Bialkali Photocathode Development

Ossy Siegmund,

Experimental Astrophysics Group,

Space Sciences Laboratory,

U. California at Berkeley

Some LAPD Photocathode Milestones

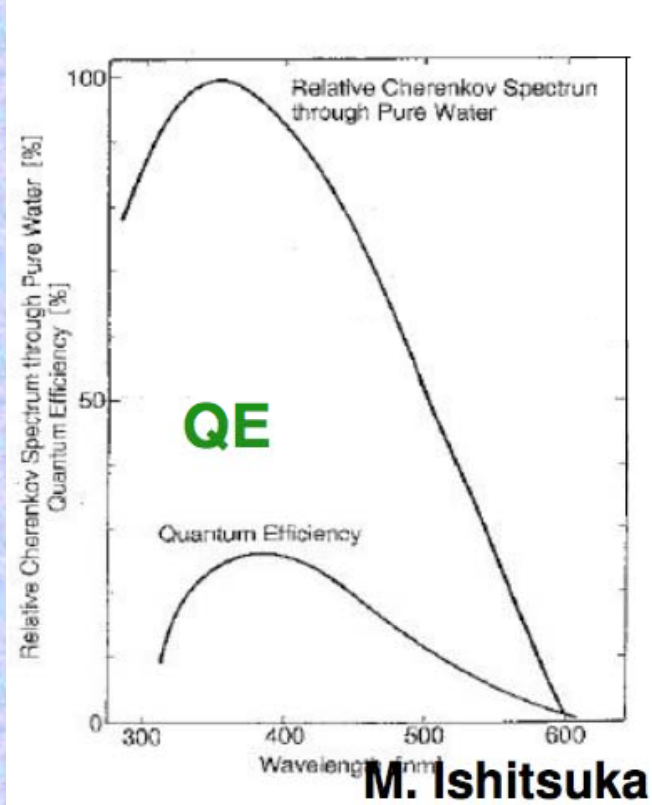
- Systematic characterization of Photo-electron Emission (PE) properties of materials for photocathode development.
- Demonstration of an operational 8”-square photo-cathode with a viable path to QE ≥ 15% for wavelengths between 300 and 450 nm.

Associated Milestones - Dependencies:-

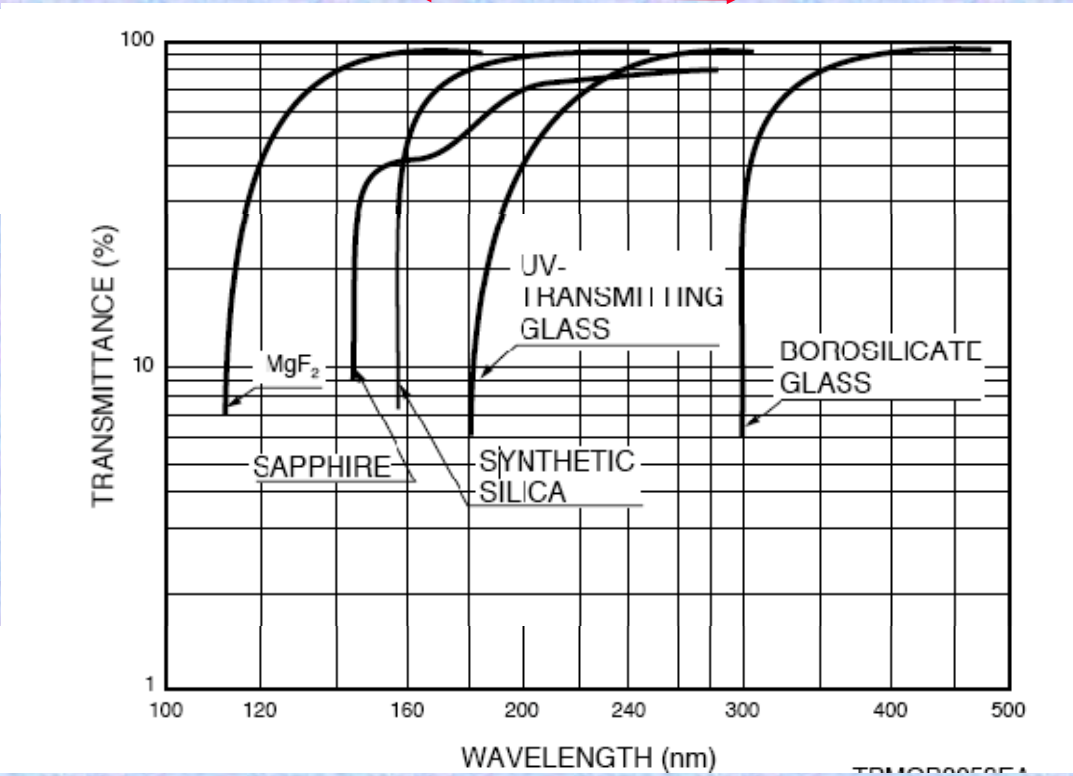
- Demonstration of the window-to-body seal solution.
- Design and costing of the vacuum-transfer/assembly facility for the 8”-square MCP module.

Cathode Bandpass and Windows

Acceptable cutoff range



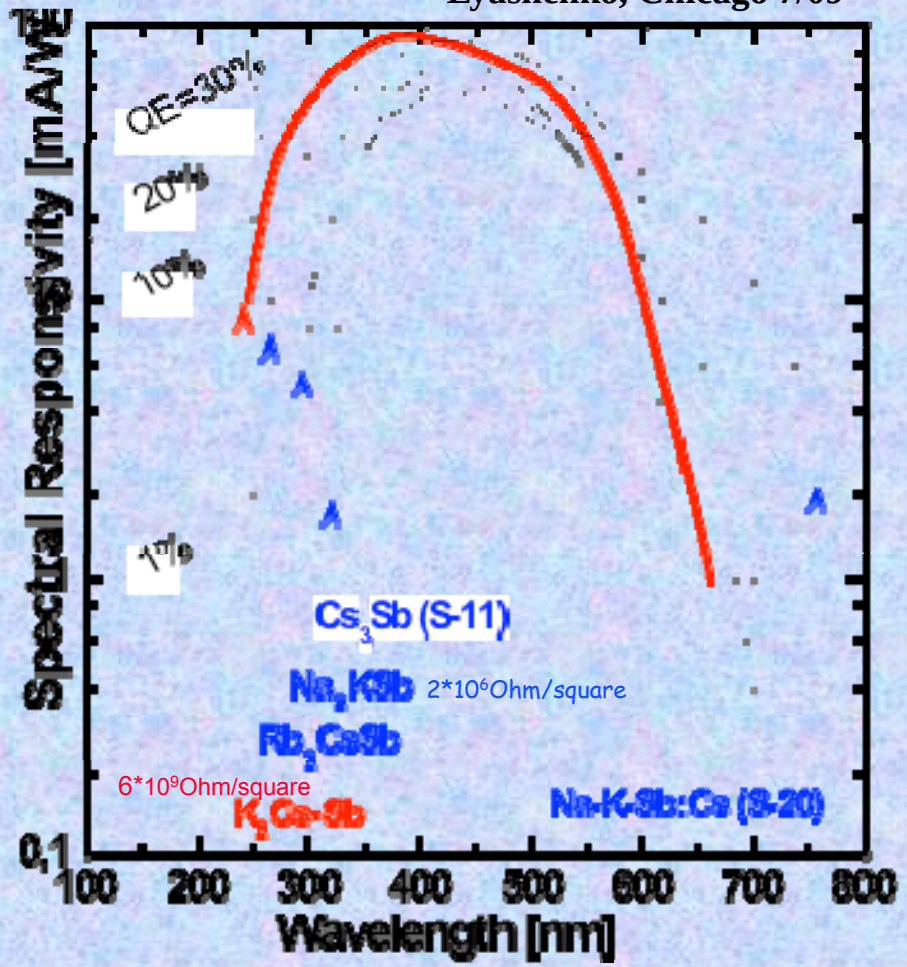
Nominal Cherenkov emission spectrum compared with bialkali



Typical window transmission curves

Bi-Alkali Cathode Characteristics

Lyashenko, Chicago 7/09

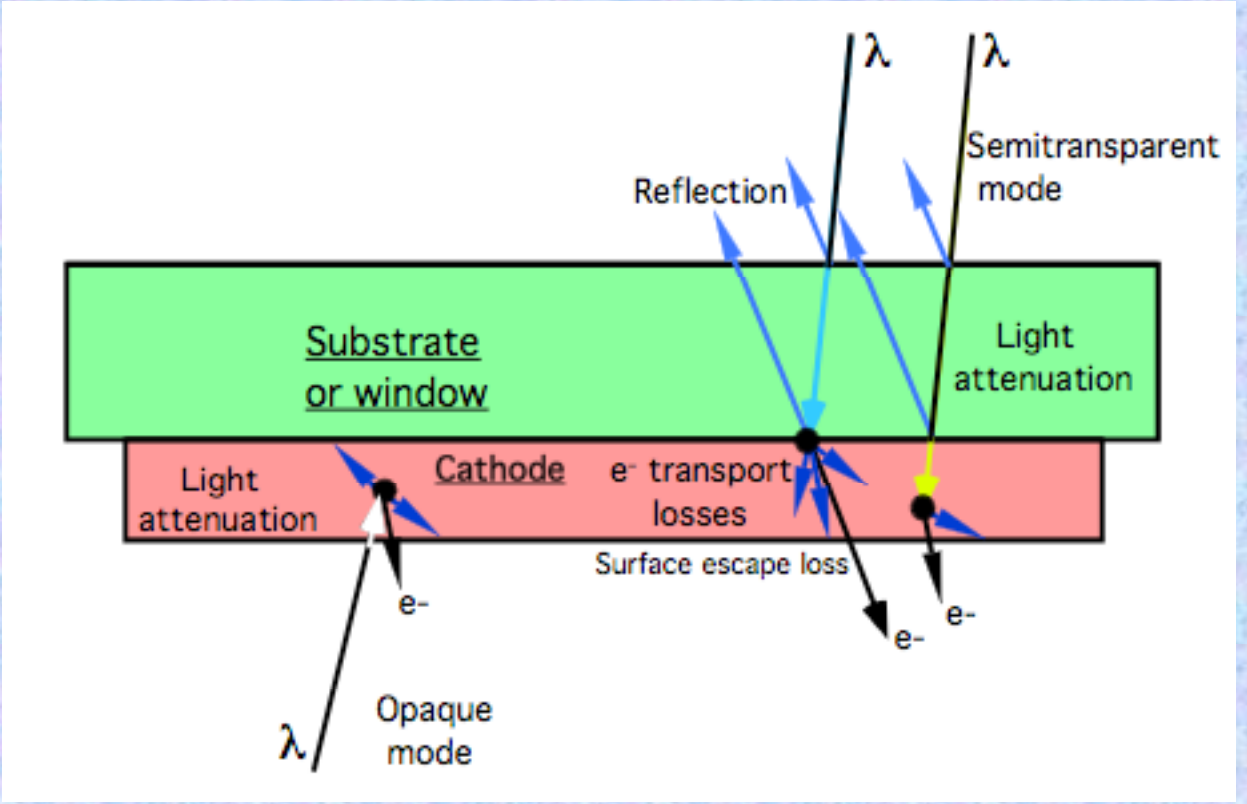


QE and resistivity for various bialkalis we will use K_2CsSb & Na_2KSb

Cathode Noise vs Temp expect 10,000 to 40,000 events/sec for 8" tube bialkali!

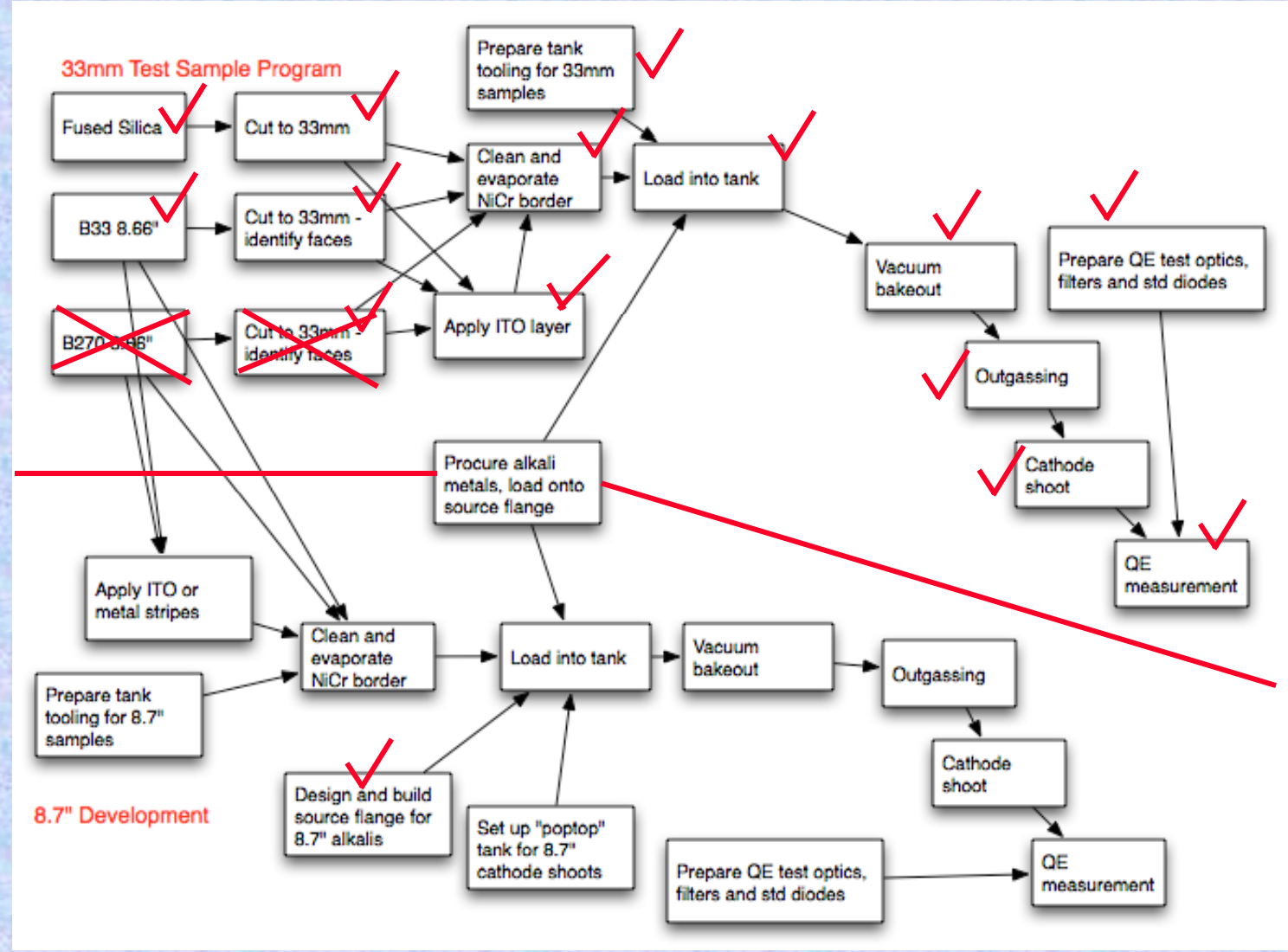
Bialkali Photocathode Configuration

Numerous processes affect the QE

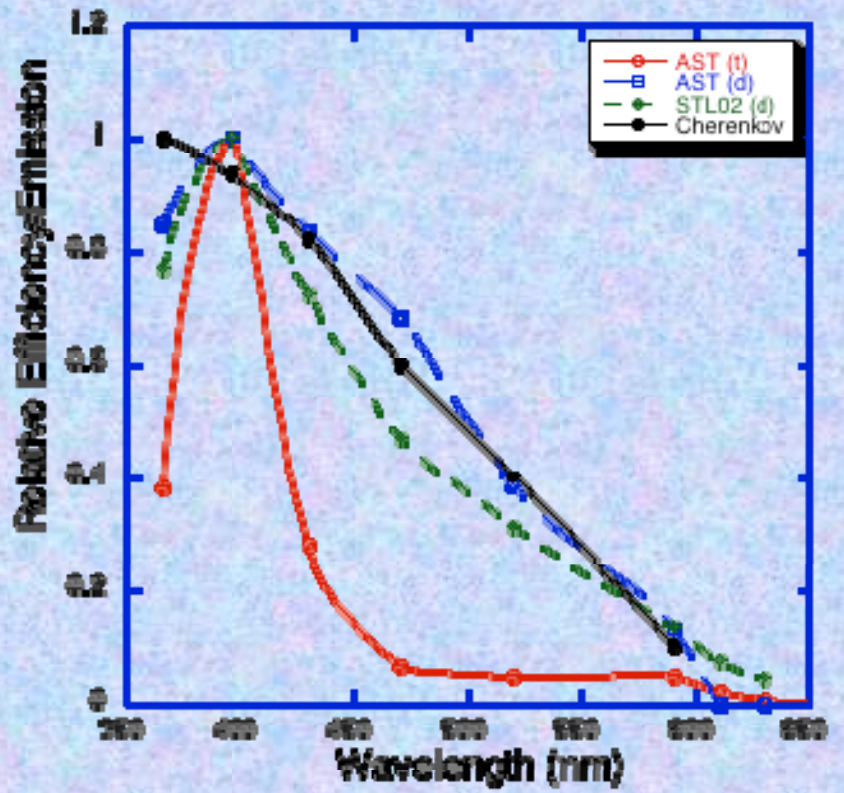


Bialkali is a few 100Å thick, and is nominally a deposition as a semitransparent layer on the window, with a proximity gap to the first MCP.

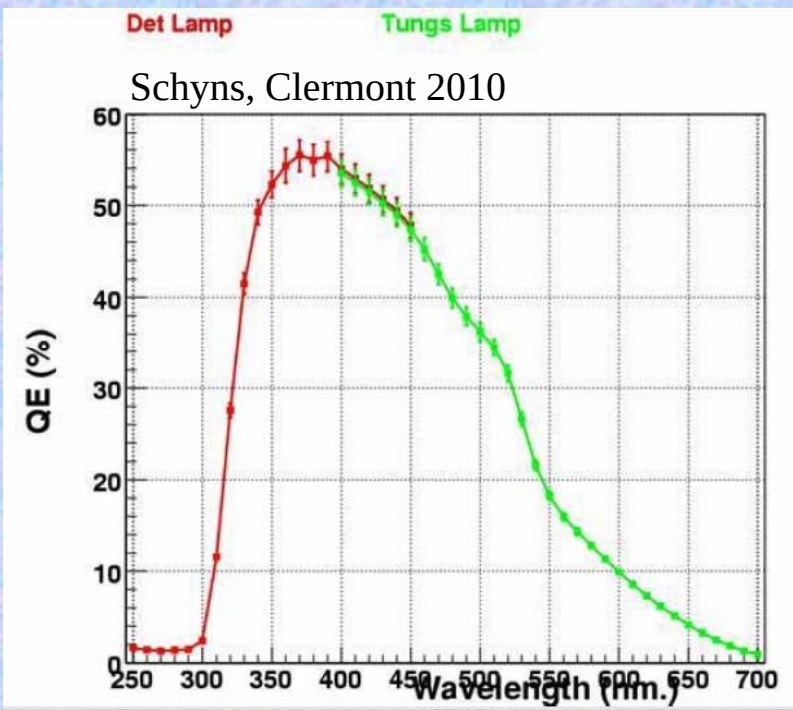
Work Flow Program for Bialkali Cathode Development



Bialkali Photocathode QE



Examples of SSL bialkali photocathode depositions with different wavelength optimizations (on fiber optics). Peak QEs 15% to 20% using Na_2KSb.

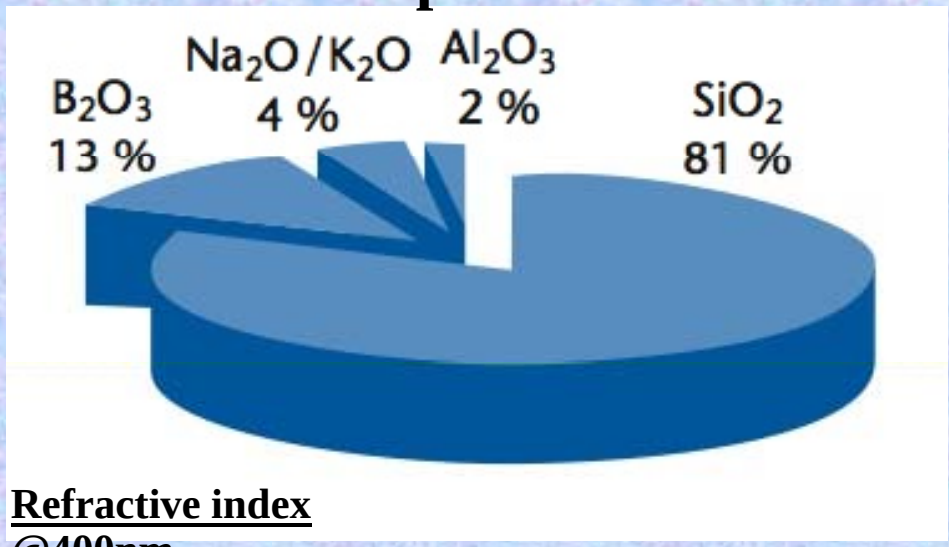


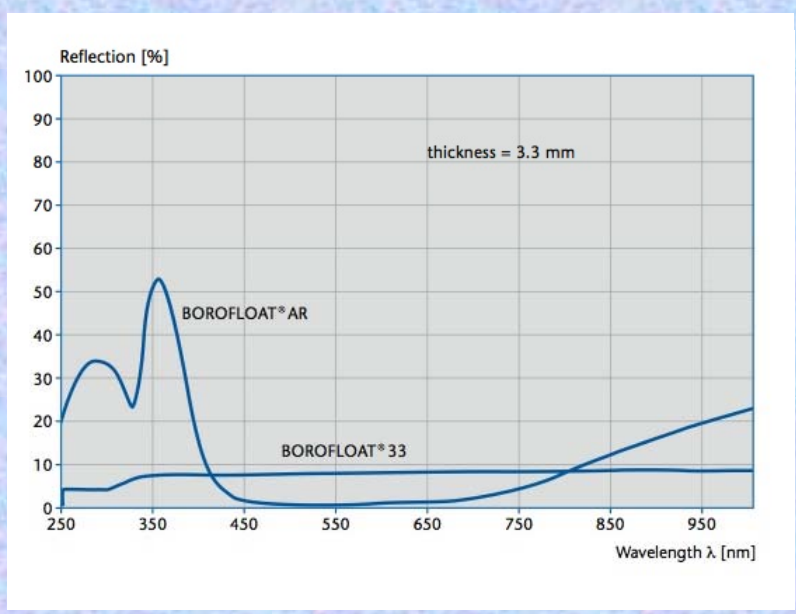
High efficiency Bialkali cathodes at Photonis. Clear room for improvement over standard bialkalis. BUT-Need to establish enhancement techniques and verify PMT - to – transfer cathode is possible.

B33 General Parameters

The cathode substrate, window or window coating, affects the photocathode performance. Quartz, fiber optics, 7056 glass are common. Borofloat B33 Borosilicate is not, and also has Tin diffused into one side from the float process, so we are testing this.

B33 Composition





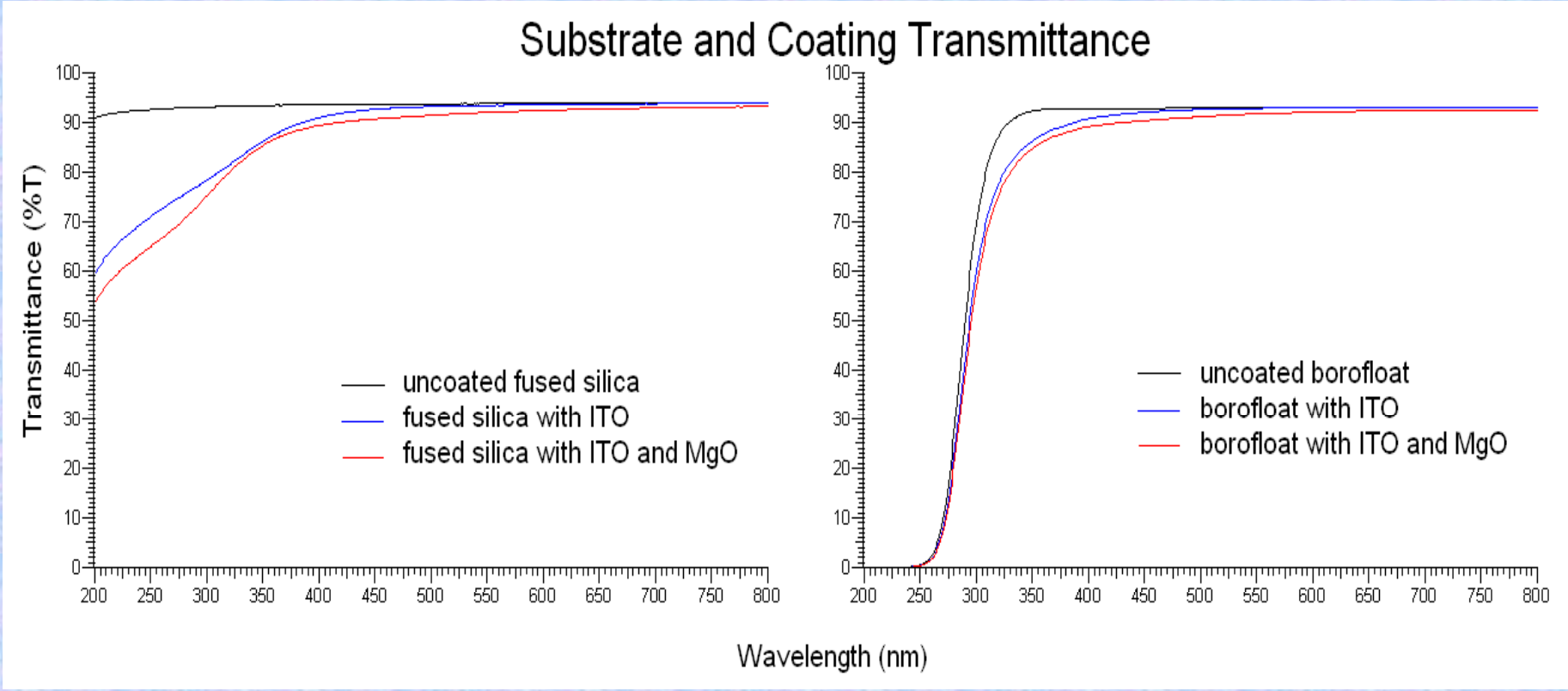
Refractive index
@400nm
B33 1.47
Air ~1.0
Water ~1.32

Standard AR coating is bad for LAPD - most likely don't need AR coating for water/B33 interface

Compatibility and Transmittance of Windows

Thermal **3.25 x 10^{-6}K**

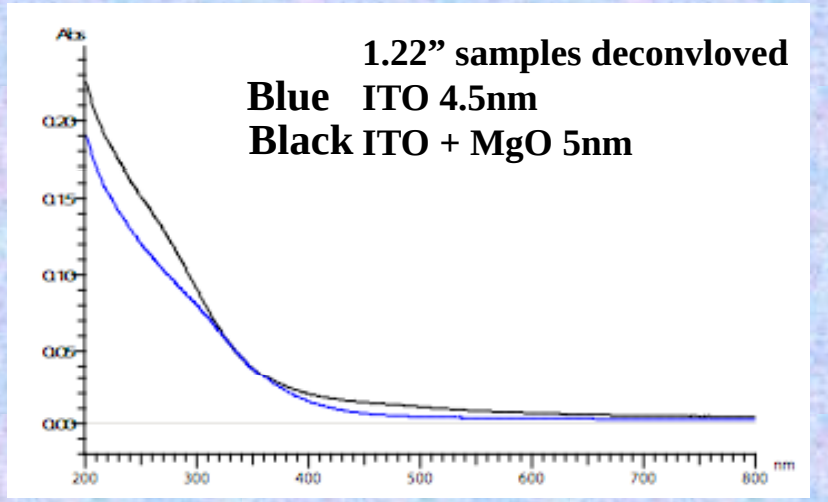
ITO and MgO layers ~ 5nm



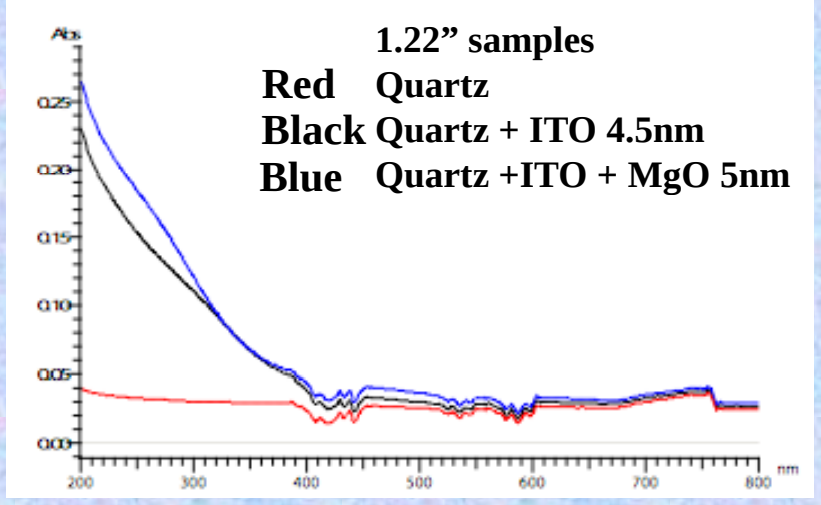
Samples coated by Joe Libera, measured by Lisa Pawlowicz

B33 Transmittance is typical for borosilicate glasses

ALD ITO/MgO Layer Properties for Windows

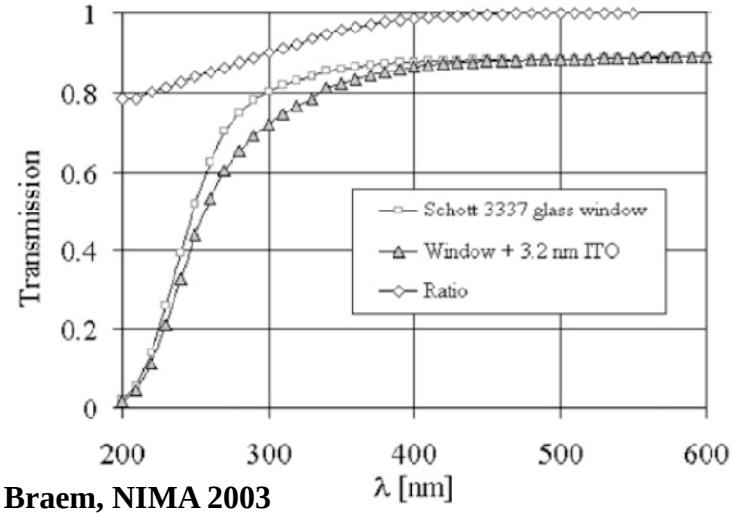


1.22" samples deconvloved
Blue ITO 4.5nm
Black ITO + MgO 5nm



1.22" samples
Red Quartz
Black Quartz + ITO 4.5nm
Blue Quartz +ITO + MgO 5nm

Samples coated by Joe Libera, measured by Lisa Pawlowicz



Braem, NIMA 2003

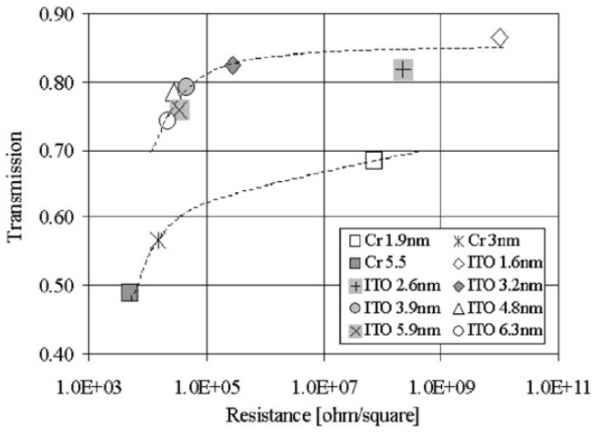


Fig. 4. Measured surface resistance versus average transmission (200–400 nm) of ITO and Cr thin films of various thickness on quartz substrates.

Our resistance measurements give about 10^4 to 10^5 Ohms/sq, So very much comparable to CERN.

Bialkali Cathode Process Program

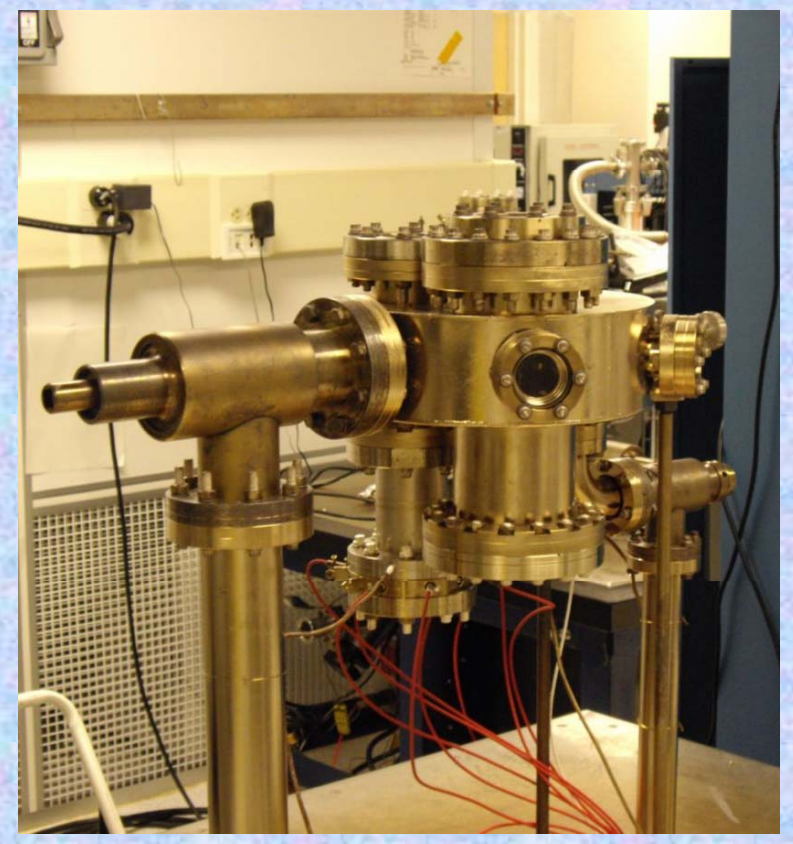
Small window cathode development, 1.22” samples

- **Process samples to optimize QE and bandpass**
  - **-Na_2KSb, K_2CsSb cathodes**
- **Use several substrate materials, SiO_2, verify B33**
- **Test MgO/ITO/conductor underlayer for cathodes**

Large size window cathode study, 8” windows.

- **Study source alkali design for large cathodes**
- **Develop techniques to make larger area uniform QE**
- **Optimize cathode QE levels**
- **Test metal/ITO conductor underlayer for cathodes**
- **Test metalization and sealing techniques**

Tube Lab, 1.2” sample test/process station.

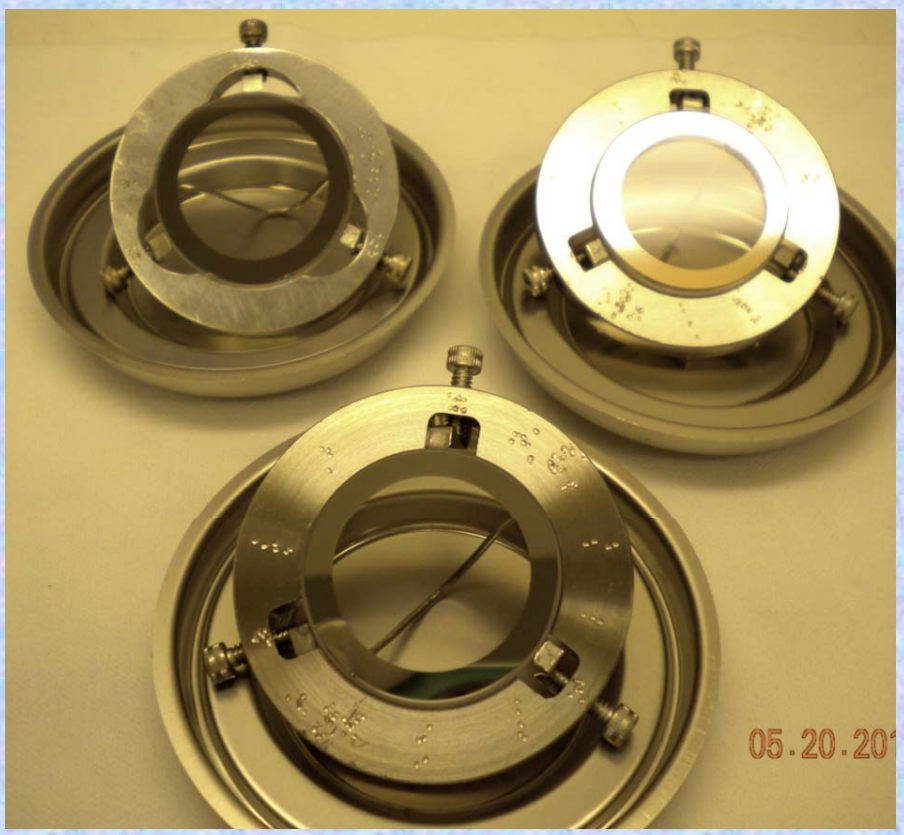


Small tank used to process alkali cathodes (33mm) and tubes of small area. Can take 4-8 samples/run. 3 runs done.

- **Small sample test runs**
- **Substrate material tests**

1.22” Cathode Test Samples

Old window holders



New window holders and mask

We have cut up one B33 window to make 30ea 1.22” test samples, also have 18ea fused silica as control samples. Inconel annular electrodes were evaporated just as they would be for In seals

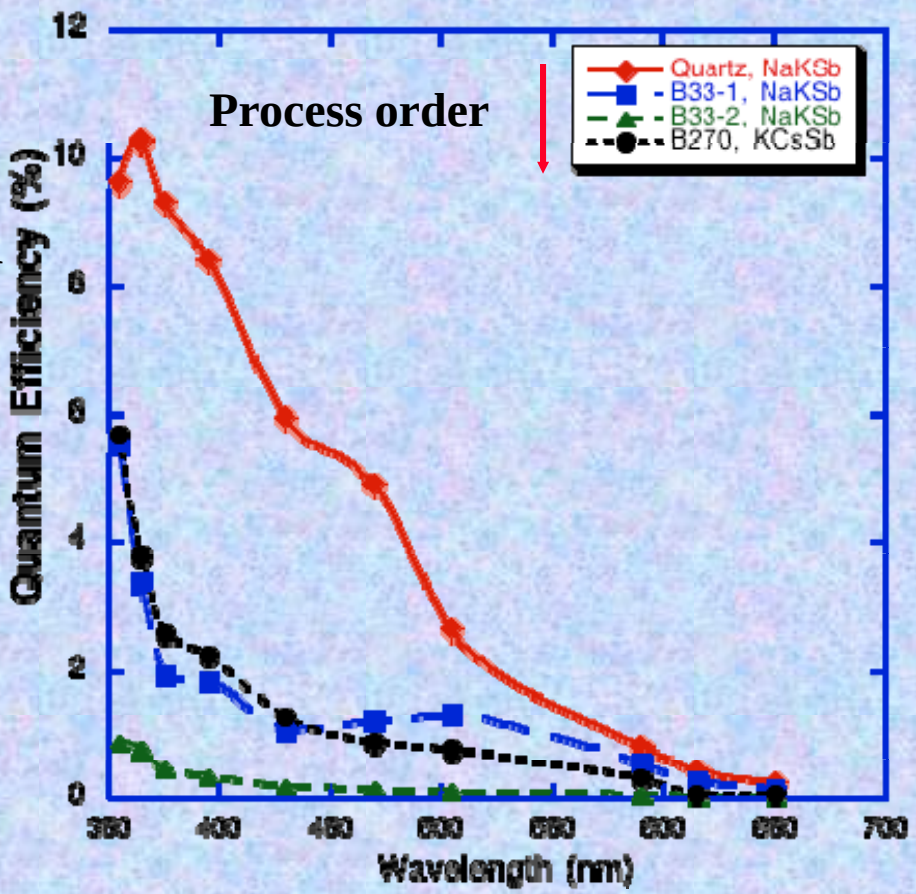
Initial Bialkali Trials on 1.2” Sample Substrates

Trying to set up process parameters for comparative tests and optimizations.

Used quartz, B33 and B270 sequential depositions in one pumpdown.

Short process / thin cathode
-ended up too blue / low QE.

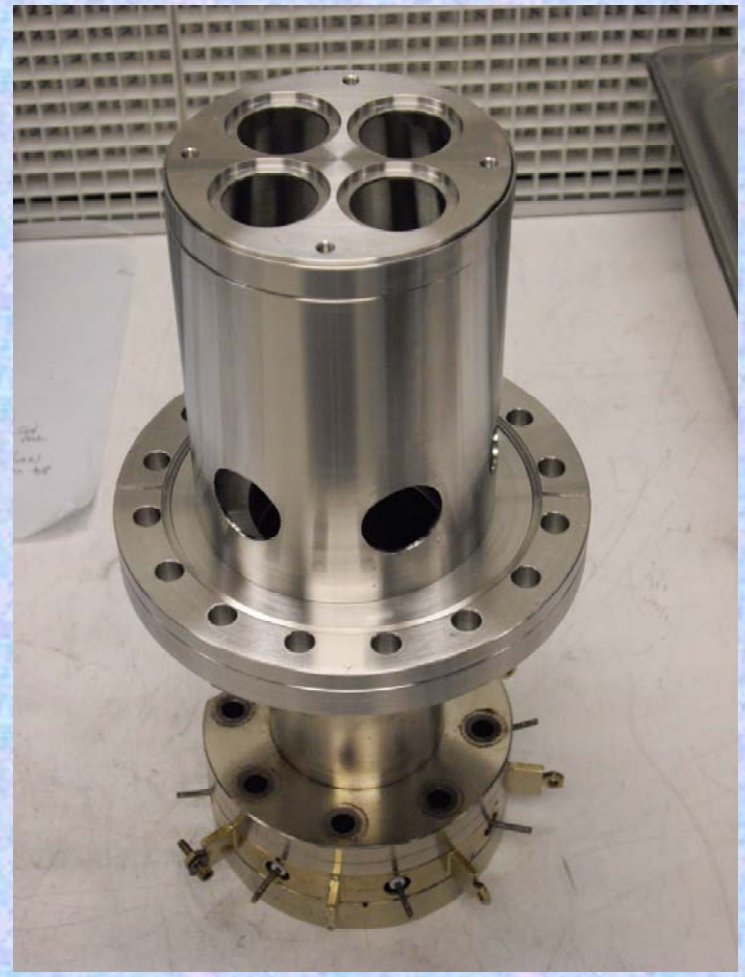
-Had problems with K channels that precluded optimal process, mostly on later depositions.



Initial cathode trials,

<u>Plan for next run</u>
-retool window holders
-shoot all substrates in one go at same time
-add extra cycles to push peak redder-higher QE

1.22” Substrate Sample test Bialkali Cathodes.



Small sample test runs, 1.22”

- **Substrate material tests**
  - **Fused silica and B33**
  - **ITO and MgO 5nm ALD layers**

Setup for 3rd run in small tank used to process Bialkali cathodes (1.22”). Can now deposit 4 simultaneous samples/1 cathode shoot.

Initial Bialkali Trials on 1.2” Sample Substrates

Setting up process parameters for comparative tests and optimizations, 3rd run.
Used quartz, B33 + coatings in simultaneous depositions in one pumpdown.
Short process / thin cathode, -ended up too blue / low QE.

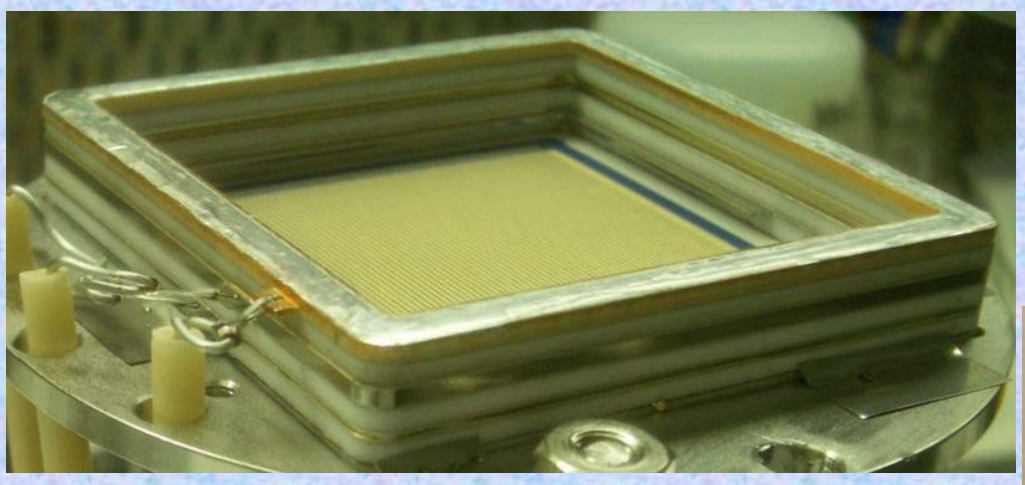
Shows that B33+ITO is good!

Plan for next run
-Add extra cycles to push peak redder-higher QE

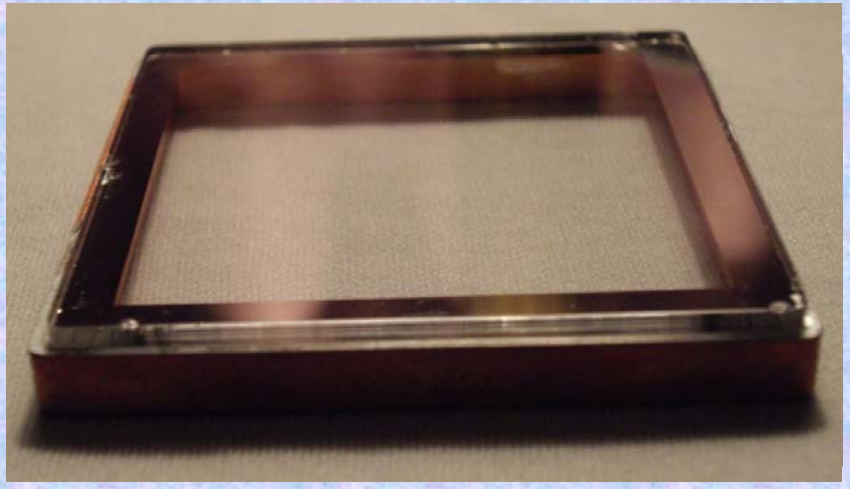
Cathode/Substrate Progress

- Wet cleaning of ITO / MgO ALD coatings is OK - once
- Oxygen plasma cleaning of ITO / MgO is NOT OK
- Proper pre cleaning of window substrates essential
  and includes precautions for handling, because
  initial samples were contaminated and had dust particles
- ITO 4.5nm has UV transmission and conductivity
  as predicted
- MgO 5nm UV transmission is good, but QE is not much
  different than bare quartz
- No problems with inconel evaporated borders
  good adhesion/conduction
- Next test run, 8 samples, mostly B33 to test the K_2CsSb
  cathode fabrication
- Then do B33 + ITO K_2CsSb

Window Seal Development and Cathode Test "Diodes"



3" ceramic body with strip anode, and metal frame with Indium seal



3" window test article on metal frame with Indium seal

Now ready to metalize 8.7"window and produce an Indium seal on a frame to test leak tightness of the seal.

8” Tube and Cathode Process Tank System

Large window cathode development, 8.66” square

- **Fully implement alkali source for large cathode areas**
- **Commission 8” cathode/window seal process tank**
- **Develop wet cleaning and plasma cleaning processes**
- **Commission large full tube process tank (Nov)**
- **Establish metalization tests**
- **Test metal/ITO conductor underlayer for 8” cathodes**
- **Develop techniques to make 8” area uniform QE**
- **Optimize cathode QE levels**
- **Trial seals on 8.66” “frames”**

- **Then**
- **Make LAPD 8” tubes**