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Large Area Micro-Channel Plates for LAPPD™

TIPP, June 2-6, 2014

Incom, Inc, Charlton, MA, USA
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Outline

- LAPPD program description
- Incom process for making large area glass capillary arrays
- Turning them into MCPs with coatings applied by Atomic Layer Deposition (ALD)
- Performance benefits over conventional MCPs
- **Manufacturing 20 x 20 cm sealed detector tiles**

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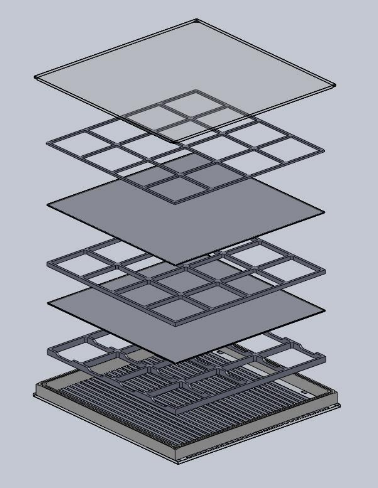
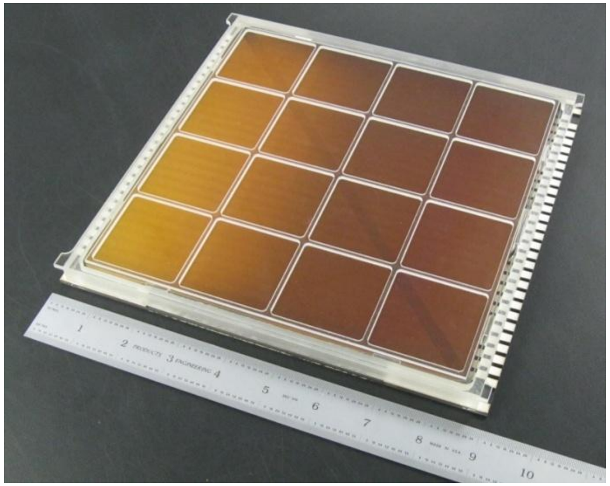
LAPPD Collaborative, LAPPD™ Detector Tile

- Large Area Picosecond Photo-Detector
- Developed under a collaboration between
  - Argonne National Laboratory
  - University of Chicago
  - Univ. of CA, Berkeley Space Sciences Lab
  - University of Hawaii
  - Fermilab
  - Incom, Inc.





Tile mock-up

20 x 20 cm (8 x 8”) low-cost,
MCP-based photodetectors for HEP, medical, defense, space, and other applications

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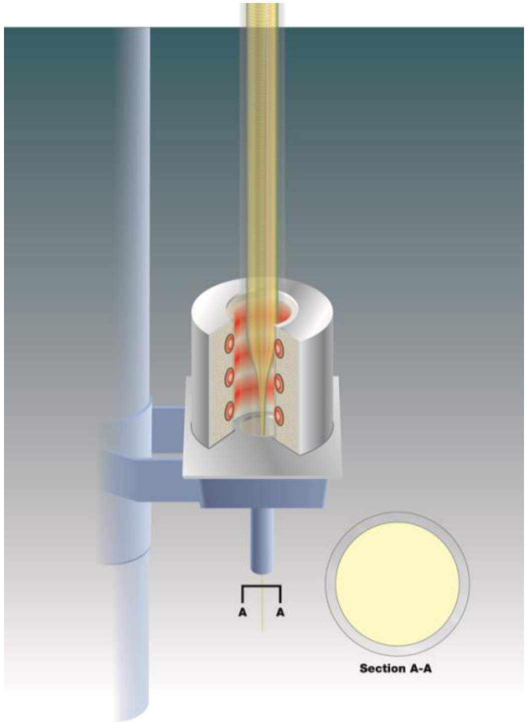
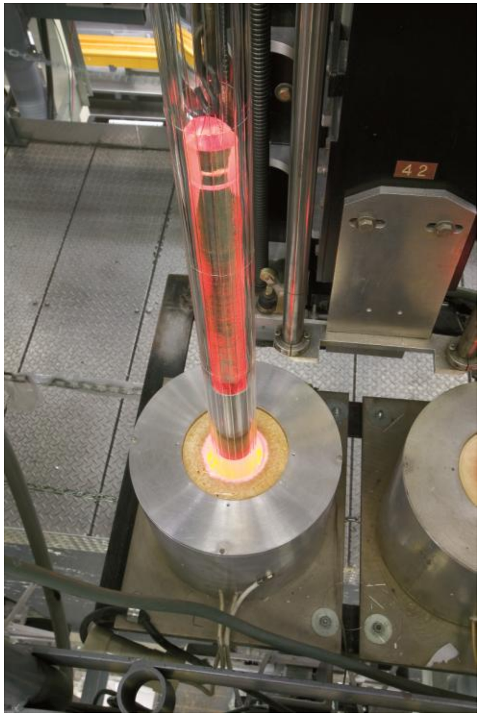
How Do You Make a Big Glass Capillary Array?

Step 1: draw glass



Incom's proprietary "etchless" approach. A wide range of glasses can be used.

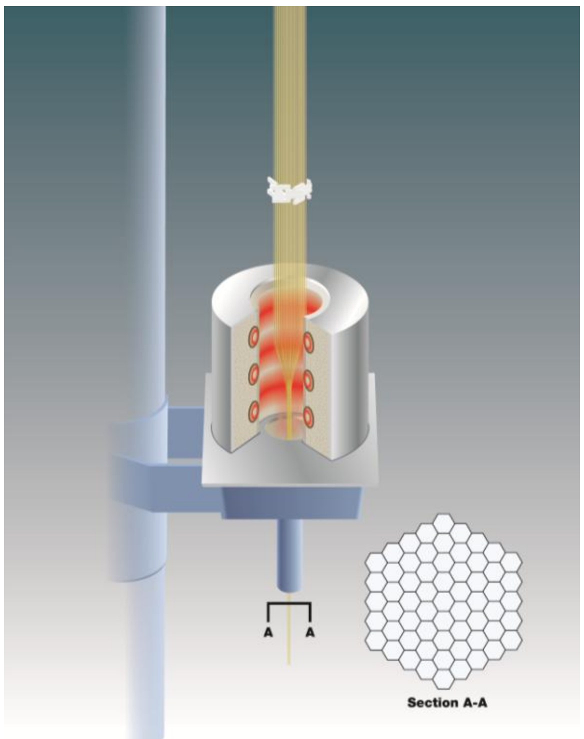
Incom draw towers

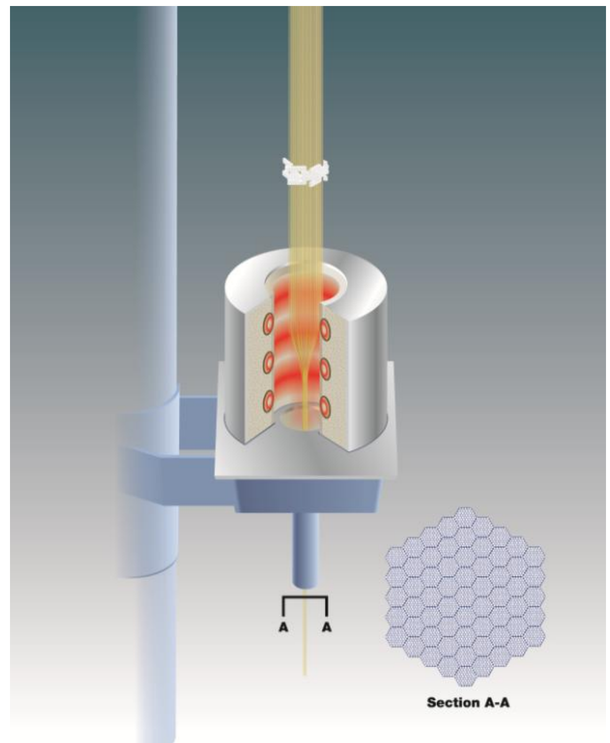


Conventional MCPs are drawn as fiber optics, with core and clad glass

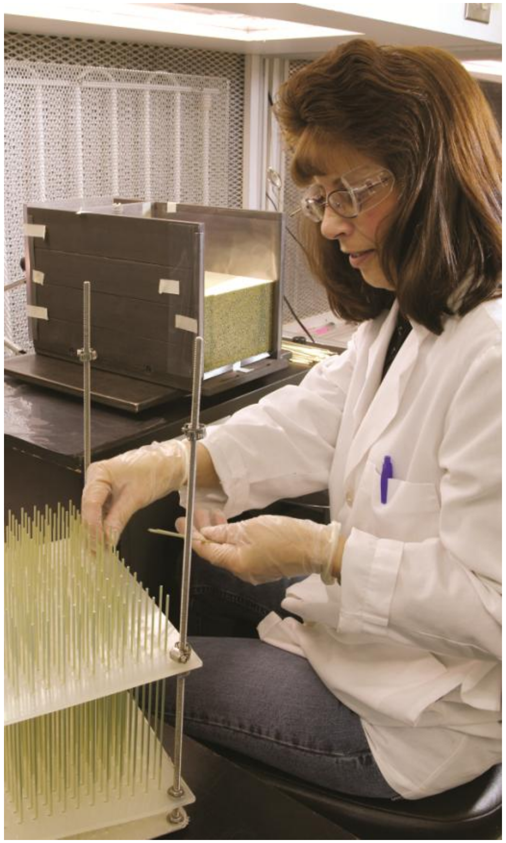
Step 2: Bundle and Redraw a "Multi"

- Dozens to thousands of fibers are bundled into a hexagonal multi (same as conventional MCPs)
- The multi bundle is drawn to make a hexagonal multi fiber
- For smallest pore sizes, process is repeated to make a "multi-multi"

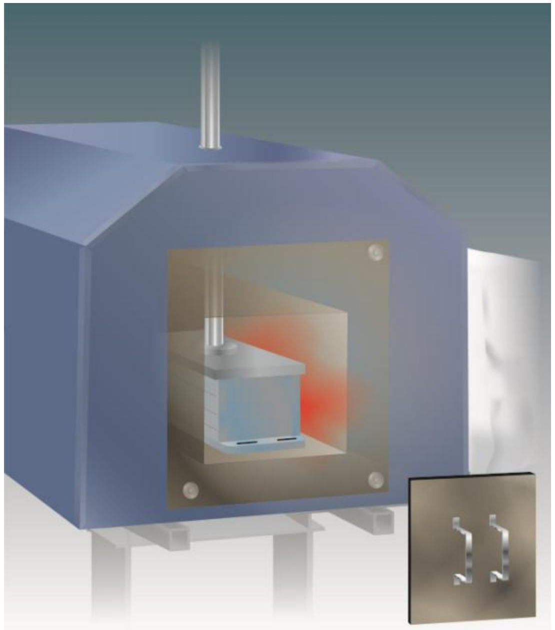




Step 3: Assemble
Step 4: Fuse



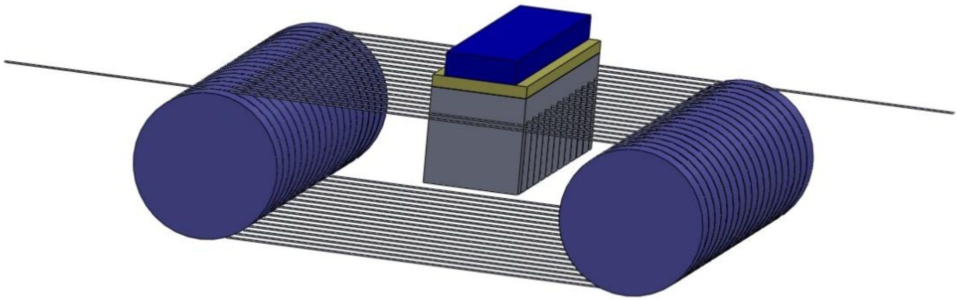
Multi fibers assembled in a shell

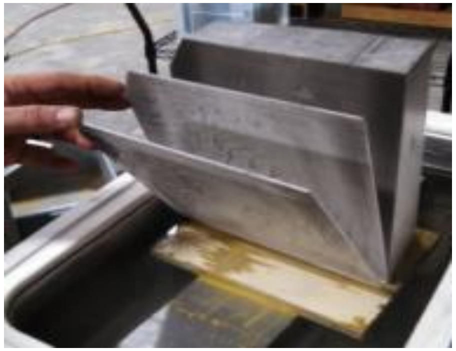


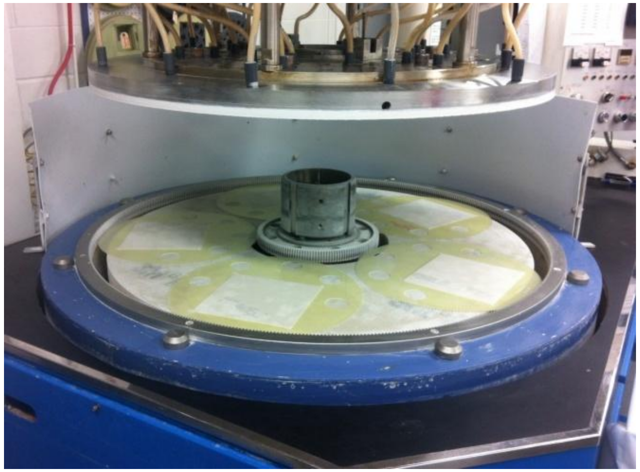
Heat & pressure applied to fuse into a block

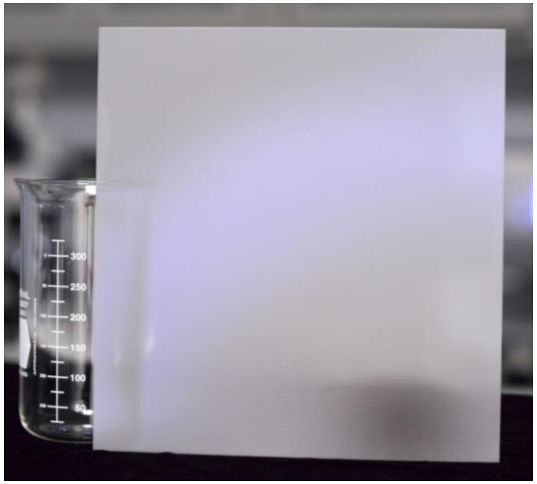
228 mm (9”) square capillary block

Step 5: Slice, Machine to Size, Grind, Polish









- To produce polished glass capillary array plates
- Conventional MCPs: polished fiberoptic plates

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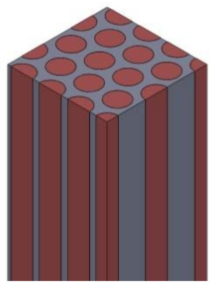
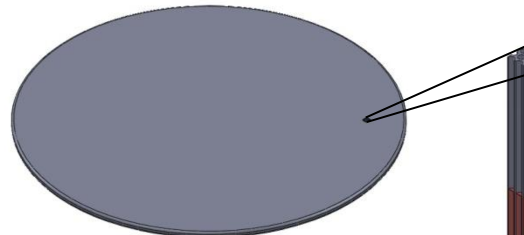
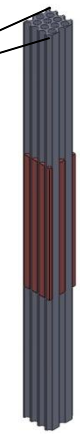
For Conventional MCPs, Next Steps Are:

Etch the fiberoptic plate to remove original core glass

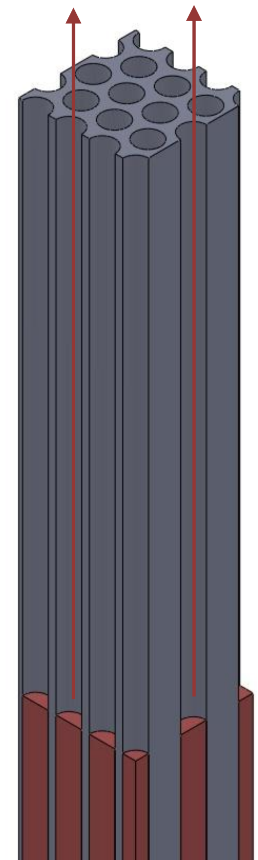




60:1 L/d ratio schematically shown (partially etched)



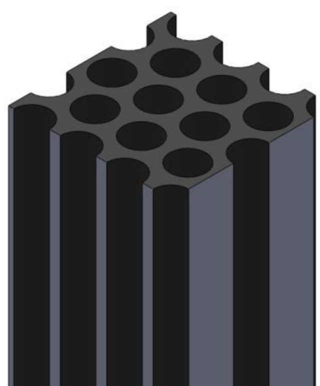
Core glass is dissolved away



Etching limits L/d ratio

H-fire to produce resistive/emissive coating

Not many glasses can be drawn, etched, and fired this way



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The Few Glasses Available for Conventional MCP Have Limits

Conventional MCP glasses are:

- Fragile. This limits overall MCP size.
- Susceptible to warping. Can warp if not stored under dry N_2 or vacuum, making detector assembly difficult.
- Noisy. The glass typically contains K or Rb. Their radioactive isotopes add to background noise.

The functional coatings produced by H-firing:

- Have limited secondary electron yield of ~2
- Require an extensive burn-in to achieve stable gain
- Have resistive/emissive characteristics that cannot be independently tuned

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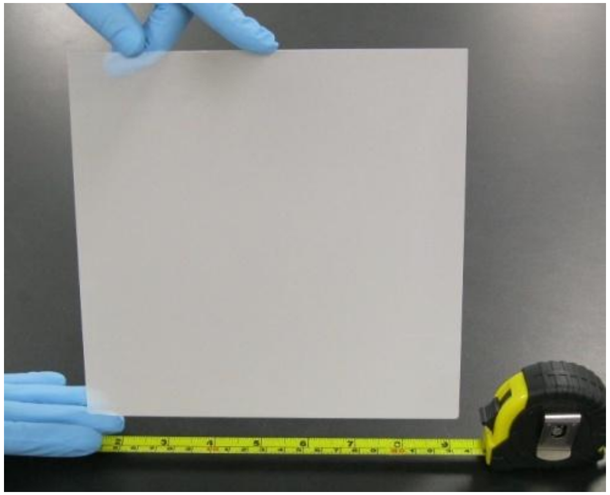
Instead, Choose Your Glass…

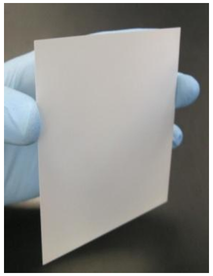
<u>Incom uses commercial glasses</u>

- Stronger = bigger for a given pore size & thickness
- Flat
- Lower cost
- Pb-free (RoHS compliance)
- <u>Alkali-free, **low noise**</u> : <0.085 events/cm^2/sec, vs. 3 events /cm^2/sec in conventional MCPs

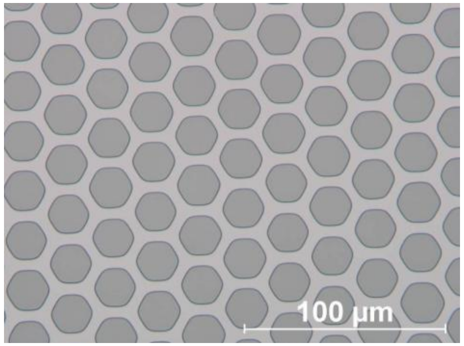


20 x 20 cm, 20 µm pore, 1.2 mm thick

O.H.W. Siegmund, N. Richner, G. Gunjala, J.B. McPhate, A.S. Tremsin, H.J. Frisch, J. Elam, A. Mane, R. Wagner, C.A. Craven, M.J. Minot, "Performance Characteristics of Atomic Layer Functionalized Microchannel Plates" Proc. SPIE 8859-34, in press (2013).



95 mm x 95 mm, 20 µm pore, 0.25 mm thick



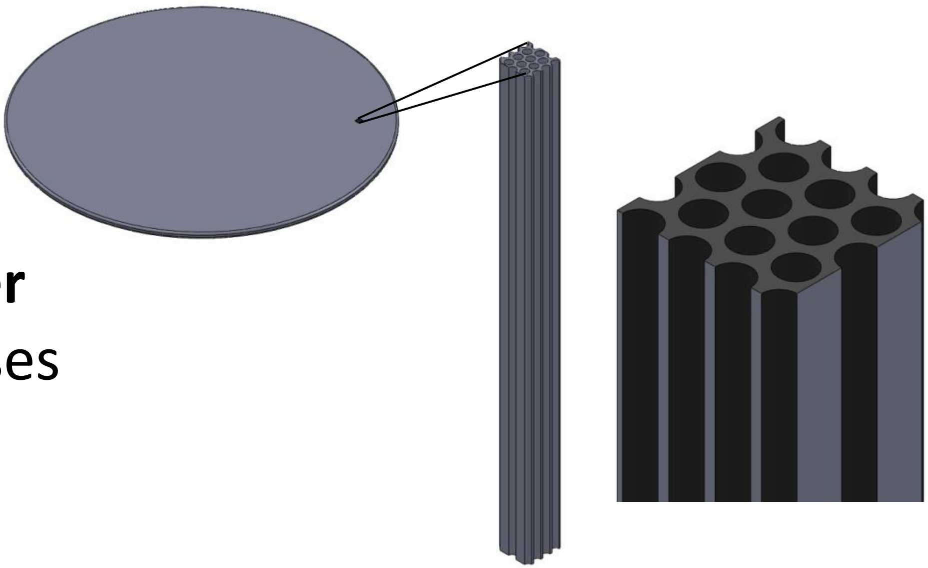
Typical glass capillary array, 20 µm pores, 60-65% OAR

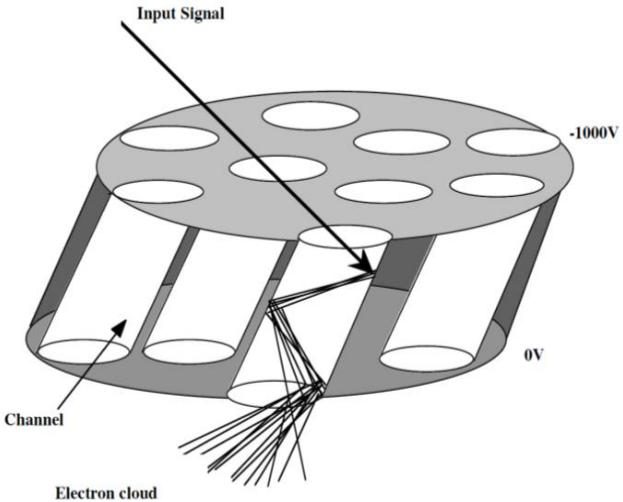
Regularly making 203 mm (8") square plates with 20 µm pores

… and Functionalize by Atomic Layer Deposition (ALD)

Engineer your coatings

- Deposit **resistive layer** to achieve desired resistance
- Deposit high yield **emissive layer**
- Can be deposited on many glasses





- Currently done by Argonne, Incom is acquiring ALD capability
- Incom is sole licensee of ALD technologies from Argonne and Arradiance

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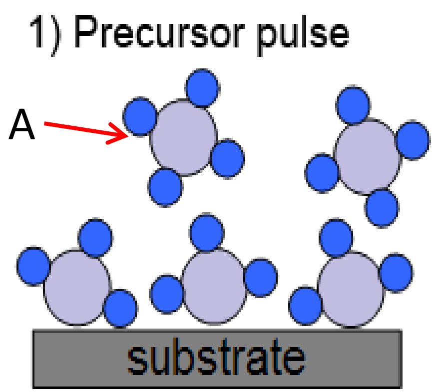
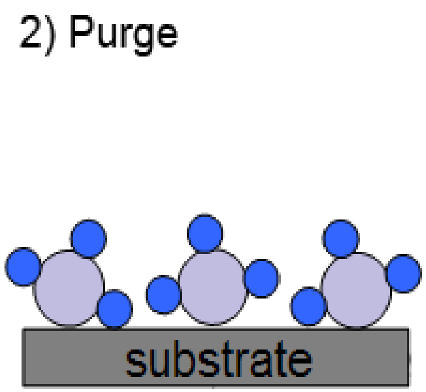
Atomic Layer Deposition

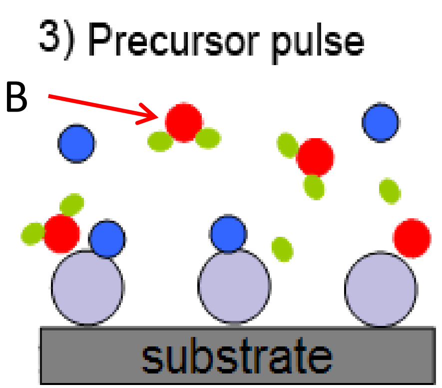
ALD is characterised by sequential precursor pulsing:



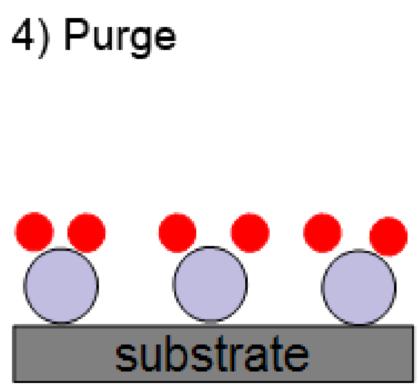
1) Pulse precursor A into chamber, which reacts with available sites.



2) Purge to remove unreacted precursors, by-products, and physisorbed species.



3) Pulse precursor B into chamber, which reacts with available sites. Reaction is self-limiting.



4) Purge to remove by-products. Repeat sequence to grow layers.

Can coat 1000:1 aspect ratios with ALD

Schematic sourced: http://www-rpl.stanford.edu/research

Gain is High and Reproducible in These MCPs

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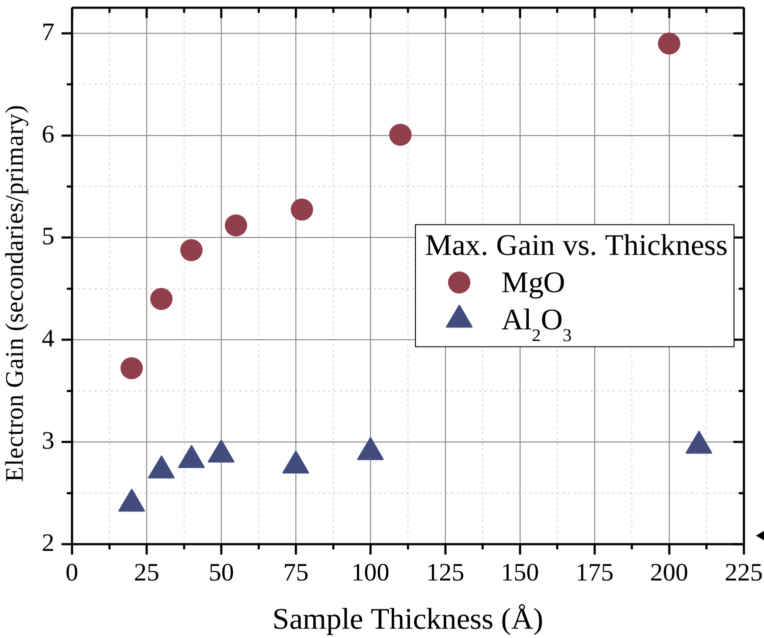
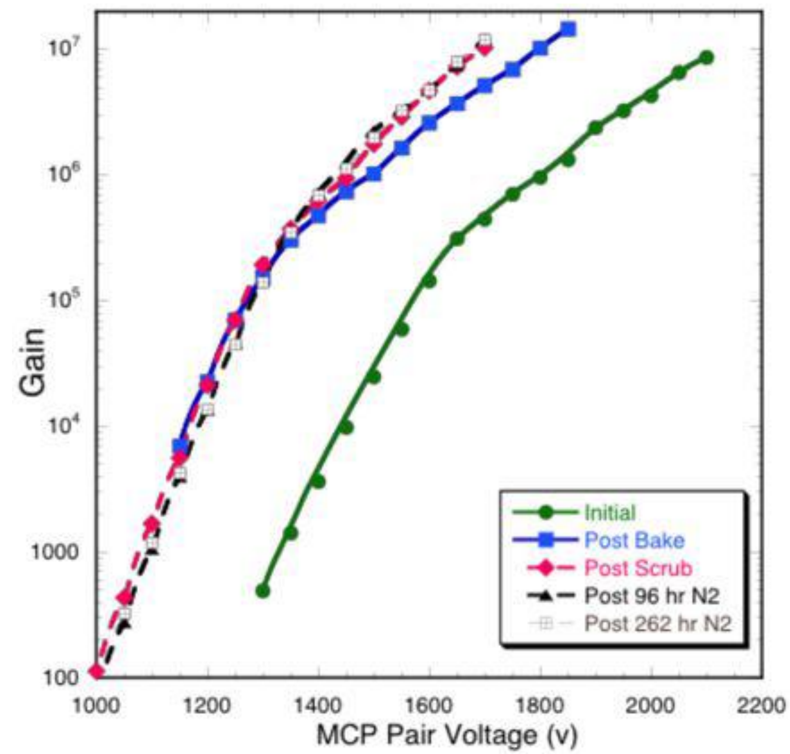
MgO and Al_2O_3 have high secondary electron yields



SEY in conv. MCPs is ~2

Slade J. Jokela, Igor V. Veryovkin, Alexander V. Zinovev, Jeffrey W. Elam, Anil U. Mane, Qing Peng, and Zinetulla Insepov, "Secondary electron yield of emissive materials for large area detectors: surface composition and film thickness dependences," Physics Procedia, 37, 740 – 747 (2012).



Gain of a pair of 33mm 20 µm pore, 60:1 L/D, MgO-ALD MCPs during preconditioning steps. Gain increases 10x after initial bake, and does not drop after storage in N_2.

O.H.W. Siegmund, J.B. McPhate, J.V. Vallerga, A.S. Tremsin, H.E. Frisch, J.W. Elam, A.U. Mane, R.G. Wagner, "Large area event counting detectors with high spatial and temporal resolution," 15th International Workshop on Radiation Imaging Detectors, 23–27 June 2013, Paris, France, JINST_072P_1213, in press

Gain is Stable vs. Extracted Charge

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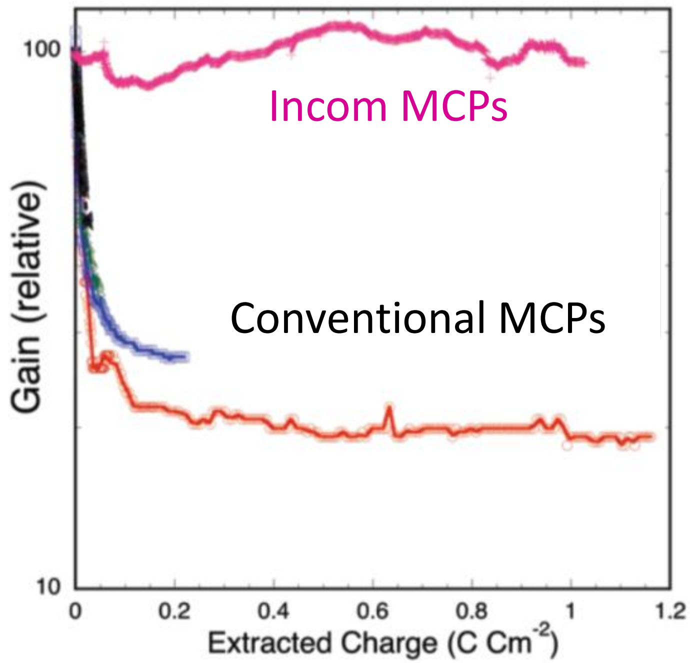
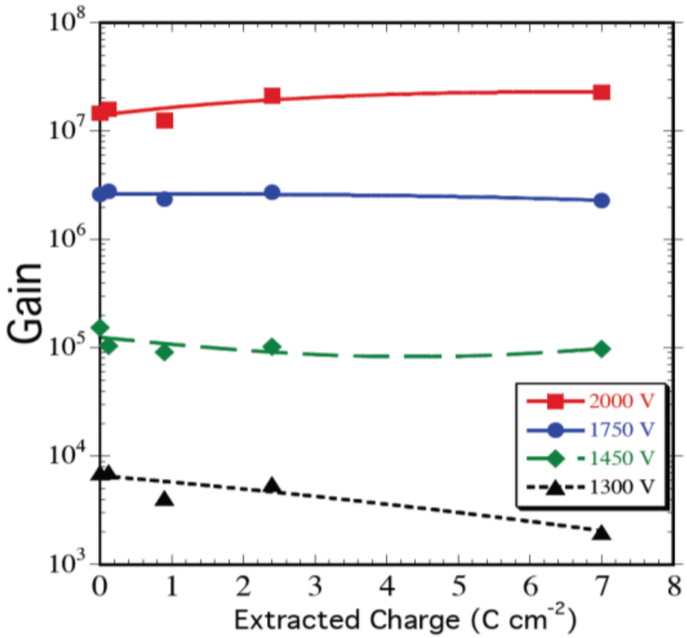




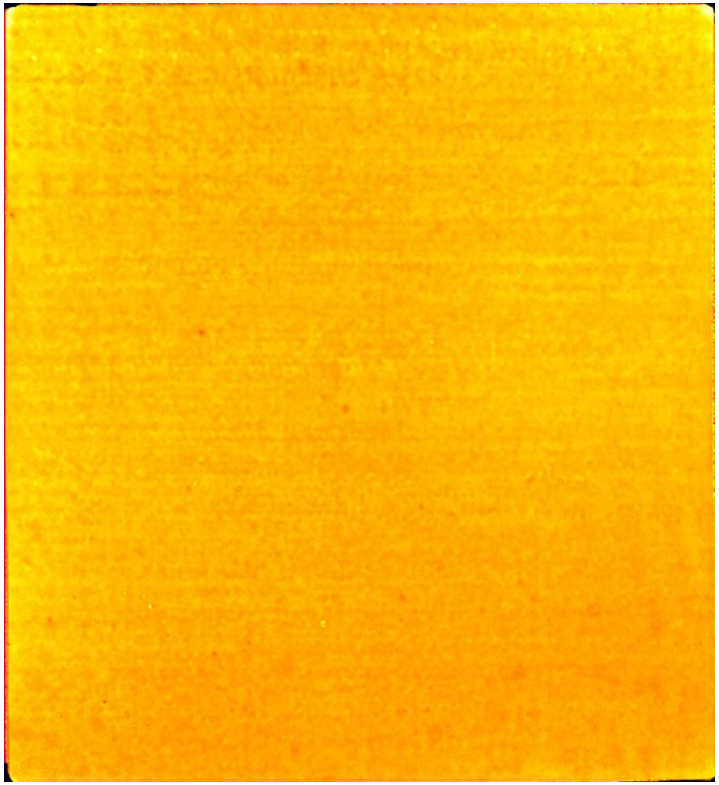
Conventional MCPs require an extensive "burn-in" to achieve a stable gain. Little burn-in is required for Incom MCPs.

O.H.W. Siegmund, J.B. McPhate, S.R. Jelinsky, J.V. Vallerga, A.S. Tremsin, R.Hemphill, H.J. Frisch, R.G. Wagner, J. Elam, A. Mane and the LAPPD Collaboration, "Development of Large Area Photon Counting Detectors Optimized for Cherenkov Light Imaging with High Temporal and sub-mm Spatial Resolution," NSS/MIC, IEEE.N45-1, pp.2063-2070 (2011)

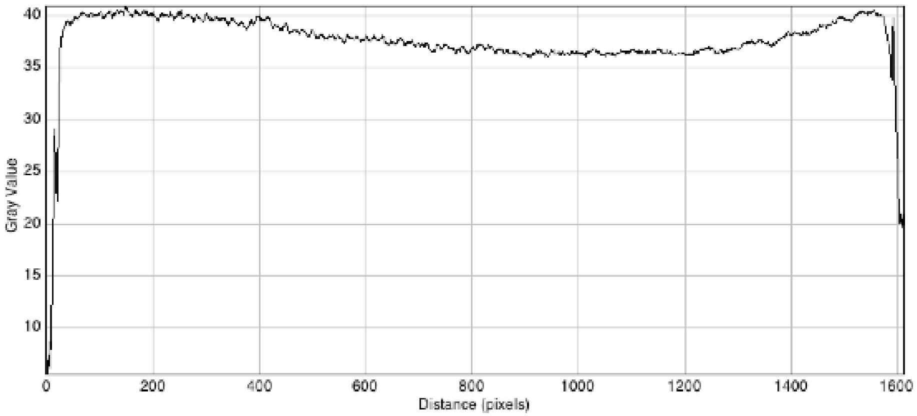
Gain is high and stable vs. extracted charge. Plot is of MCP gain at several fixed voltages during a "burn-in" test extracting 7 C/cm^2 at ~3 µA output current for a pair of 33 mm, 60:1 L/D, 20 µm pore ALD MCPs.

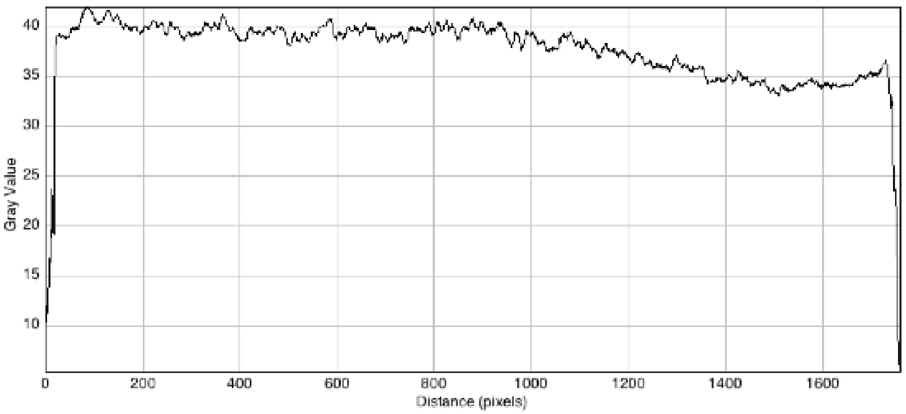
Oswald H. W. Siegmund, John V. Vallerga, Anton S. Tremsin, Jason B. McPhate, Xavier Michalet, Shimon Weiss, Henry Frisch, Robert Wagner, Anil Mane, Jeffrey Elam, Gary Varner, "Large Area and High Efficiency Photon Counting Imaging Detectors with High Time and Spatial Resolution for Night Time Sensing and Astronomy," Proceedings of the Advanced Maui Optical and Space Surveillance Technologies Conference, in press, (2012).

Gain is Uniform Across Area



Gain map image for a pair of 20 µm pore, 60:1 L/D, ALD borosilicate MCPs, 950 V per MCP, 184 nm UV





Gain is uniform within ~15% across full 20 x 20 cm area

O.H.W. Siegmund, N. Richner, G. Gunjala, J.B. McPhate, A.S. Tremsin, H.J. Frisch, J. Elam, A. Mane, R. Wagner, C.A. Craven, M.J. Minot, "Performance Characteristics of Atomic Layer Functionalized Microchannel Plates" Proc. SPIE 8859-34, in press (2013).

MCP Spatial Resolution Better than 20 μm

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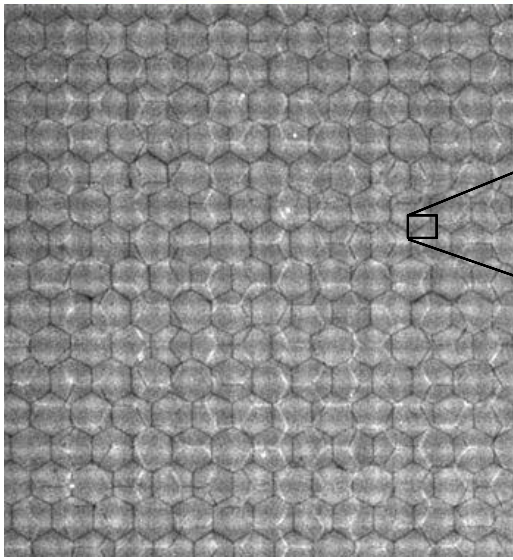
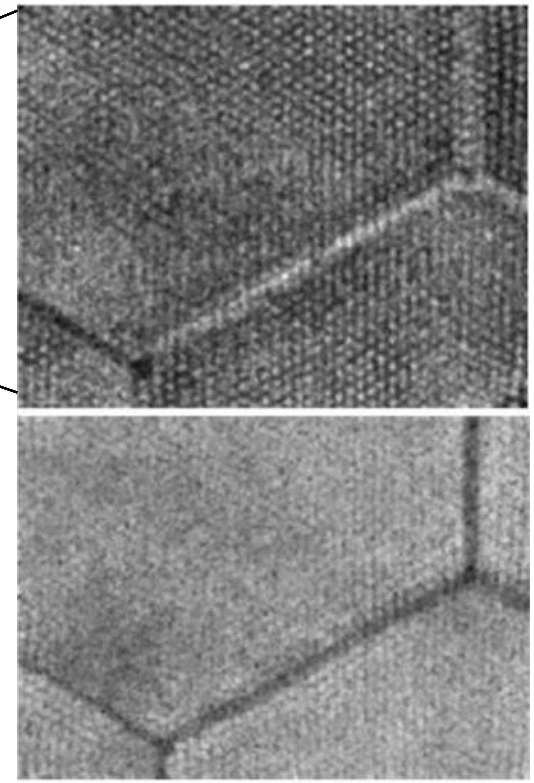


Section (~15 x 15 mm) of an accumulated image for a pair of 20 μm pore 60:1 L/D ALD MCPs at ~10^6 gain taken with a 95 mm cross strip detector, 184 nm UV



Upper: small section of image on left.
Lower: gain map image of the same area.

Using high resolution cross-strip delay line readout, individual 20 μm MCP pores are resolved (Ossy Siegmund, UC Berkeley)

O.H.W. Siegmund, J.B. McPhate, J.V. Vallerga, A.S. Tremsin, H.E. Frisch, J.W. Elam, A.U. Mane, R.G. Wagner, "Large area event counting detectors with high spatial and temporal resolution," 15th International Workshop on Radiation Imaging Detectors, 23–27 June 2013, Paris, France, JINST_072P_1213, in press

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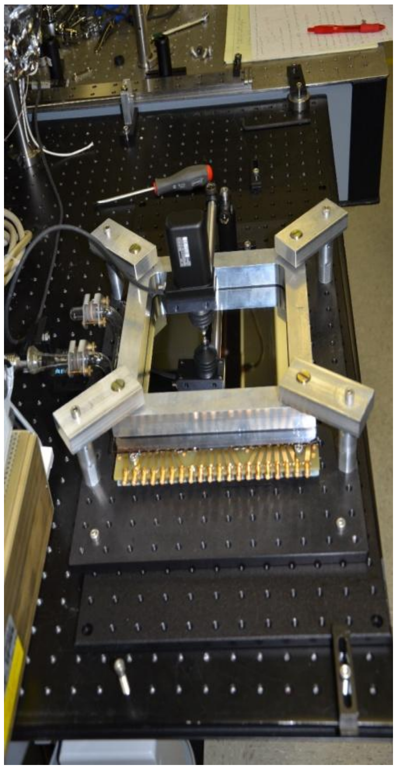
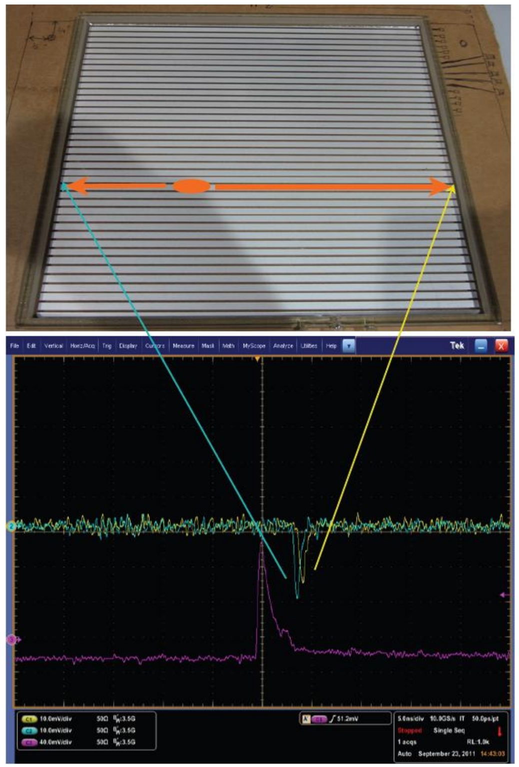
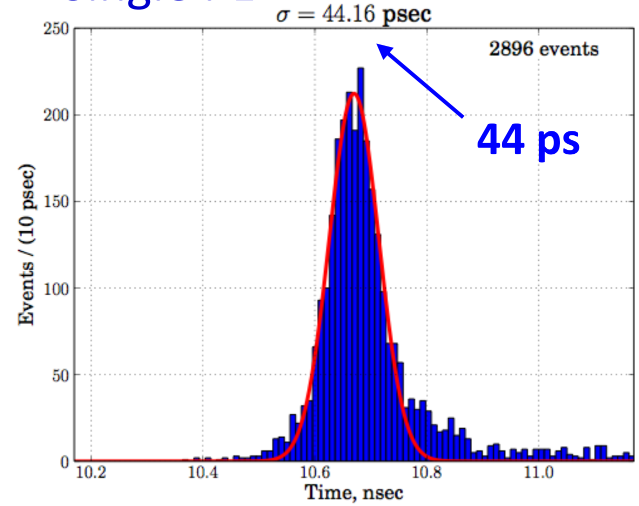
Temporal Resolution Better than 50 picoseconds



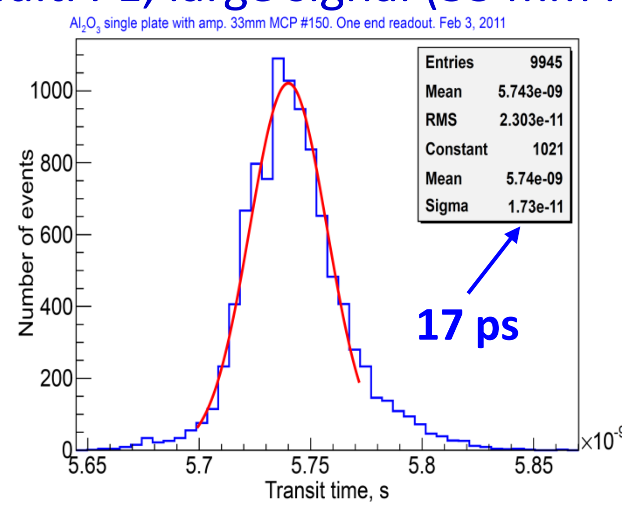


University of Chicago “demountable” station for testing 20 cm square LAPPDs (Matt Wetstein, Andrey Elagin)

Single PE



Multi PE, large signal (33 mm MCP)



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Making 20 cm x 20 cm Detector Tiles

We are developing capability to fabricate large area sealed detector tiles, not just MCPs

In-house equipment being brought in for:

- Electrode deposition
- ALD coating
- Detector tile assembly
- Additional testing electronics

- Incom is the company commercializing the LAPPD™
- 2-year contract with the US DoE, April 2014 – April 2016

20 x 20 cm Photodetector Tile

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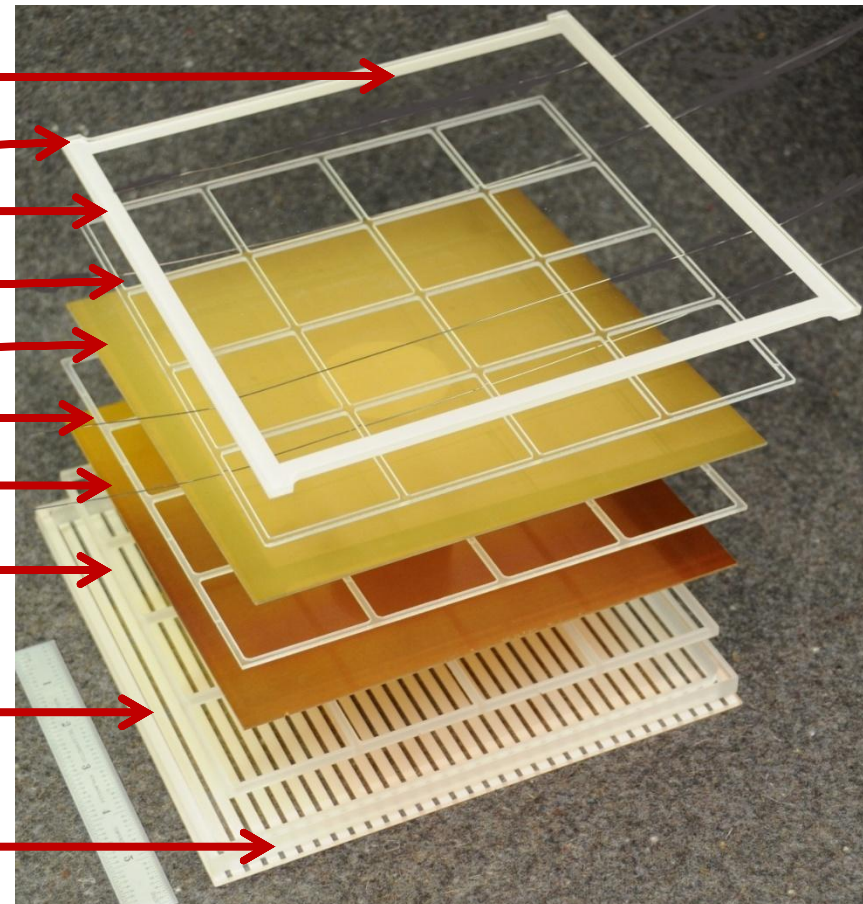
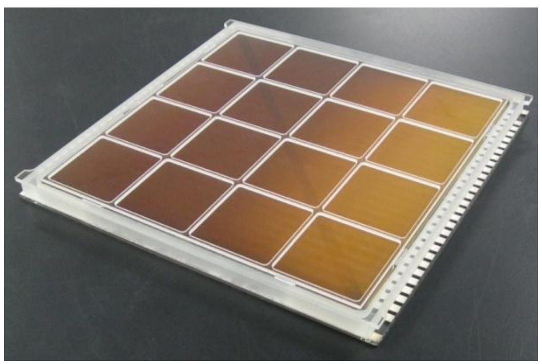
LAPPD™ Design:

- Window and photocathode
- NiCr Tab for external HV
- Indium Top Seal
- Glass spacer
- Top 8"x8" MCP
- Glass spacer
- Bottom 8"x8" MCP
- Glass spacer
- Sidewall, frit sealed to anode plate
- Bottom anode plate with 50W strips that pass through frit seal





Mock-up of detector tile (everything but photocathode)

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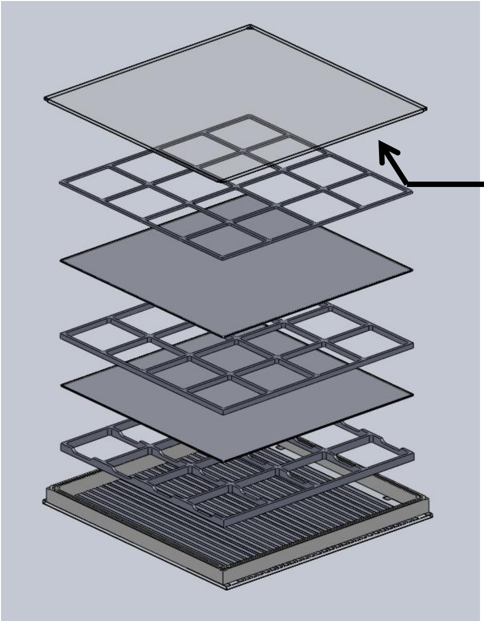
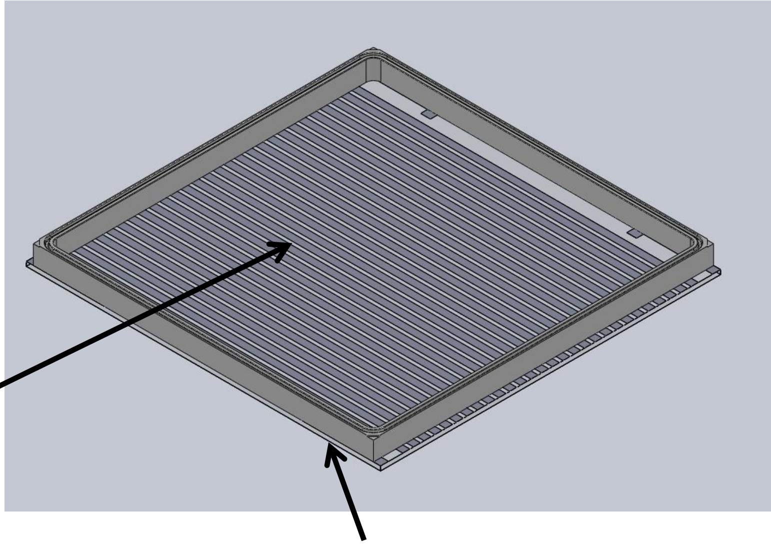
20 x 20 cm Photodetector Tile

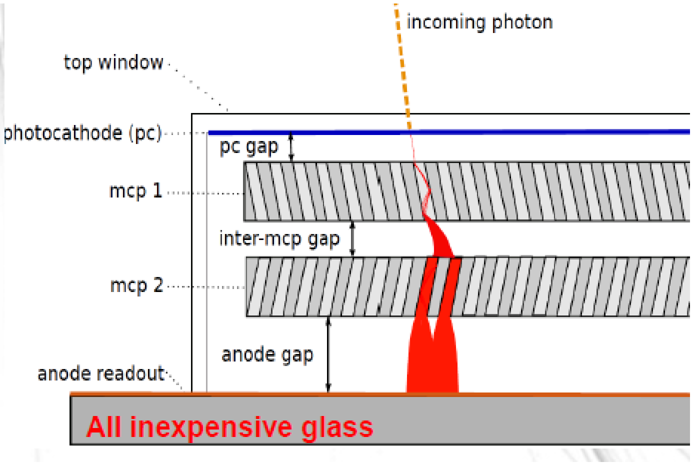


Photocathode deposited on window

Anode strips on bottom glass plate



Sidewall fritted (low melting point glass) to bottom plate, with anode strips extending outside package



MCP Description/ Specifications

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Parameter	Demonstrated Results in MCPs
Physical dimensions	Overall: 203 x 203 x 1.2 mm, flat across area ±12.7μm Operational area 200 x 200 mm Pore size 20 μm, pitch = 25 μm, OAR=60-65%
ALD coatings	Resistance: selectable, typically 10-25 MOhm SEE Layer: MgO or Al_2O_3
Gain	10^5 @ 1400 V, 10^7 @ 2000 V, (test from a pair of 33 mm MCPs of same material)
Gain Uniformity	Variability across area <20%
Background Rates	0.085 events cm^{-2} sec^{-1} at $7x10^6$ gain, 1025 V bias on each MCP. Intrinsic MCP background rate ~35kHz at the highest running gain

Sizes we have made

- 10 mm round, 20 μm pore
- 33mm round, 20 μm pore
- 33mm round, 10 μm pore
- 86.6 mm round, 10 μm pore
- 12 mm square, 20 μm pore
- 50 mm square, 10 μm pore
- 203 mm square, 20 μm pore
- Other intermediate sizes

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LAPPD™ Preliminary Specifications

Parameter	Demonstrated Results in LAPPD™ Format	Production Target
QE	**20-25%,** tested on a 20 x 20 cm bi-alkali photocathode at 350-400 nm, with ±15% uniformity over the full area	Maximize
Spatial Resolution	**5 mm for single photons, 1 mm for large signals** Also depends on software and readout electronics	Application Specific **1-5 mm**
Temporal Resolution	**<50 psec,** tested using a 610 nm laser with a spot image of <5mm FWHM at high pulse amplitudes	**≤40 psec**

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Applications

Applications

- High energy physics
  - Water Cherenkov counters (see Matt Wetstein's talk)
  - Large scintillation detectors (see Andrey Elagin's talk)
  - Vertex separation and particle I.D. in time-of-flight measurements
  - Accelerator beam diagnostics
- Defense and homeland security: neutron and neutrino detection
- Medical: PET scanners
- Space: UV detectors
- Other commercial applications: image intensifiers, streak cameras, mass spectrometers, MCP-based channel electron multipliers…

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Acknowledgements

United States Department of Energy

- Grant # DE-SC0009717, TTO Ph II, "Fully Integrated Sealed Detector Devices," 4/15/14 – 4/14/16
- Grant # DE-SC0011262, SBIR Ph I, "Further Development of Large-Area Micro-channel Plates for a Broad Range of Commercial Applications," 2/19/14 – 11/18/14

LAPPD Collaborative

- Argonne National Laboratory, University of Chicago, University of California, Berkeley Space Sciences Laboratory, Fermilab, and University of Hawaii for continuing development of the LAPPD technology

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Bright Ideas in Fiberoptics

Thanks!

Key Feature	Conventional MCPs	Incom MCPs	Incom Advantage
Size		Way bigger	Large area, lower cost
Base glass	Fragile	Stronger	Larger size, opportunity for thinner MCP or higher OAR
Flatness	Can warp if care is not taken during storage	Remains flat	Ease of device fabrication
Dark Count	~3 cm^{-2} s^{-1}	<0.085 cm^{-2} s^{-1}	Enhanced signal to noise
Secondary Electron Yield	~2	2.5-5	Greater gain, or lower voltage for same gain
Scrubbing Time	Many hours	Little or none required	Lower installed cost

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