Photocathode Studies for BNL ERL

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Outline

- Introduction
- Photocathode tests in guns
- Photocathode characterization and Optimization

Two Parallel Paths

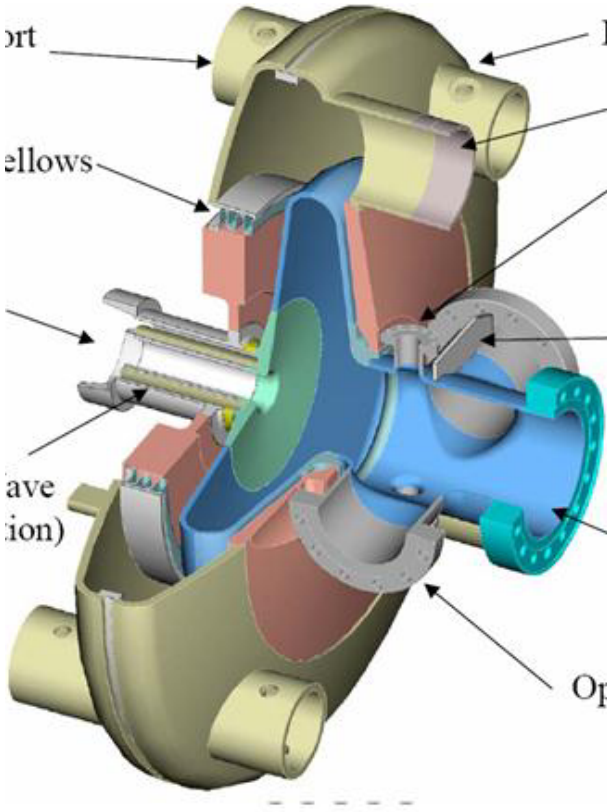
Testing in the gun

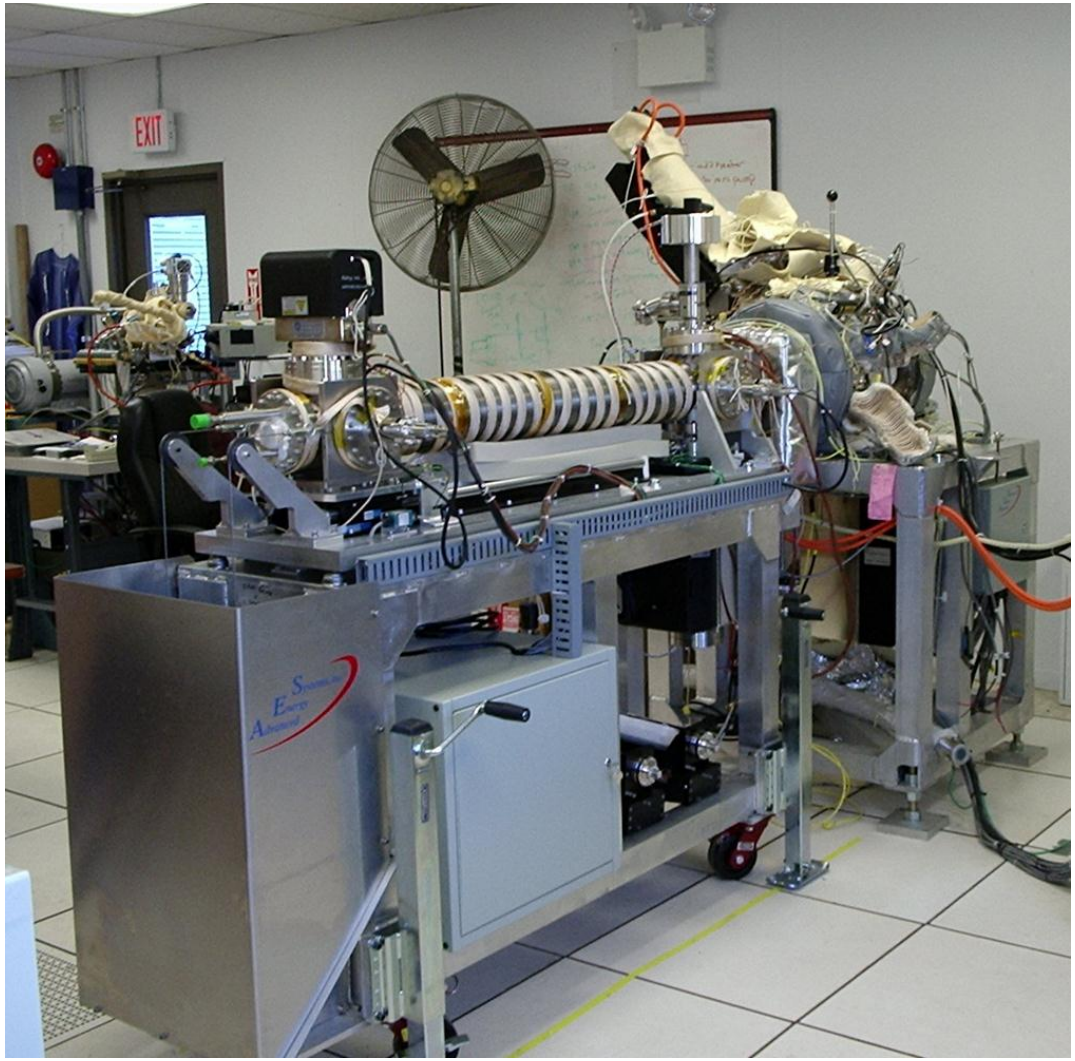
- **NCRF gun** Collaboration with LBNL
- **SCRF Gun**
  - 704 MHz
  - 112 MHz
- **DC Gun** Collaboration with JLab

Growth, Characterization and Optimization-Pre and Post analysis

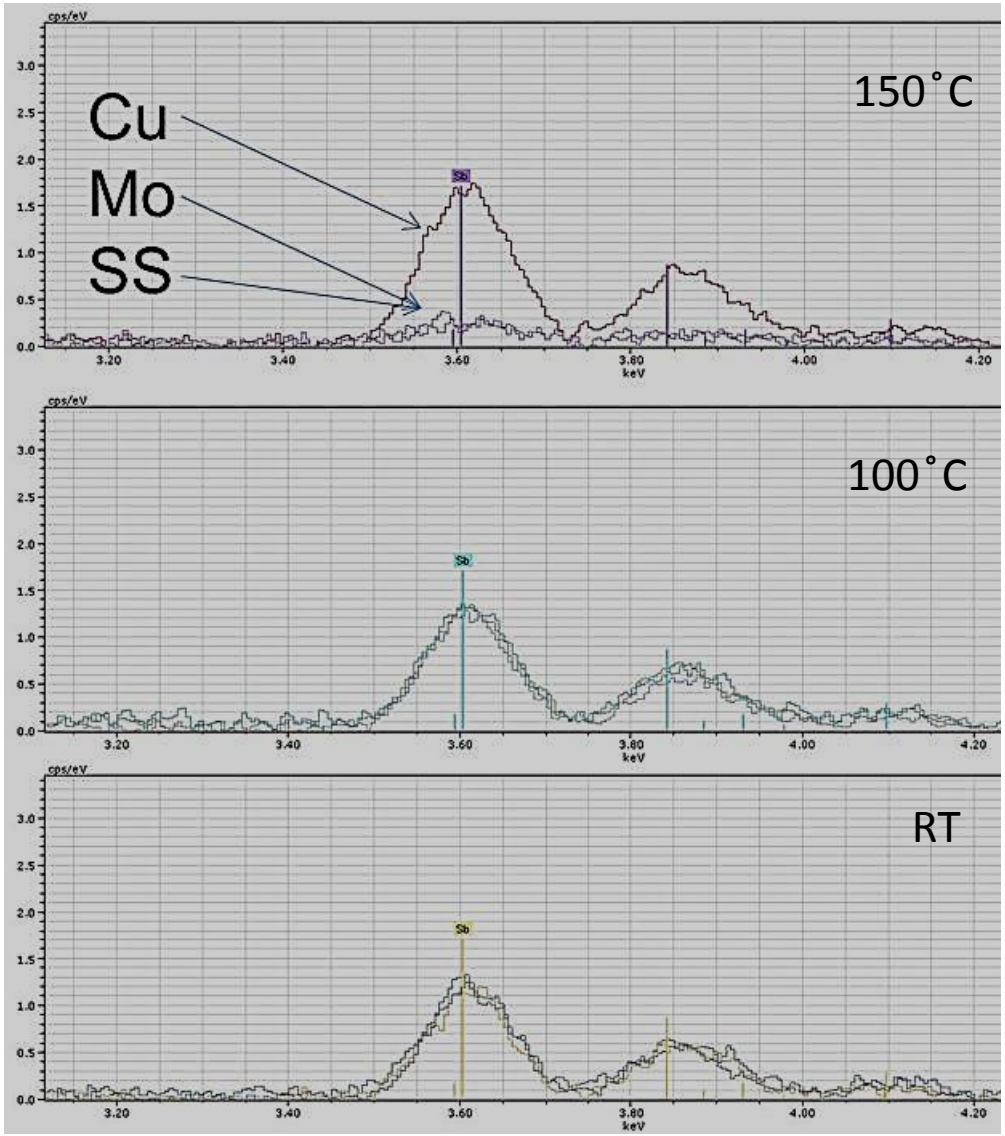
- **XRR, SEM & AFM-** Thickness and roughness
- **XRD-** Texture
- **XPS & EDS**- Material composition
- **ARPES-** electron energy, velocity distribution

704 MHz gun





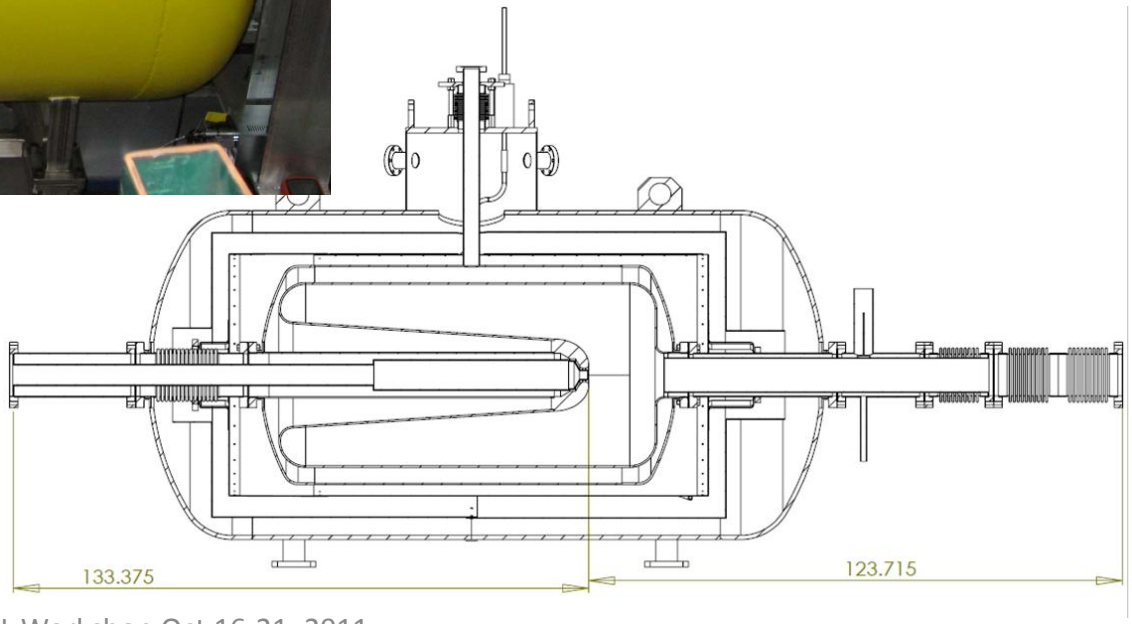
EDS of Sb on Cu, Mo, & SS



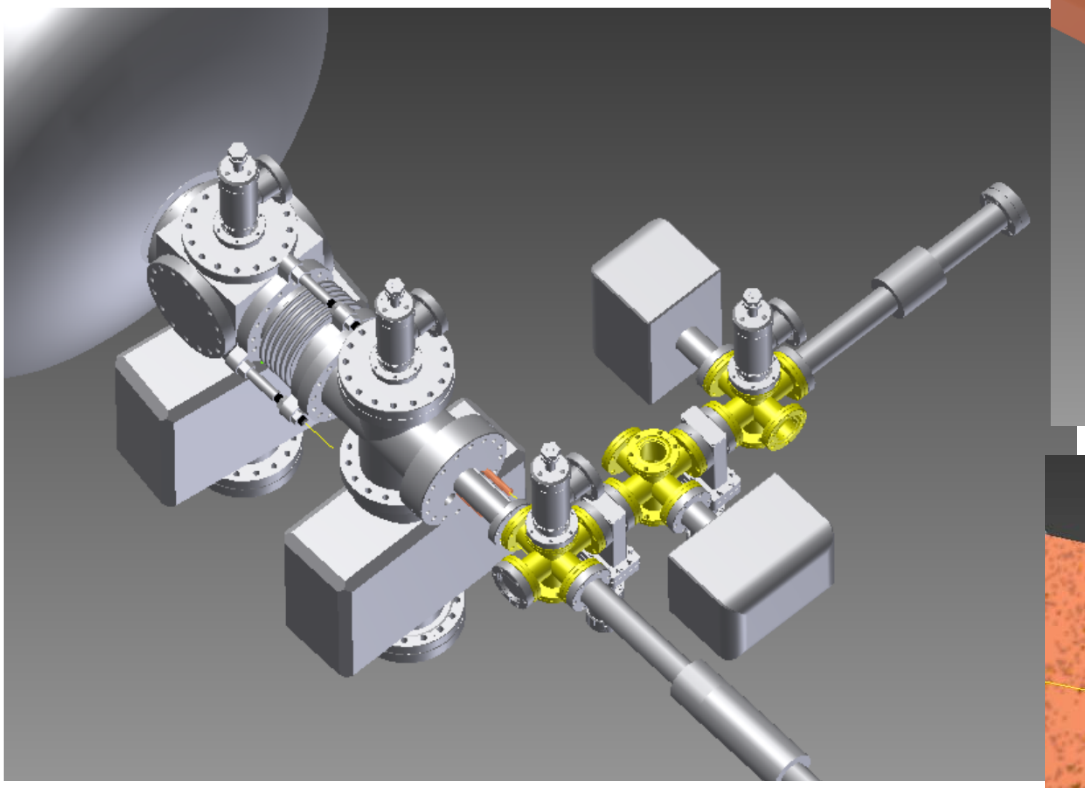
At 150C substrate temperature, the thickness on Mo and SS only 10% of that on copper (27 nm on Cu, 2.7 nm on Mo, 3 nm on SS). The coating thickness on SS and Mo is highly non-uniform. At room temperature and 100C, the thicknesses on all three substrates is equivalent (21 nm), and all three coatings are uniform to within 5%

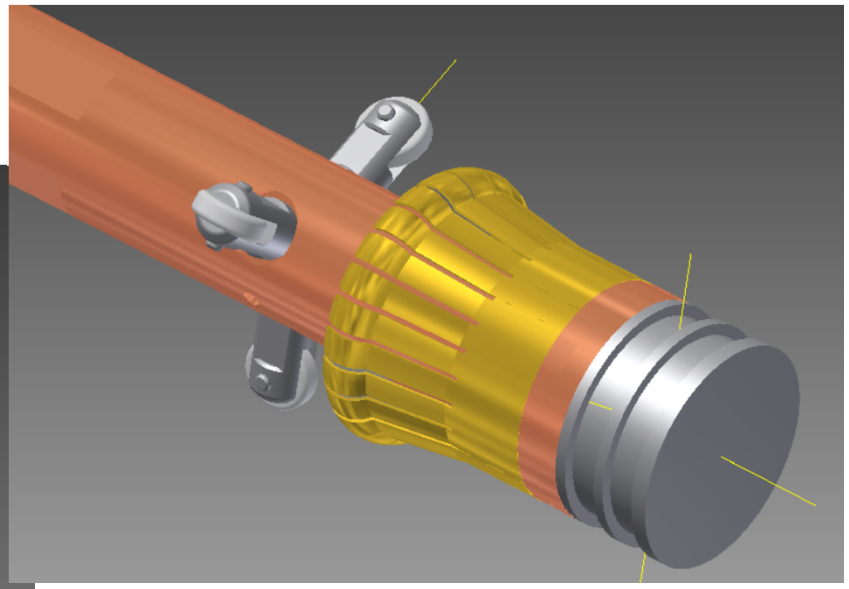
112 MHz Gun

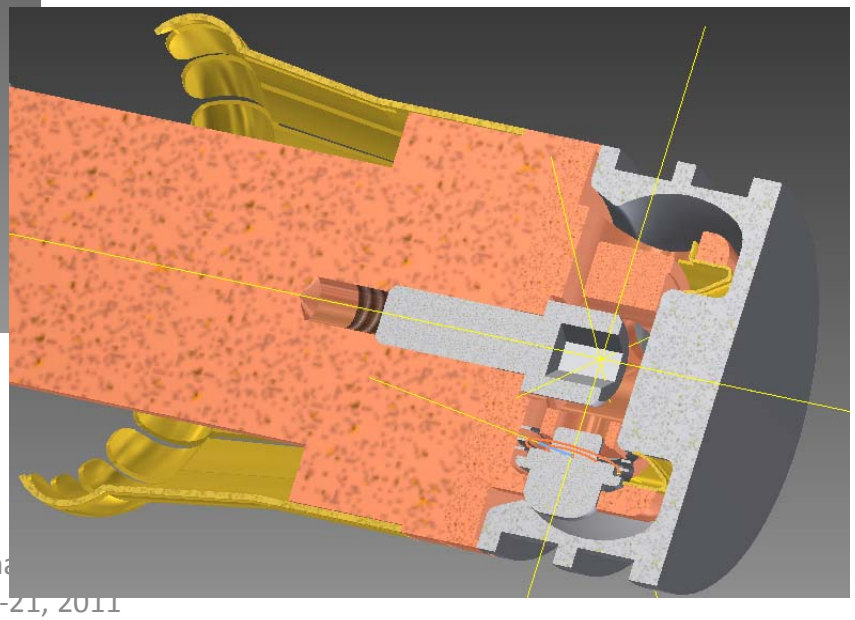
BROOKHAVEN
NATIONAL LABORATORY
NIOWAVE
www.niowaveinc.com


133.375
123.715

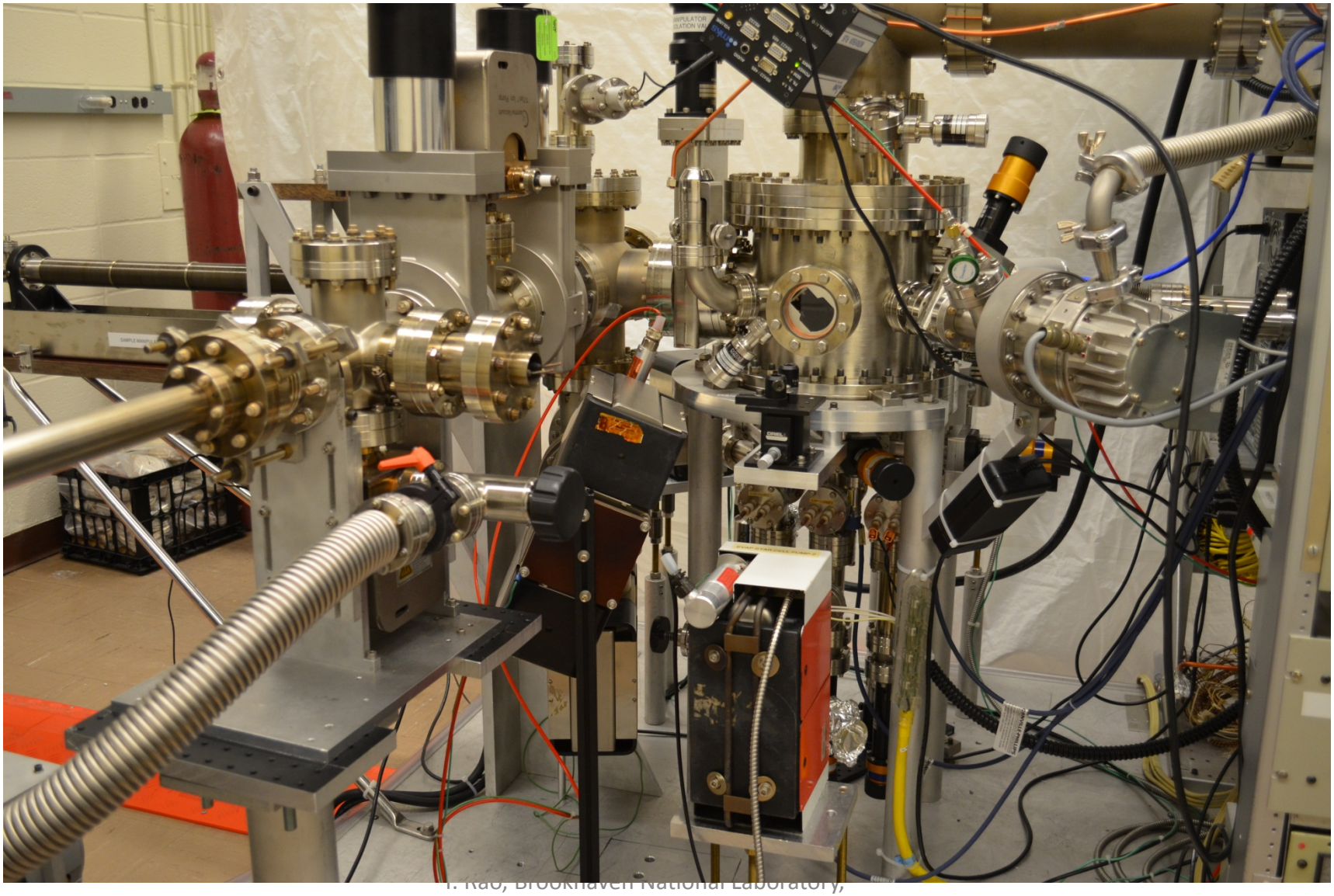
Load-Lock Design



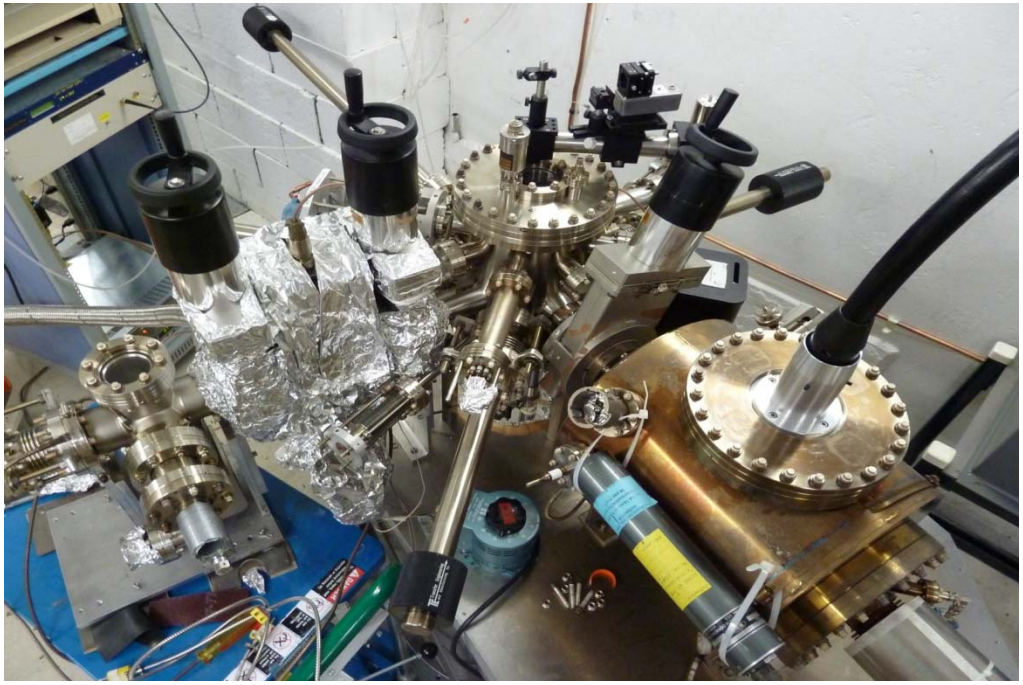


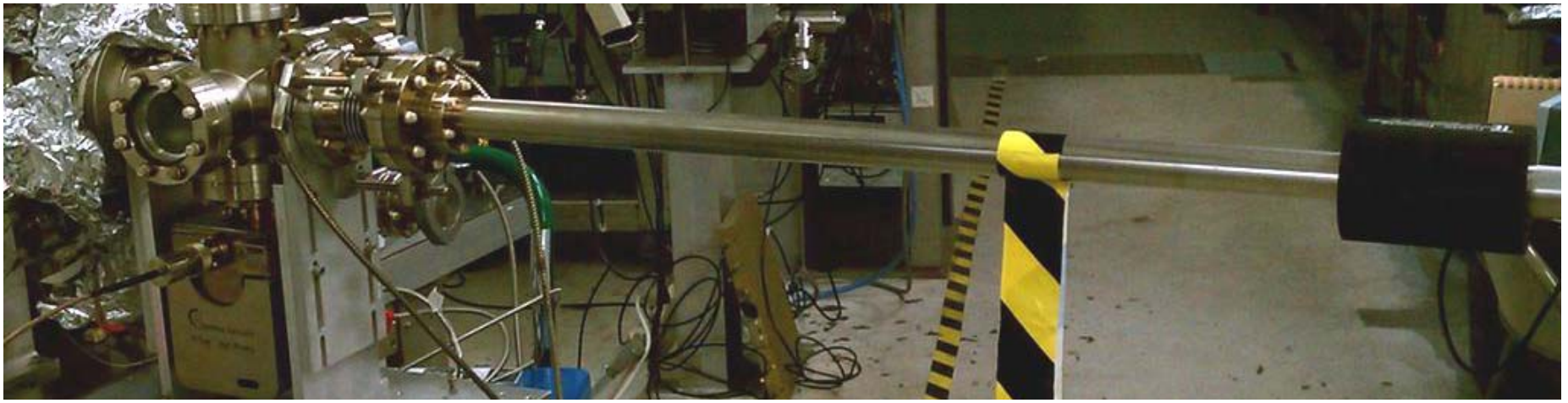


Preparation Chamber

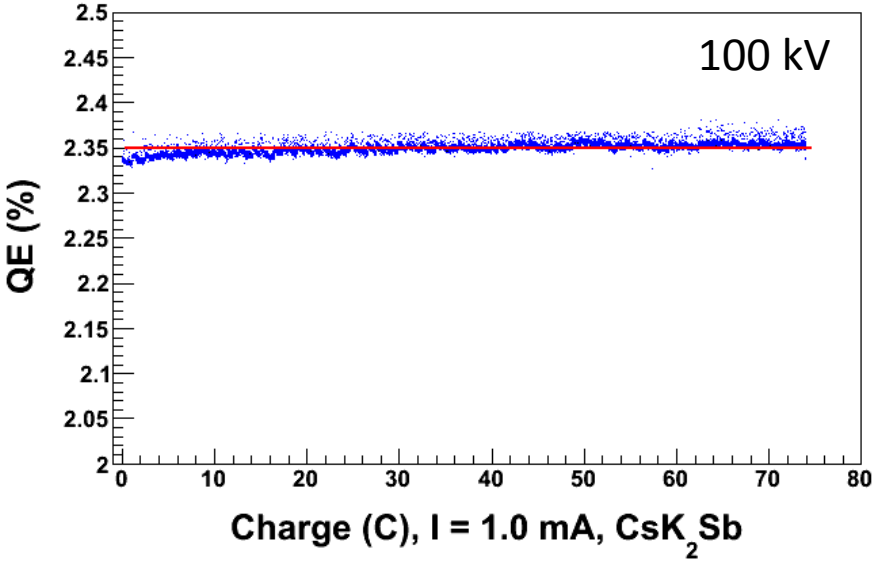


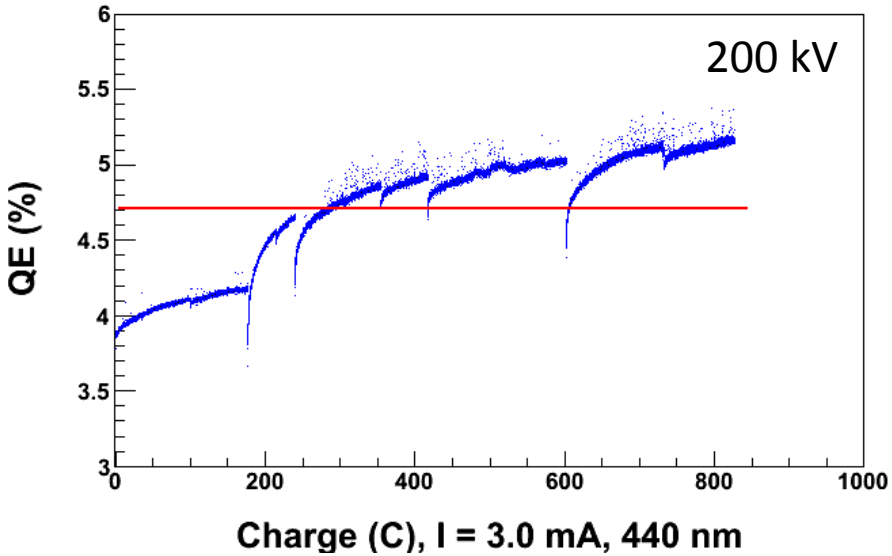
DC Gun

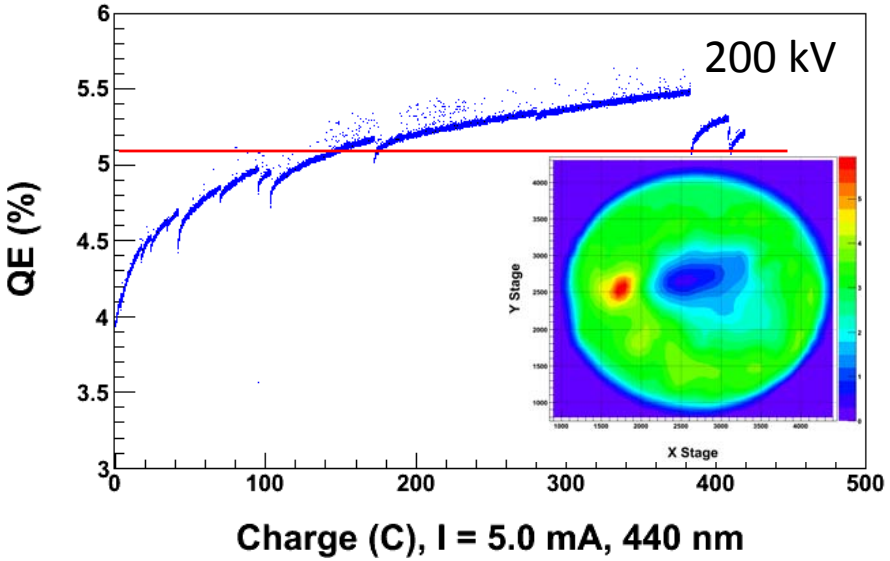




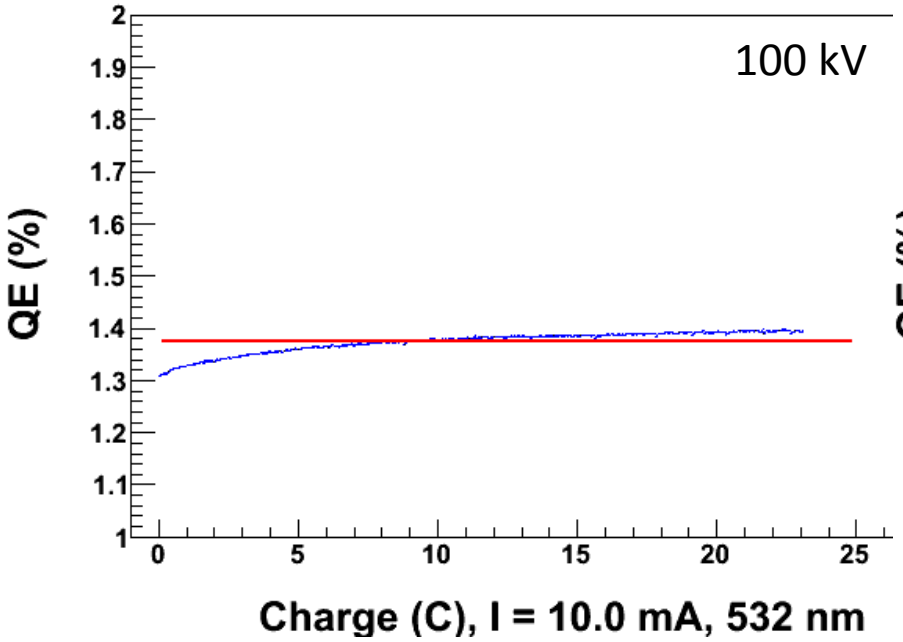
Cathode transported successfully from BNL to JLab

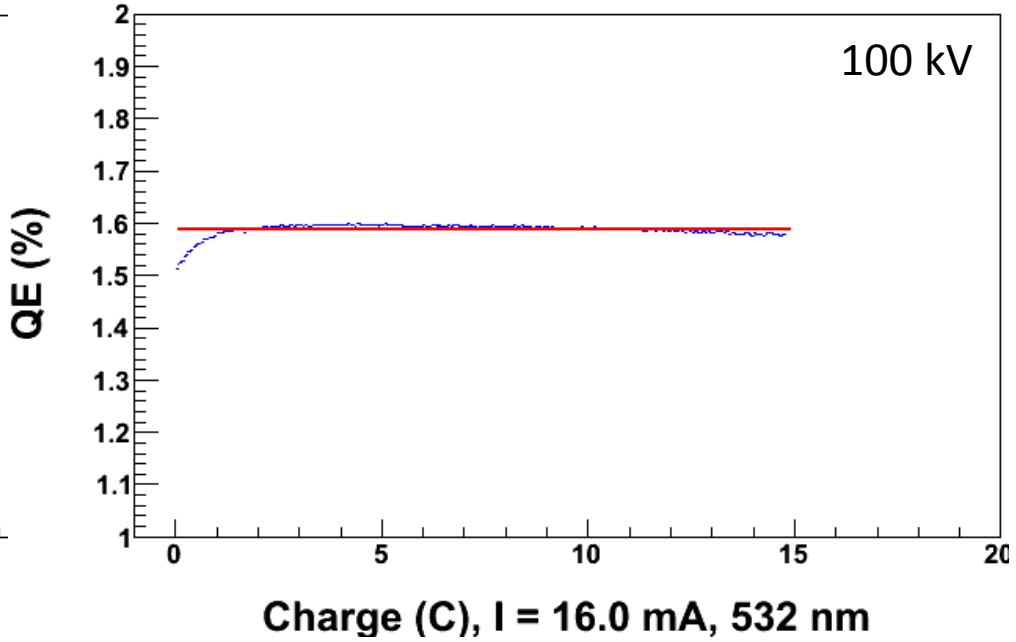






440 nm, 850 micron FWHM laser spot
Emission from EC
EC damaged during vacuum incident
Other areas still capable of emitting



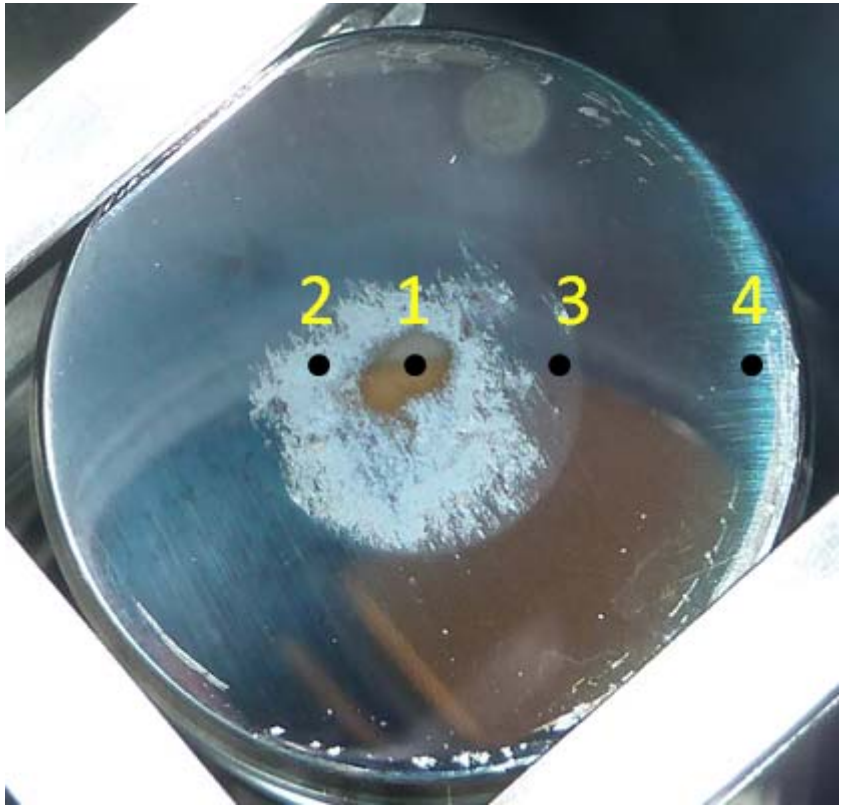


532 nm, 350 micron FWHM spot
Cathode degradation for 20 mA
Performance improved with larger spot size→ Effects due to laser heating?

More information: Poster and talk by James McCarter

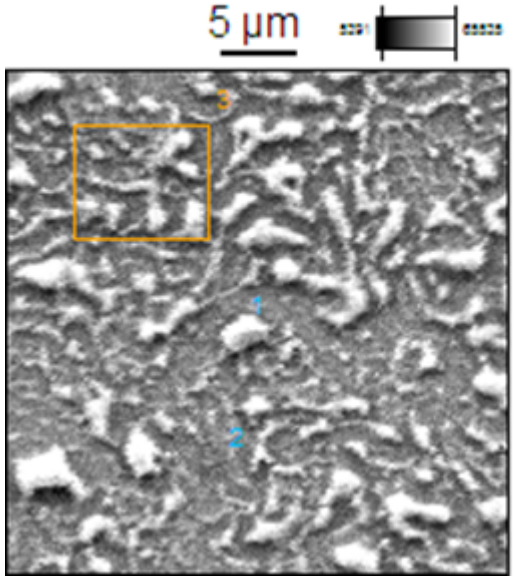
Cathode Characterization, Optimization

SEM measurements of JLab puck after use



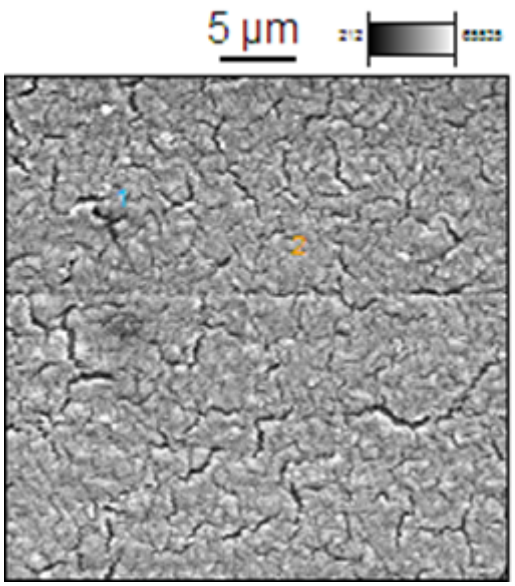
Cathode transported to SEM in microtorr vacuum/Argon environment
Images were taken at 400X or 300X and 3000X.
Xray (elemental) information was obtained at 10, 15, 20 keV electron energies

CsK2Sb_frosted_region_10kvscan_eds



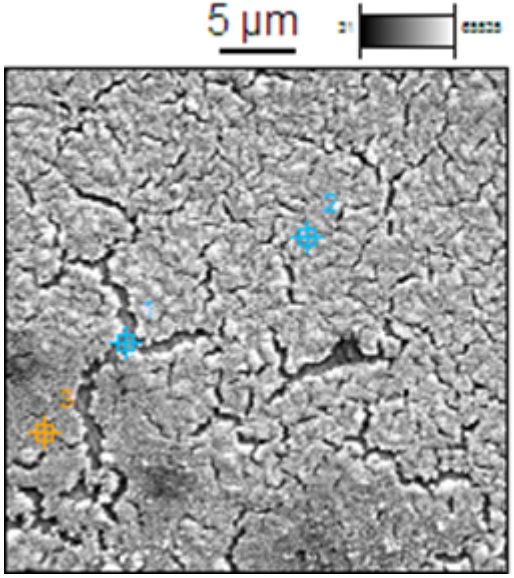
Spot 2

CsK2Sb_smooth_region_10kvscan_eds



Spot 3

CsK2Sb_edge_region_10kvscan_eds



Spot 4

Cracks and Areas between flakes are SS

Elemental Analysis

Spot 1

Element	Weight %	Weight % Error	Norm. Wt.%	Atom %	Atom % Error
C	2.51	+/- 0.31	2.51	10.65	+/- 1.29
Si	0.47	+/- 0.06	0.47	0.86	+/- 0.11
Cr	16.44	+/- 0.30	16.44	16.12	+/- 0.30
Cr	---	---	---	---	---
Mn	1.38	+/- 0.21	1.38	1.28	+/- 0.19
Mn	---	---	---	---	---
Fe	67.98	+/- 0.69	67.98	62.07	+/- 0.63
Fe	---	---	---	---	---
Ni	9.05	+/- 0.54	9.05	7.86	+/- 0.47
Ni	---	---	---	---	---
Mo	---	---	---	---	---
Mo	2.17	+/- 0.18	2.17	1.16	+/- 0.10
Mo	---	---	---	---	---
Total	100.00		100.00	100.00	

Spot 2

Element	Weight %	Weight % Error	Atom %	Atom % Error
C	4.11	+/- 0.34	15.46	+/- 1.27
O	10.91	+/- 0.30	30.80	+/- 0.86
K	2.50	+/- 0.18	2.89	+/- 0.21
K	---	---	---	---
Cr	10.46	+/- 1.14	9.09	+/- 0.99
Cr	---	---	---	---
Fe	35.93	+/- 2.78	29.06	+/- 2.25
Fe	---	---	---	---
Sb	14.21	+/- 0.69	5.27	+/- 0.25
Sb	---	---	---	---
Cs	21.88	+/- 1.06	7.44	+/- 0.36
Cs	---	---	---	---
Total	100.00		100.00	

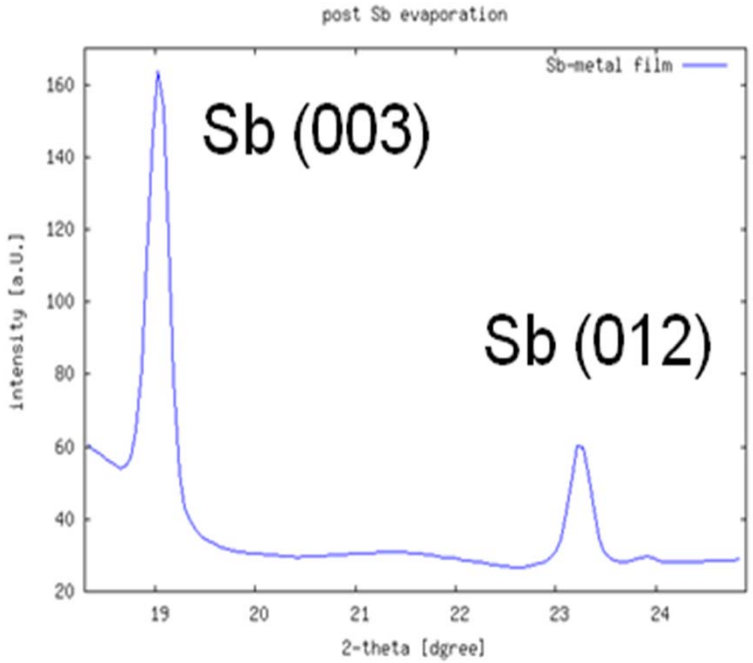
Spot 3

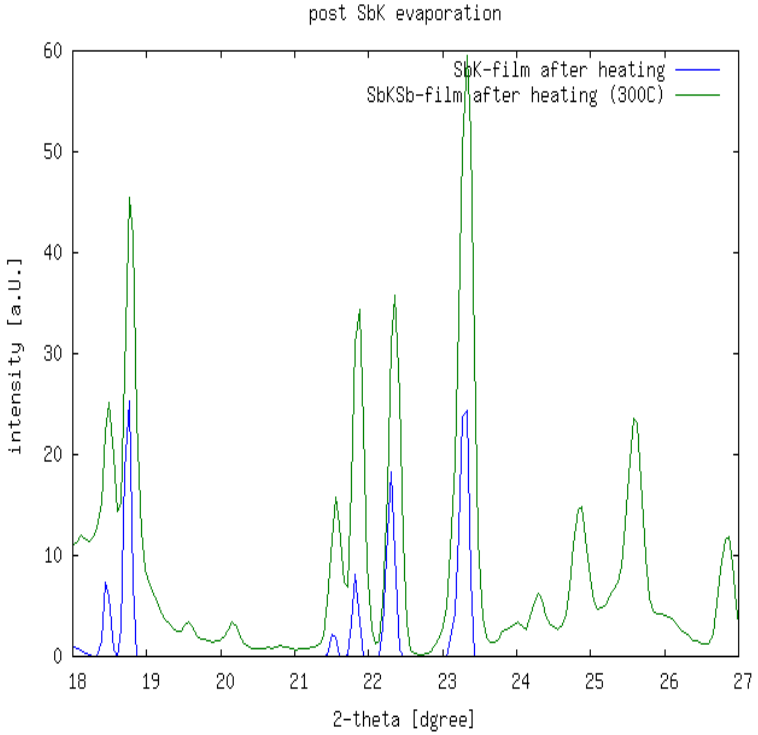
Element	Weight %	Weight % Error	Atom %	Atom % Error
C	4.74	+/- 0.38	17.55	+/- 1.42
O	13.20	+/- 0.31	36.71	+/- 0.86
F	1.08	+/- 0.56	2.52	+/- 1.31
K	4.88	+/- 0.44	5.56	+/- 0.51
K	---	---	---	---
Cr	6.32	+/- 0.99	5.41	+/- 0.84
Cr	---	---	---	---
Fe	17.59	+/- 1.40	14.02	+/- 1.11
Fe	---	---	---	---
Sb	25.22	+/- 2.09	9.22	+/- 0.76
Sb	---	---	---	---
Cs	26.97	+/- 2.41	9.03	+/- 0.81
Cs	---	---	---	---
Total	100.00		100.00	

Spot 4

Element	Weight %	Weight % Error	Atom %	Atom % Error
C	5.77	+/- 0.36	19.86	+/- 1.25
O	14.18	+/- 0.33	36.63	+/- 0.85
F	0.68	+/- 0.59	1.48	+/- 1.29
K	5.25	+/- 0.43	5.55	+/- 0.46
K	---	---	---	---
Cr	6.54	+/- 1.13	5.20	+/- 0.90
Cr	---	---	---	---
Fe	22.53	+/- 2.61	16.68	+/- 1.93
Fe	---	---	---	---
Sb	20.72	+/- 0.78	7.03	+/- 0.26
Sb	---	---	---	---
Cs	24.32	+/- 1.10	7.56	+/- 0.34
Cs	---	---	---	---
Total	100.00		100.00	

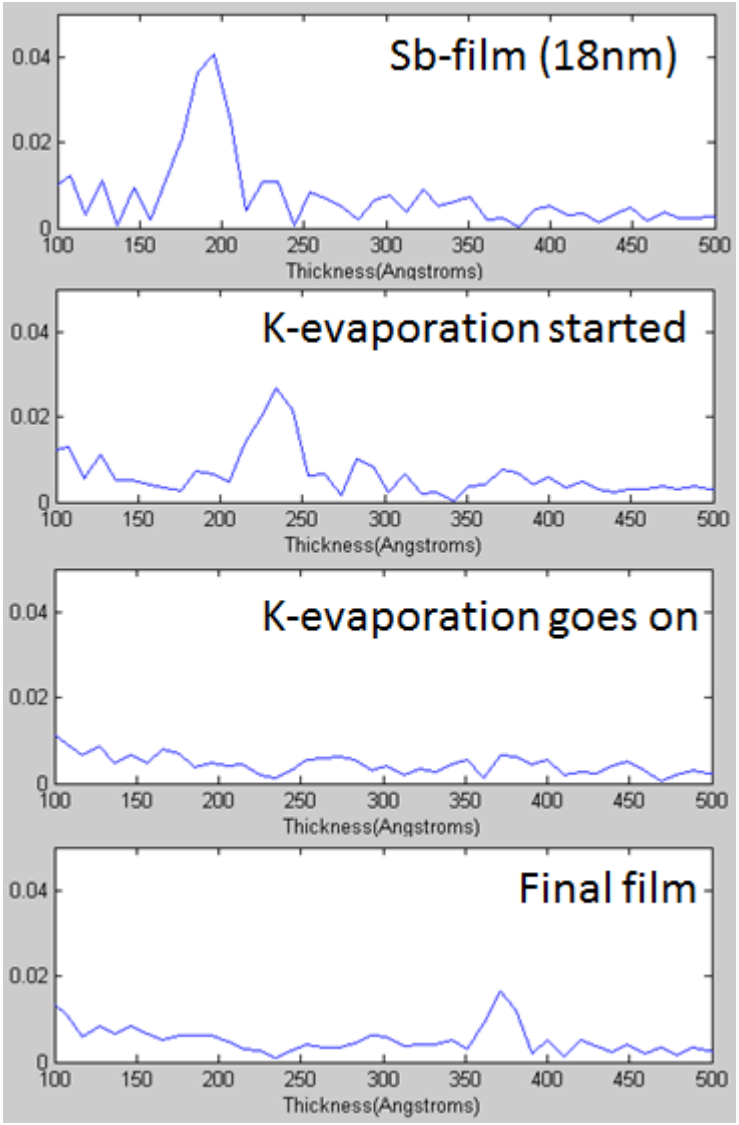
XRD Measurements: Texturing of cathode surface





Texturing of Sb-K on heating

X-Ray Reflectometry (XRR)



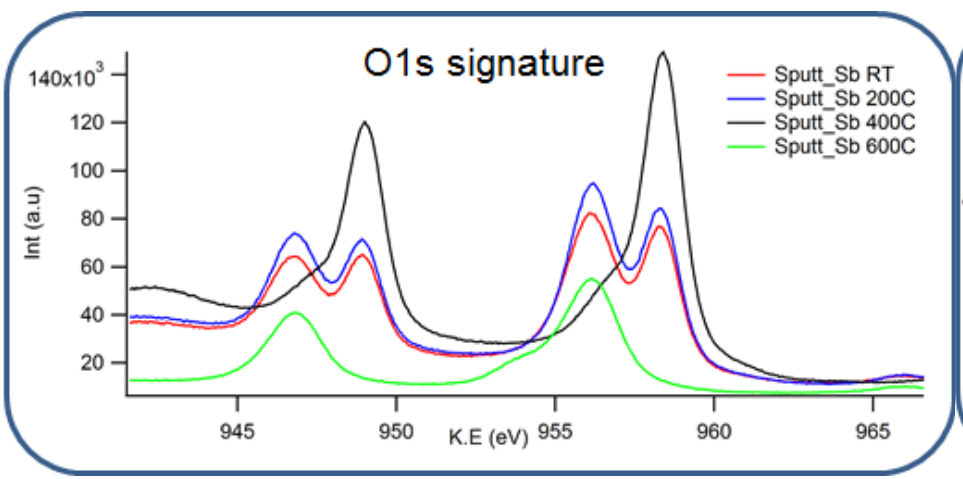
Strong Sb peak

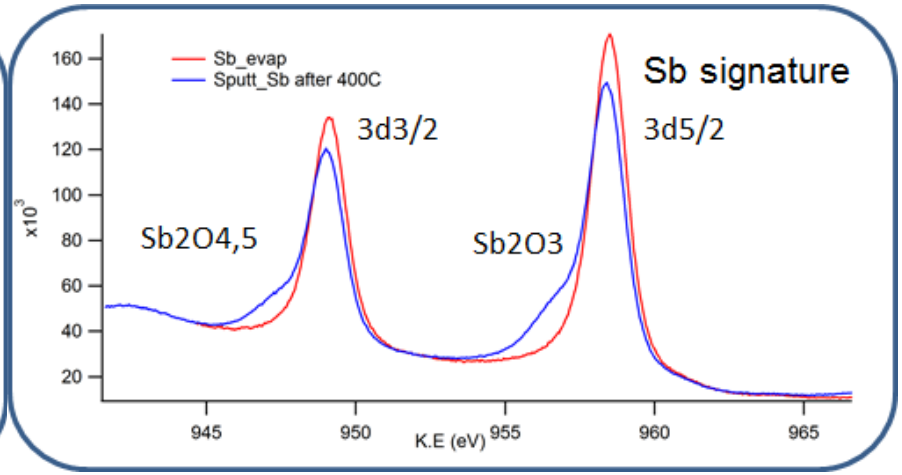
Strength of Sb peak decreases

Sb peak vanishes- Reaction to K

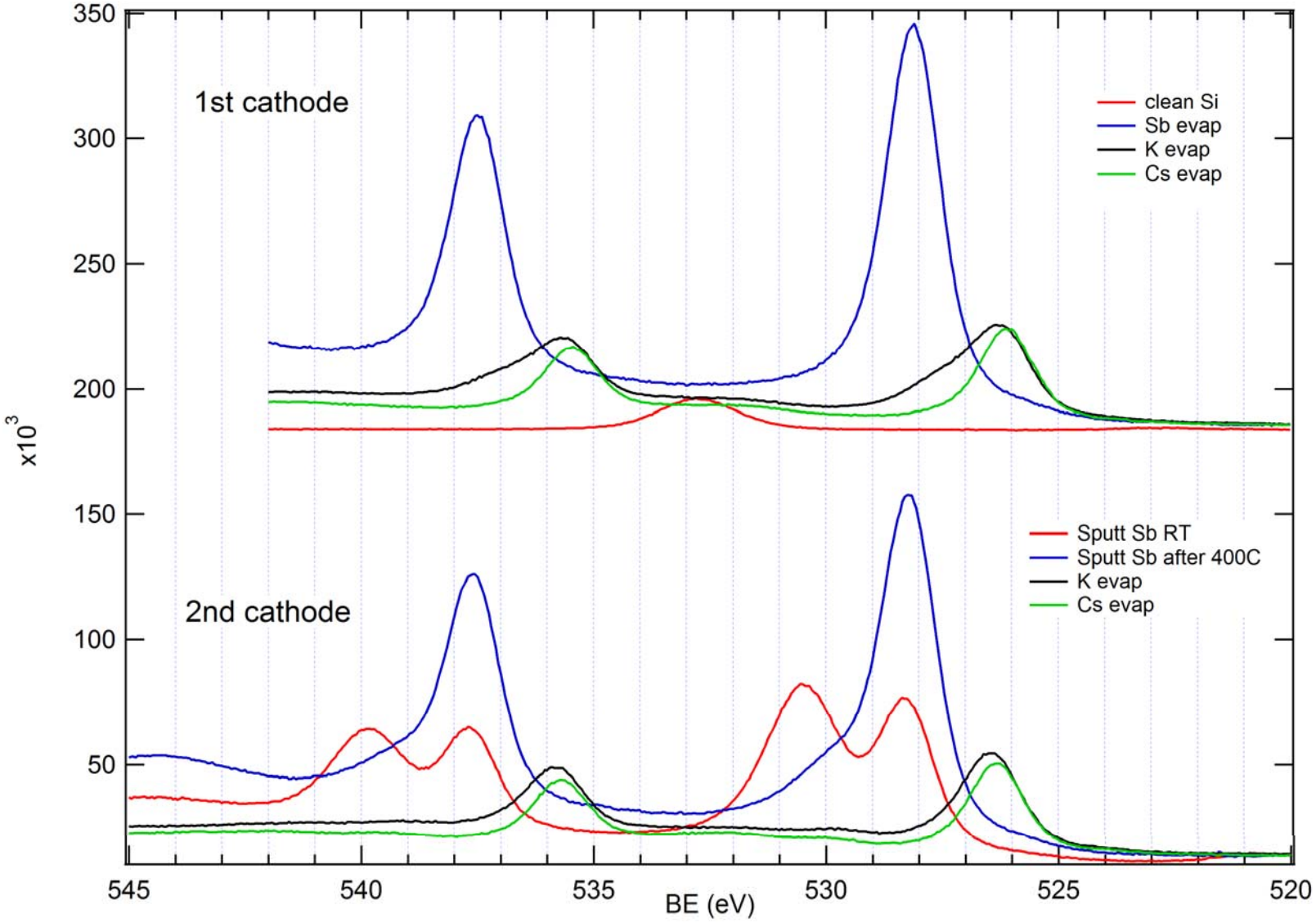
New Peak: Crystalline K_3Sb?

Comparison of Sb layer production:
Ex-situ Sb sputtered Si, heated to remove O





Comparison of Cathodes



Future Plans

- Cathode Test:
  - 704 MHz gun in a few months
  - 112 MHz within a year
  - DC gun ongoing, modify puck for X-Ray analysis
- Characterization and optimization:
  - Ongoing
  - New, UHV chamber under construction

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