ATOMIC LAYER DEPOSITED BOROSILICATE GLASS MICROCHANNEL PLATES FOR LARGE AREA EVENT COUNTING DETECTORS

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Large Area Picosecond Photo-Detector

As part of a collaborative program between University of California, Berkeley, the Argonne National Laboratory, the University of Chicago, and several other partners, we are developing a 20 cm square sealed tube MCP detector for optical photon counting/imaging/timing.

Key features:-

- The overall device will be 22 cm square and only about 15 mm thick.
- Input window is borosilicate, and the photocathode baseline is to use a semitransparent bialkali to match the Cherenkov or scintillator emission spectrum and to keep the overall background rate low.
- Amplification using a pair of MCPs with borosilicate glass substrates where the resistive and photo-emissive surfaces are applied by atomic layer deposition.
- Strip-line anodes which will give ~mm spatial resolution using novel electronics that also provide timing accuracy of a few picoseconds.

UCB/SSL – ANL Development Efforts

Sealed tube Implementation of Prototype LAPPD Detector

UCB Implement LAPPD detector using ceramic body/hot indium seal/transfer photocathode technology

ANL-UC, implement glass body/indium seal/transfer photocathode

Photocathodes/Windows

Window compatibility and >15% QE stable bialkali

High QE uniform bialkali on LAPPD 20cm windows

UHV sealing technique for 20cm windows

ALD functionalized microchannel plates

ALD MCP performance. INCOM substrates - Argonne/Arradiance ALD

Test 33mm sample imaging, gain, background, PHD, uniformity

For tube compatibility tests,- high temp vac bake, burn-in process

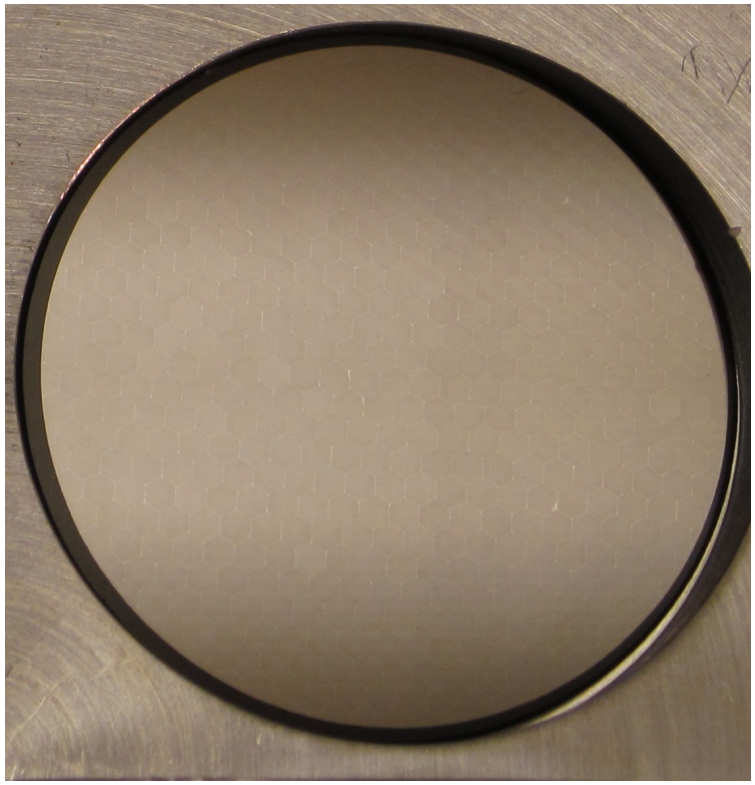
Investigate optimization of MCP pair spacings & bias, anode bias, charge footprint, imaging and timing tests

Evaluation/optimization of 20cm MCP configurations

Borosilicate Substrate Atomic Layer Deposited Microchannel Plates

Microcapillary arrays (Incom) with 20 µm or 40µm pores (8° bias) made with borosilicate glass are the substrates. Resistive and secondary emissive layers are applied (Argonne Lab, Arradiance) to allow these to function as MCP electron multipliers.

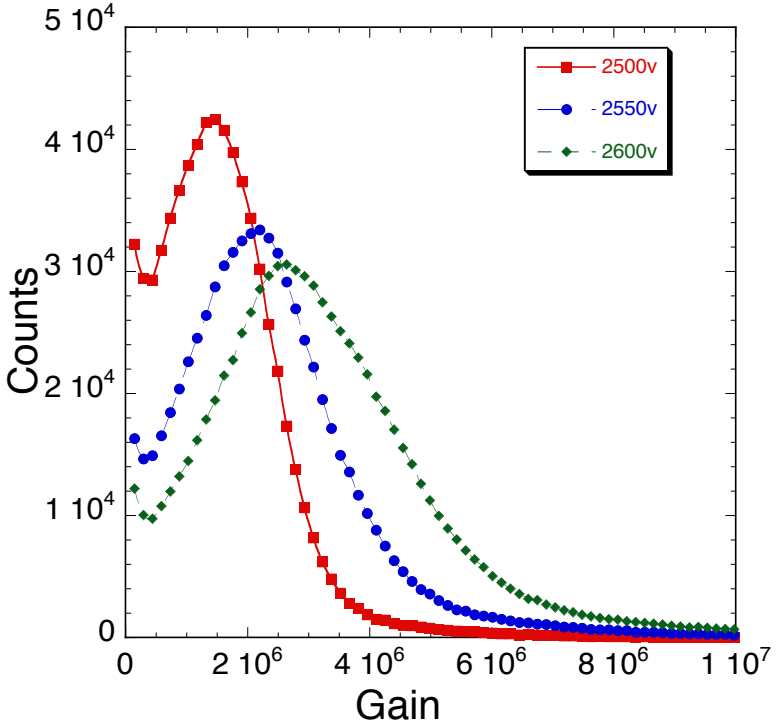
Visible light transmission for a 20 µm pore borosilicate microcapillary ALD MCP .



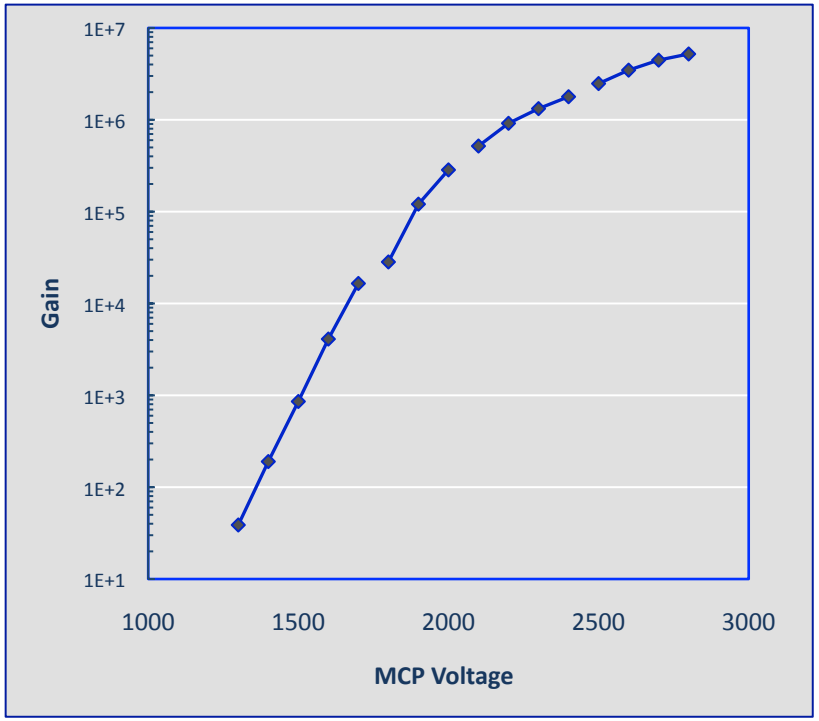
Surface photo for a 20 µm pore borosilicate microcapillary ALD MCP with NiCr electrode .

ALD-MCP Performance Tests, 33mm pairs

UV illuminated test results show similar gains to conventional MCPs, logarithmic type gain dependence for low applied voltages, then saturation effects appear above gains of 10^6.

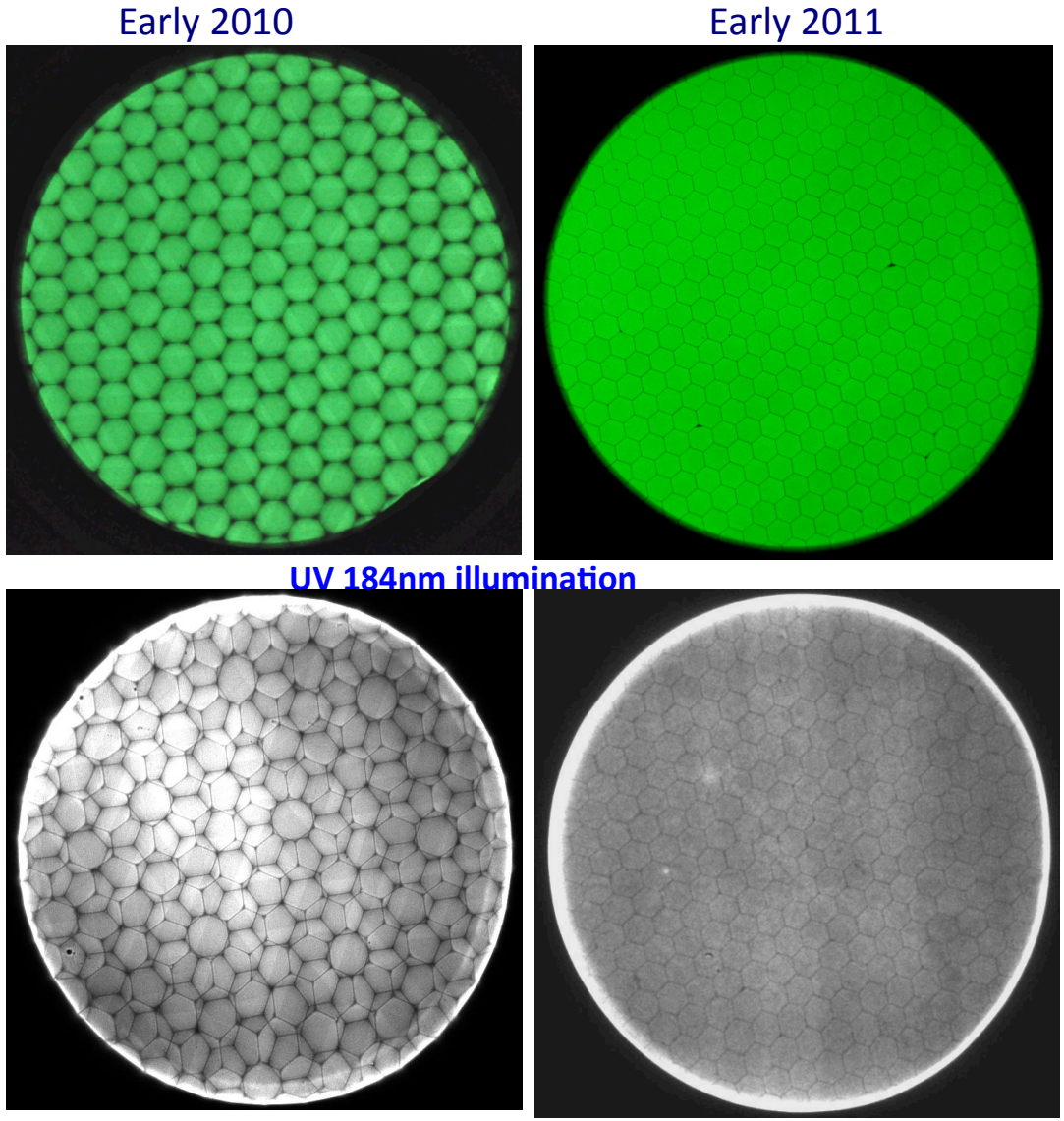


Pulse height amplitude distributions for a 33mm ALD MCP pair (voltages include a 400v anode bias).



Gain for a pair of 20µm pore 33mm ALD MCP's, 60:1 L/d, 8 degree bias, (voltage for 2 MCPs + 400v anode bias).

Imaging Performance of ALD MCPs, 33mm



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

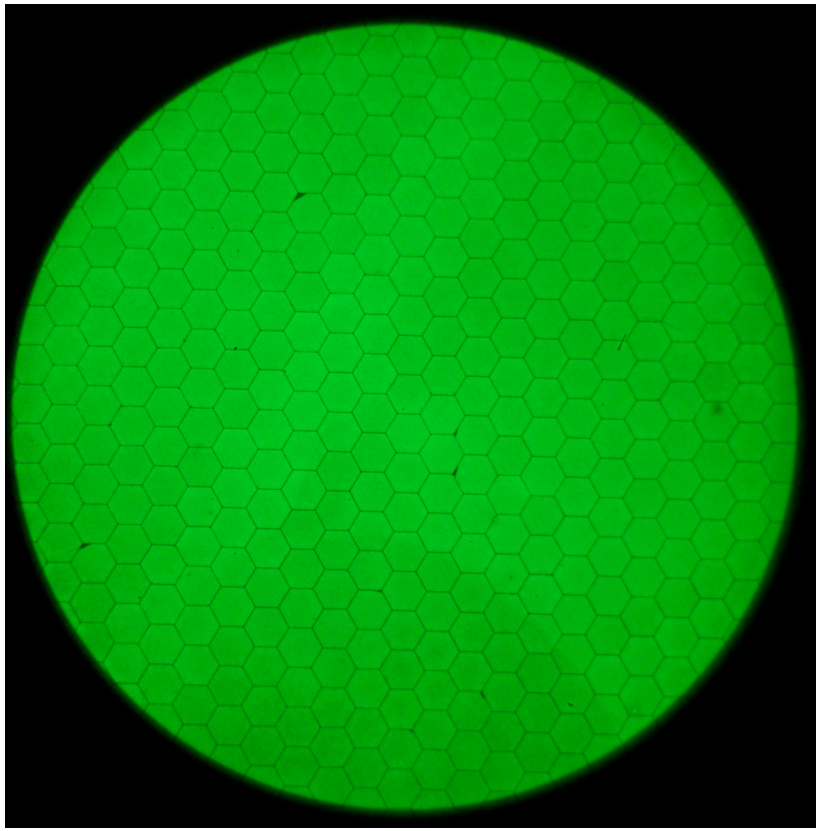
Single MCP tests in DC amplification mode show imaging and gain very similar to conventional MCPs.

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.

Robustness of ALD MCPs, 33mm

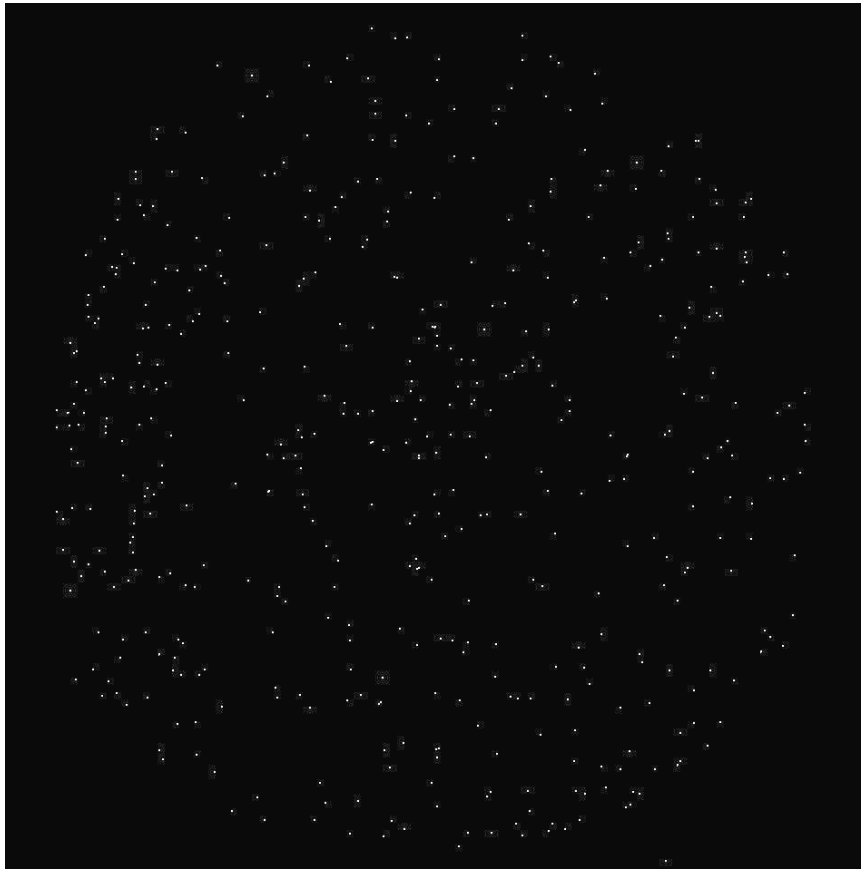
Conventional MCPs are highly likely to be physically damaged by high voltage breakdown events. We had a phosphor screen failure that damaged an ALD functionalized borosilicate glass MCP. Inspection showed no melting of the pores!



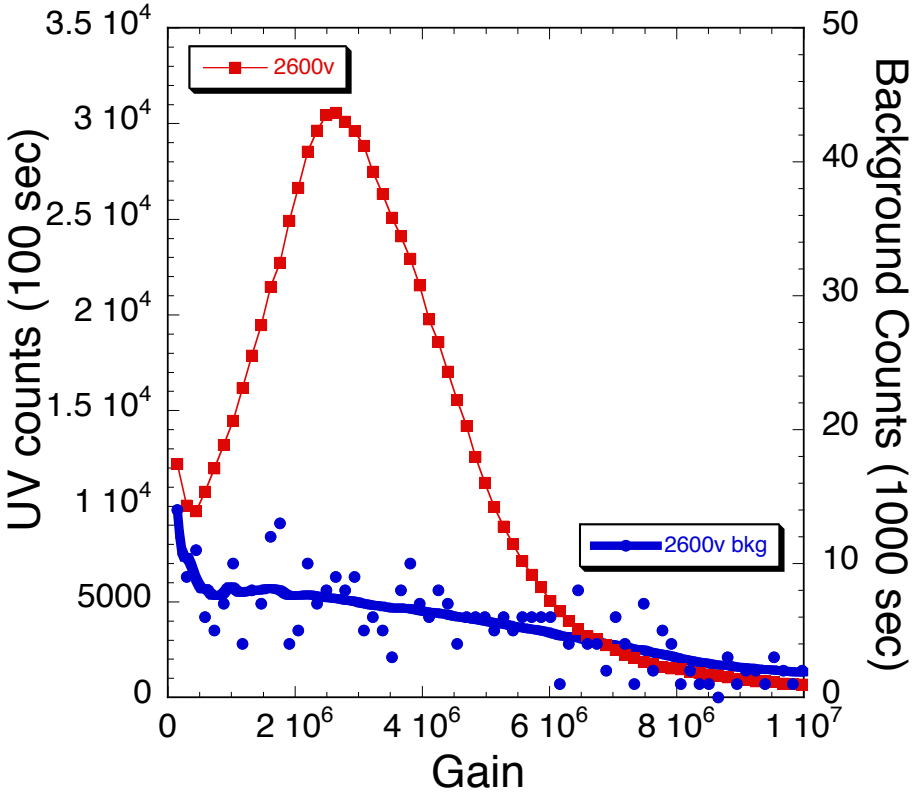
An additional electrode layer was applied on top of the damaged face and then tested in our phosphor detector – no sign of any damage in the image!!!

33mm ALD-MCP Background Rate

MCP back to back pair, 20µm pores, 8° bias, 60:1 L/d, achieves <0.1 events cm^{-2} sec^{-1}.



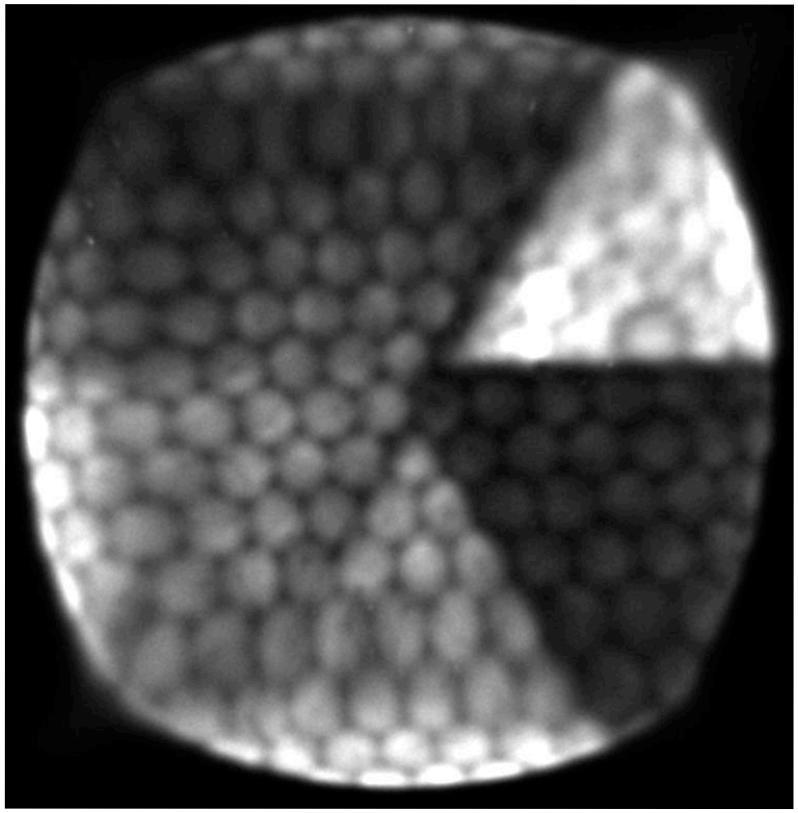
1000 sec background, 496 counts, at 2.5 x 10^6 gain, 2600v total, with 400v on anode.
Background rate is 0.099 events cm^{-2} sec^{-1}.



Pulse amplitude distributions for UV 145nm, and for background events, There may be excess background due to detection of ion pump events.

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.

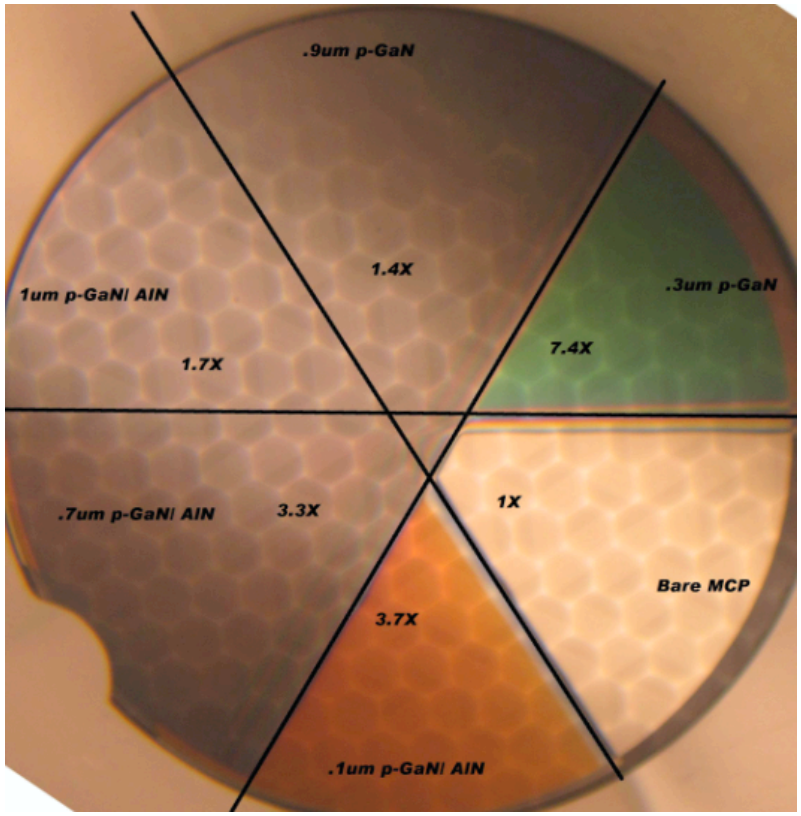
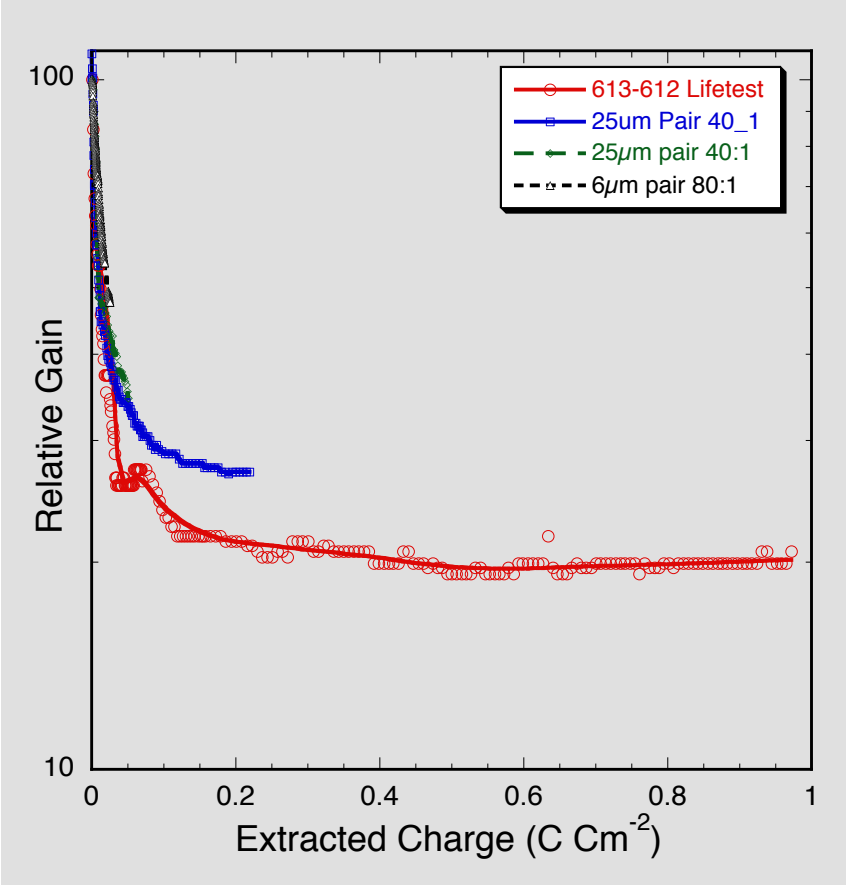


Photo of 20µm pore MCP with zones of different GaN thickness and structure.

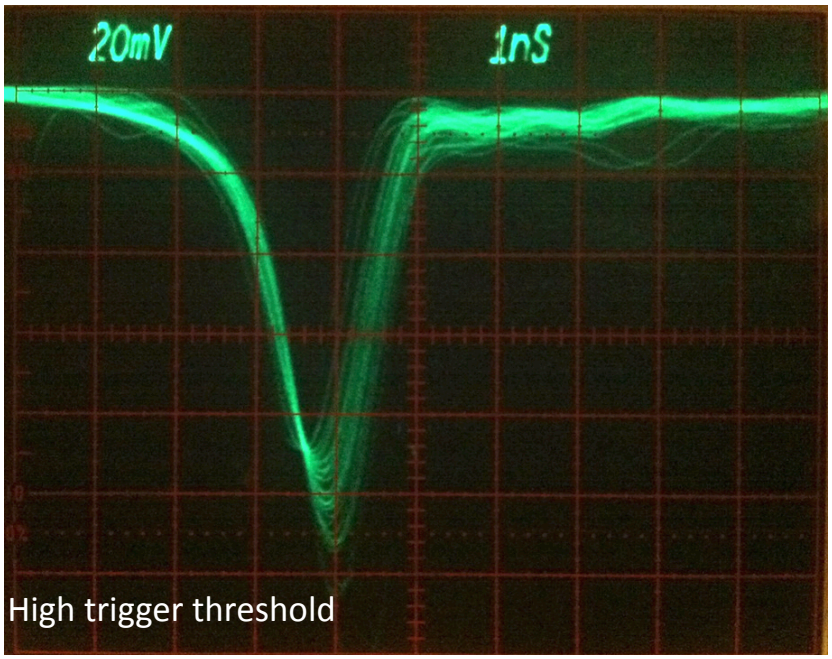
33mm ALD-MCP Performance Tests

Gain ageing test after 350°C bake



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

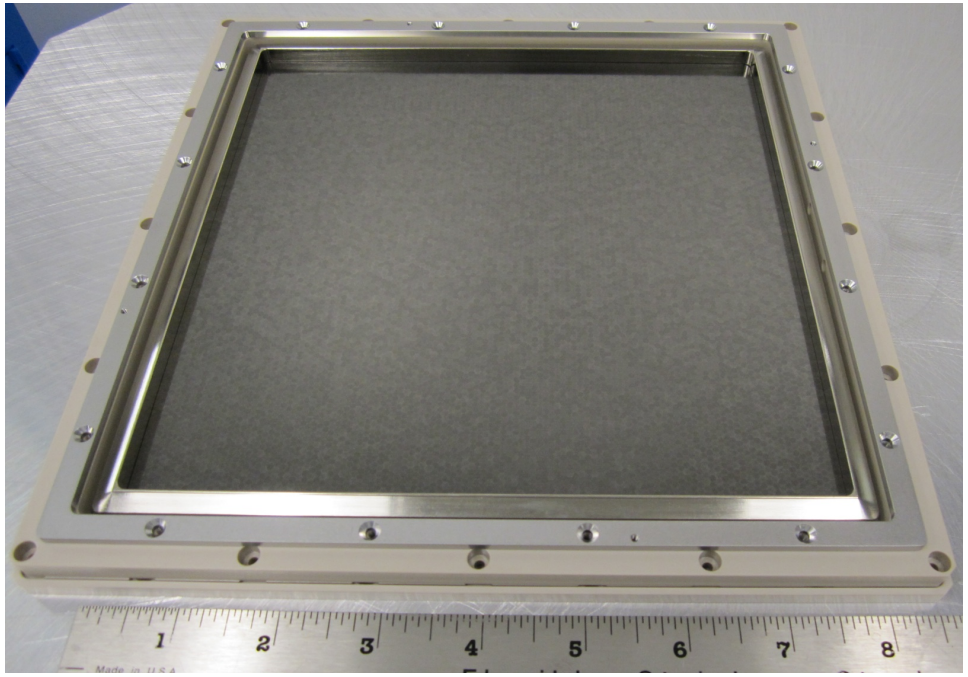
Anode Pulse Shape



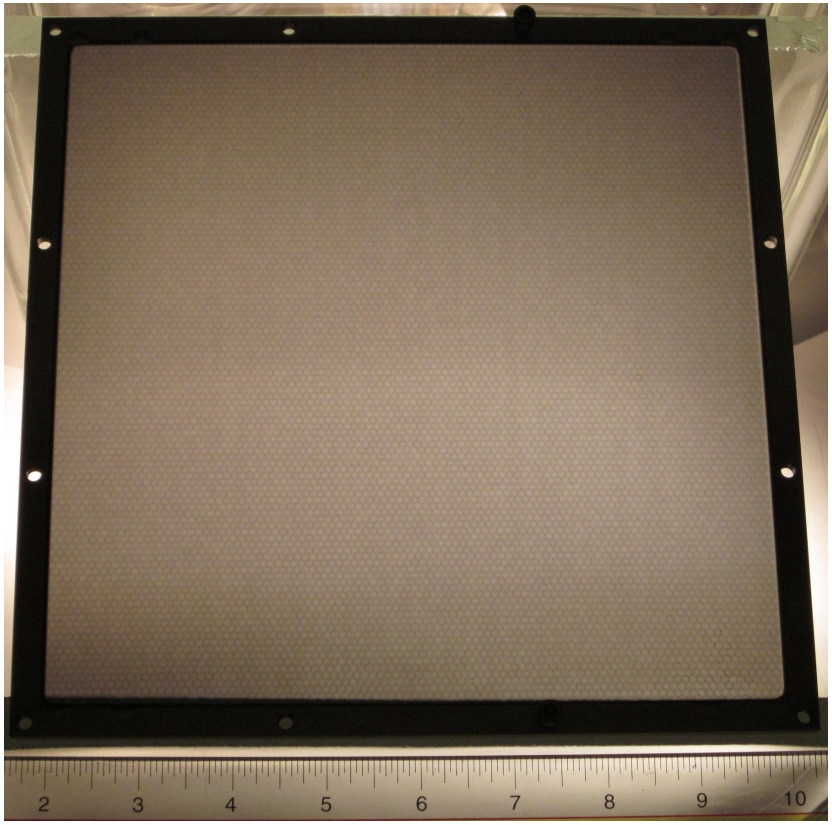
ALD borosilicate MCP pair, 20µm pore, 60:1 L/d, 8° bias, 0.6mm/1000v MCP gap. Single event pulses are ~1ns wide.

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 in conditions like the LAPPD configuration(s).

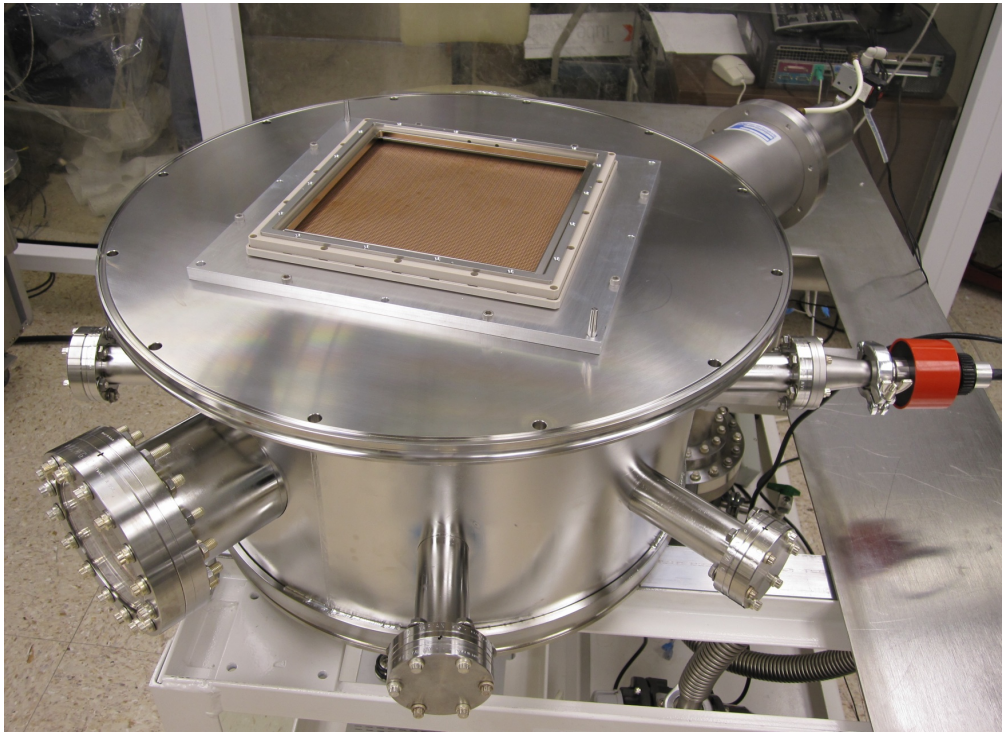


20cm electroded ALD 20µm pore MCP in detector assembly with a cross delay line imaging readout

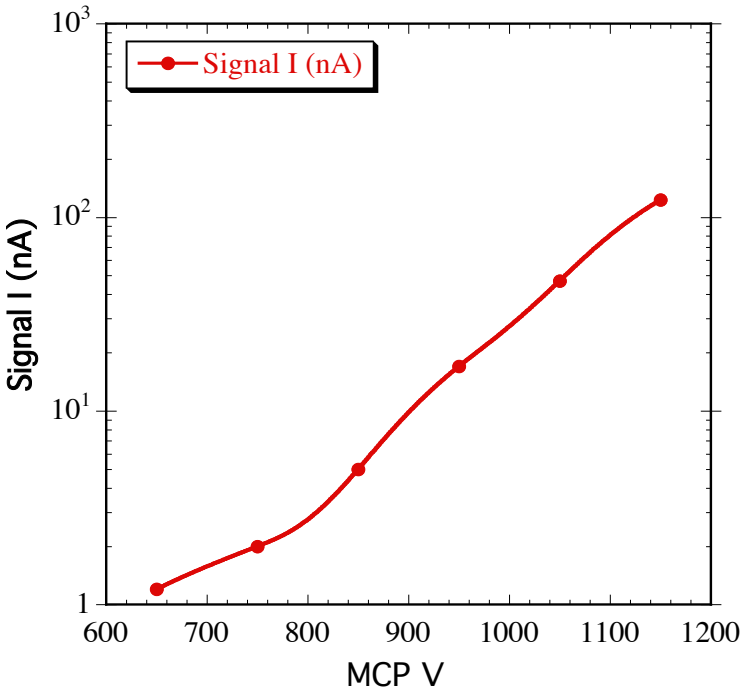


20cm MCP showing the multifiber stacking arrangement, 40µm pore, 8° bias.

Testing of 20cm, 20µm pore ALD-MCPs



20cm MCP test chamber and detector with XDL readout



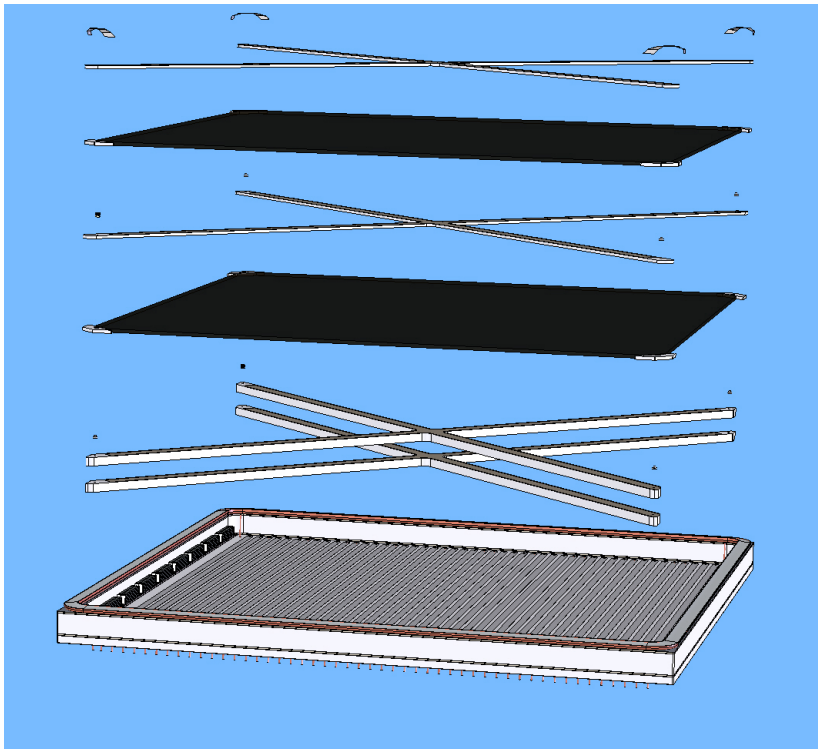
20cm MCP output signal v.s. V for UV input

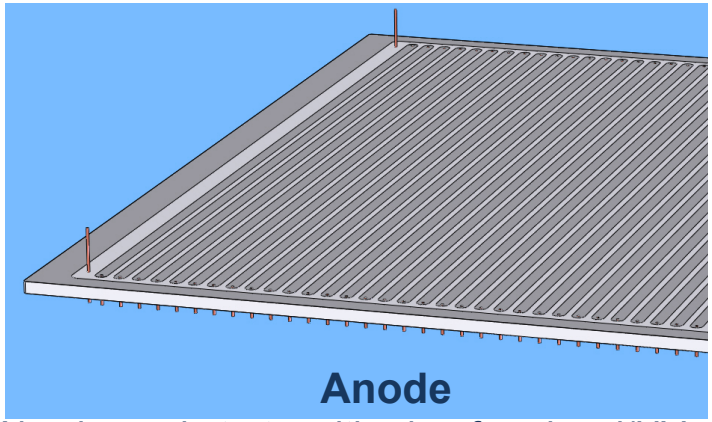
The cross delay line detector accepts 2 MCPs and spacers. It will allow <200µm spatial resolution for MCP pairs, and permit full parameter evaluation of 20cm MCPs. An initial test with one 20cm, 20µm pore, 60:1 L/d ALD-MCP shows a conventional MCP gain curve.

Ceramic Brazed housing design

Brazed Body Assembly and Preparation

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



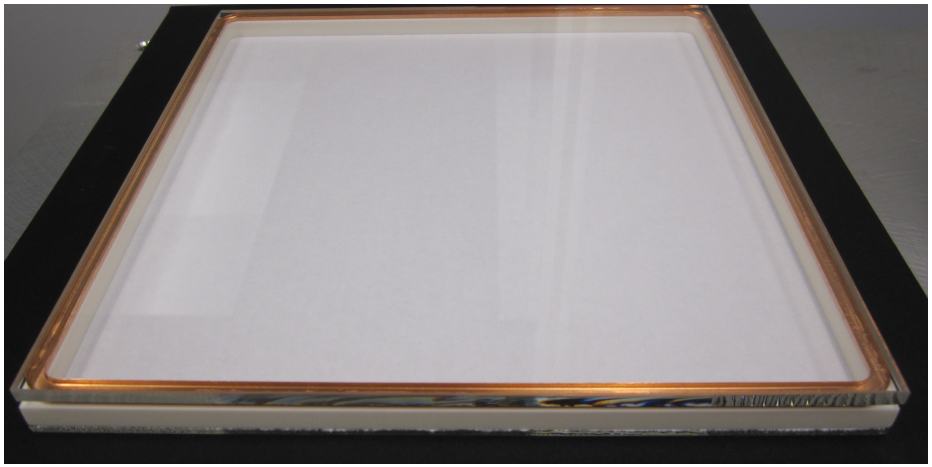


Anode

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

Brazed Body Internal Parts Assembly

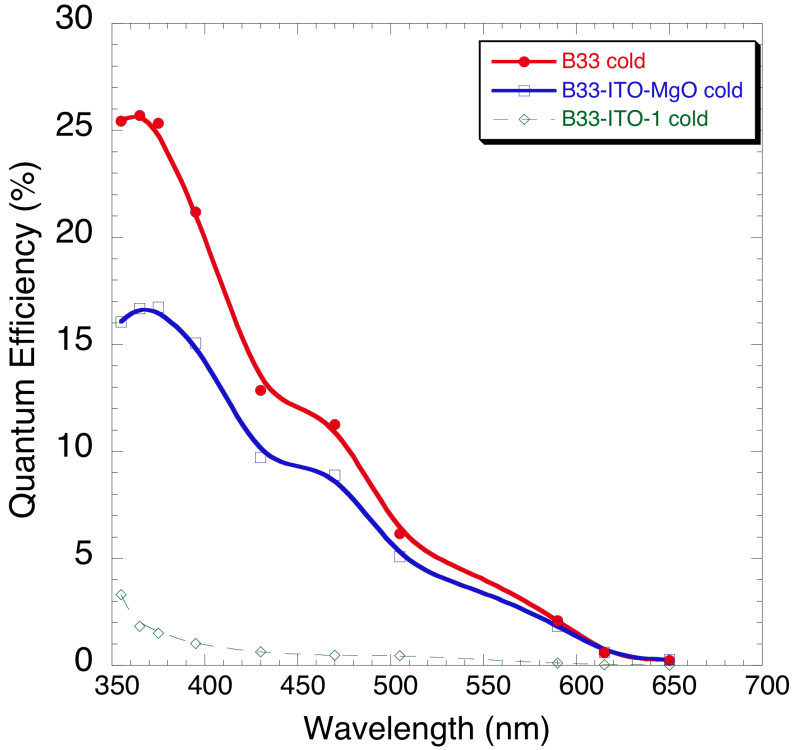
Into the body, we stack up getters and X-grid spacers and MCPs. X-grids register on HV pins, hold down MCPs, and distribute HV (via metallization contacts).



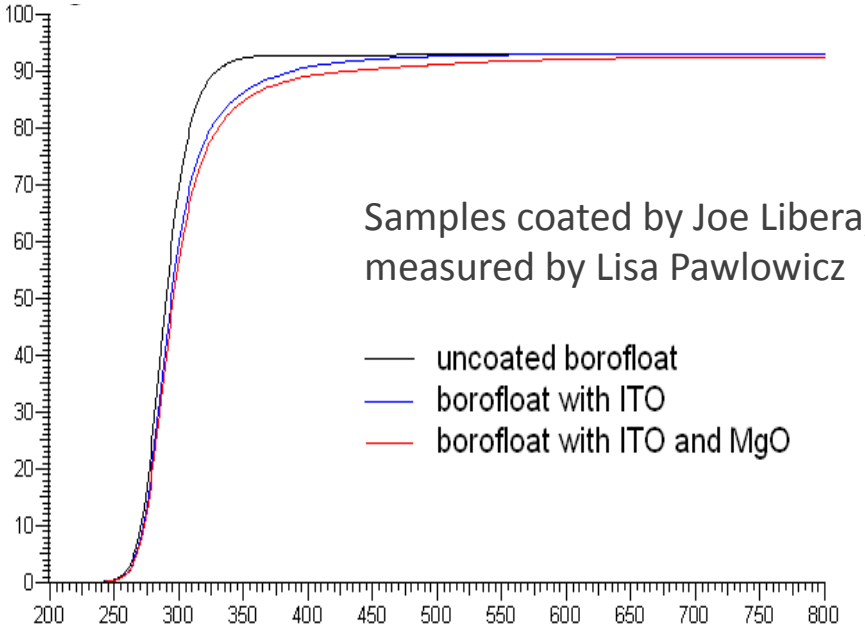
Ceramic body with Cu Indium well, 5mm thick B33 window and "blank" anode.

Bialkali Photocathode Sample Tests

Cathode test runs with Na_2KSb cathodes on borosilicate windows >20% QE achieved at 350 – 450nm QE uniformity better than ± 15%.



UHV tank for processing alkali cathodes and tubes of small area. Can take 4-8 samples/run. Purpose: - Quantum efficiency optimizations, substrate material and window coating tests.



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.

Large Area Picosecond Photo-Detector 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.
- Initial 20cm, 20µm pore MCPs show normal gain behavior.
- Borosilicate windows have been successfully used as substrates for bialkali photocathodes with >20% peak QE.
- Design and fabrication of 20cm tube structures is progressing rapidly, and processing tanks for critical tests and tube processing are well advanced.

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