Ultra-smooth and high efficiency alkali antimonide photocathodes for future light sources

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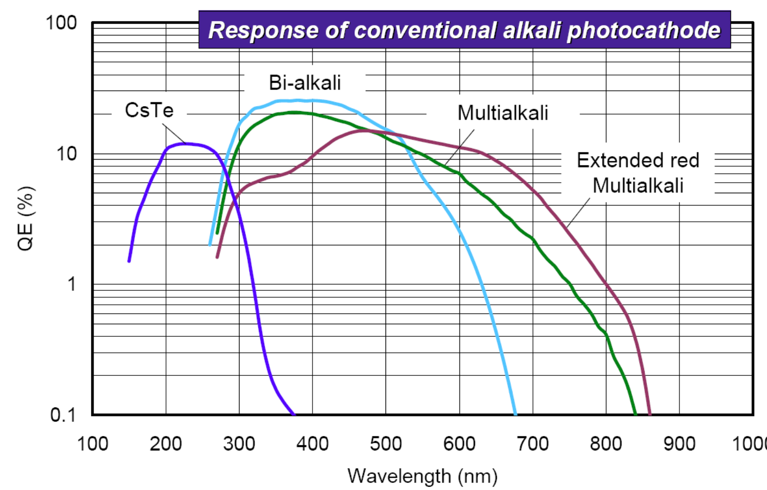
Introduction:
K-Cs-Sb photocathode as electron source

Advantages:

- ❑ High QE
- ❑ Low emittance
- ❑ Fast response time in visible light

- ❑ APEX
- ❑ BNL

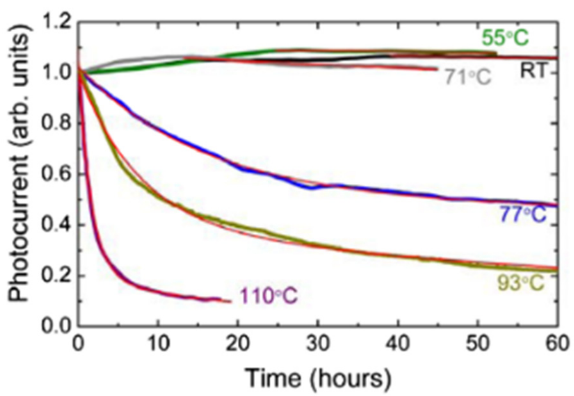


Improvement:

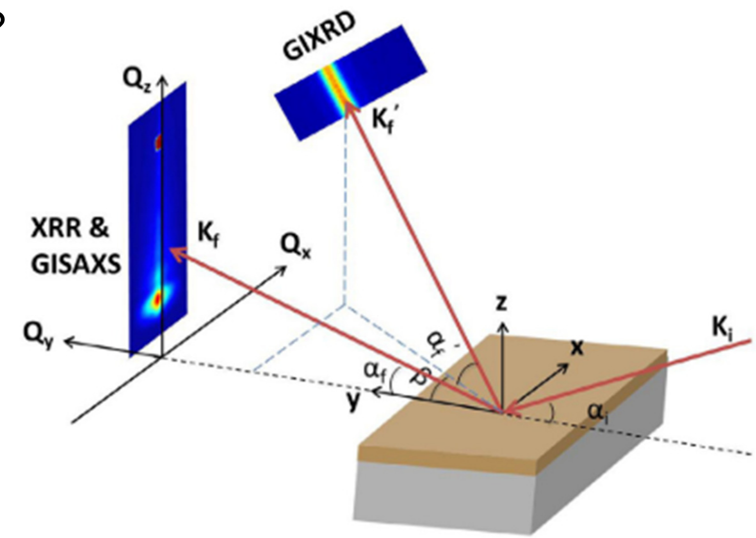
- Higher QE @ 532 nm
- Smoother surface
- Larger scale?

Introduction:
Efforts in characterization of KCsSb photocathode

How to make a good K-Cs-Sb photocathode?
- Temperature?
- K, Cs, Sb ratios?
- Surface roughness?
- Thickness, *etc.*?



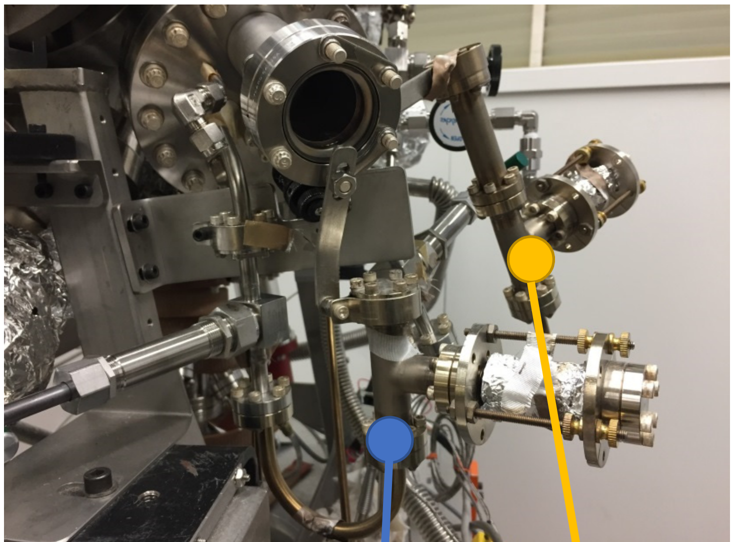
❑ Decay curves of K-Cs-Sb at different temperatures

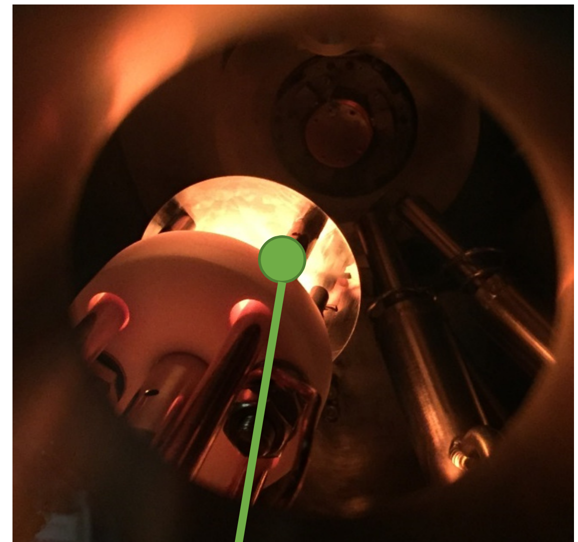


❑ *in situ* real time x-ray measurement setup on K-Cs-Sb

Z. Ding, *et al.*, *Phys. Rev. Accel. Beams.*, **2017**, 20, 113401.
J. Xie, *et al.*, *J. Phys. D: Appl. Phys.*, **2017**, 50, 205303.

Experimental Setup:
Cathode Growth with Effusion Cell





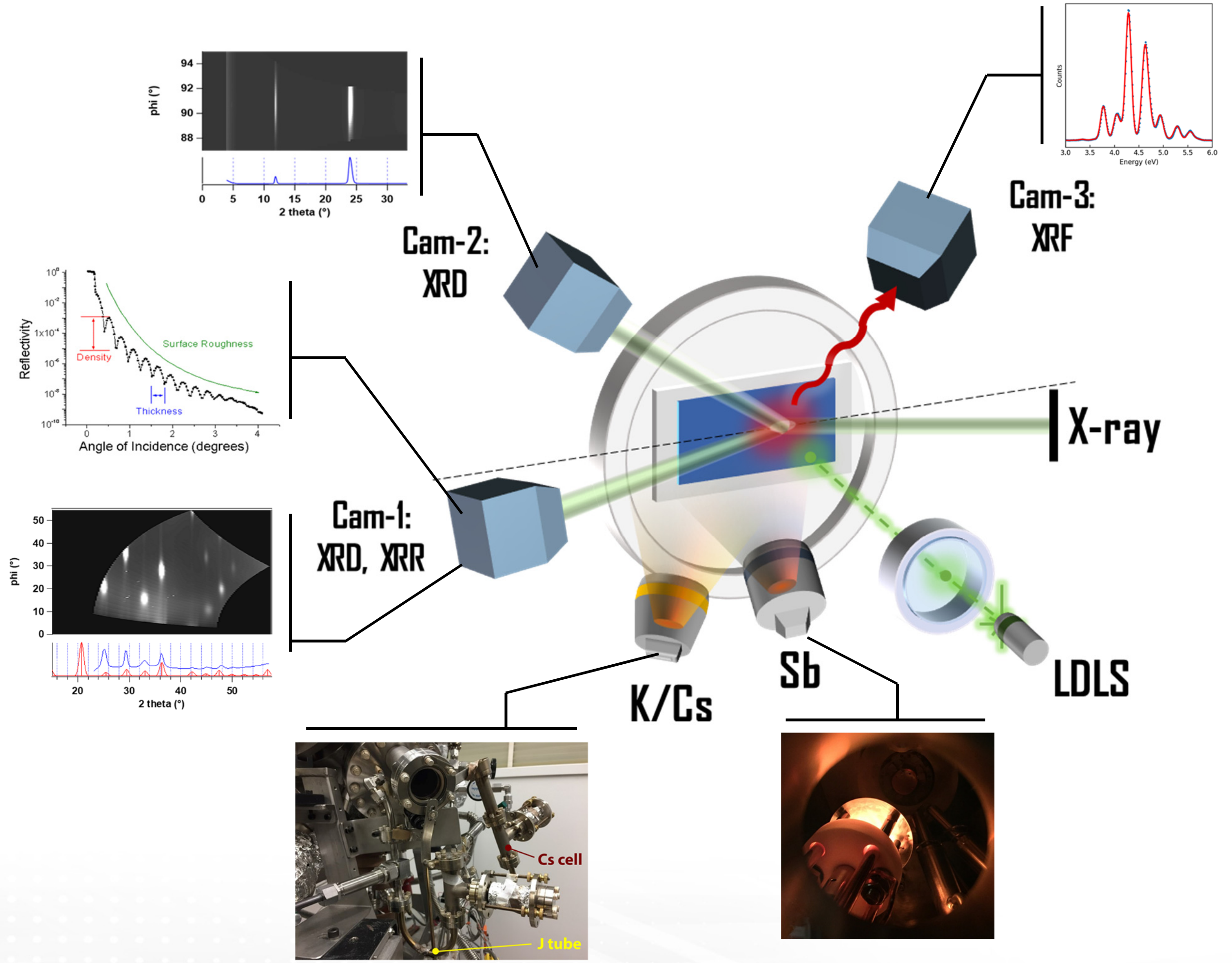
- Effusion cell → high capacity, large deposition area
- **Sequential** or **Co-dep**

Experimental setup: *Operando* chamber

Grow controls:
- ❑ T_{sub}
- ❑ Flux rate

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

Upcoming:
- ❑ Photoconductivity
- ❑ RHEED



K-Cs-Sb preparation: Ternary co-deposition vs. Two-step

Ternary Co-deposition

Cs, K, Sb
Co-deposition @ 90℃

Two-step Evaporation

K, Sb co-deposition @ 120℃ to maximize QE @ 380 nm

Cs deposition @ 100℃ to maximize QE @ 100℃

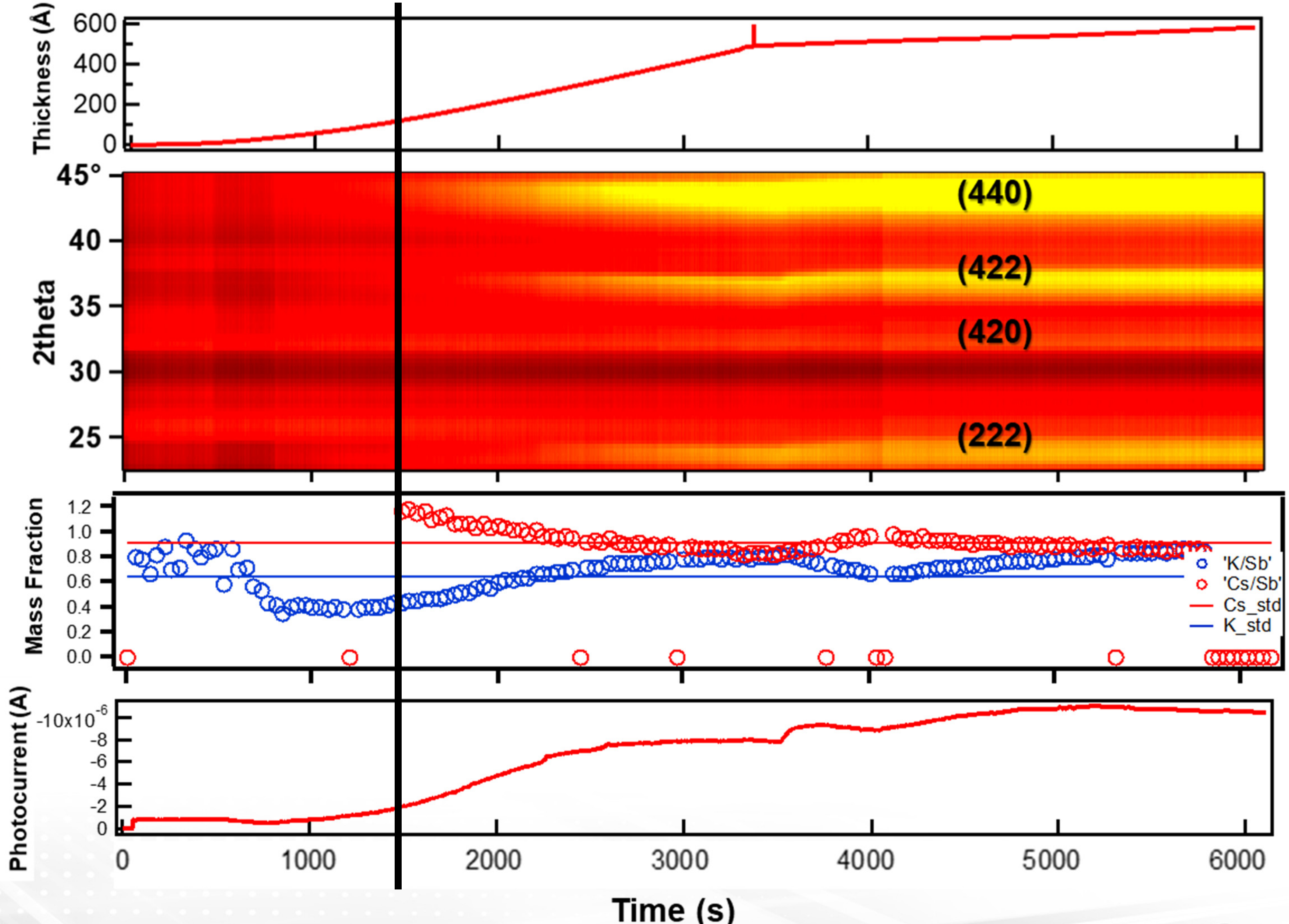
TC Method: *in-situ* monitoring

QCM
Growth rate

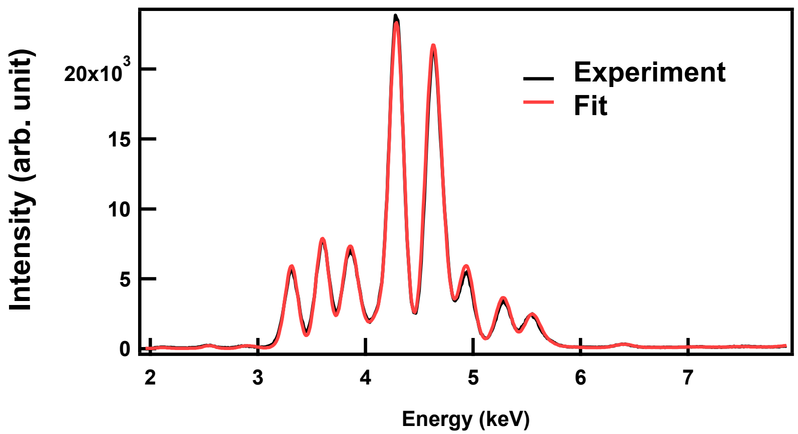
XRD
Structural Evolution

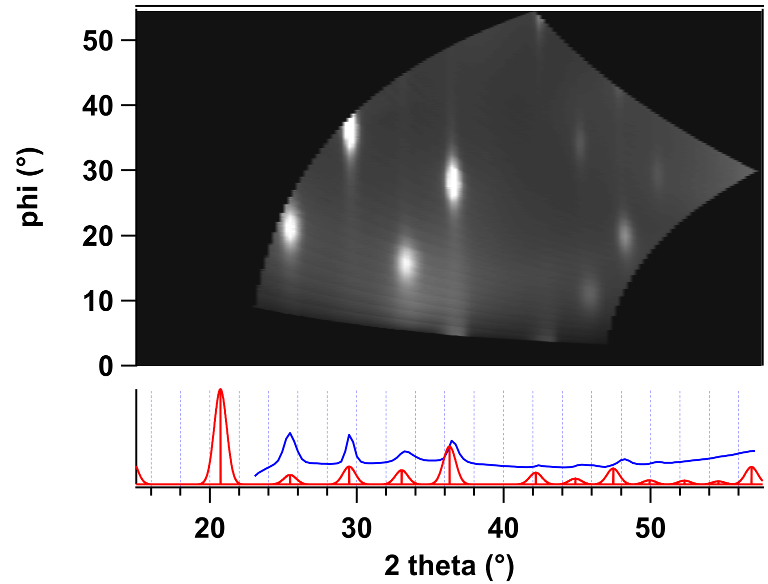
XRF
Atomic ratios

QE

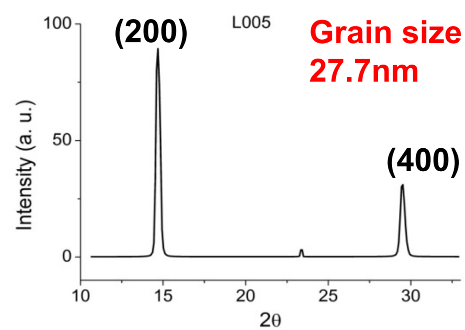


TC Method: sample analyses



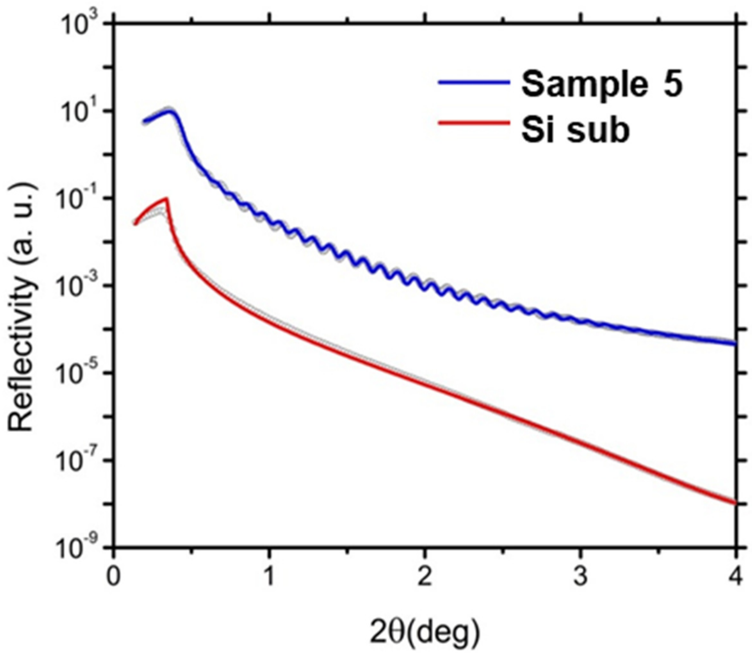


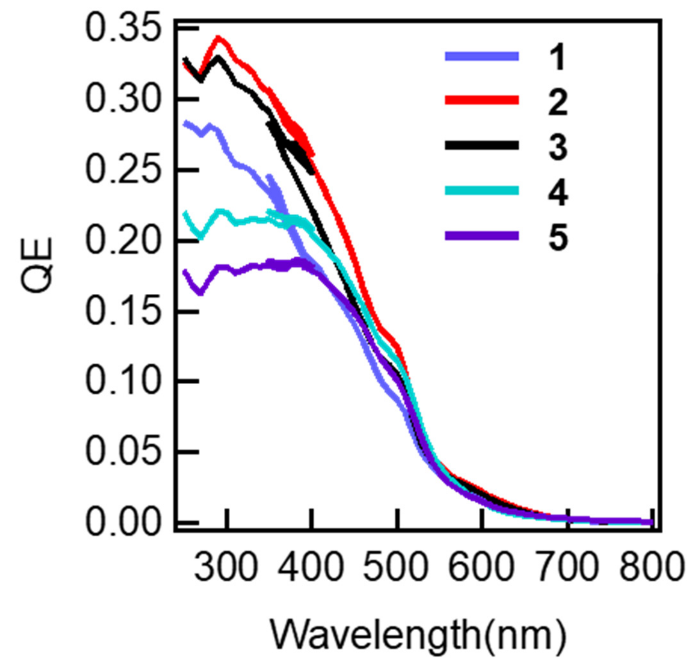
Samples	K	Cs	Sb
1	2.50	1.16	1.00
2	2.37	0.91	1.00
3	2.21	0.95	1.00
4	2.07	0.94	1.00
5	1.98	0.88	1.00
mean	**2.23**	**0.97**	**1.00**



- ❑ Good K-Cs-Sb ratio
- ❑ Highly textured K_2CsSb phase
- ❑ Large crystal grain

TC Method: sample analyses





QE @ 532 nm (%)	*R* (Å)	*d* (Å)	Grain size (nm)
5.8	11.5	815.3	27.7

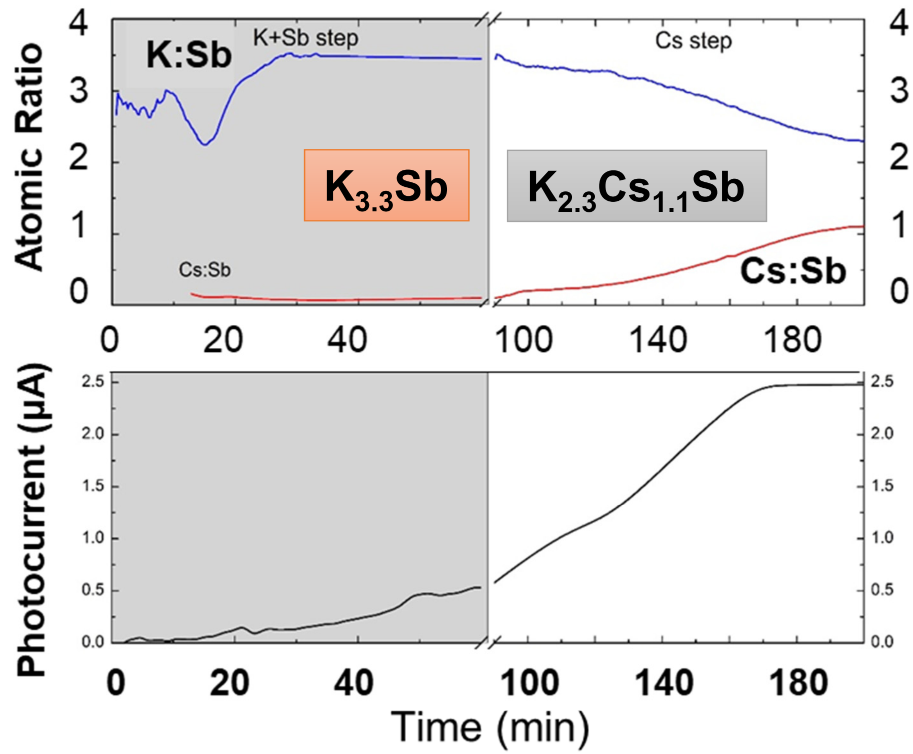
- ❑ **High QE** and **Smooth Surface**

Two-step Method:

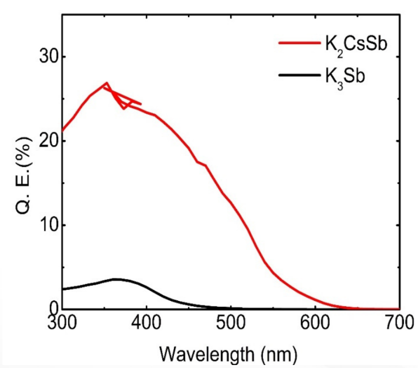
Two-step Evaporation

K, Sb co-deposition @ 120℃ to maximize QE @ 380 nm

Cs deposition @ 100℃ to maximize QE @ 532℃

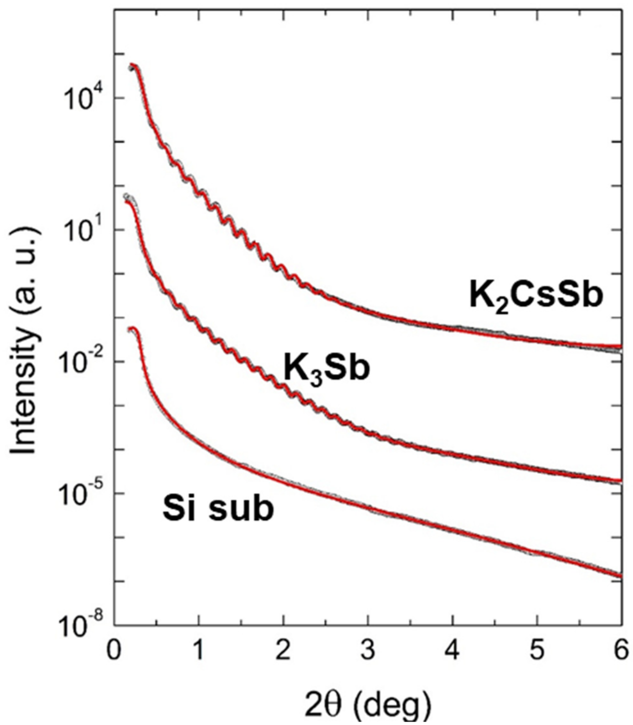


- ❑ Simply monitor the **QE**
- ❑ No need monitoring stoichiometry
- ❑ Convenient
- ❑ Comparative QE

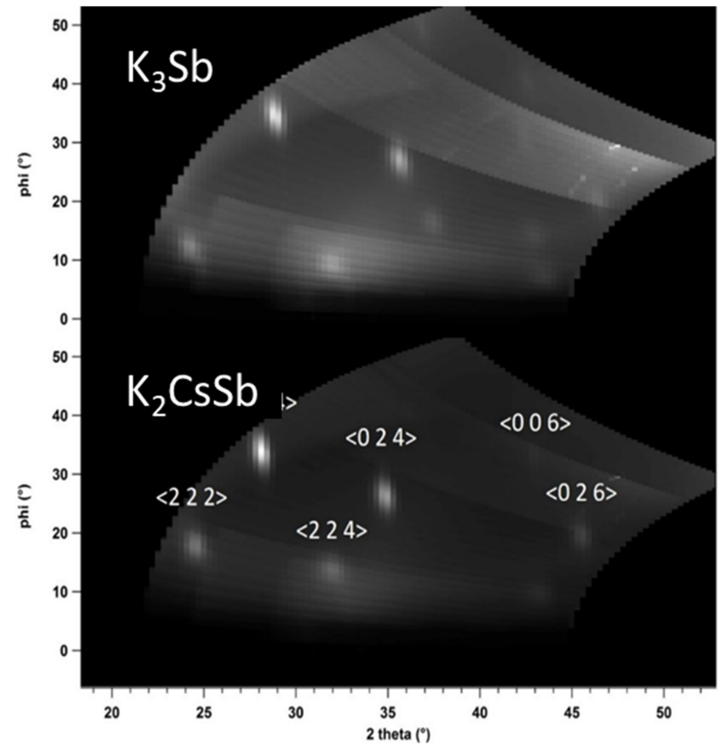


- ❑ QE after sufficient Cesiation:
- ❑ **26% @ 360 nm**
- ❑ **7% @ 530 nm**

Two-step Method: XRR and XRD



	d (nm)	R (Å)
K_2CsSb	38.8	10.0
K_3Sb	39.3	8.3
Si sub	-	2.4



- ❑ Sub-nm roughness
- ❑ Textured XRD pattern
- ❑ Hexagonal K_3Sb → cubic K_2CsSb

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Summary:
Ternary co-dep *vs.* Two-step

Method	*d* (nm)	*R* (Å)	QE @ 360 nm	QE @ 532 nm
Triple Evaporation	81	11.5	27%	5.8%
Two-step	39	10.0	26%	7.0%

Both methods:

- ❑ High QE
- ❑ Smooth surface
- ❑ Well crystallized

Triple Evaporation:

- Requires thicker thin film
- Critical crystallization
- Maintains stoichiometry

Two-step:

- Flexible
- Monitoring QE

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