20 cm Sealed Tube Photon Counting Detectors with Novel Microchannel Plates for Imaging and Timing Applications

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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. [TIPP-254].

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. The photocathode baseline is to use a bialkali to match the Cherenkov or scintillator emission spectrum and to keep the overall background rate low.
- Amplification using a pair of MCPs with novel 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 (Varner-TIPP214) 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 8” windows

UHV sealing technique for 8” 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 8” MCP configurations

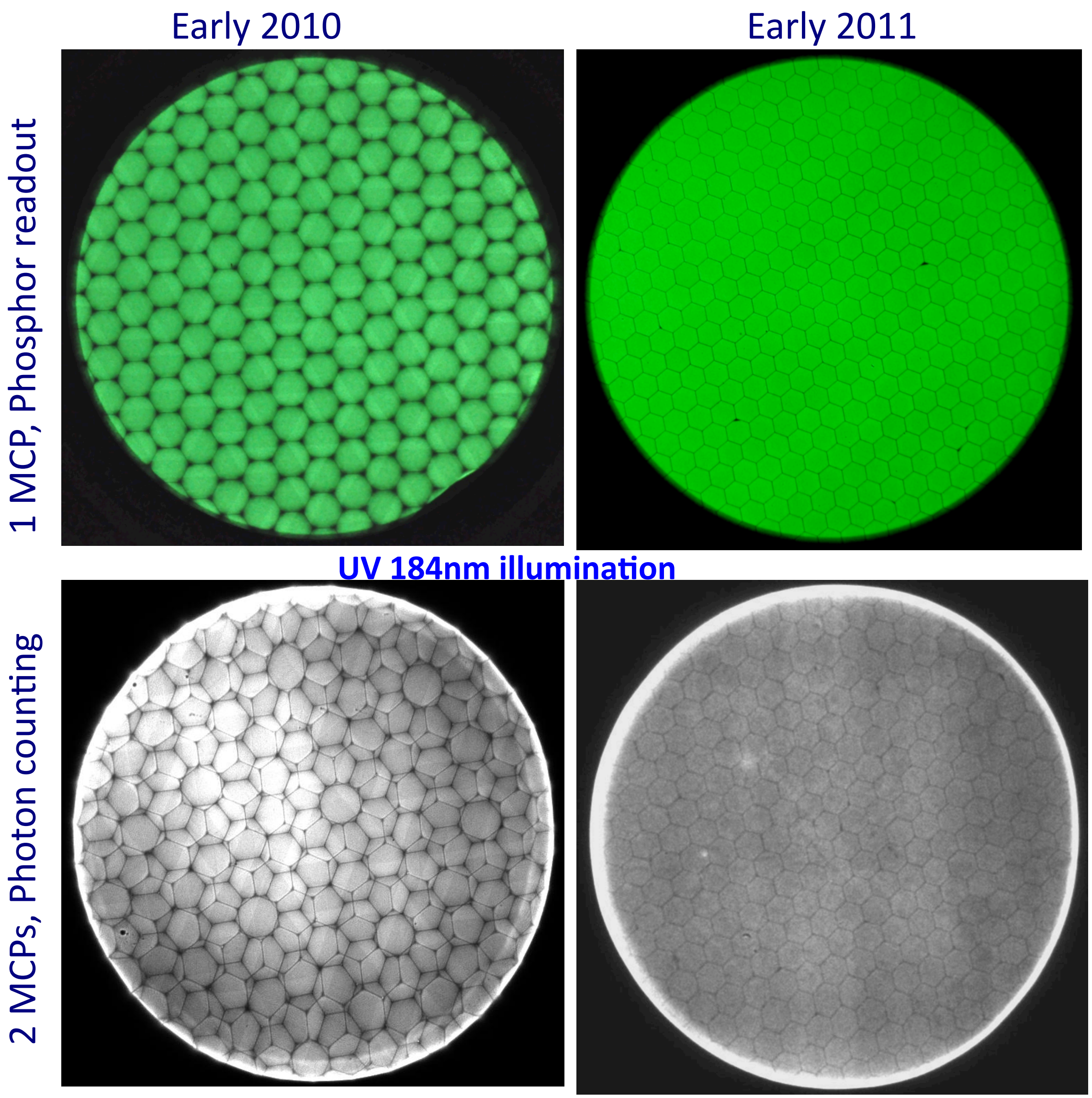
Borosilicate Substrate Atomic Layer Deposited Microchannel Plates

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) [TIPP - 60, 256, 457] 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 .

Imaging Performance of ALD MCPs, 33mm



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

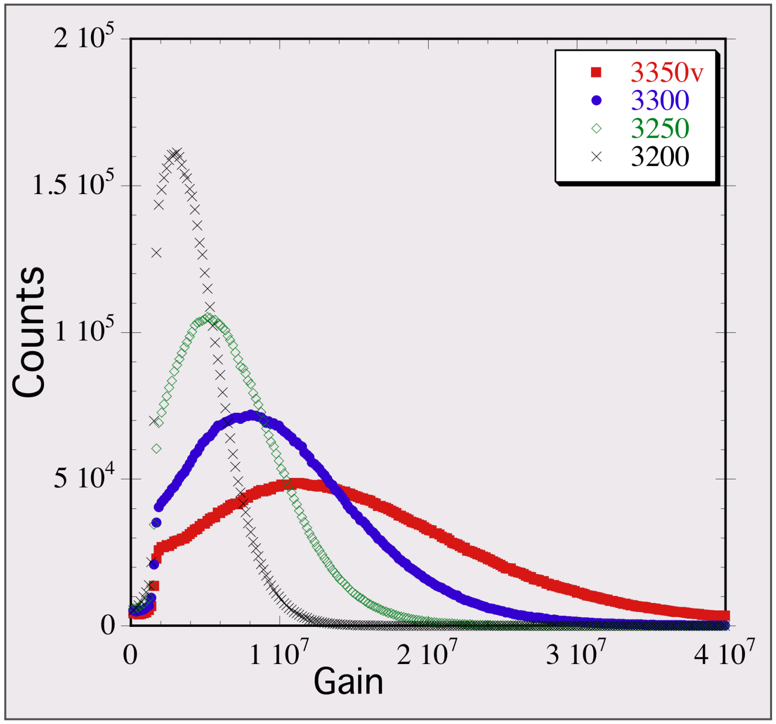
Single MCP tests in DC amplification mode show imaging and gain very similar to conventional MCPs.

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

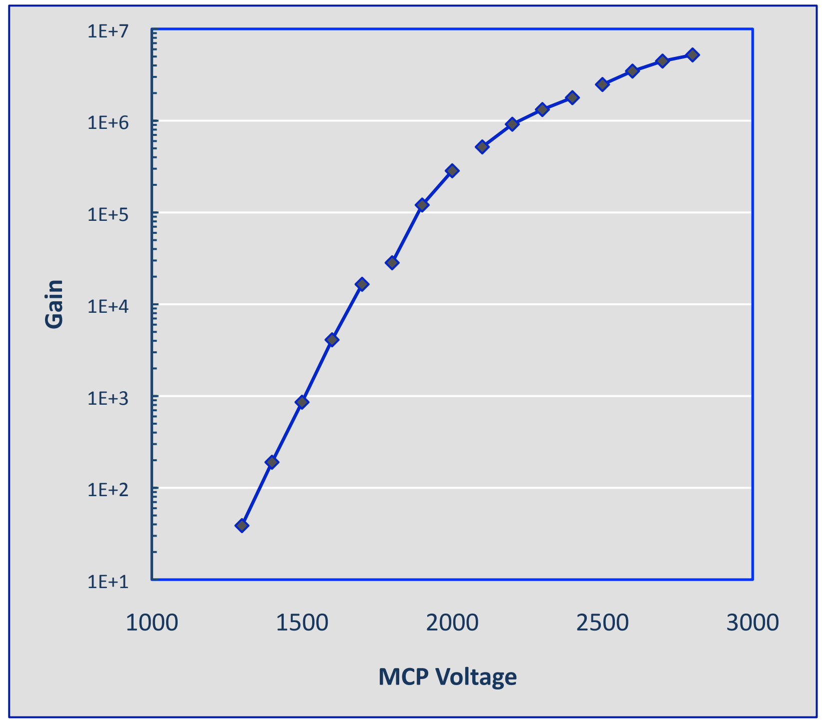
Sample performance has improved dramatically over the last 12 months due to process improvements.

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.



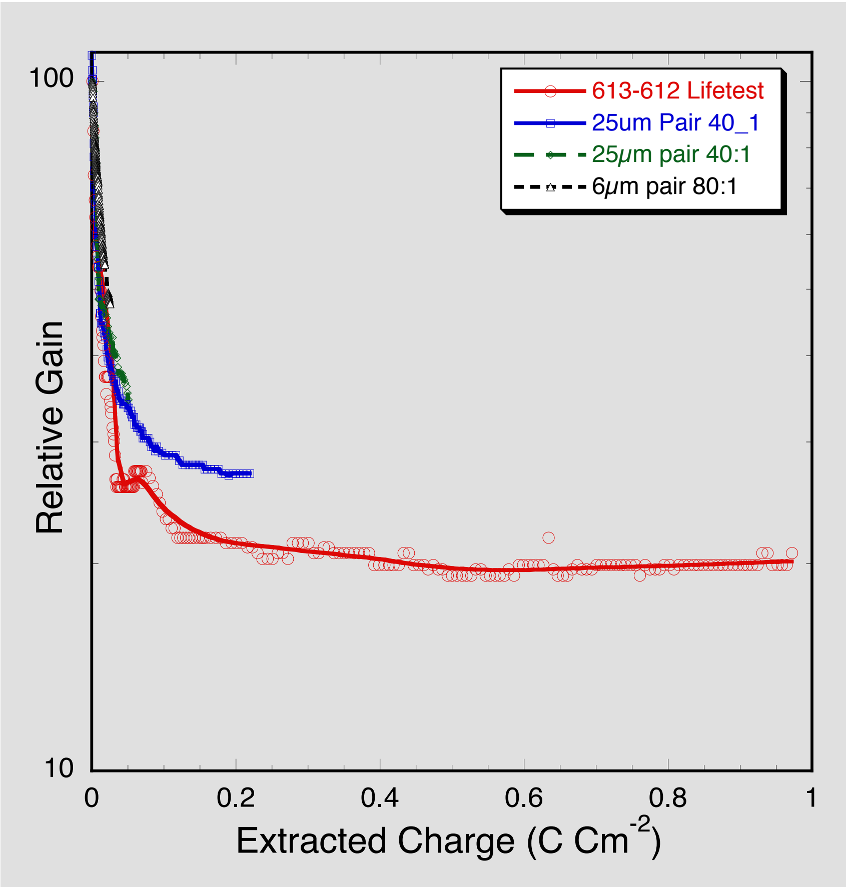
Pulse height amplitude distributions for a 33mm ALD MCP pair (voltages include a 400v anode bias).



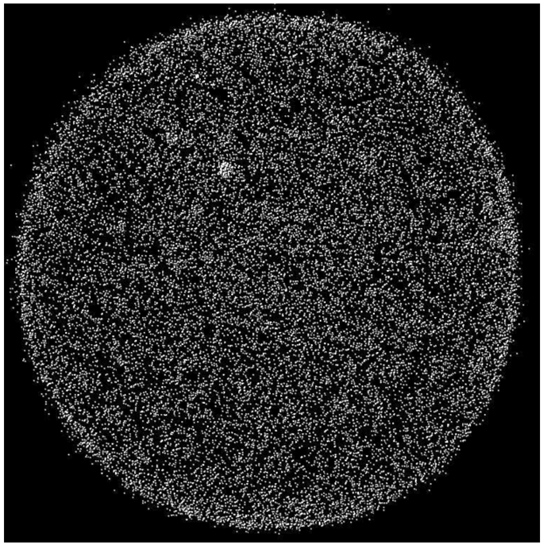
Gain for a pair of 20µm pore 33mm ALD MCP's, 60:1 L/d, 8 degree bias.

33mm ALD-MCP Performance Tests

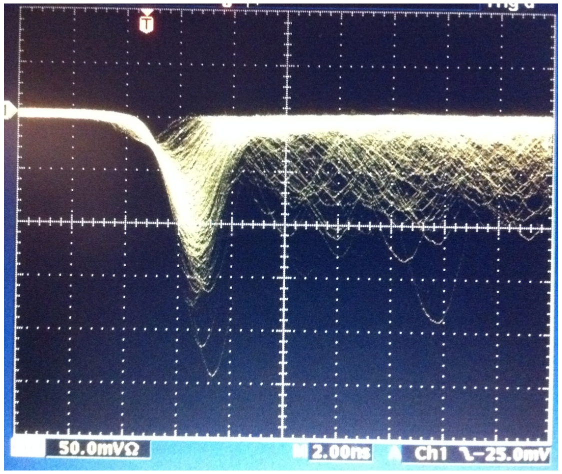
Gain ageing test after 350°C bake



Lifetest of ALD MCP pair compared with conventional MCPs. 20µm pore, 60:1 L/d.



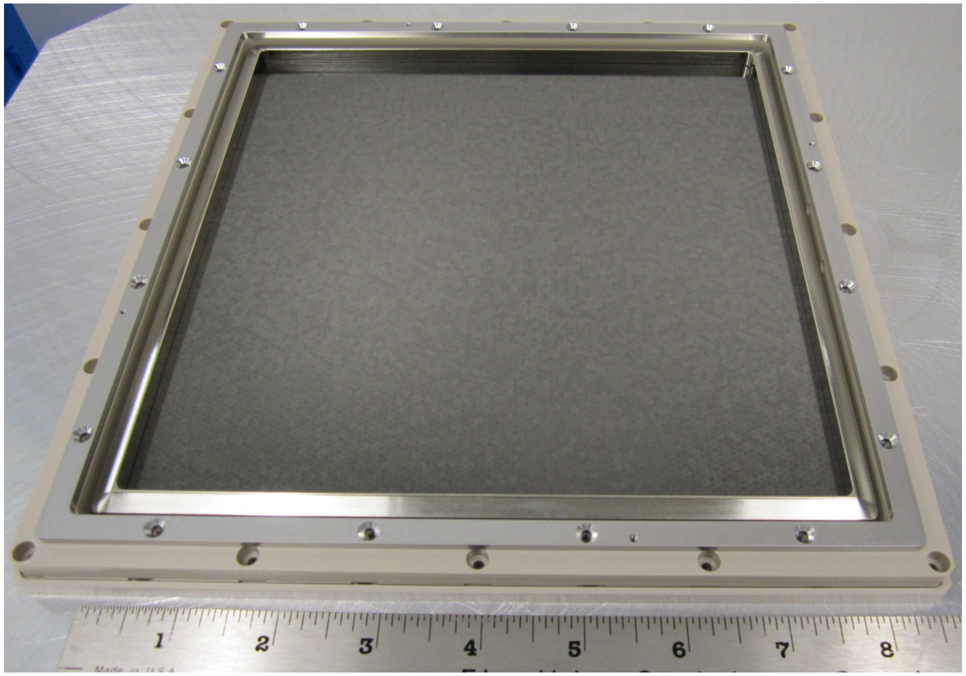
Background rate is uniform and a few events sec^{-1} cm^{-2} for an MCP pair



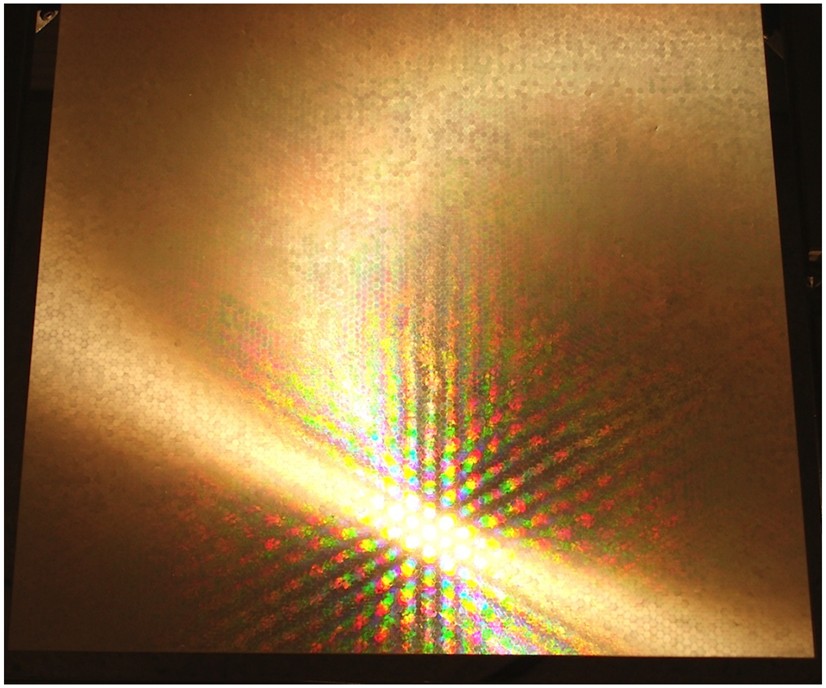
Single event pulses are ≤2ns wide

Progress with 8” MCP Development

A small number of 8” 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).

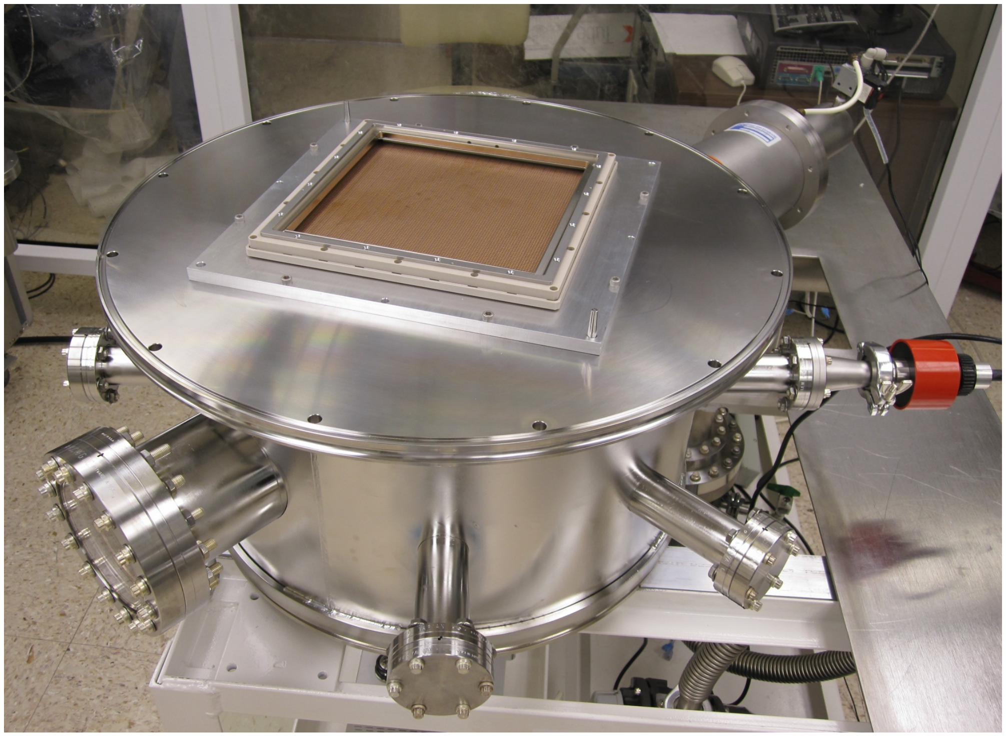


8” electroded ALD 20μm pore MCP in detector assembly with a cross delay line imaging readout

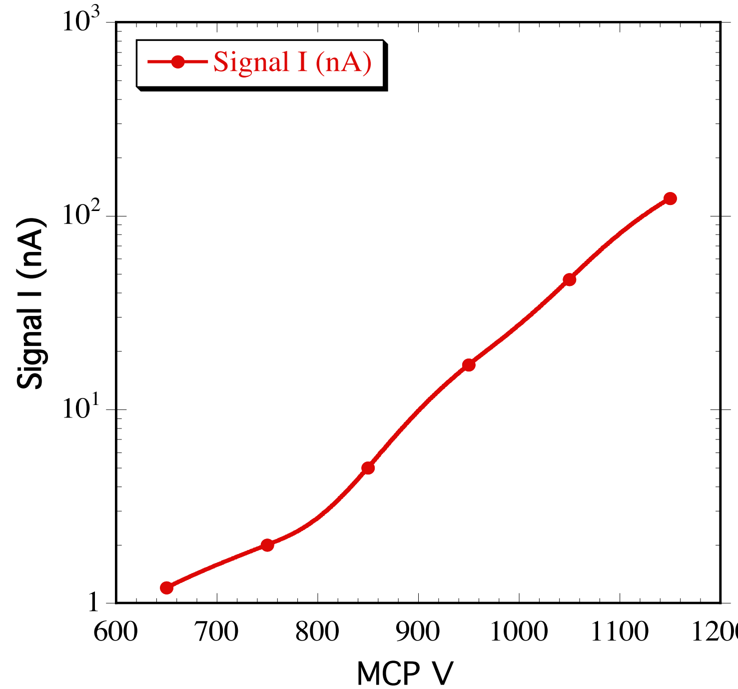


8” un-electroded MCP substrate showing the multifiber stacking arrangement

Testing of 8” ALD-MCPs



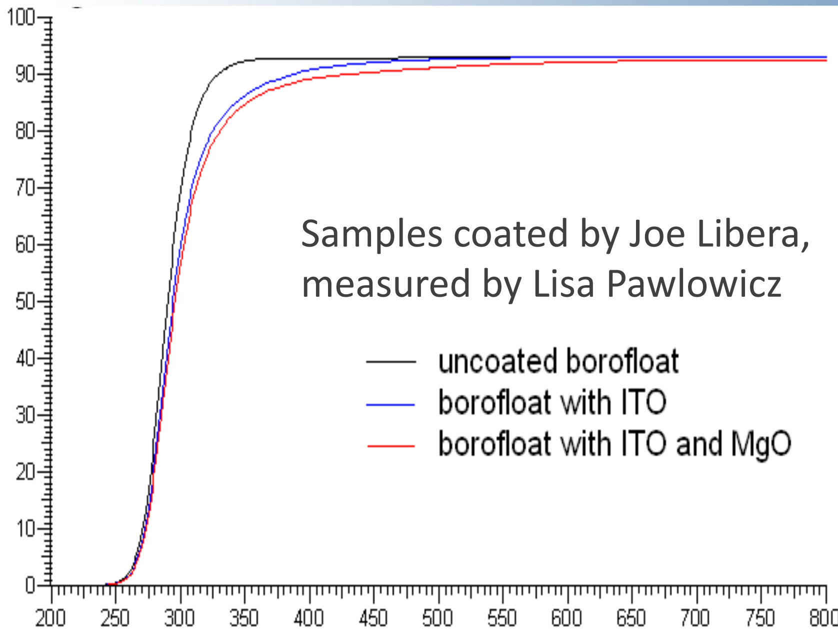
8” MCP test chamber and detector with XDL readout



8” MCP output signal v.s. V for UV input

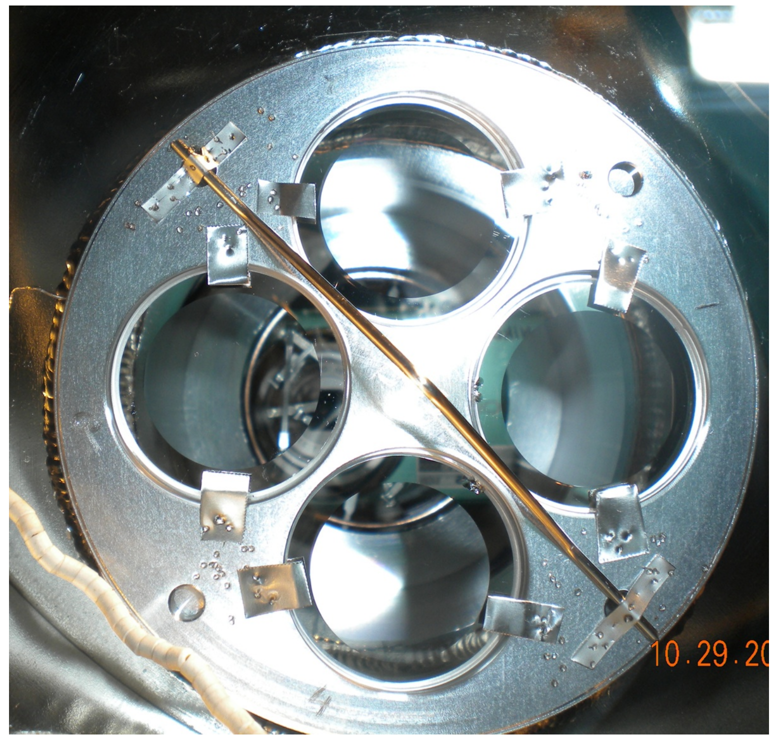
The cross delay line detector accepts 2 MCPs and spacers. It will allow <200µm spatial resolution for MCP pairs, and permit full parameter evaluation of 8” MCPs. An initial test with one 8” 20µm pore ALD-MCP shows a normal MCP gain curve.

Compatibility and Transmittance of Windows



B33 Transmittance is typical of borosilicate glasses

We have chosen a borosilicate glass (B33) as our window. 1.22” test samples with annular electrodes were used to test the windows for photocathode compatibility



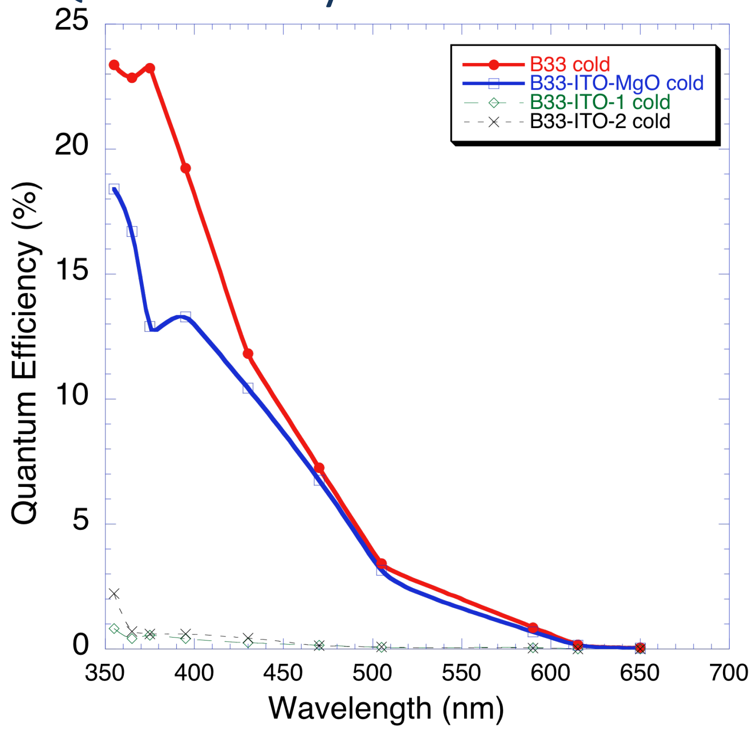
B33 transmission is adequate for the LAPPD wavelength bandpass. NiCr electrodes will be evaporated on the window borders for contacts.

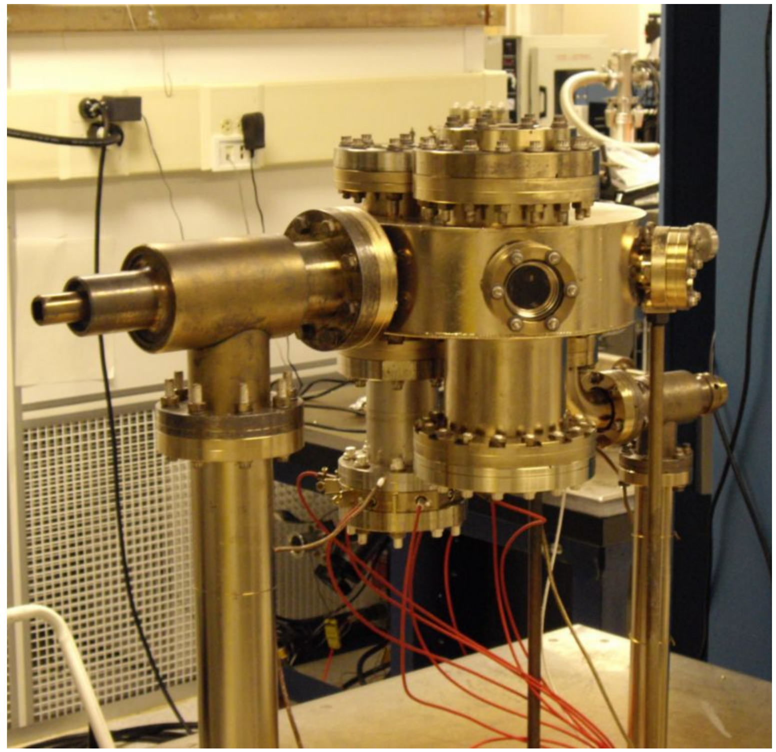
Bialkali Photocathode Sample Tests

Cathode test runs with Na_2KSb cathodes on borosilicate windows

>20% QE achieved at 300 – 400nm

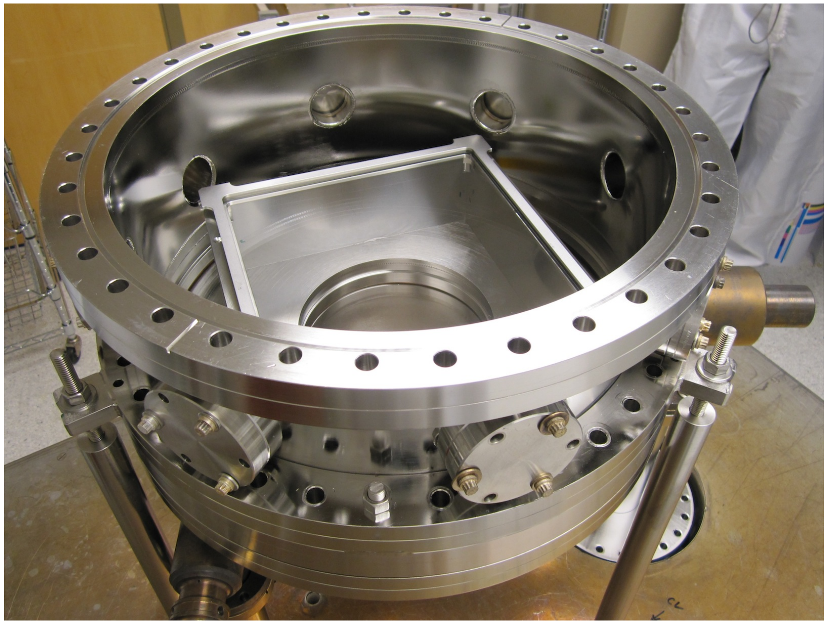
QE uniformity better than ± 15%





UHV tank for processing alkali cathodes and tubes of small area. Can take 4-8 samples/run. 7 runs done. Quantum efficiency optimizations, substrate material and under-coating tests.

8” Photocathode, and Window Seals

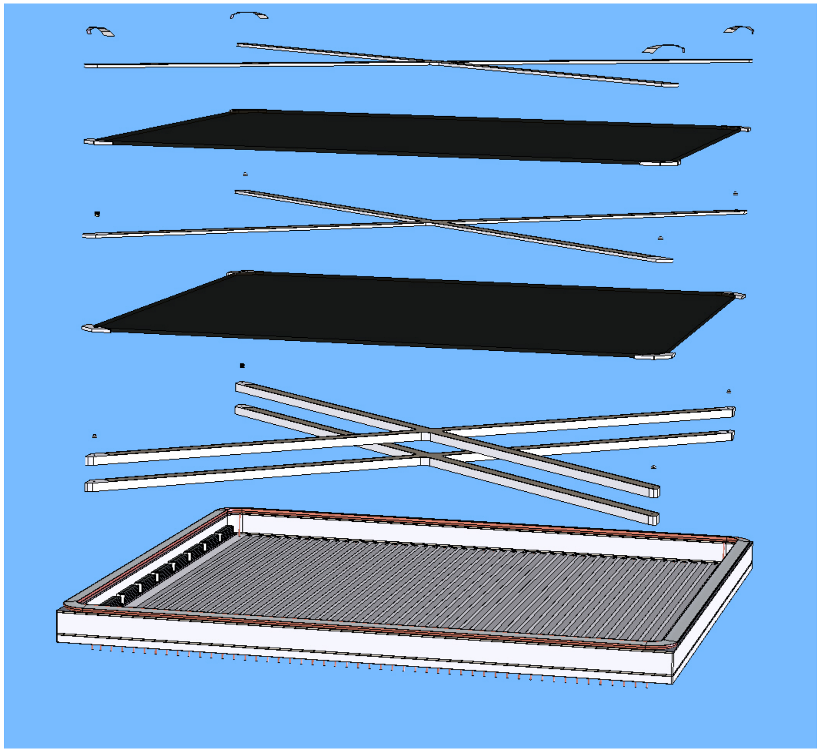


14” Diam UHV test process chamber with capability to process cathodes and seal 8.7” windows to brazed housings. Will be used to verify the processes to optimize the cathode QE and uniformity as well as the process for obtaining leak tight indium seals on 8” format.

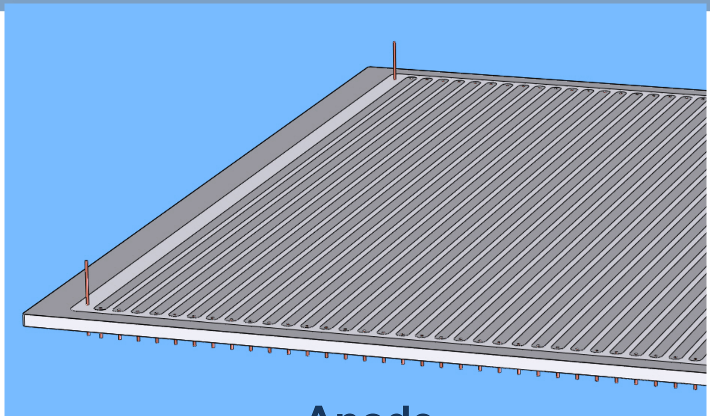
8” borosilicate window showing NiCr layer evaporated as a test sample. Only the edges will be coated for the windows used in the final sealed tube.

Ceramic Brazed housing design

Brazed Body Assembly and Preparation
The alumina/Kovar piece parts are brazed to form the hermetic package

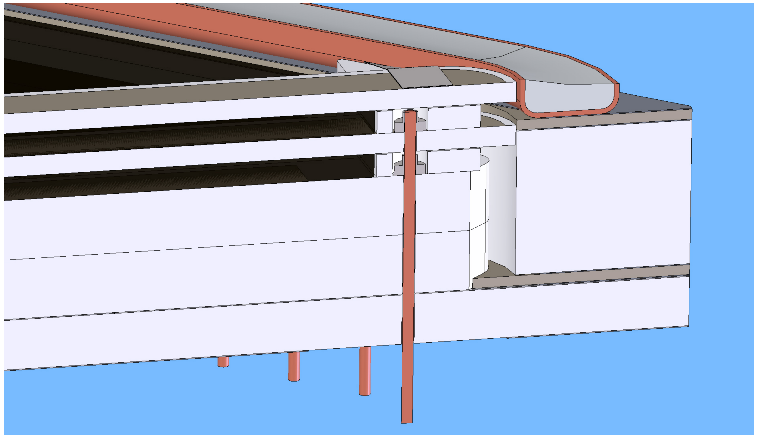


Brazed Body Internal Parts Assembly
Into the body, we stack up getters and X-grid spacers and MCPs. X-grids register on HV pins, hold down MCPs, and distribute HV (via metallization contacts).



Anode

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



8” Window Hot Indium Seals

Indium seal well

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

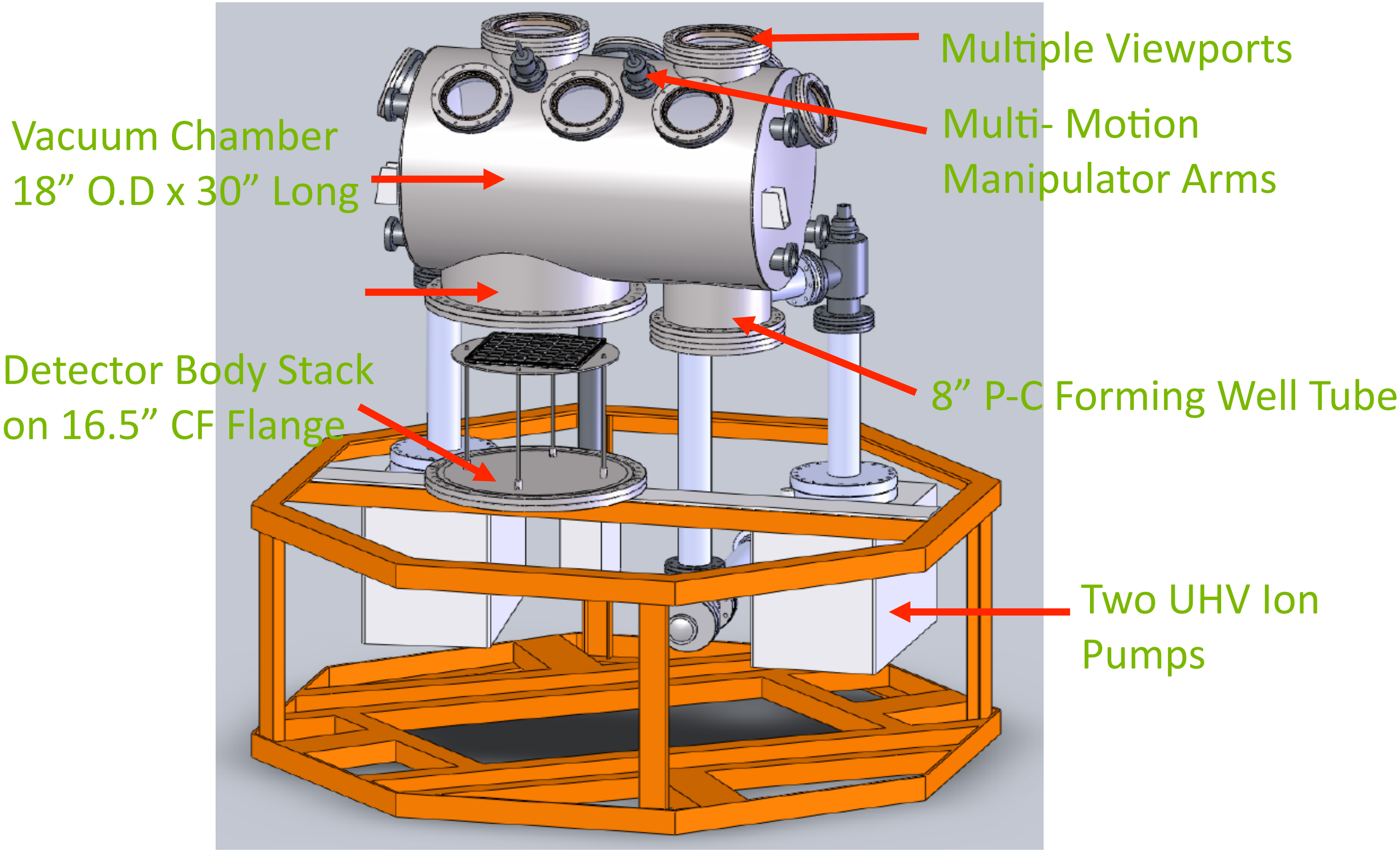
The 8” LAPPD ceramic brazed body design has a conventional Indium well, and alumina anode.

Will metalize 8.7” B33 windows and make Indium seals on a brazed frame (Indium well and body sidewall).

Utilize standard Indium eutectic alloy(s), NiCr metalization that has proven effective in previous sealed tubes.

Large Process Chamber for 8” Sealed tubes

An UHV facility for processing 8” sealed tubes is almost complete. This Will allow the fabrication of 8” bialkali photocathodes, preconditioning of 8” ALD MCPs and hot indium sealing of the completed tube.



Large Area Picosecond Photo-Detector Summary

- ALD functionalized MCPs using borosilicate glass microcapillary arrays have been successfully made in 33mm and 20cm formats
- Tests indicate that many of the performance characteristics are very similar to standard commercial MCPs both in analog and photon counting modes.
- Initial 20cm MCPs show normal gain behavior.
- Borosilicate windows have been successfully used as substrates for bialkali photocathodes with >20% peak quantum efficiency.
- 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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