Development of a Small Form Factor Picosecond Photodetector as a Path towards the Commercialization of Large Area Picosecond Photodetector (LAPPD) Devices with Incom, Inc.

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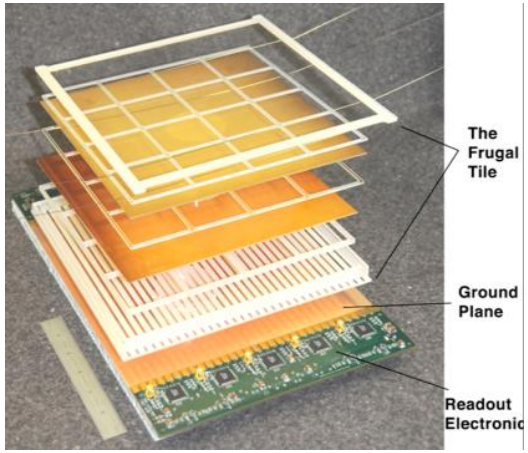
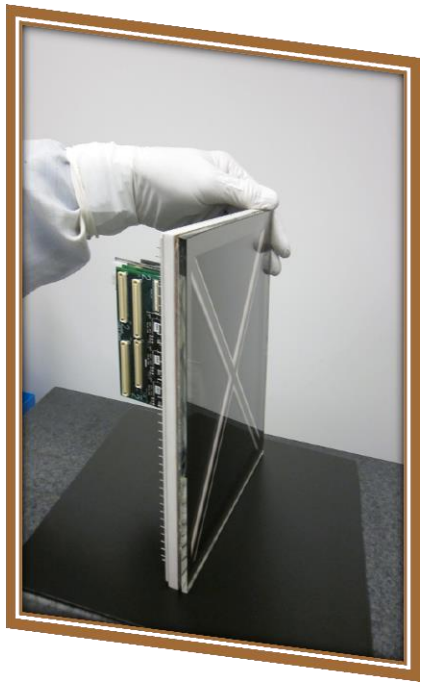
The Large Area Picosecond PhotoDetector Project

- **The Large Area Picosecond PhotoDetector (LAPPD) program has its origins in proposals to develop fast timing detectors in early 2000's (H. Frisch); early exploratory funding (2007 - 2009) through DOE Advanced Detector R&D to Univ. Chicago and Argonne LDRD (internal lab seed funding)**
- **LAPPD funded as a project by DOE OHEP detector R&D program (2010 – 2013) to reinvent photodetectors using transformational technology**





LAPPD Collaboration During the First 4+ Years

- National Labs
  - Argonne
    - HEP Division (management, photocathodes, 6cm tiles)
    - Energy Systems Division (MCP functionalization)
    - Nuclear Engineering Division (vacuum eng.)
    - Glass Shop (glass fabrication, bonding)
    - X-ray Sciences Division (UV laser test stand)
    - Materials Science Division (material characterization)
    - Mathematics and Computer Science Division
  - Fermilab (MCP electroding)
- Universities
  - University of Chicago (readout, glass package)
  - Space Sciences Lab/UC-Berkeley (ceramic package, photocathodes, MCP testing)
  - University of Hawaii (readout)
  - Washington University (advanced photocathodes)
  - University of Illinois — Chicago (pressure seal)
  - University of Illinois — Urbana/Champaign (photocathodes)

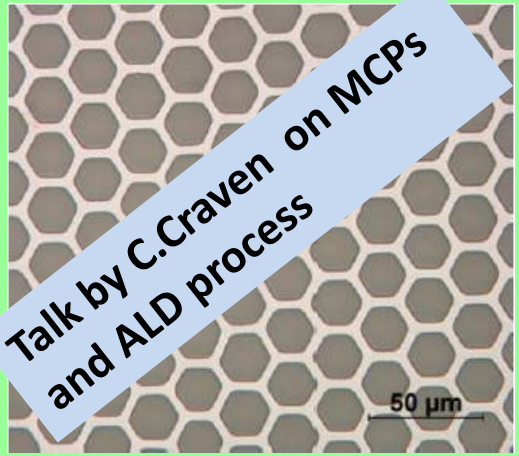
- U.S. Companies
- Incom, Inc. (glass capillaries, SBIR tube production)
- Arradiance, Inc.
- Synkera Technologies, Inc.
- Minotech, Inc.
- Muons, Inc.

Large Area Picosecond Photodetectors

see keynote talk H. Frisch (Large Area Detectors)

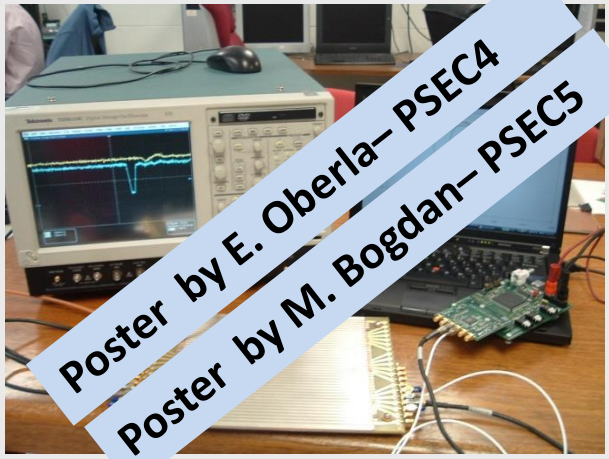
Four Main Areas of LAPPD

Micro-Channel Plates



Talk by C.Craven on MCPs and ALD process

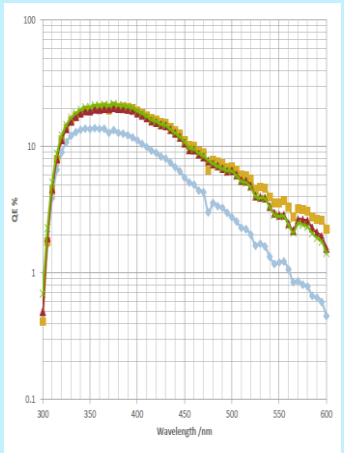
Electronics / Integration



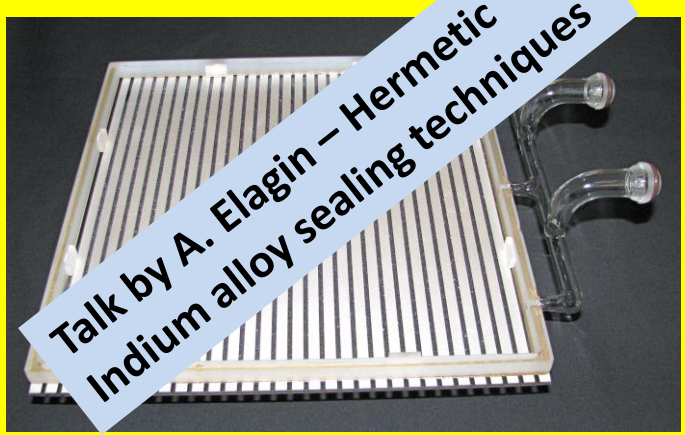
Poster by E. Oberla– PSEC4

Poster by M. Bogdan– PSEC5

Photocathode



Hermetic Pack



Talk by A. Elagin – Hermetic Indium alloy sealing techniques

Some Achievements of the LAPPD Collaboration

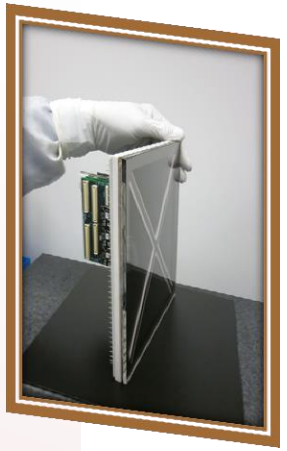
Five patents;
One license for ALD process

SBIR/STTR
Phase-I Submitted

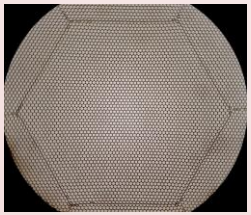
R&D 100 Award

LAPPD program was a new instrumentation initiative, not an ongoing program; no pre-existing group, started with transient seed funding

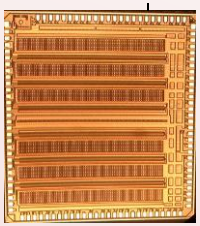
ALD Technology Licensed



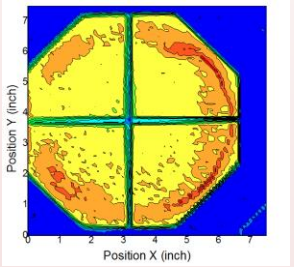
Met all sub-component milestones for constructing full device



MCP Technology select



PSEC4, fastest sampling chip, 17 GHz



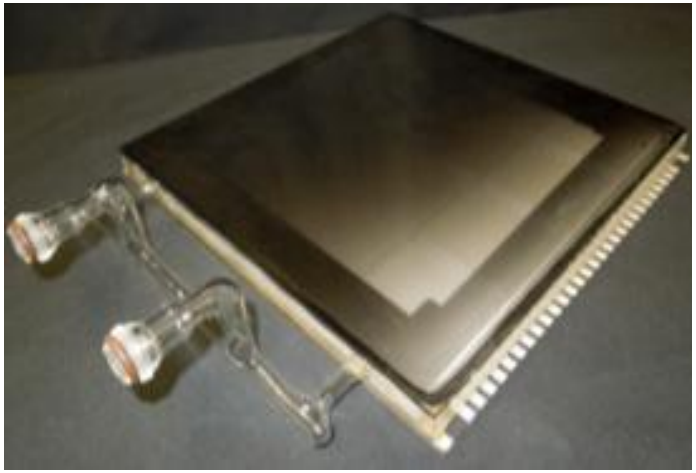
7” Photocathode

t=0 t=1yr t=2yr t=3yr

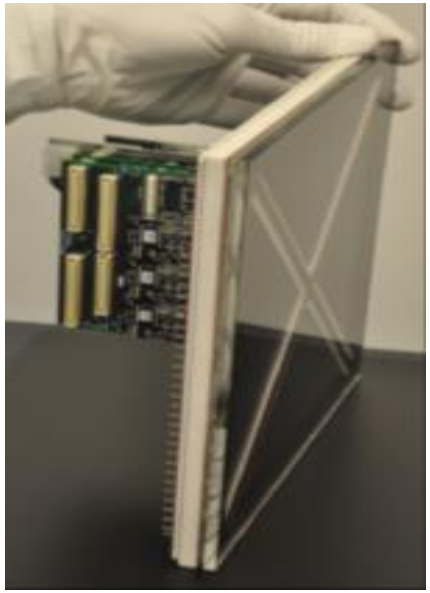
time

LAPPD Detectors - *Phase II - Commercialization*

- ***DOE SBIR Phase II to Incom for Path to commercialization of LAPPDs***
- DOE SBIR Phase I to Incom for future dev. Of LAPPD
- NGA award for mini-time cube project
- DOE SBIR Phase II to Innosys for high bandwidth LAPPD anode
- DOE SBIR Phase-II to RMD for high QE photocathode studies



All glass LAPPD dynamically pumped prototype with ANL Indium thermo pressure seal



SSL fully integrated sealed ceramic LAPPD, with readout electronics (G. Varner, U. of Hawaii)

LAPPD Detectors - *Phase II - Commercialization*
Argonne's Role in the 2 year SBIR program and beyond

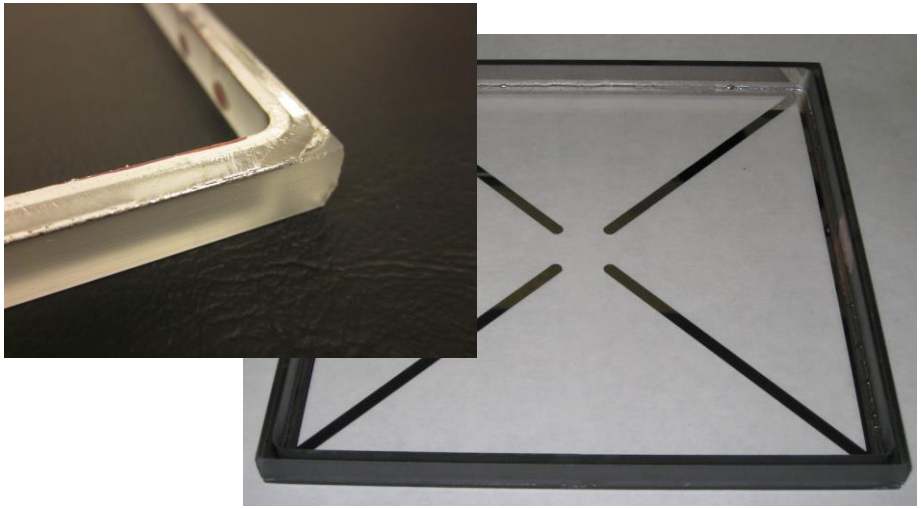
Argonne Roles in Commercialization Process

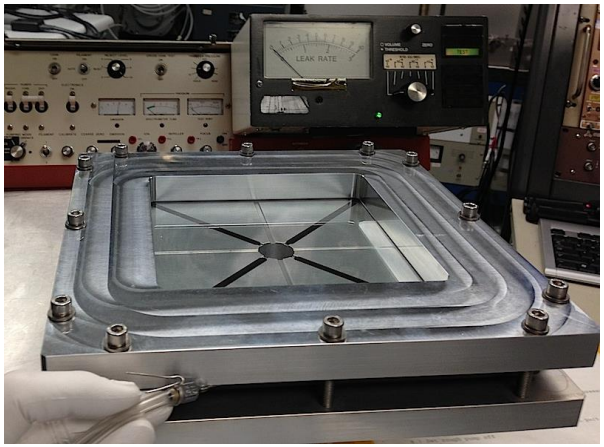
- Argonne licensed the ALD process to Incom, Inc. **ALD technology transfer process**,
- **Glass Package Design Support**
- MCP and detector **testing and quality assurance at Argonne**
- **Thermo-pressure Sealing Technique and Development of a small form factor all glass device facility.** ***This Talk***
- Development of a 20cm single processing tank ("mini-SSL"),

LAPPD Detectors - *Phase II – Commercialization*
Argonne's Role in the 2 year SBIR program and beyond

- A challenge of the LAPPD program has been to produce a commercially viable all glass economic hermetic seal within the vacuum transfer process

- Incom, Inc. plans to replicate the single tank process developed at SSL for first devices – sealing a glass grooved sidewall to a thin front window with an Indium alloy similar to the SSL ceramic package.





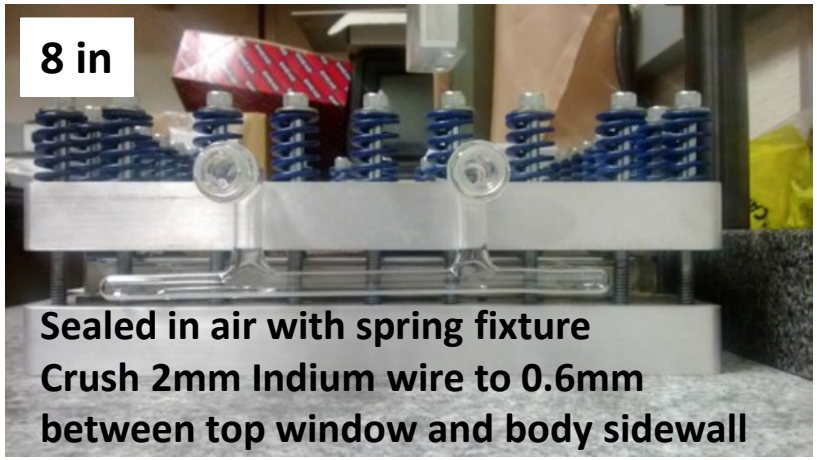
Tested and no leaks at 10^{-10} torr

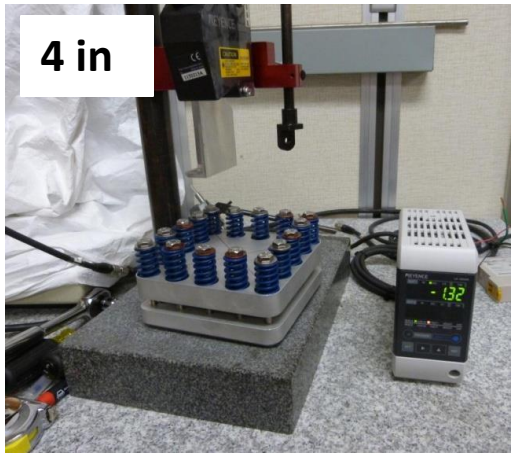
Glass seal has been demonstrated with full process of high temp bake (>300C) vac bake and seal on the cool-down with a weight added inside the chamber

LAPPD Detectors - *Phase II - Commercialization*
Argonne's Role in the 2 year SBIR program and beyond

- Argonne and Univ. Chicago have pursued techniques compatible with all glass economical package. Argonne developed a pressurized sealing technique *(A. Elagin Talk on Indium alloy solder seal technique)*

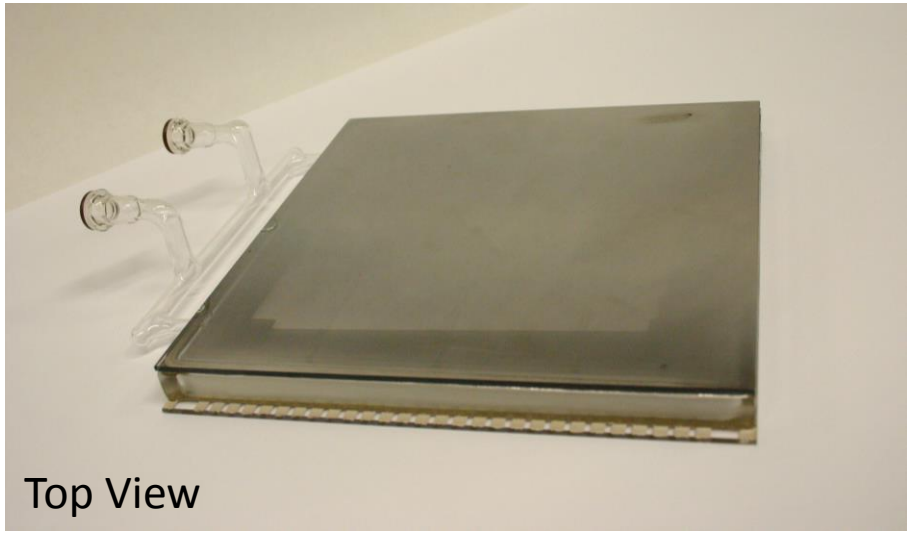
- ANL demonstrated a hermetically sealed 8" glass package using thermo-compression technique with no evidence of leaks during prolonged vacuum pumping
  - Technique was developed in collaboration with M. Kupfer & E. Indacochea, Materials Science and Engineering at U. of Ill. at Chicago. (Kupfer's Master Thesis); M. Kupfer and D. Walters (ANL) have Patented this technique.

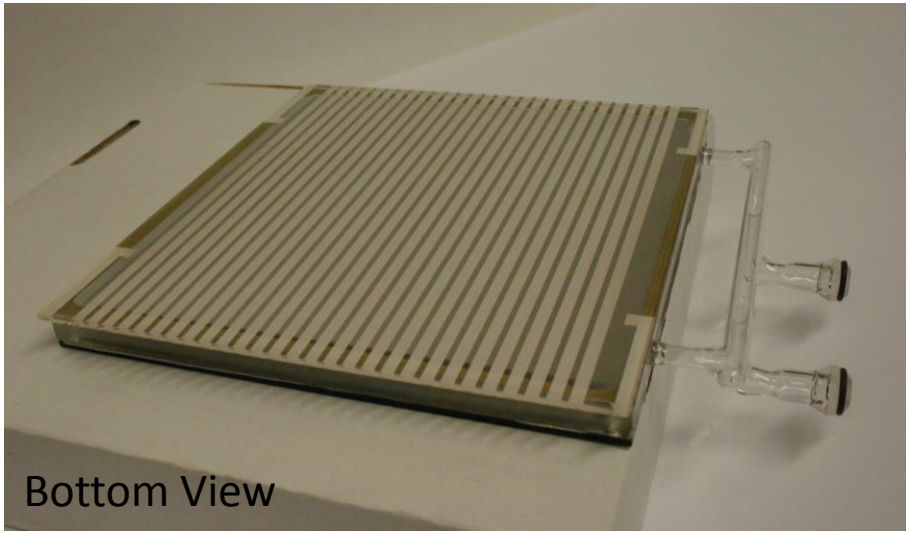




LAPPD Detectors - *Phase II - Commercialization*
Argonne's Role in the 2 year SBIR program and beyond

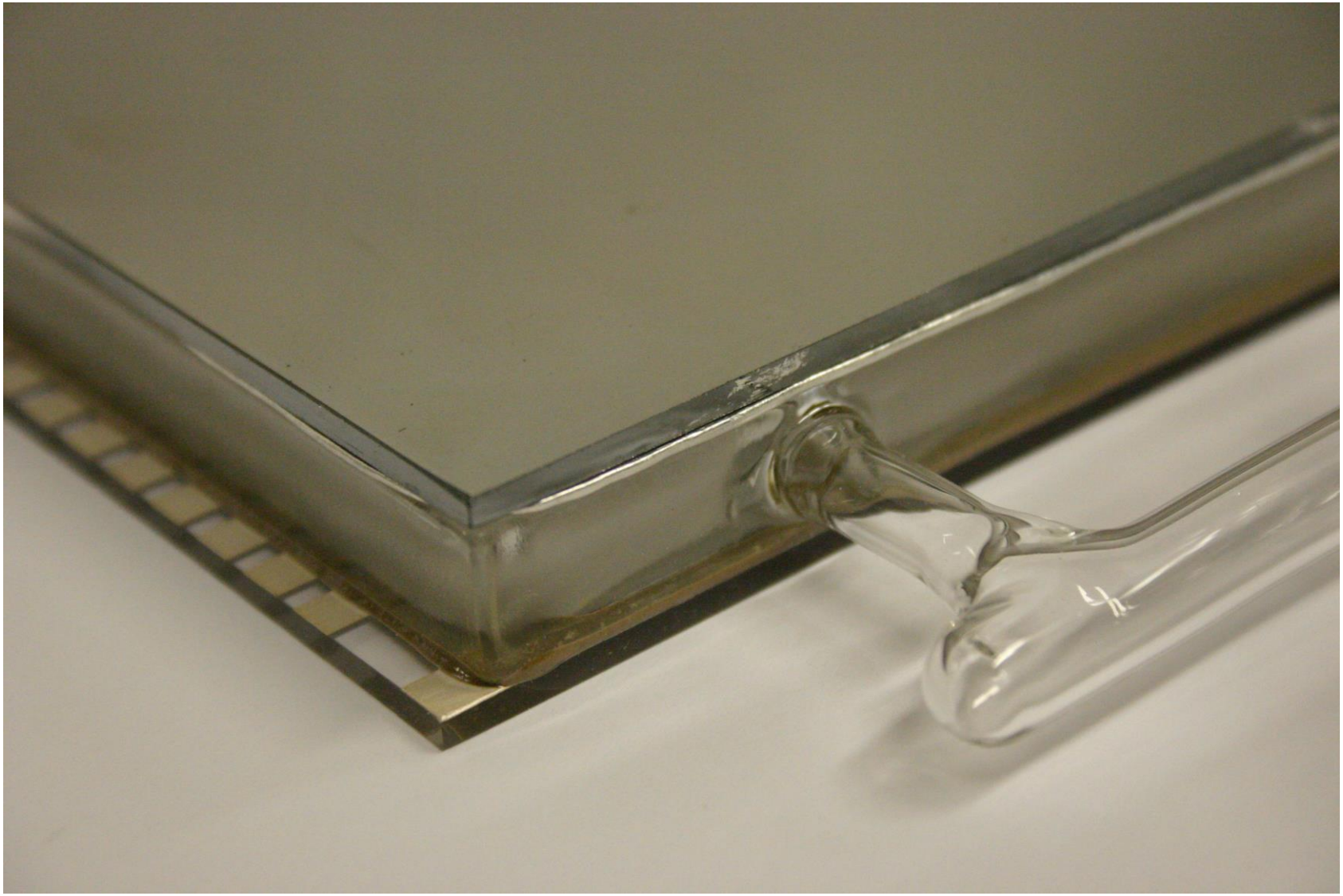
- Bench sealing tests on 1", 2", 4" and 8" devices
- Seal is an Indium alloy "thermo pressure" seal applied to a flat sidewall
  - A cold wire indium alloy gasket is placed between sidewall and top window; the wire is pressed, exposing clean, oxide free alloy that bonds to the glass when heated to make the seal.


Top View


Bottom View

- Full 20cm all-glass body was hermetically sealed and leak tight
  - All components in format of a real device
  - Note: 20cm technique demonstrated under ambient conditions, no photocathode.

Sealed 20x20cm^2 Device – no photocathode



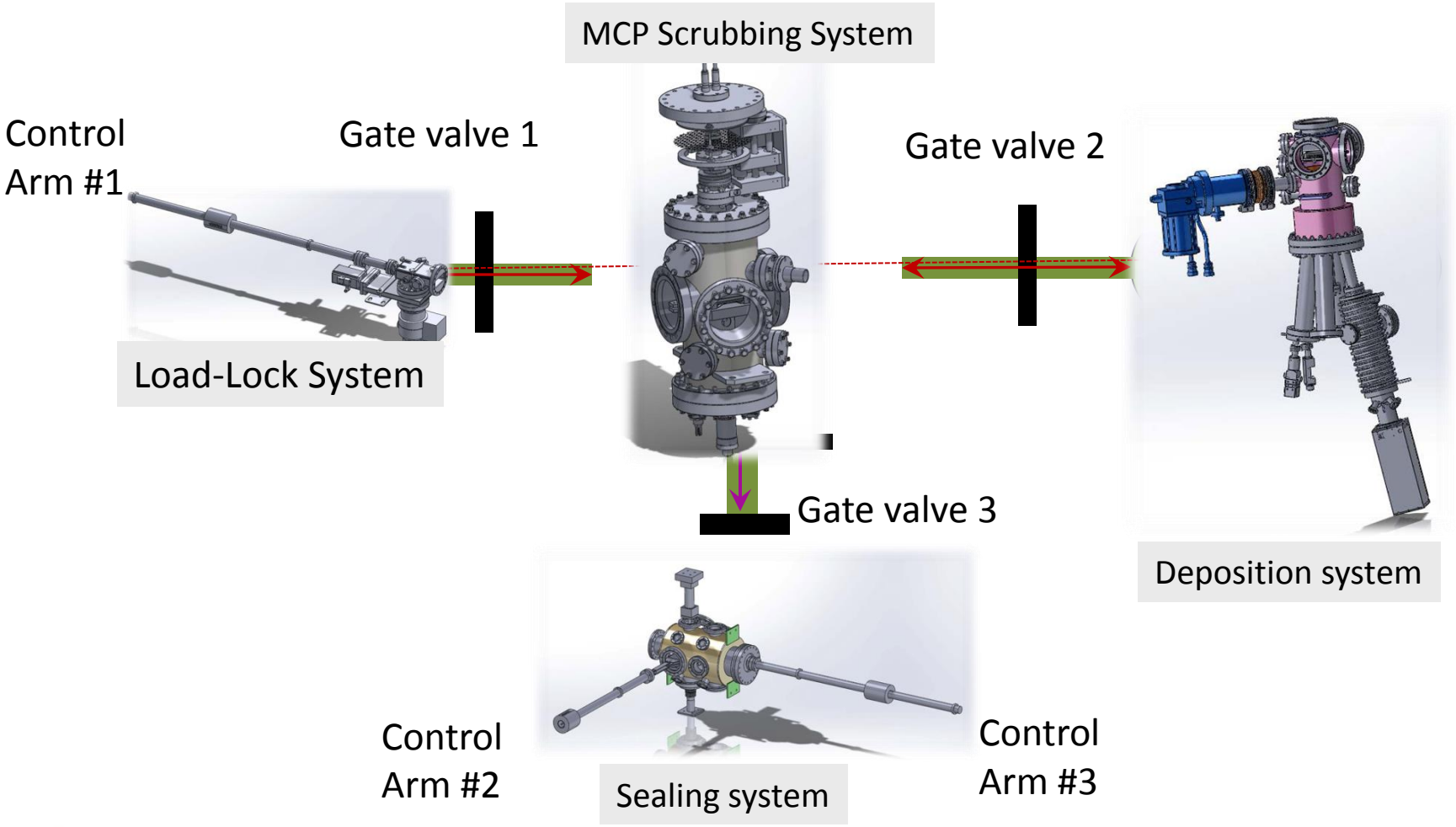
LAPPD Detectors - *Phase II - Commercialization*
Argonne's Role in the 2 year SBIR program and beyond

Development of a small form factor (6cm) all glass device facility

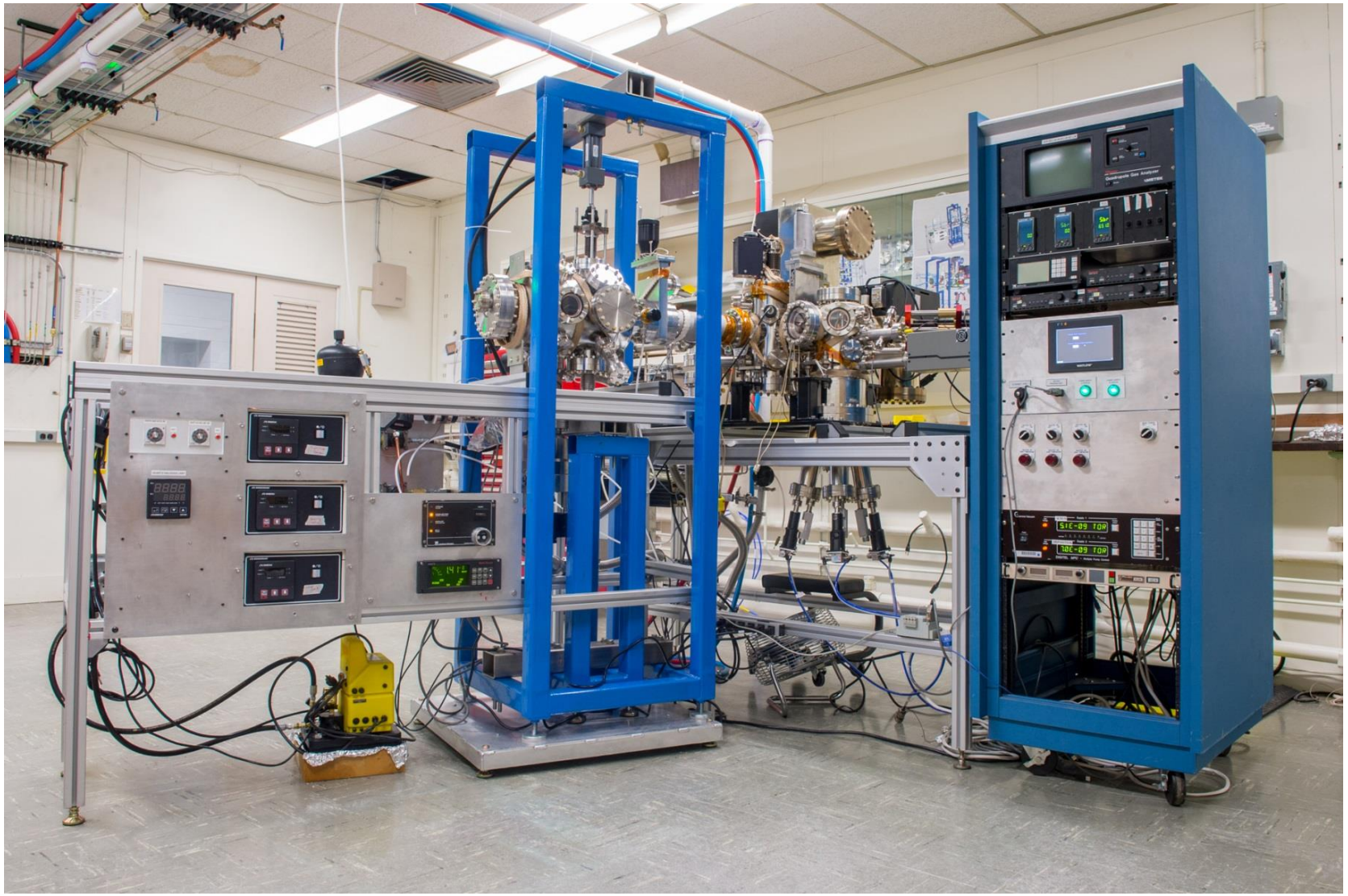
- Grow in house R&D expertise in photo detector system and capabilities
  - System developed using pre-existing components (6cm dimension was determined by largest process tank system available)
  - System is designed to have independent subsystems and be able to transfer parts between subsystems
  - System flexible to change of procedure and sequence; capable of studying any isolated steps (we use a thermo-pressure seal, but could adapt to other techniques)
- It is also a test prototype system
  - Produce the first batch of fully functional small form factor devices, and make them available to the user community for evaluation
  - The expected production rate is ~ 1 tile/week

Development Facility for 6cm Tile Production

- The whole system consists of four major parts
- The four parts are connected with gate valves
- Three transfer arms can move components between different part of the system



Development Facility for 6cm Tile Production



Photodetector Fabrication and Testing of 6cm Tiles

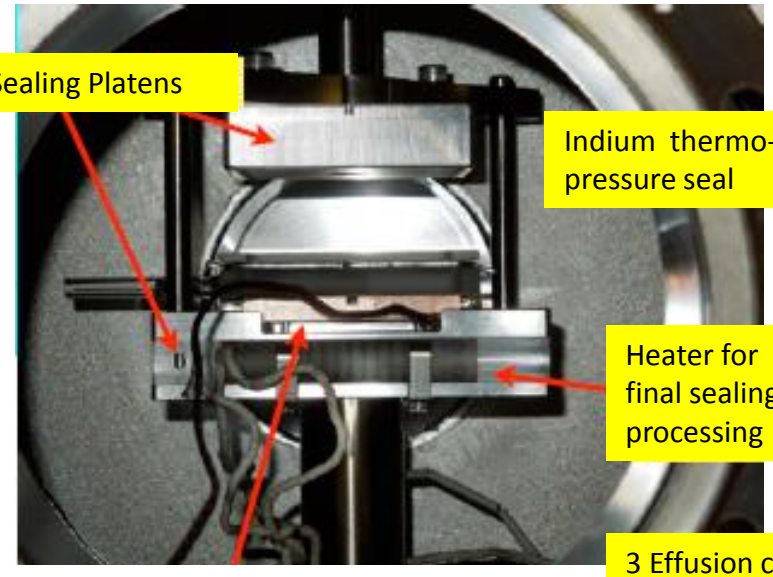
- **The 6cm system installation is mostly complete** (except installation of scrubbing heater) and a trial run which includes tile scrubbing
  - Sealing chamber: commissioned late 2013; many sealing tests to date: in air/ in vacuum, stand alone / with other subsystems
  - Deposition chamber: commissioned a few months ago. Effusion cells, heater, deposition monitoring system, RGA; several photo cathode deposition tests done
    - Typical QE ~ few %
    - Needs a good system wide bake out to improved QE
  - Scrubbing Chamber: Electron gun and HV connections are in place and functional; started commissioning without heater 2 weeks ago
    - Scrubbing Heater to be installed soon
    - Currently, tile base/MCP stack bake out is done in sealing chamber at 180^{o} C
    - Activation of getter material is not possible at the moment, but should be available within the next month
- **System tests have begun (within the last month)**
  - Short bake out at relatively low temperature (3 weeks ago)
  - Current base pressure is in the low 10 $^{-8}$ to high 10 $^{-9}$ torr scale after short bakeout
    - System achieved mid 10 $^{-10}$ torr in the past, after more intense bake out
  - System wide component transfer and alignment thoroughly tested
  - ***System was ready for first trial run on May 20 , 2014***

Photodetector Fabrication and Testing of 6cm Tiles

- **The 6cm system installation is mostly complete**; now debugging/optimizing the device fabrication procedure

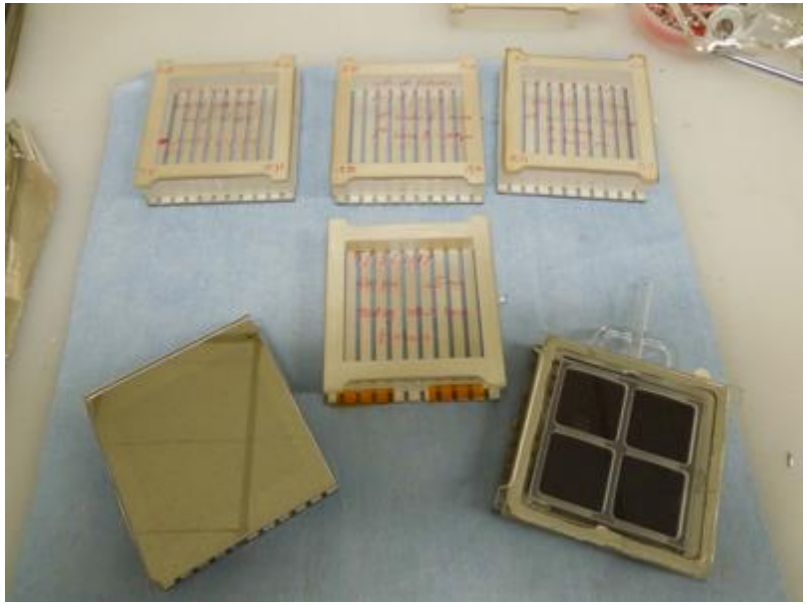
13 tiles assembled in system:

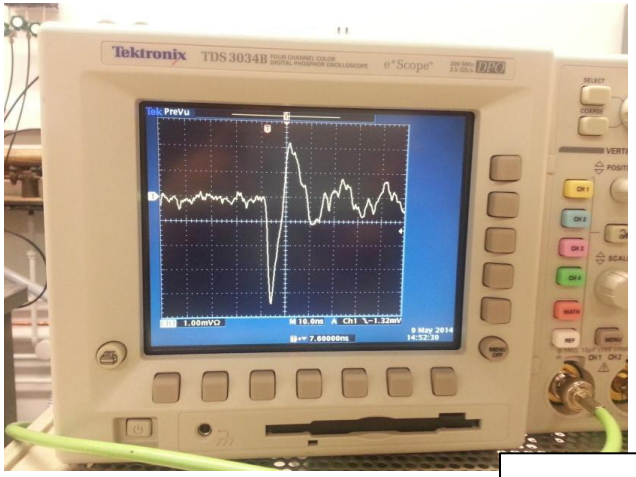
- 7 pump port devices for seal qualification
- 1 complete parts assembly for radioassay at Pacific NW Lab
- 1 NiCr & 2 Al photocathode tiles
- 2 K_2CsSb complete tiles



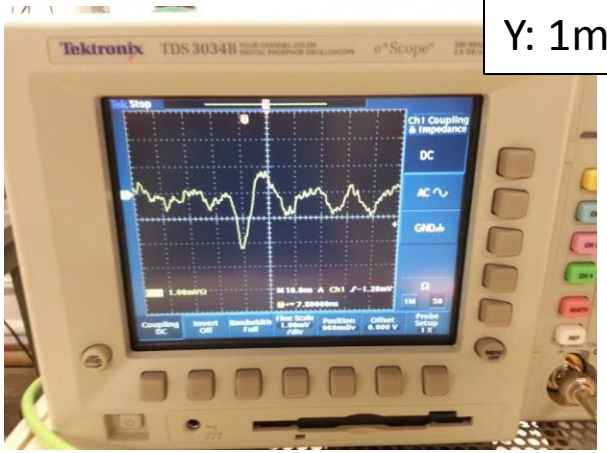
Detector turn-around time ~ 2 days, but this will increase as baking and scrubbing are included.

Photodetector Fabrication and Testing of 6cm Tiles





X: 10ns/div
Y: 1mV/div



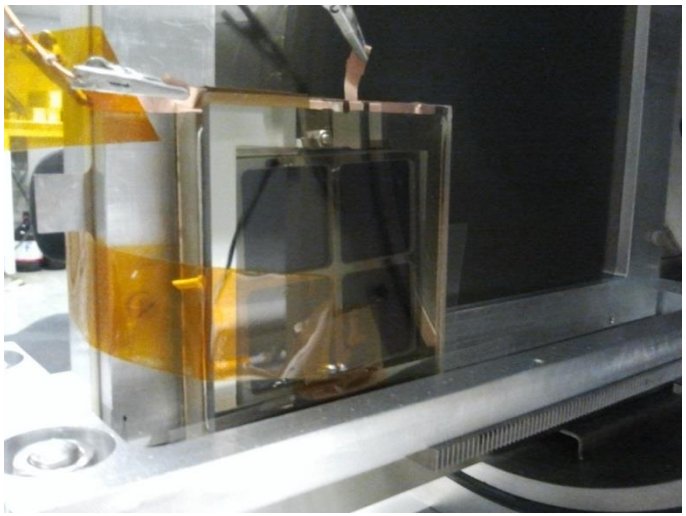
Signals obtained from 6cm Al photocathode detector operated in Phosphor Chamber

Photodetector Fabrication and Testing of 6cm Tiles

- Device with K_2CsSb photocathode showed current increase with HV light shining on it – strong indication of UV light induced signal ☺
- This also suggest a pretty good seal

Goal is to have first working 6cm all glass devices by early fall

- Lifetime will be the highest priority for initial production of tubes
- Establish useful QE > 20% (lower QE on first tubes acceptable with a path to higher QE)
- Uniform and stable response (similar to the 20cm devices)



Summary

- The next two years will be critical for the commercialization of Large Area Picosecond Photodetectors:

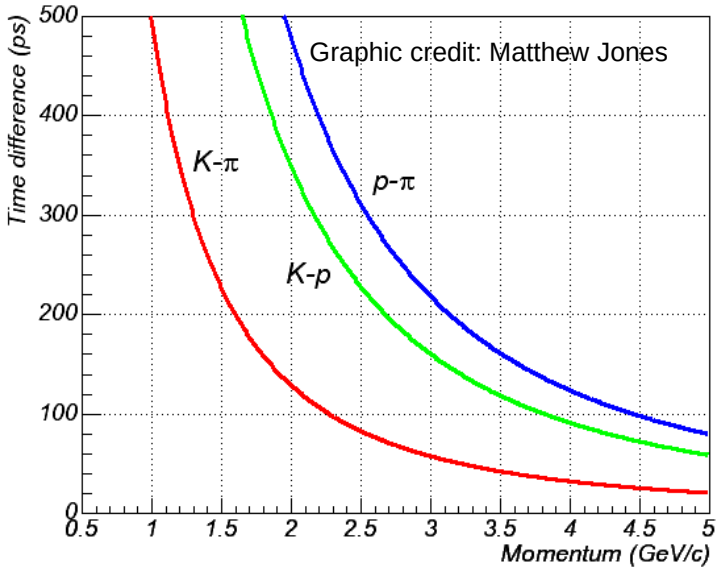
- The LAPPD project has seeded many new SBIR efforts including a Phase II SBIR award to Incom, Inc.

- Argonne (and U. Chicago, SSL and Hawaii) are committed to supporting Incom through the commercialization process
  - Argonne is supporting Incom through multiple areas, including ALD, Glass kits, and 20cm mini-SSL process tank

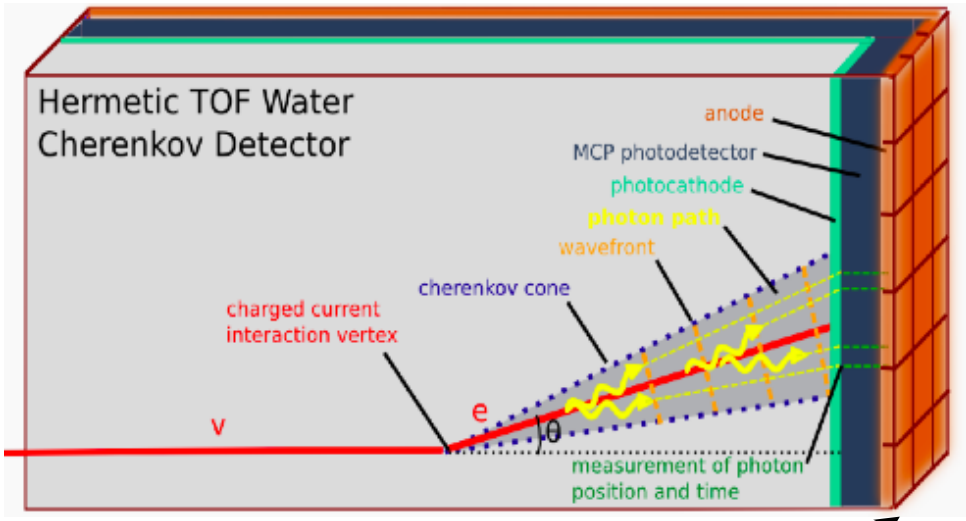
- Argonne's small form factor R&D facility is mostly complete; commissioning and optimization of system testing have begun.
  - Produced the first 6cm sealed all glass device with a K_2CsSb photocathode
  - Goal is to have first working 6cm all glass devices by early fall

Backup

Motivation for LAPPD: Time Resolution for Particle ID and Economical Large Area Photodetectors for "HEP"



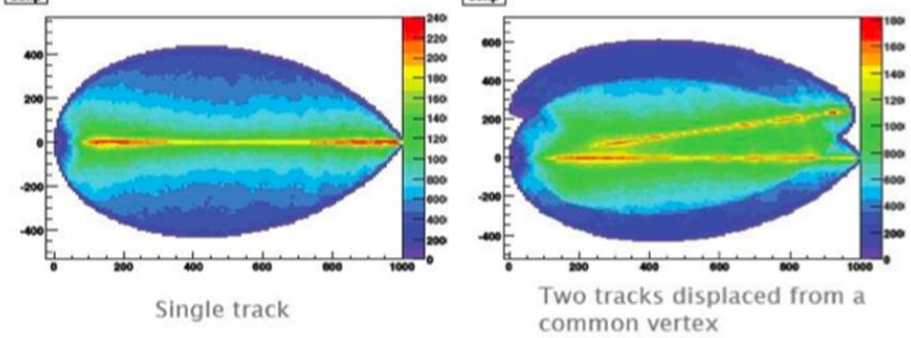
1ps ⇒ 1σ π-K separation @ 22 GeV/c in 1.5m & B=1.5T



Tessellation of detector with Large Area MCP-PMTs

Goal is to measure ALL information allowing for identification of quarks producing jets. Requires particle ID for momentum of 10's of GeV/c

Results of a toy Monte Carlo with perfect resolution.



Graphic credit: Matt Wetstein