Development of Bialkali Transfer Photocathodes for Large Area Micro-Channel Plate Based Photo Detectors

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On behalf of LAPPD Collaboration

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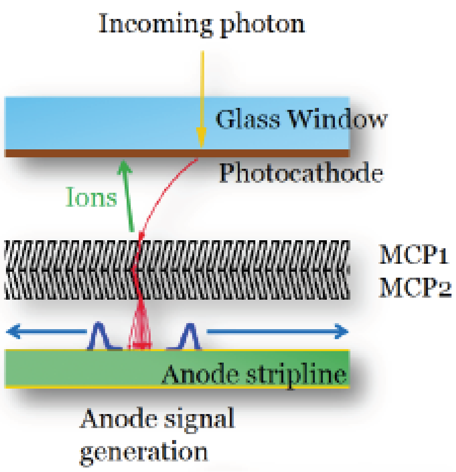
Outline

- Motivation
- Small PMT Photocathode Growth and Characterization
- Large Area Photocathode Growth and Characterization
- Summary
- Future Work

Motivation: LAPPD Approach

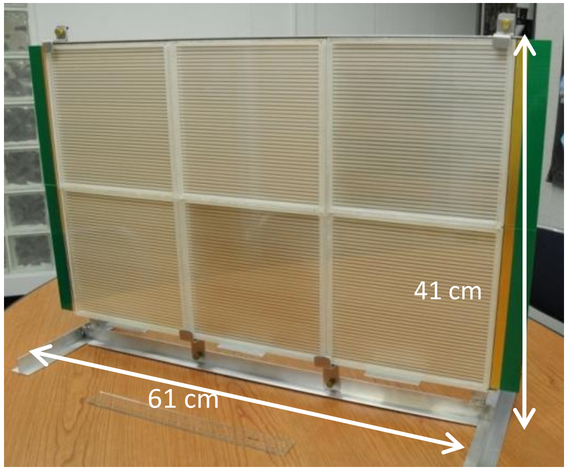


Based on existing Technology: Micro Channel Plate (MCP) photo-multiplier

New Aspect: reinvent the technology, exploiting advances in materials science and electronics, driven by science goals

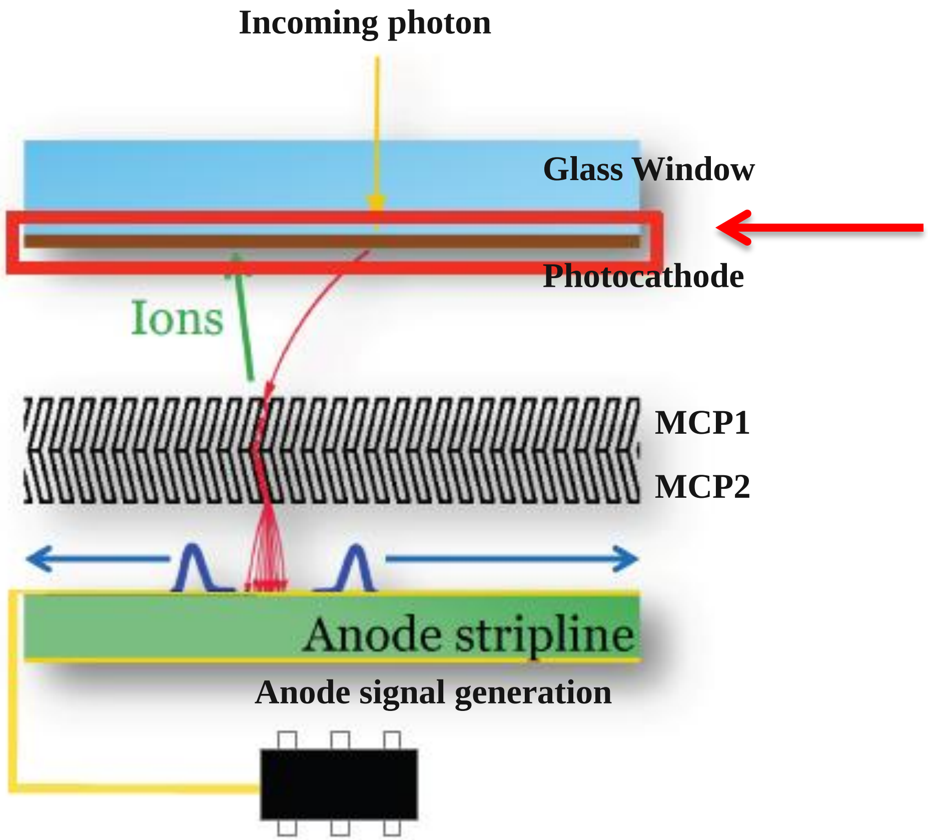
- Fully Integrated Approach
- Gain an order of magnitude in at least one performance characteristic

PMT



LAPPD

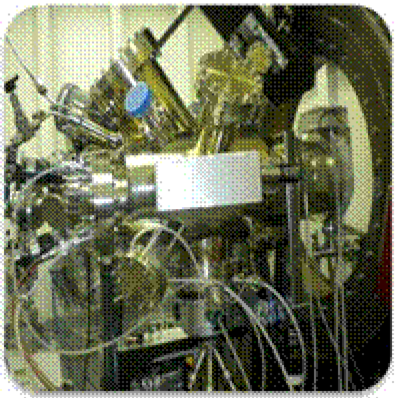
Motivation: Photocathode

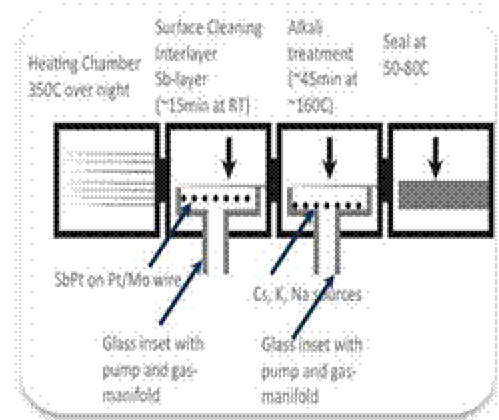


Photocathode:
Convertion of photons to electrons

Many fundamental detector properties such as dark current, quantum efficiency, response time, and lifetime are determined by the properties of the photocathode.

Resource: Infrastructure





Microscopic Property ⟷ Macroscopic Property → Industrial Fabrication

Basic Sciences Program

- Growth and Characterization Facility
- General Lab-Infrastructure
- User facility use
  - APS
  - NSLS
  - Nano center BNL/ANL

Large Area Development

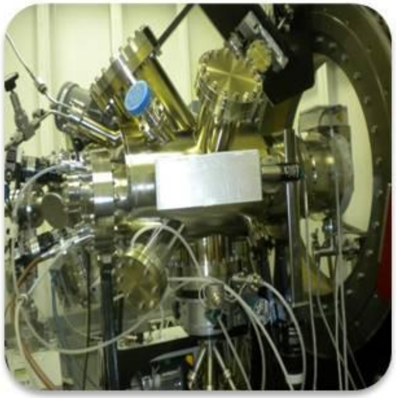
- Growth Equipment
- Source Development Infrastructure

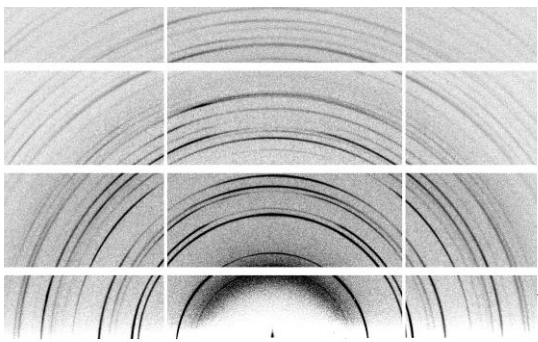
Production Unit (8"X8") (not yet existing)

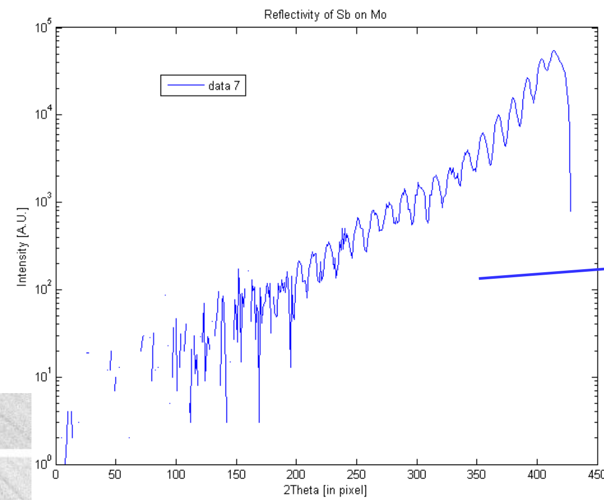
- Test Facility for Recipe optimization (industrial standard)
- Detector integration Facility

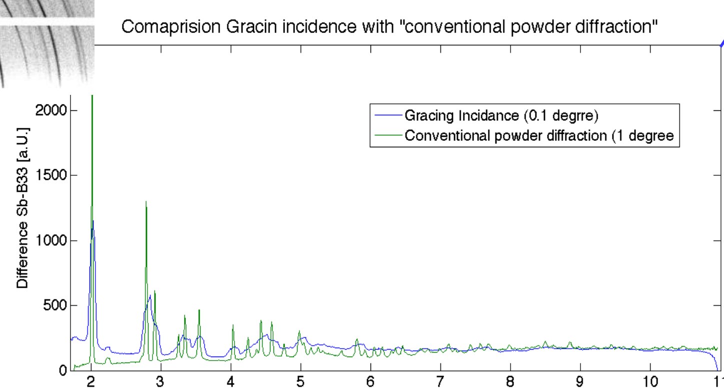
In-Situ Structural and Chemical Characterization

In-situ X-ray Scattering (by K. Attenkofer and S. Lee)









Movie like characterization during the growth:

- Macroscopic film properties
  - Film thickness
  - Roughness
- Microscopic composition
  - Which phases are present
  - Lateral and transversal and homogenuity
  - Crystalline size
  - Preferential crystal growth
- Surface composition
  - Local workfunction
  - Chemical composition

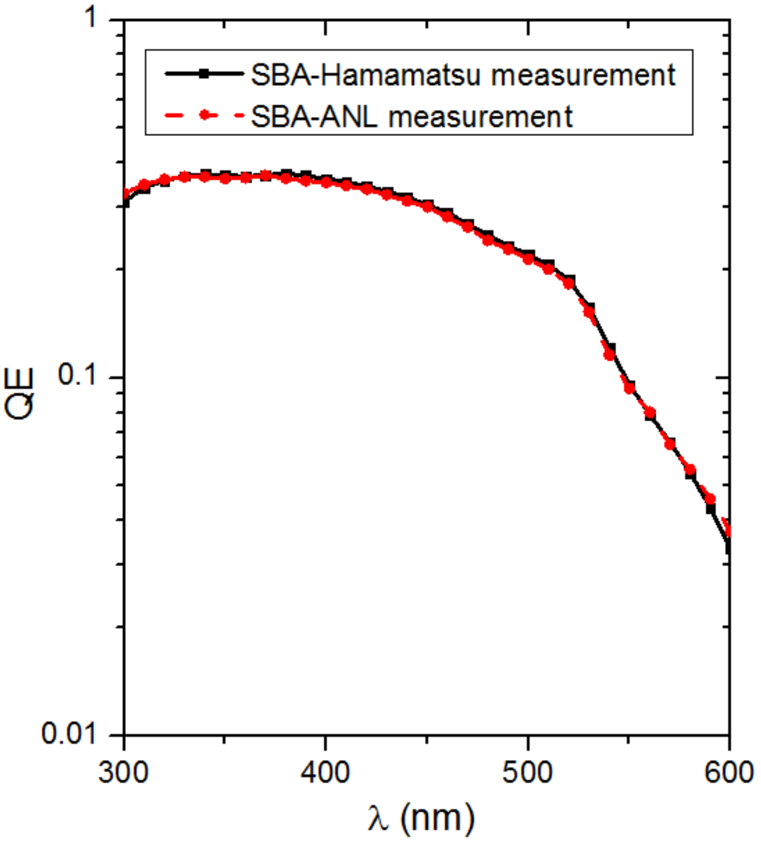
- ➢ An Sb phase transition was observed from amorphous to crystalline at 7~8 nm by XRD.
- ➢ In-situ Sb layer growth and K inter-diffusion process were monitored by real-time XRR.

Small PMT Photocathode Growth Process

- Oxygen discharge cleaning and oxidation;
- Sb deposition monitoring via reflectivity measurement;
- Bake out temperature, deposition temperature;
- Control of alkali metals deposition.

Apply these to the fabrication of large area photocathode.

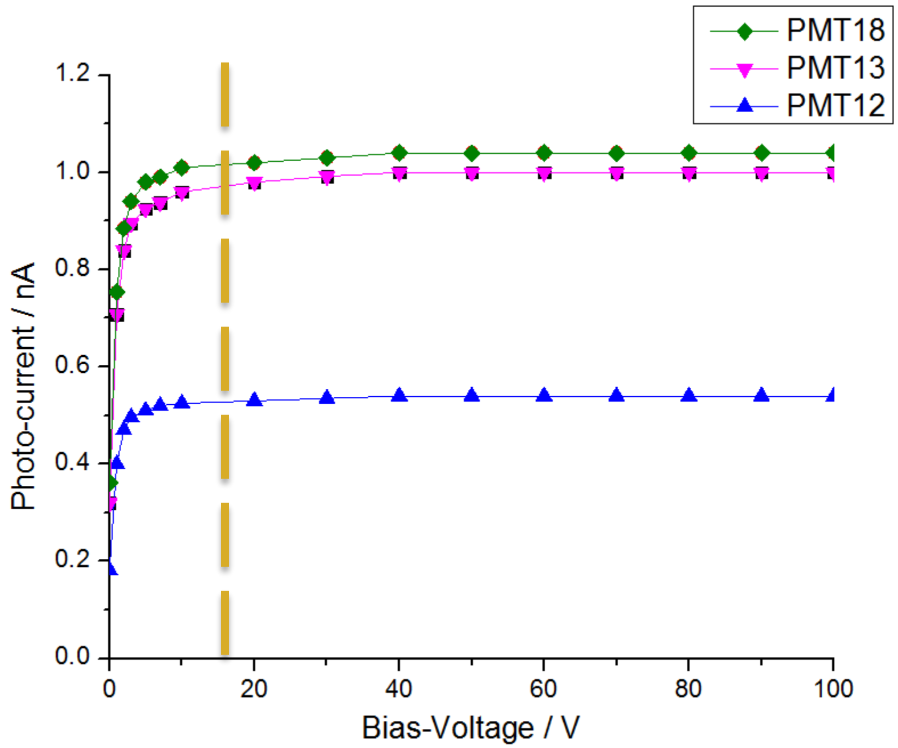
Commissioning of Optical Station



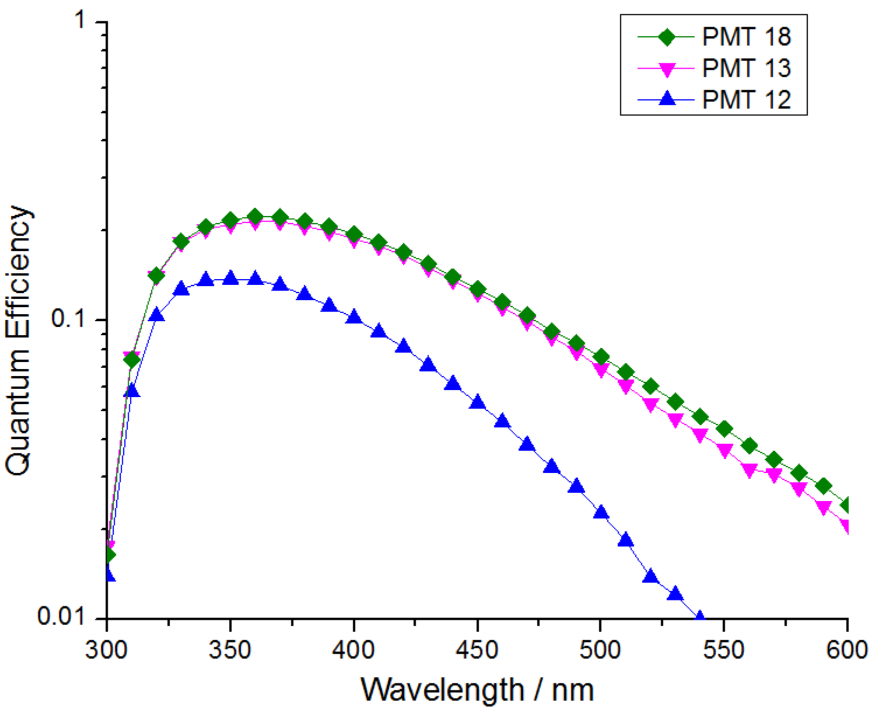
- Movable optical station can be used for both in situ and ex situ optical and electrical measurements.
- QE measurement by Hamamatsu and ANL optical station agree well with each other indicating the home-built optical station is reliable.

Small PMT Photocathode Characterization

I-V Characteristic

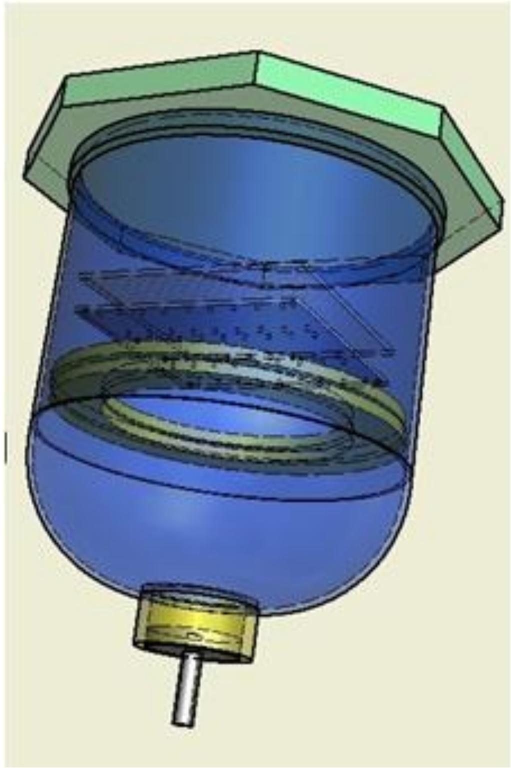


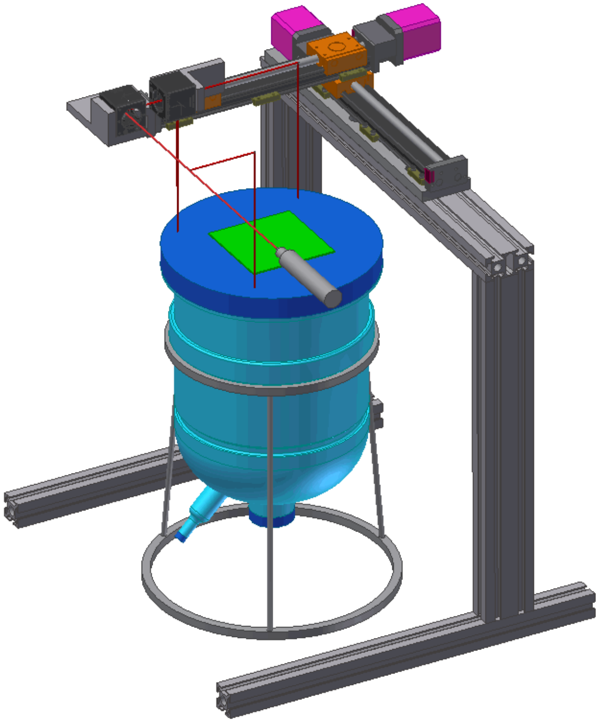
QE Measurement



- Cathodes exhibit characteristic I-V behavior, with QE as high as 24% at 370 nm.
- The quick drop at short wavelength is due to glass absorption.

The Chalice Design

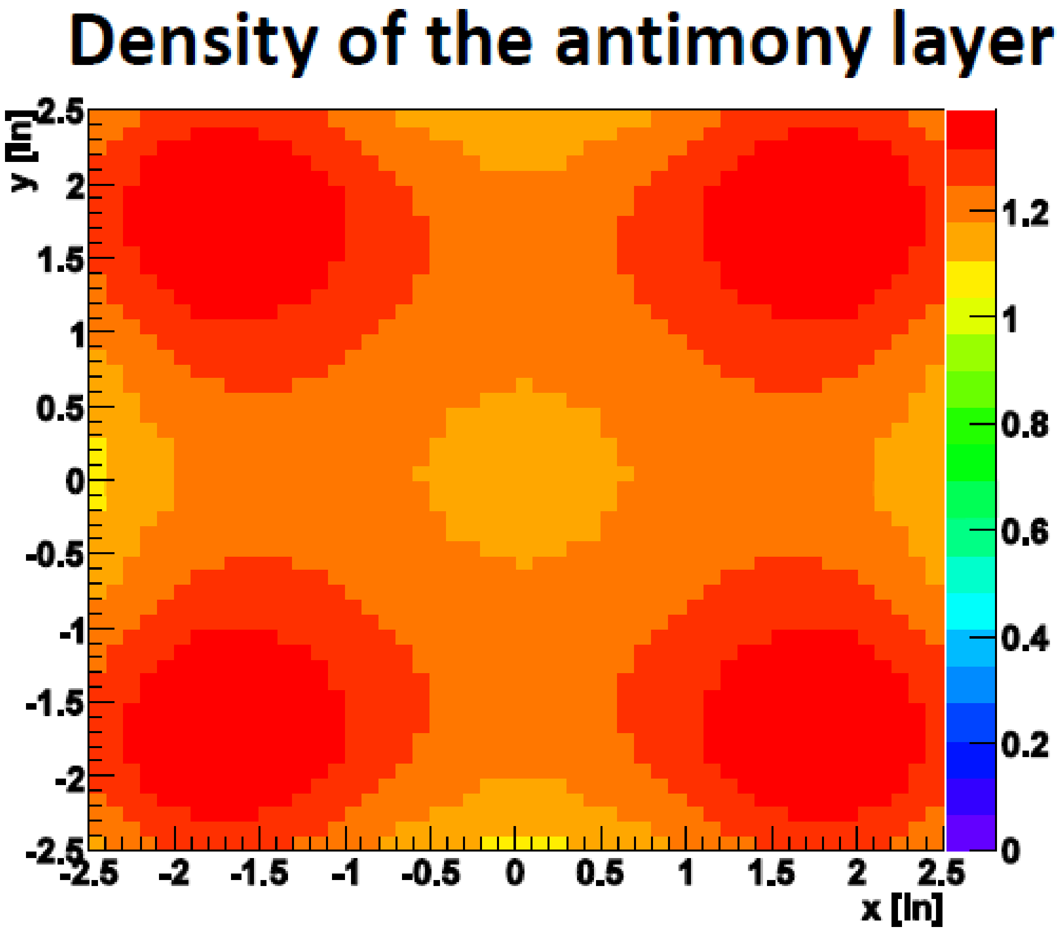




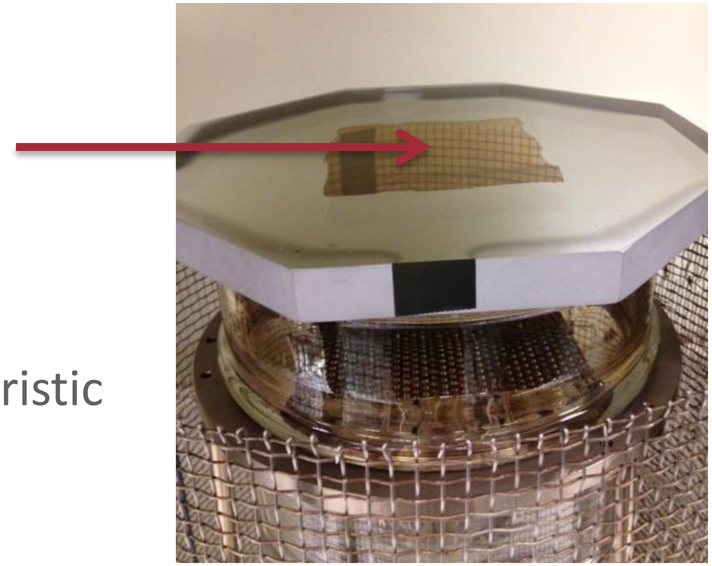
- Design is based on the small PMT tube, the chalice can be seen as a LARGE PMT tube.
- Top glass plate is replaceable for reuse.
- Chalice structure is supported by external legs.
- An X-Y scanner was designed and built for QE scan.

Sb Beads Arrangements for the Chalice

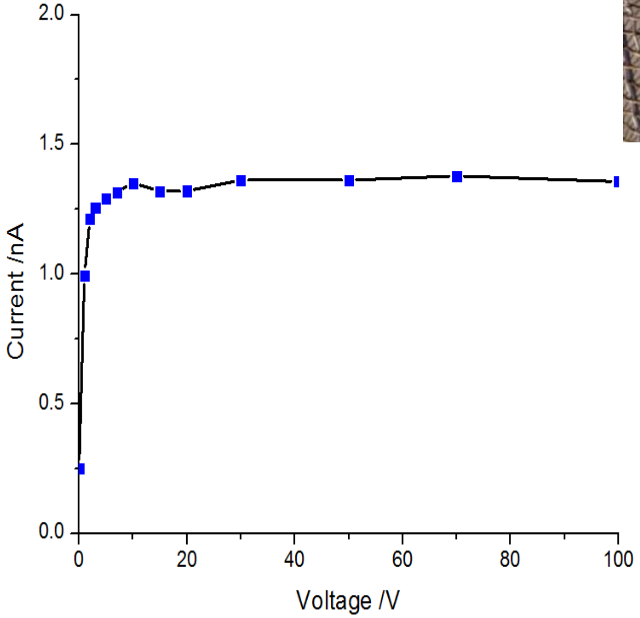
- Numerical simulation of Sb thickness as a function of Sb beads arrangements and distance from window;
- 4 Sb beads arrangement
- 2.5” distance from the window;
- This arrangement produces sufficient uniformity on a 4”x4” window as our starting point;
- This assumes all the beads perform identically.



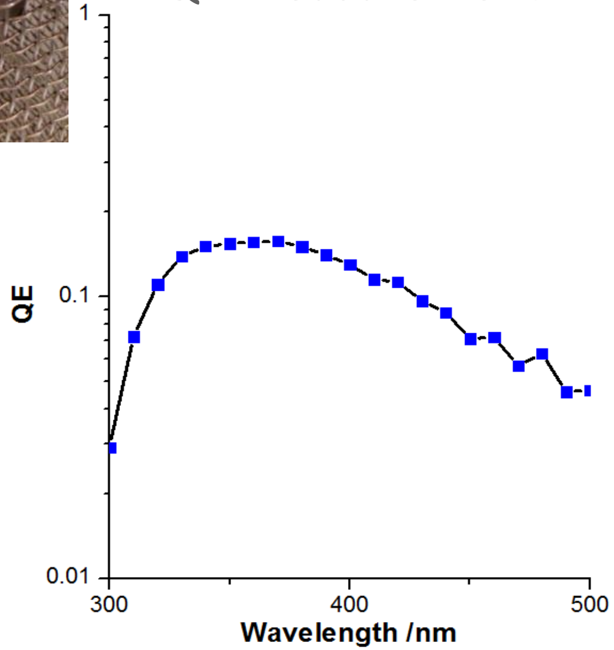
Chalice Photocathode Characterization



I-V Characteristic



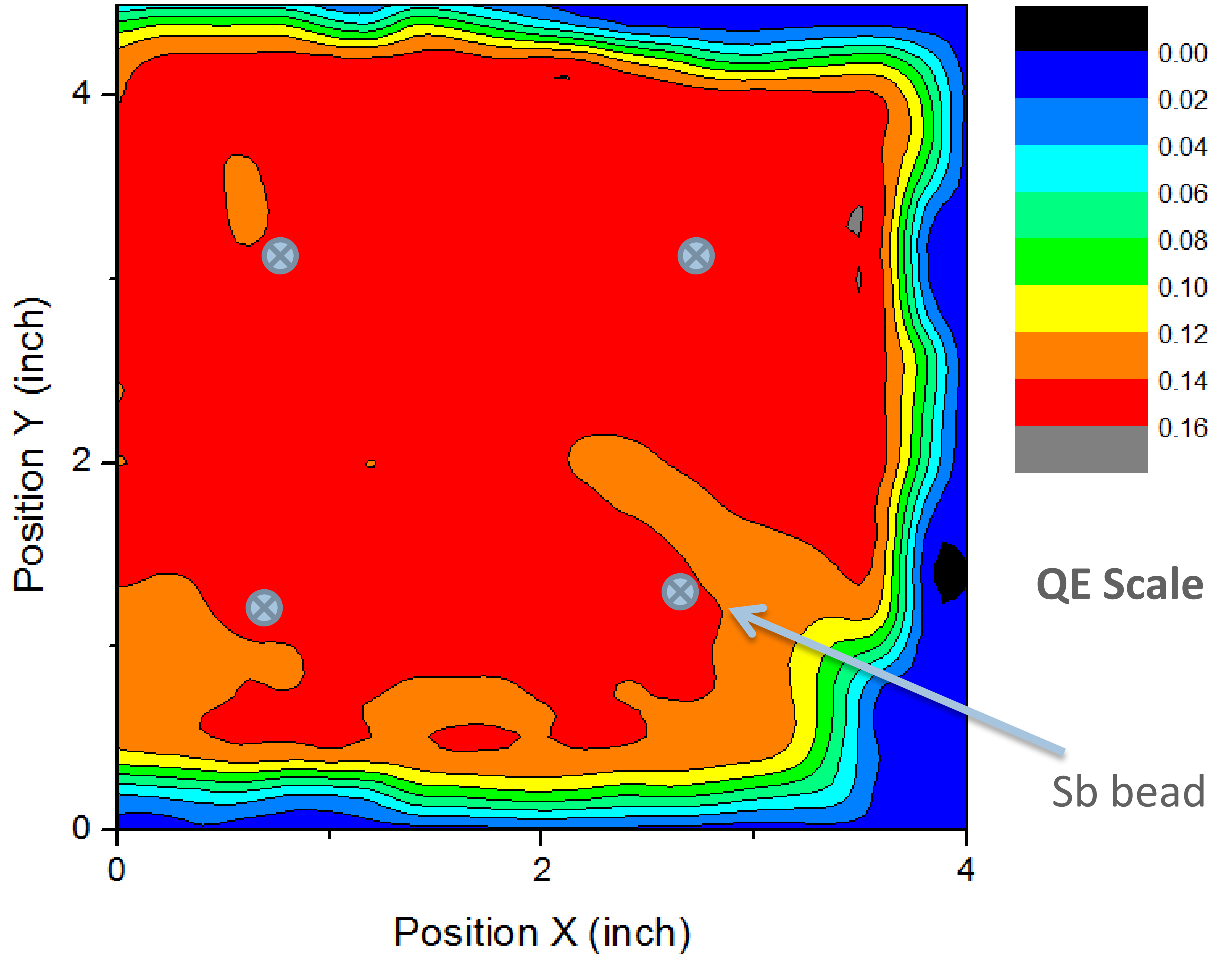
QE Measurement



- Plasma was not performed properly, due to low plasma power supply.

Chalice Photocathode Deposition

The QE mapping is obtained at 350 nm wavelength, scan step size: 0.2 inch

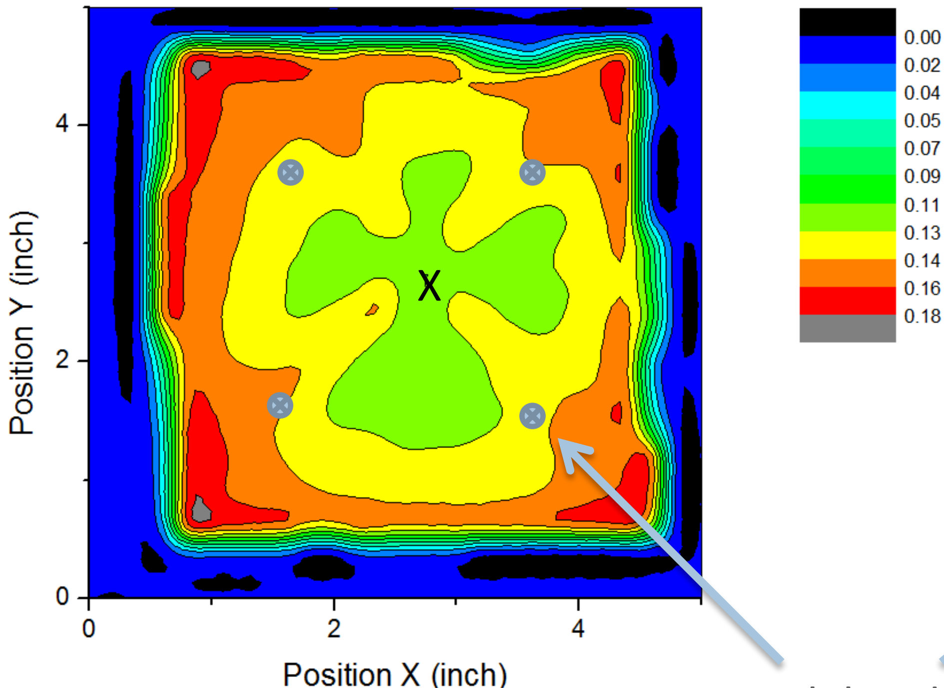


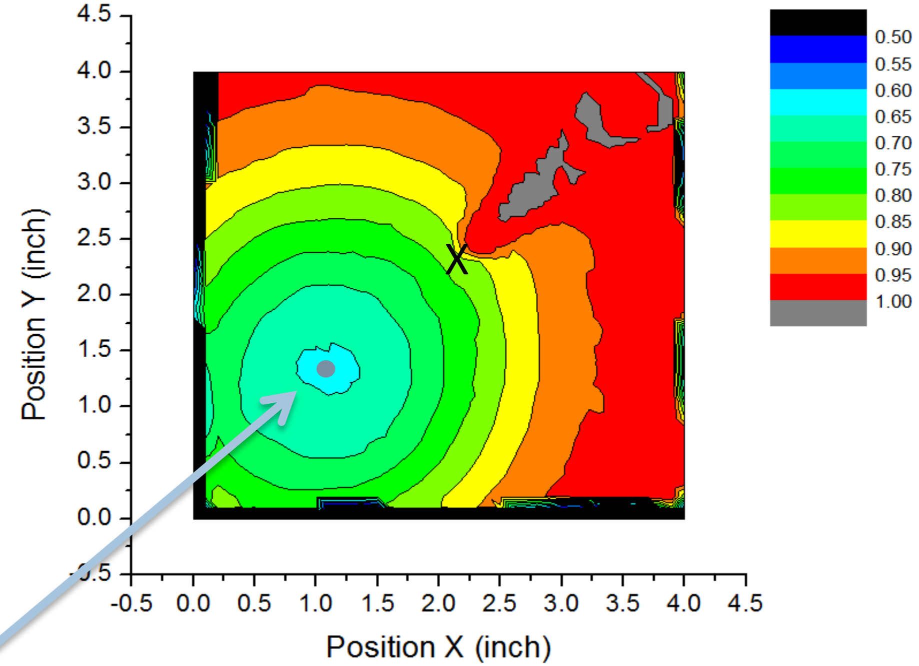
- The blue area is the 4''X4'' window edge.
- QE is uniform (15%) at a large area.

Comparison of QE Map and Sb Transmission Map

4 beads

1 bead





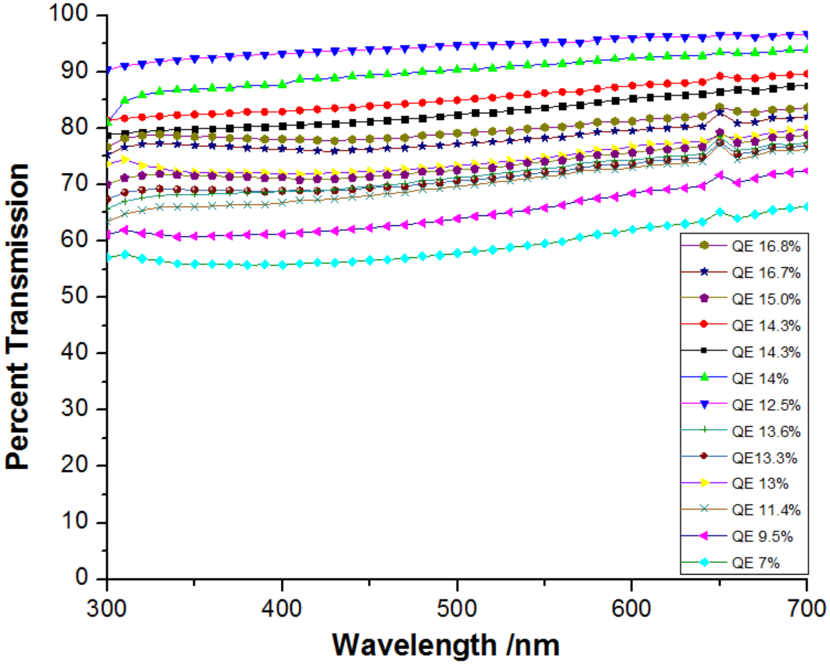
Sb bead

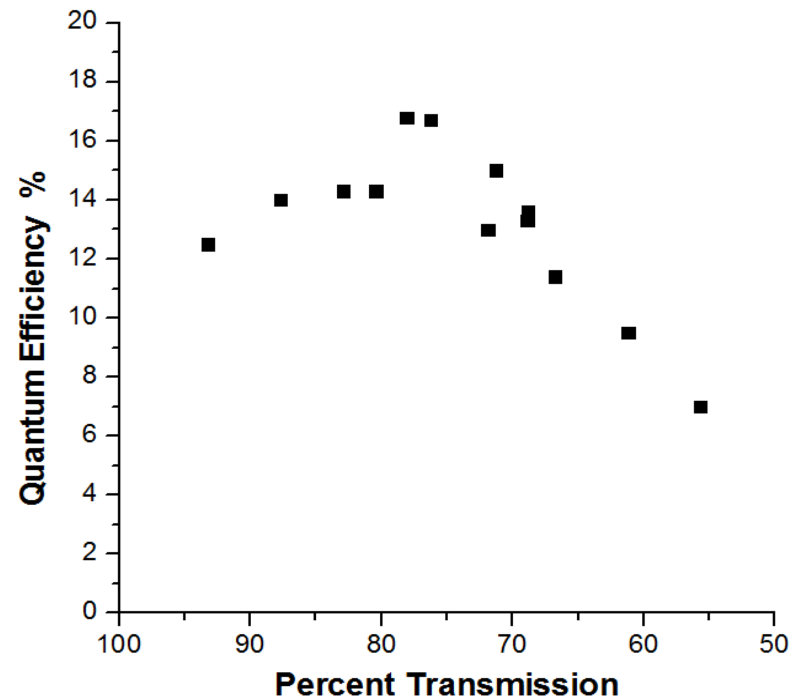
Center X: Lighting rod, which affect the Sb film deposition

QE Map

Sb Film Transmission Map

Sb Film Transmission Curve with Different Photocathode QE





- Film transmission with known QE were measured and plotted.
- Film transmission increases as wavelength increases without regarding the QE value
- The film transmission values at 400 nm were chosen to plot the relation between KCs-Sb cathode QE and film transmission.
- The highest QE is around 78% Sb transmission (400nm beam).

Summary

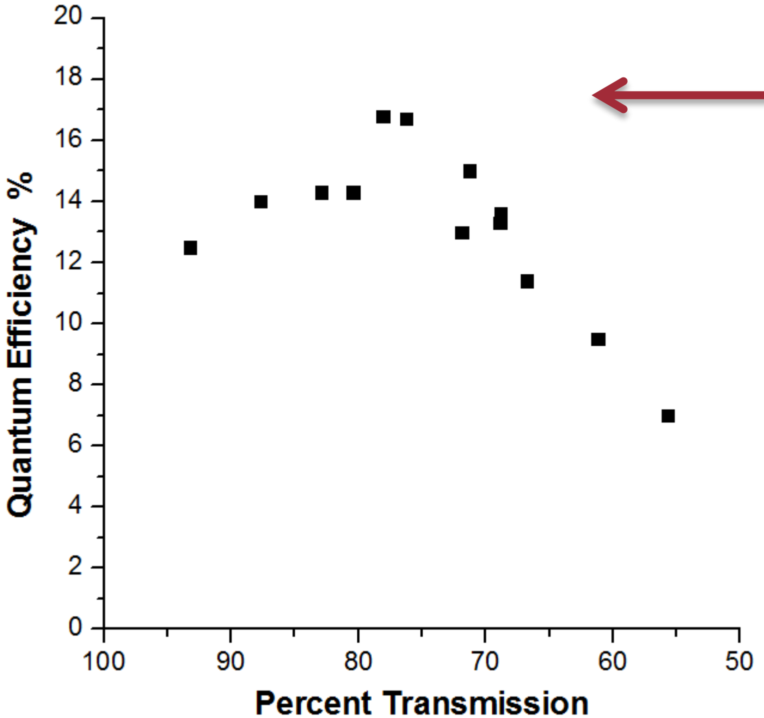
- Photocathode growth and characterization instruments were set up.
- PMT photocathodes with QE as high as 24% have been produced.
- Large area (4’’X4’’) photocathode with uniform QE (15%) were achieved even without proper oxygen plasma cleaning and oxidation.
- All photocathodes show typical I-V characteristics.
- QE of the photocathode is related to base Sb layer thickness.
- The optimized Sb thickness for KCs-Sb photocathode is around 78% transmission (400nm beam).

Next Steps

- Work out the plasma configuration to obtain uniform photocathode.
- Complete absolute reflection measurement of Sb films and relate to the film transmission data.
- Study the effect of plasma cleaning and oxidation to the photocathode QE.
- Optimize the process for higher QE cathode based on the micro and macro studies.

Back Up

Relation between Cathode QE and Sb Film Transmission



Relate the QE of the KCs-Sb cathodes with the Sb film transmission at 400 nm.

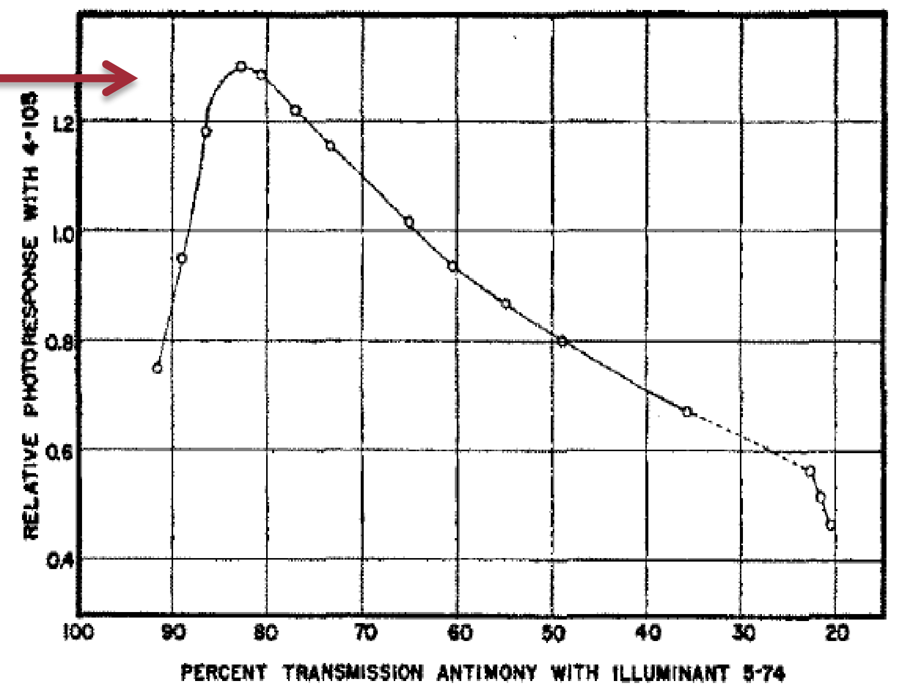


FIG. 5. Photoresponse in arbitrary units of Cs–Sb under reverse illumination *vs* transmission in percent of the original antimony

MARTIN ROME, *J. Appl. Phys*, **26**, 166, 1955

➢Note that the highest QE is around 78% Sb transmission (400nm beam), similar to that of Cs-Sb cathode at around 82% Sb transmission (blue light) as reported.