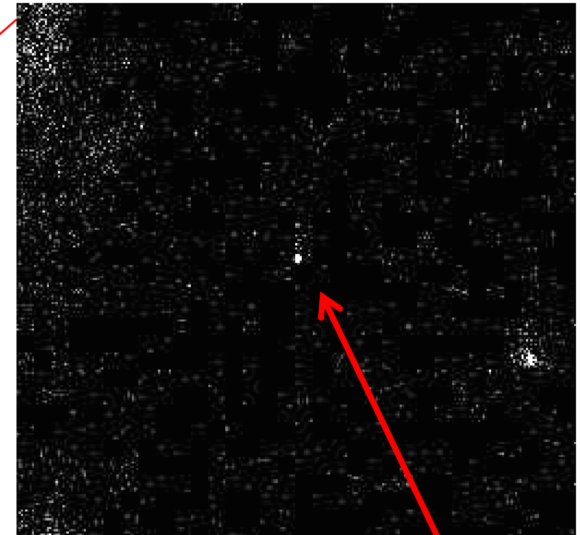
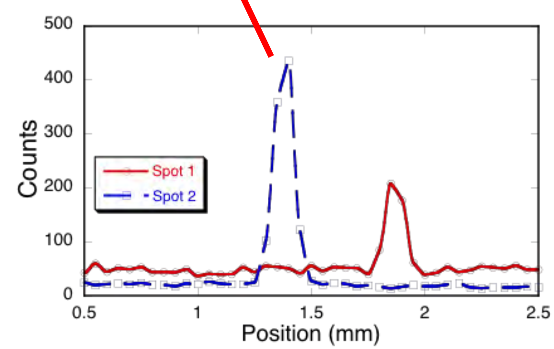


Image section showing a "warm" spot

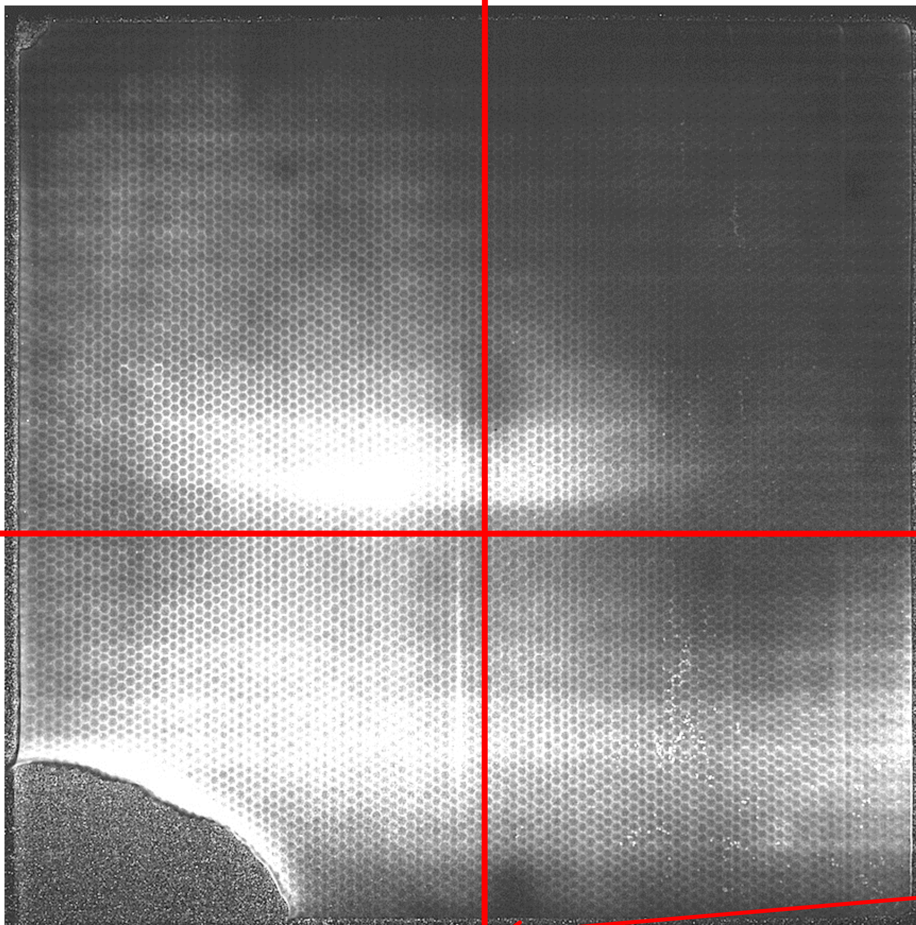


Spot histograms, shows ~100μm FWHM resolution

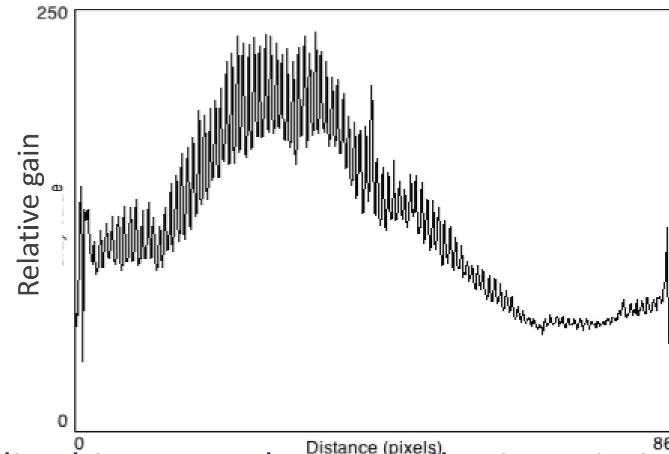
40μm pore, 40:1 L/d ALD-MCP pair, 0.7mm gap/400v. Shows field emission and hotspots – needs cleaning/cleanup. BUT – background still very low !! Spatial resolution is ~100μm FHWM for small hotspot (single active pore!?). 2k x 2k resels!

Testing of 20cm, 40µm pore ALD-MCP Gain

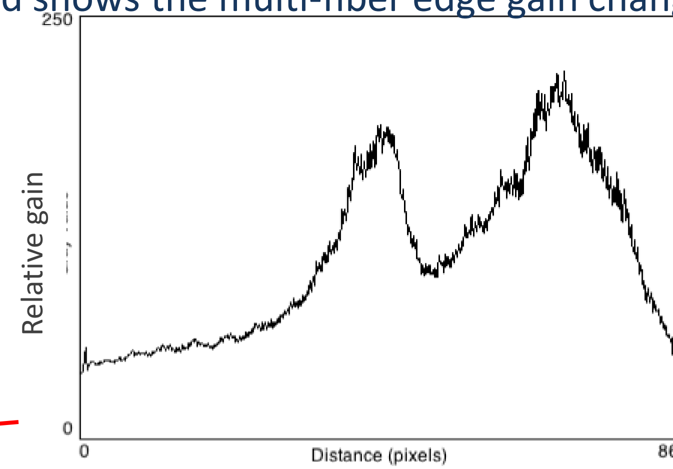
Mean gain ~4 x 10^6



20cm MCP pair average gain map image



X slice histogram, has overall gain variation and shows the multi-fiber edge gain changes



Y slice histogram, shows gain variation

40µm pore, 40:1 L/d ALD-MCP pair. Average gain image map shows the MCP gain variations are significant. However, ALD improvements are underway -- much better coating uniformity has been achieved in system tests - just need to optimize now.

Borosilicate ALD MCP 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.
- Many of the performance characteristics are similar to standard commercial MCPs both in analog and photon counting modes.
- MCP preconditioning shows very good gain, low outgas and good stability with implications for tube fabrication & lifetimes.
- Background rates are low, <0.1 events cm^{-2} sec^{-1}.
- With large MCPs fabrication of 20cm sealed tube is possible.
- Semitransparent Bialkali (25%) cathodes on Borofloat-33.
- Opaque GaN cathodes with high QE can be made on MCP.
- High 80%+ OAR gives better UV QE + better electron efficiency?!

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