Large Area Picosecond Photo-Detector (LAPPD™): Present Status and Prospects

A. Lyashenko, Incom Inc.

INCOM

Bright Ideas in Fiberoptics

LAPPD Collaboration:

- A. Lyashenko (alyashenko@incomusa.com), M. J. Minot, B. W. Adams, M. Aviles, J. L. Bond, C. A. Craven, T. Cremer, M. R. Foley, M. A. Popecki, M. E. Stochaj, W. A. Worstell, **Incom Inc, Charlton, MA**
- J. W. Elam, A. U. Mane, **Argonne National Laboratory**
- O. H. W. Siegmund, C. Ertley, **University of California, Berkeley**
- H. J. Frisch, A. Elagin, **University of Chicago**

Motivation:

- Large Area: 200 x 200 mm^2
- Picosecond Timing: resolution <100pS for SPE
- PMT Sensitivity: QE ~20% w/bi-alkali photocathode
- Lower Cost per Unit Area
- Sub-mm spatial resolution
- Flat Geometry

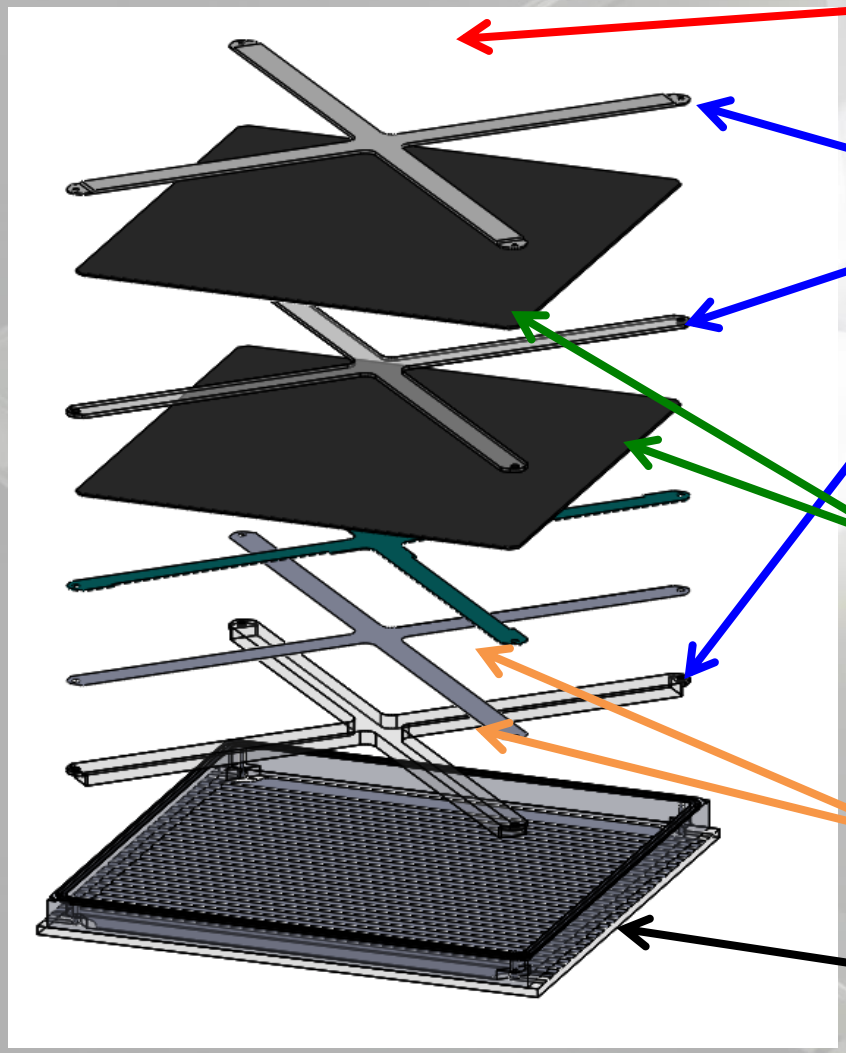
Applications:
HEP and others [homeland security sensors, astronomy, electron microscopy, TOF mass spectrometry, molecular and atomic collision studies, fluorescence imaging, plenoptic and medical imaging (PET scanning) applications]

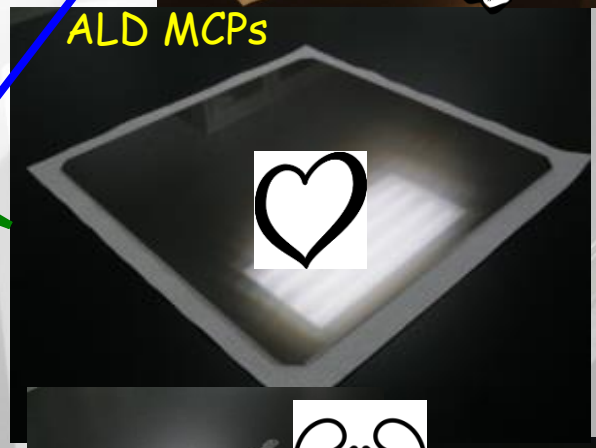
Goals

- Produce Fully Functional Detector
- Demonstrate Pilot Production

Henry J. Frisch, et. al., A Brief Technical History of the Large-Area Picosecond Photodetector (LAPPD) Collaboration, http://arxiv.org/abs/1603.01843 March 2016

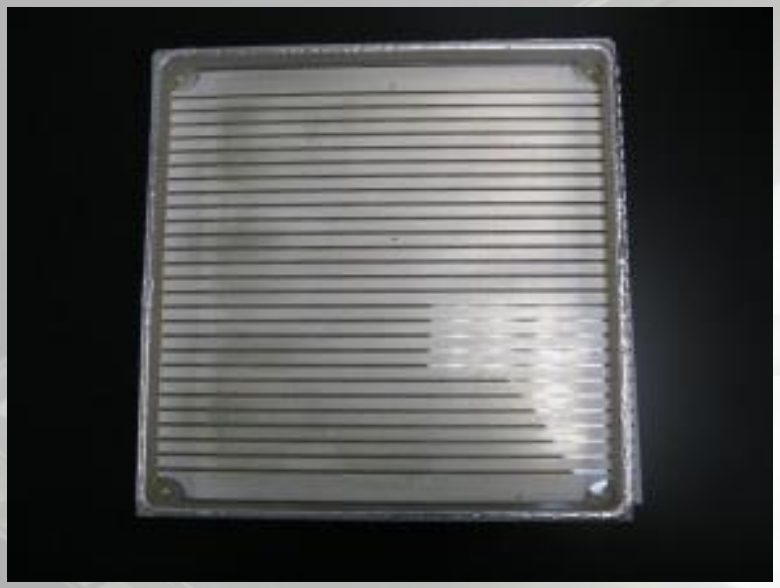
LAPPD Anatomy:





Very Few Components, Mostly Glass

Lower Tile Assembly

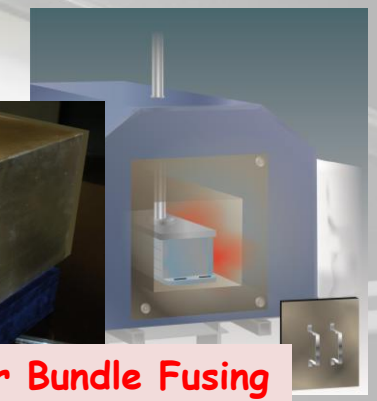


Power & Signal Anode Strips - pass under the hermetic seal providing a "penetration free" connection into and out of the tile.

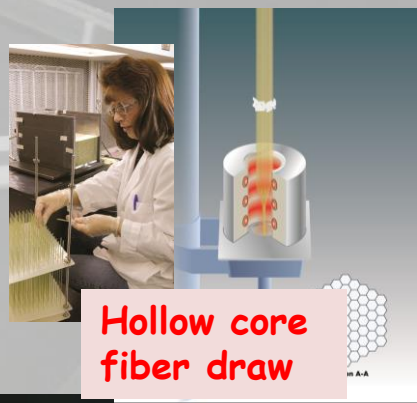
Groove Filled with Molten Indium Alloy - for top window sealing

Incom ALD MCPs:

Wire Saw Cutting



Fiber Bundle Fusing

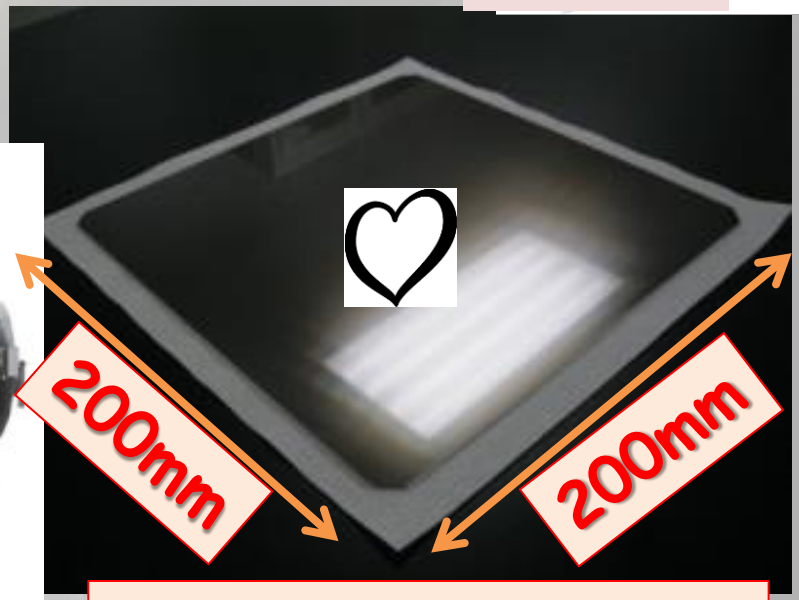


Hollow core fiber draw

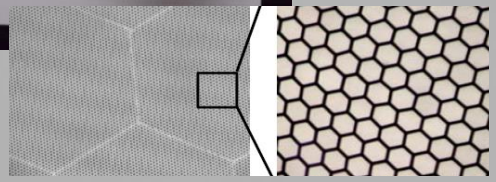
Grinding and polishing

Metallization

ALD Coating

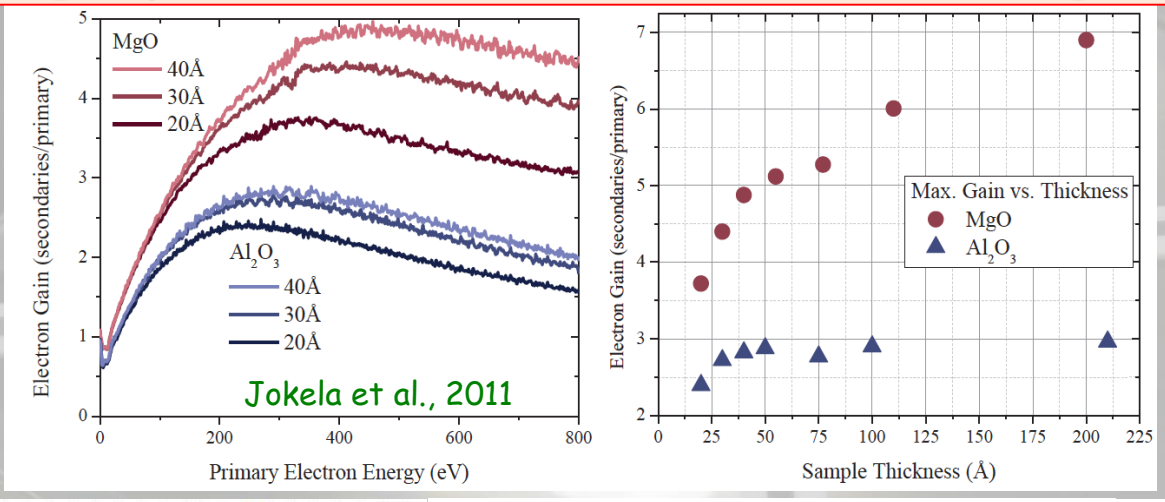


World Largest MCPs

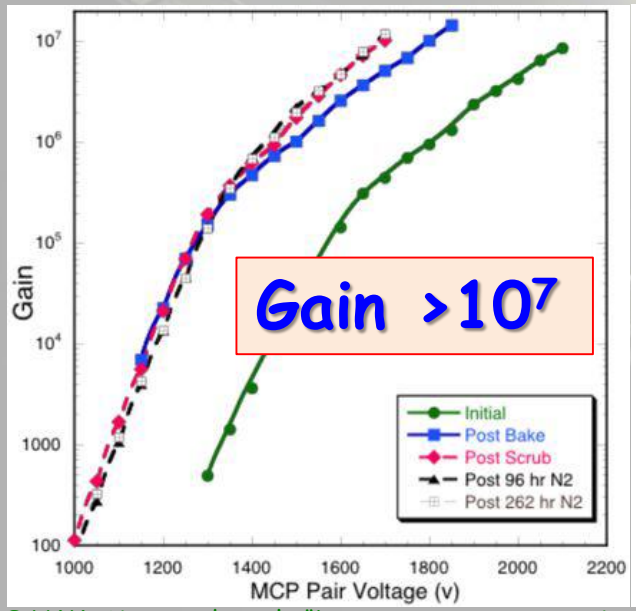


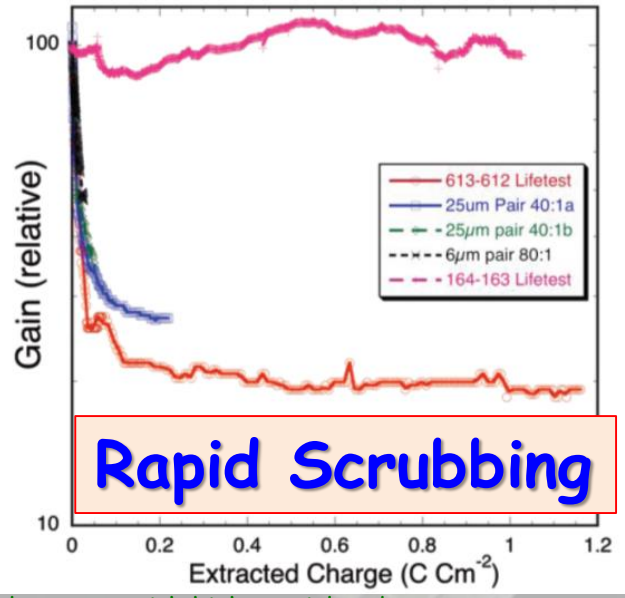
ALD MCP Performance:

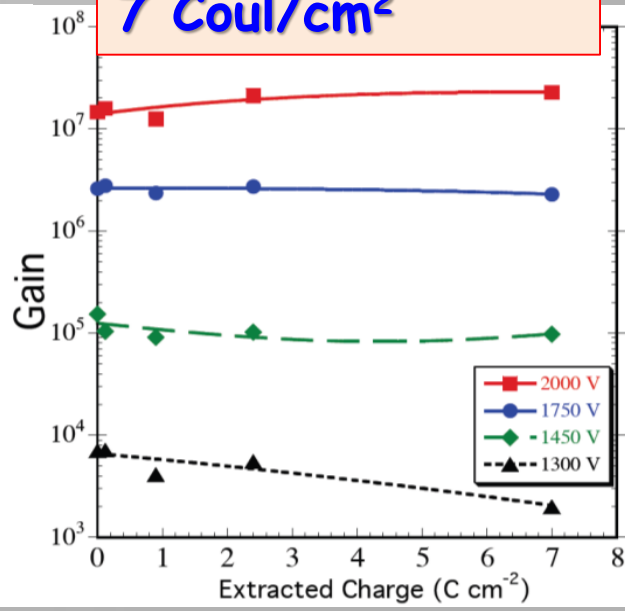
Coating options: Al_2O_3 (SEE 2-3) or MgO (SEE 3-7)



Stable Gain after 7 Coul/cm²



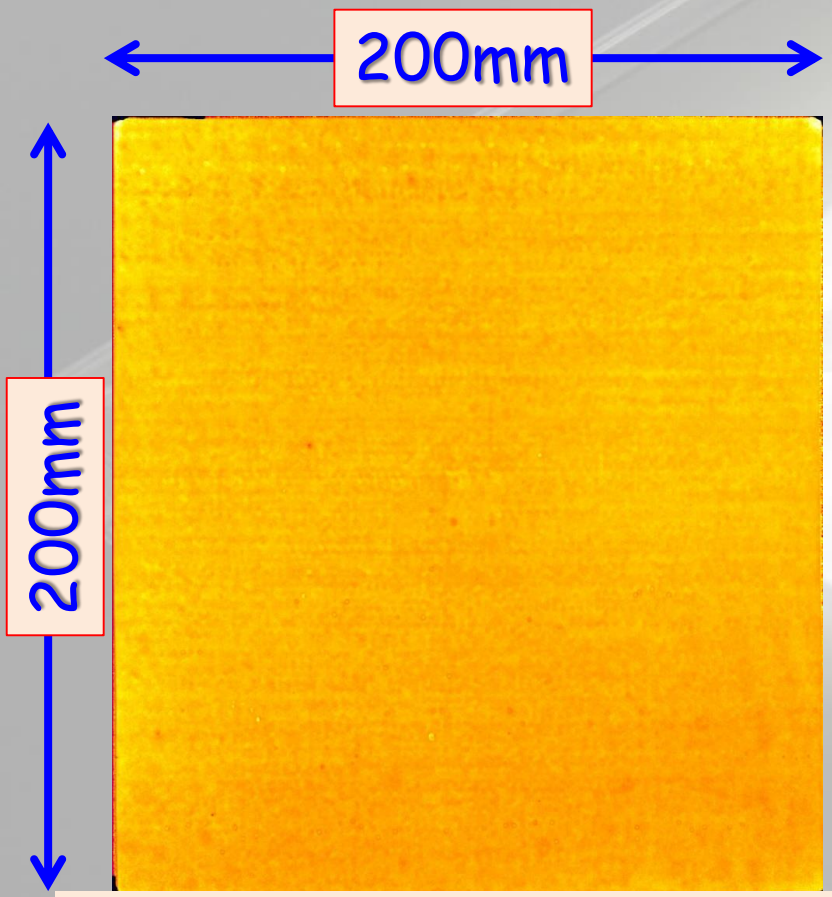




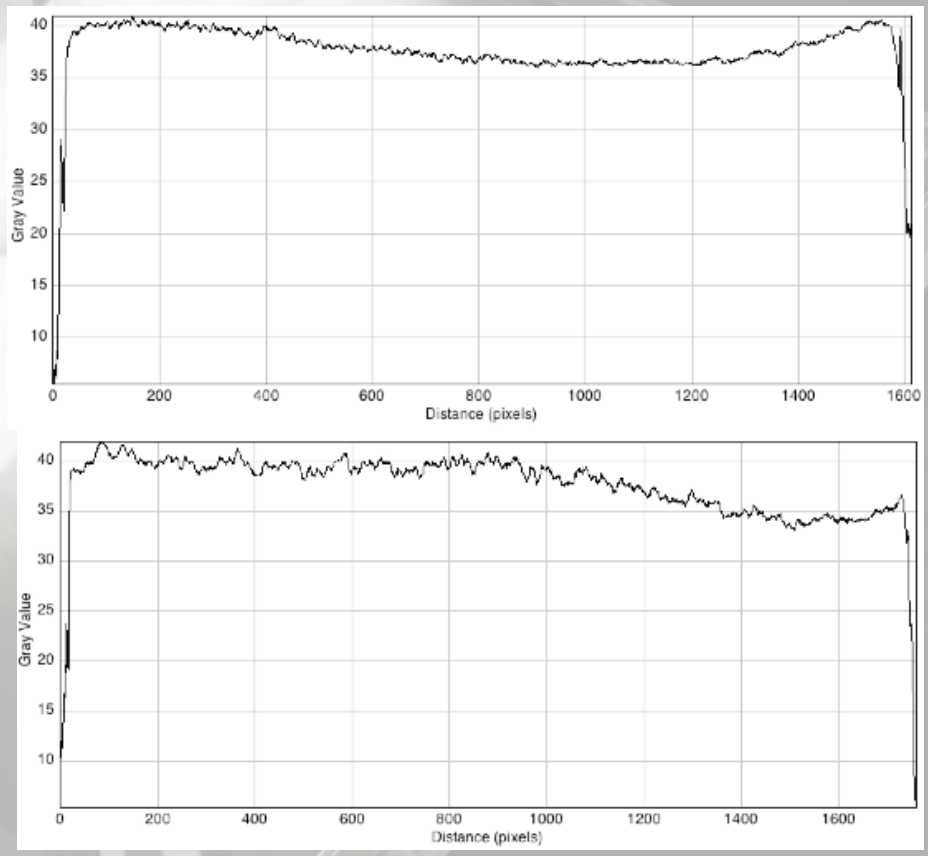
O.H.W. Siegmund et al., "Large area event counting detectors with high spatial and temporal resolution," 15th International Workshop on Radiation Imaging Detectors, 2013

O.H.W. Siegmund et al., NSS/MIC, IEEE.N45-1, (2011) 2063

ALD MCP Performance:



Gain Uniformity Map



20 micron pores

Dark Noise: 0.1 – 1 cts/sec/cm^2

Uniform Gain within ~15% across the area

O.H.W. Siegmund et al., "Large area event counting detectors with high spatial and temporal resolution," 15th International Workshop on Radiation Imaging Detectors, 2013

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Timing characteristics of Large Area Picosecond Photodetectors

B.W. Adams [a], A. Elagin [b], H.J. Frisch [b], R. Obaid [c], E. Oberla [b], A. Vostrikov [b], R.G. Wagner [a], J. Wang [a], M. Wetstein [b,*]

[a] Argonne National Laboratory, United States
[b] Enrico Fermi Institute, University of Chicago, United States
[c] University of Connecticut, United States

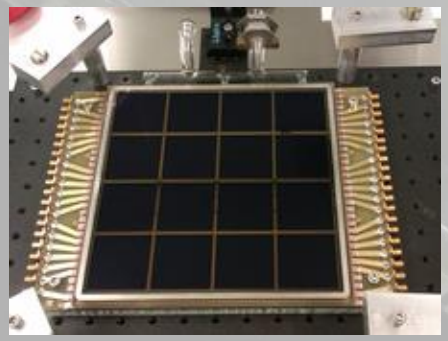
The performance of LAPPD is well established based upon testing of the "Demountable"

Absolute time resolutions

- Single-PE: consistently < 100 ps, typically < 60 ps,
- Large pulses < 5 ps (differential)

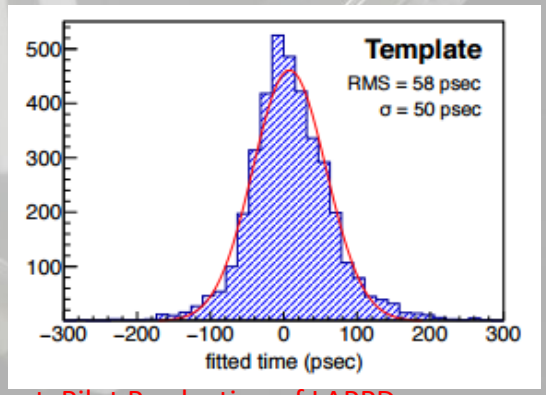
Spatial Resolutions

- Single-PE: ~500 microns



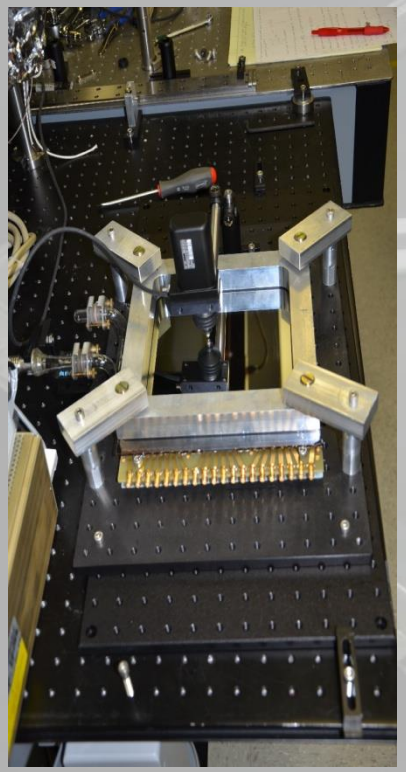
The Demountable LAPPD (unsealed)

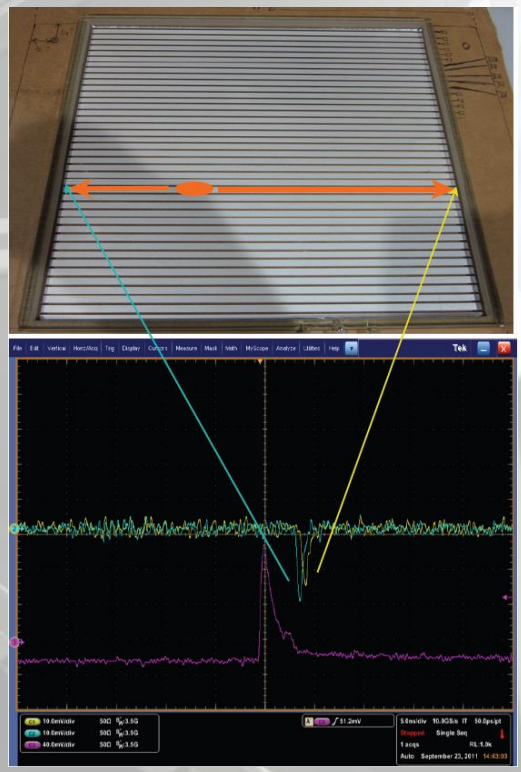
- **Dynamically pumped LAPPD Test Stand**
- Incorporates standard LAPPD components
- Aluminum photocathode
- O-ring Top seal and retainer



Measured 50psec Transit Time Variation for Single Photoelectron

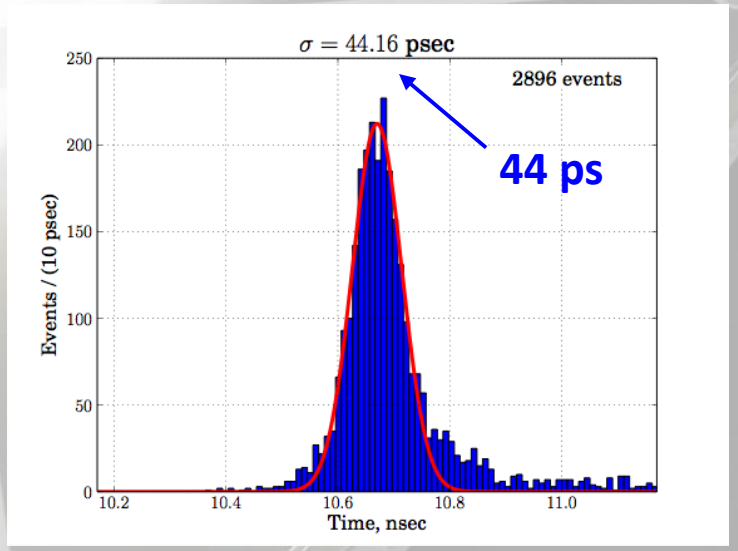
Temporal Resolution Better than 50 picoseconds



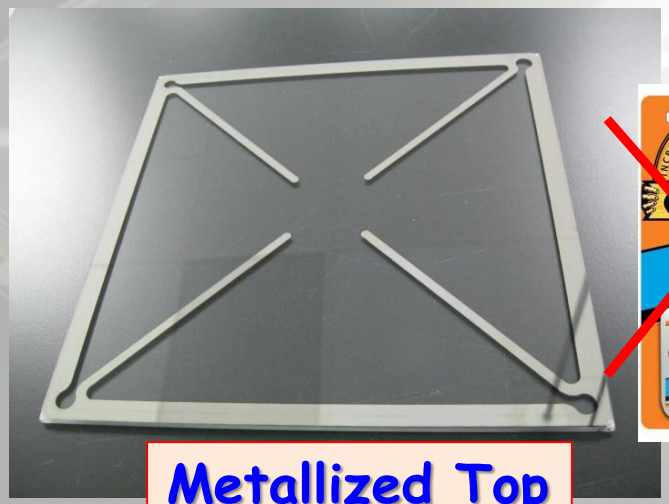


University of Chicago "demountable" station for testing 20 cm square LAPPDs (Matt Wetstein, Andrey Elagin)

Single PE

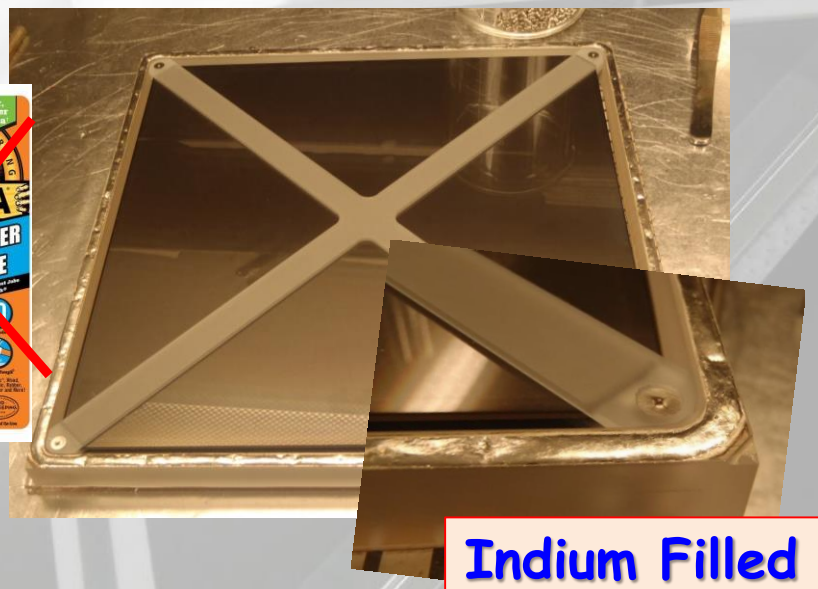


Sealing is the key



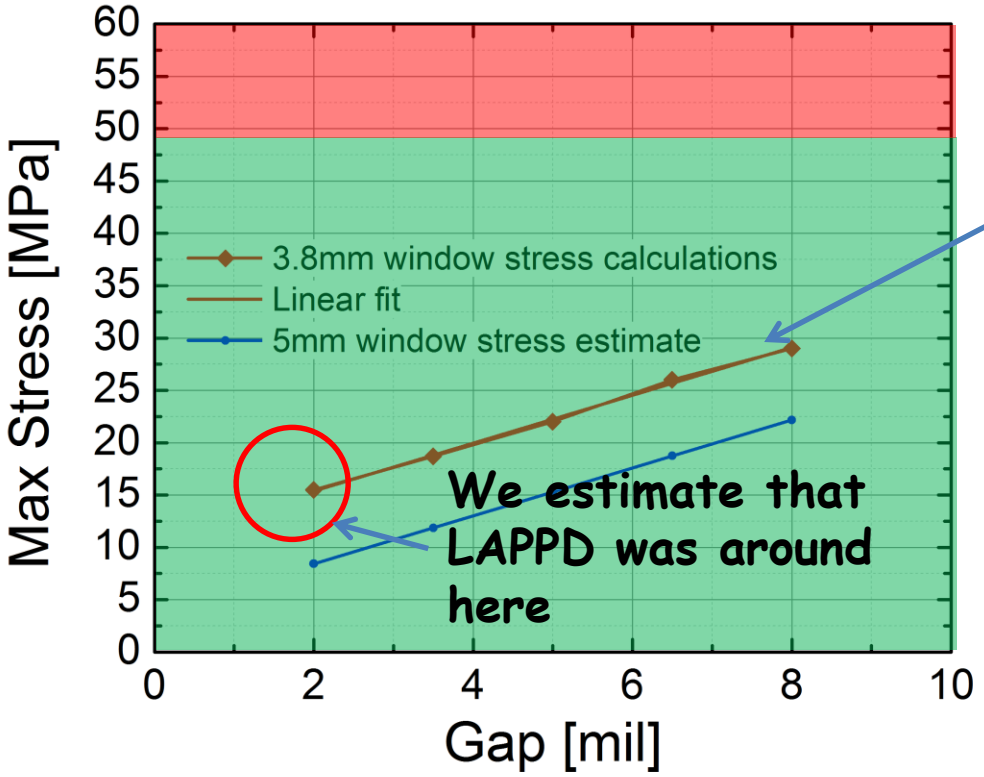
Metallized Top Window

Vacuum Transfer



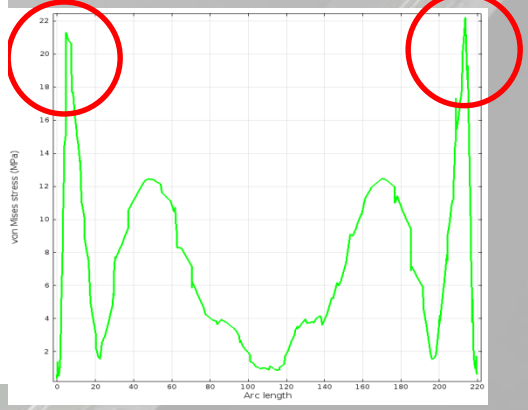
Indium Filled Sidewall

Window Stress vs Gap width



Calculated stress for fracture, 3.8 mm thick fused silica

Max Stress

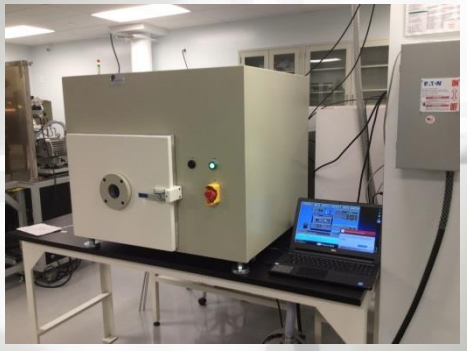


3.8 mil thick fused silica strength is ~ 2X that of borofloat, calculated stress for fracture is doubled

LAPPD Manufacturing Process:

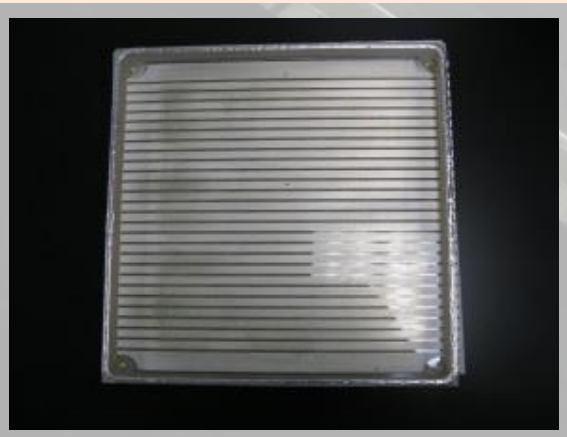
1. Ultrasonic Cleaning

2. Plasma Cleaning



3. Metallization

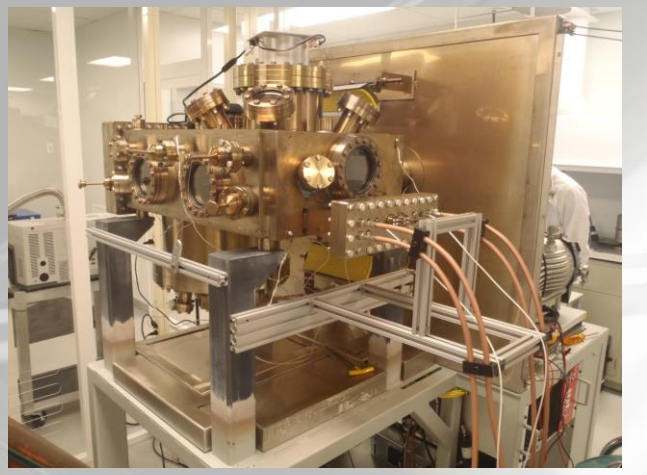
4. Indium Mounting

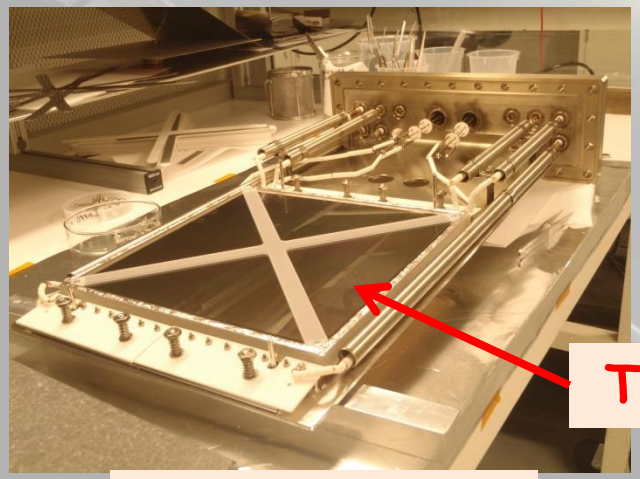


5. Stack Assembly

6. Sealing

LAPPD Sealing Tank





Tile Assembly

Loading Tray

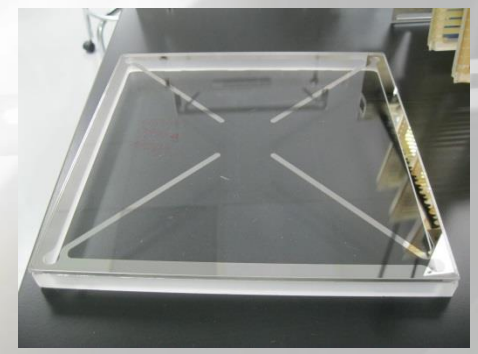
Fully Bakeable up to 400C
Base Vacuum <10^{-10}Torr
Multi-Alkali Photocathode deposition
Hot Indium Seal

Sealing Trials

Sidewall to window sealing trials

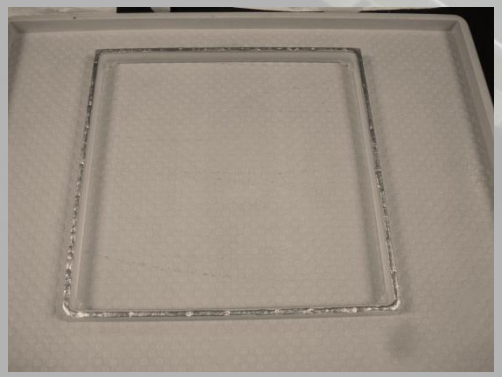
Goal: Two Consecutive Seals

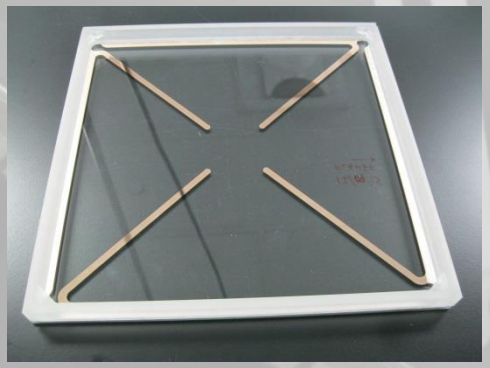
Sealing Trial #3



Leak rate <1x10-9 Torr-l/s, SEALED

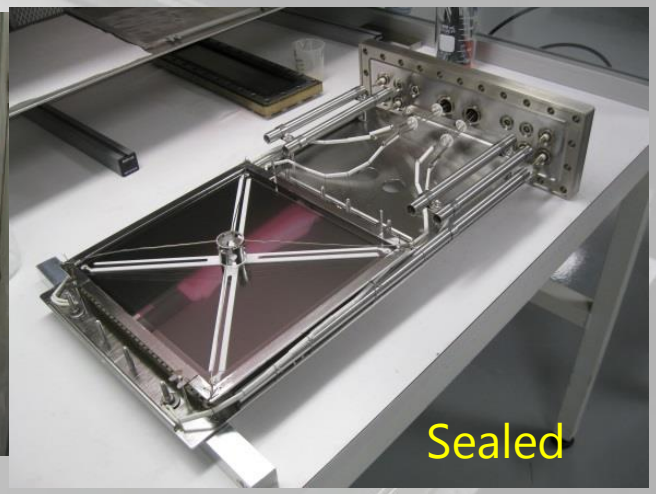
Sealing Trial #4





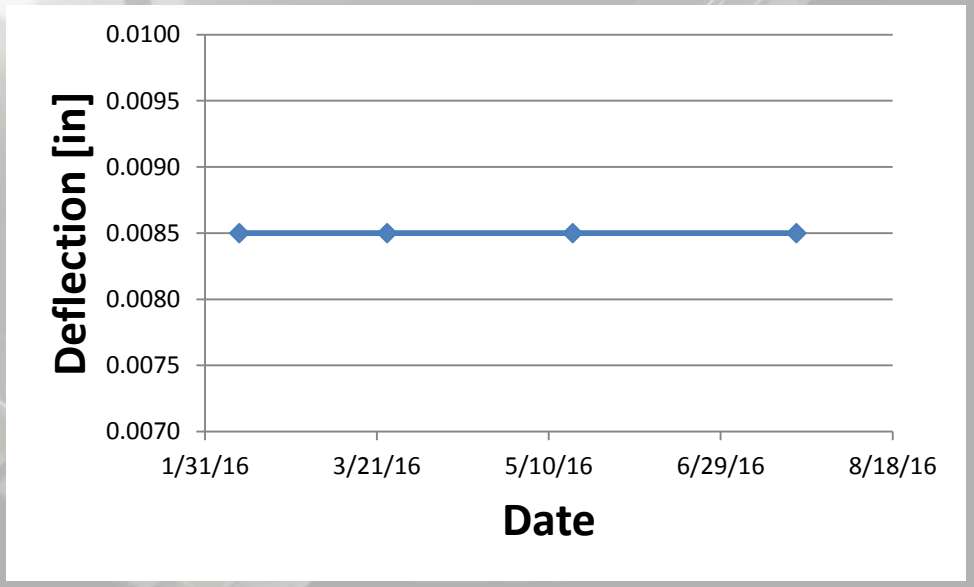
Leak rate <1x10-9 Torr-l/s, SEALED

Sealing Trials (Mock Tile)

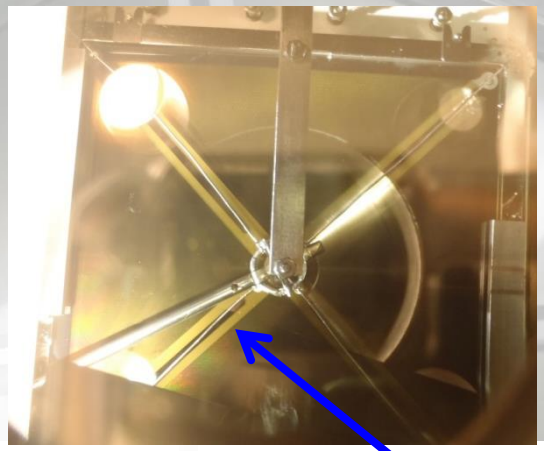


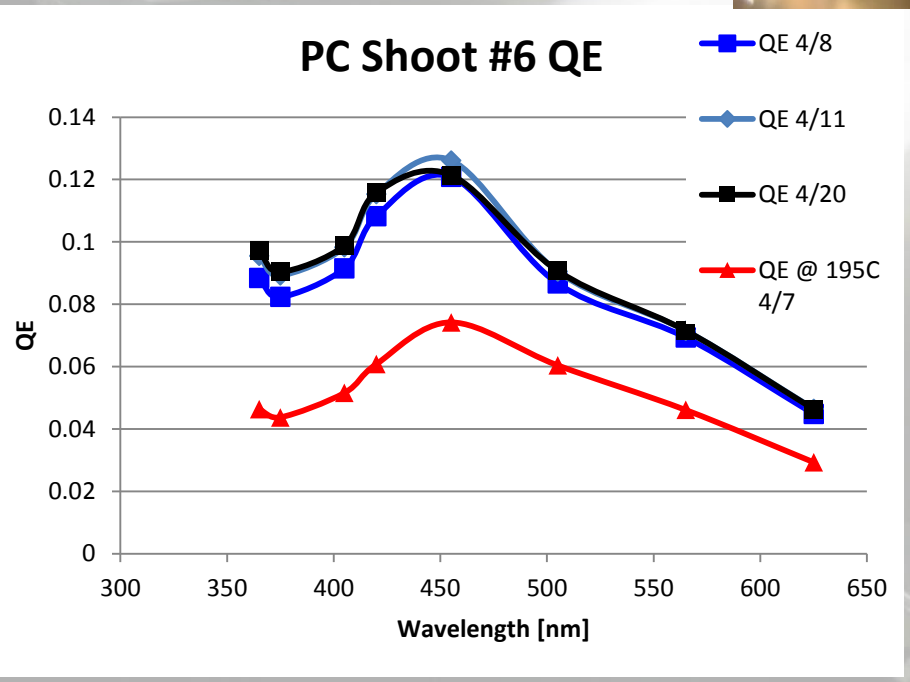
Window Deflection Measurements

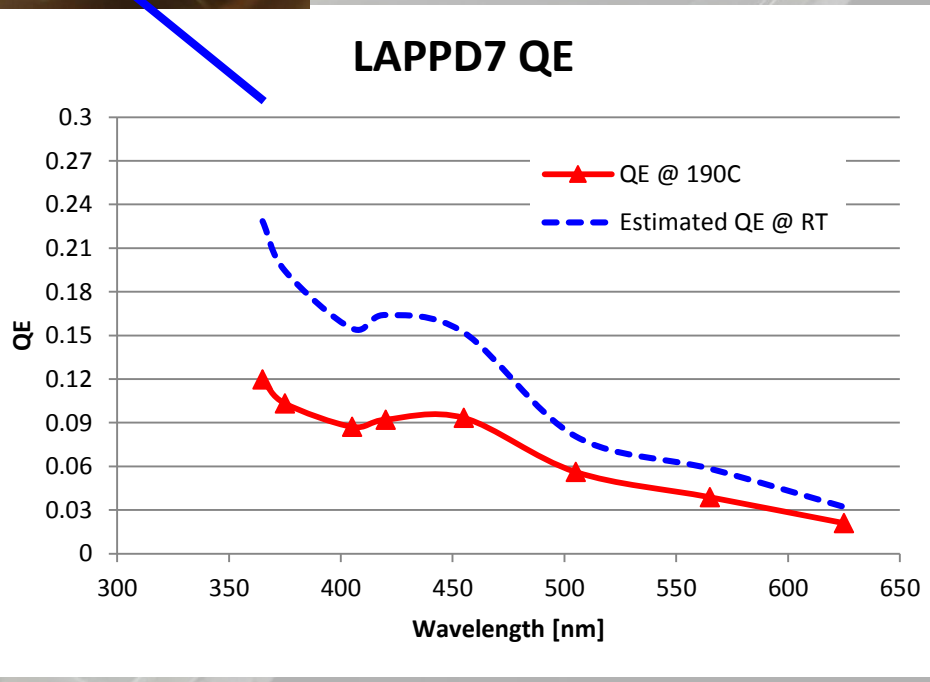
No Changes after 5 months



Photocathode QE





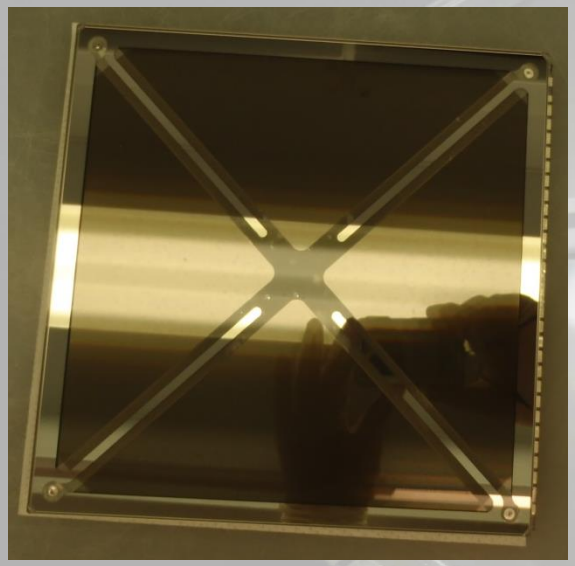


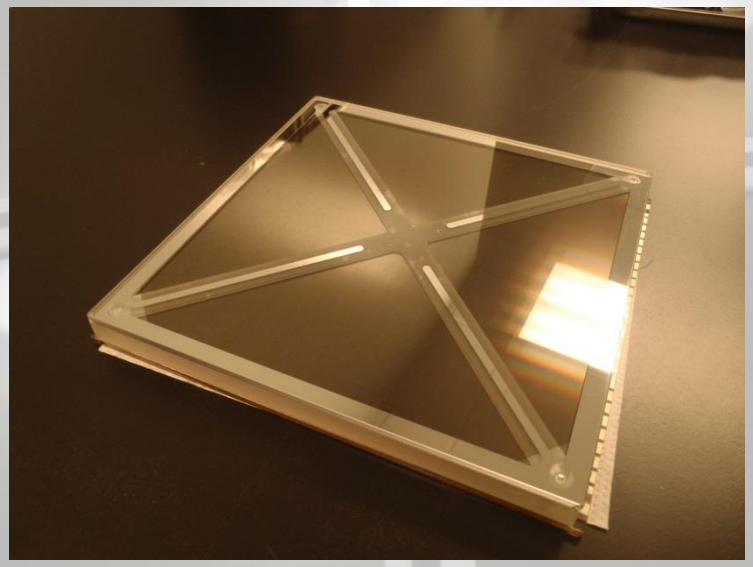
Na-K-Sb, Cs-Na-K-Sb QE~10% @ 190C, higher at RT

2016 LAPPD Pilot Production Commissioning Trials

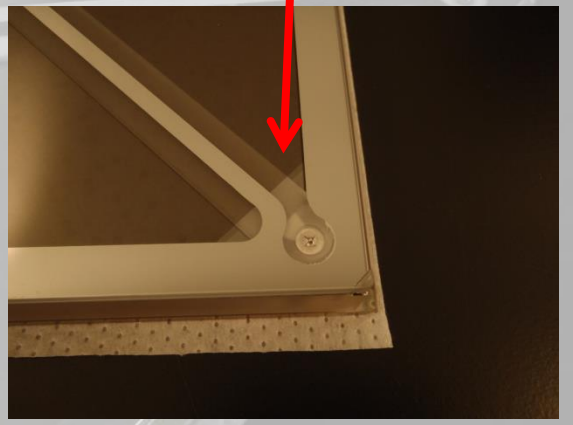
Performance Metric	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10
2016 Seal date	02/05	02/22	03/10	04/28	5/20	06/08	07/13	8/23	9/13	Pending
PC QE @190C, @365 nm	1%	4%	1%	6%	9.4%	4.5%	12%	9%	n/a	
HV Discharge Problems	NO	YES	NO	NO	NO	NO	NO	NO	NO	
Shorts or Connectivity Issues	YES	Signal lost upon venting	Signal lost upon venting	NO	NO	NO	NO	NO	NO	
Dark Current Detected	NO	??	??	YES.	YES	YES	YES	YES	YES	
Stack Height	Excellent	Low	Low	High	High	Low	Excellent	Excellent	Excellent	
Indium Seal	Pass	Pass	Pass	Fail	Fail	Pass	Fail Dirty Window	Fail Dirty Window	Pass	
Vacuum Integrity	Excellent	Cracked window	Cracked window	Failed	Failed	Cracked window	Failed	Failed	Excellent	

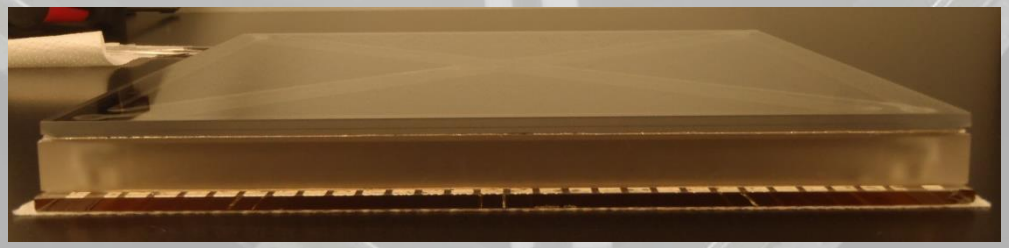
LAPPD9 out of the chamber





10nm thick Al photocathode



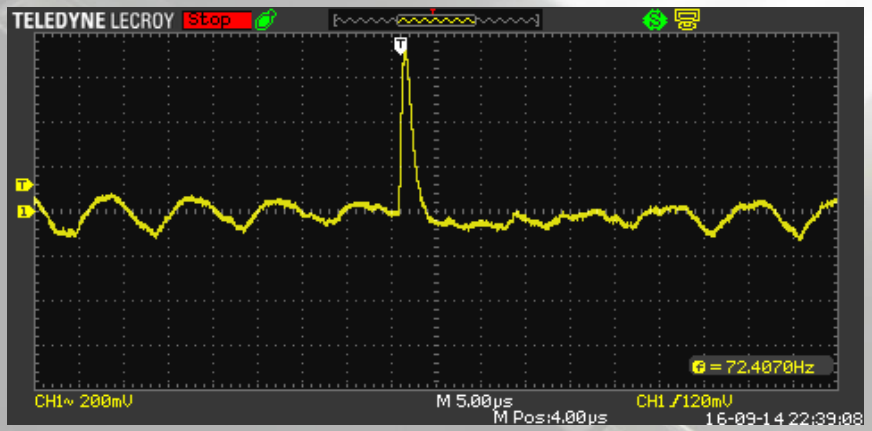


Equipped with Incom MCPs

Sealed LAPPD9 pulses

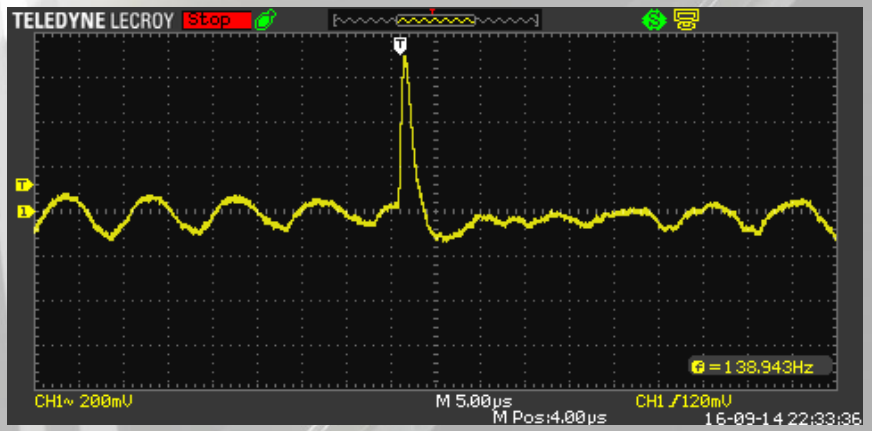
Recorded on the sealed tile in air

Hg(Ar) lamp off



72Hz

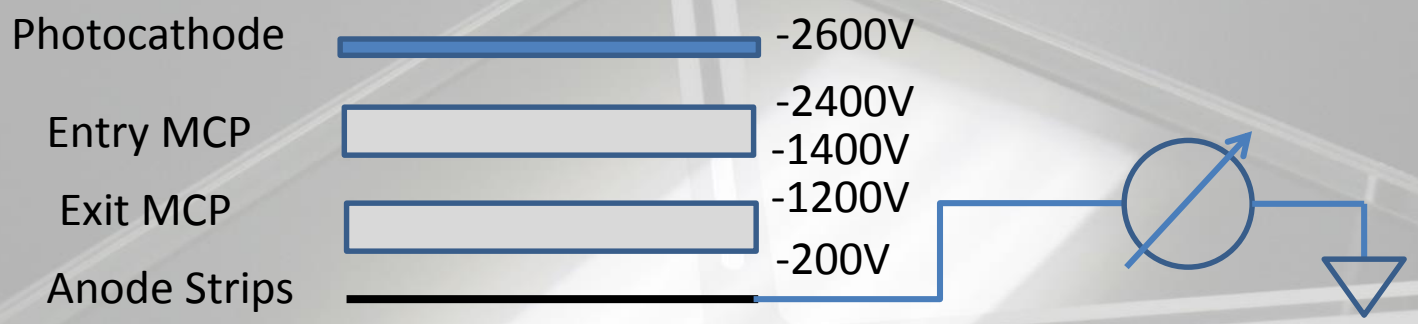
Hg(Ar) lamp on



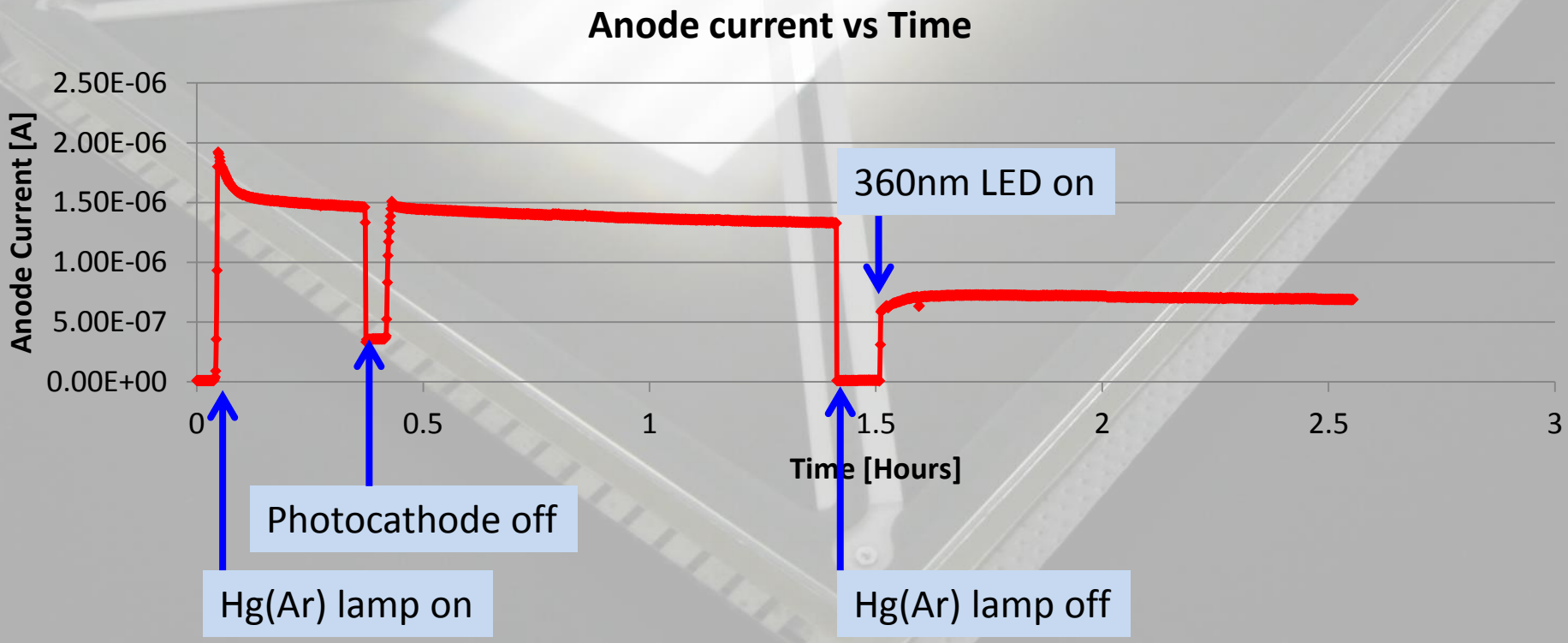
140Hz

High trigger threshold due to periodic noise from the lamp

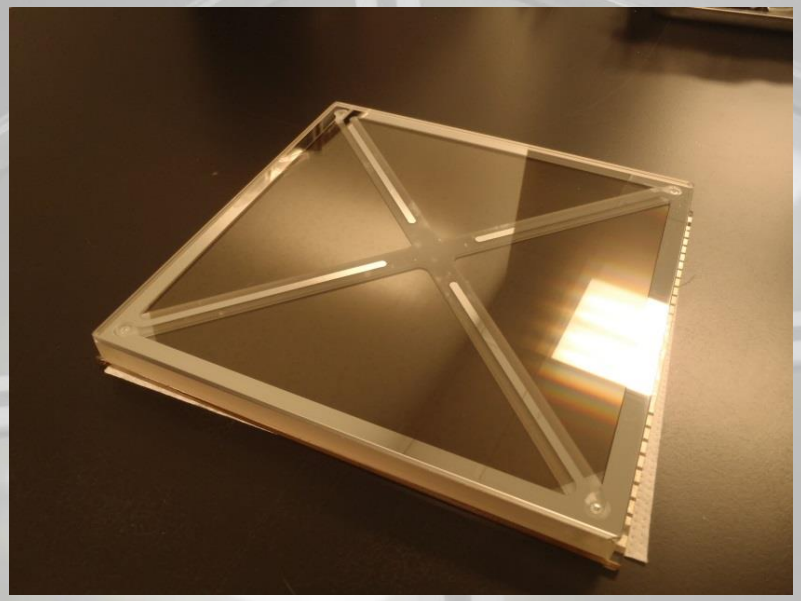
LAPPD9 DC operation



1000V Across MCPs, Gain >10^6, Sealed Tile In Air



Conclusions



First 200mm x 200mm sealed Fully Functional LAPPD

Major Milestone!

To Do

- Pulse-height Spectra
- Timing Properties
- Spatial Resolution
- LAPPD with bi-alkali photocathode

Status of Pilot Production of LAPPD™s

- **Progress on infrastructure and process development has been steady:**
  - A first-rate pilot production infrastructure, has been created, starting with **empty clean room about a year ago**
  - A talented, experienced team of scientists, engineers, and technicians has been assembled.
- **Evolutionary optimization** – Steady progress on identifying & resolving technical issues:
  - Photocathode QE ☺
  - HV stability ☺
  - Shorts & Connectivity ☺
  - Dark Current ☺
  - Stack height issues ☺
  - Stack Height ☺
  - Vacuum Integrity ☺
  - **UHV window transfer hardware improvements** – down pressure
- **No technical roadblocks** or insurmountable barriers encountered to date.
- **A reproducible pilot process is expected shortly as identified component and hardware improvements are implemented and process experience is gained!**

Prospects: Advanced LAPPD Development

Application specific requirements are motivating further LAPPD development in the following key areas:

ALD-GCA-MCPs with Enhanced Life Durability

Life durability of Incom ALD-GCA-MCPs is being further enhanced with development of a custom (C-14) glass that has virtually no alkali elements. Dark counts achieved are 10-25 X Lower (0.025-0.040 vs. 0.25-1.0) compared to conventional MCPS, further improving signal to noise (S/N).

GEN II Ceramic Package LAPPD™

A second generation LAPPD with a ceramic body allows capacitive coupling of detector signals through the ceramic, to strips or pads on the outside. This novel design will allow fabrication of a generic detector tile, enabling end users the option of specifying the design of the signal output.

ALD-GCA-MCPs with reduced, near-zero TCR,

Allowing their use over very wide temperature ranges. Three process variables are being studied to evaluate their impact on TCR ; 1) Film thickness, 2) ALD metal chemistry and 3) ALD nanocomposite nanostructure.

Funding & Personnel Acknowledgements:

DOE, NASA, and NGA Contracts

- DOE, DE-SC0009717 "LAPPD Commercialization – Fully Integrated Sealed Detector Devices"
- DOE, DE-SC0011262 Phase II - "Further Development of Large-Area Micro-channel Plates for a Broad Range of Commercial Applications"
- DOE, DESC0015267, Development of Gen-II LAPPD™ Systems For Nuclear Physics Experiments
- NASA: NNX15CG22P Curved Microchannel Plates for Space Flight Mass Spectrometers
- NGA-IV, NGA-V Next Generation Neutron Imager
- DOE, DESC0015729, Resistive coatings for high-performance, low-background MCPs operating across broad temperature ranges and at cryogenic temperatures
- DOE, DE-SC0009717 Phase IIA - LAPPD Commercialization – Fully Integrated Sealed Detector Devices

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