Manufacturing and Packaging of Reliable Bialkali Photocathodes via Sputtering

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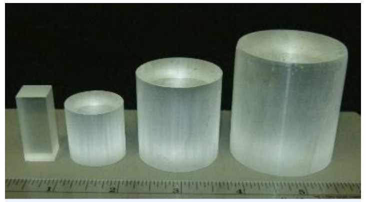
- **Dr. Jeffrey DeFazio**, Photonis USA Inc. (Collaborator)
- **Dr. Luca Cultrera**, Cornell University (Collaborator)

DOE SBIR Phase II Grant: DE-SC0017202

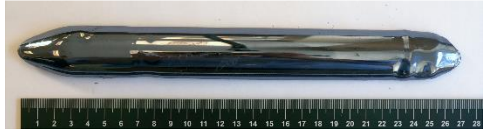
POP: 5/21/2018 – 5/20/2020

RMD Basic and Applied Research and Development

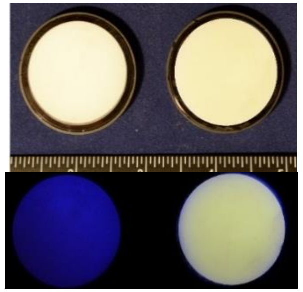
Materials Science



Scintillators

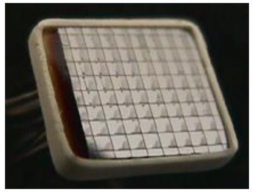


Semiconductors

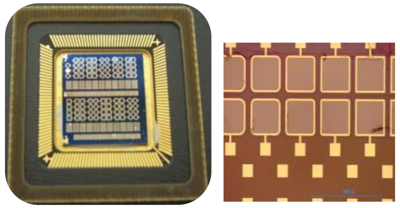


Imaging Screens

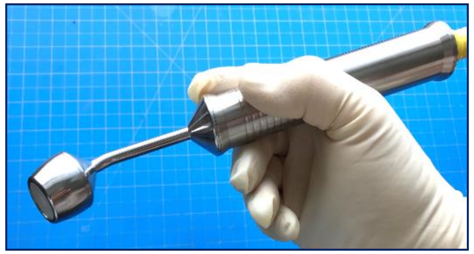
Sensors



APDs SSPMs
Photosensors

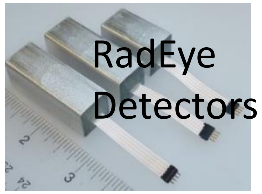


Wide Band Gap
Geiger Photodiodes



Surgical Beta-Probe

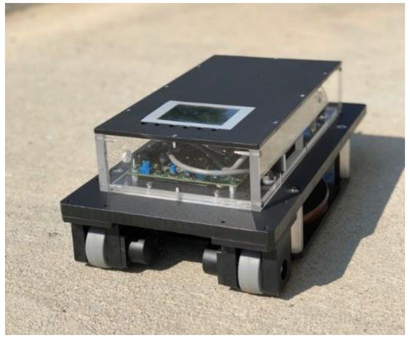
Instruments & Systems



RadEye
Detectors

HiRIS – High Resolution
Imaging System

Hermes G/n
w/ isotope ID



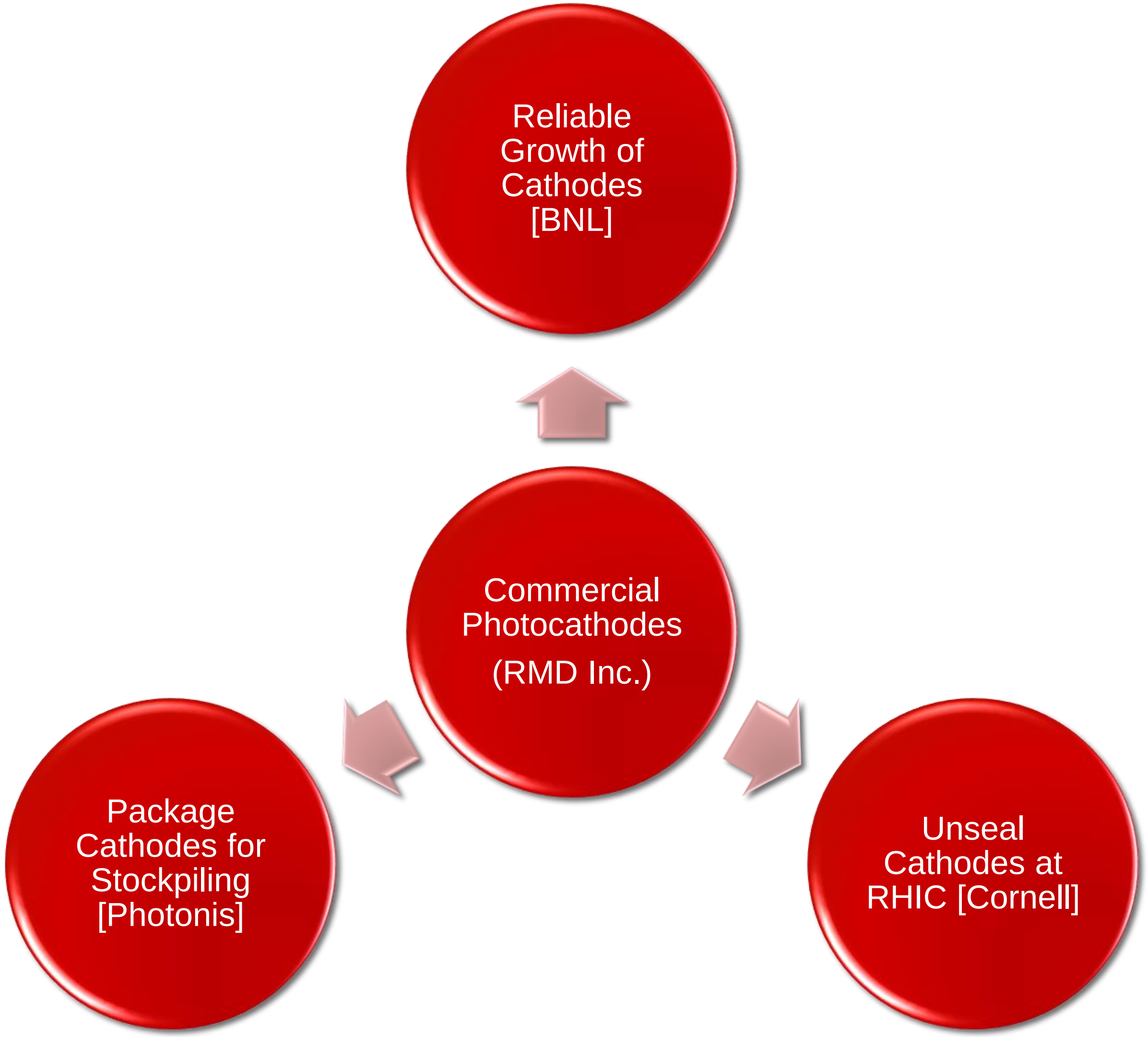
Robotic nuclear power
plant concrete
analyzer

Motivation

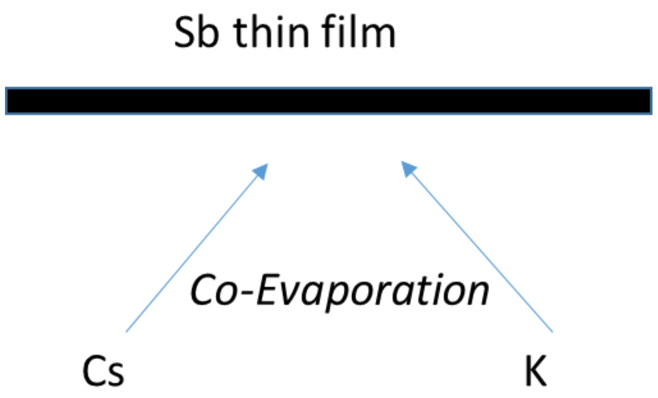
- Future upgrade for the Relativistic Heavy Ion Collider (RHIC) at BNL calls for electron cooling, where ultra-cold electron beams will be generated via photocathodes
- K_2CsSb bialkali photocathode has demonstrated the desired high average current (~50 mA) required for electron cooling operation at RHIC
- These bialkali cathodes will need to be replaced almost daily, based on their operating conditions

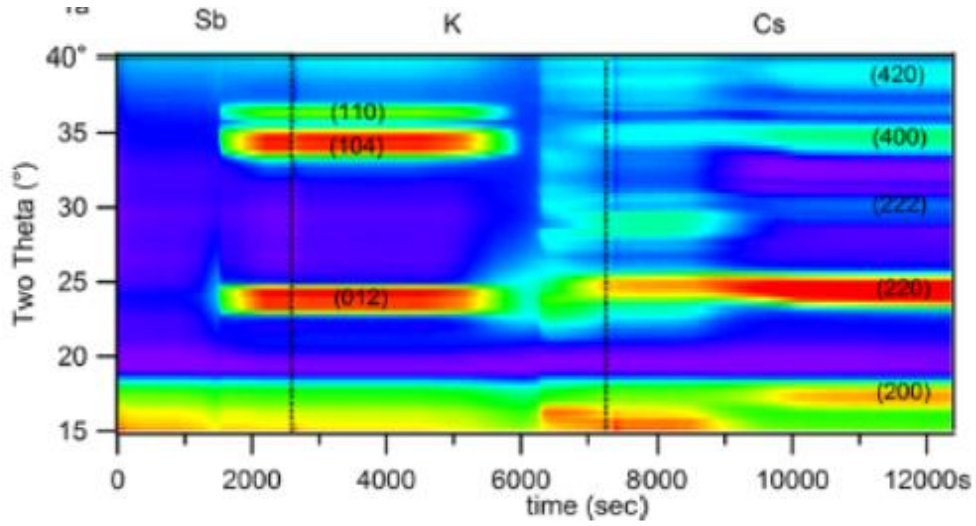
❖ *Hence, there is a need for commercially-available photocathodes that can be reliably produced and supplied in sufficient quantities.*

SBIR Technical Objective

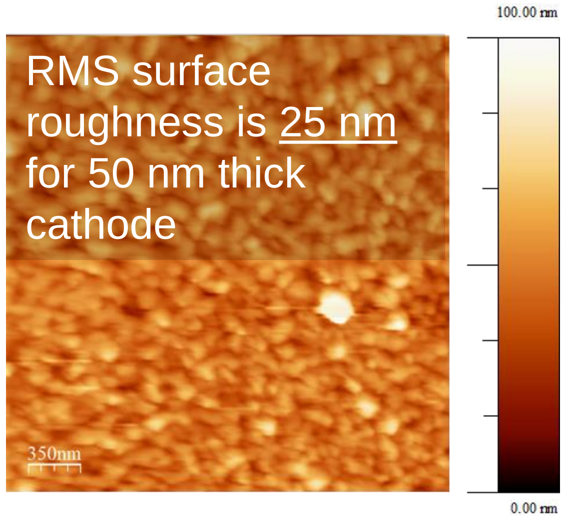


K_2CsSb Cathodes – Traditional Growth

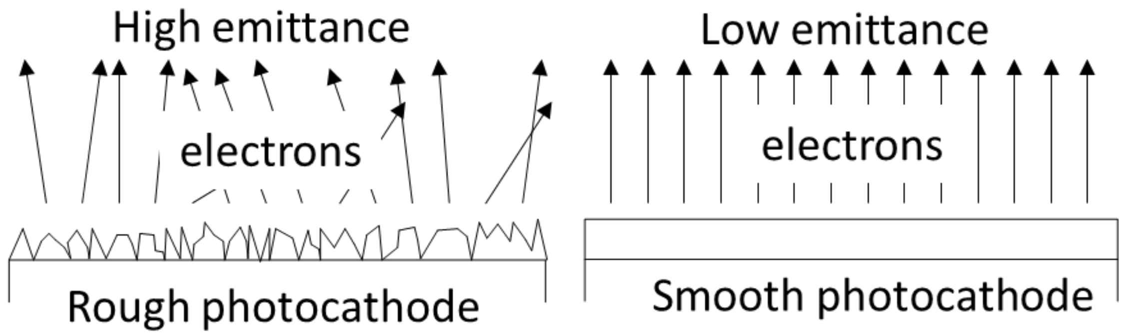




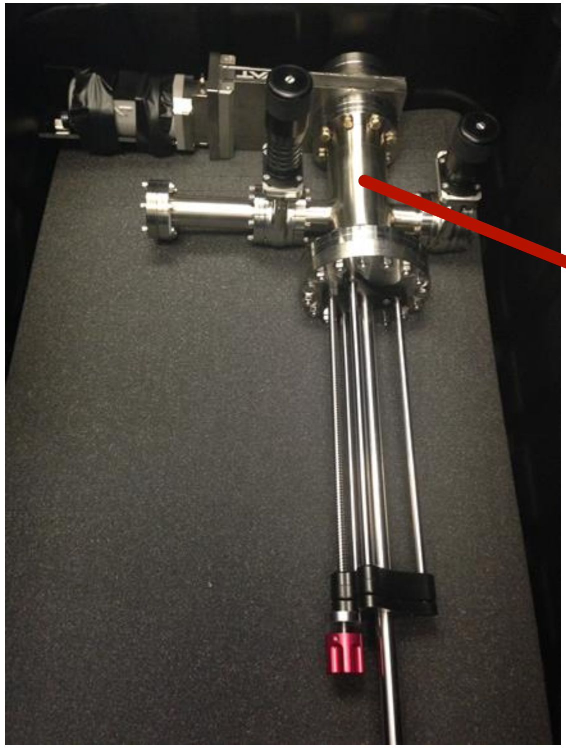
Ruiz-Osés et al., APL materials 2.12 (2014): 121101.



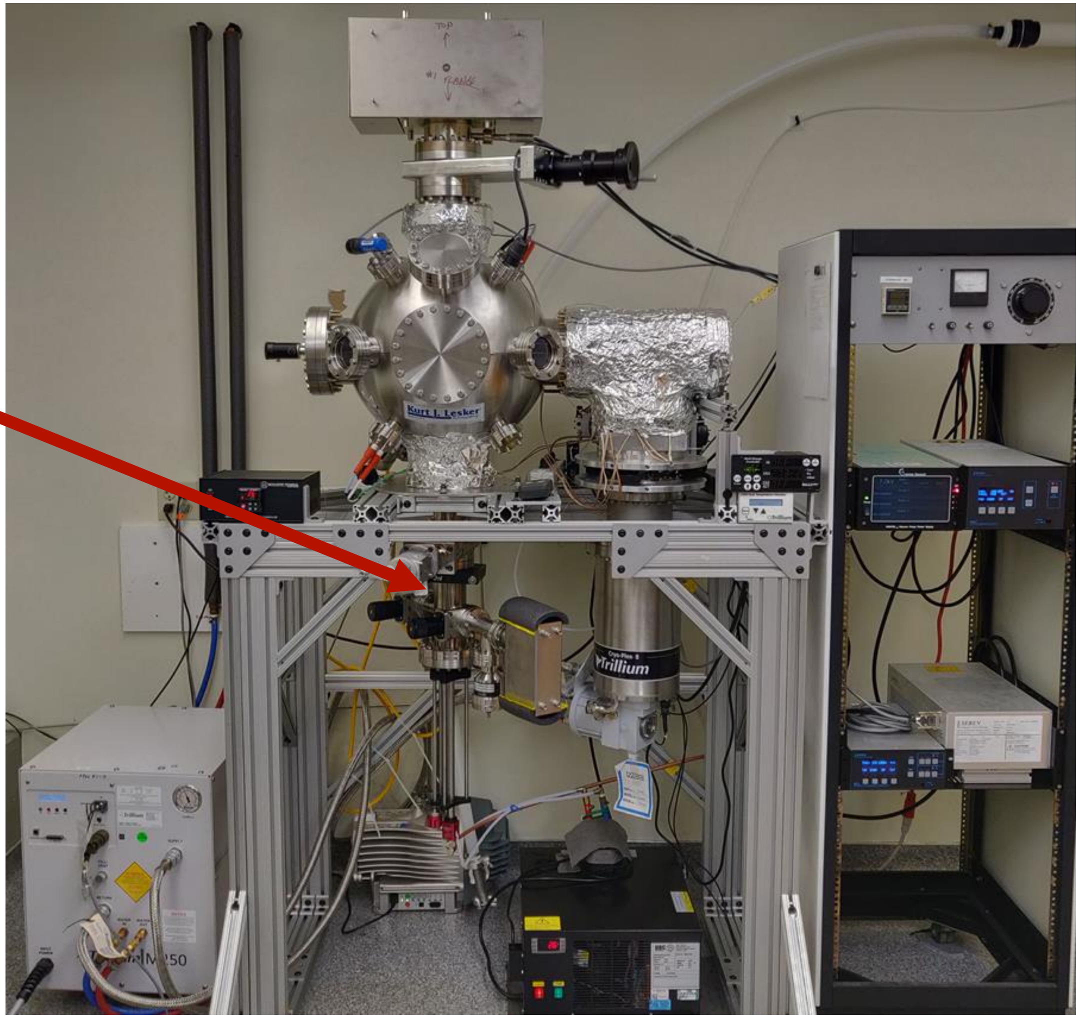
Schubert, S., et al. " APL Materials 1.3 (2013): 032119.



Sputtering – A Reliable Cathode Growth Process



Target in a vacuum suitcase

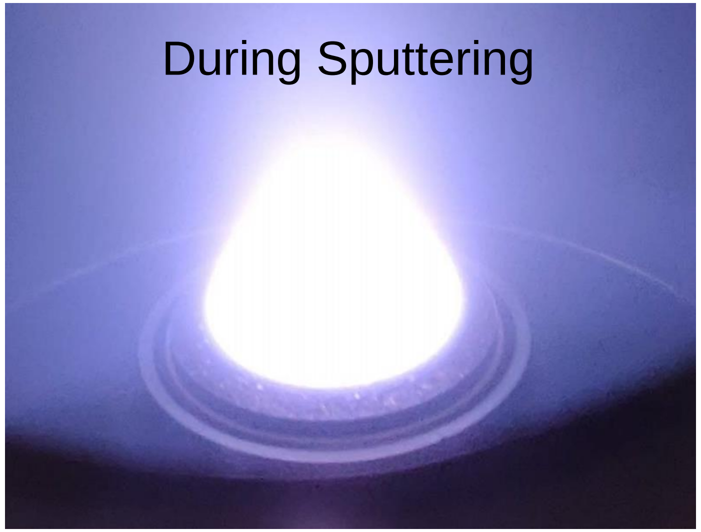


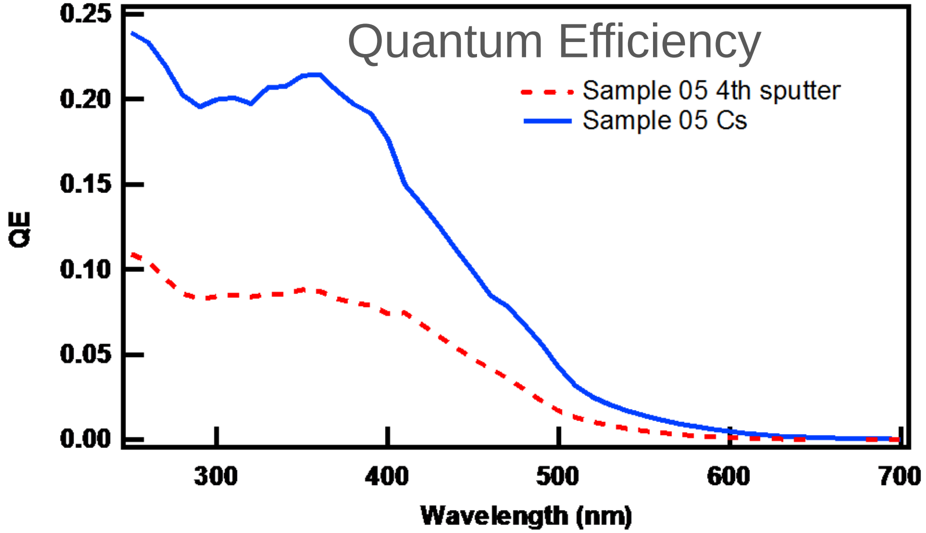
Sputter deposition chamber

Process Specifications

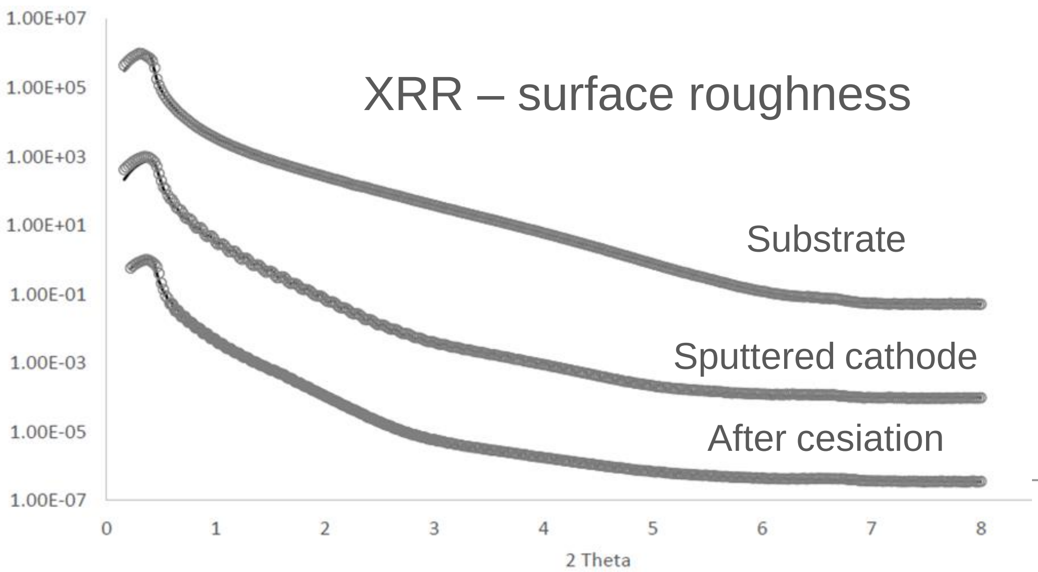
- Cryo and ion pump
- RGA
- Base P 2x10^{-9} Torr
- Operating Gas: Ar
- Sputtering Power: 10-15 W
- Operating P: 30 mTorr
- Growth rate > 2 nm/min
- Cathode thickness: 50 nm
- 2 cathodes/hour

Sputtering – A Reliable Cathode Growth Process





	QE_360 nm	QE_530 nm
sample 05 sputter	6.8%	0.5%
sample 05 Cs	21.4%	2%



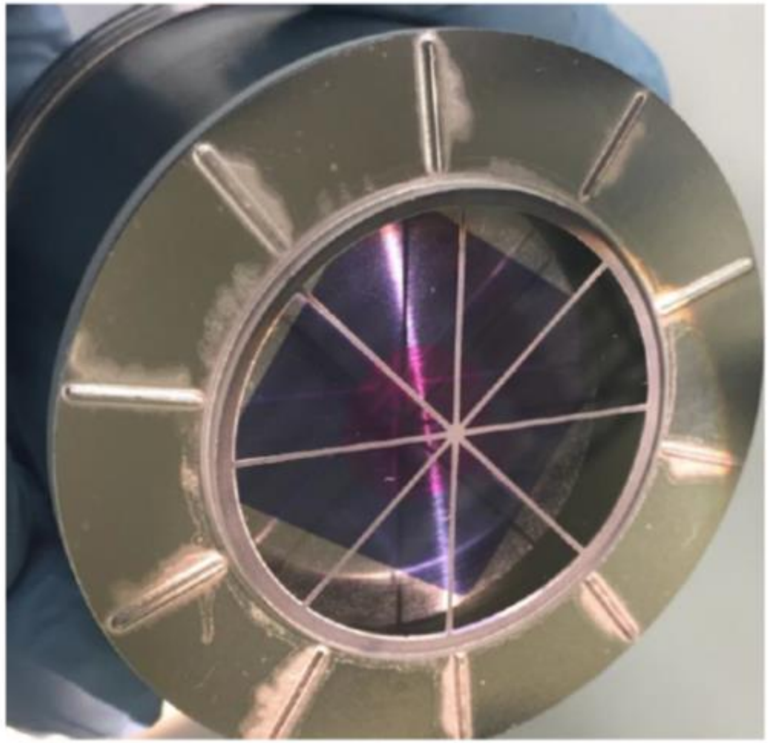
	Thickness (Å)	Roughness (Å)
Substrate Si		3.75
SiO2	7.36	3.94
1st sputter	532.9	5.75
After Cs	796.5	5.57

Photocathode Packaging

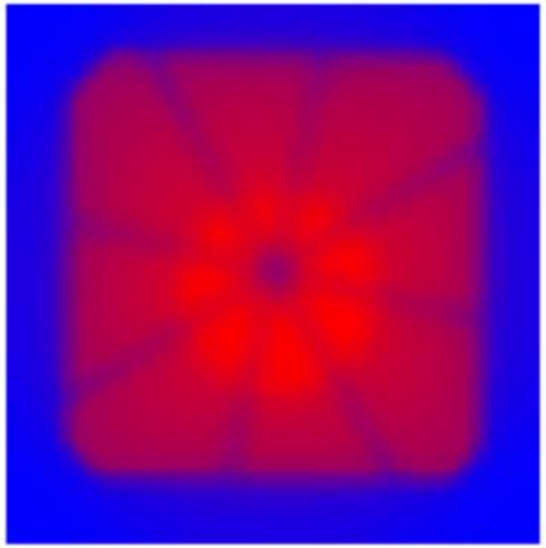
Cornell Puck – #2 cartridge sealed cathode

PHOTONIS
Scientific Detectors

- Detail

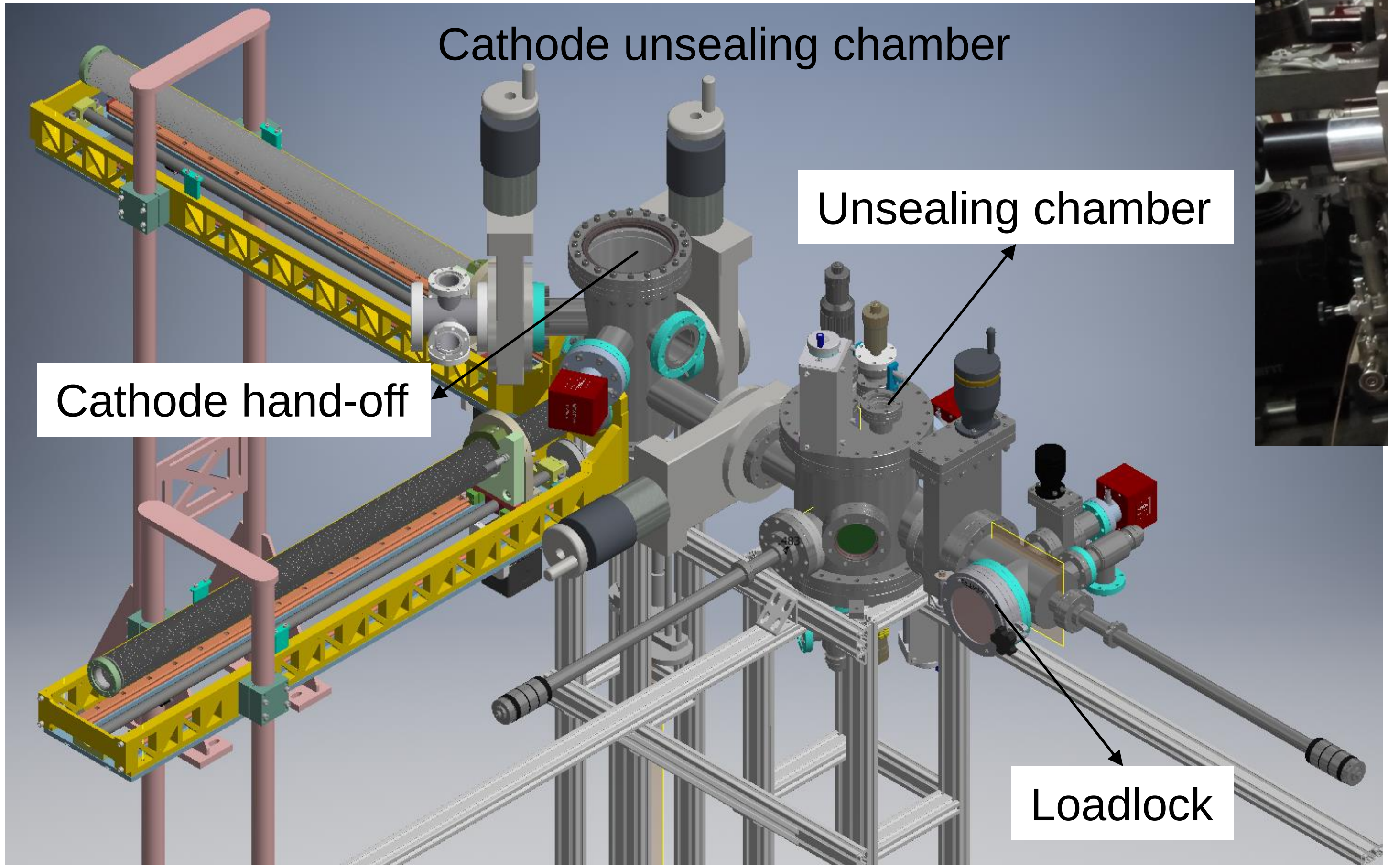


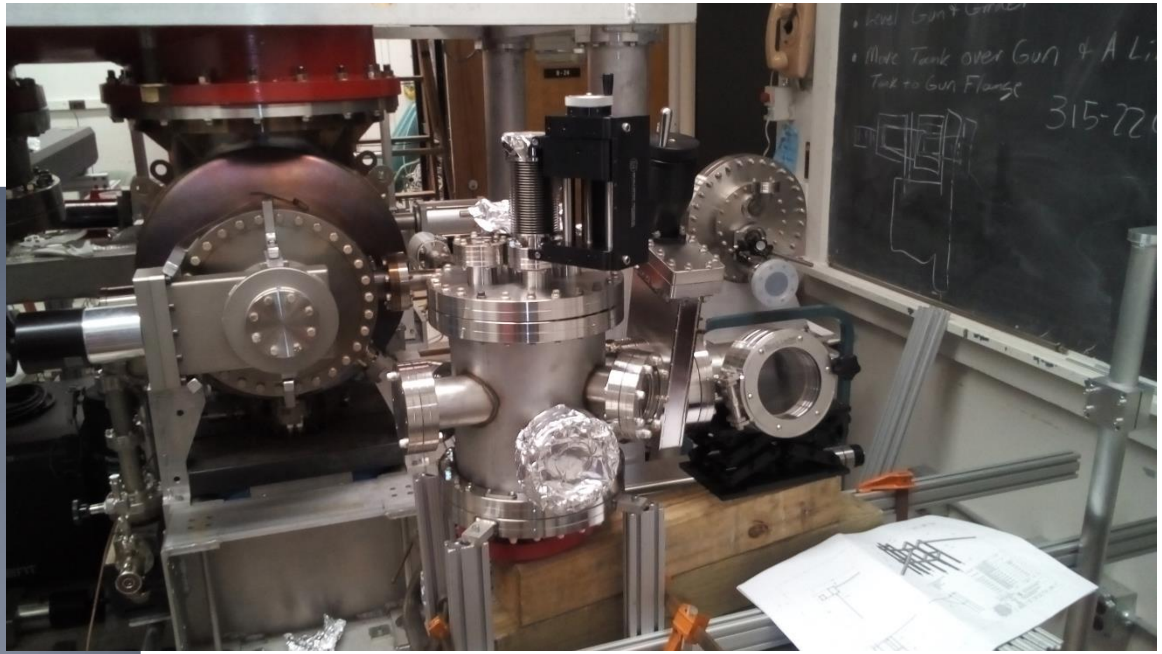
- Central (round) => Al film passivated region
  - SS puck surface chemically cleaned instead of thermally (different than #1)



- 405 nm LED photoemission map
  - ⇒ 16.4 % QE @ Al passivated region (24% on #1)
  - ⇒ ~ 10% on SS (13% on #1)

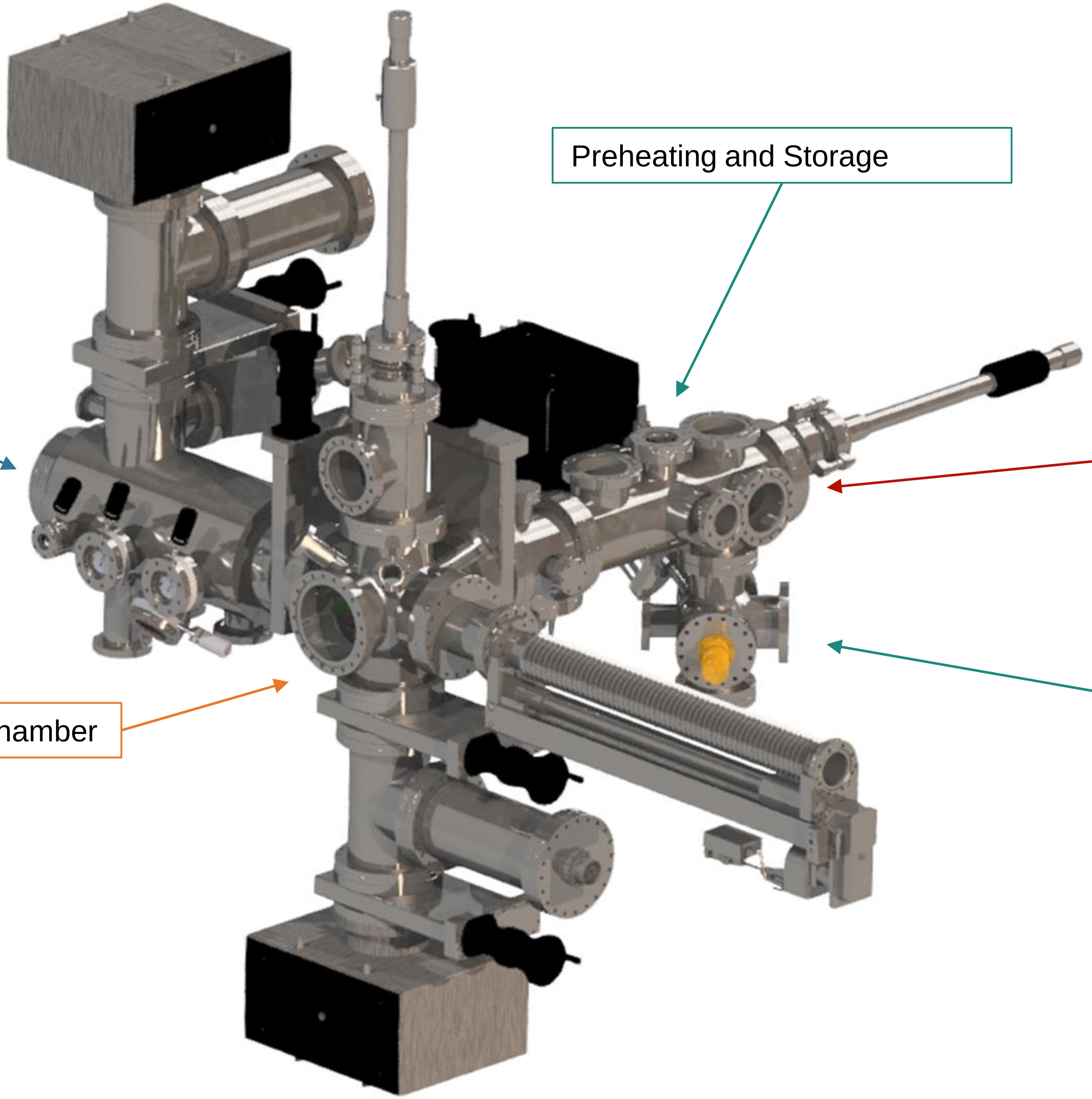
Unsealing the Cathode





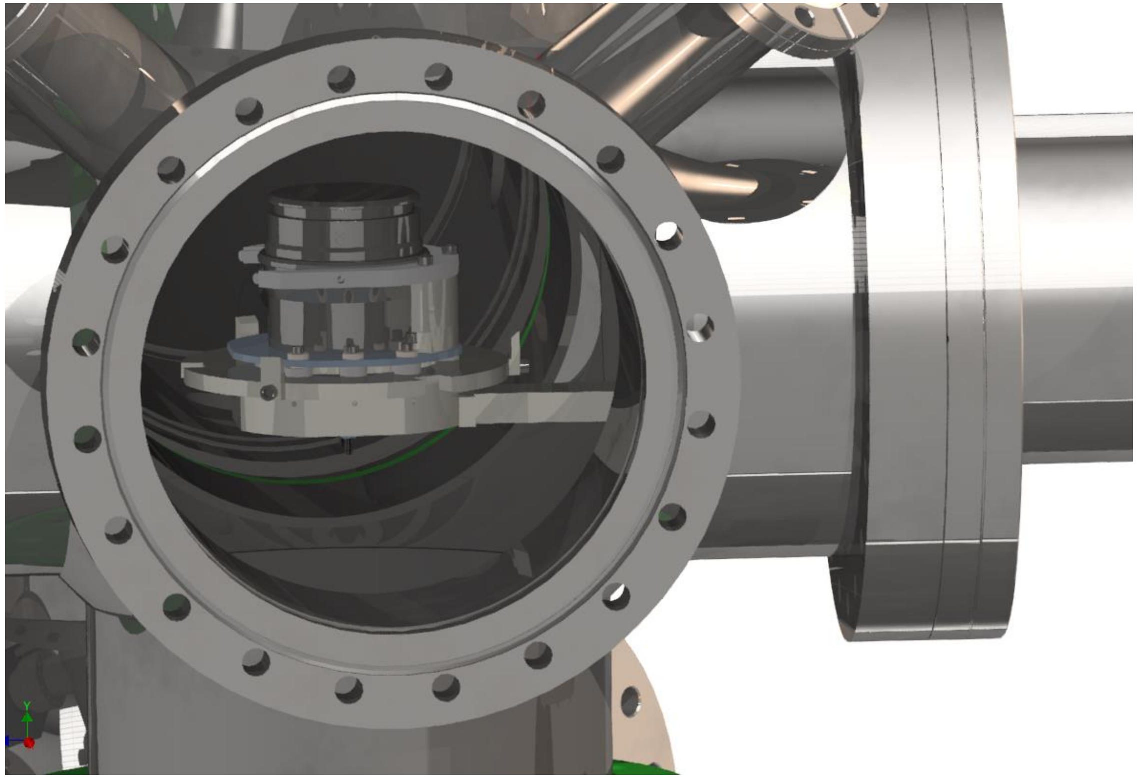
- Sealed cathodes shipped to Cornell
- Unseal the cartridge in vacuum
- Hand off the cathode puck to electron gun
- Generate and analyze the electron beam

Integration – Cathode Growth and Sealing (RMD)

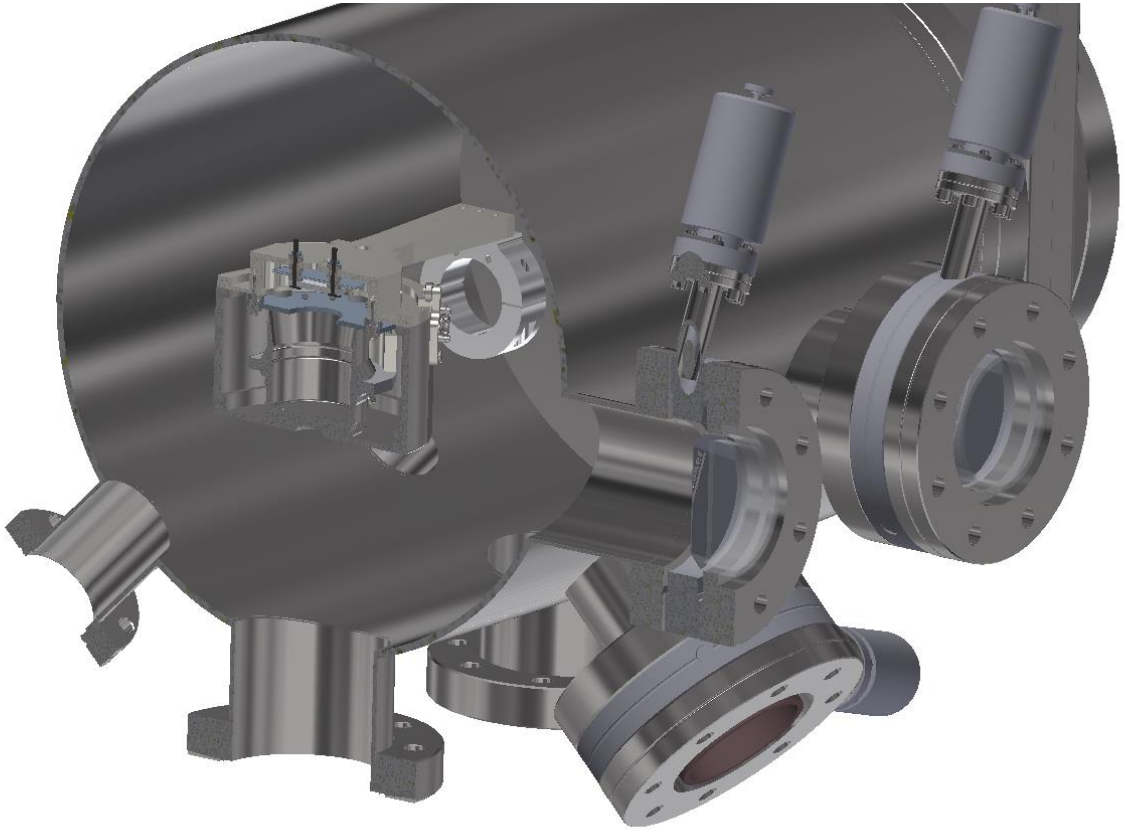


UHV Vacuum: 10^{-10} Torr
Bake-able : 200 C

Cathode Growth Chamber

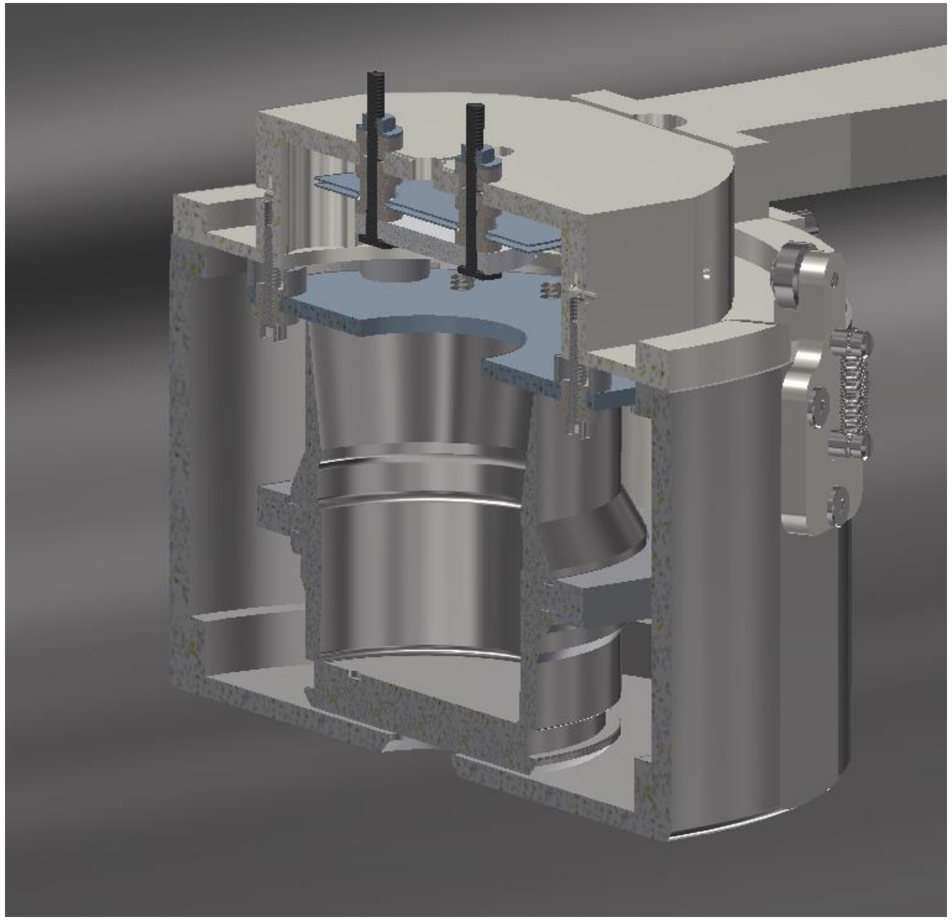


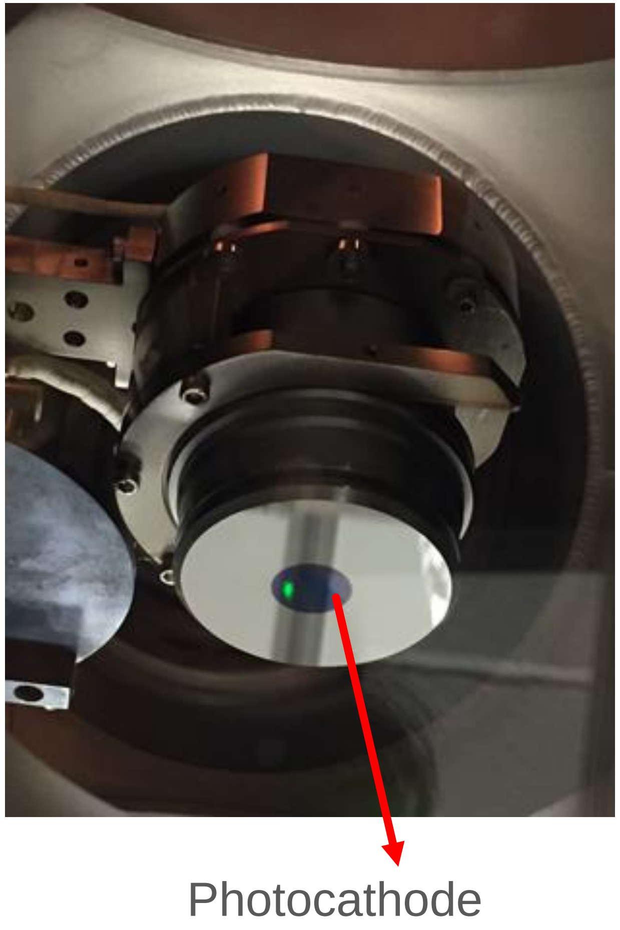
Cathode puck on a heater stage



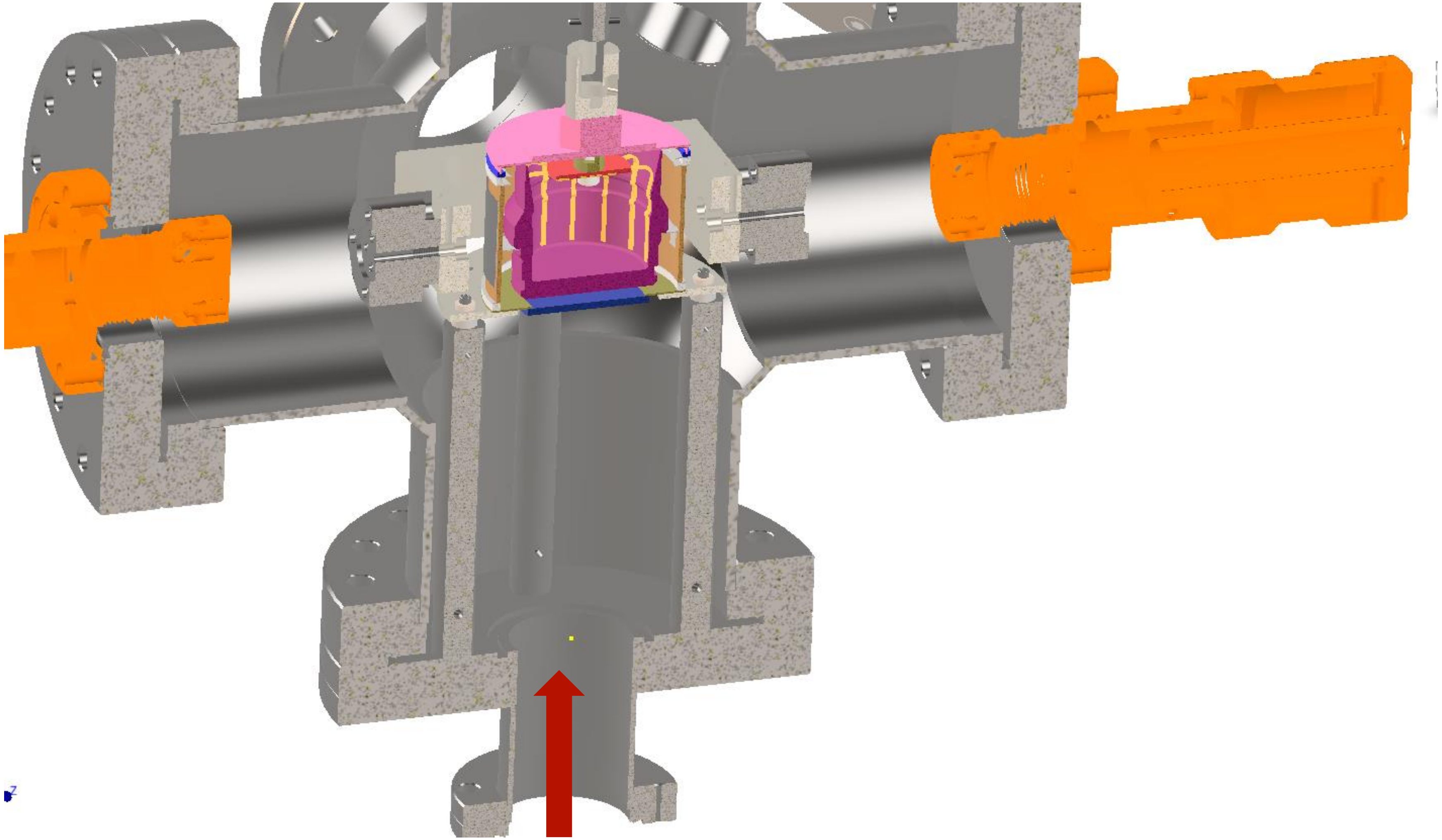
Puck with a mask (upside down) ready for sputter deposition

Masking the Cathode



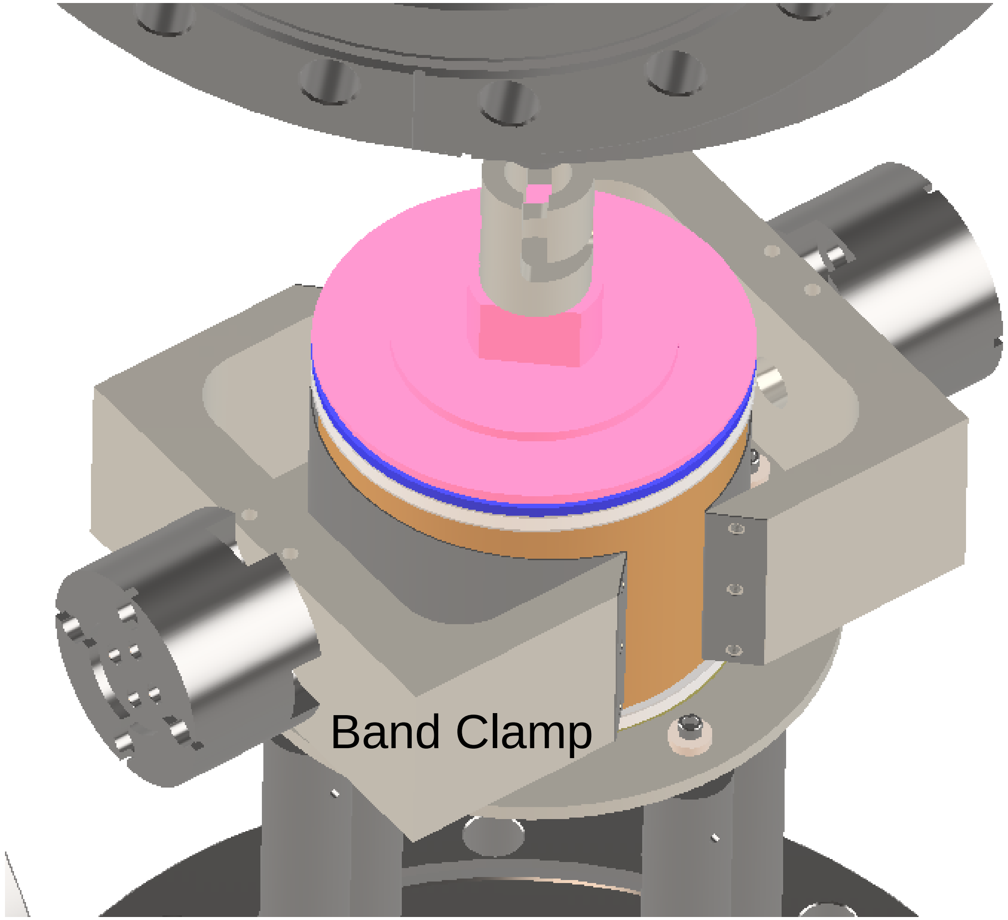


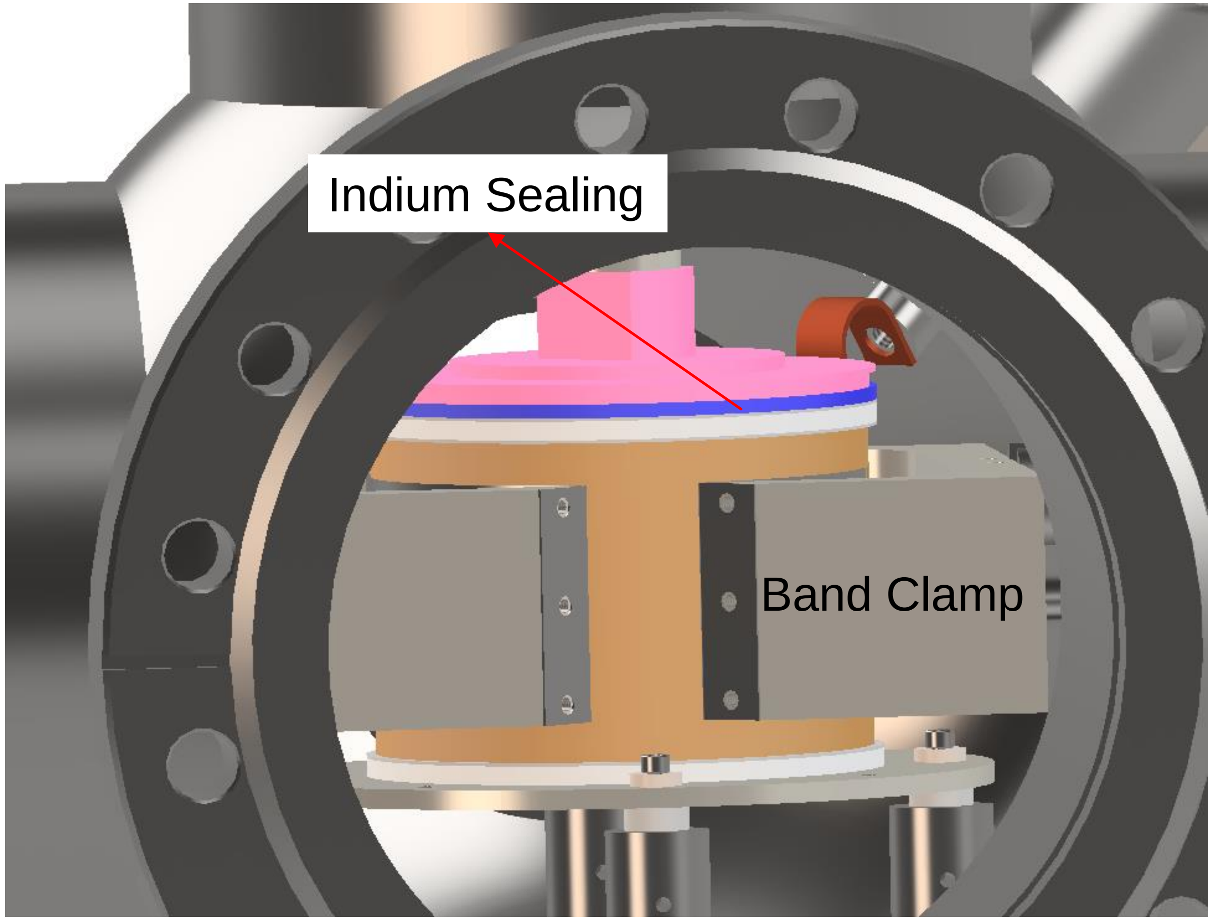
Cathode Sealing Chamber



Light Source for QE monitoring during sealing

Indium Sealing





Deposition Chamber Under Construction (BNL)

Acknowledgement:
John Walsh (BNL)
Brian Walsh (BNL)

Commercialization Potential

- RHIC – 300 cathodes/year
- SLAC (LCLS-II)
- TRIUMP – 300 cathodes/year
- JLABS EIC
- RI Research Instruments GmbH (New Accelerator in Germany) – 200 cathodes/year
- Cornell - CBETA

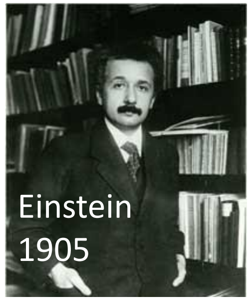
- *RMD is supplementing the current SBIR R&D effort with internal funding*

Phase II Schedule

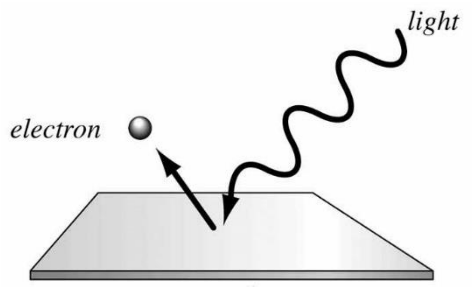
- A traditionally-grown cathode to be sealed in the new cathode cartridge design – August’ 19
- The sealed cathode to be unsealed and evaluated at Cornell – September’ 19
- The sputter-grown cathodes to be demonstrated in the new growth chamber - October’19
- The sealing of the sputter grown cathode will be demonstrated – Dec’19
- The unsealing of the sputter-grown cathode will be demonstrated – Jan’20
- The SBIR Phase II ends May’ 20

Questions ?

What is a Photocathode?



Nobel prize for photoelectric effect - 1921

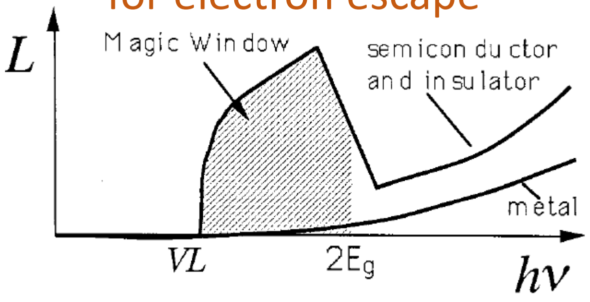


- In 1951 Dr. Alfred Sommer discovered a process for "alkali antimonides" (M_3Sb) preparation that performed better than metal photocathodes
- Hamamatsu uses Sommer's process in PMT's (1980's)
- Process involves reactive evaporation of alkalis' on Sb

The Spicer "3-Step" Photoemission Model (1958)

1. Optical absorption
2. Electron transport
3. Escape across the surface

"Magic Window" for electron escape



"Band Bending" for low work function