High QE photocathode preparations and tests at SHINE

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SHINE

Outline

- Background
- Photocathode systems
- Photocathode preparation
- Photocathode tests
- Summary

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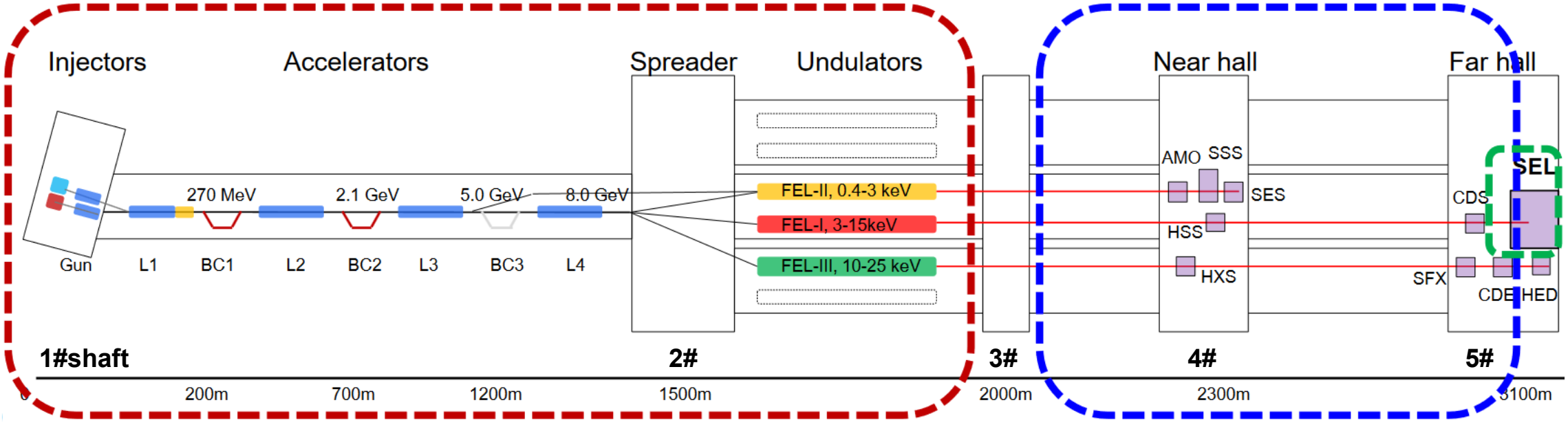
Background

- **SHINE:** Shanghai HIgh repetitioN rate XFEL and Extreme light facility
  - **Linac: 1 MeV** electron source, **8 GeV** CW SRF linac
  - **Undulator:** FEL I/II/III (**0.4-25 keV**)
  - **End station:** 10
  - **Cryogenic plant:** 4kW*3@2K



SHINE

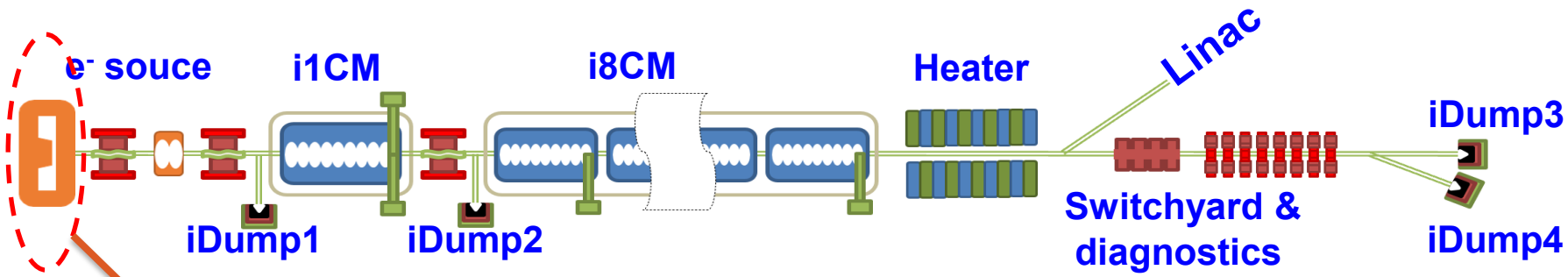
SARI/STU

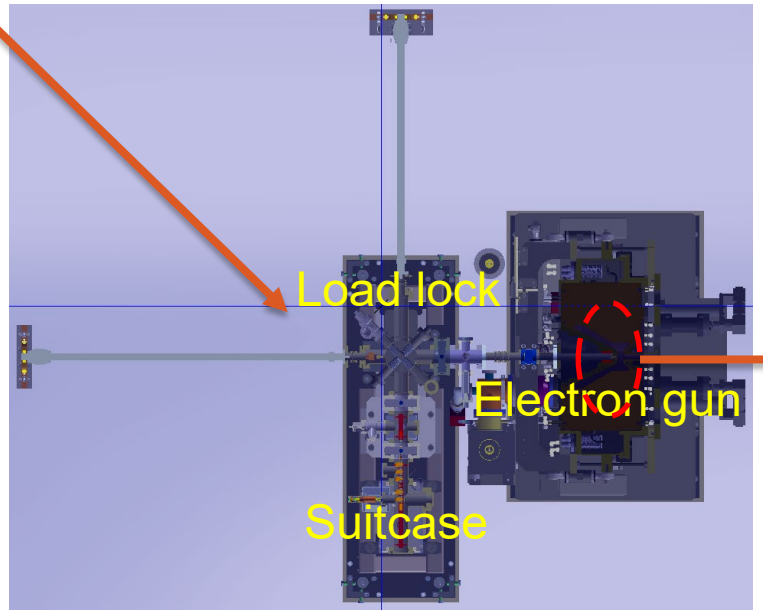
STU/SARI

SIOM

Background

- **SHINE injector layout**





High QE photocathode

100pC*1MHz

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Background

- **Ideal photocathode:**
  - High QE (>1%)
  - Long lifetime (~months)
  - Short response time (sub ps)
  - Low thermal emittance (<1μm/mm)
  - Low dark current
- **Current SHINE cathode**
  - Cs_2Te

	GaAs-Cs/O	K_2CsSb	Cs_2Te
Wavelength	Green（532nm）	Green（532nm）	UV（266nm）
Fresh QE	>10%	>5%	>10%
Gun type	DC,SRF	DC,NCRF,SRF,DC-SRF	NCRF(VHF),SRF, DC-SRF
Vacuum requirement	~10^{-9} Pa	~10^{-8} Pa	~10^{-7} Pa
Response time	~10ps	~1ps	~1ps
Operational lifetime	hours~days	days~weeks	weeks~months
Laboratory	Jlab, Cornell University, KEK, BNL…	BNL, LBNL(APEX), Jlab, Cornell University…	INFN-LASA, DESY, SLAC, FNAL, CERN, ANL, KEK…

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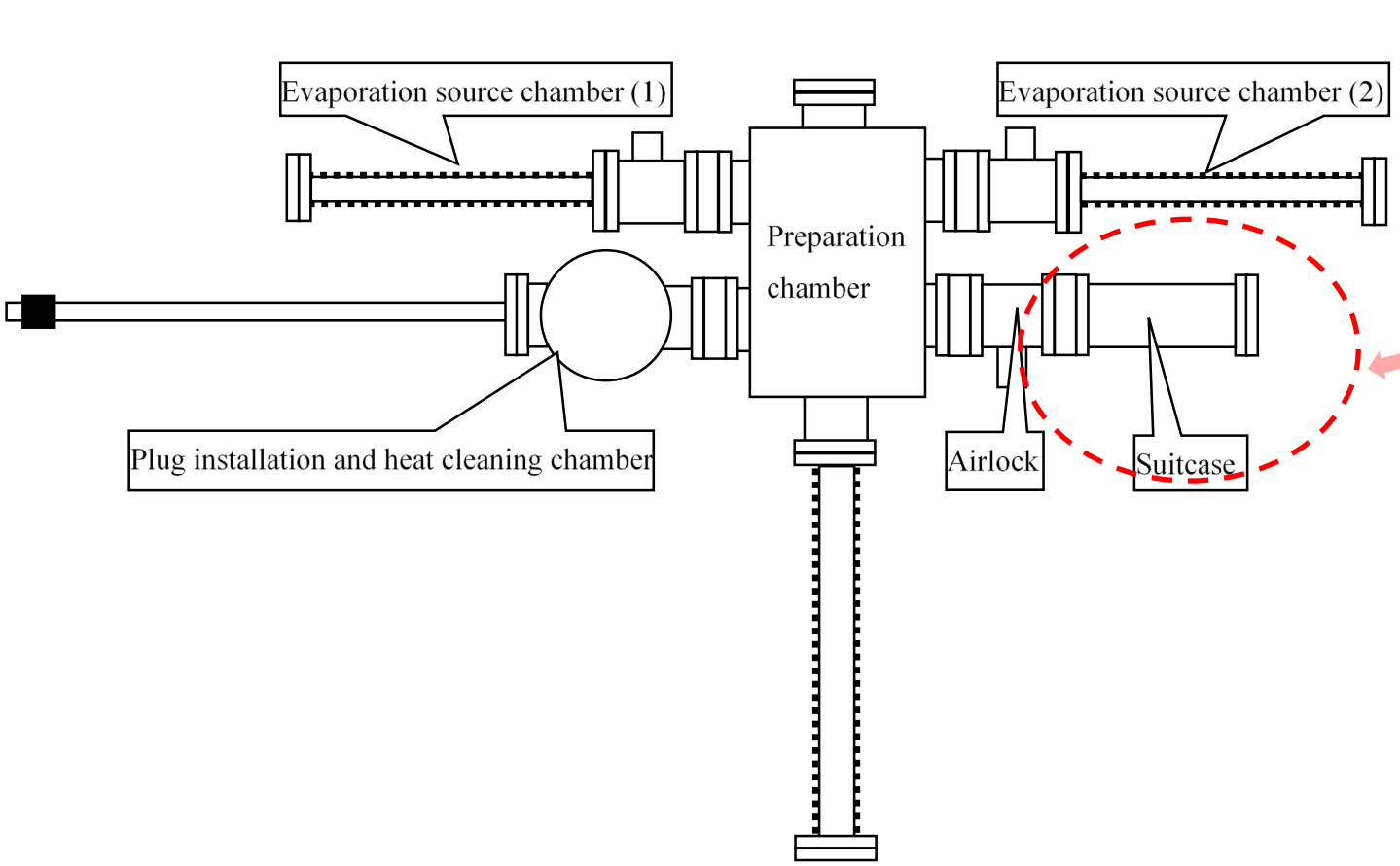
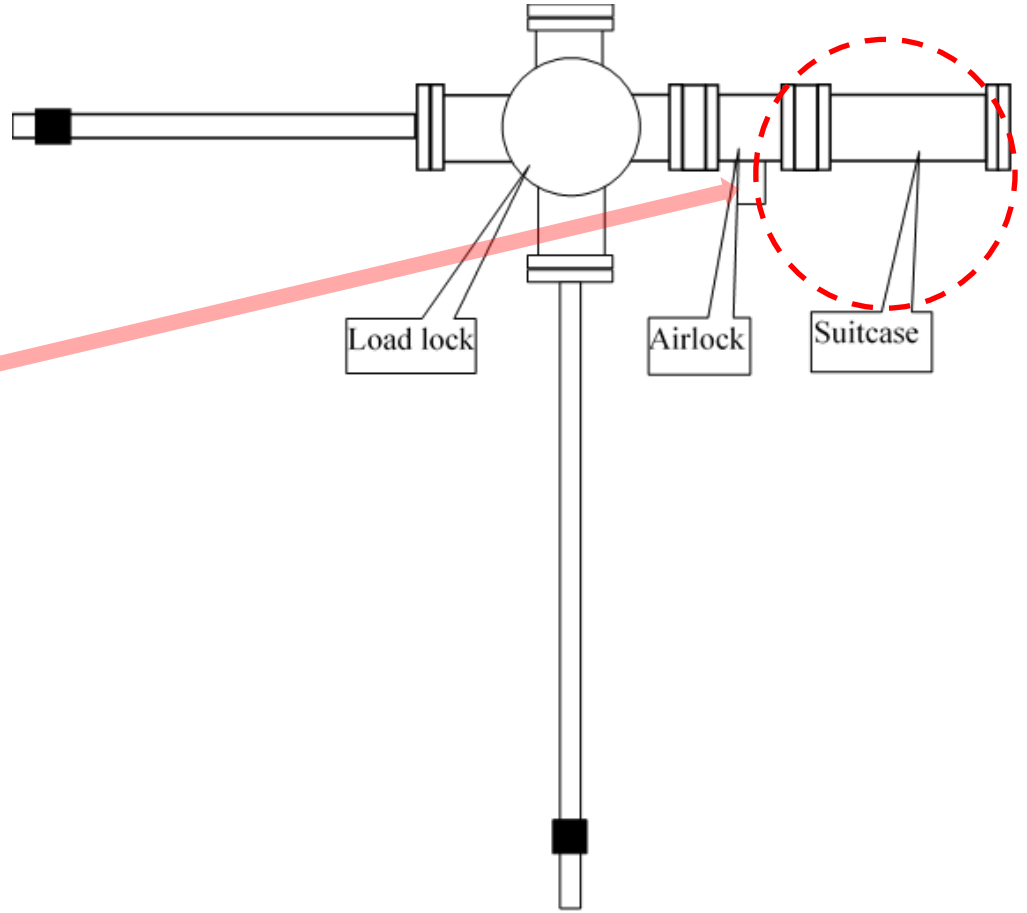
Photocathode systems



Photocathode preparation system



Photocathode load lock system

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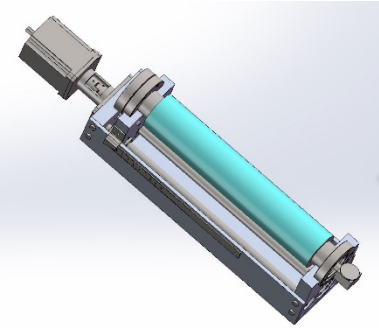
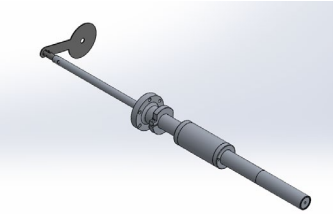
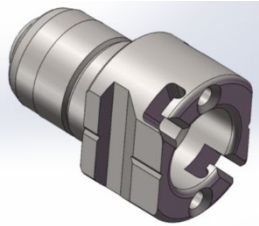
Photocathode preparation system



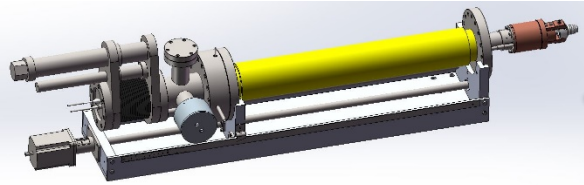
Thickness meter



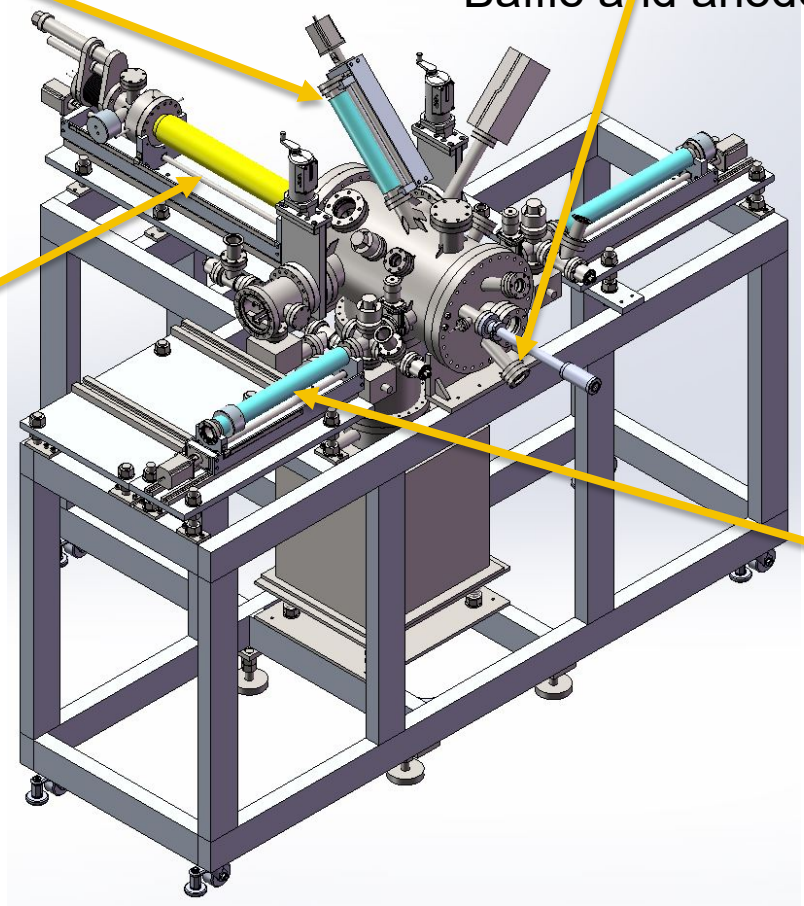
Baffle and anode

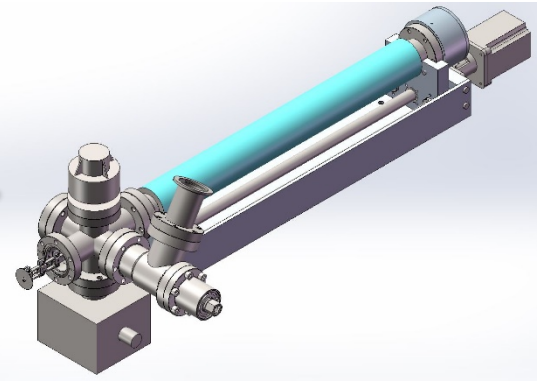


Mo substrate(INFN type)



The substrate/photocathode heating, cooling, temperature measurement and control component





Cs or Te evaporation source

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Photocathode preparation system

- **Some features of the photocathode preparation system**
  - The distance between source and substrate is adjustable (2-10cm)
  - The deposition thickness and rate of evaporation source can be measured in real time.
  - The substrate can be heated and cooled quickly.
  - Both positive and negative voltage collect electrons.
  - Sequential deposition and co-evaporation of two elements

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Photocathode preparation

- **Te, Cs sequential deposition**

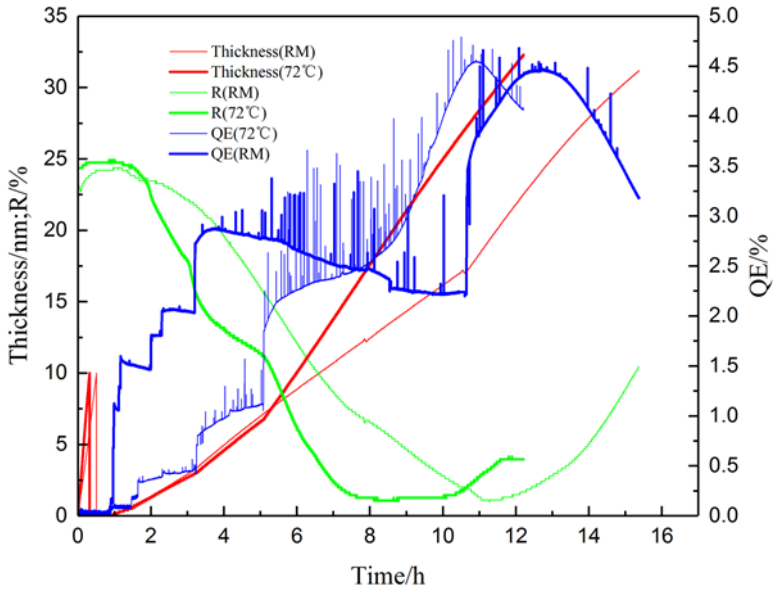
Substrate treatment

- Mechanical polishing
- Chemical cleaning
- Vacuum heat cleaning

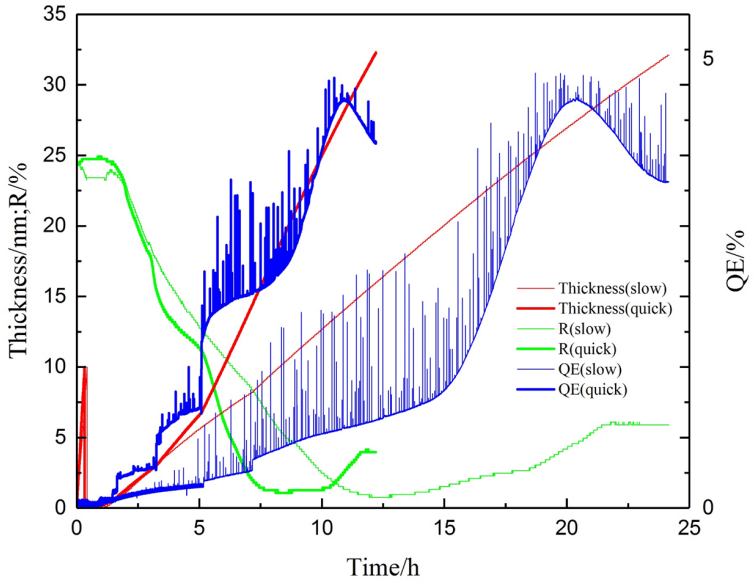
Te ,Cs sequential deposition

- Te,Cs degas
- 10nm Te deposition(@100℃)
- Cs deposition until the maximum QE (@100℃, 10μW 265nm)

QE>4.5% @ 265nm



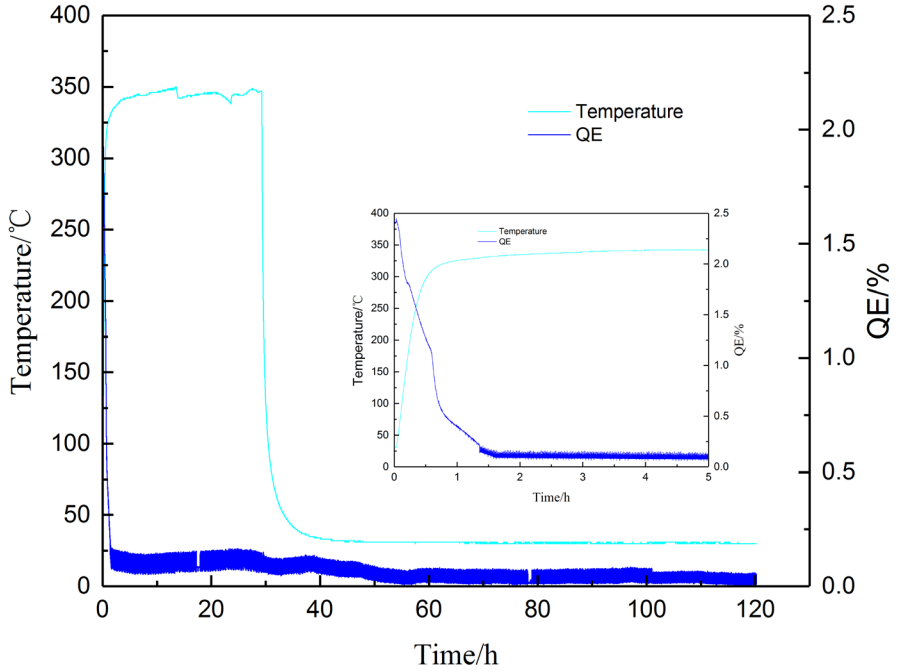
Substrate temperature



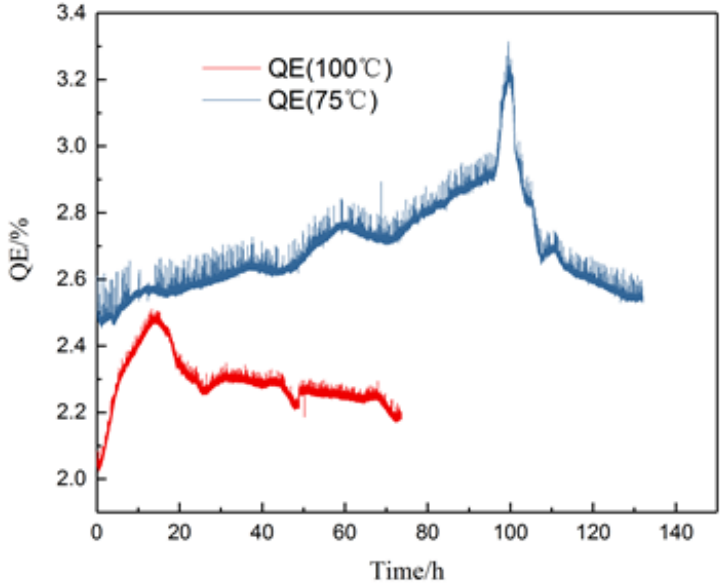
Cs deposition rate

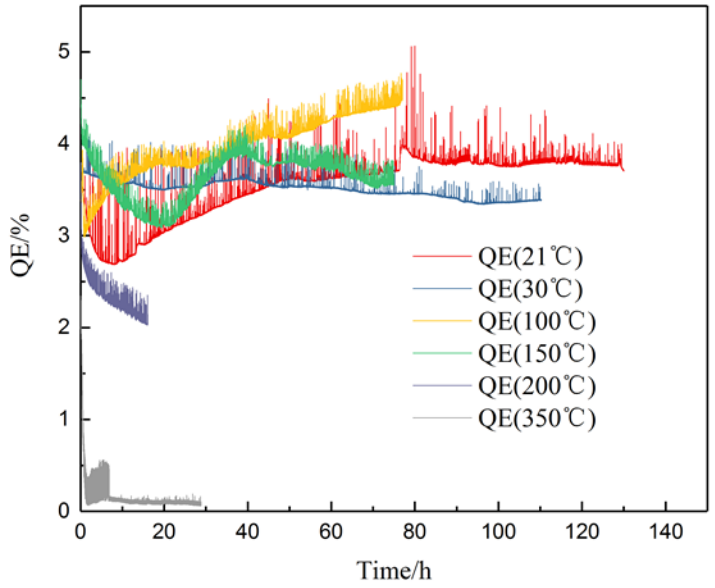
Photocathode preparation

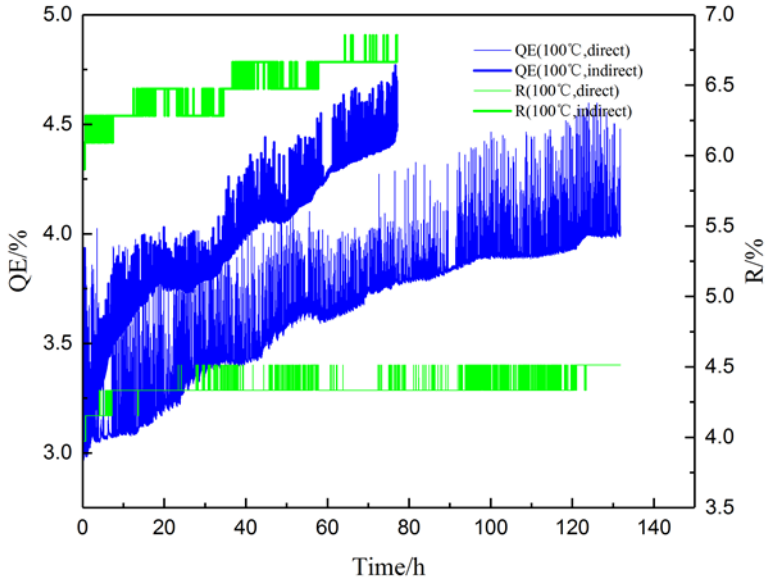
- **Te, Cs sequential deposition**



Heating removal







Thermal annealing

Photocathode preparation

- **Te intermittent, Cs continuous deposition**

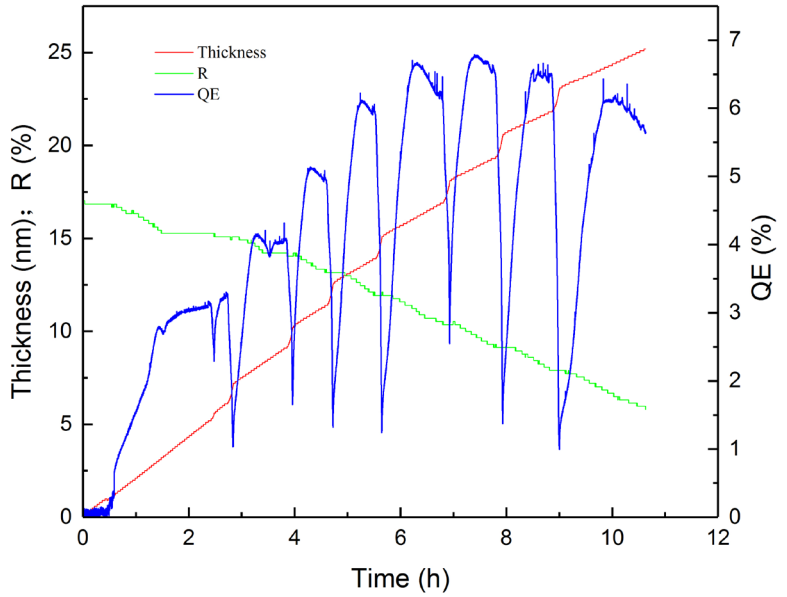
Substrate treatment

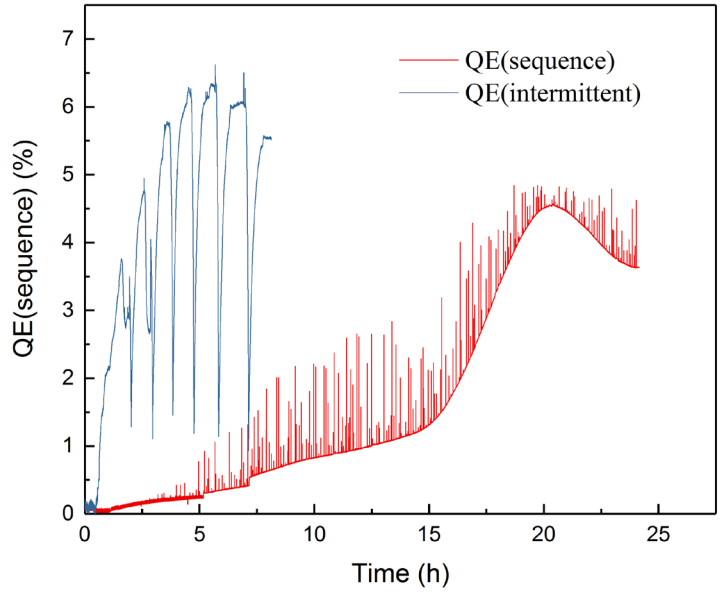
- Mechanical polishing
- Chemical cleaning
- Vacuum heat cleaning

Te intermittment,Cs continuous deposition

- Te,Cs degas
- 1nm Te deposition(@100℃)
- Cs deposition until the first maximum QE (@100℃, 10μW 265nm)
- Te intermittent, Cs continuous deposition until the final maximum QE

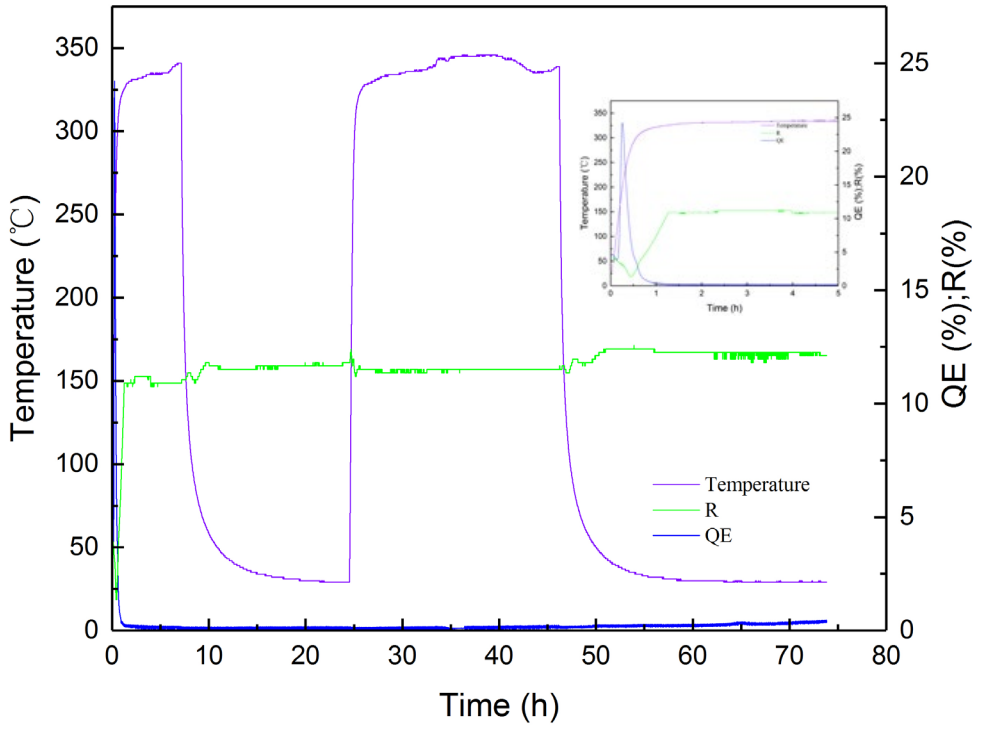
QE>6% @ 265nm



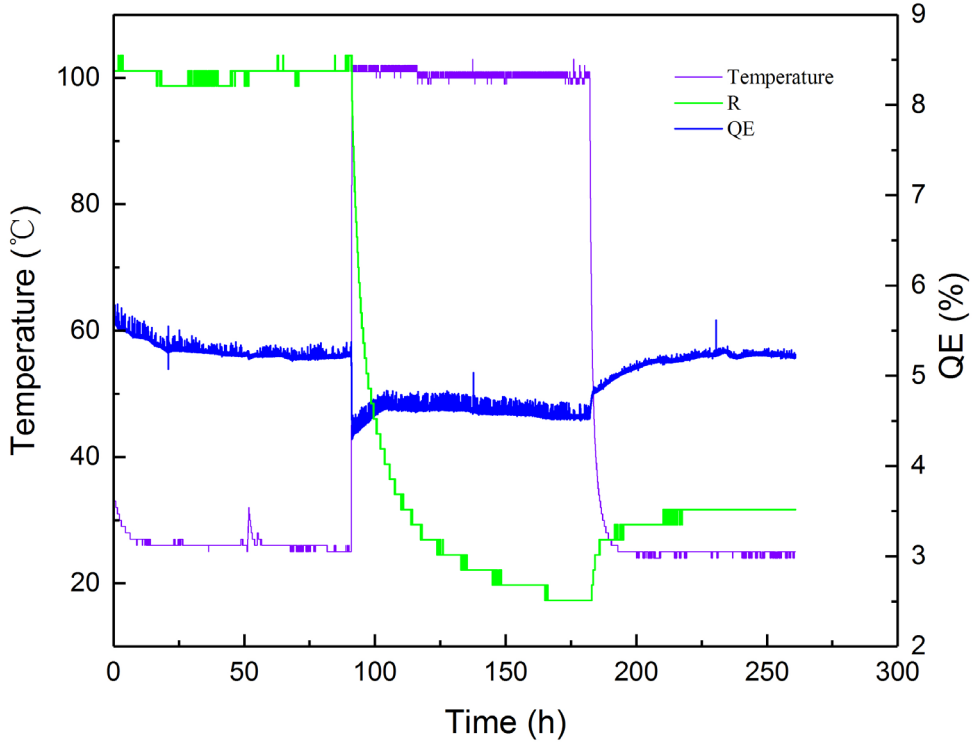


Photocathode preparation

- **Te intermittent, Cs continuous deposition**



Heating removal



Thermal annealing

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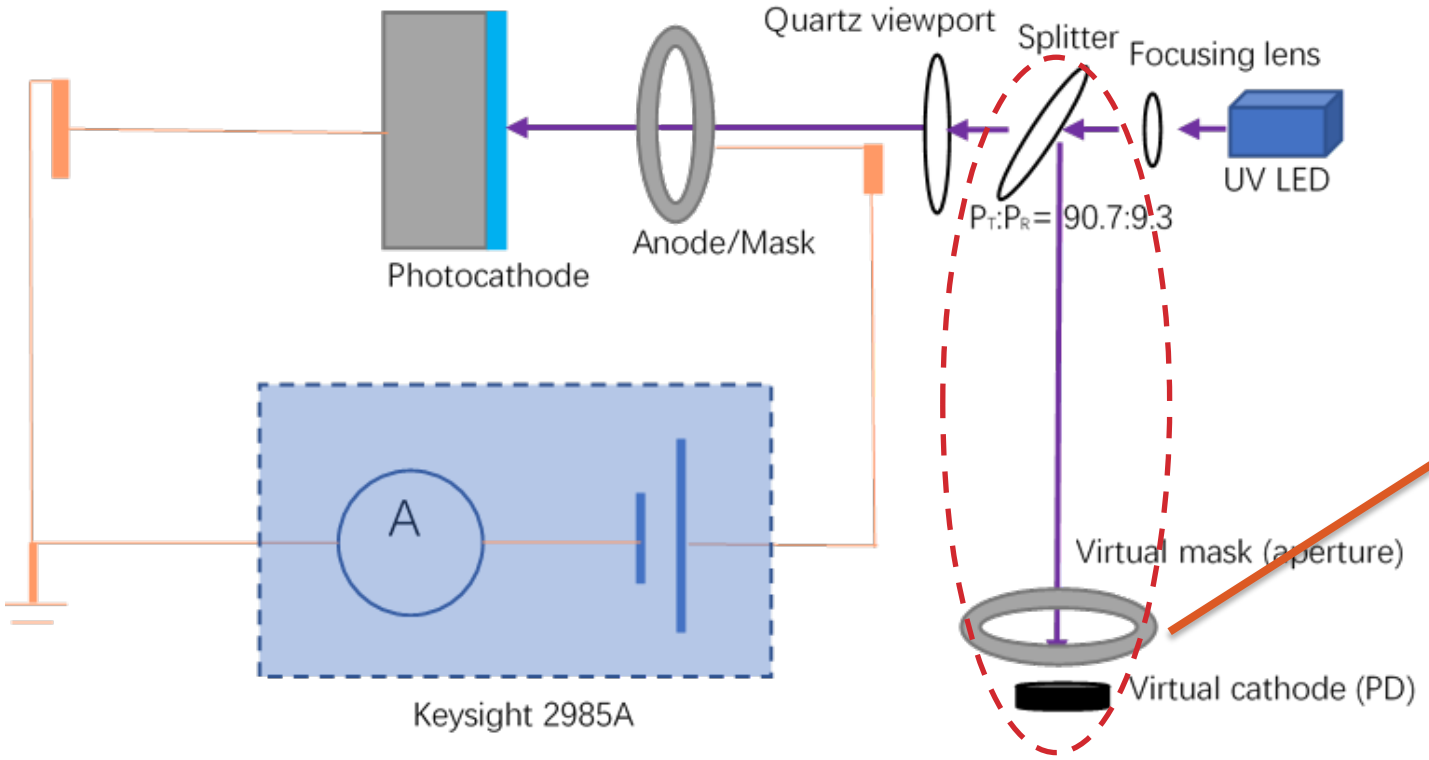
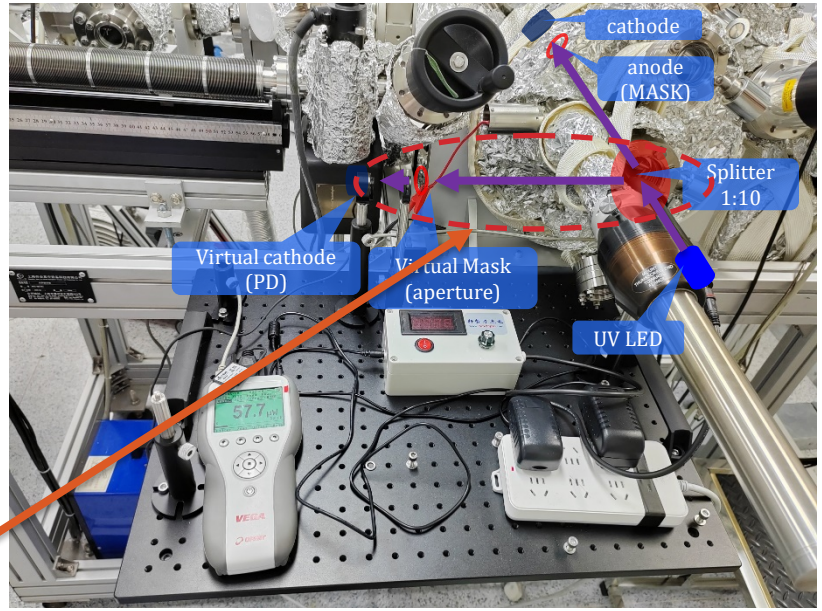
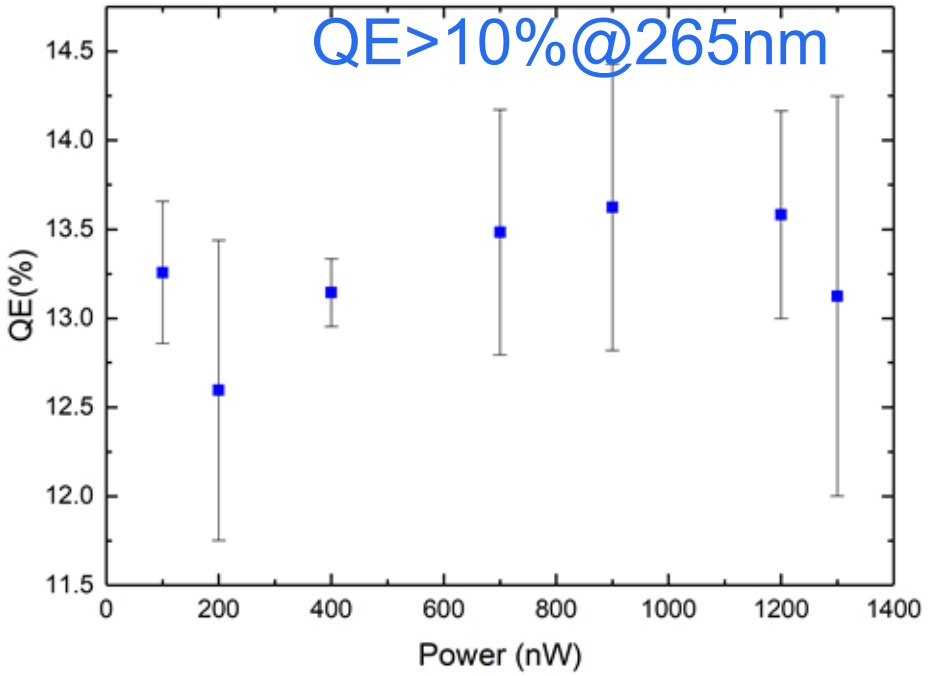
Photocathode QE measurement







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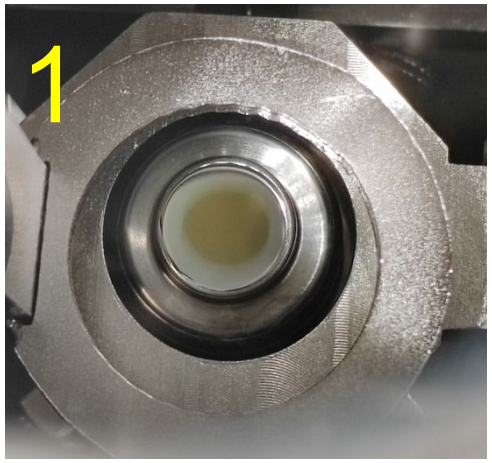
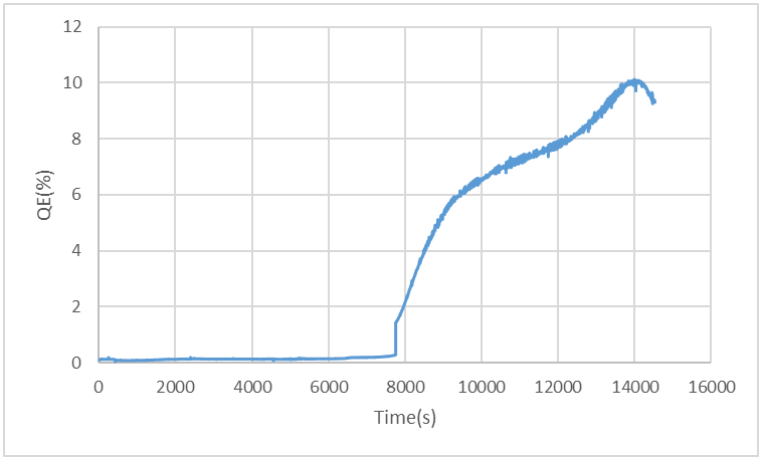
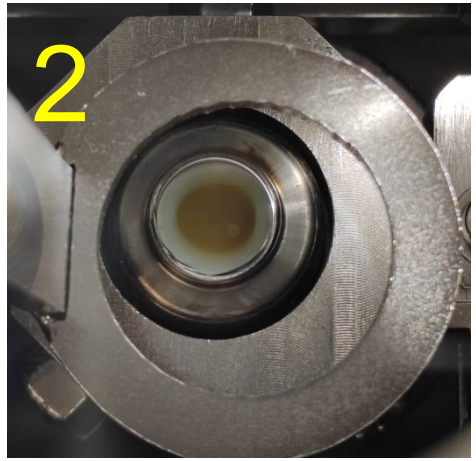
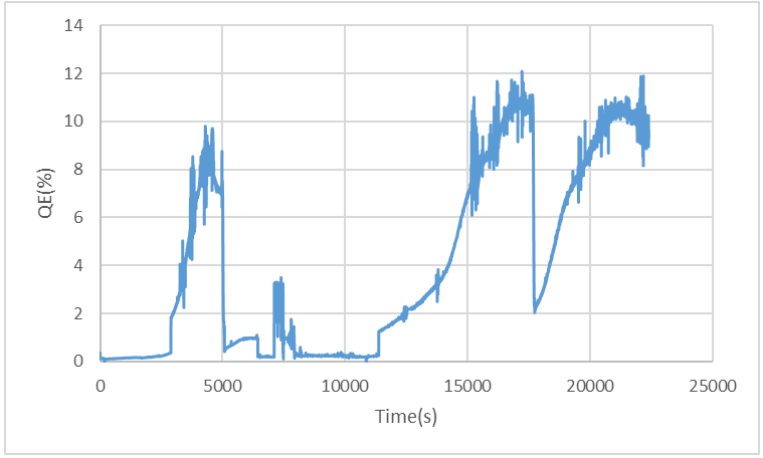
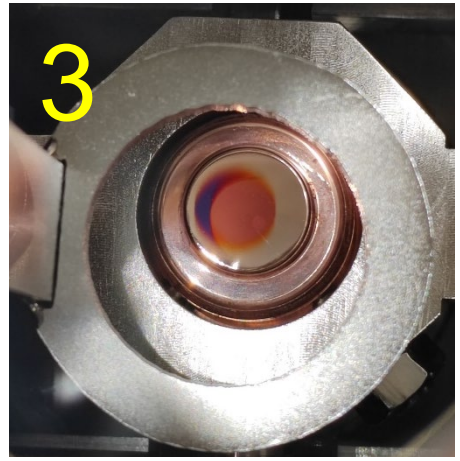
QE of three typical Cs-Te photocathodes

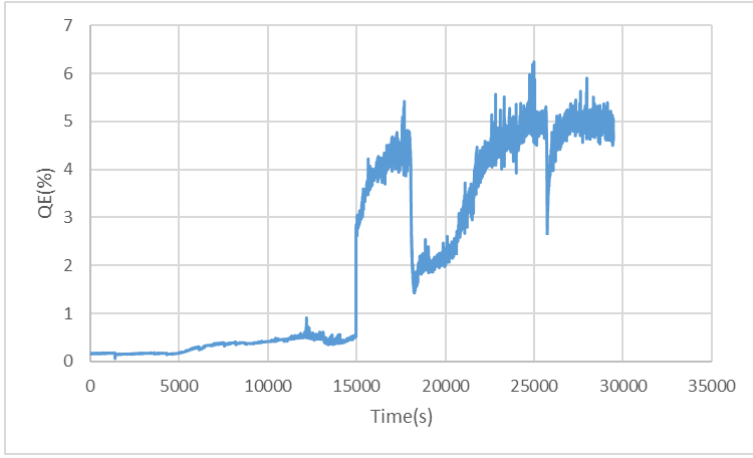












	Substrate	Preparation method	QE@ Preparation chamber	QE@ Suitcase
1	Mo	Te, Cs Sequential	8%@255nm	11%@255nm
2	Mo	Te Intermittent, Cs continuous	10.5%@255nm	15%@255nm
3	Cu	Te Intermittent, Cs continuous	5%@255nm	7%@255nm

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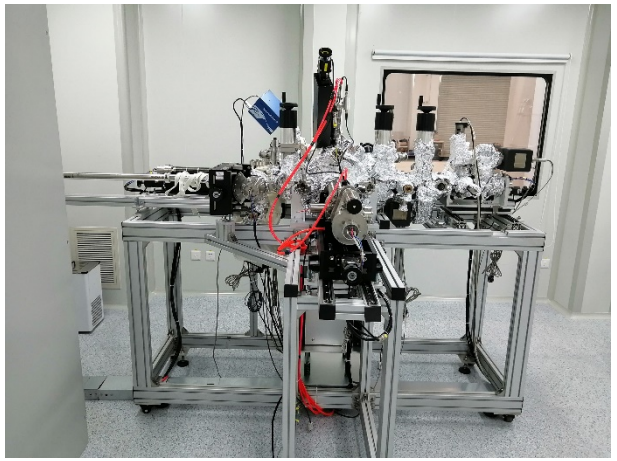
Photocathode transport

Photocathode preparation system

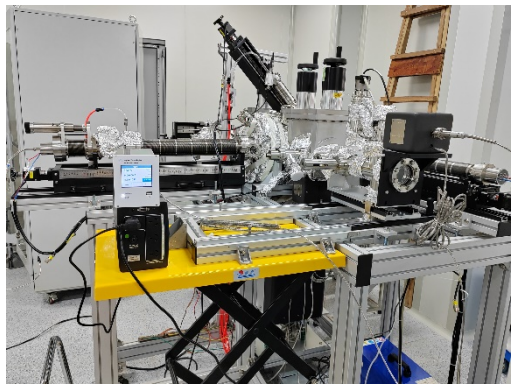
Photocathode suitcase
(Ultra high vacuum，1km)

Photocathode loading system

Photocathode VHF electron gun



Cathode lab



Suitcase unload

~1 km distance

Cathode load lock @Injector tunnel

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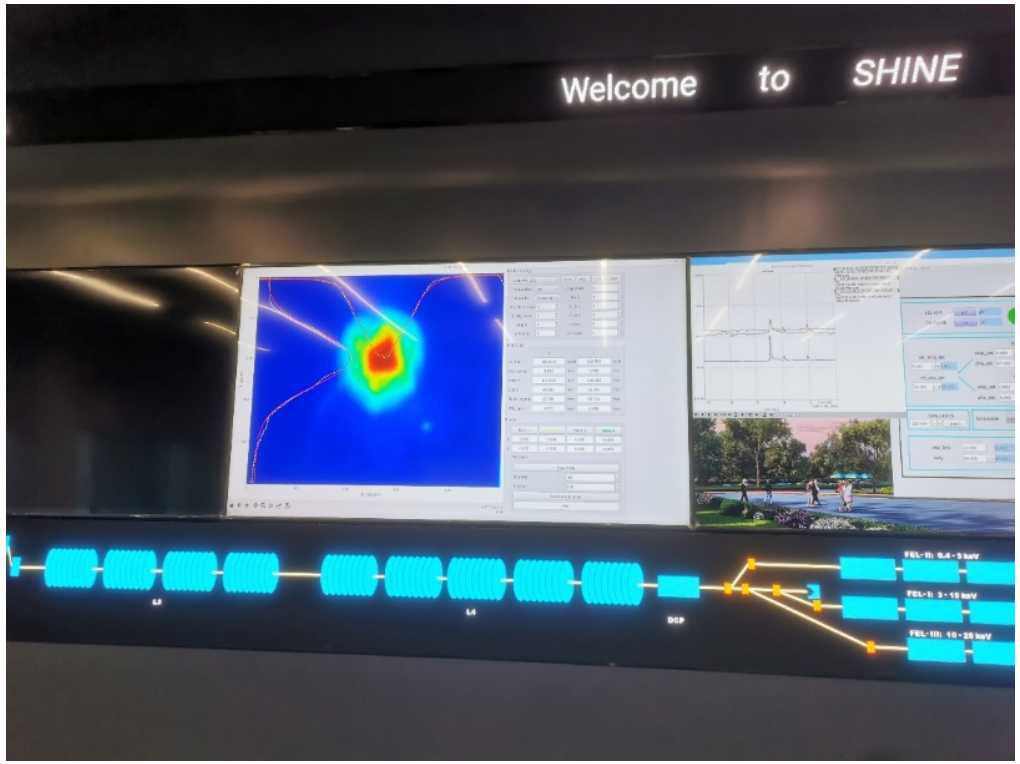
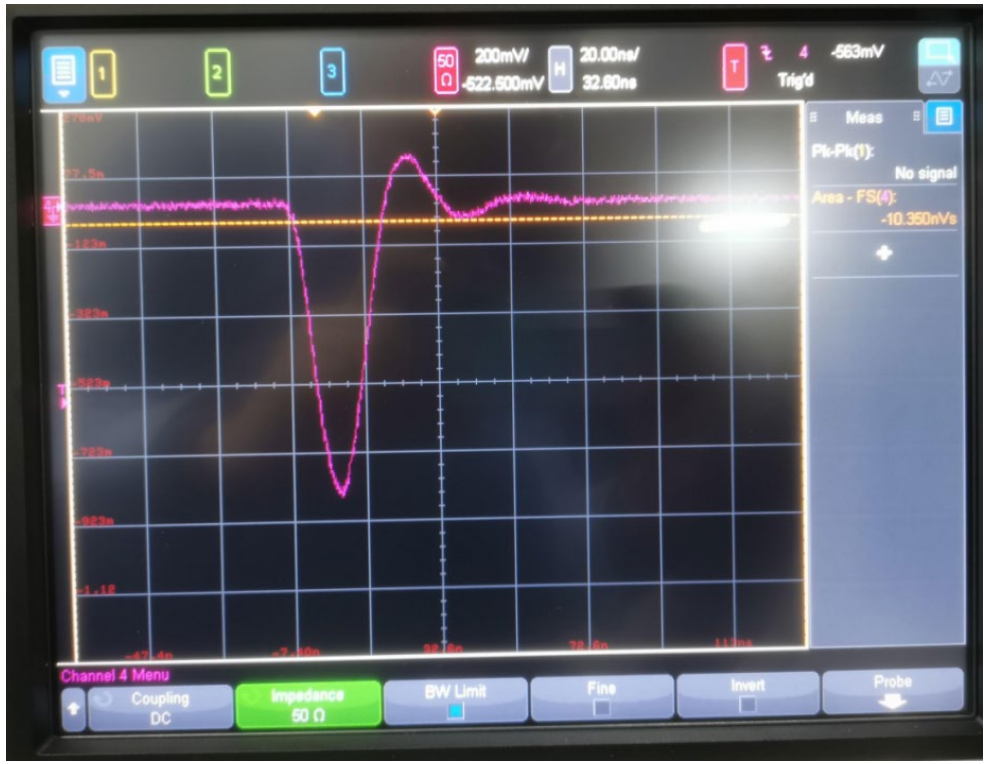
Photocathode emission in SHINE gun

- **Photoelectron beam commissioning started on 2023.12.01**
  - 2023.12.03, 1st photoelectron beam of 200 pC @10 Hz



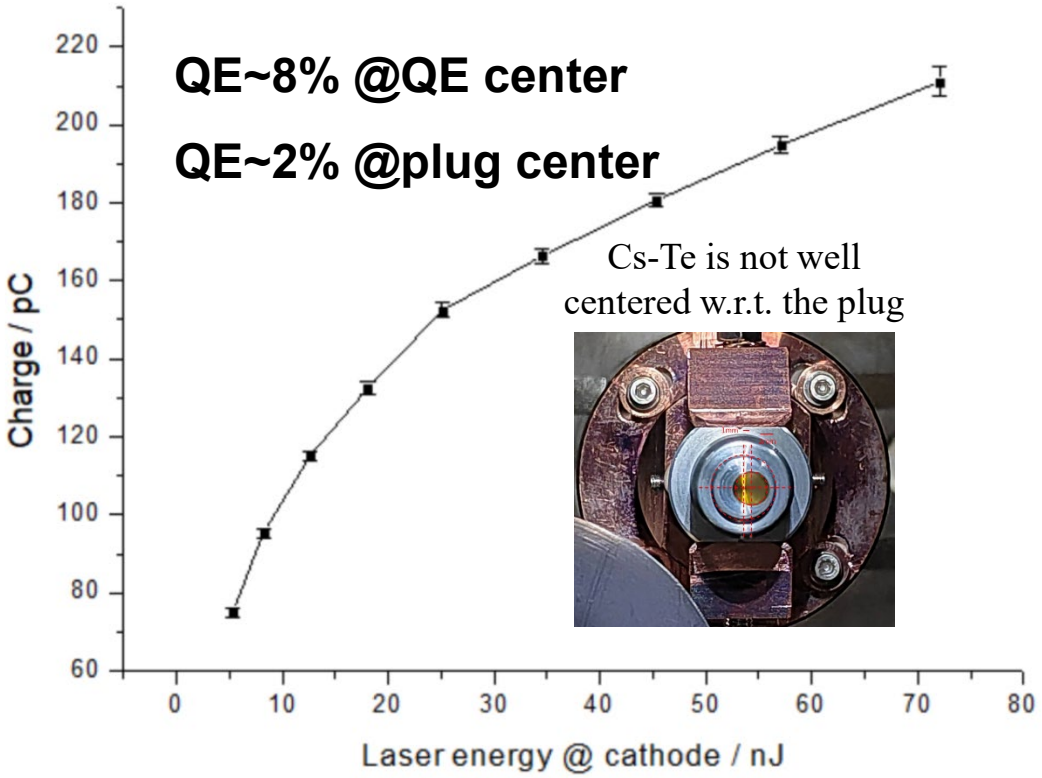
First beam @control room

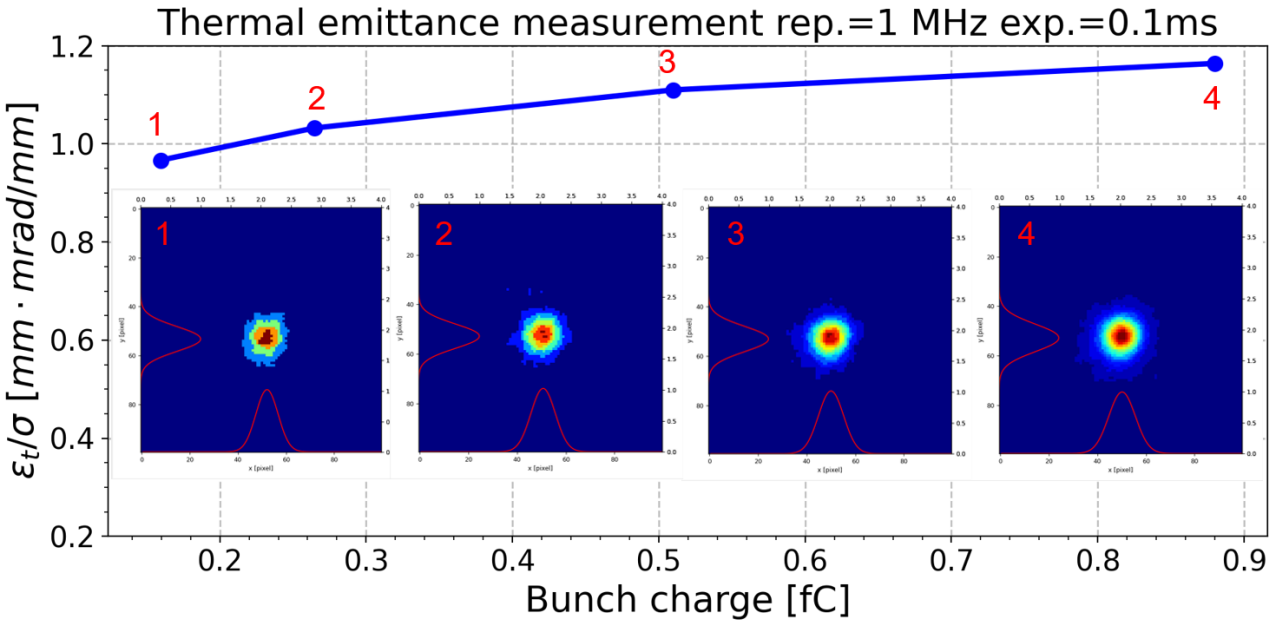


200 pC beam faraday cup signal

Photocathode measurement at SHINE gun

- **Photoathode emission curve, QE and thermal emittance**
  - ~20 ps FWHM, 0.25 mm rms (Gaussian laser)





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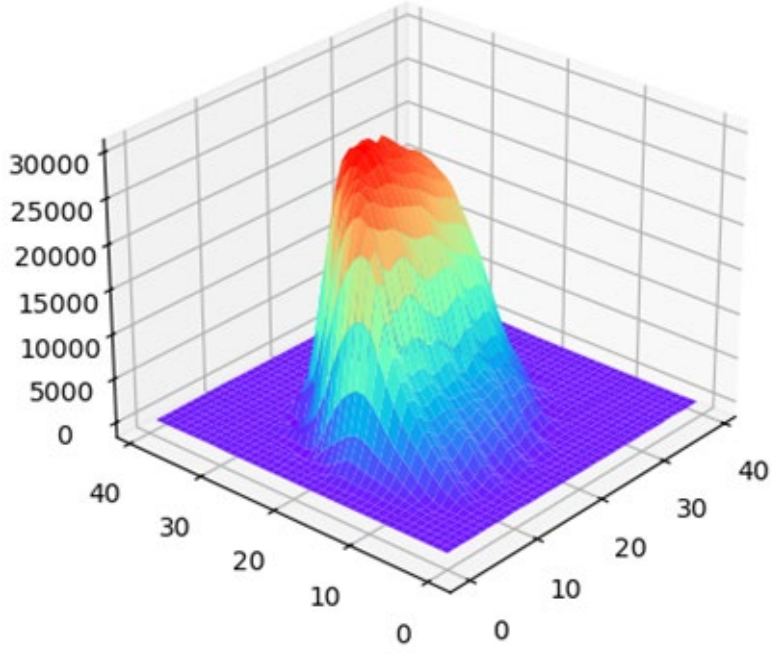
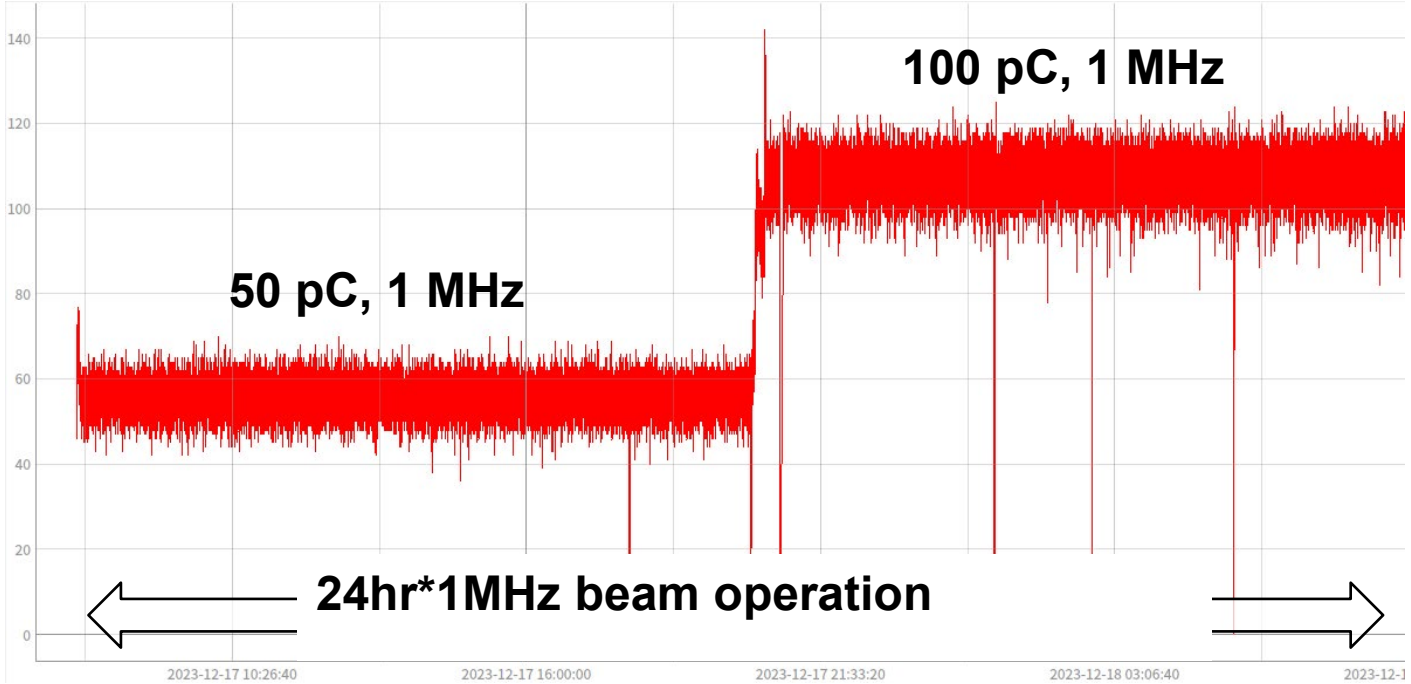
Photocathode measurement at SHINE gun

- The QE map of the Cs-Te photocathode
- The Cs-Te photocathode can operate for a long lifetime in the SHINE VHF electron gun at 50pC and 100pC





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Summary

- **The design, assembly, and debugging of the photocathode system was finished.**
- **Two Cs-Te recipes were developed, and the QE is typically >5%@265nm.**
- **1 MHz beam was generated at the SHINE gun.**
- **Future plans**
  - Further optimize the cathode recipe based on the gun operation results (thermal emittance, lifetime, dark current, QE uniformity…).
  - Explore other high QE photocathodes (UV and green photocathodes).
  - Study on the prepared photocathode properties.

Thank you for your attention!!!