Cornell Laboratory for
Accelerator-baSed Sciences and Education (CLASSE)

ERL 2011
the 50th ICFA Advanced Beam Dynamics Workshop
on Energy Recovery Linacs

Photocathode Development for the Cornell Injector

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Introduction

Cathode status at Cornell

We no longer use GaAs for injector commissioning and operations. Is still being studied as a source for sub-thermal emittance. It is a good cathode for low average current, but . . .

Problems:

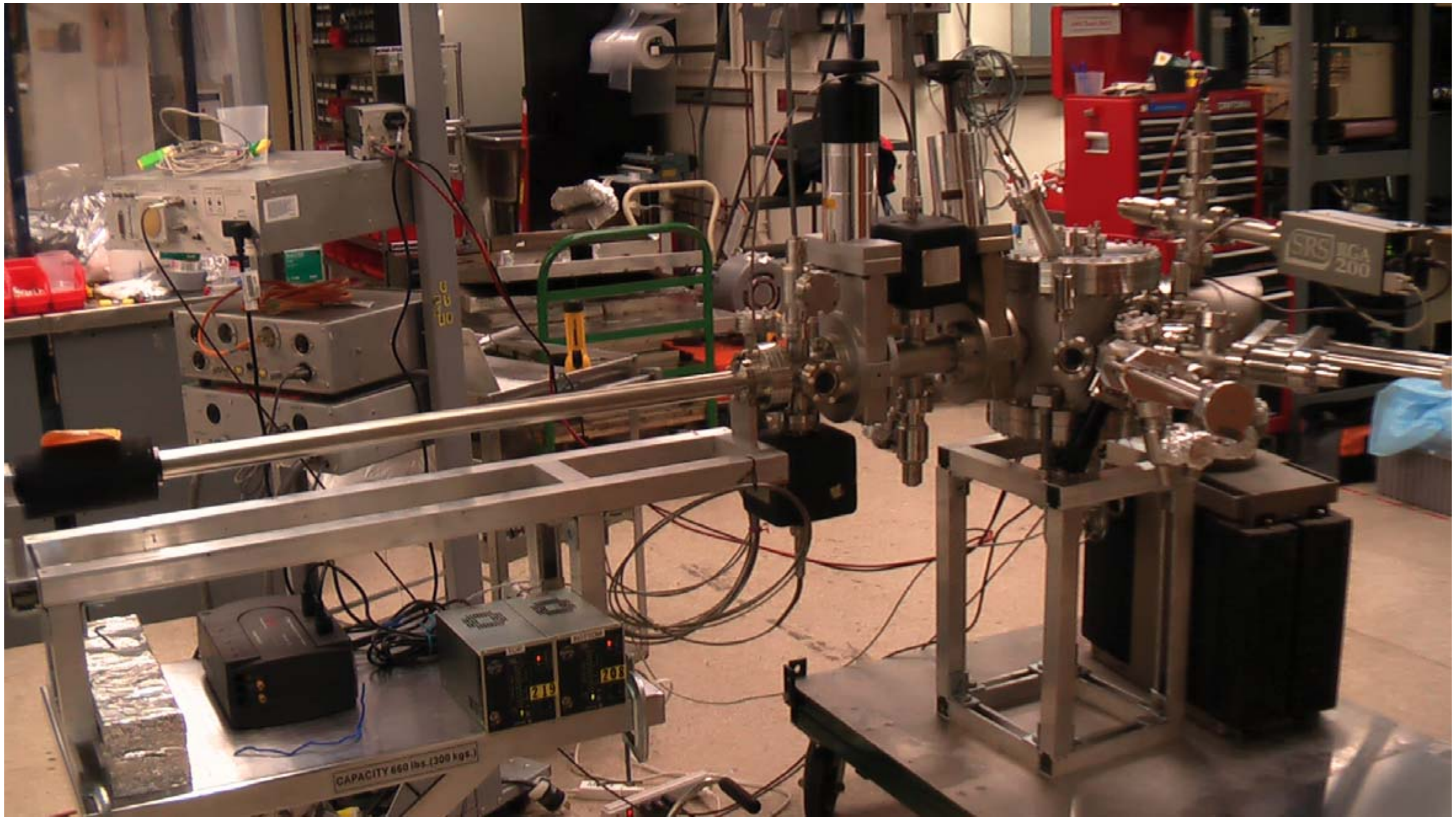
-Short lifetime at high current

-long tails for high QE (>5%) (could make thin layers)

-machine problems often kill the cathode, causing long delays for commissioning

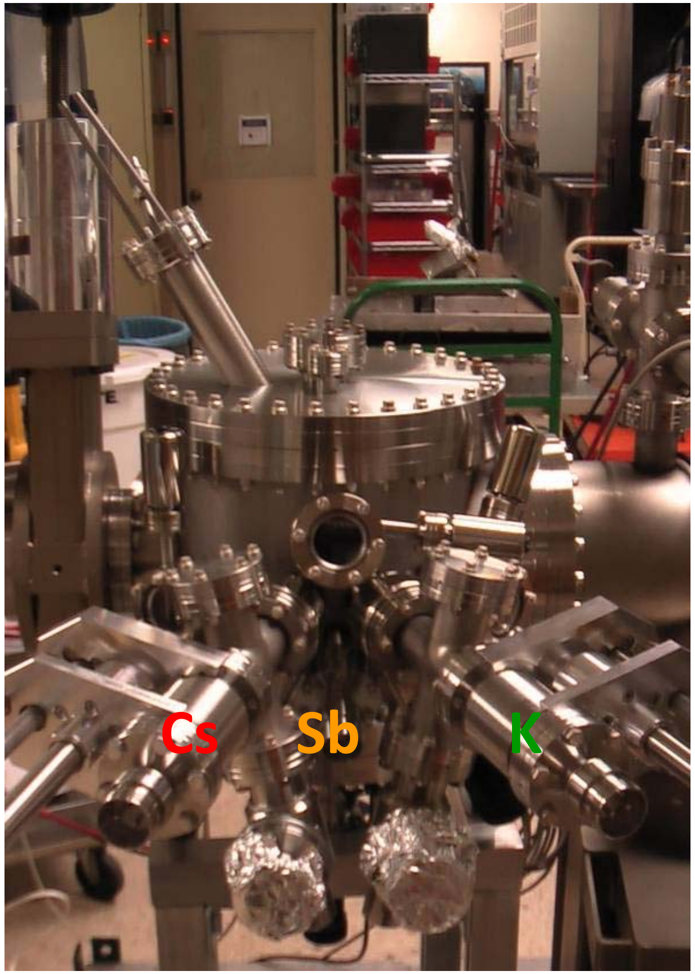
Alkali Cathode Progress

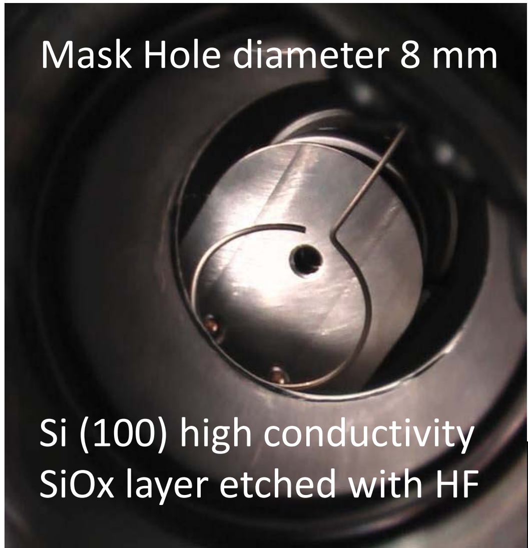
Alkali UHV Growth Chamber



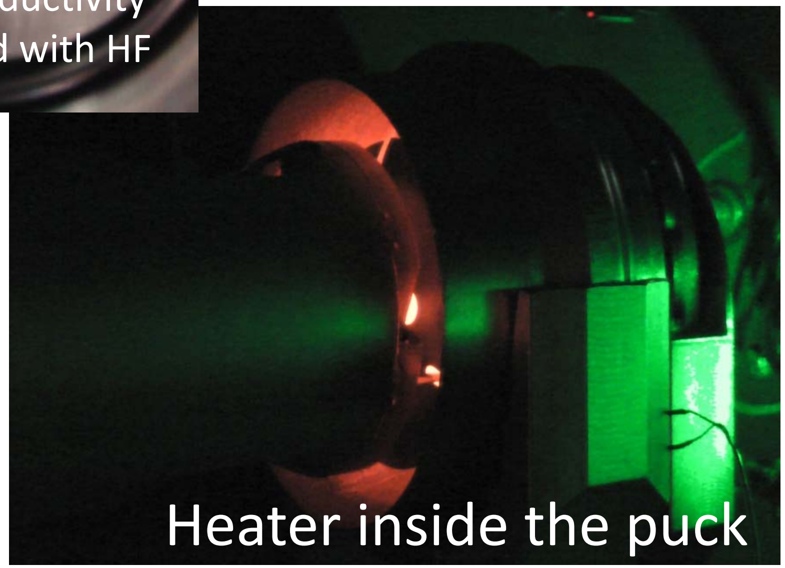
Growth chamber, load lock and transfer mechanism

UHV Growth Chamber





First deposition has been carried out using SAES alkali metal dispenser. Now using using high capacity ALVATEC sources.



Vacuum Suit Transfer Cart

A vacuum-suitcase transfer system is used to transport the cathode from the growth chamber to the electron gun. The left side shows the GaAs preparation system.

Preliminary Results

- Few preliminary deposition test have been carried out during past year:
  - Cs_3Sb
  - CsK_2Sb
  - NaK_2Sb
- So far the better results in terms of QE have been achieved with CsK_2Sb depositions

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Spectral response

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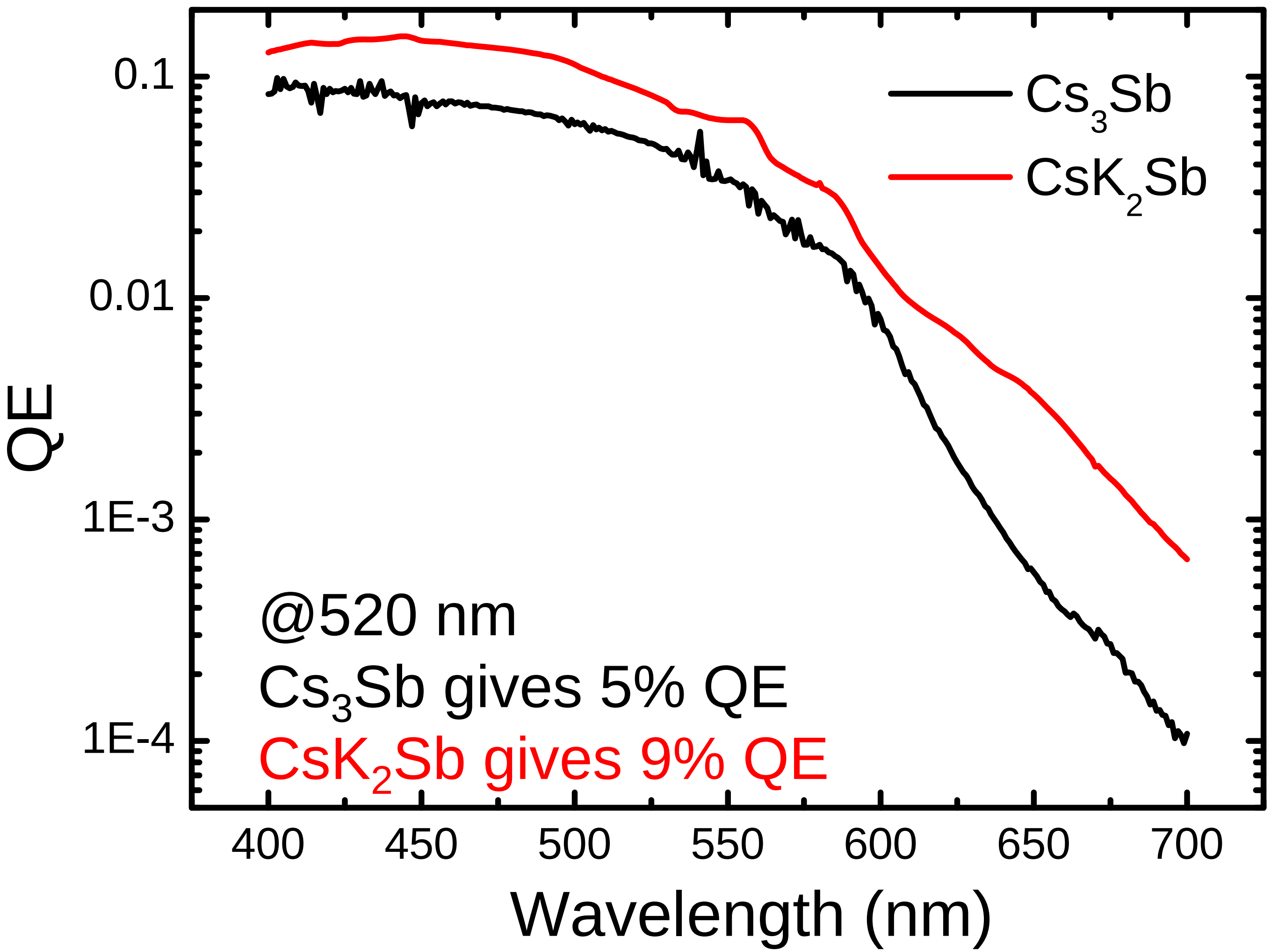
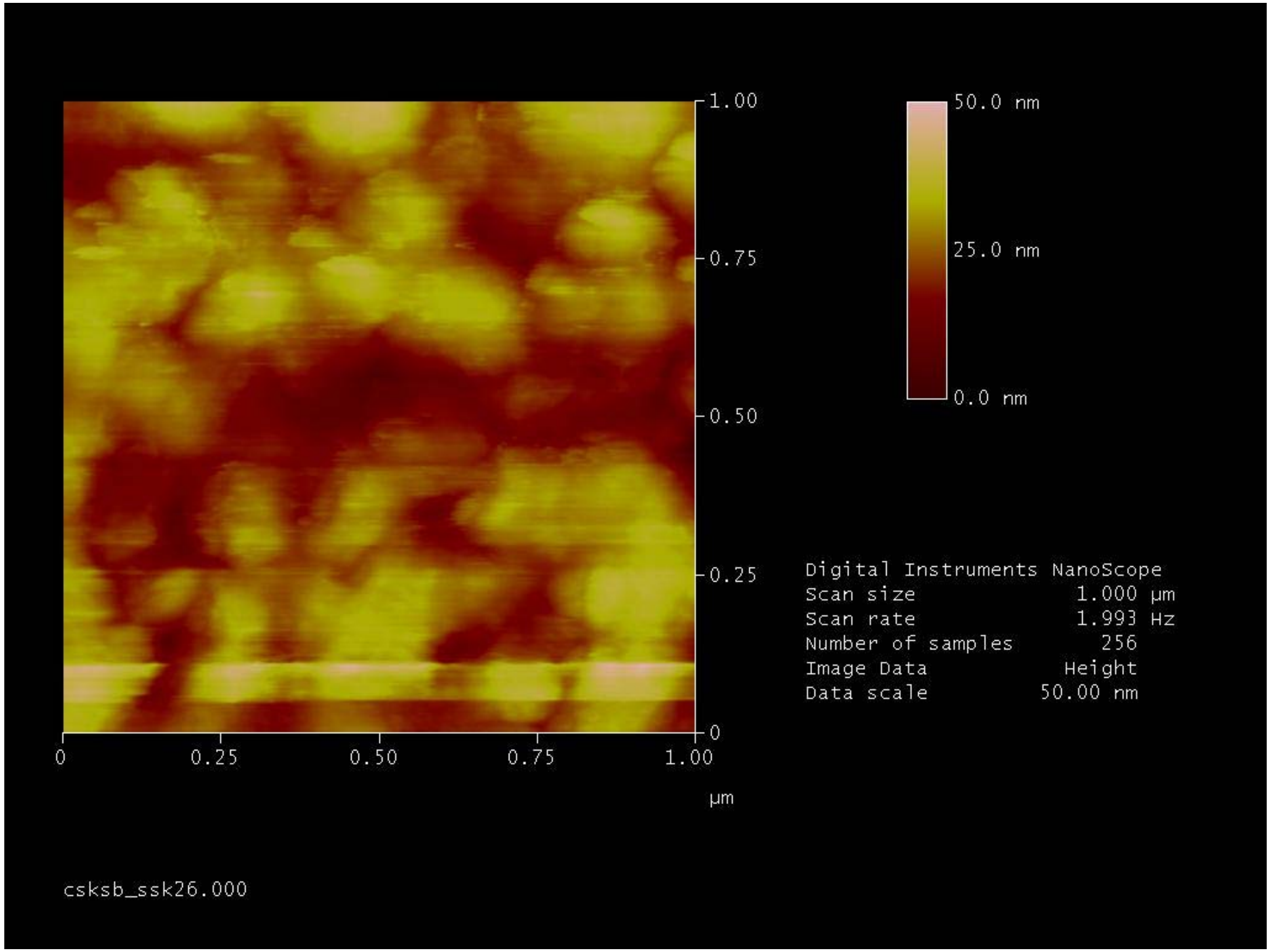
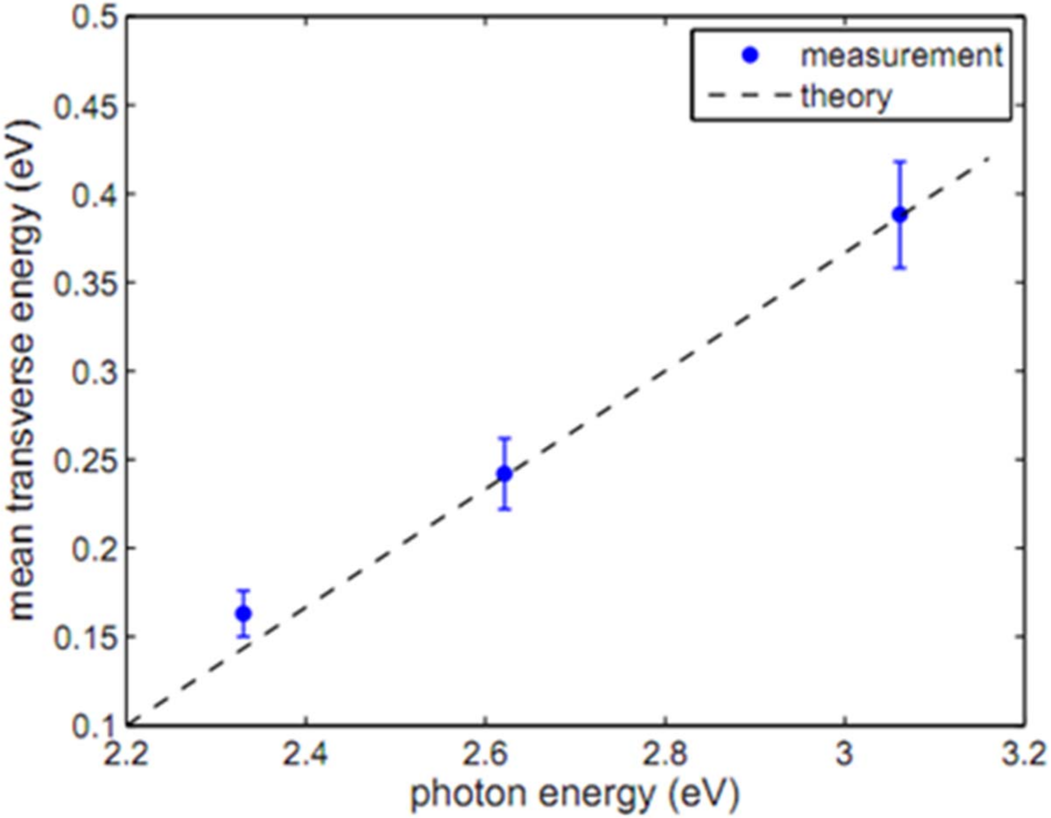


CsK_2Sb



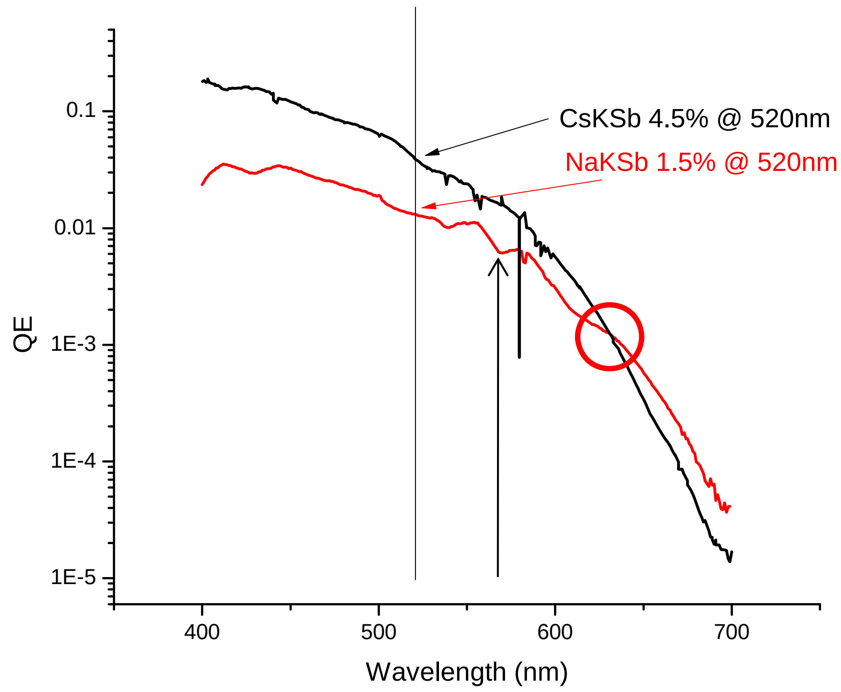
Roughness "peak-to-peak" less than 50 nm

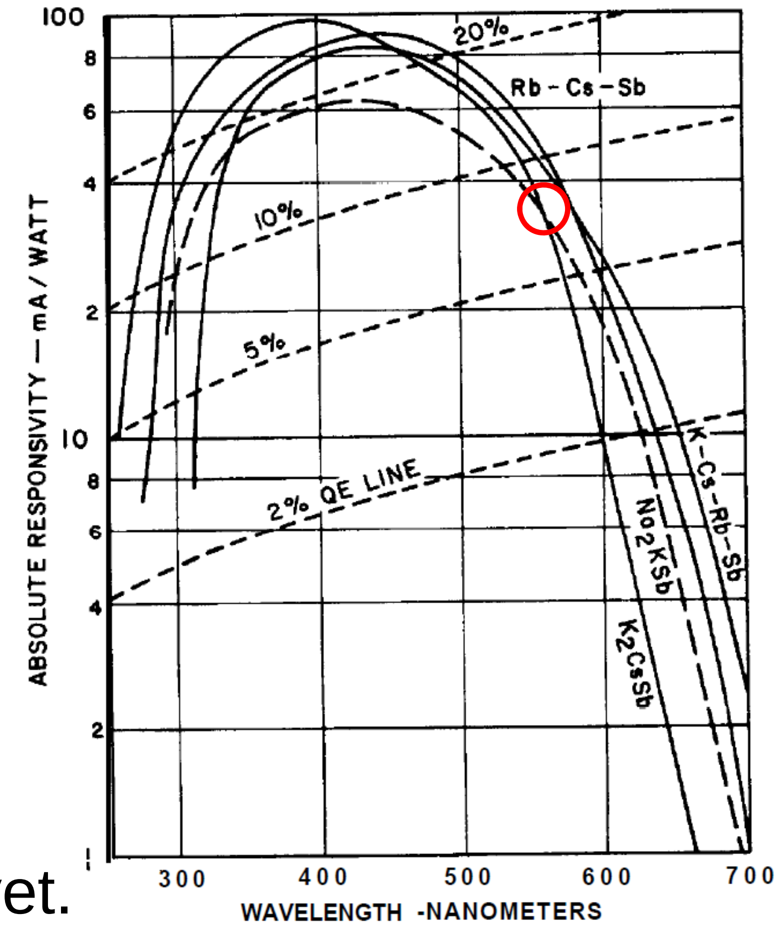
Thermal Emittance - MTE



CsK_2Sb thermal emittance measurement (MTE). 25% higher than GaAs at 520nm, good enough! Cs_3Sb gives the same results

NaK_2Sb



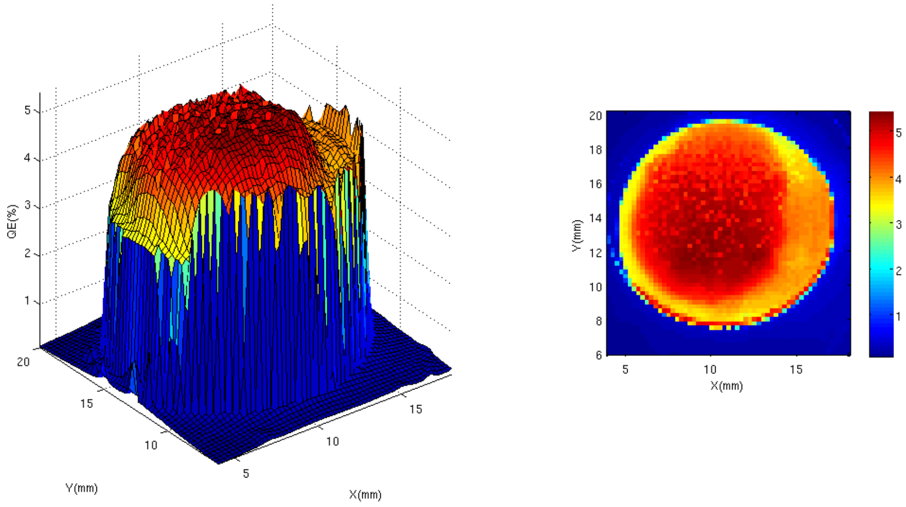


Not much experience with these yet. This material is reported to operate well at elevated temperatures.

CsK_2Sb Recipe

- The growth of the CsK_2Sb photocathode onto Si(100) substrates follows this procedure:
  - The substrate is heated to 600˚C to remove the hydrogen passivation from the Si surface (it comes from HF Si wafer rinsing)
  - Temperature is lowered to approximately 160 ˚C and then evaporation of 15 nm of antimony is performed;
  - Evaporation of the K is carried out while the substrate is slowly cooling down and the quantum yield is constantly measured until a peak on the photocurrent is reached;
  - When the substrate temperature falls below 100˚C Cs evaporation starts until the photocurrent reaches a maximum;
  - The substrate is allowed to cool down to room temperature.

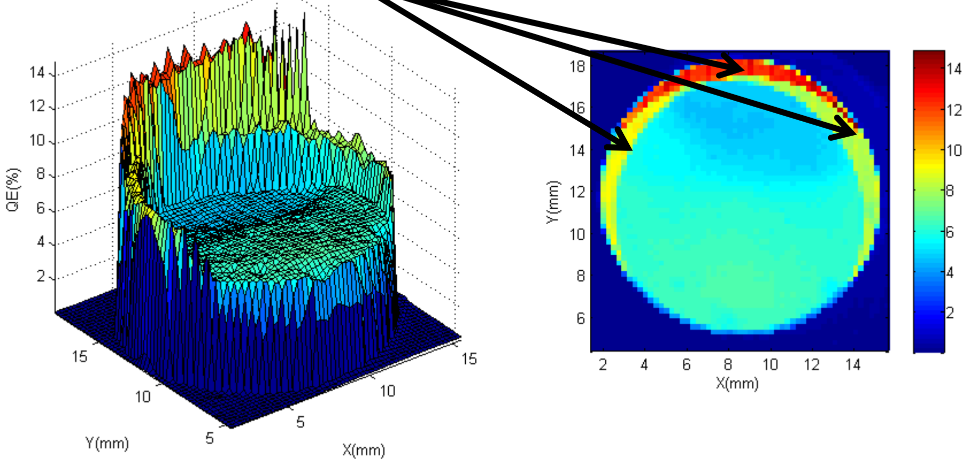
QE uniformity



Cs_3Sb QE map @532nm

High QE on the edges:
Excess of alkali on the center?

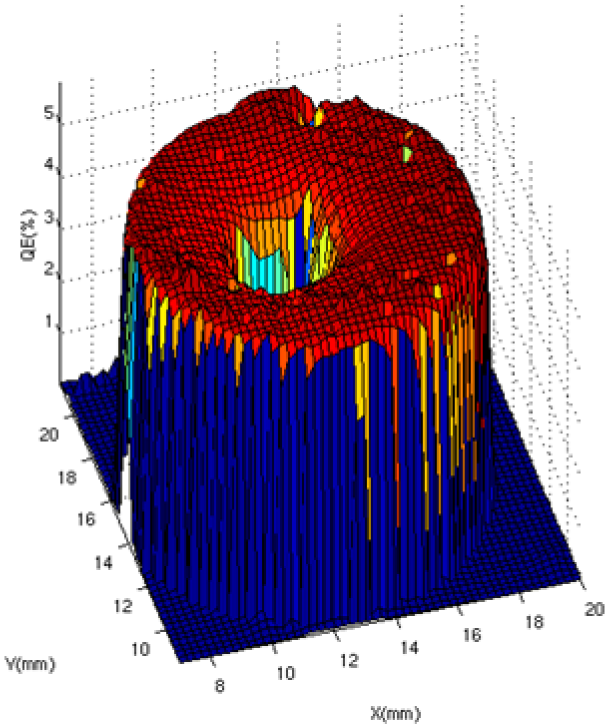
CsK_2Sb QE map



Damage at high currents

GaAs Damage

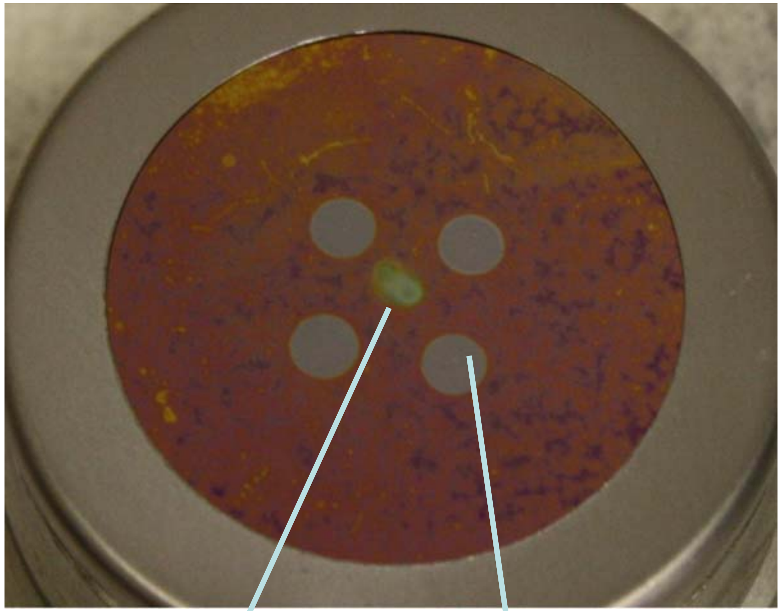
Non-recoverable QE damage on GaAs at high current– can't be recovered by heat treatment and reactivation



Cause of Damage?

•Ion Backbombardment
•Ion implantations
•Rise in vacuum pressure
•Field emission/arcing

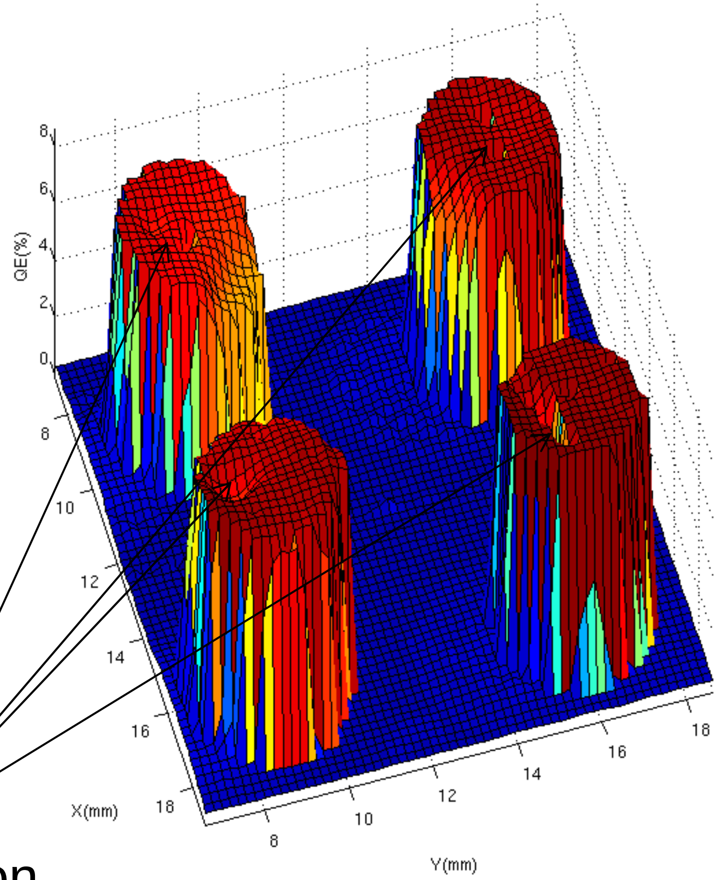
Off-Center Cathodes



Discoloration
due to damage

Active area (4
spots)

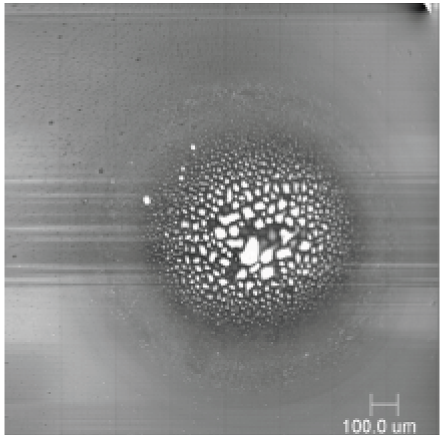
GaAs

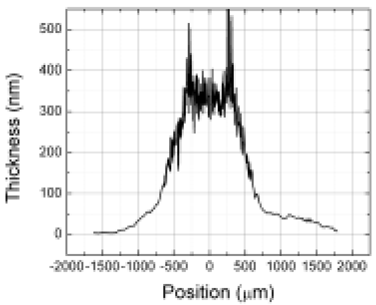


Laser location

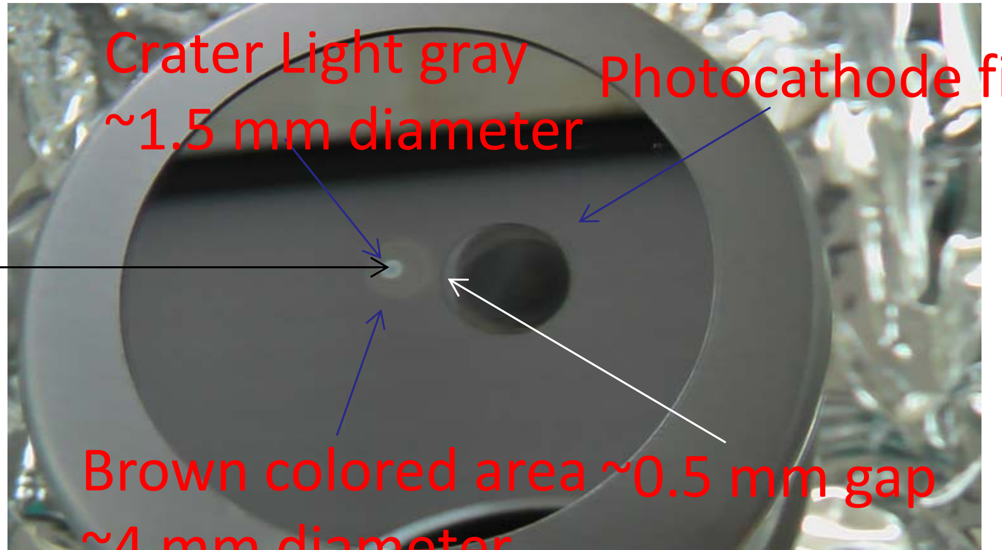
CsK_2Sb Damage

Analysis after 8 hour/ 20 mA run – CsK_2Sb on Si





Large bump in the middle!



XRD Analysis

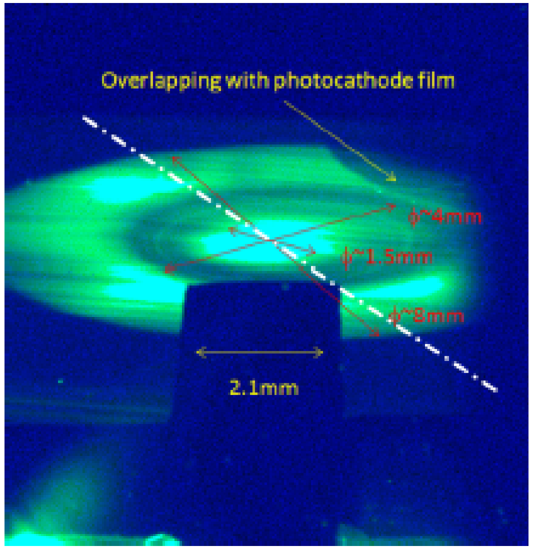


FIG. 10: Various diameters of the regions of interest from the XRD C
dotted line is the diameter over which data was sampled for Fig. (11).

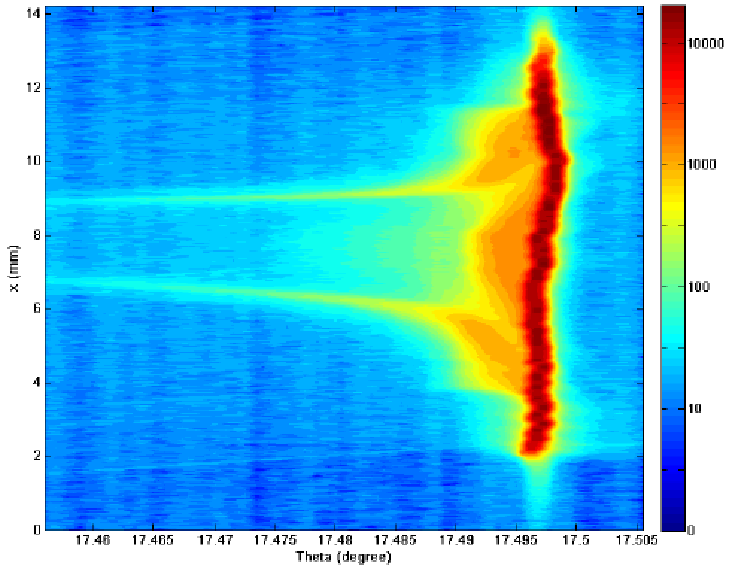


FIG. 11: Counts on the CCD detector as a function of the position along a diameter of damage region (x, vertical axis) and the diffraction angle.

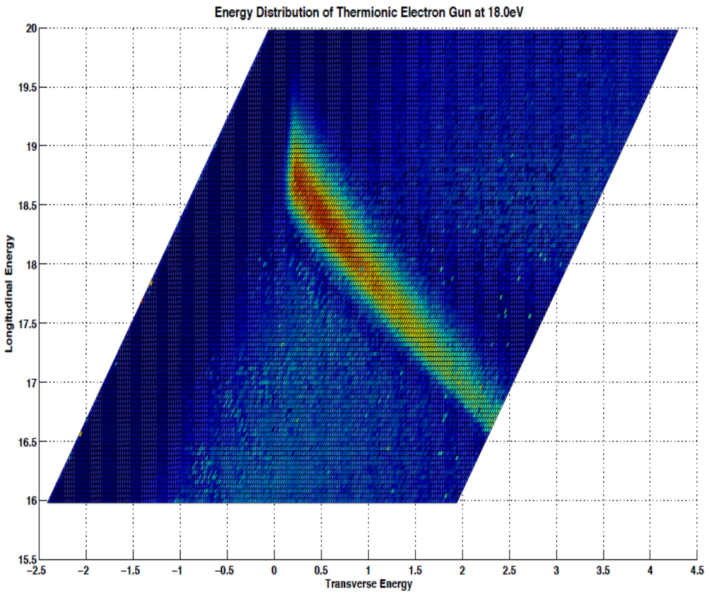
X-ray diffraction measurements indicate crystallographic changes to the substrate at the center of the cathode

Future R&D Efforts

2D Electron Energy Analyzer

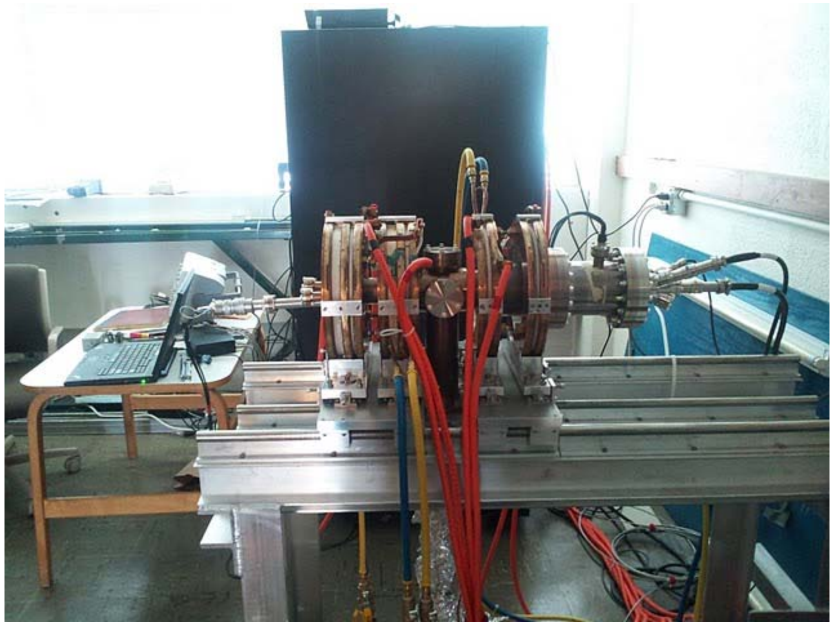
•Employs strong longitudinal magnetic fields and adiabatic invariance principle to get longitudinal and transverse electron distributions simultaneously

•Energy resolution up to 10meV possible so far (can go down to 2meV)



Longitudinal Energy

Transverse Energy

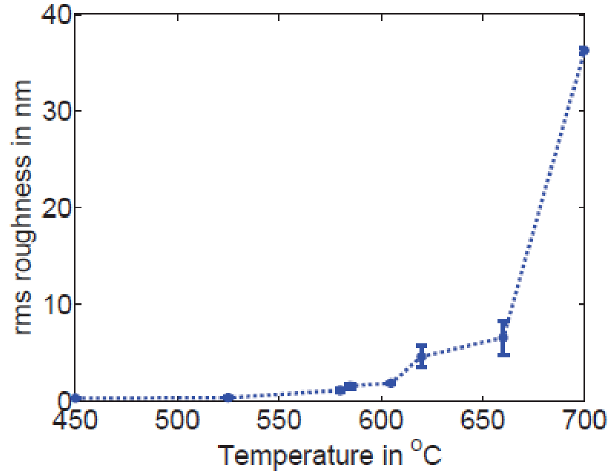


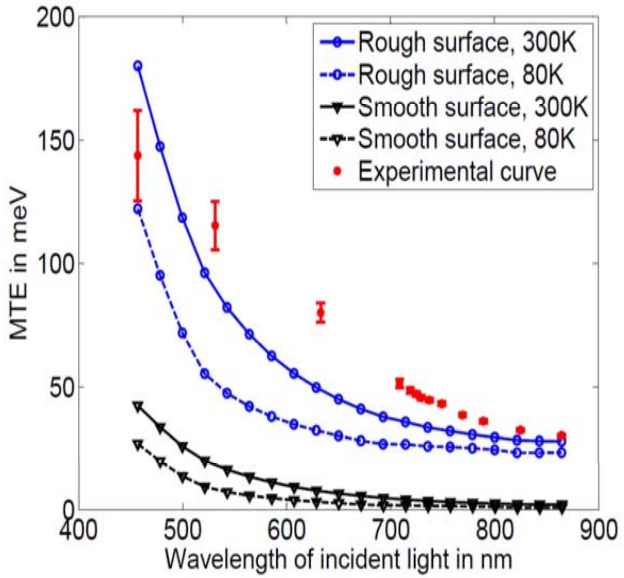
Similar to Orlov apparatus

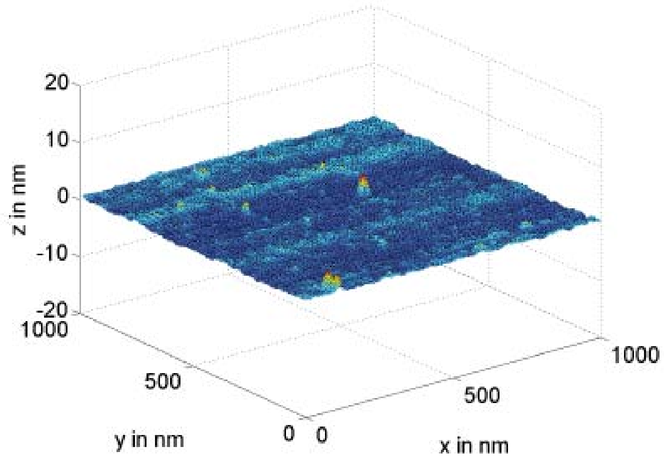
MTE from GaAs – a mystery?

- Due to small effective mass of gamma valley electrons, theory predicts MTE as low as 2meV at 800nm
- Some groups have observed these small MTE values
- But most do not (including us). Why???
- Possible causes – Surface roughness or dirty GaAs surface or different structure of Cs/F layer

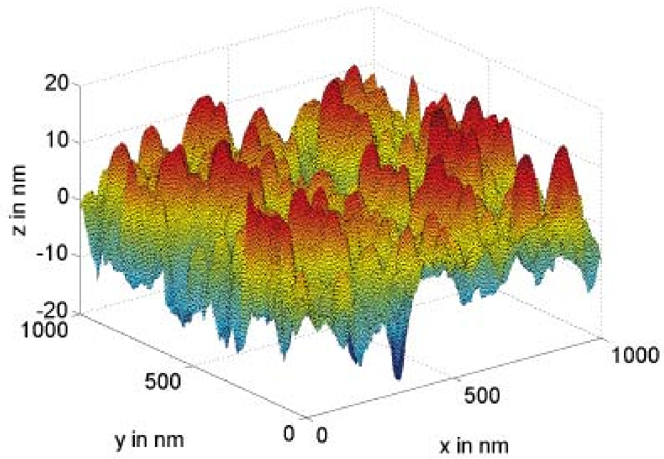
Surface roughness of GaAs





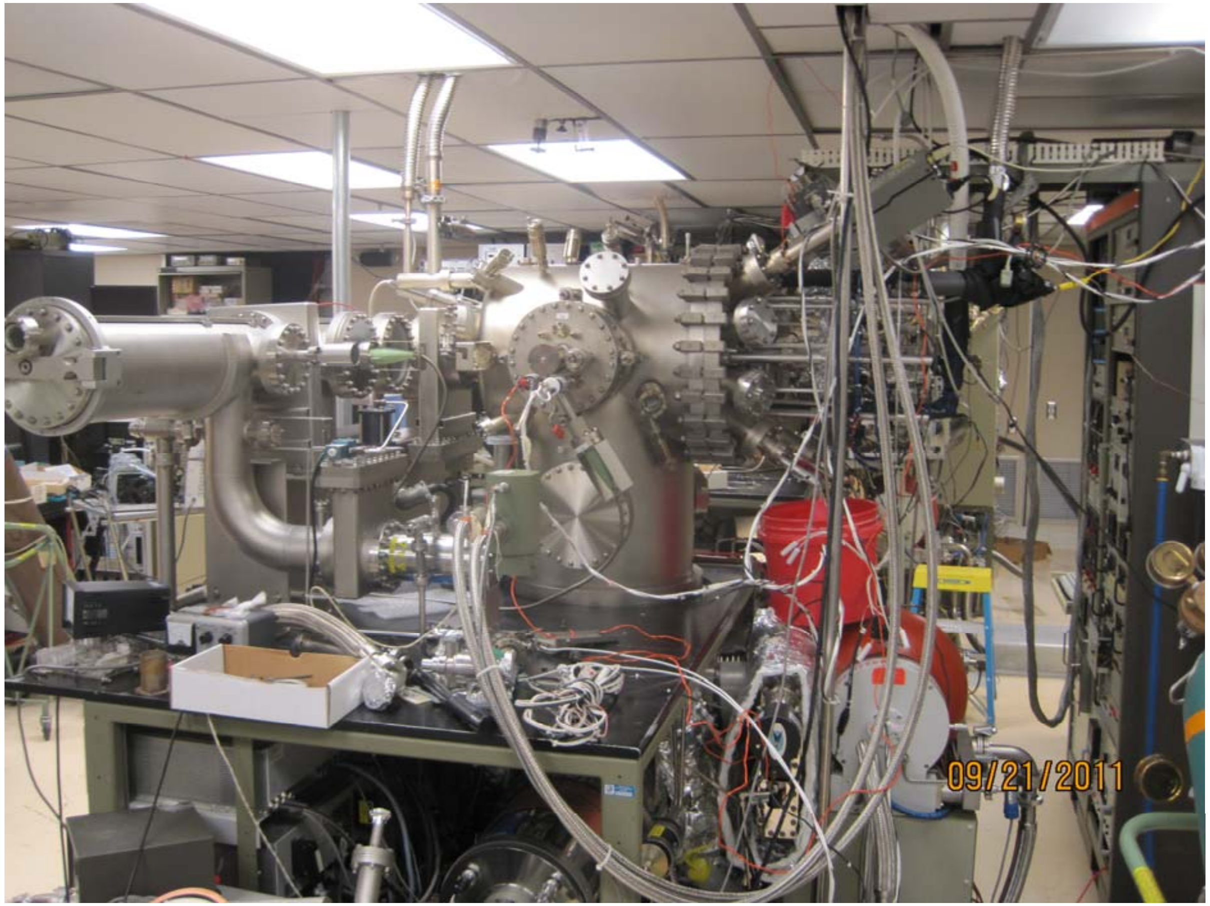


(a) Surface of atomically polished GaAs crystal before heat cleaning (smooth surface)



(b) Surface of heat cleaned and activated GaAs crystal used in the Cornell dc photoemission gun (rough surface)

Cathode Growth



We now have access to MBE machines for growing both GaAs-like and GaN-like cathodes. Just about ready for our first growth run

Summary

- We no longer use GaAs for high current running or for machine commissioning
- Still studying GaAs properties as a source for sub-thermal electrons
- Have growth facilities for CsK_2Sb, Cs_3Sb, NaK_2Sb and other
- Measured the MTE of CsK_2Sb and Cs_3Sb to be 160 meV @ 520nm
- Operated CsK_2Sb at 20 mA CW, 5 MeV, for 8 hours
- Research plans for growing and characterizing other cathode materials

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