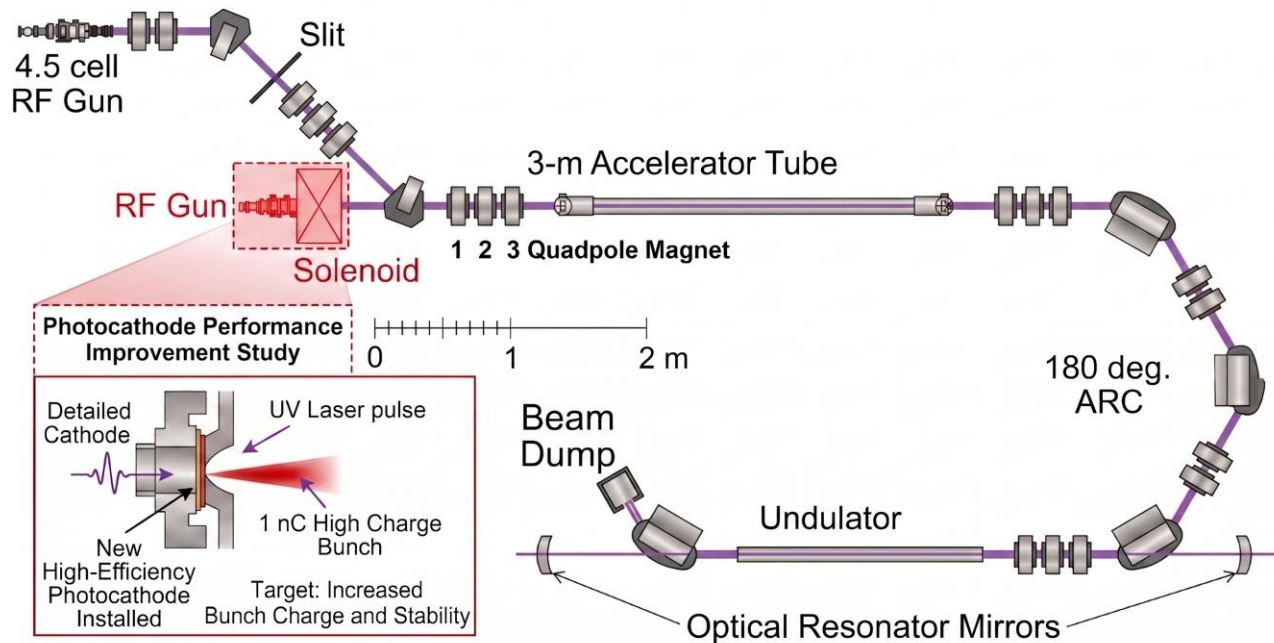


Introduction of a co-deposition method for improvement of quantum efficiency and lifetime of Cs-Te photocathodes in KU-FEL

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1. Background

KU-FEL (Kyoto University Free Electron Laser)

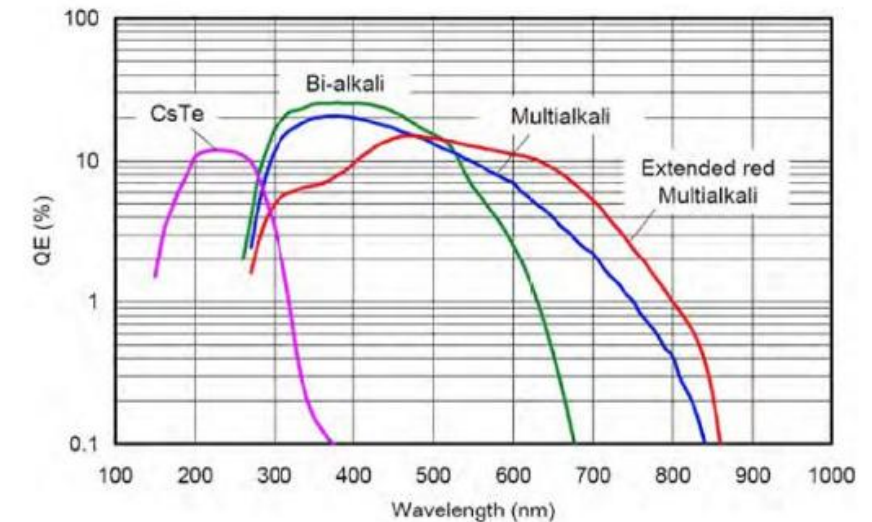


mid-IR (3.4-26 μm) oscillator FEL

200 pC $\Rightarrow$ 1 nC

Photocathode materials*

Material	Wavelength (nm)	QE (%)
Cs-Te	262	10
Cs ₃ Sb	405	9
K-Cs-Sb	405	25



High QE with long lifetime $\Rightarrow$ **Cs-Te**

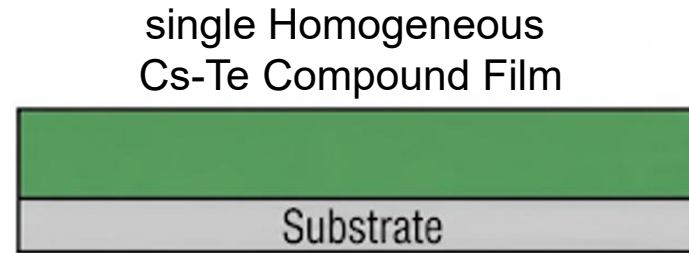
*Triveni Rao and David H. Dowell AN ENGINEERING GUIDE TO PHOTOINJECTORS (2013).

2. Method

Sequential deposition (conventional)



Co-deposition (this work)



Objective

Co-deposit Te + Cs

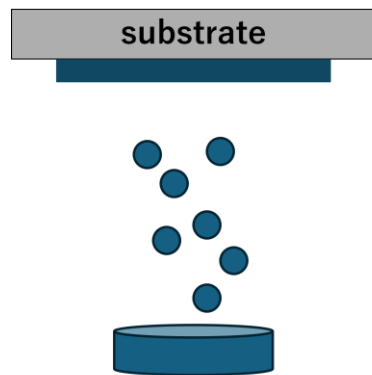


Depth-uniform film

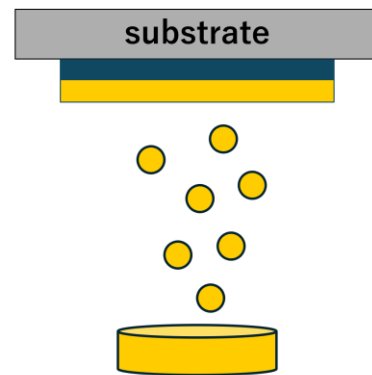


High QE, longer lifetime

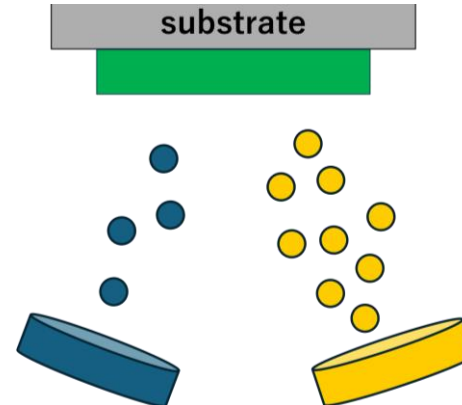
Experimental procedure**



**Step 1: Te deposition
(~50 nm)**

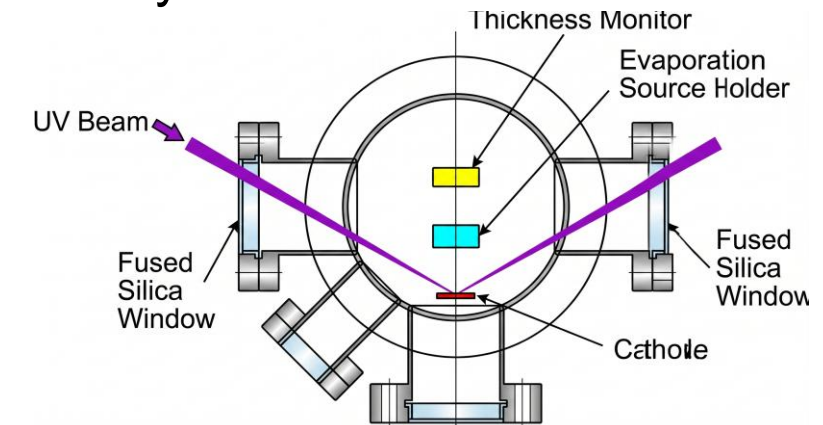


**Step 2: Cs deposition
(until QE peaks)**



**Te: fix the rate at 0.10 nm/min
Cs: adjust rate to have high QE**

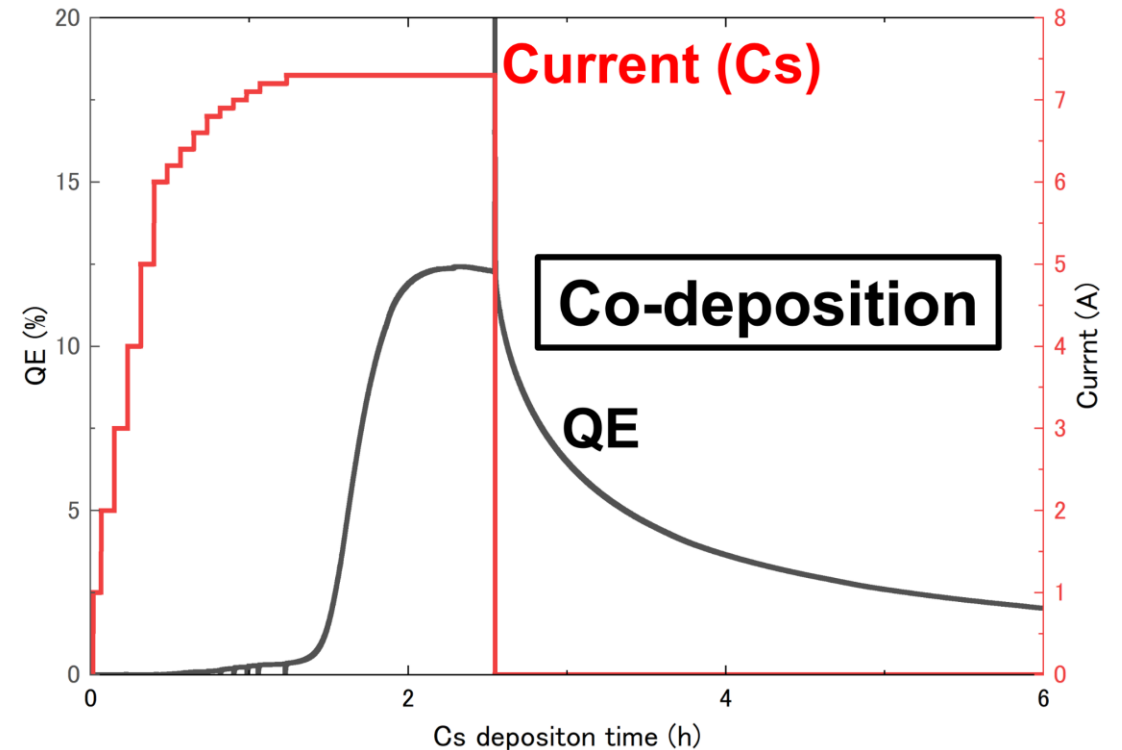
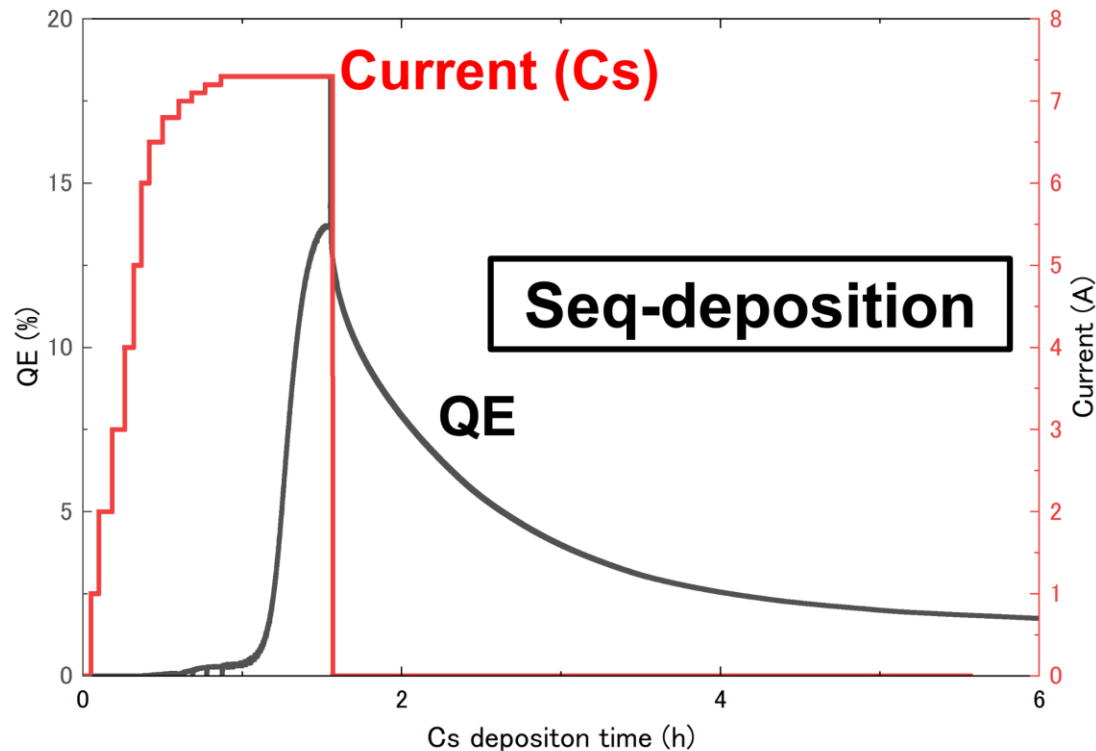
Layout



Base pressure : $1.2 \sim 1.7 \times 10^{-6}$ Pa

**M. Martinez-Calderon et al., Phys. Rev. Accel. Beams 27, 023401 (2024).

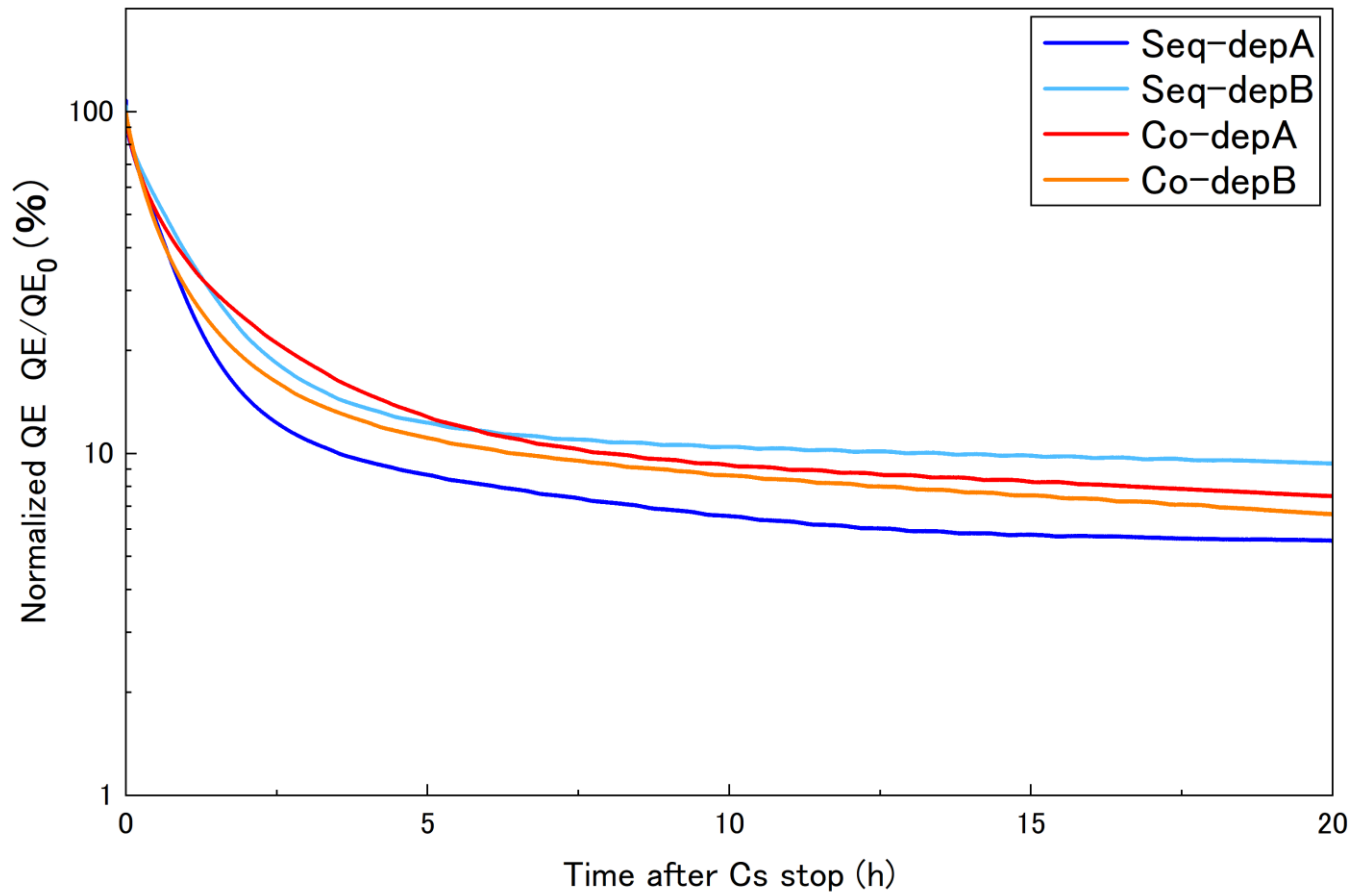
3. Results - QE curves during Cs deposition



- Sharp QE peak followed by a rapid drop

- Stable QE plateau maintained

4. Results - QE evolution after stopping Cs deposition



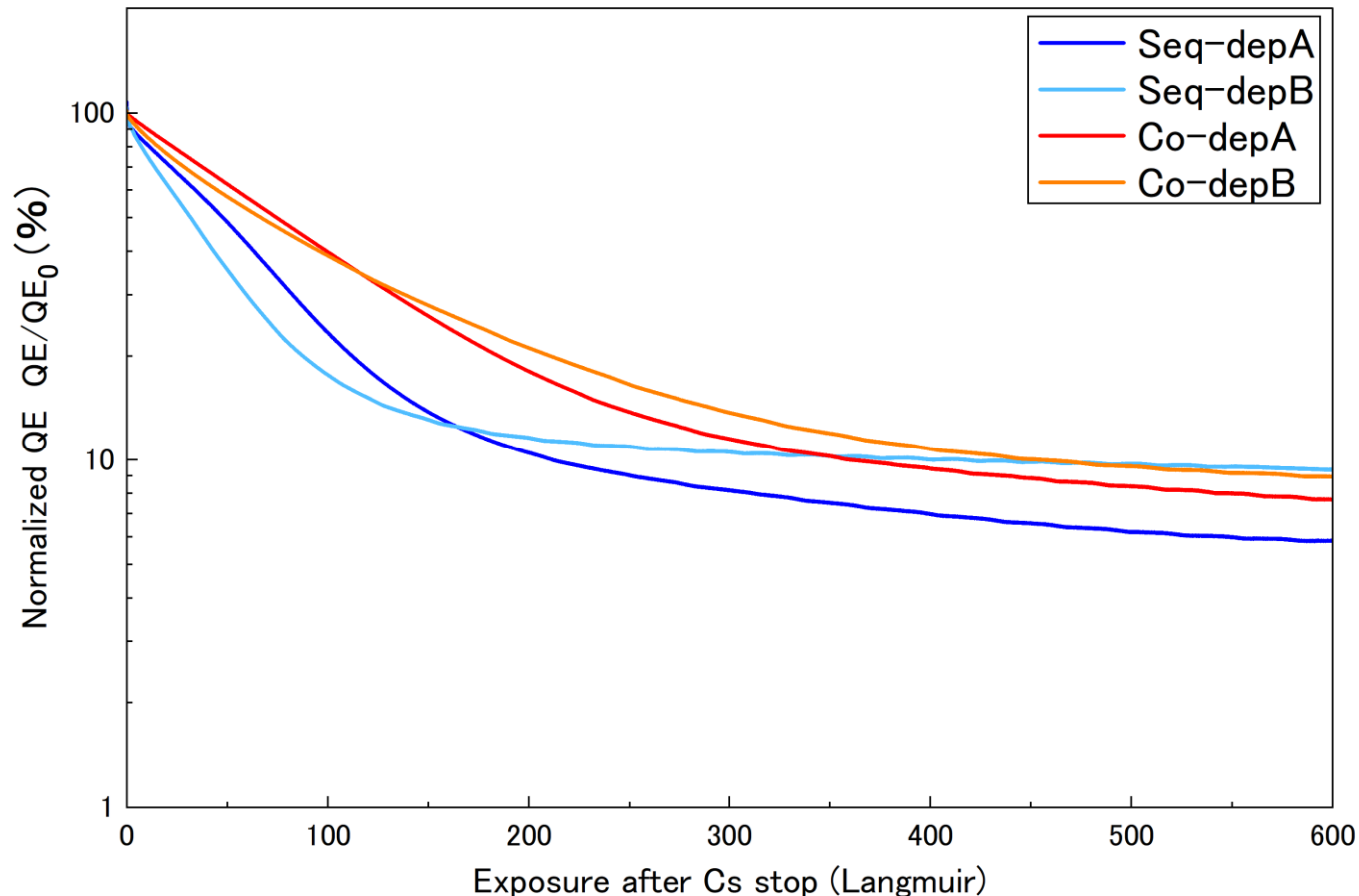
Double-exponential fit

$$QE(t) = A_1 \cdot e^{-\frac{t}{\tau_1}} + A_2 \cdot e^{-\frac{t}{\tau_2}}$$

Run	A ₁ (%)	τ_1 (h) fast	A ₂ (%)	τ_2 (h) slow
Seq-dep A	78.4	0.72	9.6	33.9
Seq-dep B	71.5	1.01	12.5	63.5
Co-dep A	66.4	1.03	14.4	28.5
Co-dep B	75.6	0.67	13.9	24.9

- Co-deposition and Seq-deposition have similar lifetimes.
- The vacuum conditions of those runs are different. → Should be considered.

5. Results - QE depending on the gas exposure



Double-exponential fit

$$QE(D) = A_1 \cdot e^{-\frac{D}{L_1}} + A_2 \cdot e^{-\frac{D}{L_2}}$$

Run	A ₁ (%)	L ₁ (L) fast	A ₂ (%)	L ₂ (L) slow
Seq-dep A	89.3	58.0	8.8	1501
Seq-dep B	83.6	39.5	11.8	2625
Co-dep A	78.3	91.2	14.0	1232
Co-dep B	92.6	90.2	8.8	4651

- Co-deposition films tend to have larger L_1 .
- L_2 does not seem to depend on the deposition method. There could be hidden parameters that determine L_2 .

6. Summary and next steps

Successful Co-deposition — Te+Cs co-deposition with deposition-ratio control

High Max QE — Both sequential and co-deposition achieved maximum QE > 10%.

Lifetime improvement — Co-deposition showed a longer gas lifetime for the fast decay component (L_1).

Protective layer — Apply a CsBr layer to further extend lifetime and verify differences.

RF Gun Integration — Install in an actual RF electron gun and demonstrate long-term stable operation.