The performance of K_2CsSb photocathode in DC-SRF-II gun

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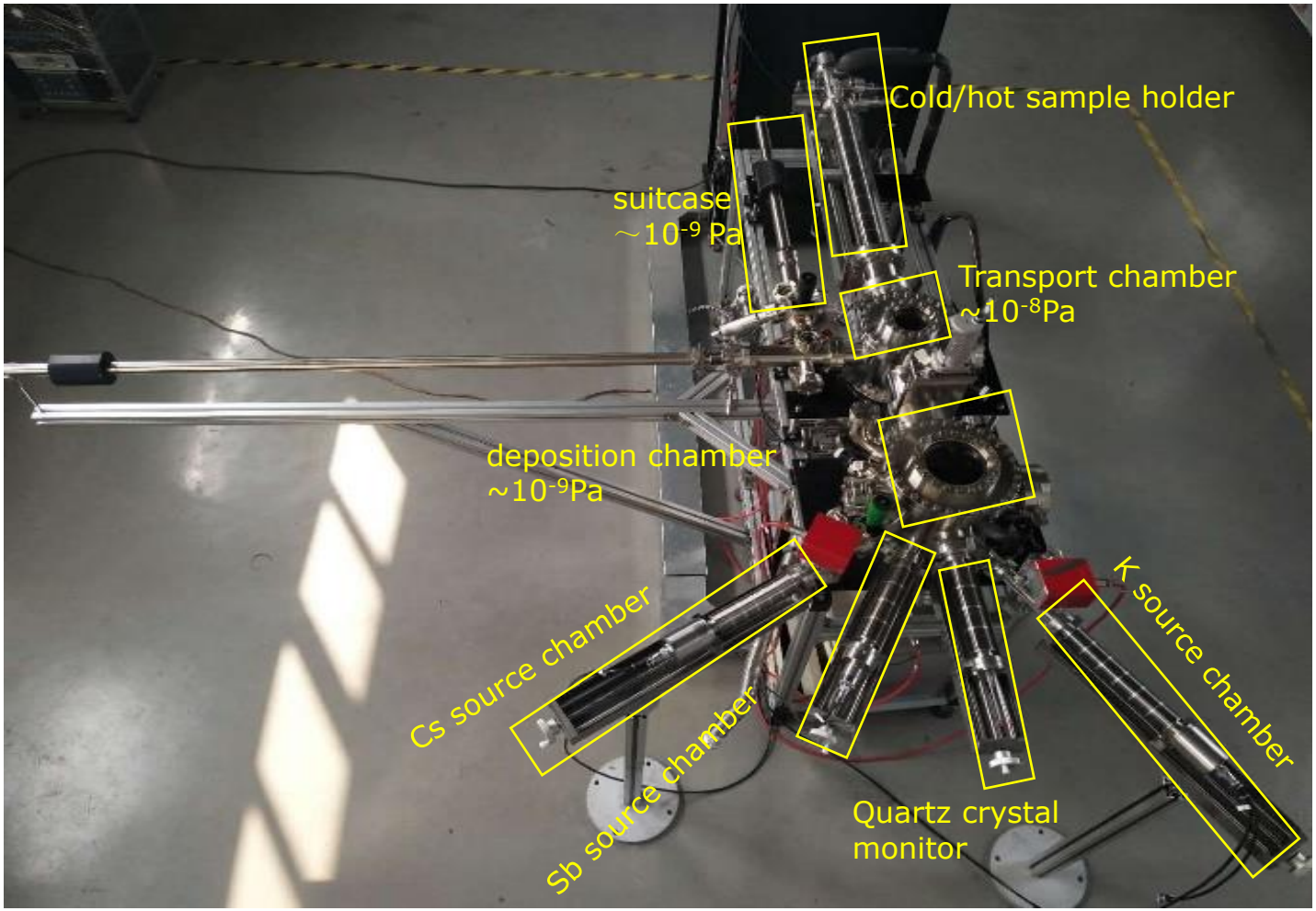
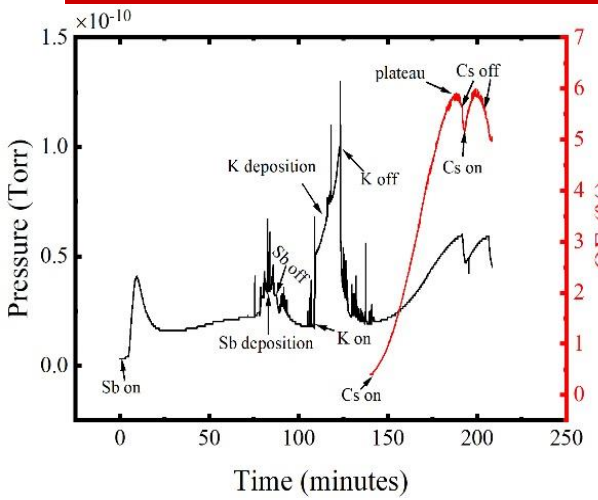
Outline

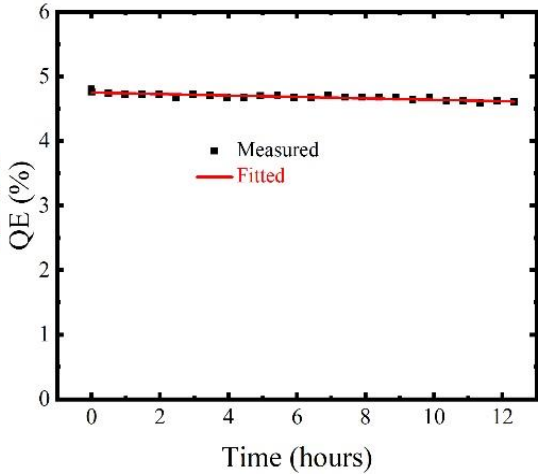
- Deposition and transportation
- Cryogenic operation in the gun
- Conclusion

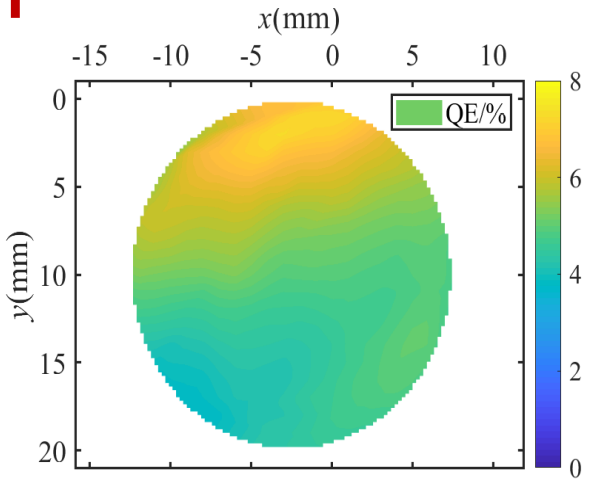
Deposition system



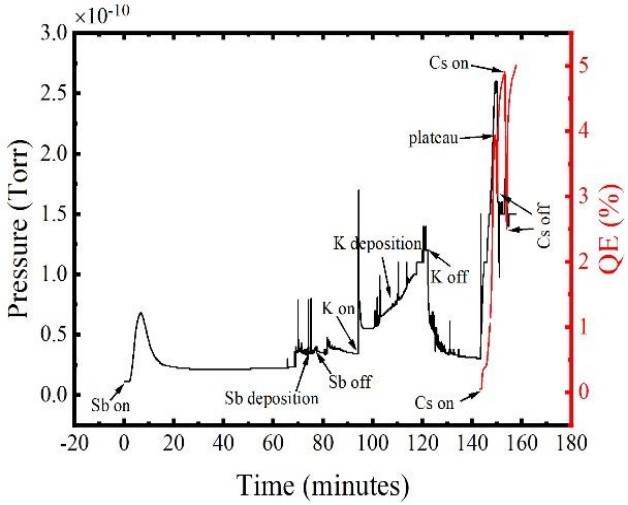
Deposition Recipe

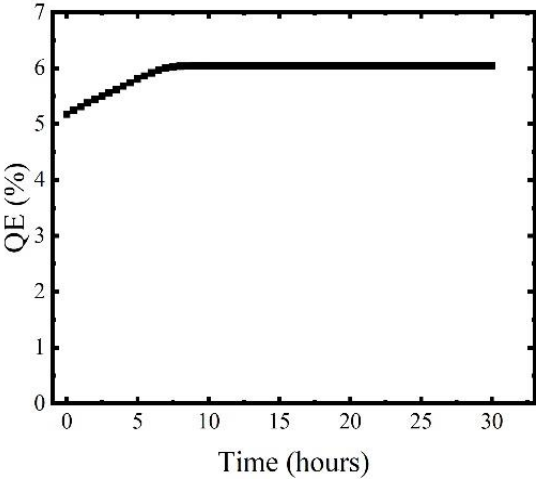


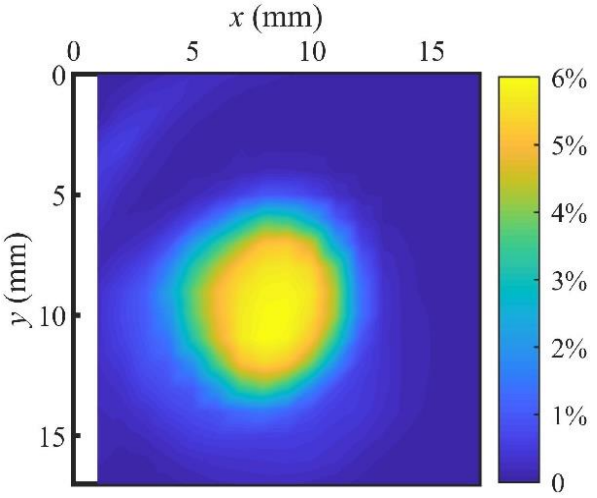




The fabrication process of a typical sample (#1) with regular recipe



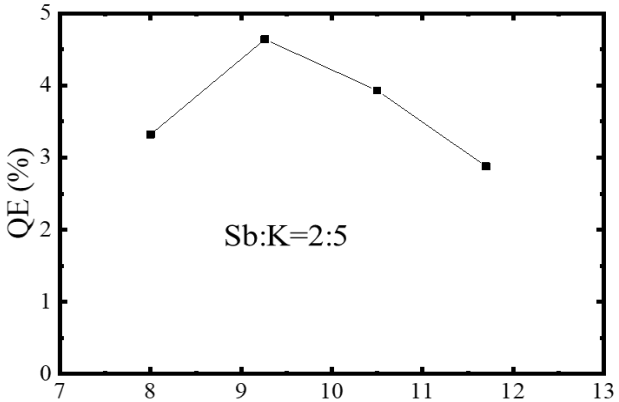


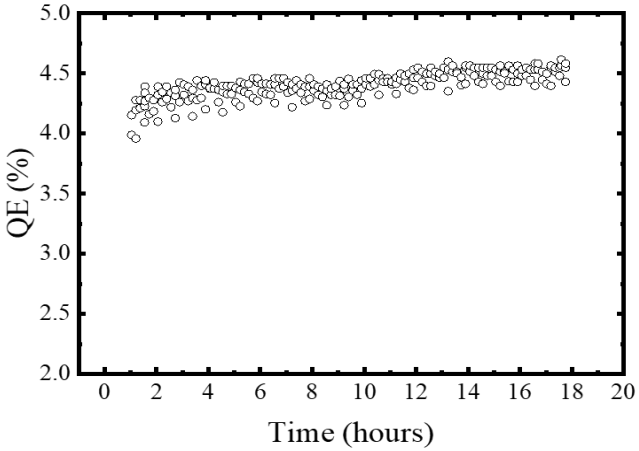


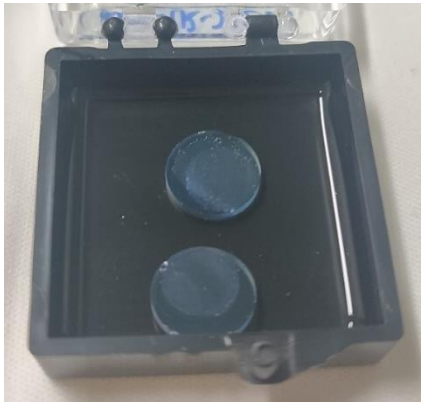
The fabrication process of a typical sample(#2)with improved recipe

Transmission mode photocathode

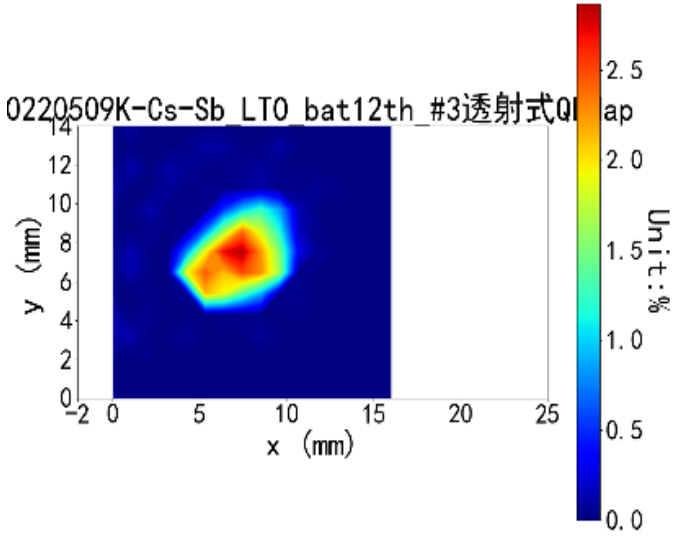
ITO



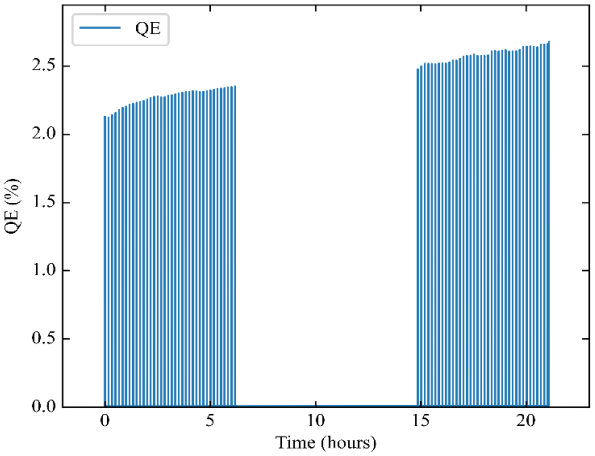




LTO

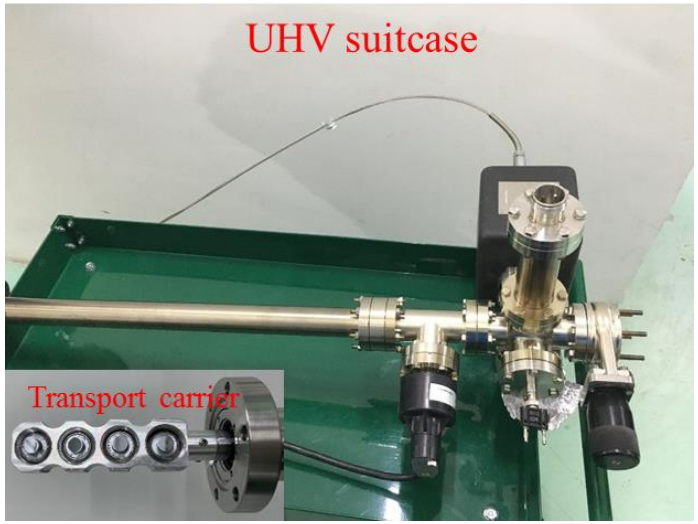


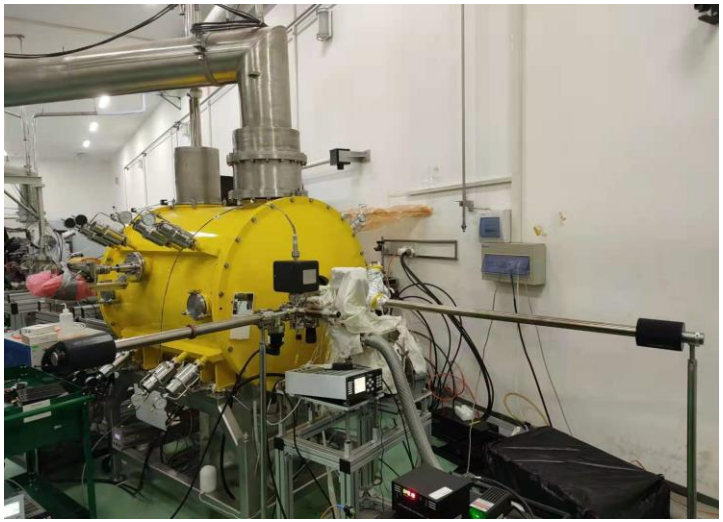
Transmission mode QE Map

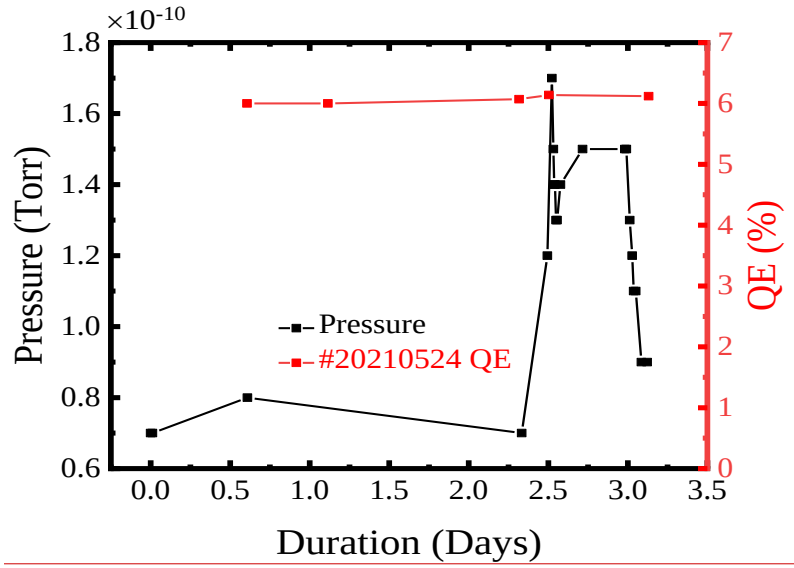


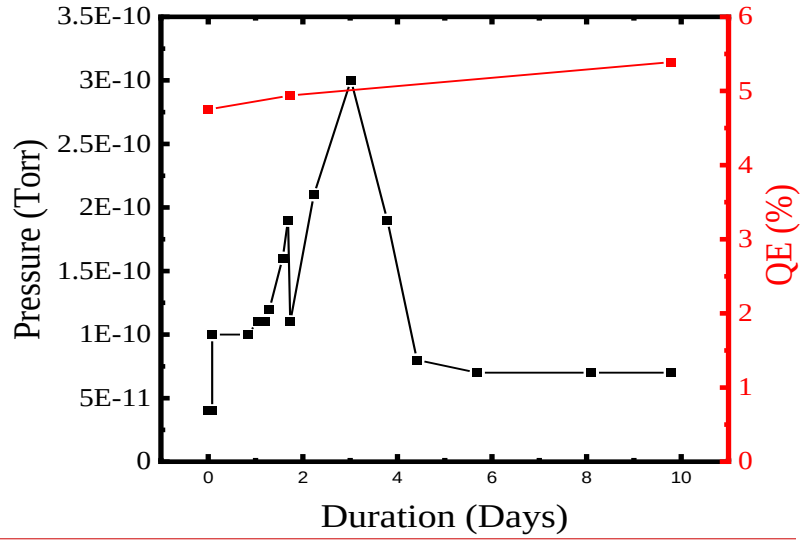
Lifetime test

Transport by Suitcase









Outline

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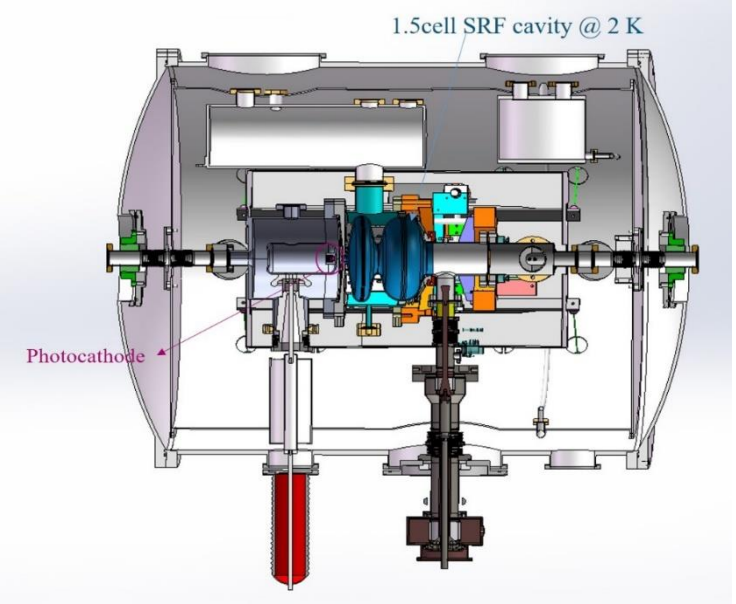
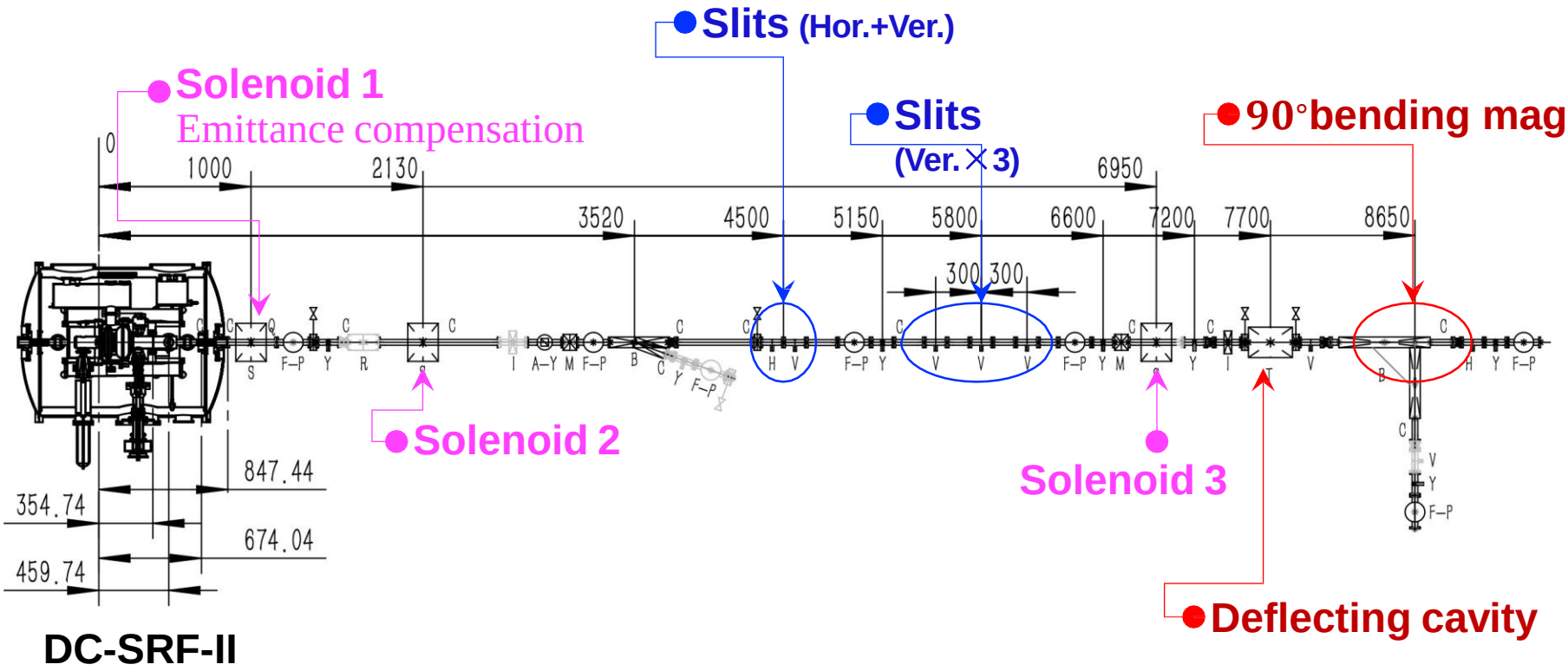
DC-SRF-II First Beam Test

- Assembled in Jan. 2021
- Cooled down on April 20, 2021
- First beam test from Apr. 29, 2021 to Jul. 21, 2021



DC-SRF-II test beam line



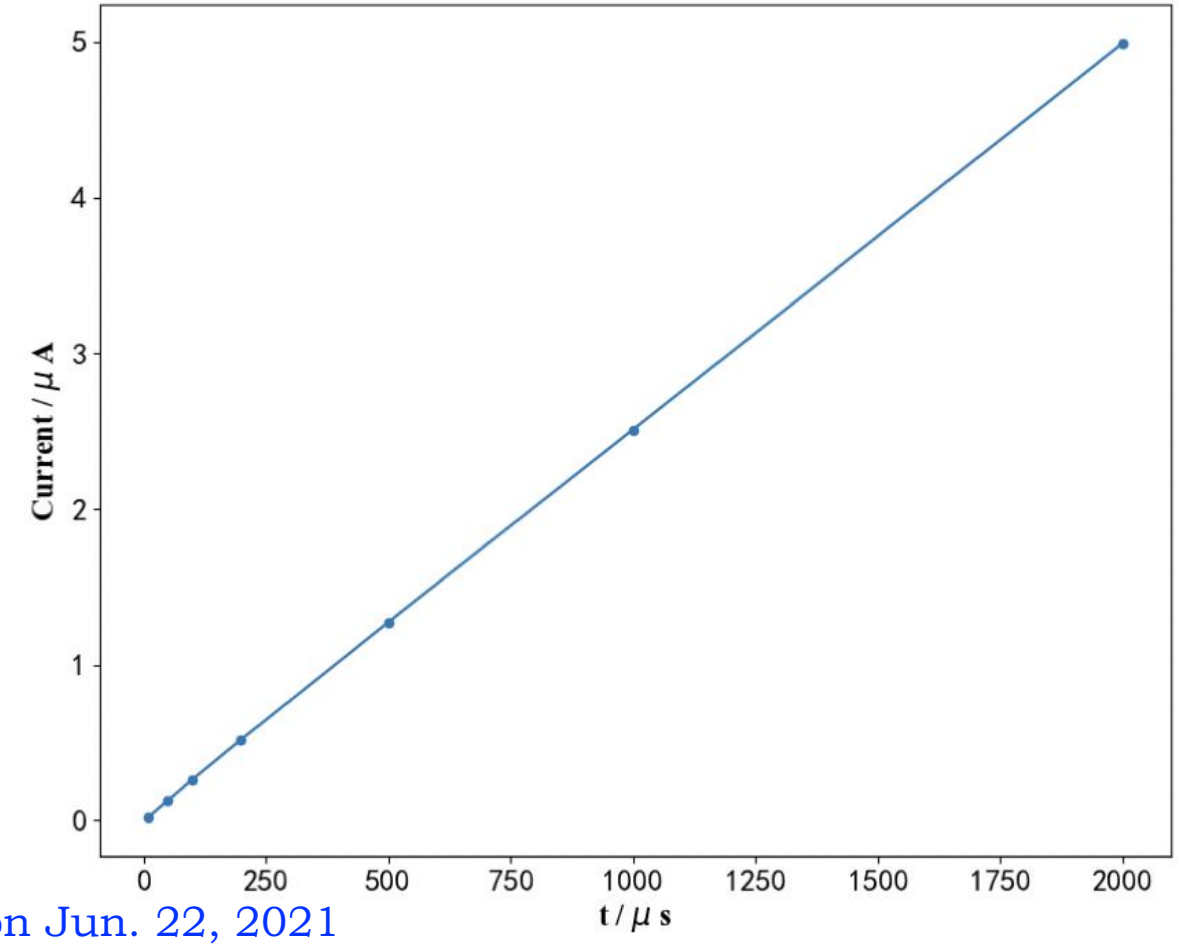
- ✓ **Emittance measurement**: scanning single slit method
- ✓ **Beam energy measurement**: 90° bending magnet; scanning solenoid
- ✓ **Bunch charge measurement**: Faraday cup + current integrator; FCT

DC-SRF-I operation parameters

Parameters	2020	2014-2016
DC voltage	**50 kV**	**45 kV**
SRF cavity frequency	1.3 GHz	
SRF cavity gradient	**7 MV/m**	**9 MV/m**
Driven laser longitudinal profile	Gaussian (nearly)	
Driven laser transverse profile	Gaussian (nearly)	
Driven laser pulse width (RMS)	**1.5 ps**	**5-6 ps**
Driven laser radius (RMS)	1 mm	
DC dark current	**0.13 nA**	**< 1 nA (total)**
RF dark current	**1.6 nA**	
Electron energy	2.7 MeV	3.4 MeV
Bunch charge	**40-80 pC**	**10-40 pC**
Bunch repetition rate	**1 MHz, 10 MHz**	**0.8125 - 81.25 MHz**
Macro pulse length	1 - 10 ms	1 - 7 ms
Macro pulse repetition rate	5 - 10 Hz	
Average current in macro pulse	0.8 mA (max.)	0.5 - 1 mA

Bunch Charge Test

Average beam current vs macro pulse duration

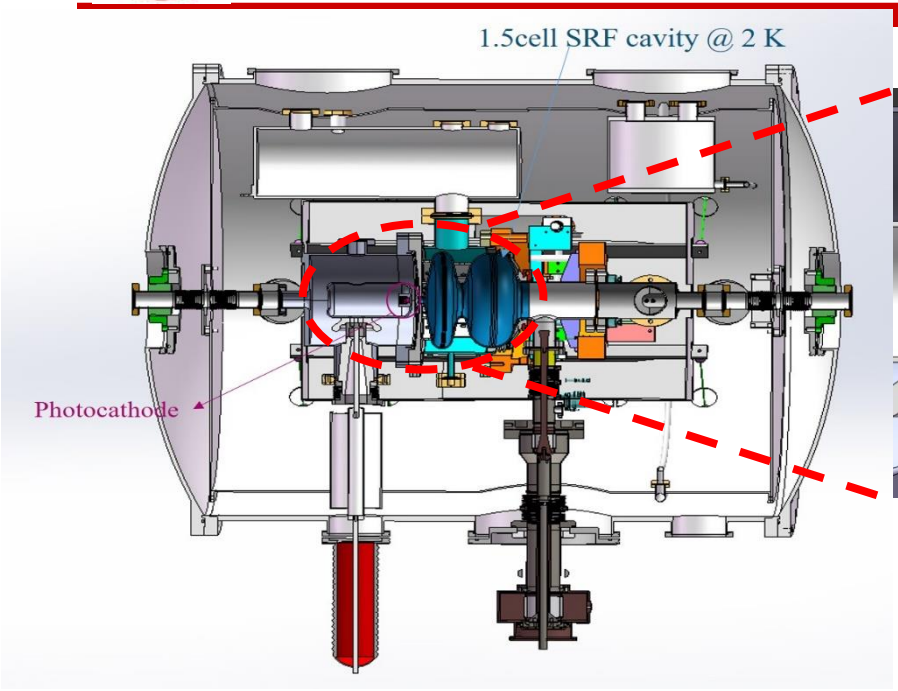


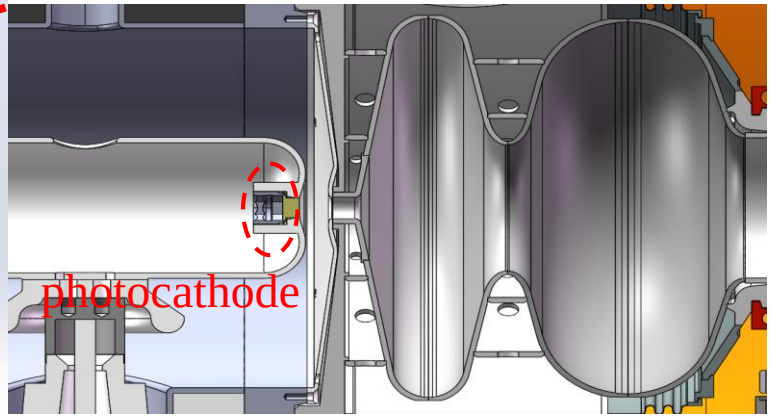
Bunch charge
250 pC

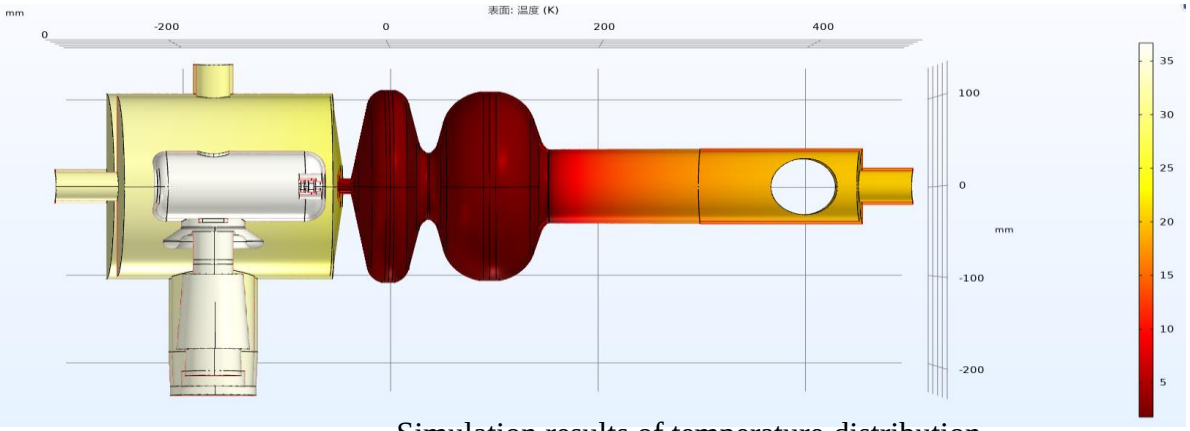
Experiments on Jun. 22, 2021
Preliminary results

Macro pulse repetition rate 10 Hz, w/o laser shaping

Cryogenic performance



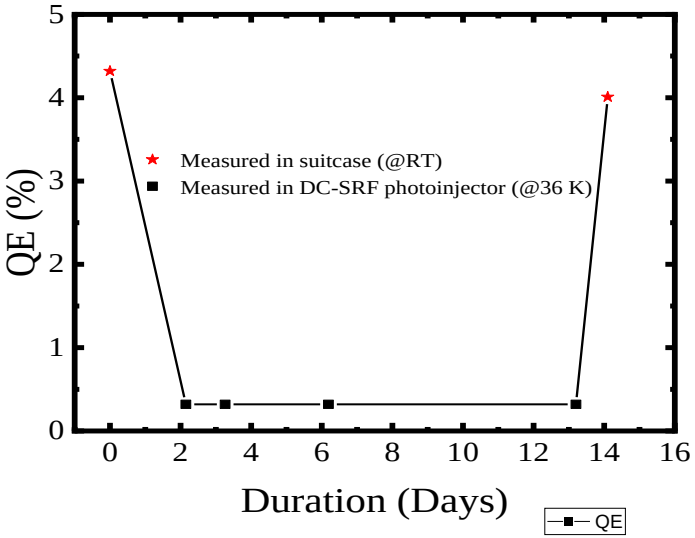


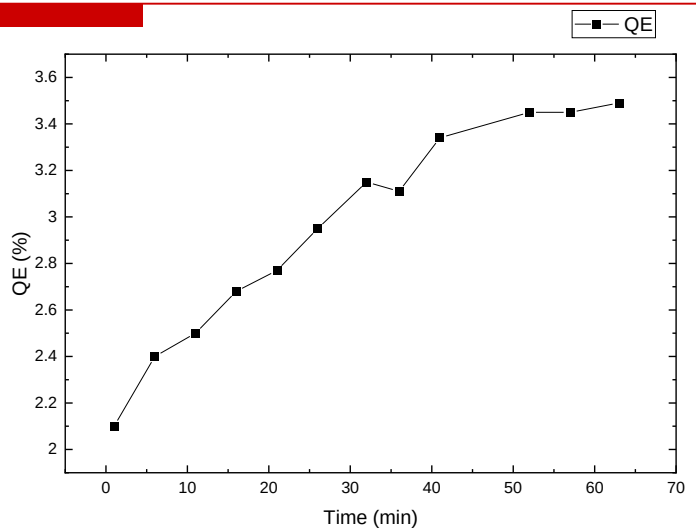


Simulation results of temperature distribution

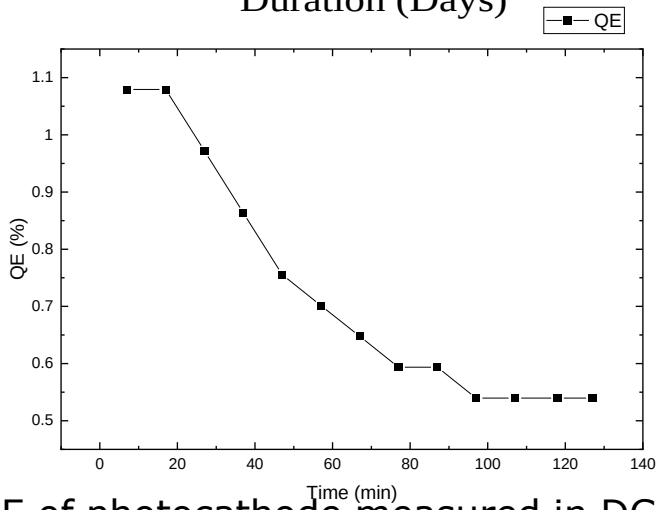
position	Valve	cathode	Beam tube
measured/K	35.17	TBD	17.06
simulation/K	32.53	36	18.64
error	7.9		9.3

Cathode test in the Gun





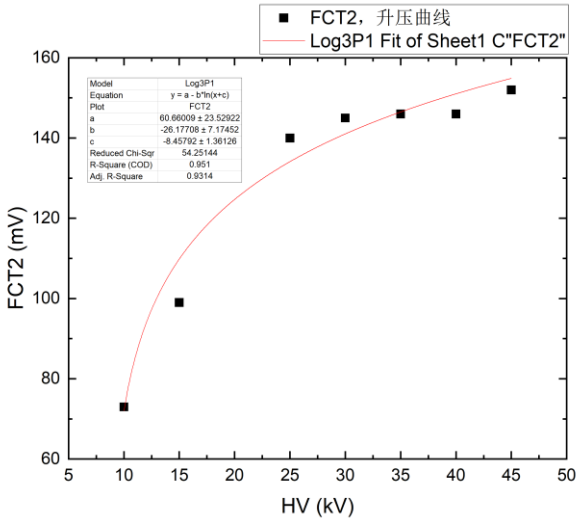
QE of photocathode measured in suitcase after extracting from DC-SRF photoinjector

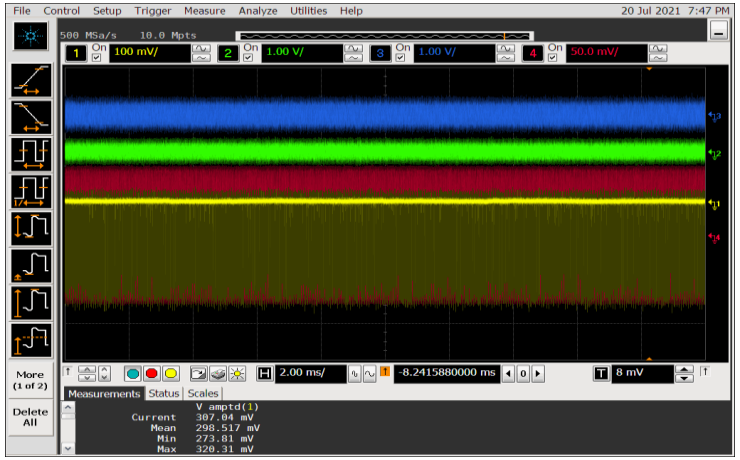


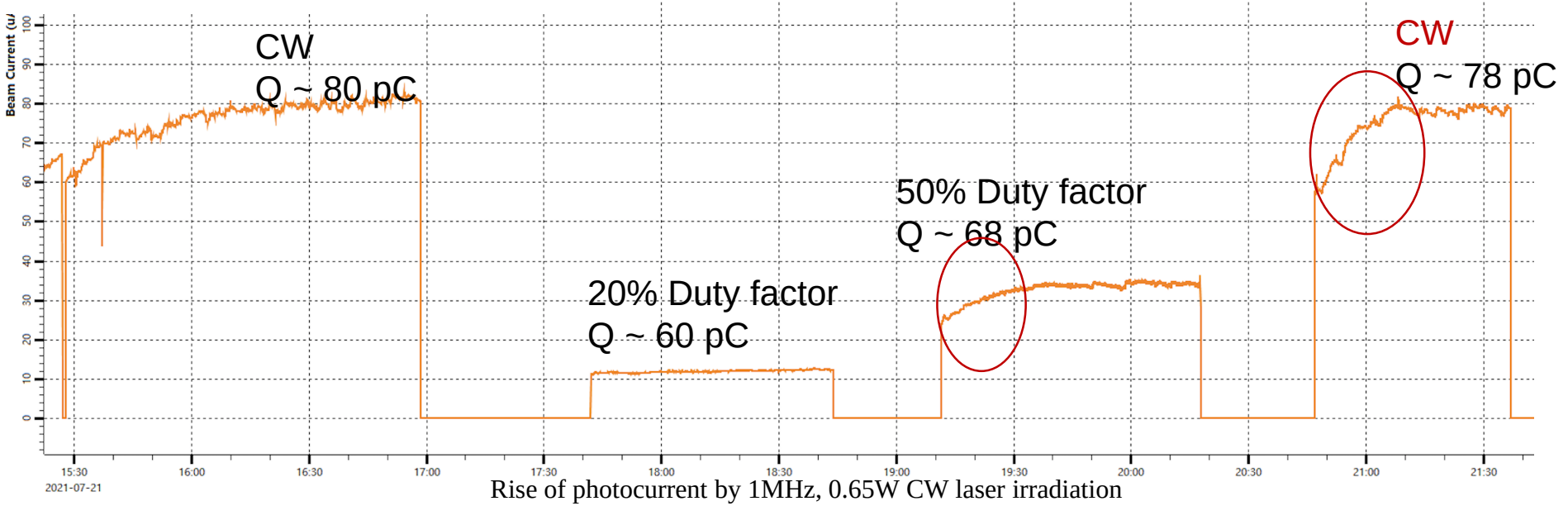
QE of photocathode measured in DC-SRF photoinjector

The manipulator after opening the suitcase

First CW Operation



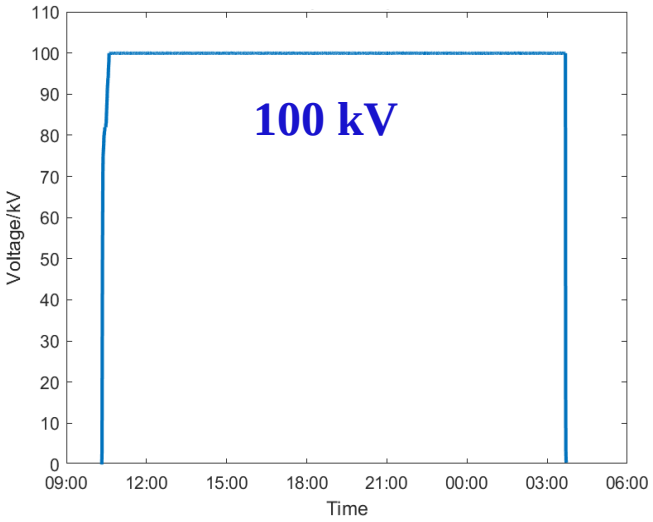




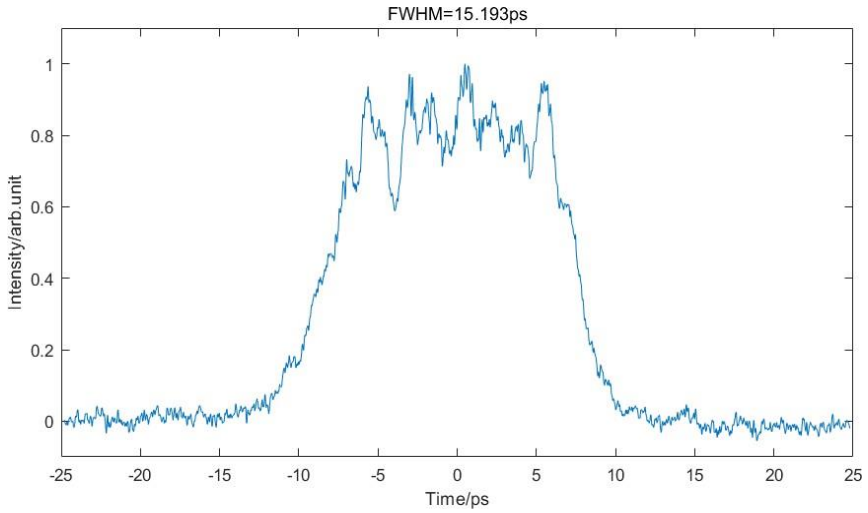
Rise of photocurrent by 1MHz, 0.65W CW laser irradiation

Second beam test of DC-SRF-II

- SRF cavity
  9 MV/m → **13 MV/m** after High pressure rinsing (HPR)
- DC voltage: 45 kV → **100 kV**



DC high voltage

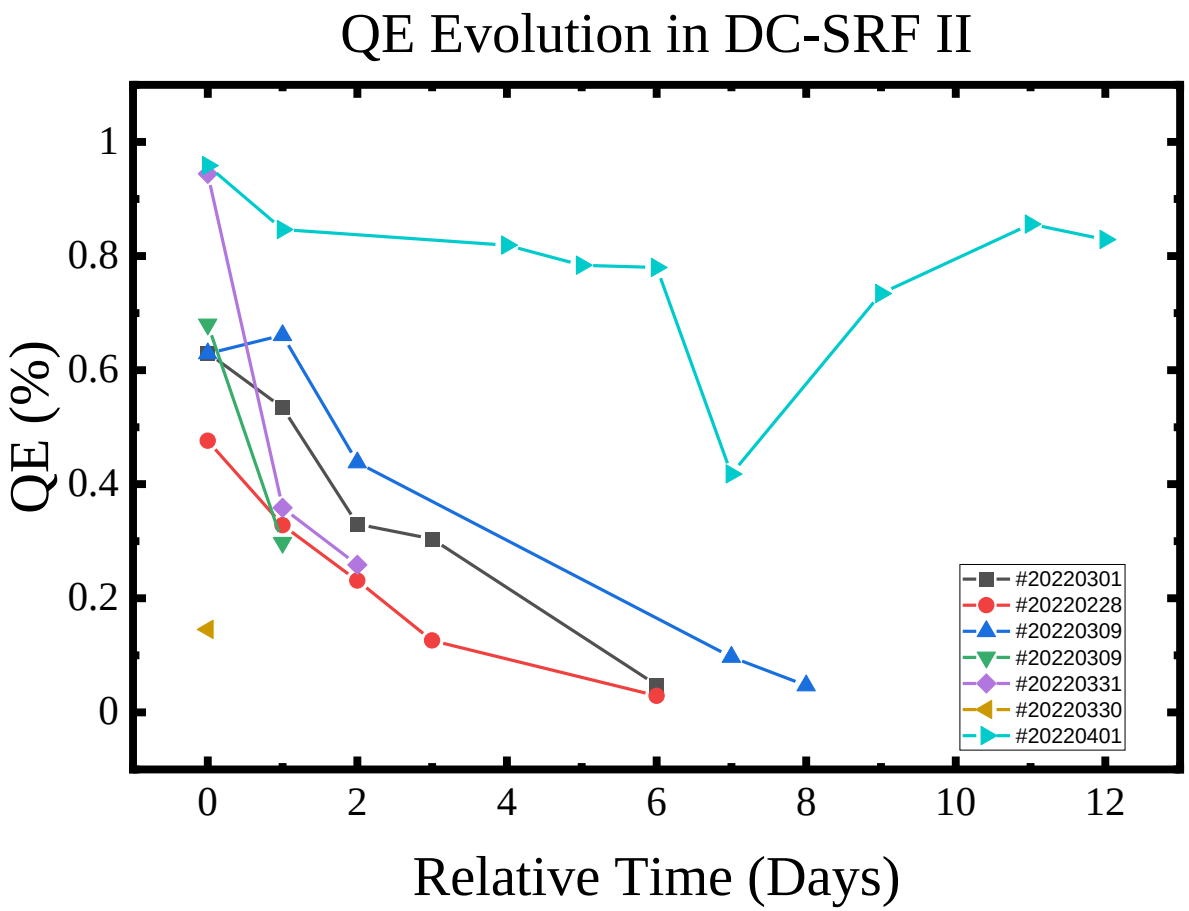


Laser After pulse stacking @ 519 nm

Other improvement:

Beam line vacuum, cryostat vacuum, steering magnets stability (new power supply), beam diagnostics, and control system, etc

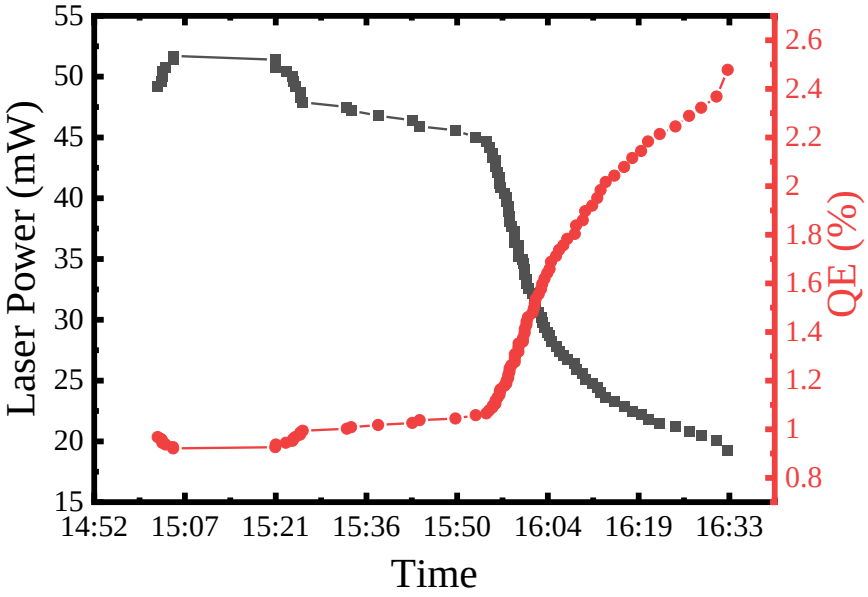
Lifetime of photocathode in the gun



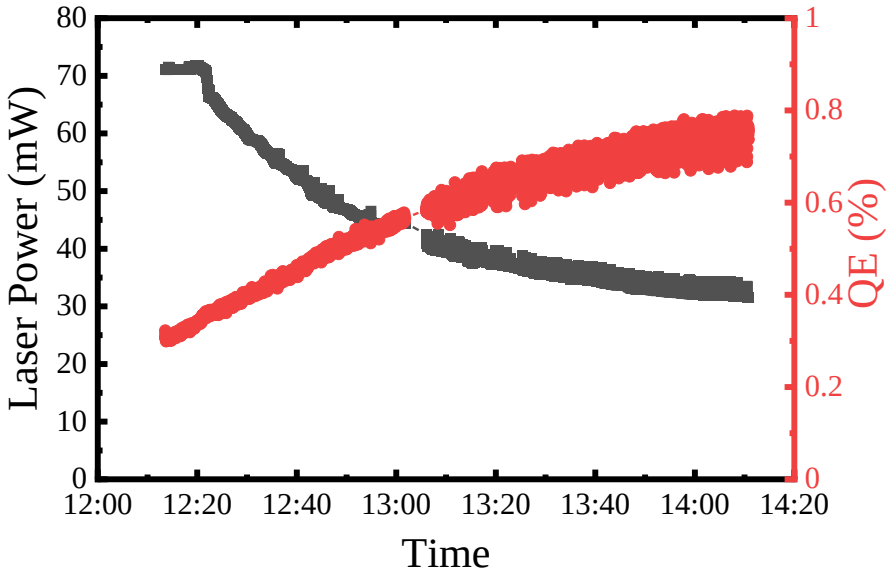
The main difference: vacuum of the beam line

Results of CW Operation

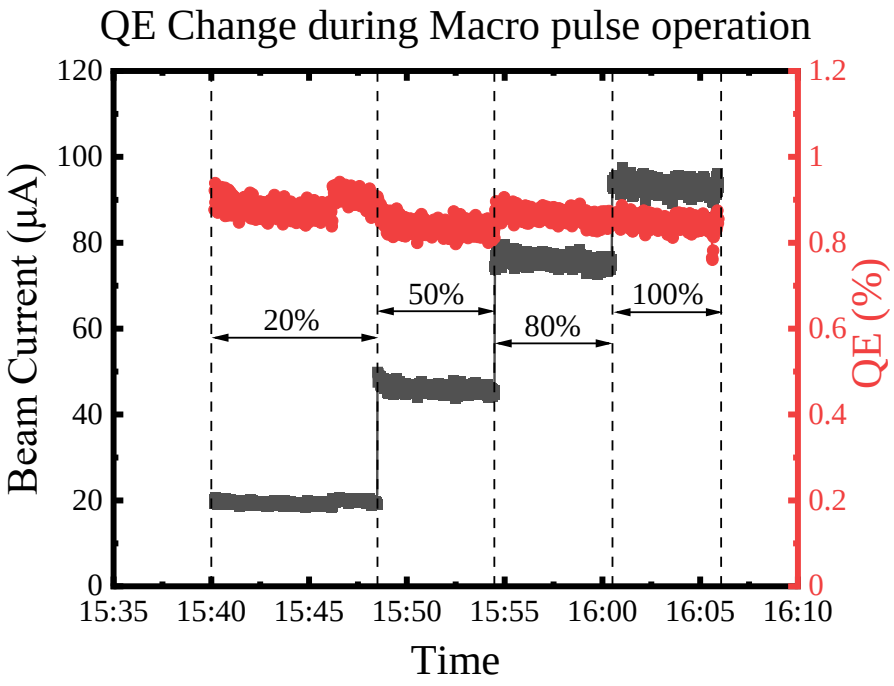
Laser Power Change during 126 μA CW Operation



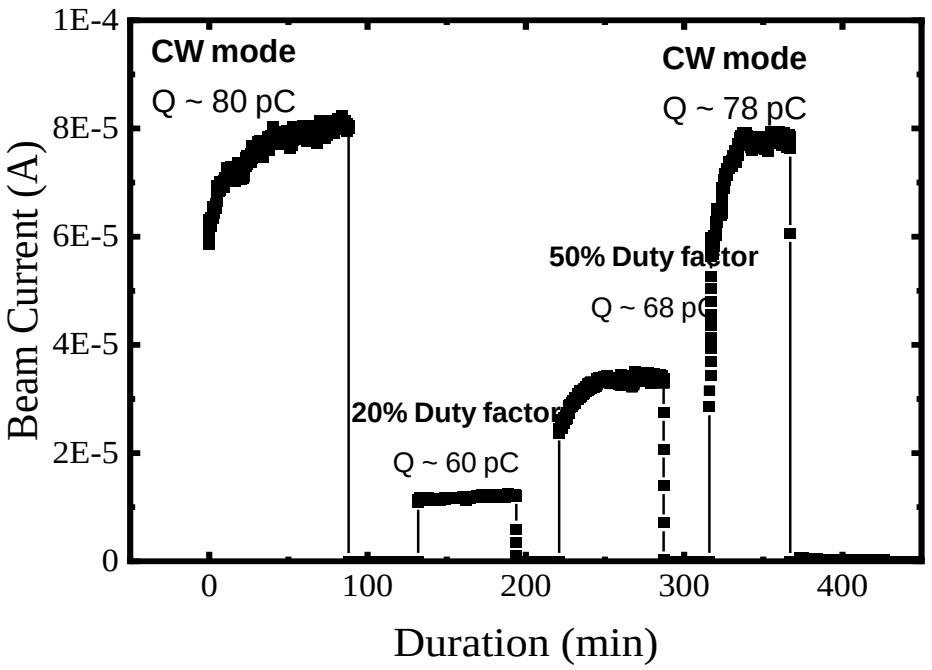
Laser Power and QE Change during 100 μA CW Operation



Macro-pulse Operation results

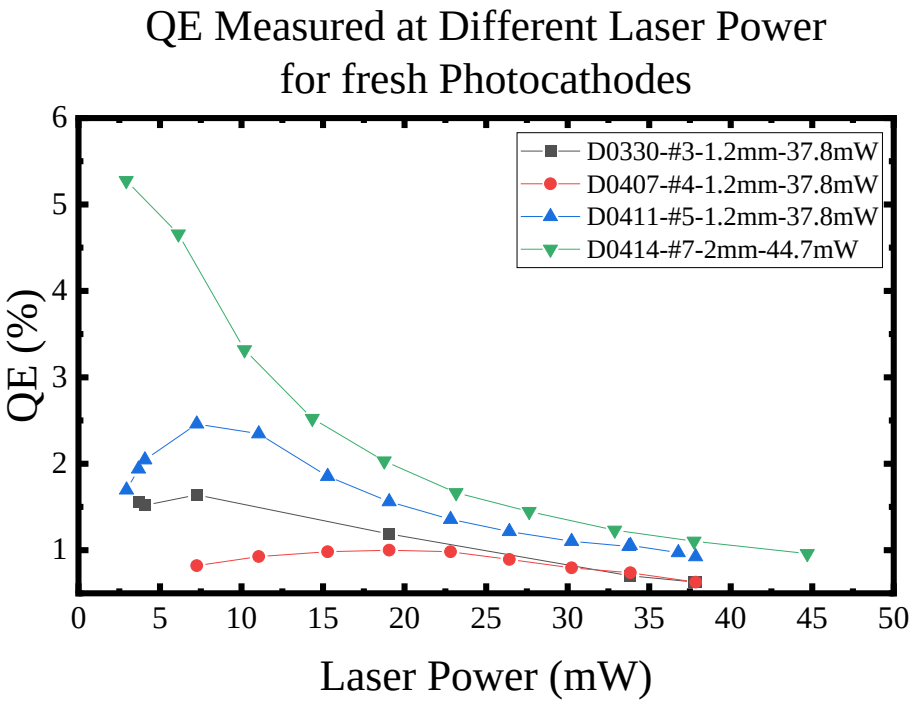


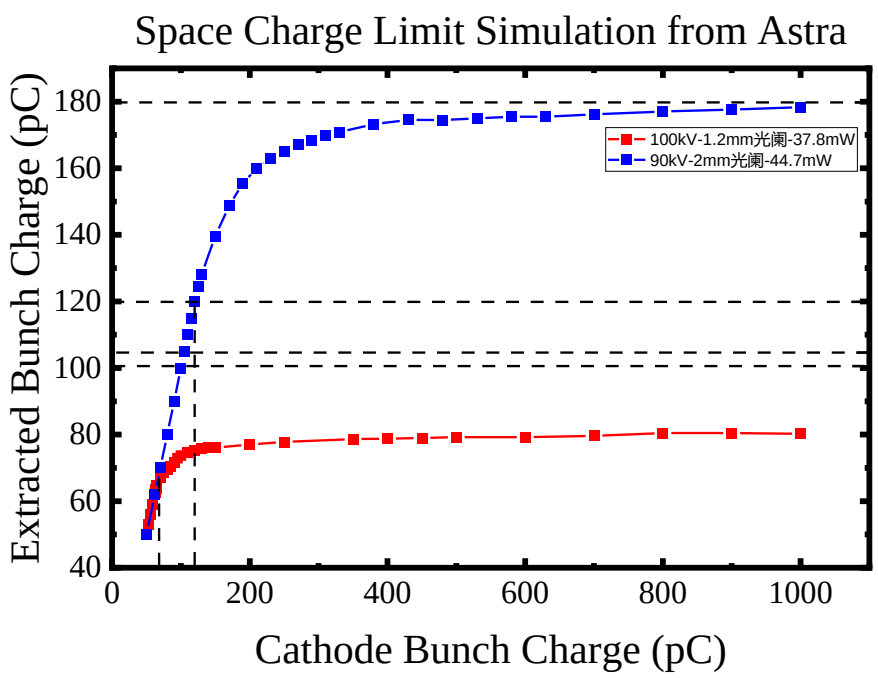
Experiment on 2022.04



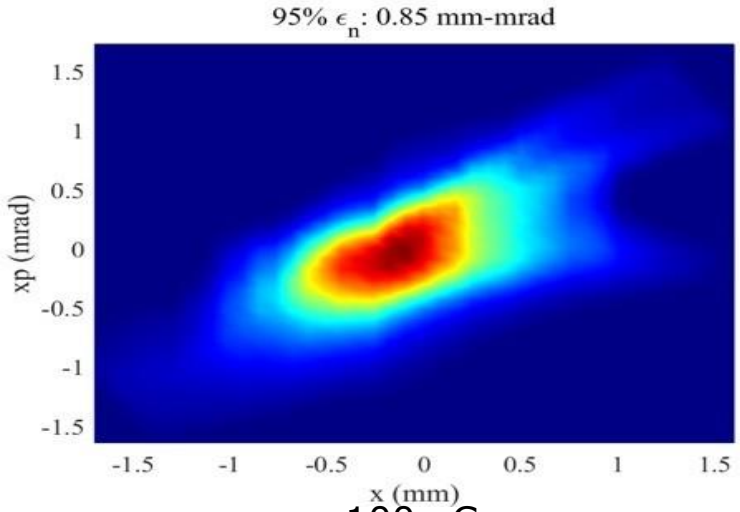
Experiment on 2021.07

QE Measurements at different Power for fresh Cathodes

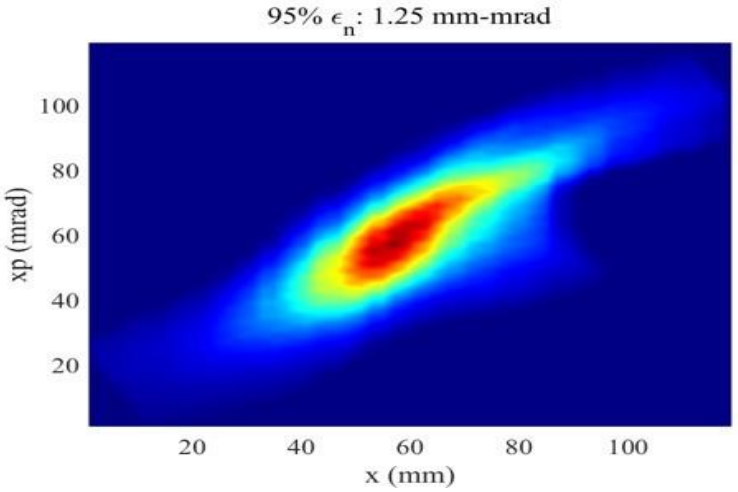




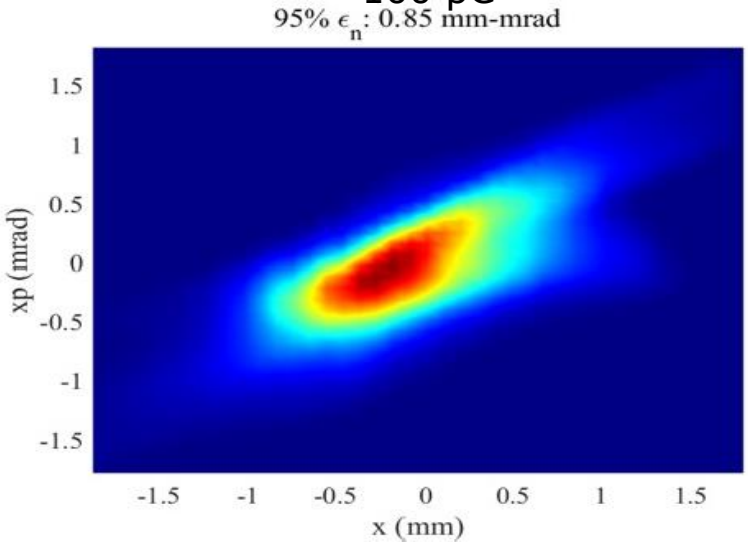
Emittance measurement @ 100 pC and above



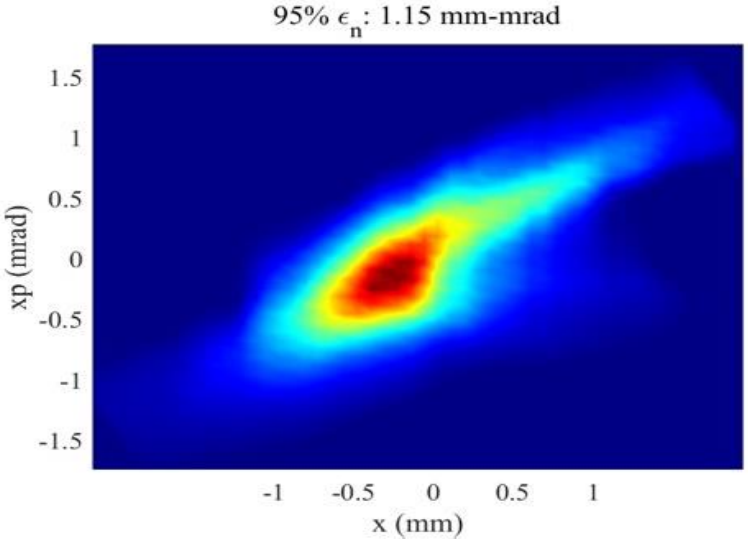
100 pC



260 pC



100 pC



230 pC

Future work

- The QE of the photocathode can fulfill the demand of the DC-SRF gun during the beam experiment.
- The intrinsic emittance of the K_2CsSb photocathode at 36 K will be measured in the following beam experiments with the DC-SRF photoinjector.
- The cryo-photocathode can deliver ultra-low emittance electron beam in the DC-SRF photoinjector.

Conclusion

- Transmission mode bialkali photocathode has been repeatedly fabricated at PKU with QE around 5% and long lifetime.
- The bialkali photocathode has been used in the DC-SRF-II gun. The typical QE of the photocathode was around 1% at about 36 K, which is about 20% of the value at room temperature. The lifetime can be several weeks, which is strongly correlated to the vacuum of the gun.
- The measured normalized rms emittance of the electron beam at the exit the gun is around 0.5 mm-mrad @ 20 pC, 0.85 mm-mrad @ 100 pC, and 1.25 mm-mrad @ 260 pC.
- The cryogenic performance of the K_2CsSb photocathode has been investigated in the DC-SRF-II gun, and the intrinsic emittance of the photocathode at cryogenic temperature will be measured in the next experiment.

Thank you for your attention!