Progress on cathode R&D for high intensity electron source in support of EIC

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On behalf of the collaboration

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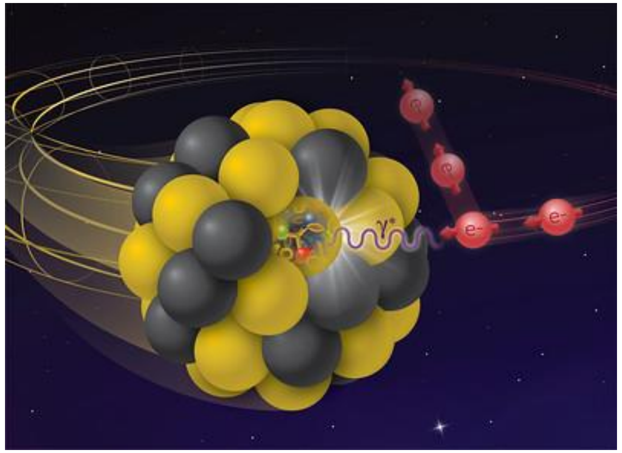
Unpolarized photocathodes for EIC electron cooling

- **To maintain a luminosity of L= $10^{34} cm^{-2} s^{-1}$ in the Electron Ion Collider (EIC) during long collision runs, it is desirable to cool the hadron beams in order to balance emittance growth rates due to intrabeam scattering (IBS)**
- **Electron cooling is a promising technique to improve the luminosity of high current beams and has been demonstrated to cool proton beams**



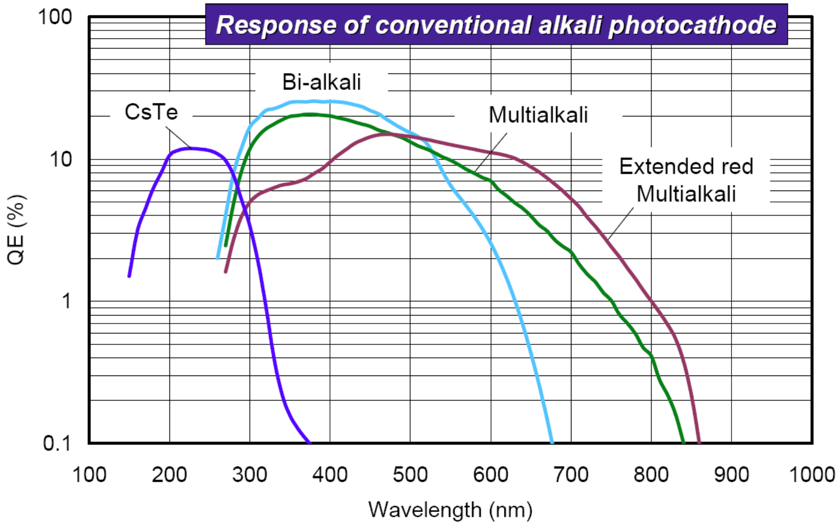
Electron beam required for e-cooling in EIC

- High average current (> 100 mA)
- High bunch charge (1nC)
- Long lifetime (> 1 week)
- Reproducible

Current state-of-the-art/practice: alkali antimonide photocathode

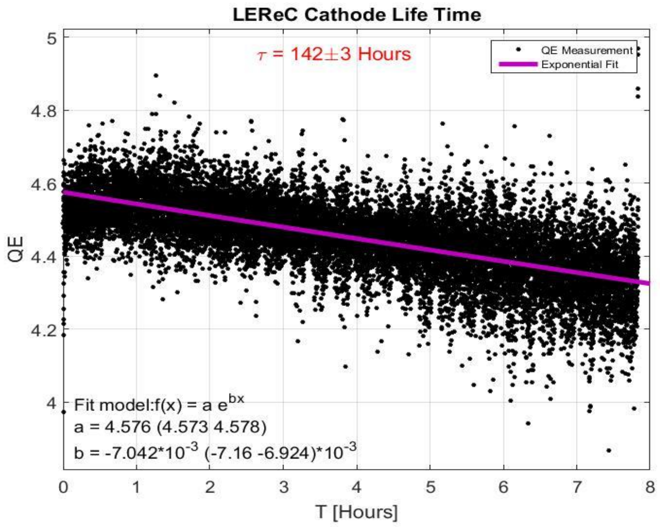
Excellent photocathode for electron cooling: good combination of properties

- High quantum efficiency in visible light range
- Less sensitive to vacuum than GaAs:Cs



Has been demonstrated in practice

- Cornell University: 65 mA, 60 pC bunch charge for 2 days
- LEReC @ BNL: 50mA for hours; 15~20 mA average current for weeks of operation, and 20K C charge lifetime



25 mA;
t = 142 h;
QE > 4%

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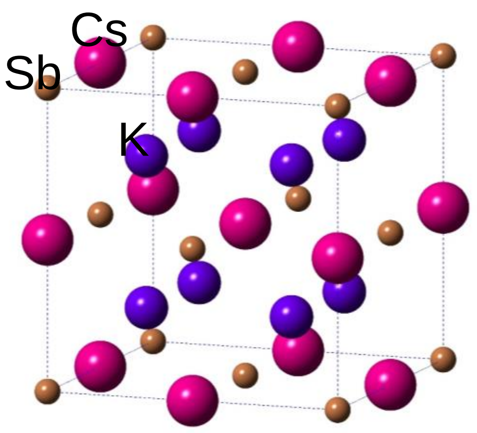
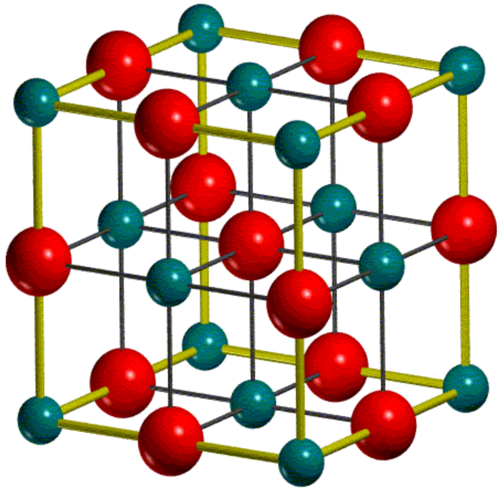
Research Approach

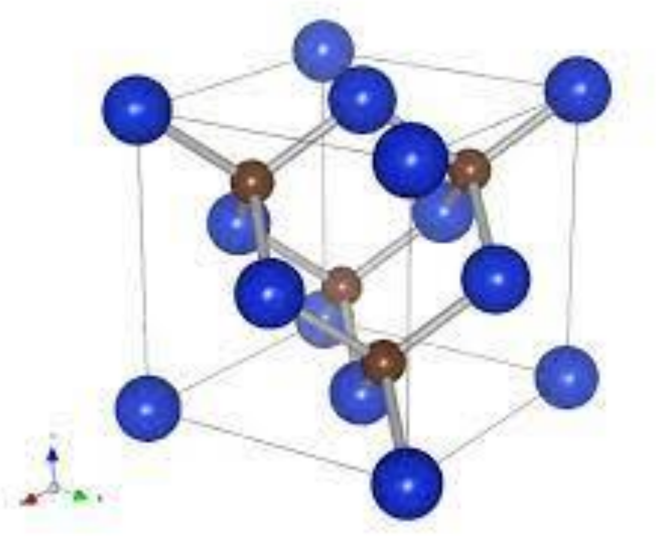
Cathode Material development	Transfer system development	High current test
• **Epitaxial growth of single crystal cathode material** • **Upgrade with RHEED** • **Bulk single crystal growth**	• **Existing design and experience**	• **High current test chamber** • **Gun test in tunnel** • **Material characterization for degraded cathodes**

Epitaxial growth of alkali photocathode



K_2CsSb unit cell





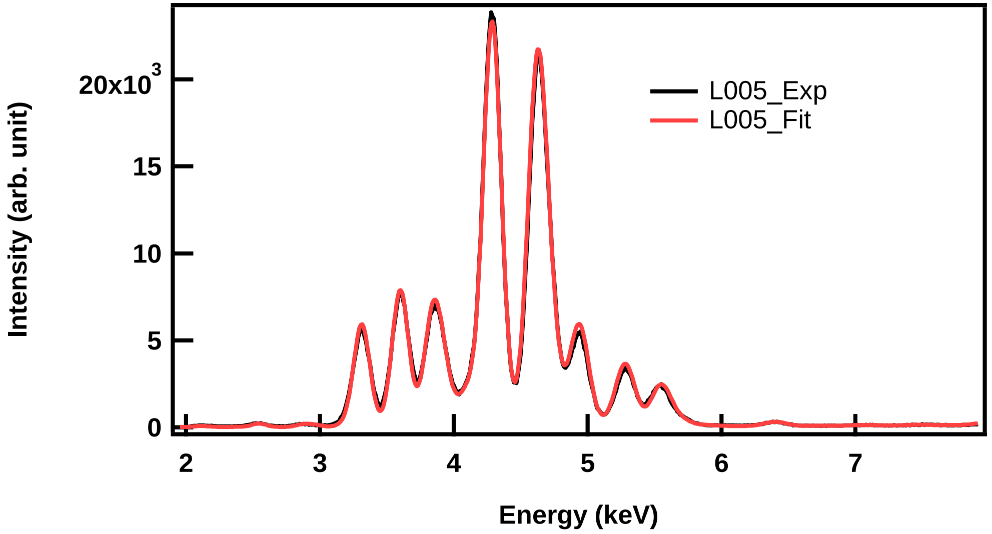
K_2CsSb, Cs_3Sb: b.c.c. crystal structure
Lattice parameter: 8.615 Å, 9.18 Å

MgO: f.c.c. crystal structure
Lattice parameter: 4.21 Å

3C-SiC: f.c.c. crystal structure
Lattice parameter: 4.35 Å

Co-evaporation for epitaxial growth

XRF analysis

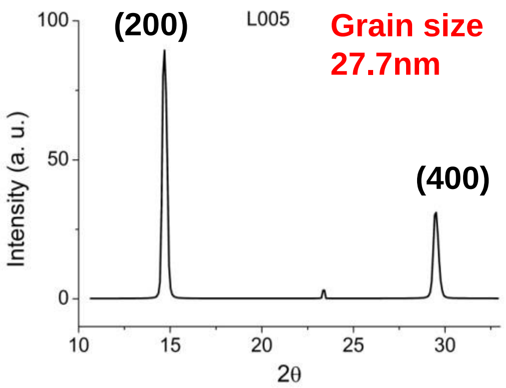


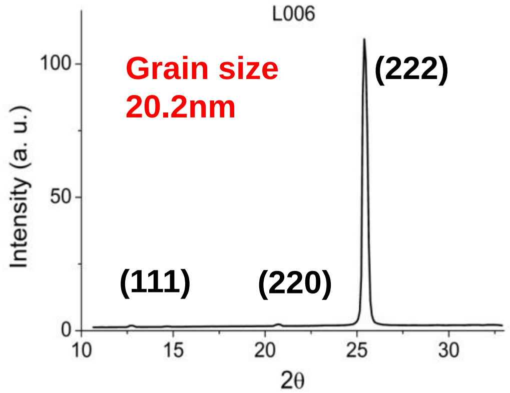
Calculated atomic compositions

	K	Sb	Cs
L005 Si	2.37	1.00	0.91
L006 Si	2.21	1.00	0.95
L011 Si	2.07	1.00	0.94
L012 MgO	1.98	1.00	0.88

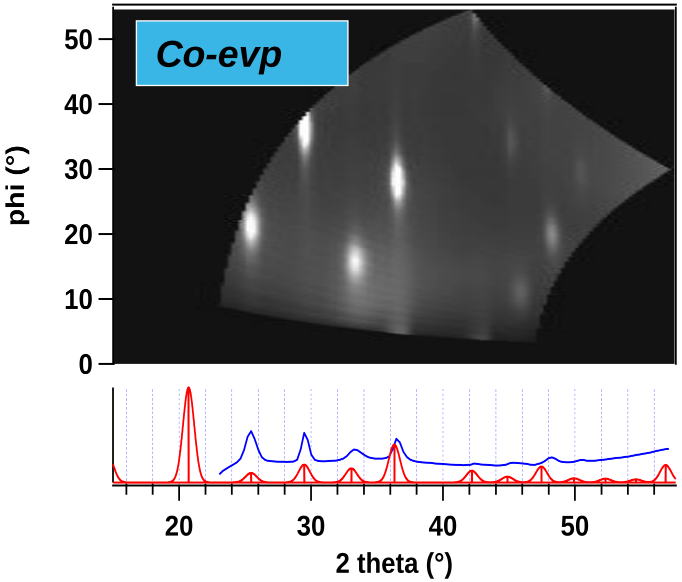
Good K/Cs/Sb ratio!

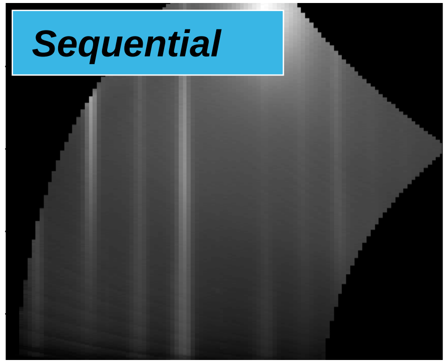
XRD: Camera 1



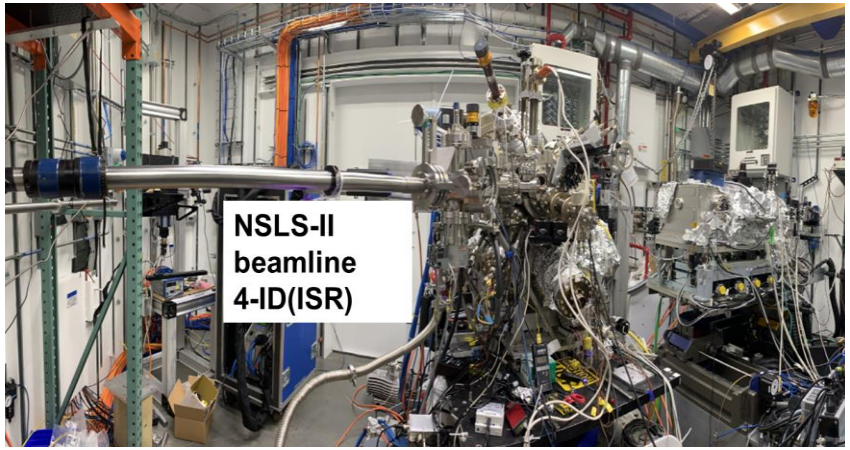


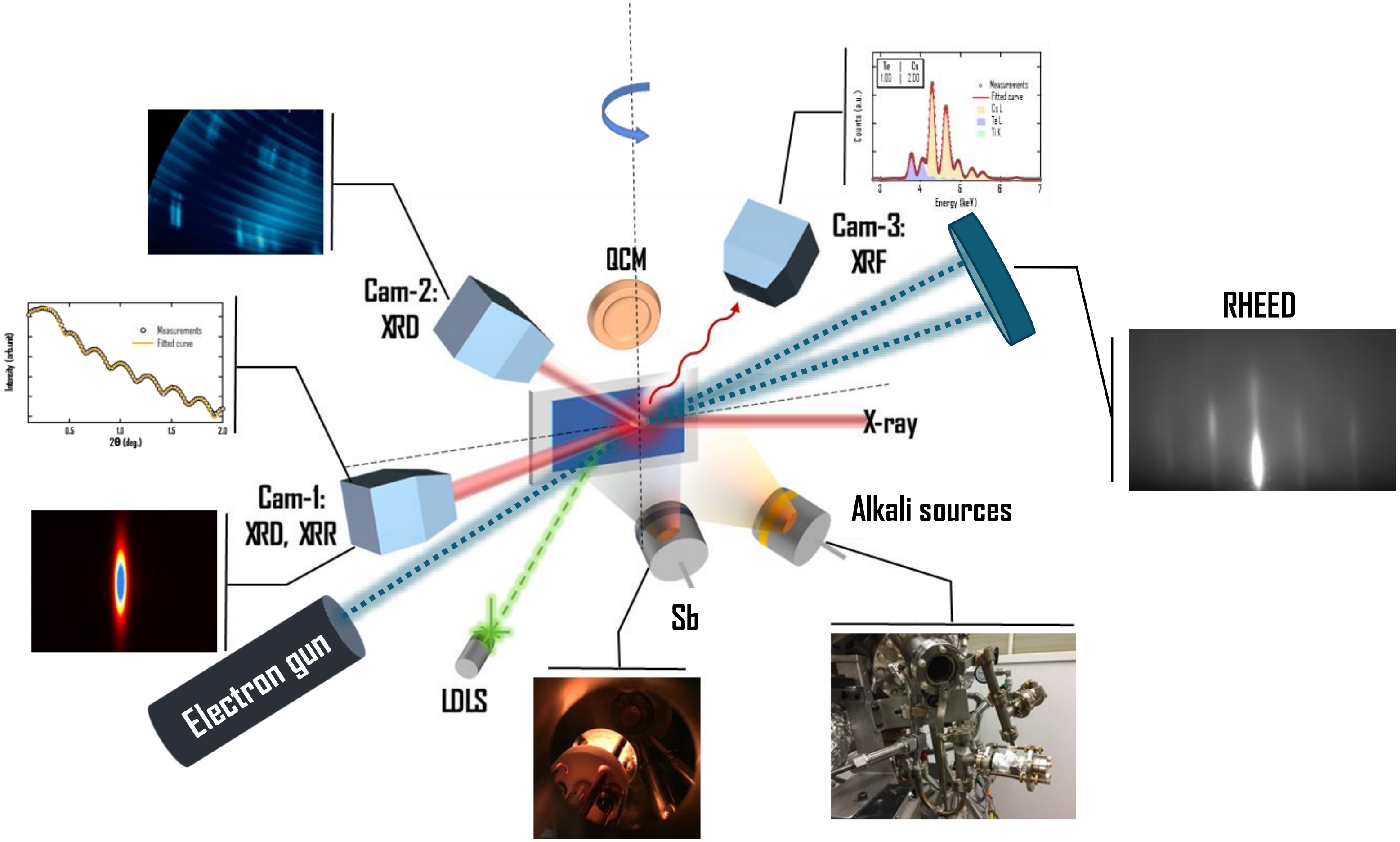
XRD: Camera 2





Cathode Material development
--Scientific basis





Evaporators:
- ❑ Thermal Sb/Te
- ❑ Alkali metals
- ❑ PLD Sb/Te

Characterization:
- ❑ QCM
- ❑ XRD
- ❑ XRR
- ❑ XRF
- ❑ QE
- ❑ RHEED

Experiment participants come from various institutions: LANL, SLAC, Cornell U, ASU, IBM, Leiden U, U Vienna, HZB, and more

Upgrade for offline characterization: RHEED

A reflection high energy electron diffraction (RHEED) system is a standard in-situ diagnostic that is mainly sensitive to the film surface structure, can provide qualitative information on the growth mode such as island nucleation, texture and crystallinity.

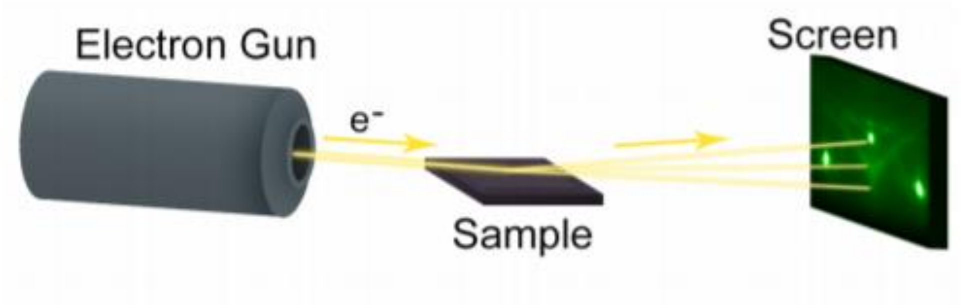
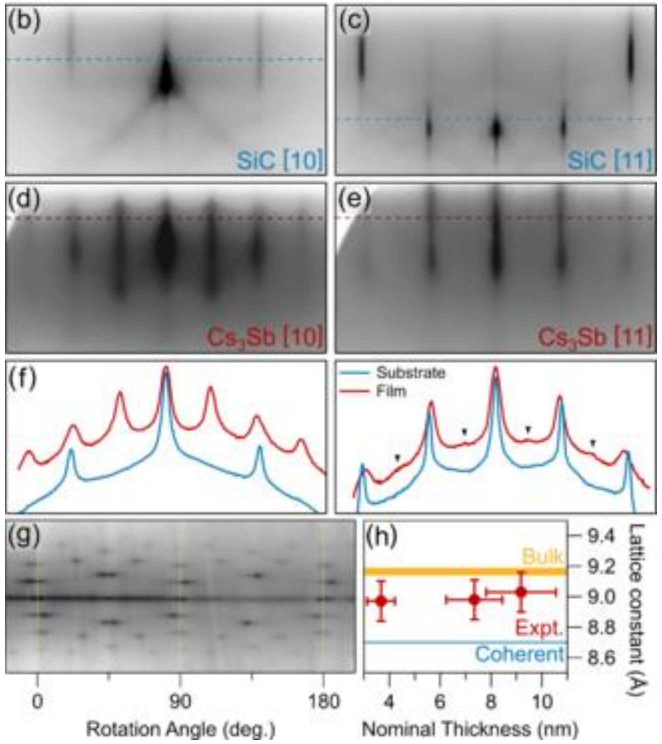


FIG. 1. The simplest RHEED set up includes an electron gun, a sample, and a fluorescence screen across from the gun.

RHEED: Cs_3Sb/3C-SiC

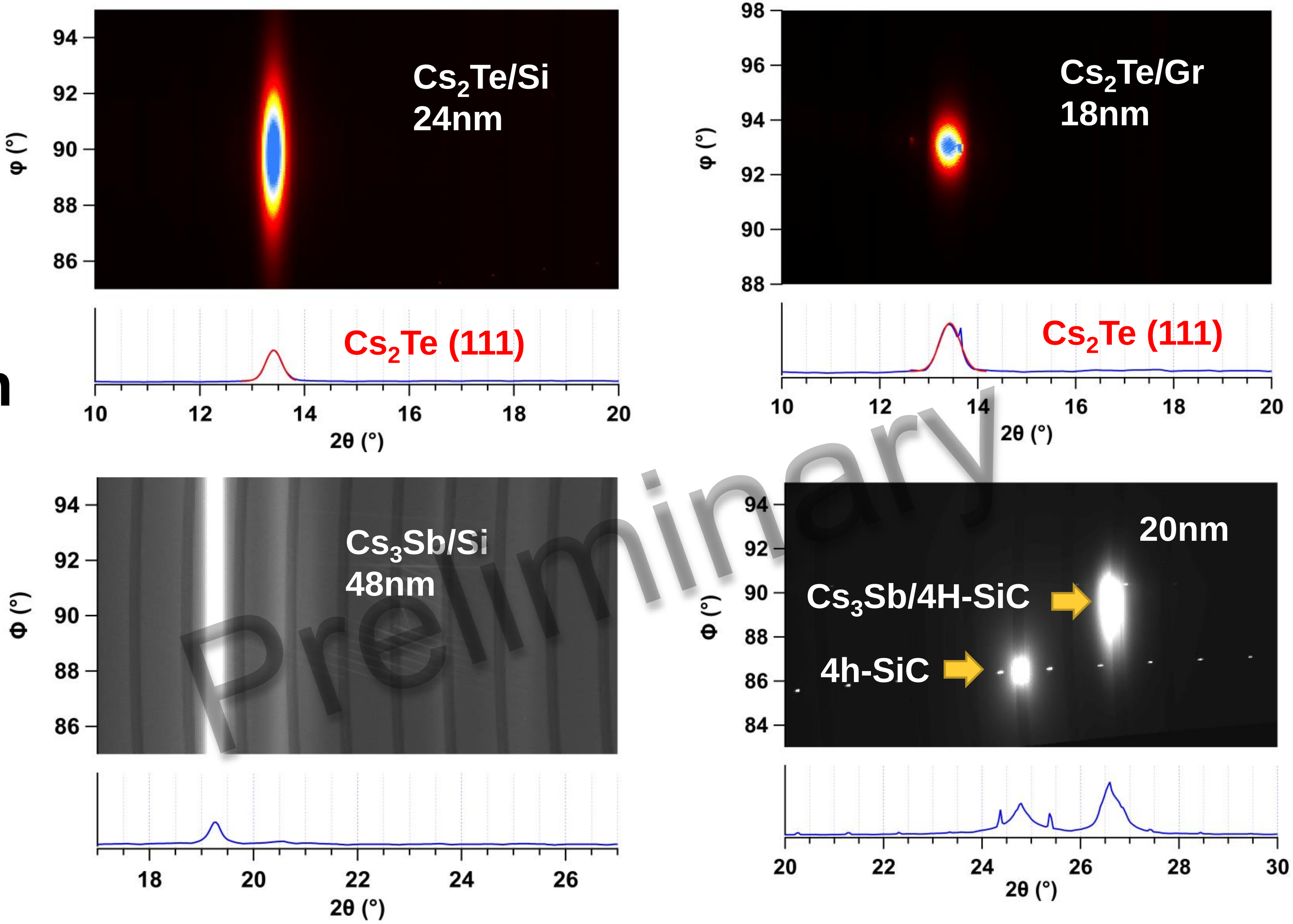


C. T. Parzyck, et al
Phys. Rev. Lett. 128, 114801 – Published 18 March 2022

Reference:
Reflection High-Energy Electron Diffraction, Nassim Derriche et al, 2019
Shuji Hasegawa. Characterization of Materials (Second Edition), chapter Reflection High-Energy Electron Diffraction, pages 1925–1938. 2012.

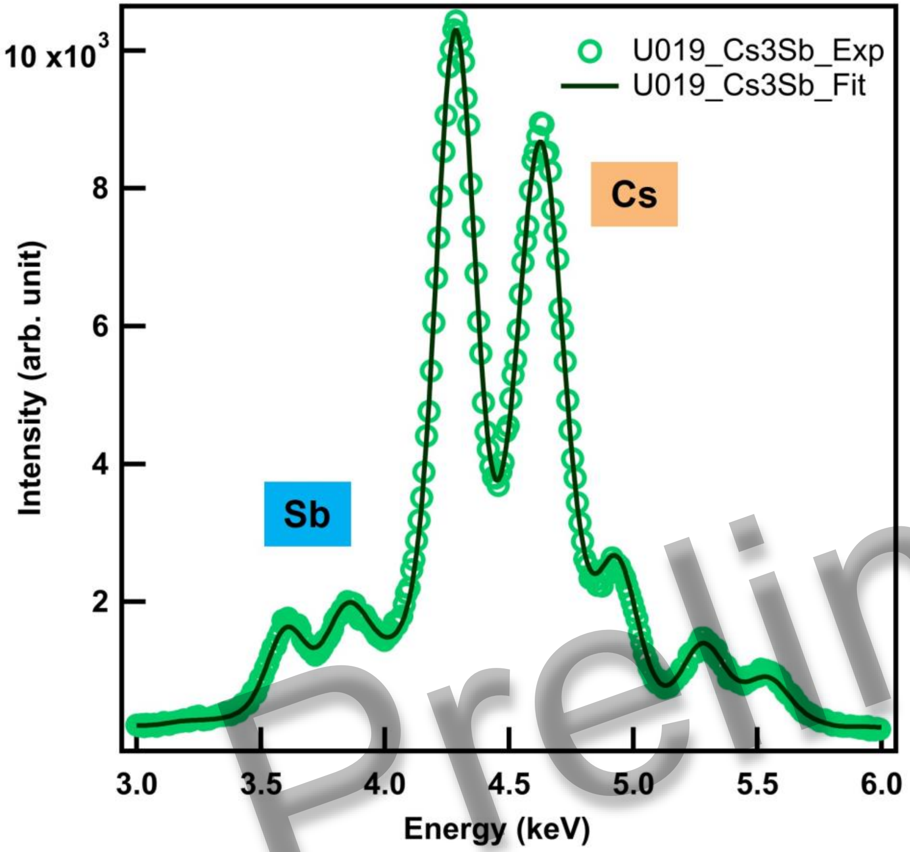
Epitaxial growth of alkali photocathode

X-ray Diffraction



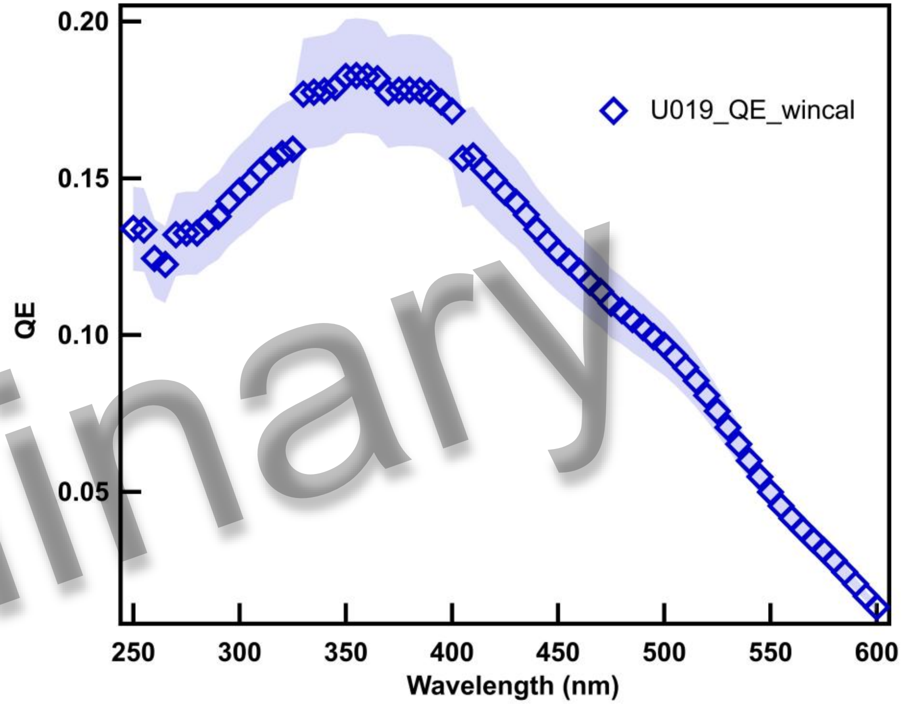
Cs_3Sb on 4-H SiC: Post growth Characterization

X-ray Fluorescence



	K/Sb	Cs/Sb
Cs3Sb/4H-SiC	/	2.95

Spectral Response



- 350 nm (peak): 18.2%
- 530 nm: 7%

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Summary

- Here we report Progress on cathode R&D for high intensity electron source in support of EIC. We have successfully performed RHEED measurements along with the x-ray characterization of the cathode material. We found evidence for the nucleation of Cs_3Sb on 4H-SiC and for Cs_2Te on Gr. Both films are remarkably smooth with desirable QE.

Acknowledgements

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