Challenges in Photocathode Deposition for Large Area MCP Proximity Focus Devices

Oswald Siegmund

Experimental Astrophysics Group,

Space Sciences Laboratory,

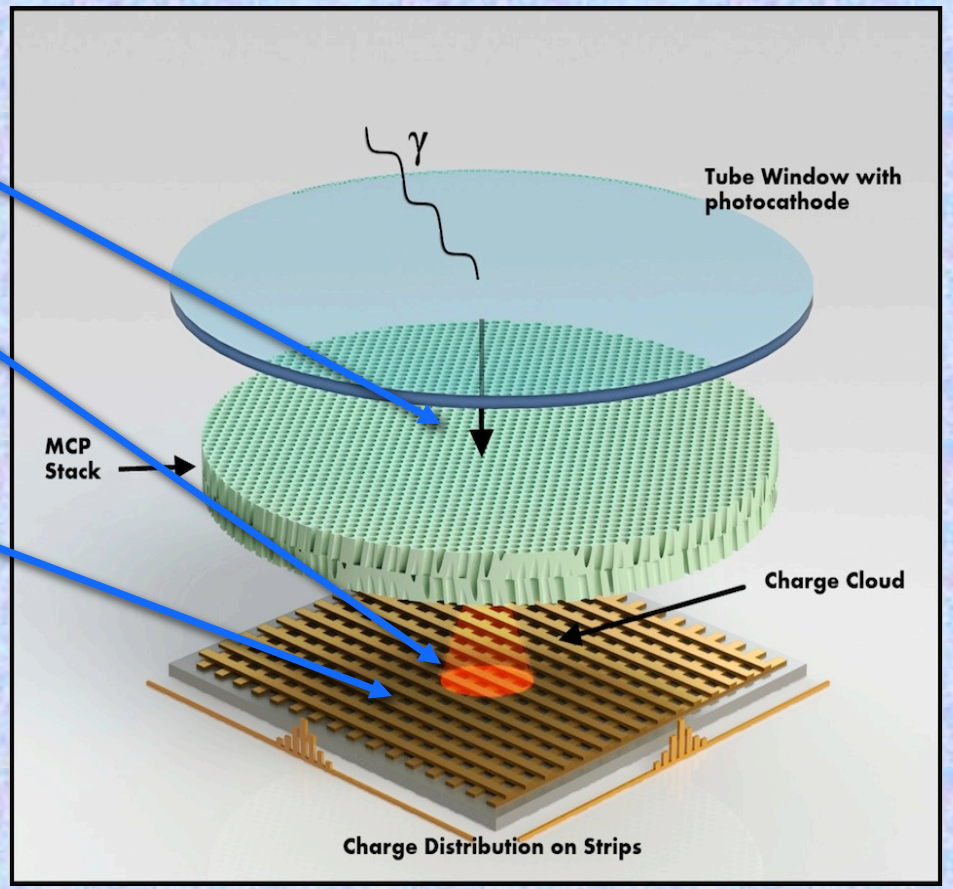
U. California at Berkeley

Microchannel Plate Detector

Photocathode converts photon to electron

MCP(s) amplify electron by 10^4 to 10^7

Patterned anode measures event charge centroid position

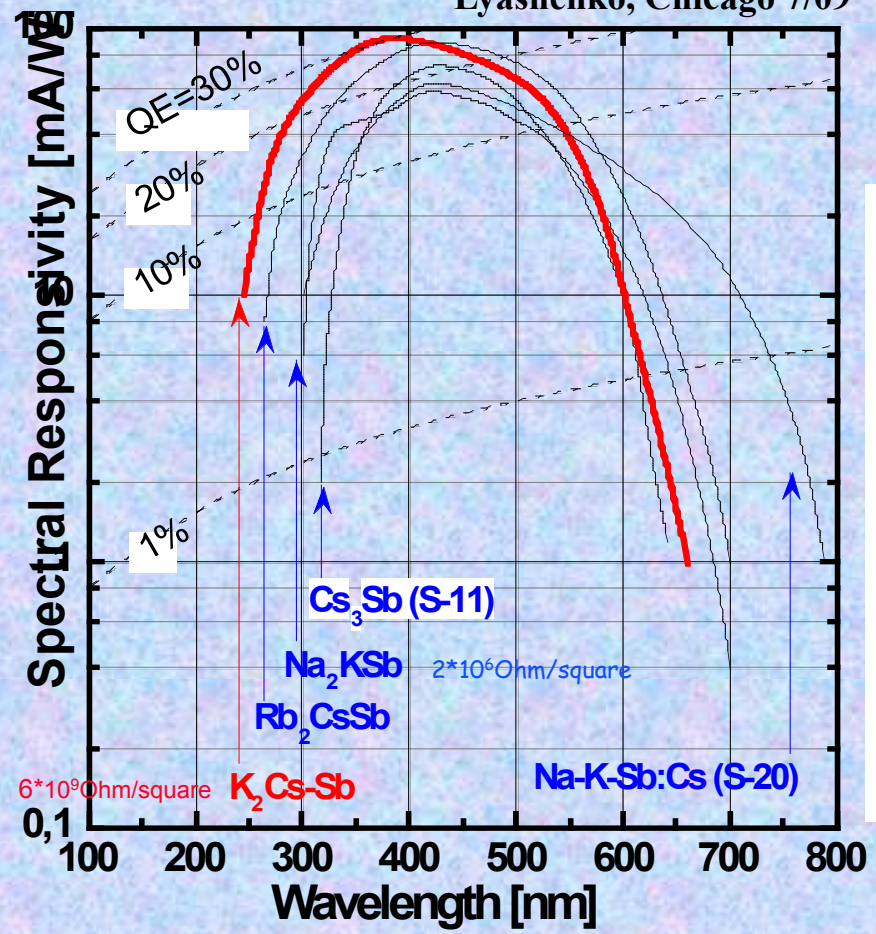


Have made sealed tube devices up to 65mm with proximity focus (CsTe) and opaque (CsI) photocathodes

Photocathode - Configurations

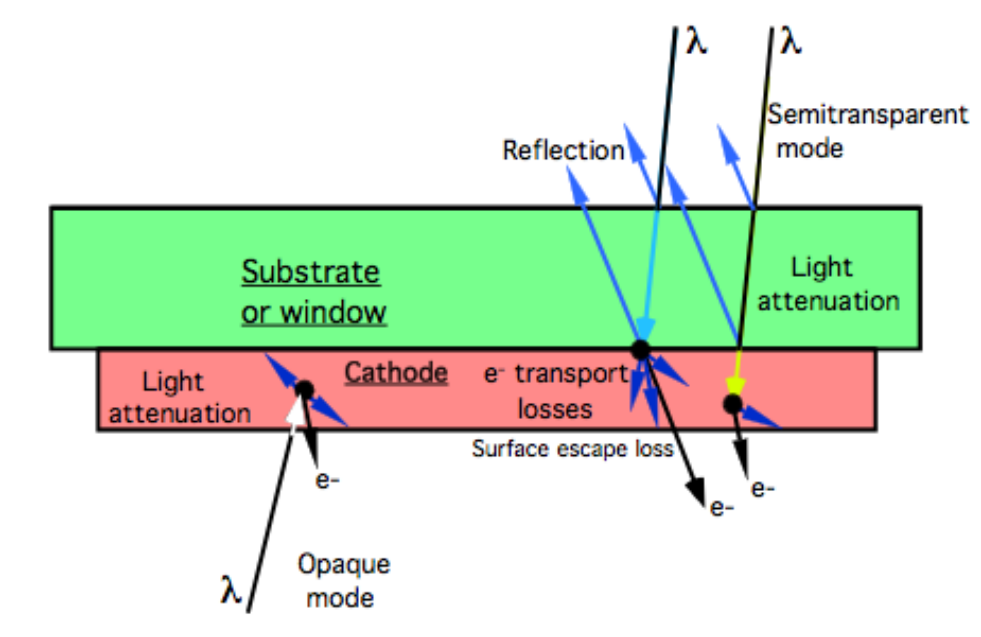
Photocathode Types

Lyashenko, Chicago 7/09



Photocathode Schemes

Semitransparent layer or opaque layers on the window. Proximity gap to the first MCP, or E/B field focusing onto MCP.



Deposition Issues for Large Area Microchannel Plate Device Proximity Photocathodes

Transfer Photocathodes

Make cathode "separately" and then install onto the device

+ Can use "favorite" photocathode recipe with minimal consequences
+ Can optimize for large areas with adjustable deposition geometry
+ Can set and control small proximity gaps even over large areas
+ Can minimize effects of photocathode process on device "innards"
– Thermal control can be tricky – especially for large devices
– Have to manipulate a large, heavy, window & do vacuum manipulations
– Need to establish a reliable way to do the final seal

Non-Transfer Photocathodes

Deposit the photocathode "in situ" inside a completed detector assembly

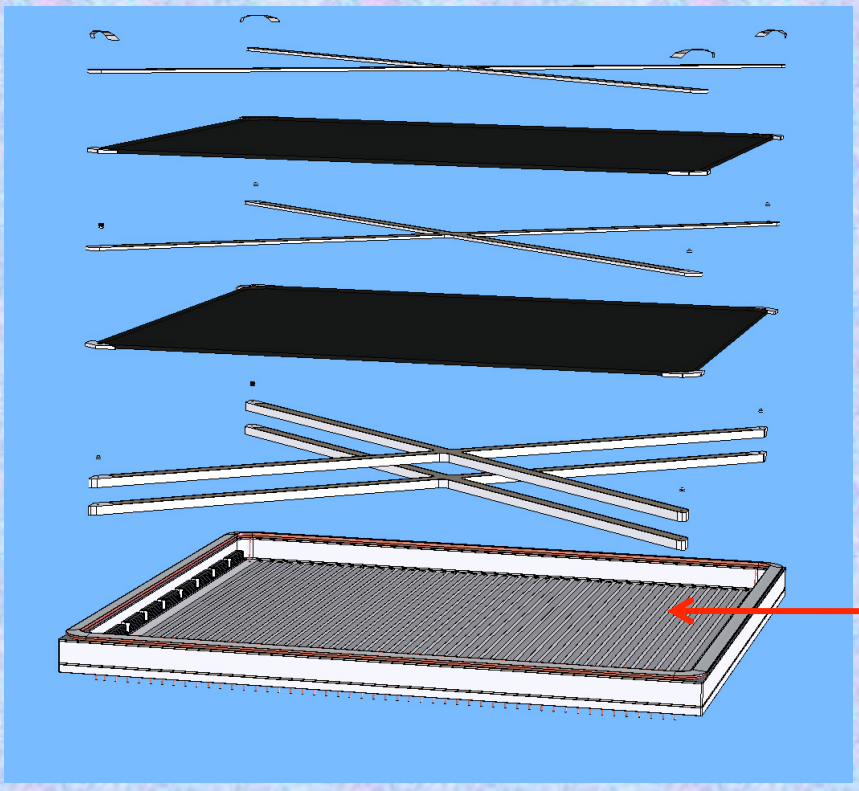
+ Seal pre-established (except for pinch-off)
+ No component manipulations or vacuum manipulations
+ Better handle on thermal control
– Effects of local photocathode deposition on MCP operation
– Small gaps/large area deposition very hard to deal with – geometry
– Cant use some photocathode recipes

Large - 20cm - Optical Photodetector Design

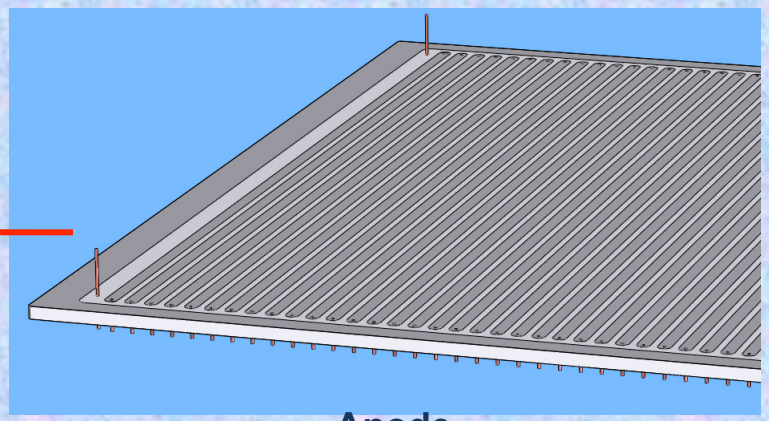
DOE Argonne Lab High Energy Physics – LAPPD

Input Window (not shown) borosilicate, 5mm thick input window, using Indium seal, semitransparent bialkali photocathode.
Objective 5ps time resolution, 0.5mm spatial for HEP.

Ceramic body with Cu Indium well and strip anode.



Brazed body assembly to form the hermetic package

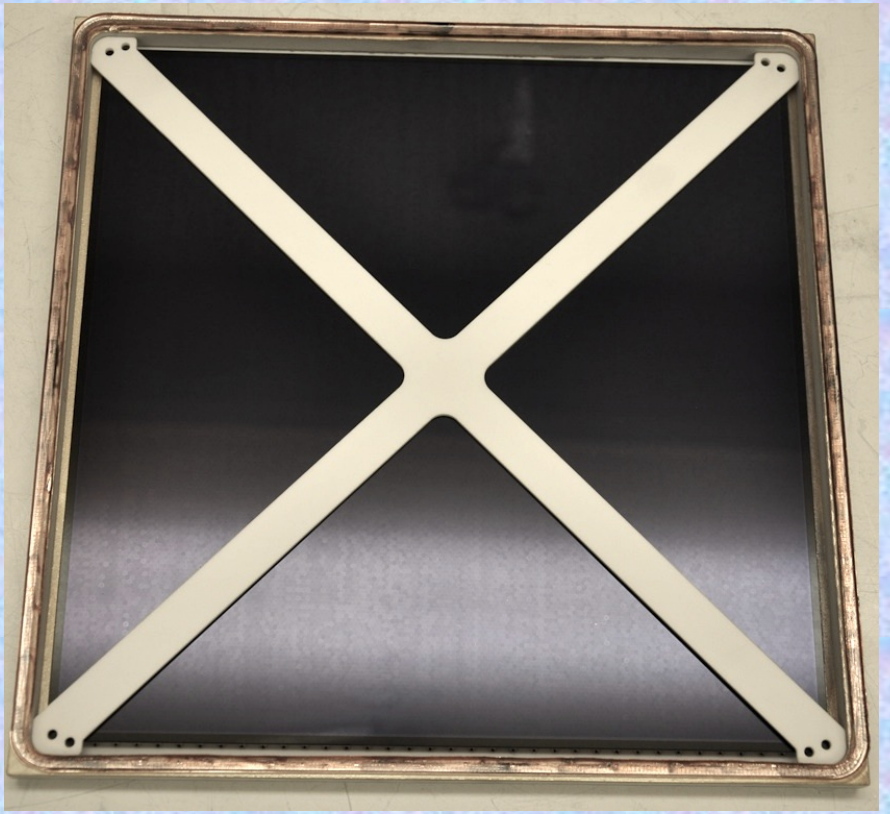


Anode

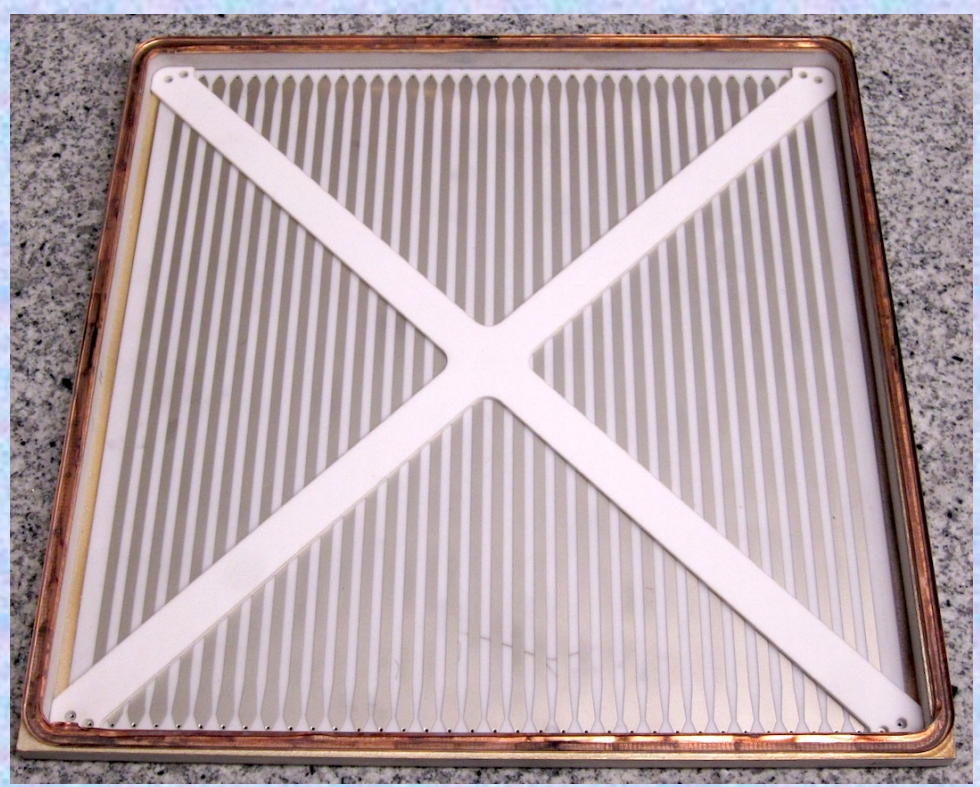
Alumina substrate with signal and HV pin contacts.
48 signal strips inside, complete Gnd plane outside.

Large 20cm - Optical Photodetector Implementation

Input Window (not shown) Borofloat 33, 5mm thick



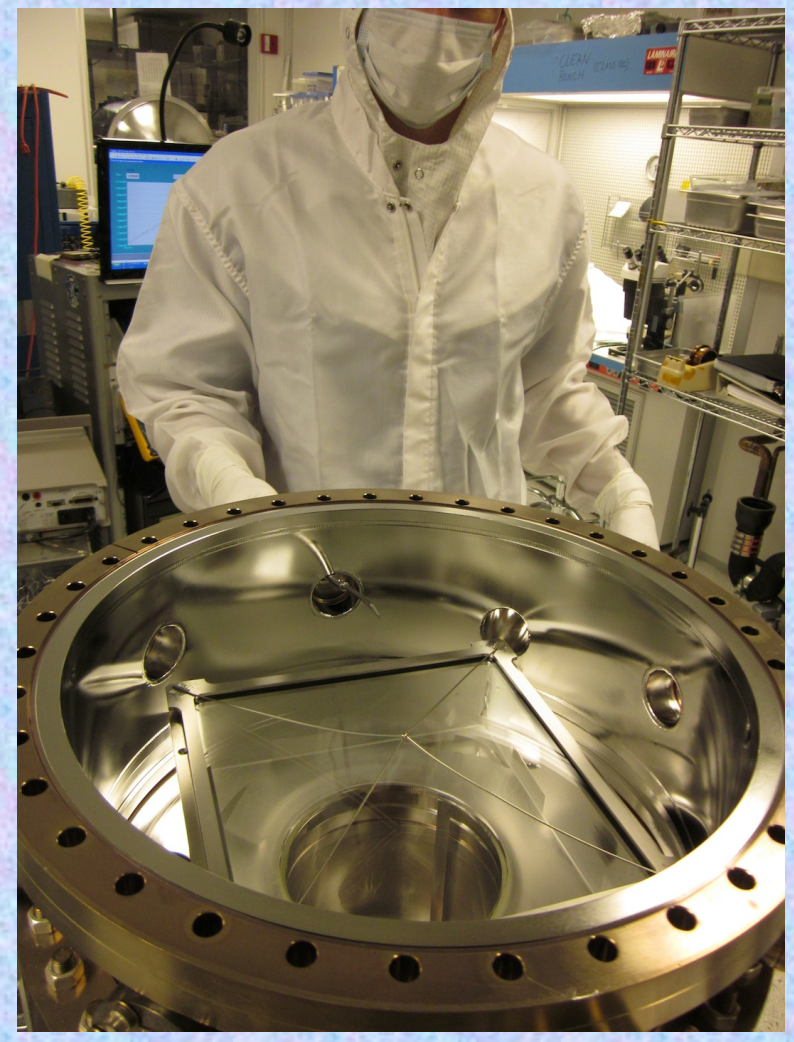
Brazed body assembly with 20cm MCPs and "X" spacers installed



Brazed body assembly

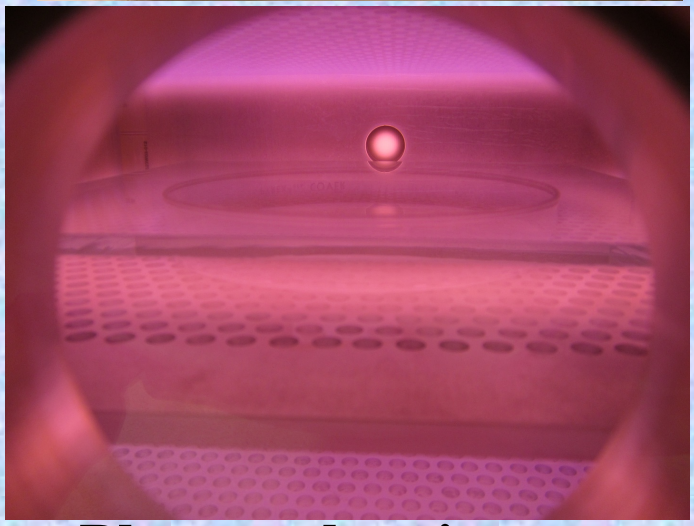
Alumina brazed assembly with "X" spacer for vacuum support and MCP spacing.

20cm Photocathode Processing



22cm window loaded

Final window adjustments

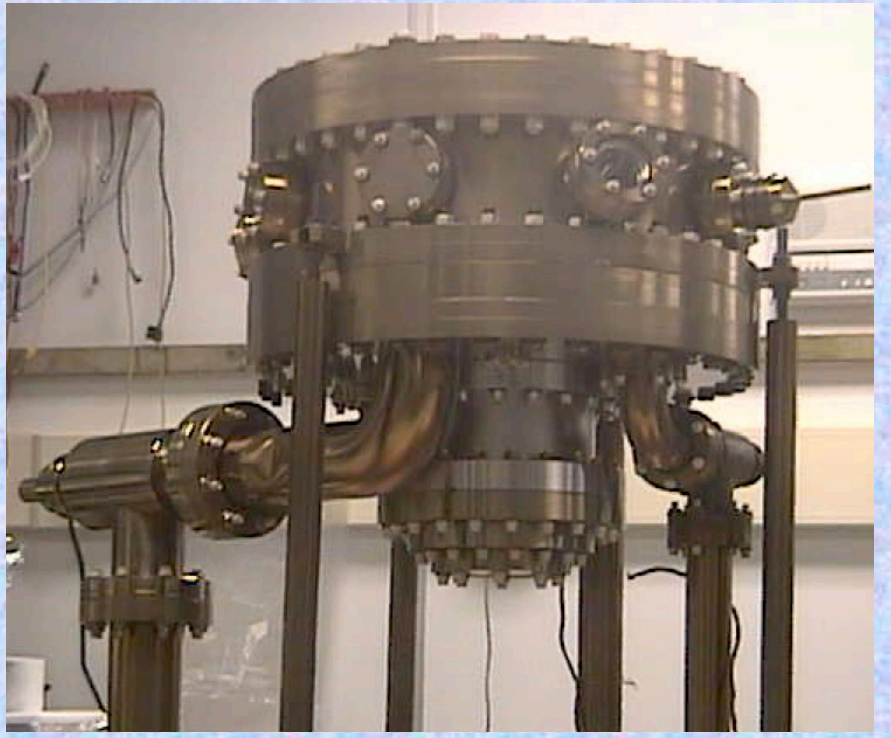


Plasma cleaning

20cm PhotoCathode Test Chamber & Sealed Tube Device Process Tank

Process test chamber:- to evaluate

- Quantum efficiency
- QE Uniformity
- Seal tests



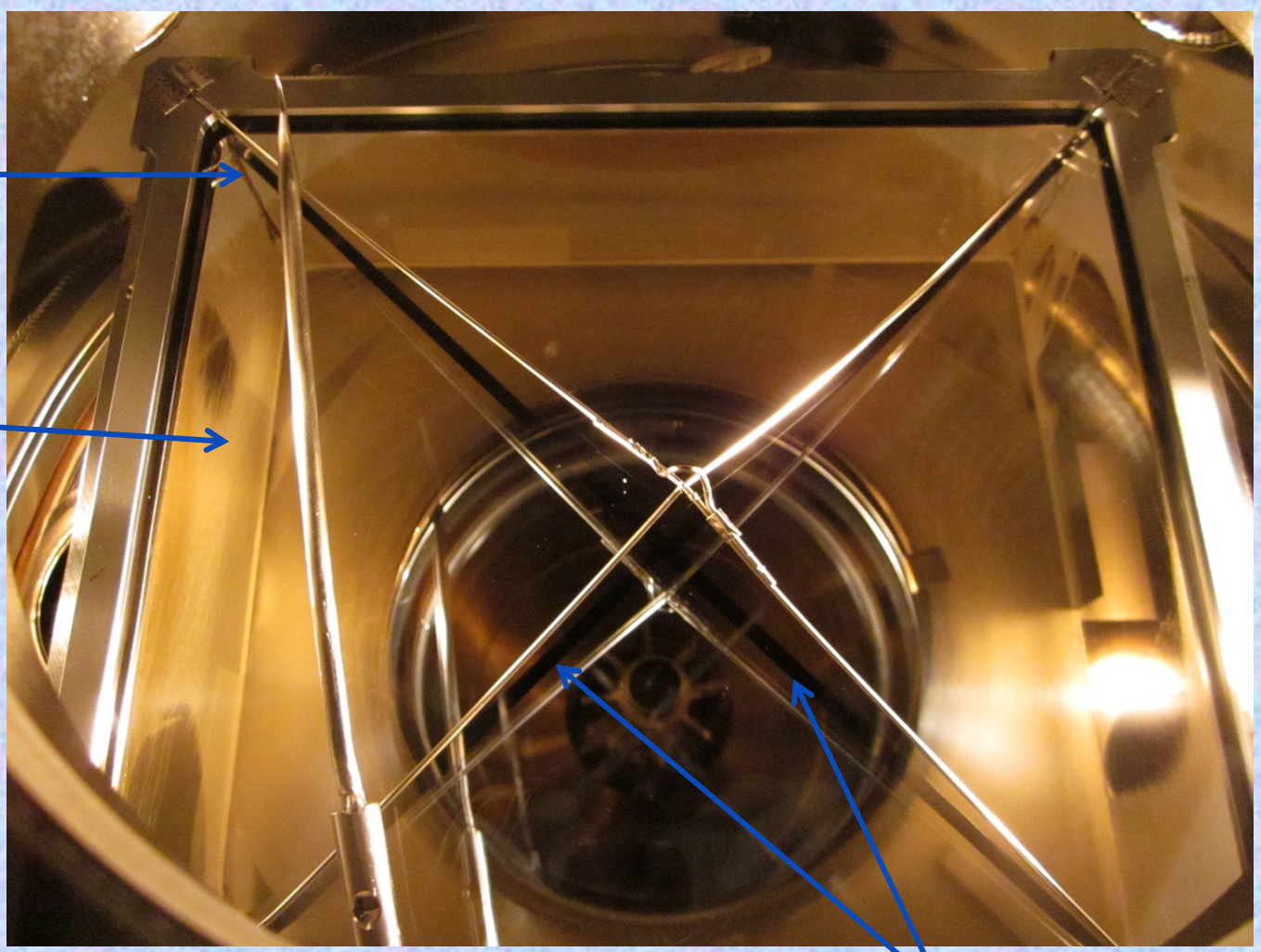
Sealed Tube Device Process Tank

MCP conditioning, photocathode process and transfer seal.

20cm -Na_2KSb Bialkali on Borofloat 33

No Cathode

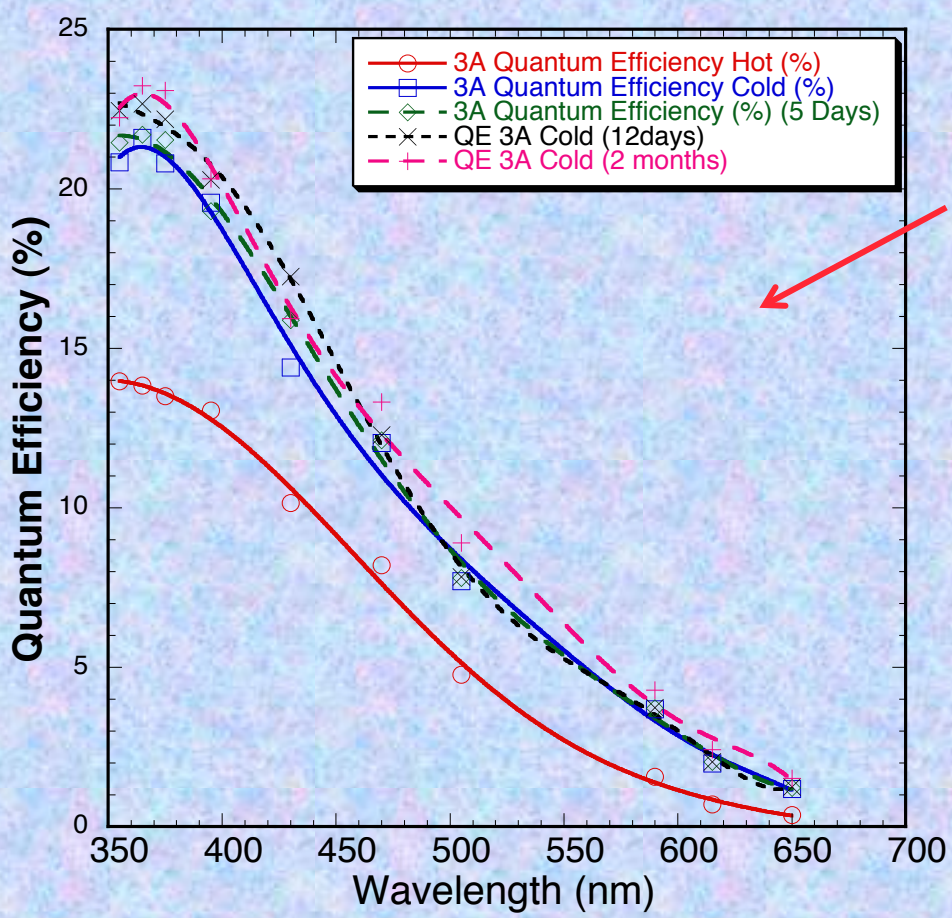
Cathode



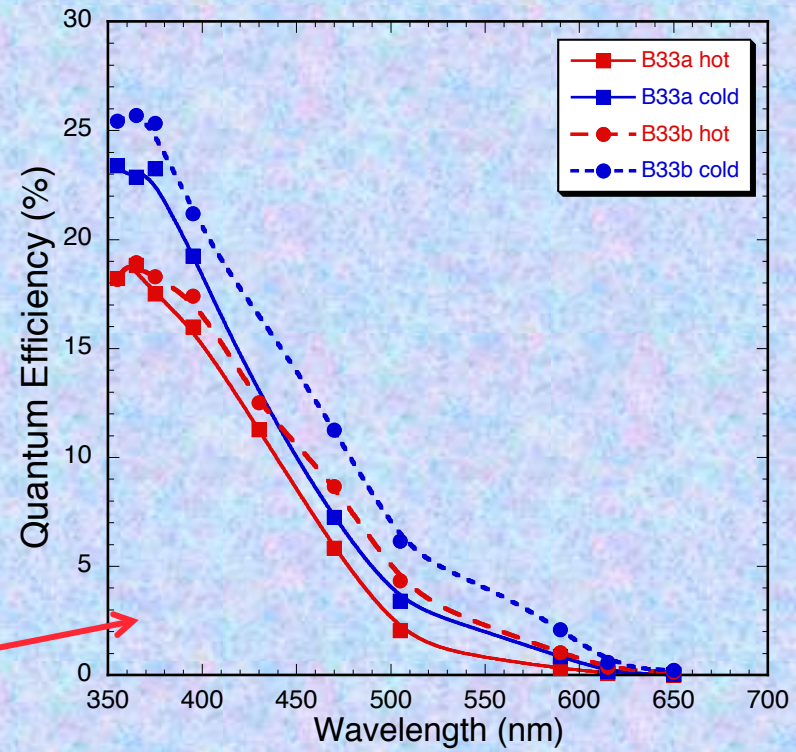
"X" electrode

Window (hot) was lifted after process to simulate an indium hot seal procedure

20cm - Na_2KSb Bialkali on Borofloat 33



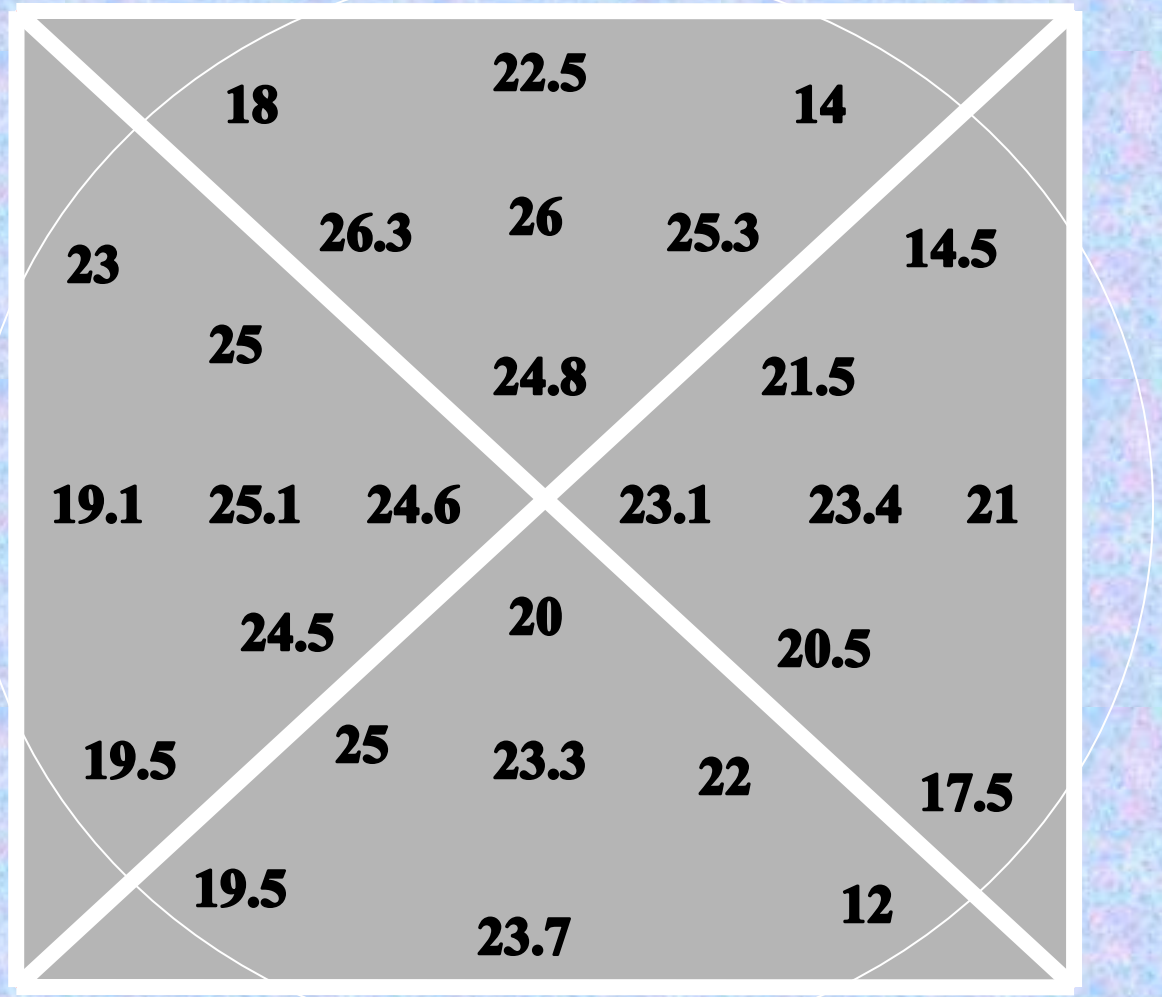
Basic process is a co-evap technique. We get an enhancement of the QE after cool-down. The QE has remained stable over the 2 months since deposition.



Smaller 31mm windows give similar results (deposited in different process tank)

20cm -Na_2KSb Bialkali on Borofloat 33 Photocathode Uniformity

Majority of the area is within ±15% of the average QE, There is some obscuration by tooling in some places.



Non-Transfer Large Area Microchannel Plate Device Proximity Photocathodes?

Transfer Photocathodes

Seem viable from recent demonstrated experiences.

Non-Transfer Photocathodes

Potential problems in placing antimony for uniform deposition using co-evap techniques, cant use PMT (large gap) strategies.

Pre-deposition of antimony on window has significant potential downsides:-

- handling during device construction
- potential for contamination/damage during process run

Other potential solutions?

Opaque photocathodes on the MCPs directly?

Multialkalis- issues with direct deposition on MCPs – still transfer window

Different type of photocathode that fundamentally changes the process?

GaN or other III-V type material?

Photocathodes, 250nm - 500nm

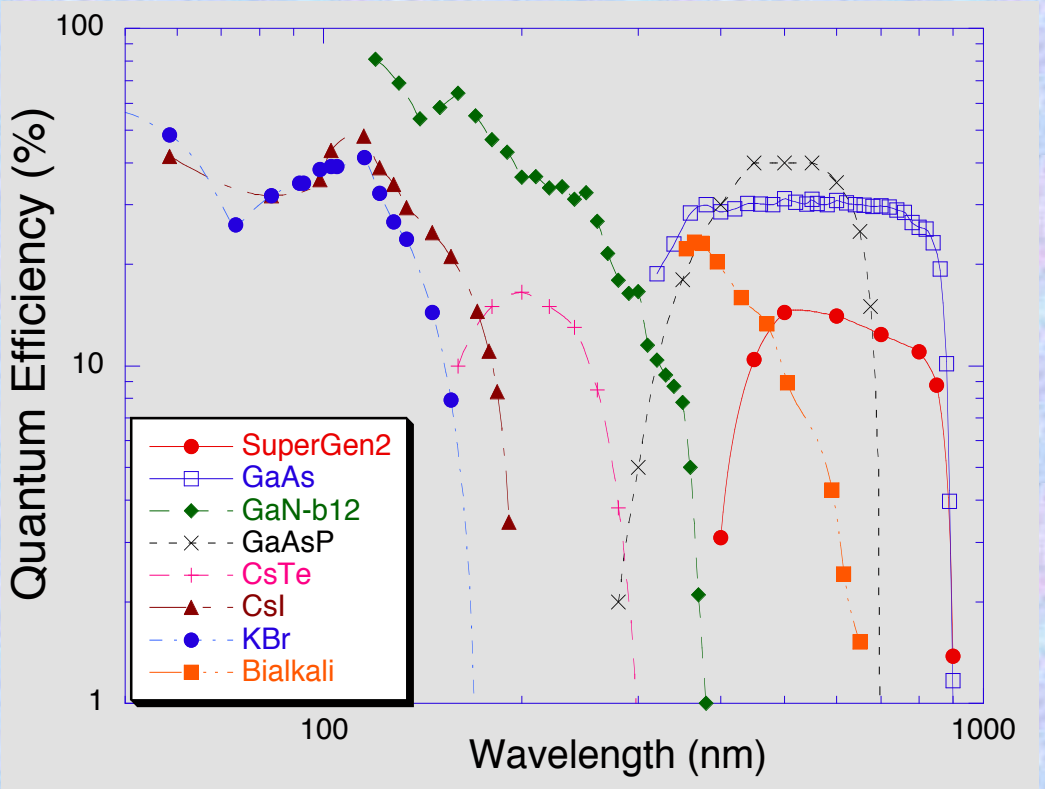
Many photocathode types,

Alkali halides, only UV

GaAs(P) tough to make over large areas

GaAs " " " " "

CsTe/RbTe poor QE, too far into UV

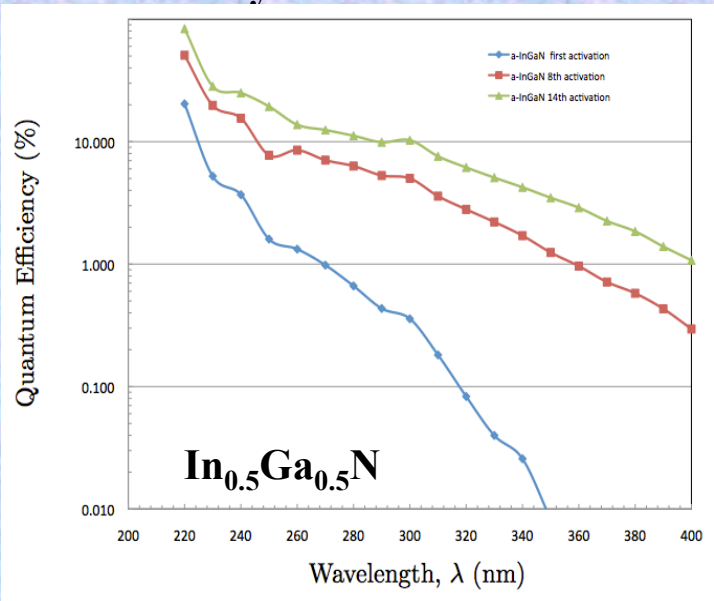


Comparison of conventional and GaN photocathodes.

GaN – InGaN

Potentially workable to 450nm by extending the band gap with In.

Jim Buckley – Wash. U.



GaN Photocathode Development

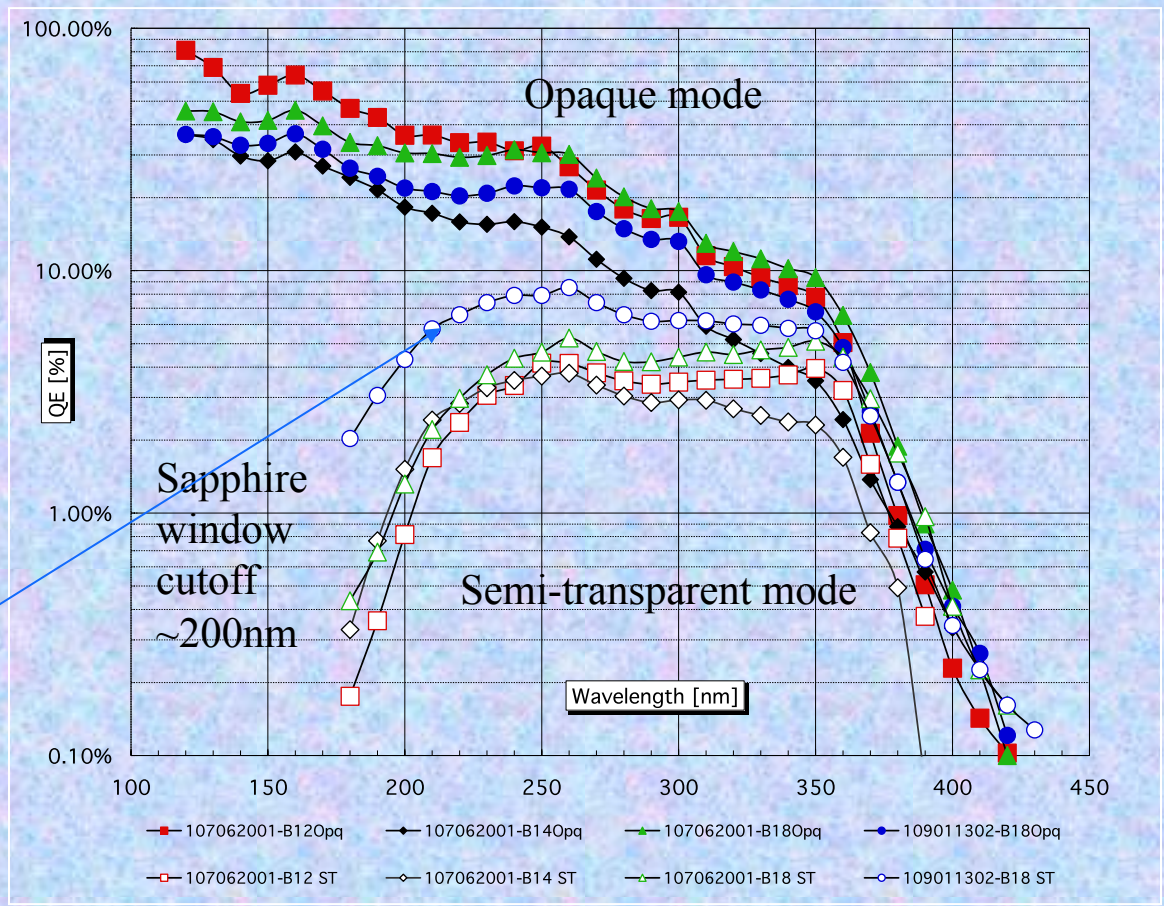
- "Solar blind" efficient cathode for 100nm-400nm
- Band gap energy 3.5 eV, (~355nm)
- Robust, compatible with sapphire substrates
- p (Mg) doped to promote bulk electron transport
- NEA is established by surface cesiation
- >100nm GaN layers typical
- semitransparent or opaque

GaN Cathode Performance
(opaque and semi-transparent)

GaN is a robust material with good handling properties. (Not hygroscopic)
Samples have been re-cleaned and reprocessed many times achieving same QE
GaN sample in a sealed tube has not changed in QE measurably in over 5.5 years.

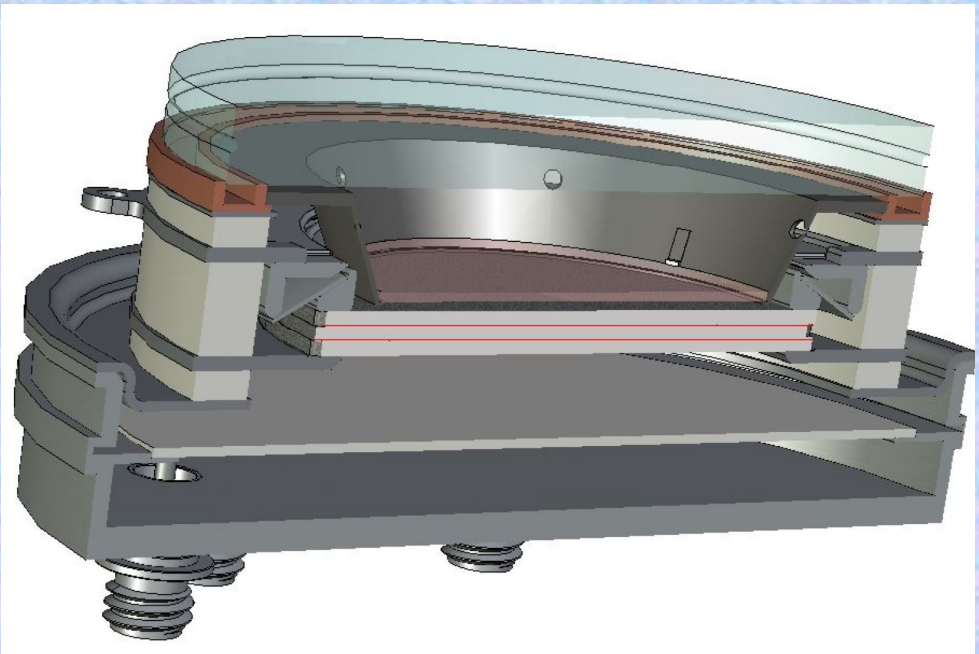
Response is a function of thickness, dopant, layer structure and process techniques (cleaning, heat treatment, cesiation).

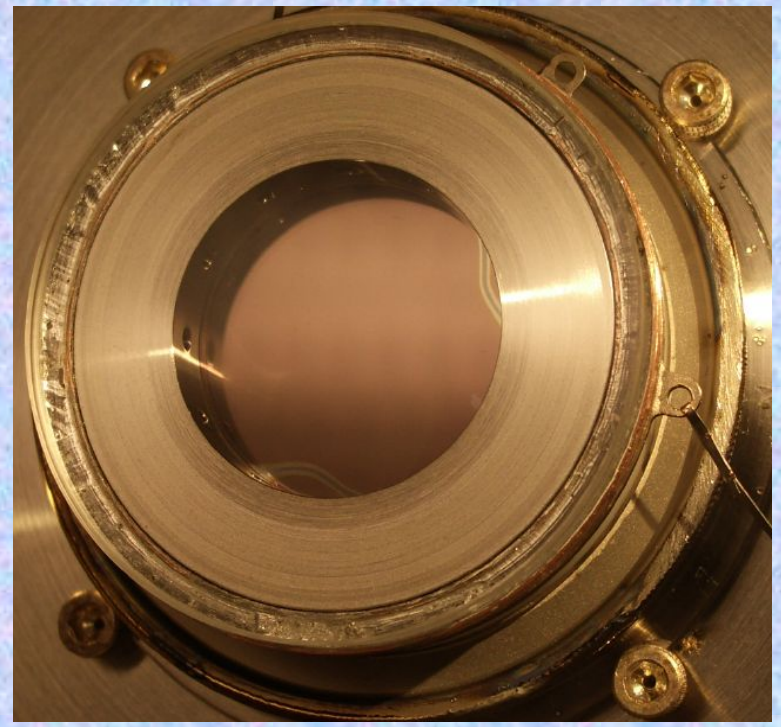
Achievable Semi-Trans cathode QE is actually a factor of two higher than the average measured value here since the high QE is only on 50% of the patterned substrate.



Various process runs and samples of GaN photocathodes on sapphire, measured in both opaque and semitransparent mode.

GaN Proximity Focus Imaging Detectors



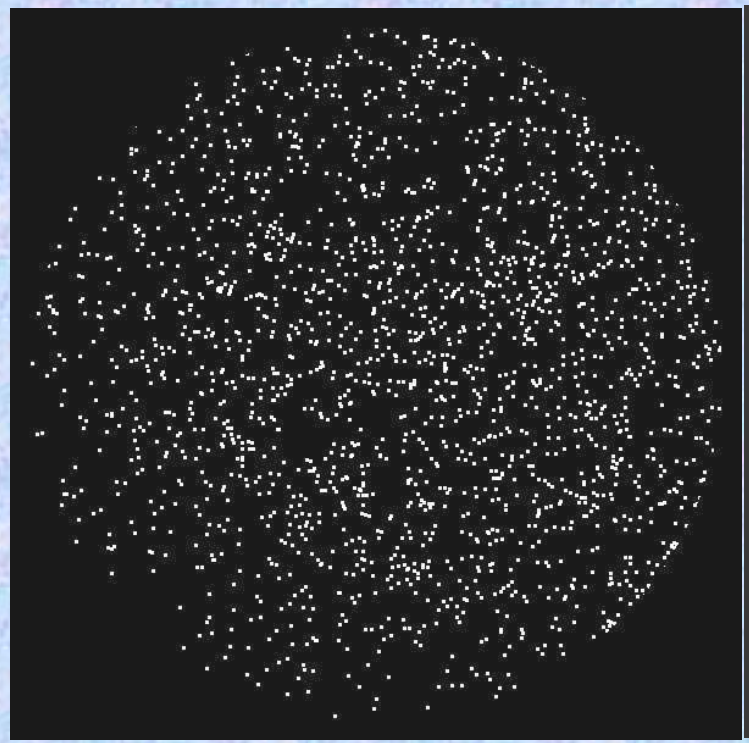


- We have built an imaging detector using semitransparent GaN on sapphire
- Uses a cross delay line anode and a MCP triplet to image individual photon events
- Several GaN cathodes have been evaluated for their imaging properties

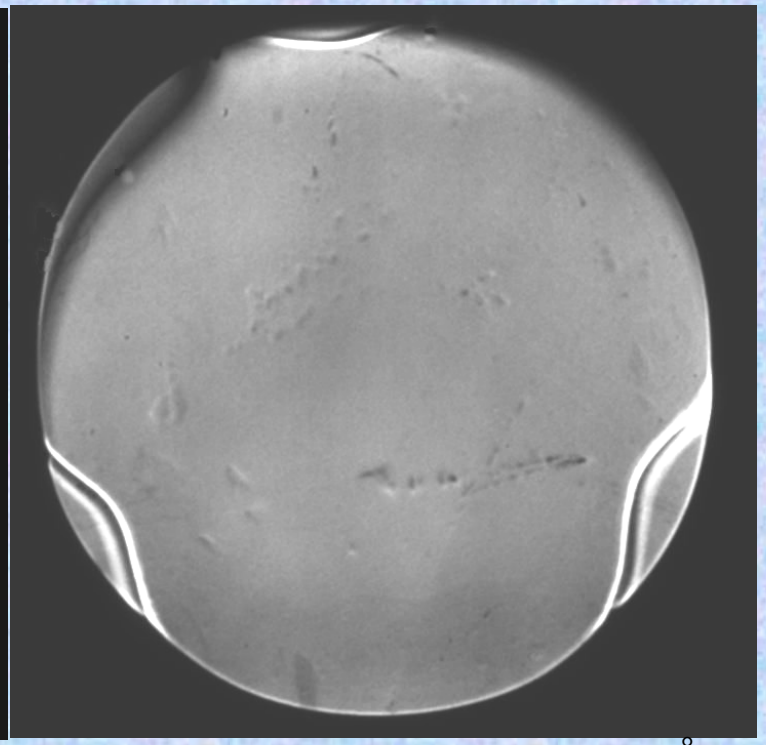
Semitransparent GaN Cathode Imaging

0.1μm GaN

120v GaN bias



Background image ~0.9 events cm^{-2} sec^{-1}, 600 sec integration



Flood illumination with 2537Å 10^8 events

- The 0.1μm GaN gives OK overall response, but GaN defects / scratches on sample show up
- There are edge shadows due to mounting hardware at the edges
- Much higher QE at the edges of the deposition wire shadows
- Background rate of 0.9 cm^{-2} sec^{-1} with GaN bias, 0.45 cm^{-2} sec^{-1} without bias

Non-Transfer Large Area Microchannel Plate GaN Photocathodes?

GaN Semitransparent Transfer Photocathodes

Have been done, not the best QE, best on Sapphire window.

Use ALD to apply Al_2O_3 underlayer to borosilicate window?

Use ALD to deposit GaN?? Potential problems – defects - dopants?

Non-Transfer Photocathodes

Pre-deposition of GaN on window :- Semitransparent

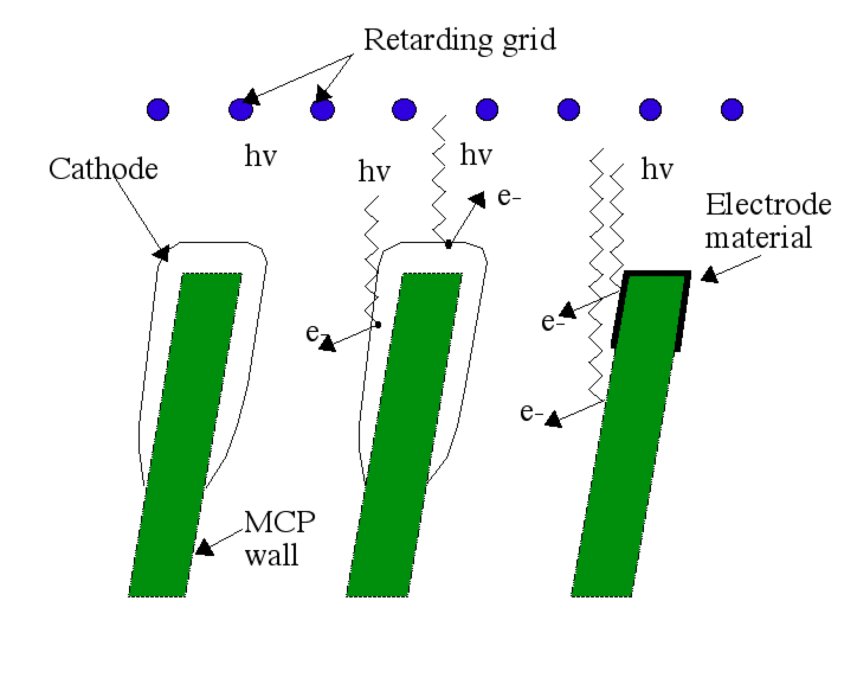
- handling during device construction?
- potential for contamination/damage during process run?
- Adequate NEA activation with Cs in closed device?
- Effects on the MCP of in situ Cs activation?

Pre-deposition of GaN on MCP :- Opaque

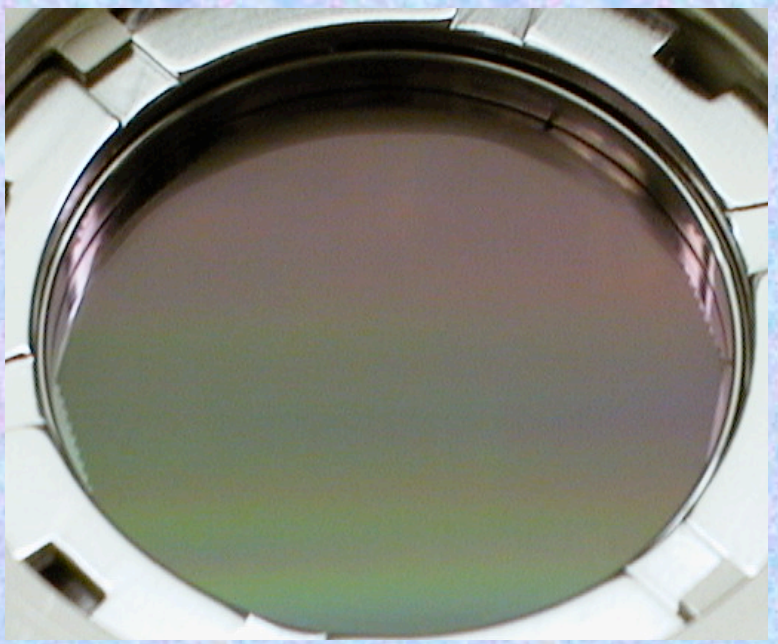
- handling during device construction?
- deposition over large areas?
- Adequate NEA activation with Cs in closed device?
- Effects on the MCP operation of in situ Cs activation?

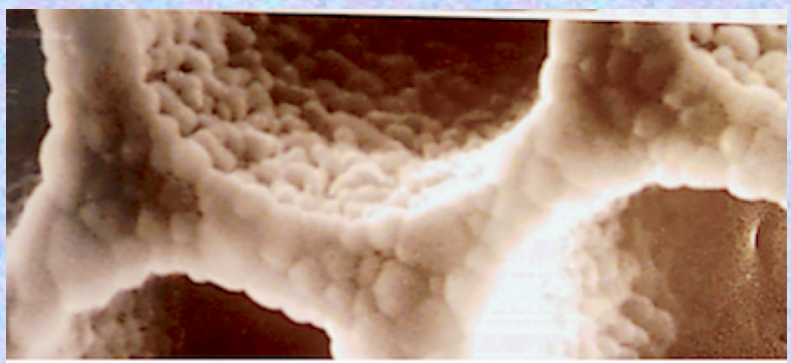
Photocathodes – Opaque on MCP Surface

Alkali Halide Opaque Photocathode Scheme



Photocathode Deposited on Microchannel Plate

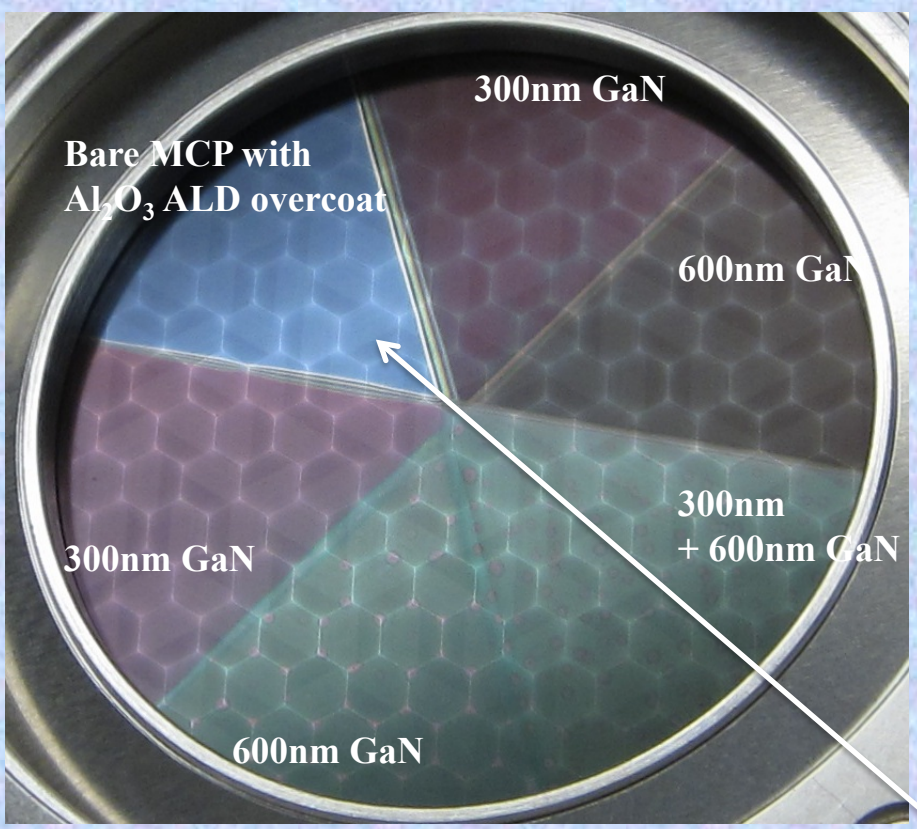


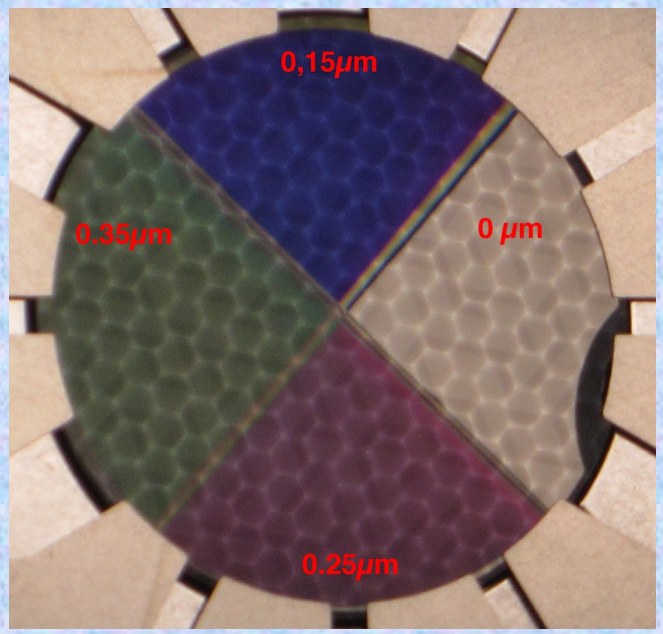


Opaque photocathode layer structure deposited onto microchannel plate

Get quantum efficiencies >50% in the UV

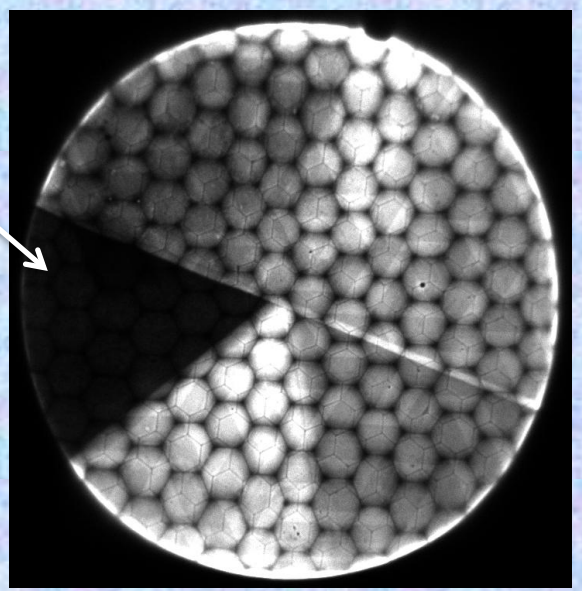
GaN Cathodes on ALD Borosilicate MCPs





More samples being made to optimize process

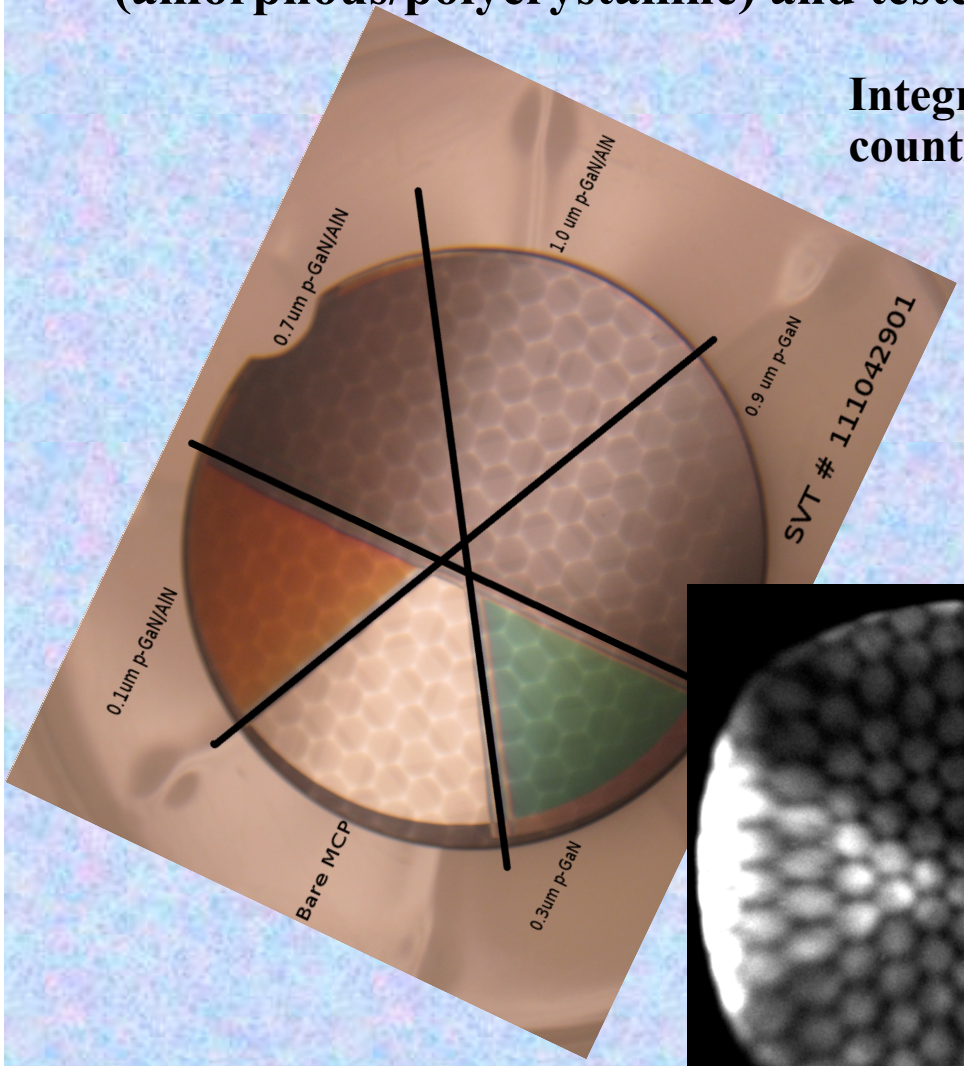
ALD Sapphire (lattice match to GaN) on borosilicate ALD MCP as base layer for GaN(Mg) deposition. [Older MCP base substrate].



185nm UV image (pre-Cs) – photon counting

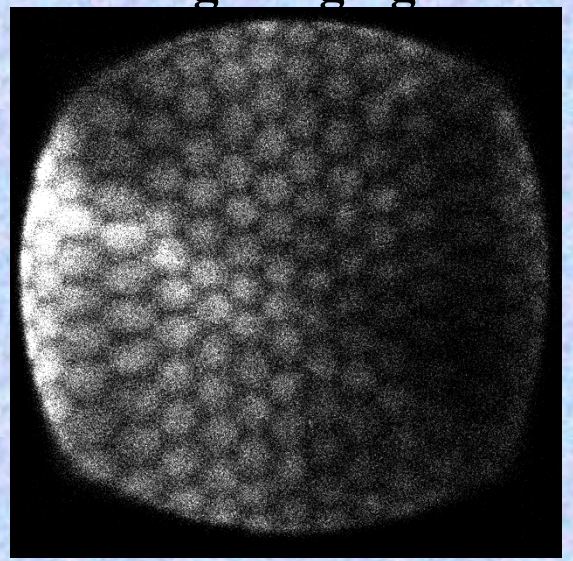
Opaque GaN Deposited on ALD MCPs

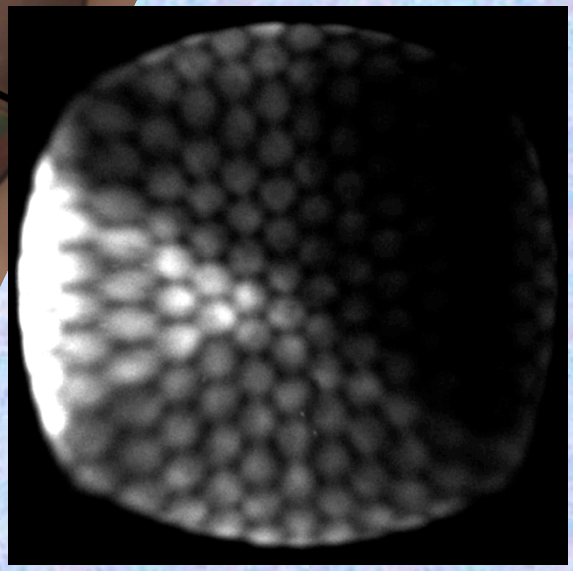
Borosilicate/ALD MCP coated by MBE with P-doped GaN/AlN (amorphous/polycrystalline) and tested in a photon counting imaging detector



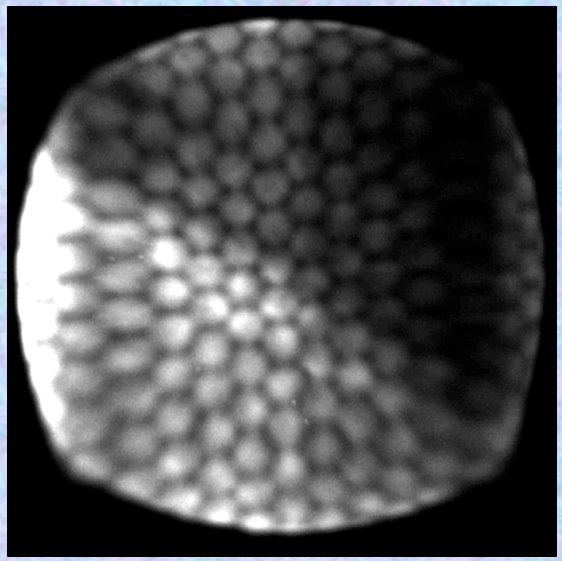
Integrated photon counting images

Background





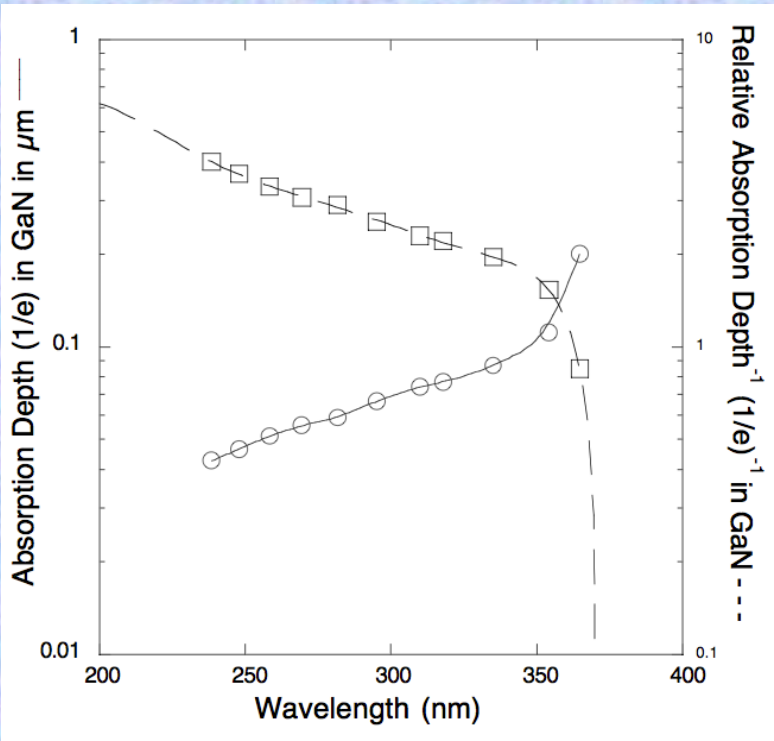
214nm



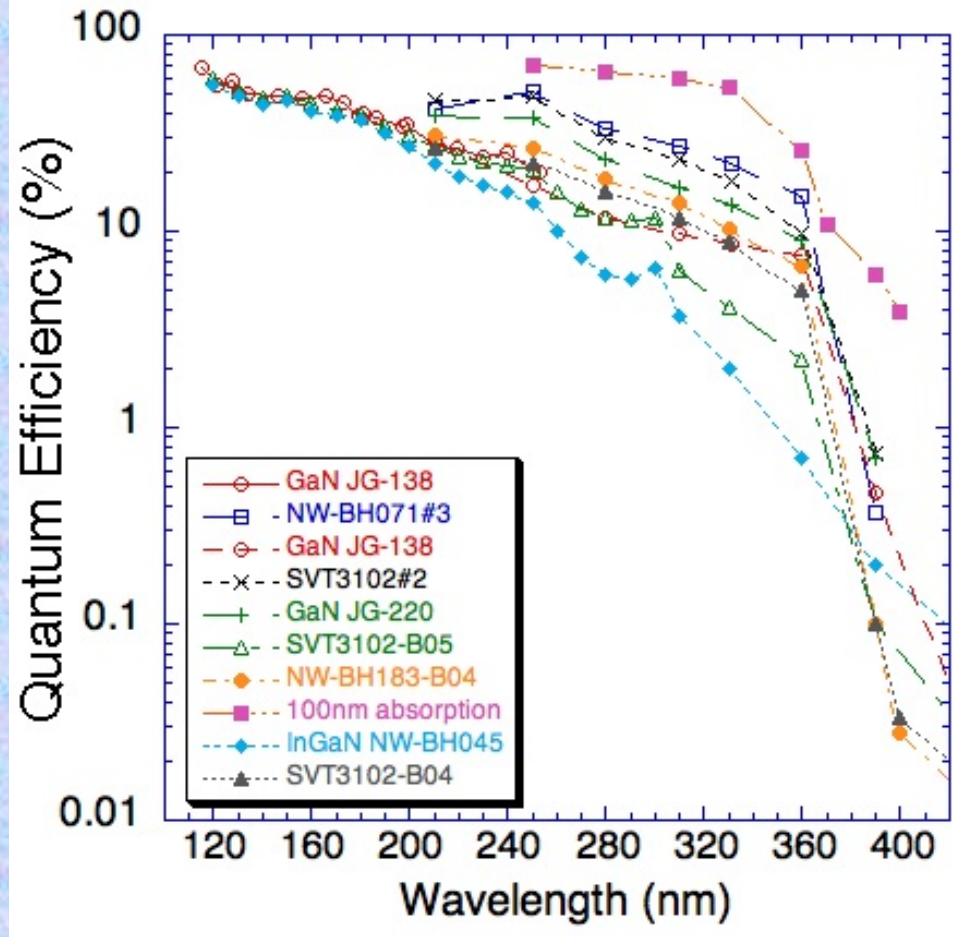
360nm

GaN Cathode Performance
(opaque)

As is the case for UV cathodes, use of grazing incidence opaque cathodes is advantageous. Allows maximization of absorption lengths while minimizing the photoelectron escape distance. Reflectivity is an issue but is modified by grain structure.



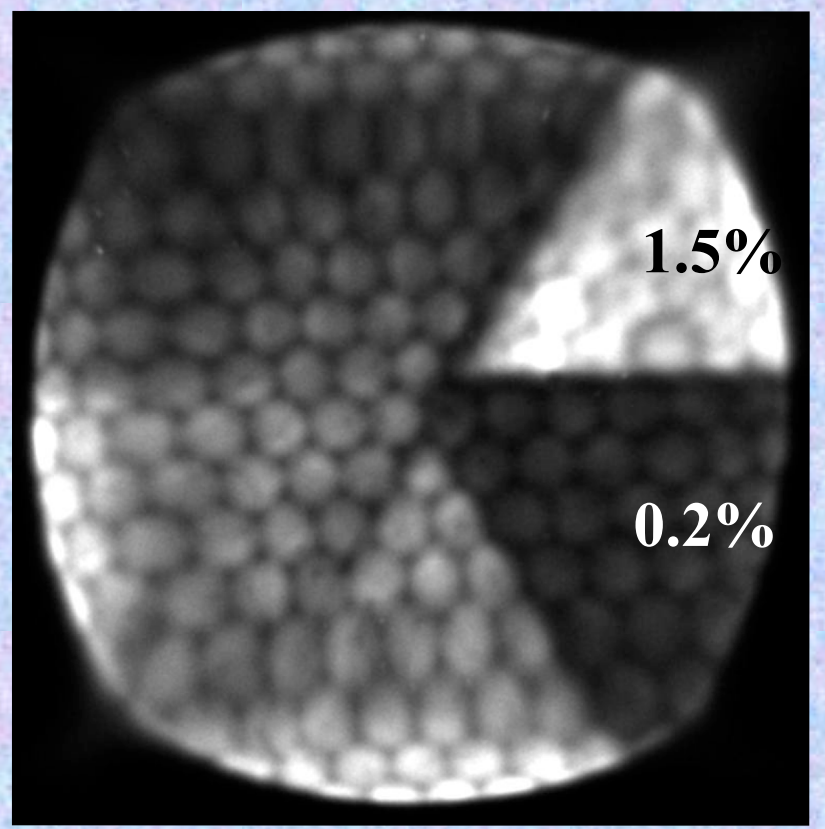
Photon absorption length in GaN



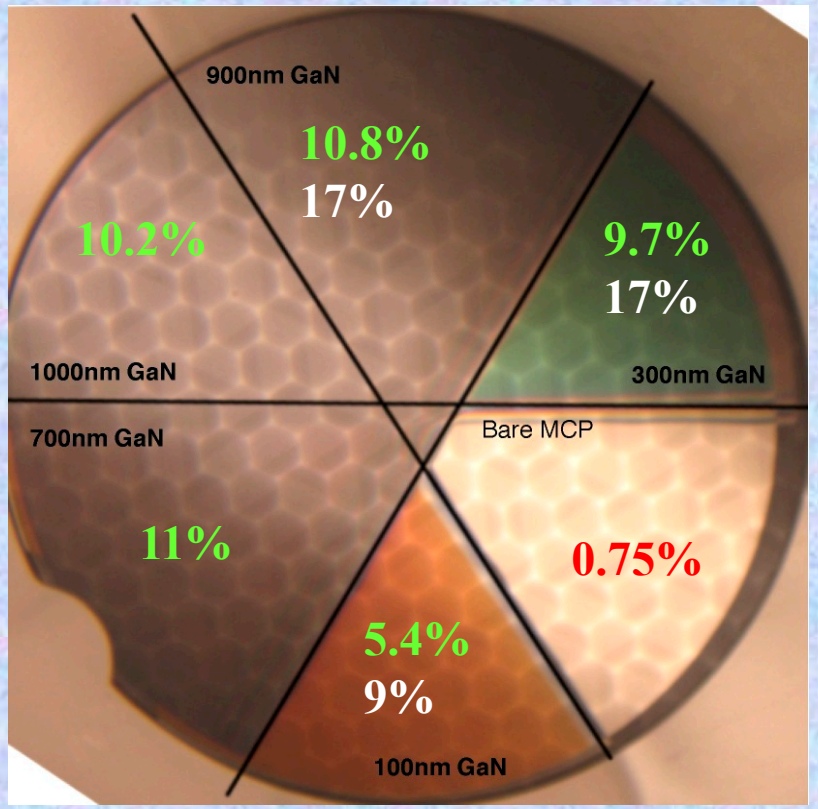
Various process runs and samples of GaN photocathodes on sapphire, measured in opaque mode.

Opaque GaN Deposited on ALD MCPs

Borosilicate/ALD MCP coated by MBE with P-doped GaN/AlN (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.



QEs measured after Cs (@214nm UV) 10º (green) or 45º (white) graze angle.

[GaN on NiCr – not optimized substrate]
[No photoelectron collection field]

Non-Transfer Large Area Microchannel Plate GaN Photocathodes?

Non-Transfer GaN Photocathodes

Reasonable chance of success with GaN on MCP :-

- **Details of handling during device construction**
- **Accomplish deposition over large areas**
- **Minimize effects on the MCP operation of in situ Cs activation?**
- **Need to optimize the GaN penetration of the MCP pore structure**
- **Difficulty in extending beyond ~400nm**