Thermal Degradation of Alkali Antimonide Cathodes

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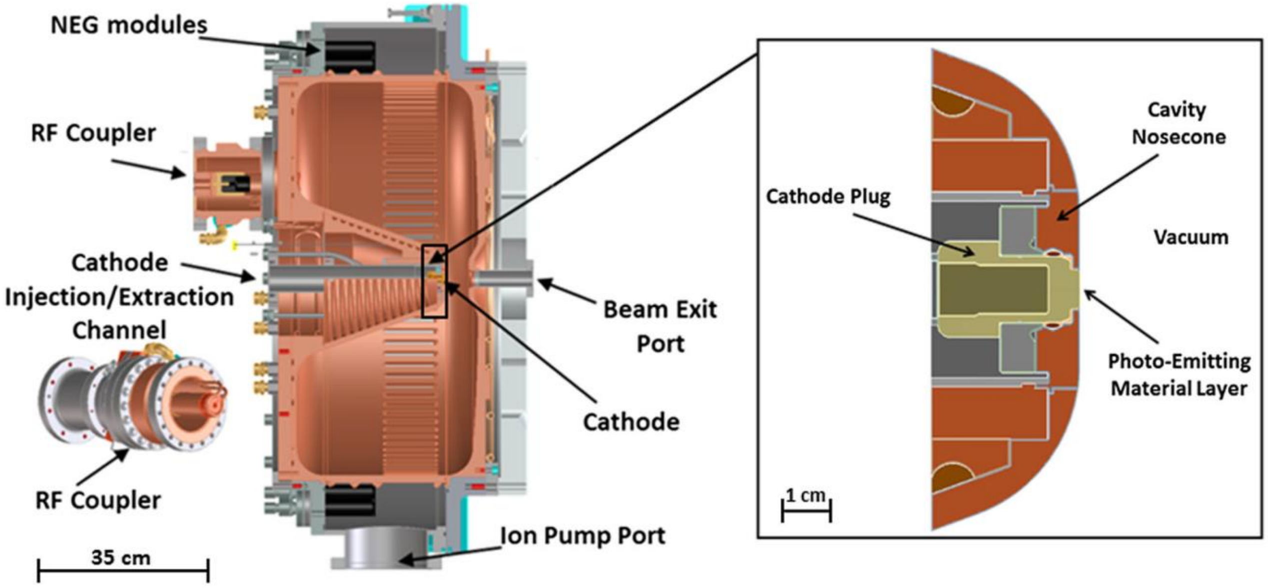
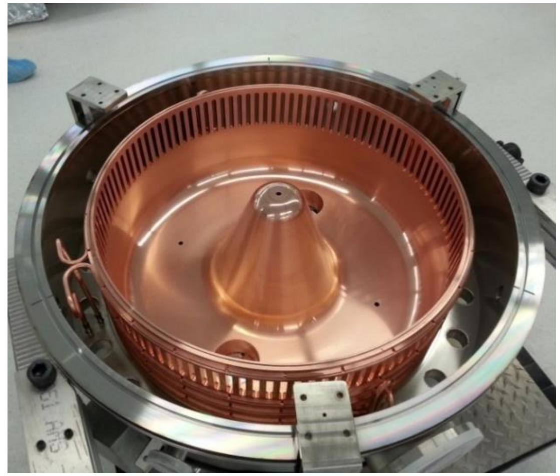
APEX Photoinjector

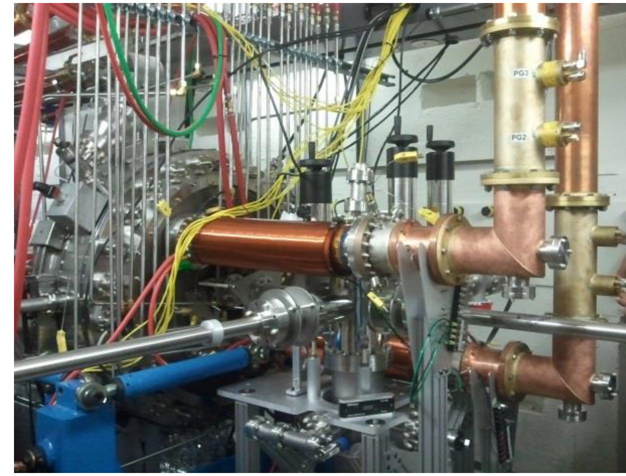
F. Sannibale *et al.*, Advanced photoinjector experiment photogun commissioning results, Phys. Rev. ST Accel. Beams **15**, 103501 (2012).

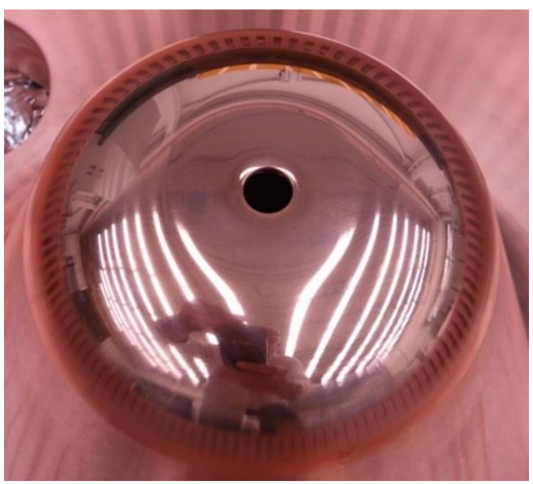


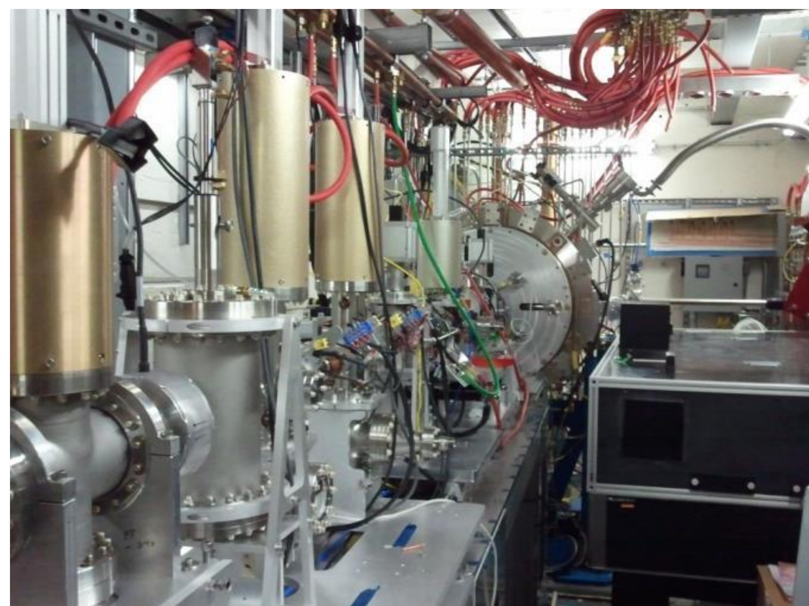
Frequency (7th sub-harmonic of 1.3 GHz)	186 MHz
Operation mode	CW
Gap voltage	750 kV
Field at the cathode	19.47 MV/m
Q_0 (ideal copper)	30887
Shunt impedance	6.5 MΩ
RF Power @ Q_0	87.5 kW
Stored energy	2.3 J
Peak surface field	24.1 MV/m
Peak wall power density	25.0 W/cm^2
Accelerating gap	4 cm
Diameter/Length	69.4/35.0 cm
Operating pressure	~ 10^{-10}-10^{-9} Torr

APEX Photoinjector



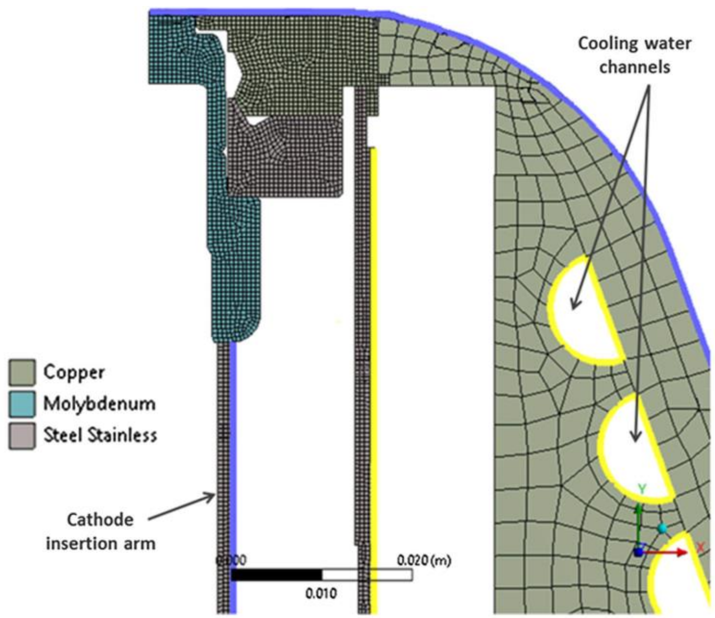


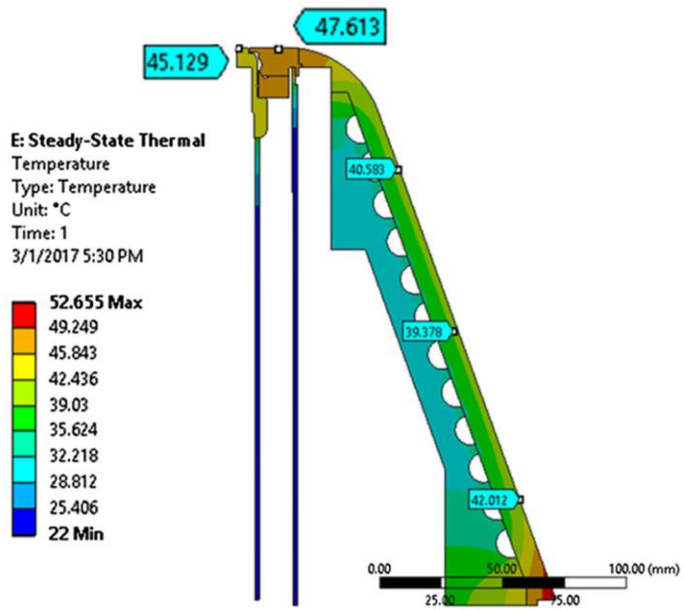




APEX Nosecone Heating

F. Sannibale *et al.*, Advanced photoinjector experiment photogun commissioning results, Phys. Rev. ST Accel. Beams **15**, 103501 (2012).



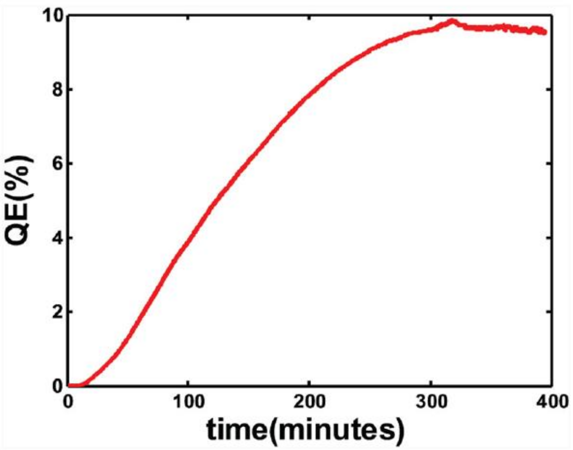


APEX cathode plugs

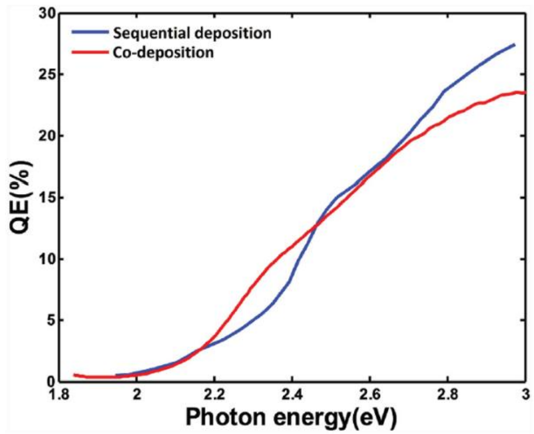
Maximum temperature under full power ~ 52°C

Ternary Co-evaporation of cathodes for APEX

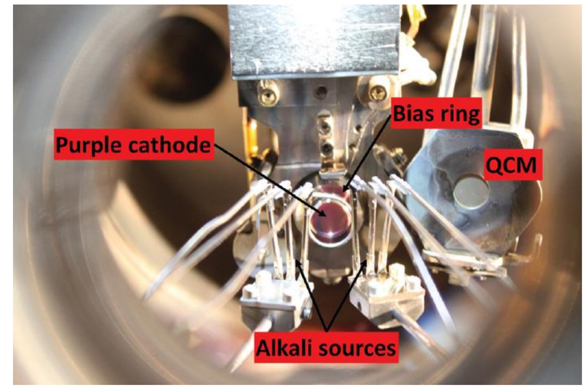
K_2CsSb yield growth curve

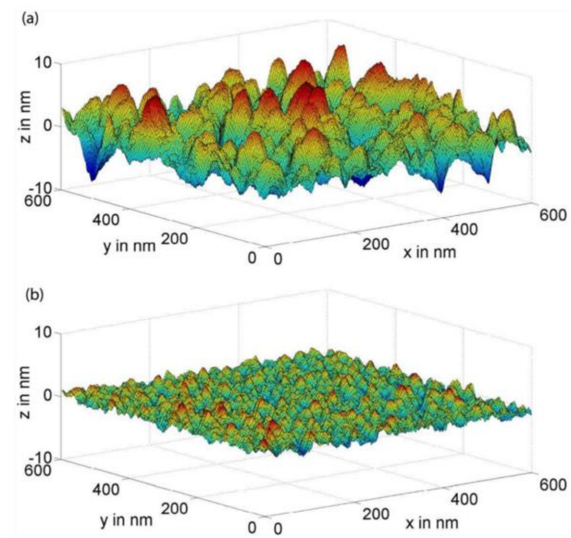


K_2CsSb QE(energy)



distinctive purple color cathodes





- Simultaneous deposition of Sb, K, Cs (90C)

  - 4 parameter initial search for correct conditions

- Very robust and repeatable method

- 7% QE is routinely achieved @ 532 nm

JOURNAL OF APPLIED PHYSICS **121**, 044904 (2017)

Near atomically smooth alkali antimonide photocathode thin films

Jun Feng,[1,a)] Siddharth Karkare,[1] James Nasiatka,[1] Susanne Schubert,[1] John Smedley,[2] and Howard Padmore[1]

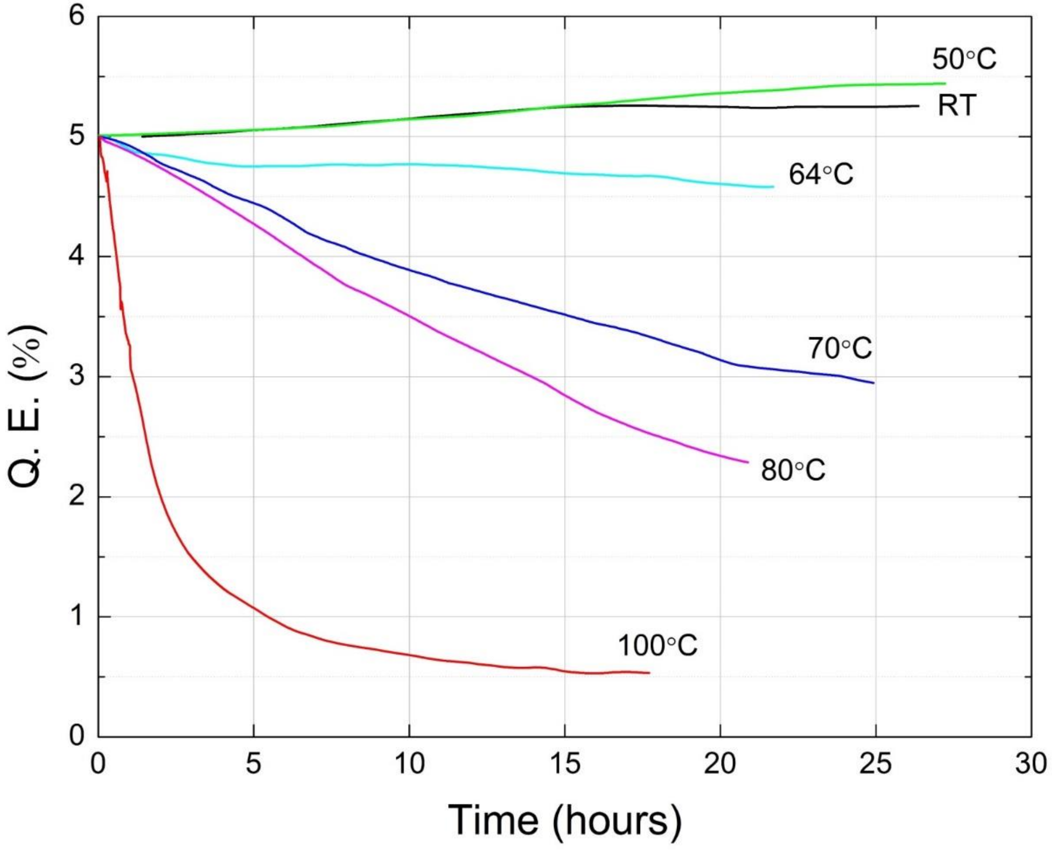
Questions

- How is cathode lifetime affected by operating temperature
- What is the mechanism of thermal damage
- Can the QE be recovered in some way

Method

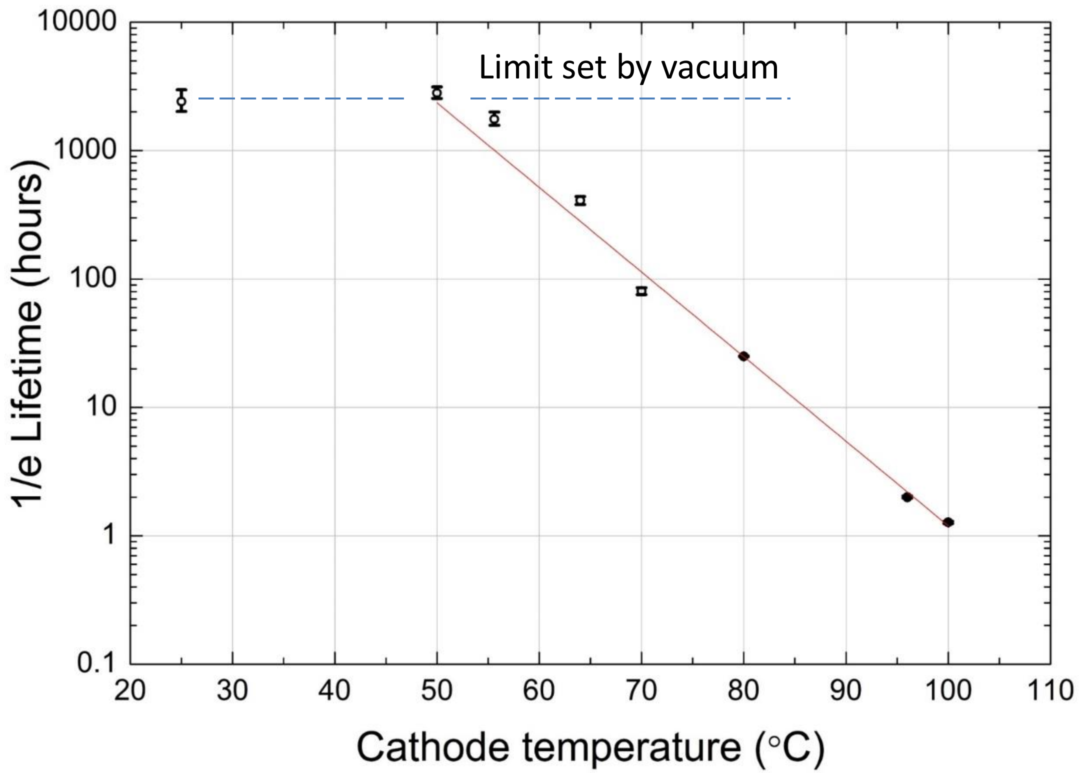
- Prepare many cathodes by co-deposition (K_2CsSb, Cs_3Sb)
  - measure QE (wavelength)
  - refine method to make cathodes as close to identical as possible
- Measure QE (time) at defined temperature
- Repeat for range of temperatures
  - 1 cathode for each temperature….a tedious measurement

QE decay curves of K_2CsSb at 532 nm

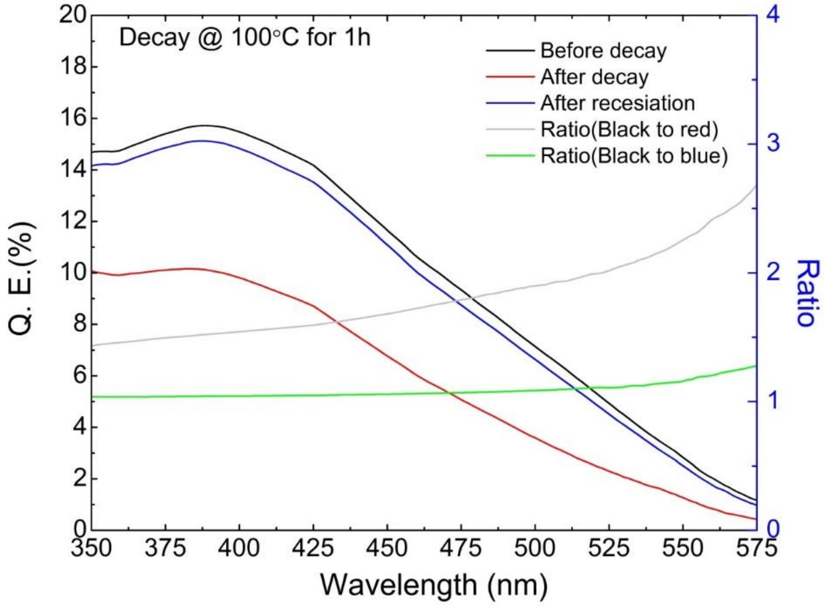


Initial QE in range 4.5 – 5.5% and normalized to 5%

Lifetime of K_2CsSb at 532 nm



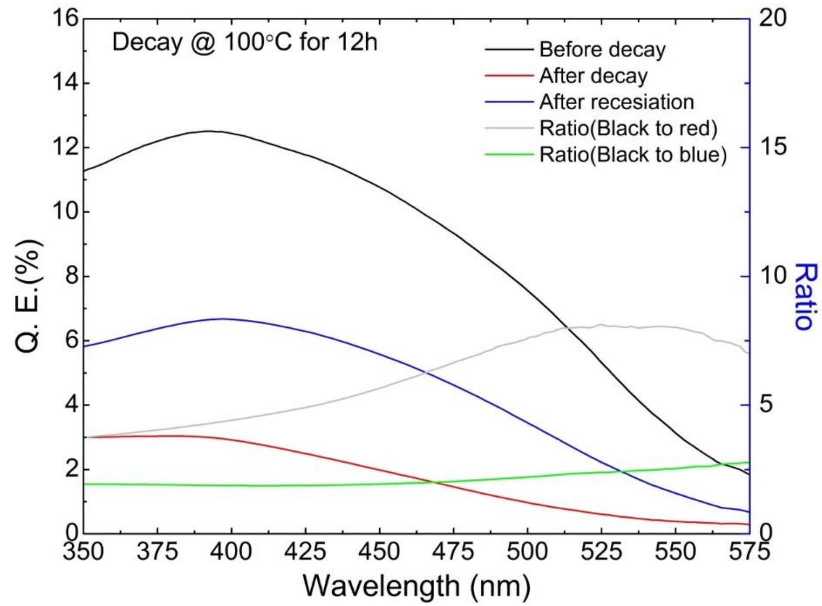
K_2CsSb: Full recovery of yield by re-cesiation: 100°C for 1 hr



100°C for 1 hour

- Factor of 2.7 loss in QE @ 575 nm, 1.4 @ 350nm
- Re-cesiation recovers ~100% of QE

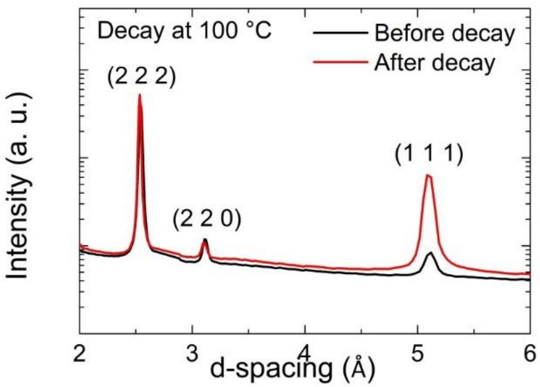
K_2CsSb: Partial recovery of yield by re-cesiation: 100°C for 12 hrs



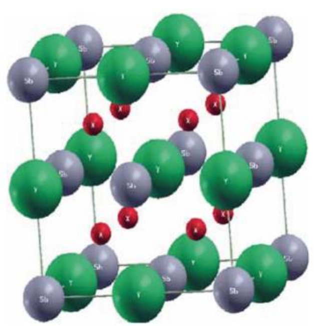
100°C for 12 hrs

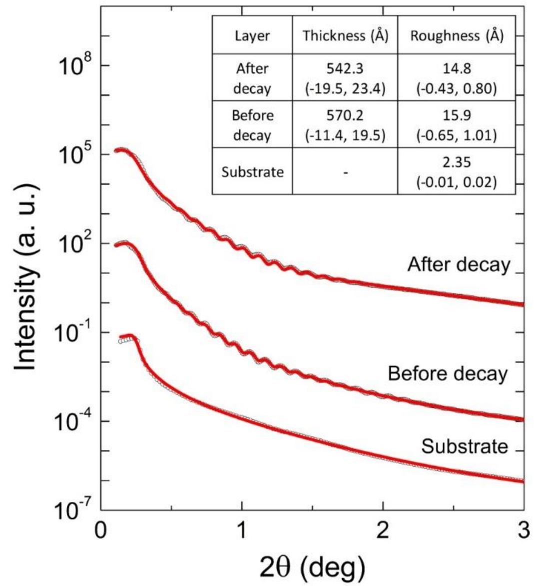
- Factor of 7 loss @ 575 nm, 3 @ 350 nm
- Re-cesiation recovers only a fraction of initial QE
  - 40% at 575 nm and 53% at 350 nm

K_2CsSb: 100° C and 1.5 hrs induces structural changes



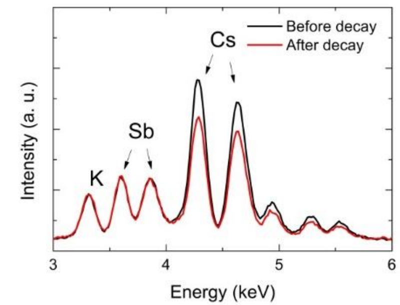
- (111) reflection not allowed
- (111) indicates strain or disorder
- Large (111) intensity after heating indicates disorder
- crystal symmetry remains the same after heating

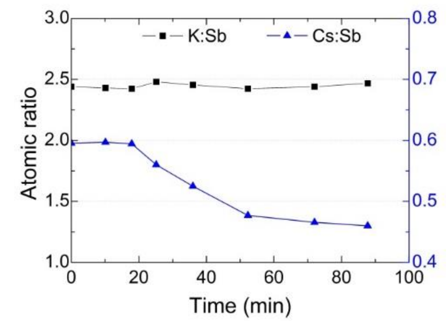




Layer	Thickness (Å)	Roughness (Å)
After decay	542.3 (-19.5, 23.4)	14.8 (-0.43, 0.80)
Before decay	570.2 (-11.4, 19.5)	15.9 (-0.65, 1.01)
Substrate	-	2.35 (-0.01, 0.02)

- Thickness reduced by 5% after heating
- Out of plane roughness similar after heating





- x-ray induced x-ray fluorescence
  - Indicates loss of Cs
  - No loss of K or Sb

Summary: Thermal decomposition studies

- Safe operating range with K_2CsSb up to around 55°C
  - Slightly higher than APEX cathode when under full power
- Decomposition via loss of Cs, and partial recovery possible
- Cs_3Sb much less stable, NaKSb much more stable

Workfunction Imaging using LEEM

S. Karkare*, S. Emanian, G. Gevorkian*, H. A. Padmore (ALS, LBNL: * now ASU)

A. Galdi (Cornell)

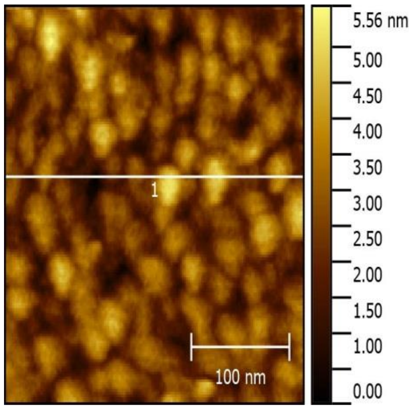
A. Schmid (Molecular Foundry, LBNL)

- Emittance depend on physical and chemical roughness
    - Physical roughness UHV AFM
    - Chemical roughness KPFM, LEEM and PEEM

Work function variation for K_2CsSb and Cs_3Sb

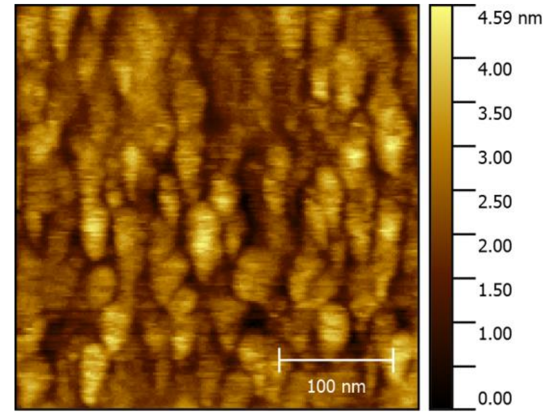
K_2CsSb

Height:
Rms 0.8 nm: pp 5.5 nm



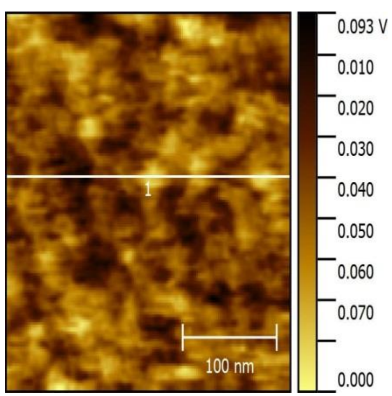
AFM measurements

Height:
Rms 0.7 nm: pp 4.6 nm



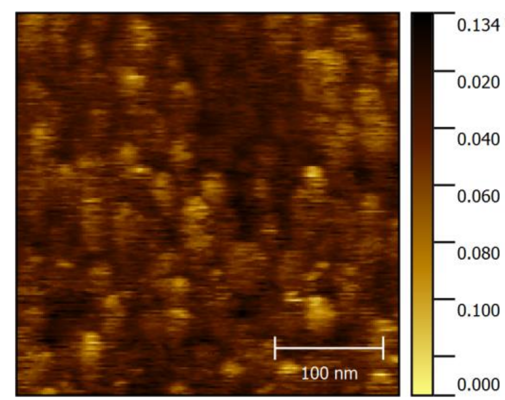
Cs_3Sb

Work function:
rms 14 meV: pp 93 meV



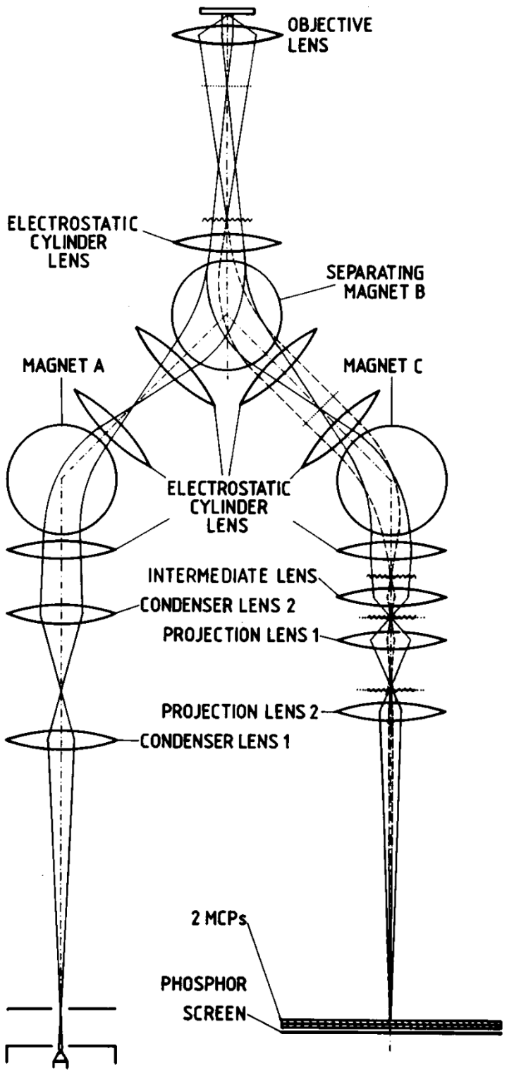
Kelvin probe measurements

Work function:
rms 15 meV: pp 134 meV



- KPFM measurements difficult and somewhat unreliable
- Use LEEM to measure work function

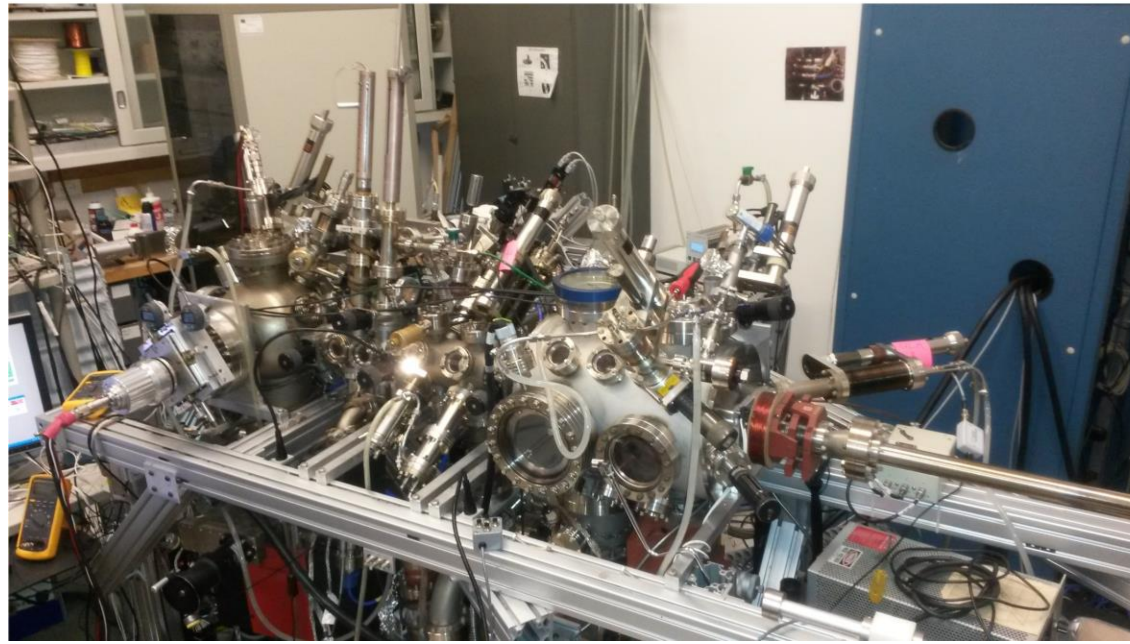
Spin Polarized Low Energy Electron Microscopy (SPLEEM)

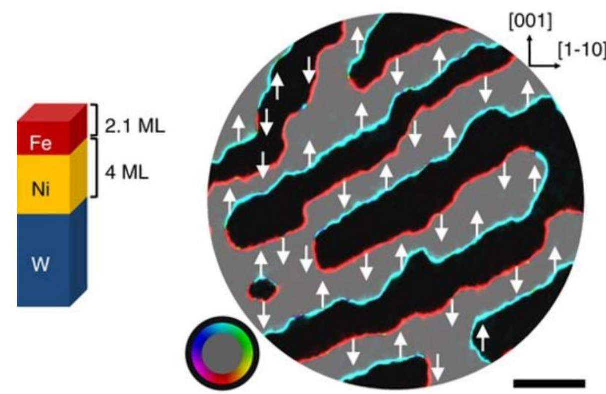


A flange-on type low energy electron microscope

K. Grzelakowski[a)] and E. Bauer
Physikalisches Institut, Technische Universitaet Clausthal, D 38678 Clausthal-Zellerfeld, Germany

Rev. Sci. Instrum. 67 (3), March 1996



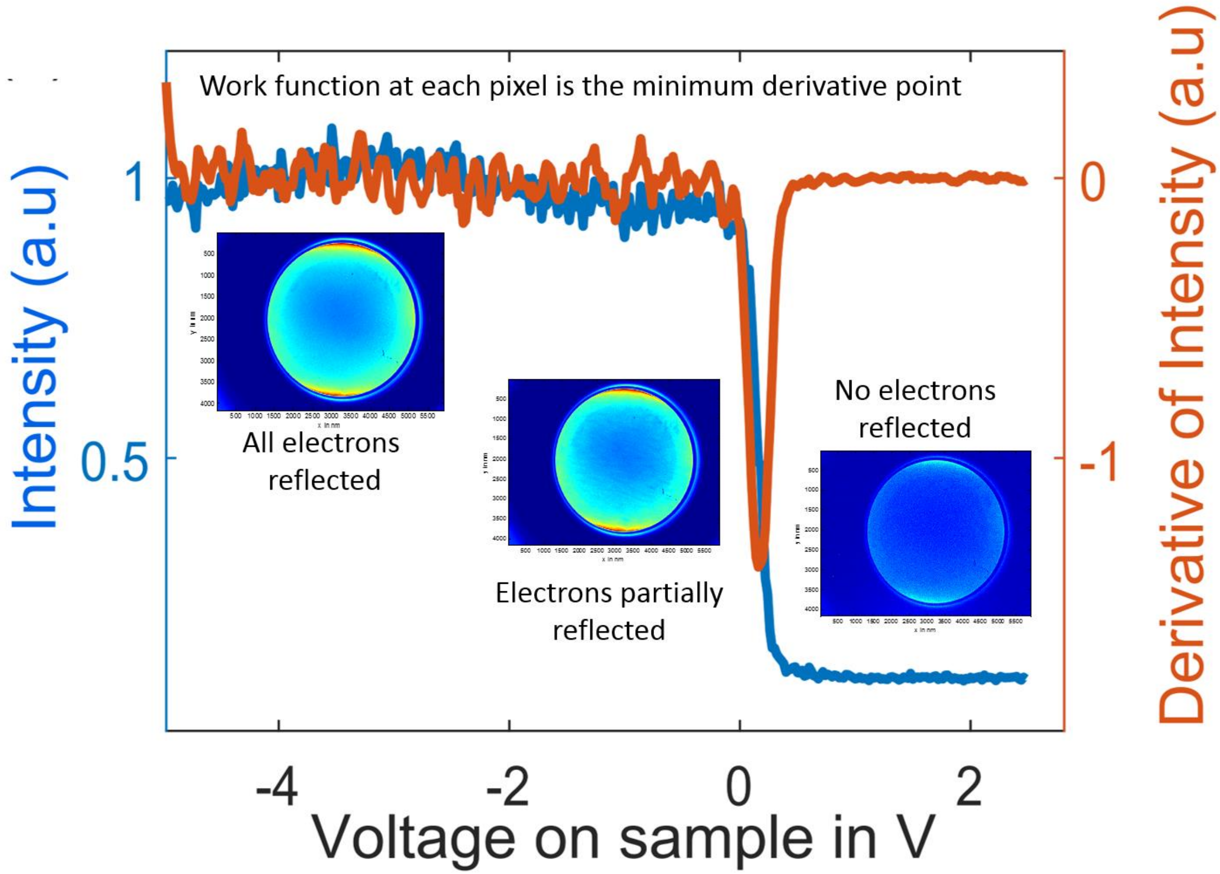


Unlocking Bloch-type chirality in ultrathin magnets through uniaxial strain

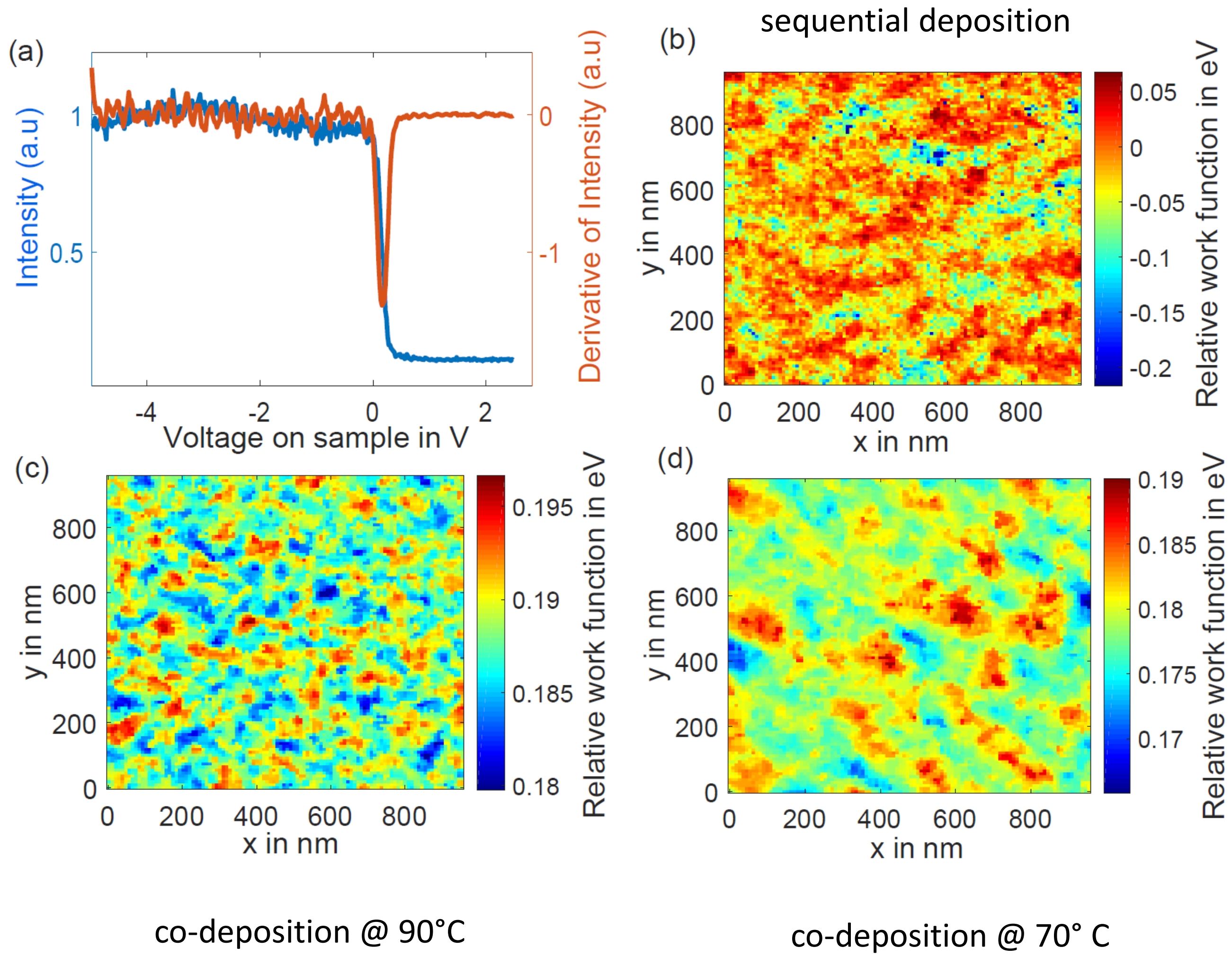
Gong Chen, Alpha T. N'Diaye, Sang Pyo Kang, Hee Young Kwon, Changyeon Won, Yizheng Wu, Z. Q. Qiu & Andreas K. Schmid

Nature Communications **6**, Article number: 6598 (2015) | Download Citation

(SP)LEEM measurements of work function



LEEM measurement of work function of Cs_3Sb



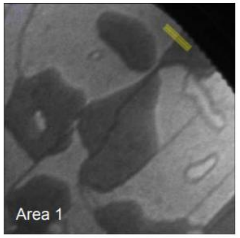
Same amplitude, much lower spatial frequencies at 70°C (lower transverse fields)

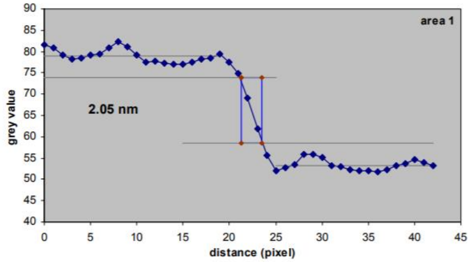
Summary: work function imaging using LEEM

Aberration corrected LEEM, 2 nm resolution

- 20 nm spatial resolution (2 nm)
- 5 meV work function 'noise'
- Chemical potential roughness causes strong lateral potential gradients that degrade emittance
- Strong dependence of gradients on deposition temperature
- More work to be done on Cs3Sb at different growth temperatures, rates, and other antimonides

SPECS





Ultramicroscopy

Volume 110, Issue 7, June 2010, Pages 852-861

A new aberration-corrected, energy-filtered LEEM/PEEM instrument. I. Principles and design

R.M. Tromp [a], J.B. Hannon [a], A.W. Ellis [a], W. Wan [b], A. Berghaus [c], O. Schaff [c]

The best probe should be PEEM (photon energy)…..1st attempt not successful due to low flux

New coherent supercontinuum source being tested…..a Fowler plot / pixel at few nm resolution!

QUESTIONS