



The Cryogenic operation of K_2CsSb photocathode in the DC-SRF photoinjector

XIE Huamu
Peking University

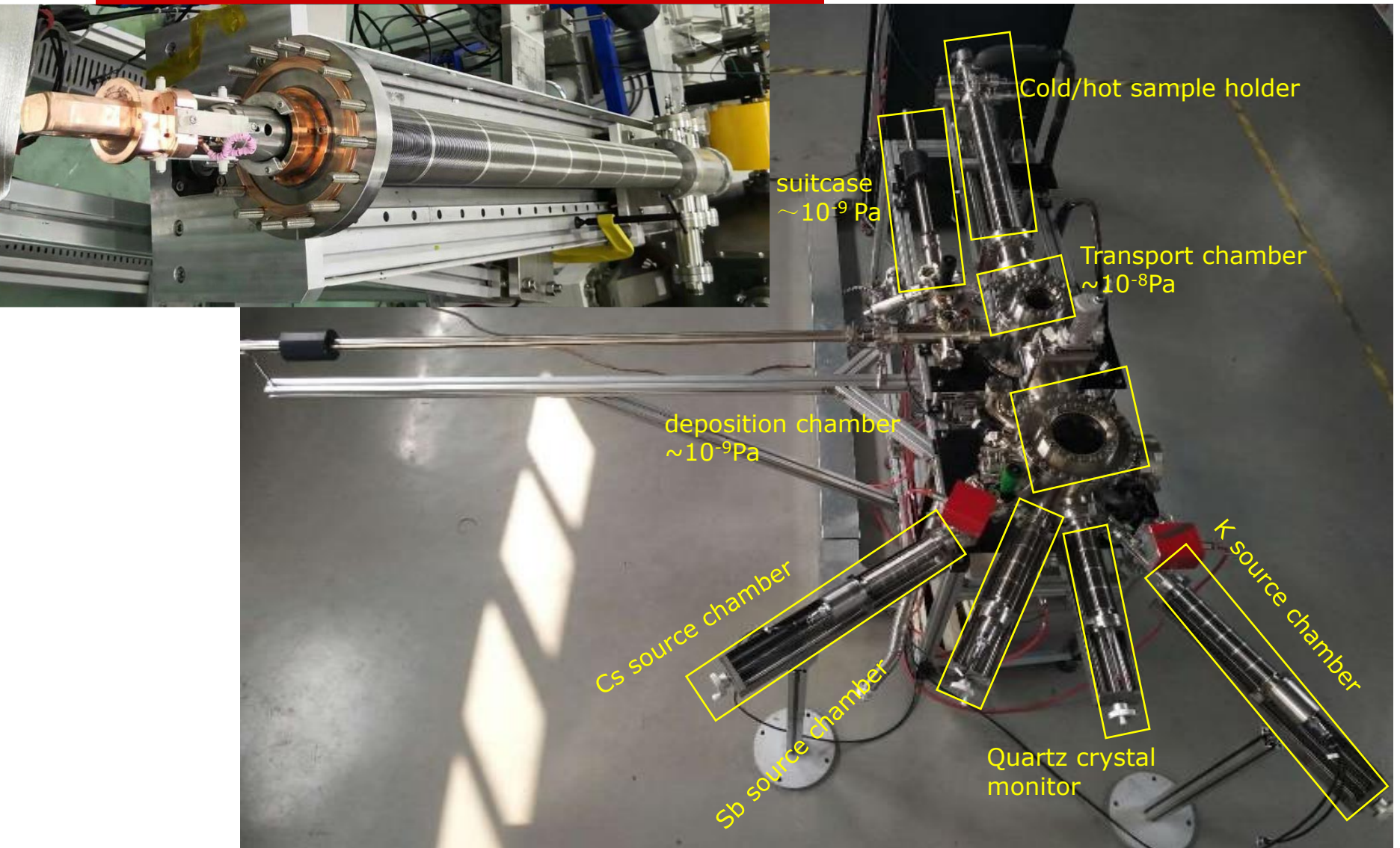


Outline

- Deposition and transportation
- Cryogenic operation in the gun
- Cryogenic performance of K_2CsSb photocathode
- Conclusion

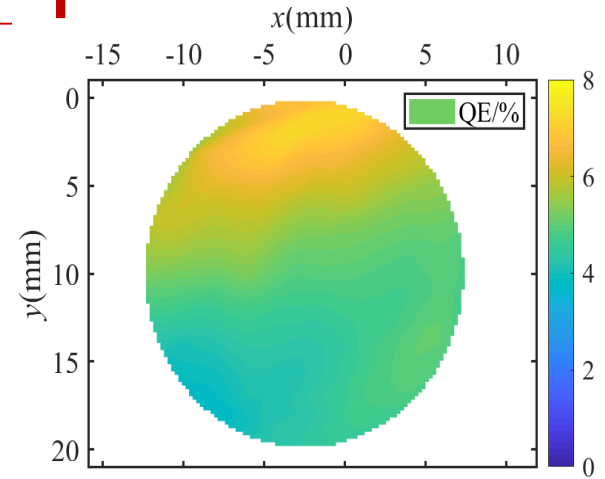
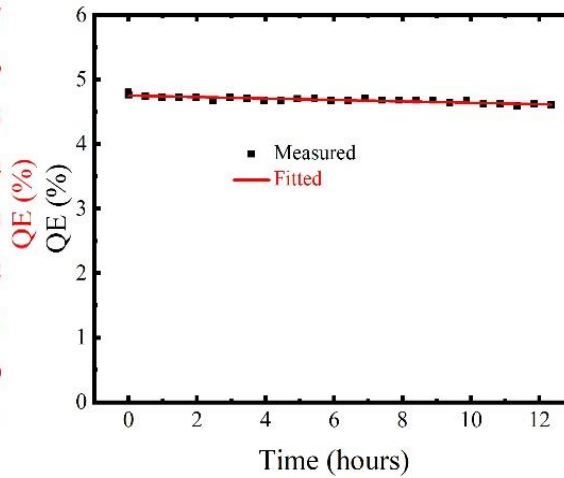
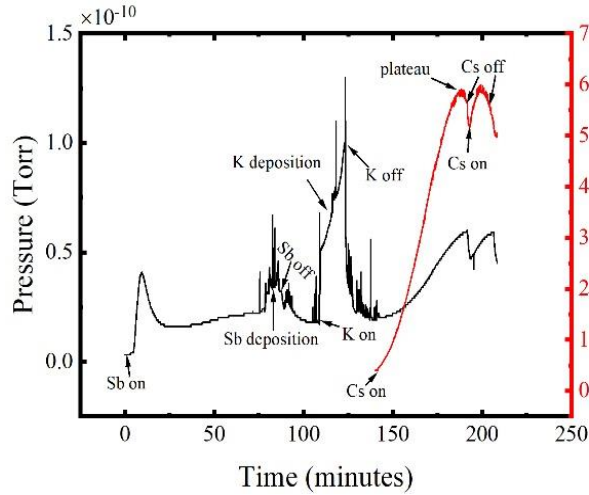


Deposition system

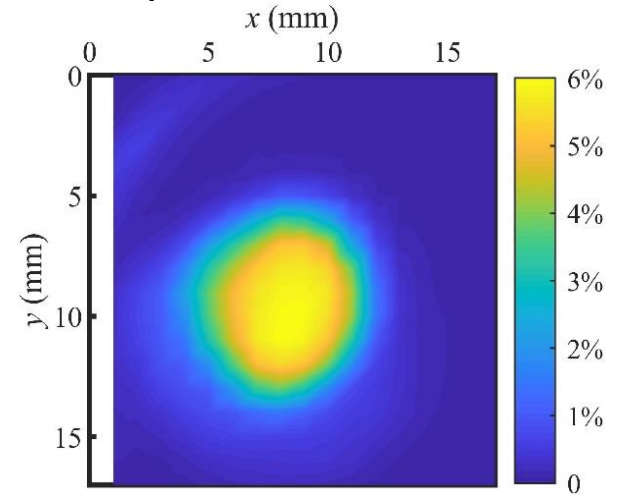
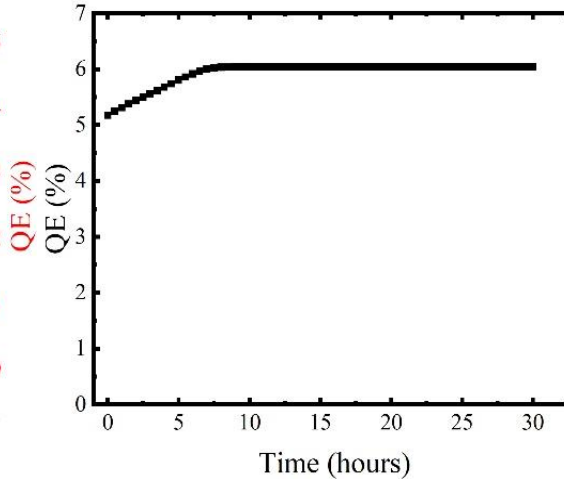
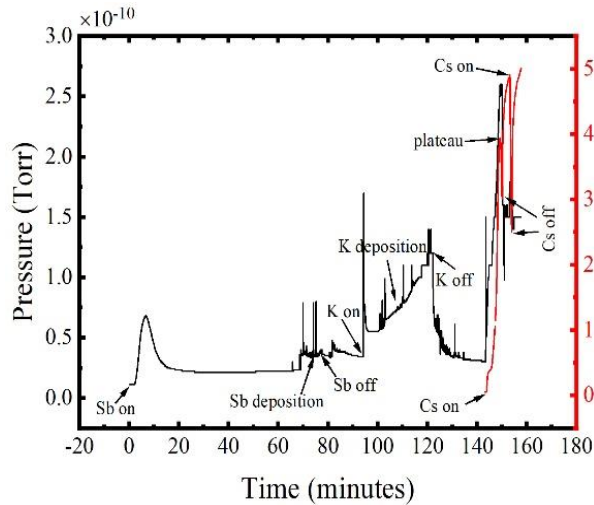




Deposition Recipe



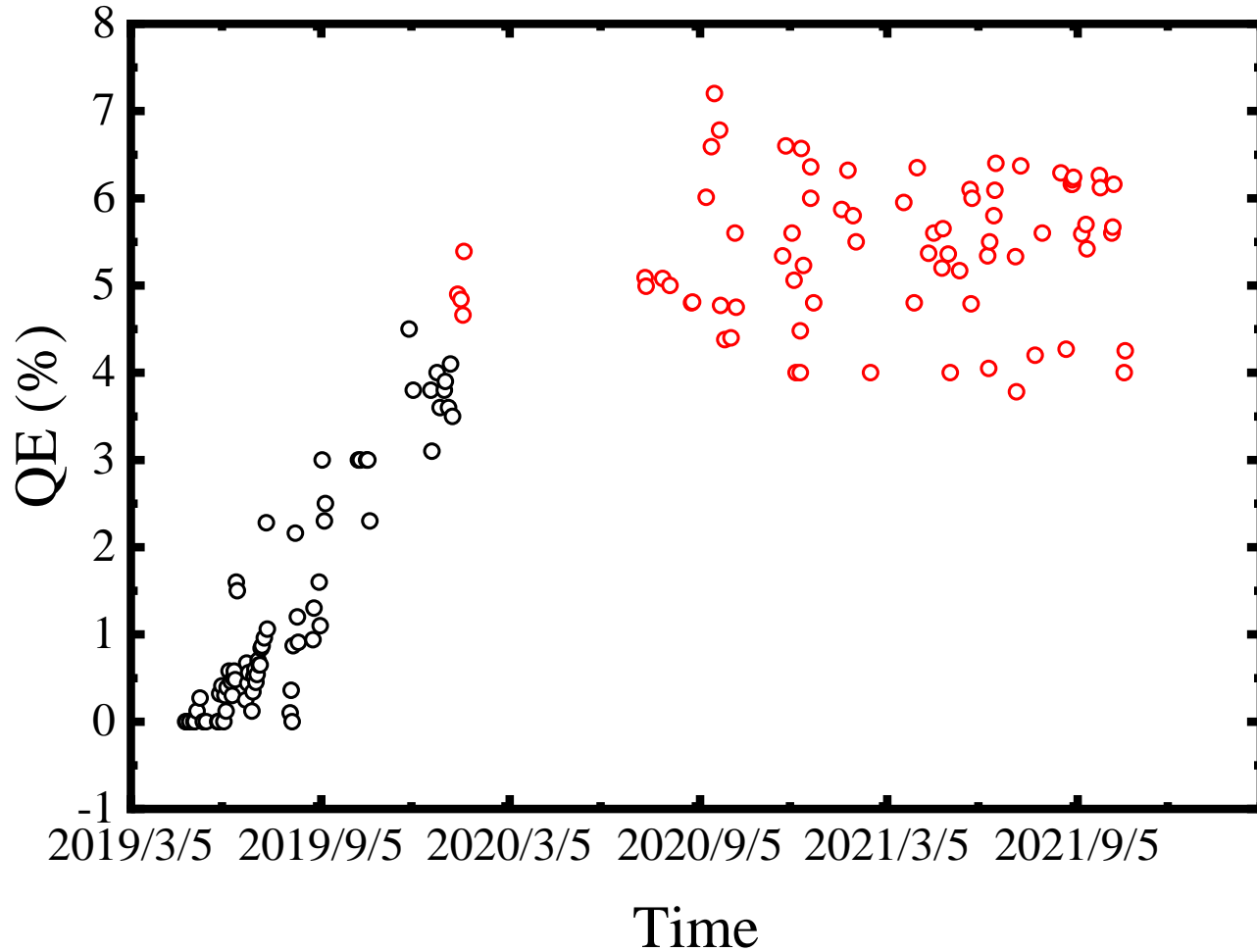
The fabrication process of a typical sample (#1) with regular recipe



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

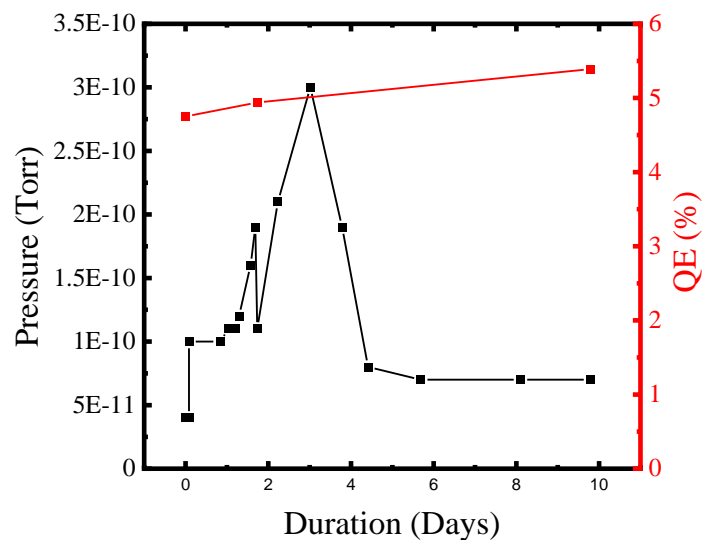
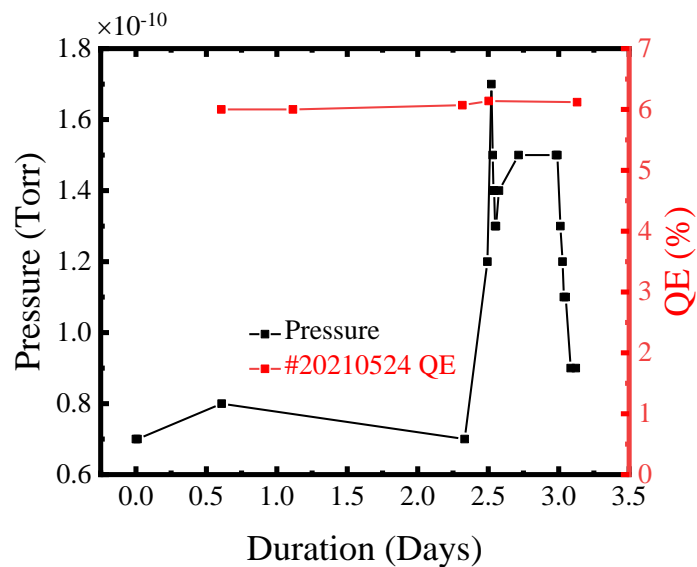
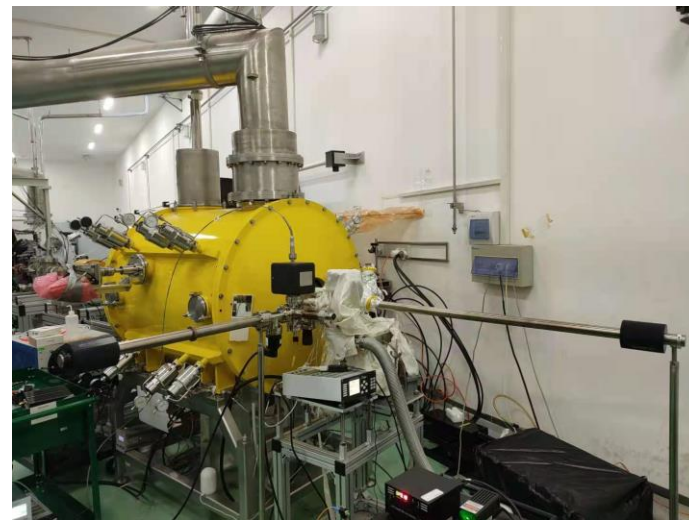
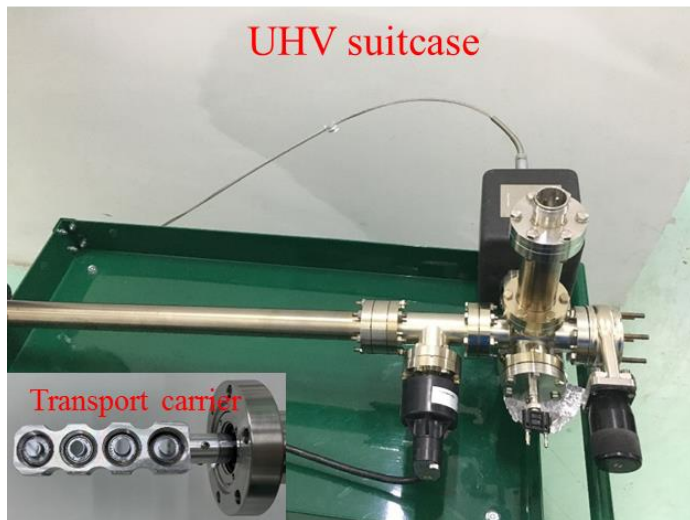


Deposition Recipe





Transport by Suitcase





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- Cryogenic performance of K_2CsSb photocathode
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DC-SRF-II First-Stage Beam Test

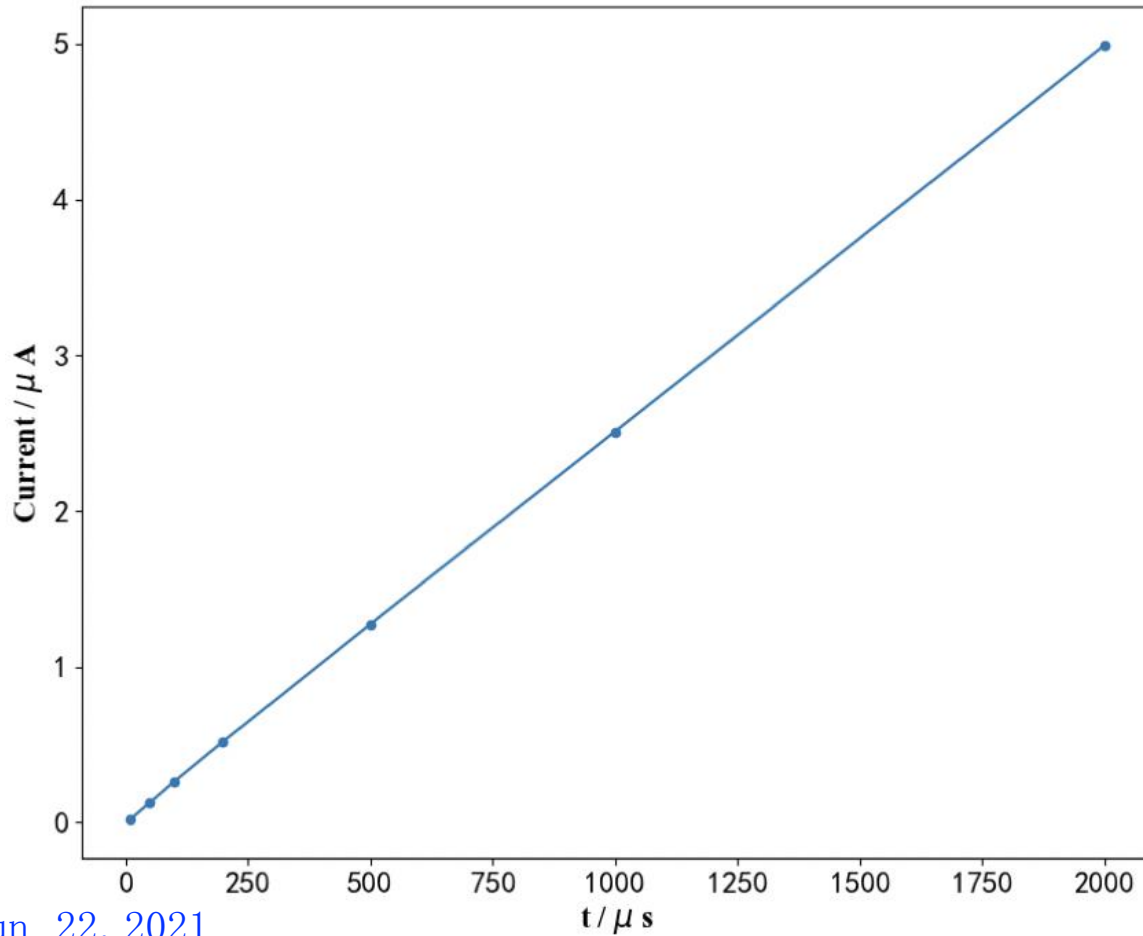


- ❑ Assembled in Jan. 2021
- ❑ Cooled down on April 20, 2021
- ❑ First-stage beam test from Apr. 29, 2021 to Jul. 21, 2021



Bunch Charge Test

Average beam current vs macro pulse duration



Bunch charge
250 pC

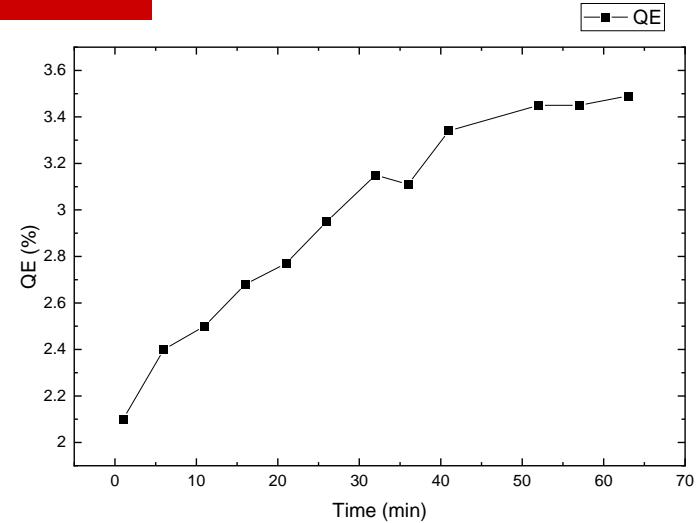
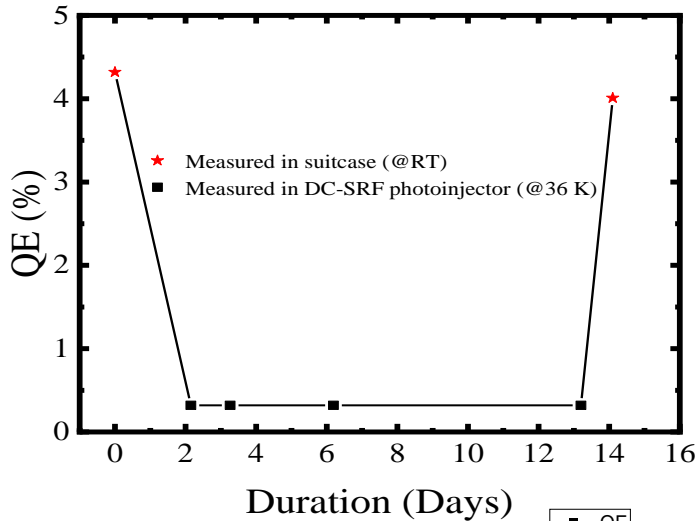
Experiments on Jun. 22, 2021

Preliminary results

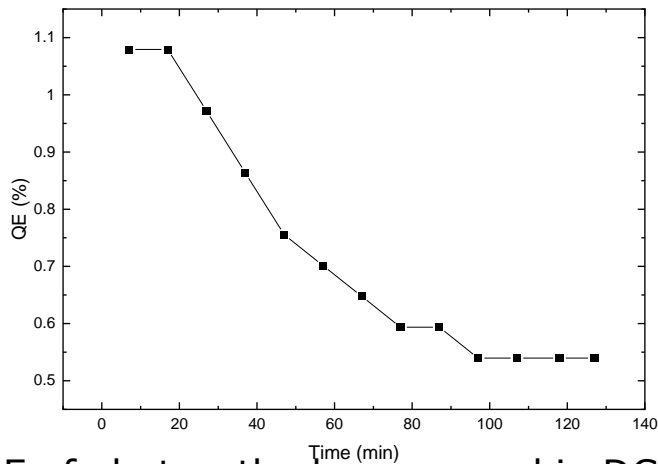
Macro pulse repetition rate 10 Hz, w/o laser shaping



Cathode test in the Gun



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



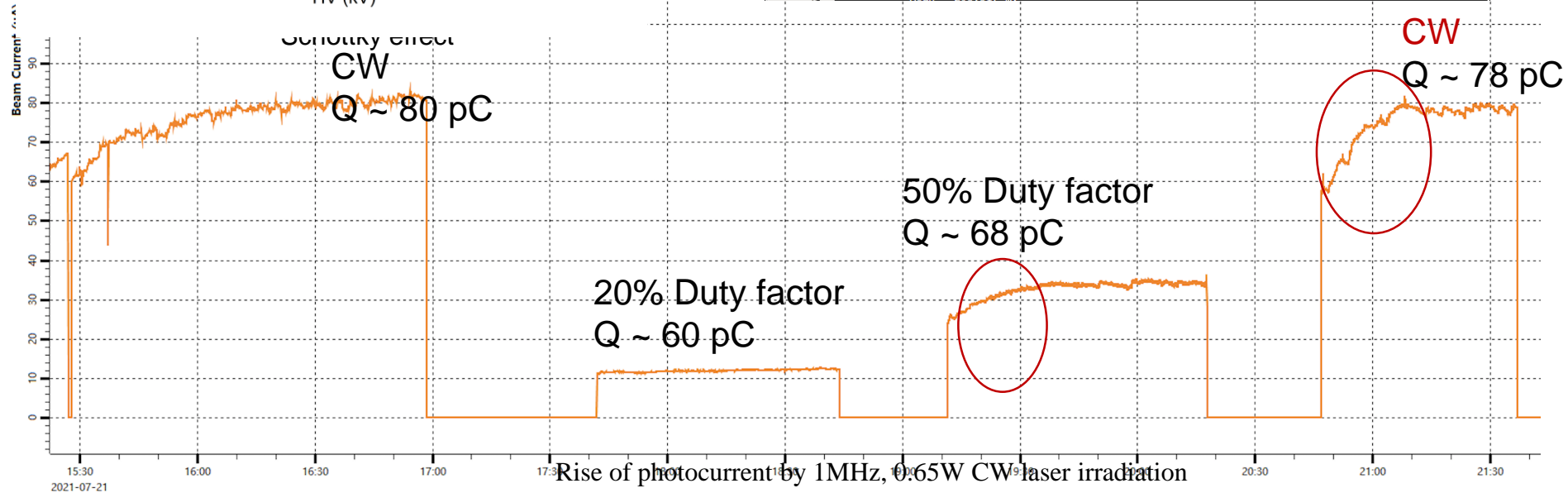
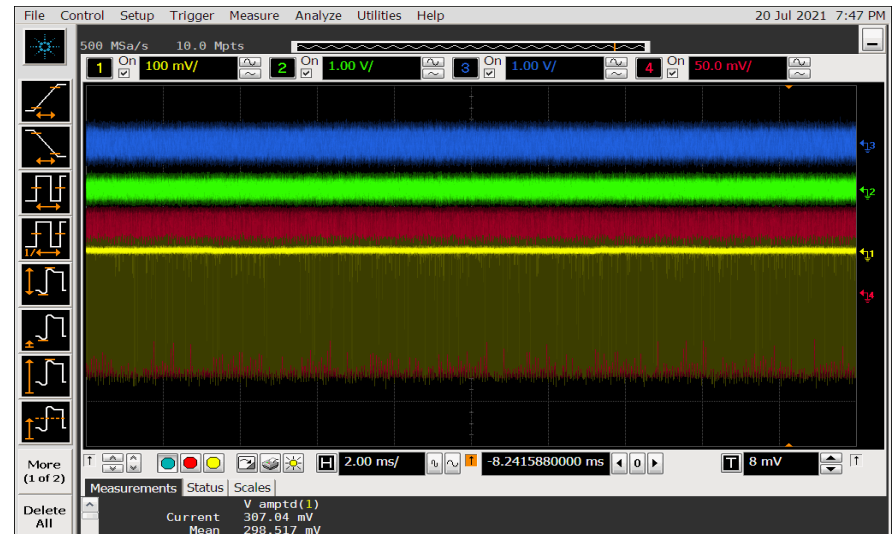
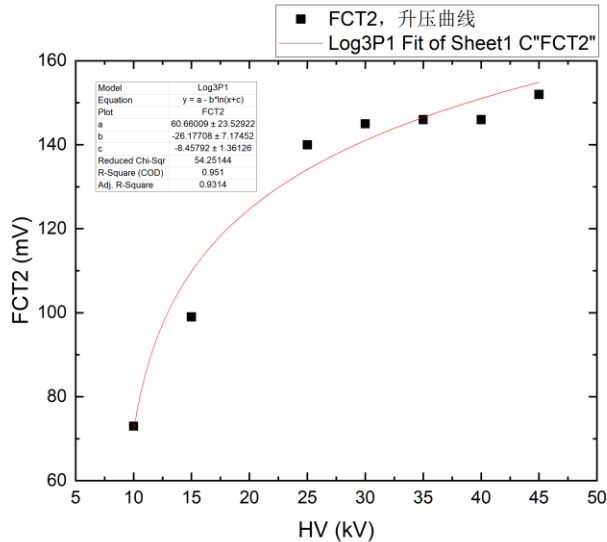
QE of photocathode measured in DC-SRF photoinjector



The manipulator after opening the suitcase

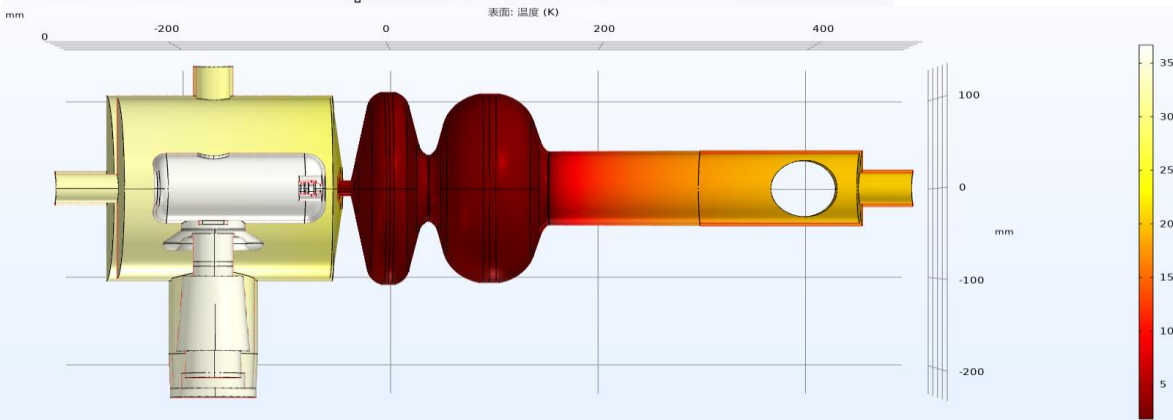
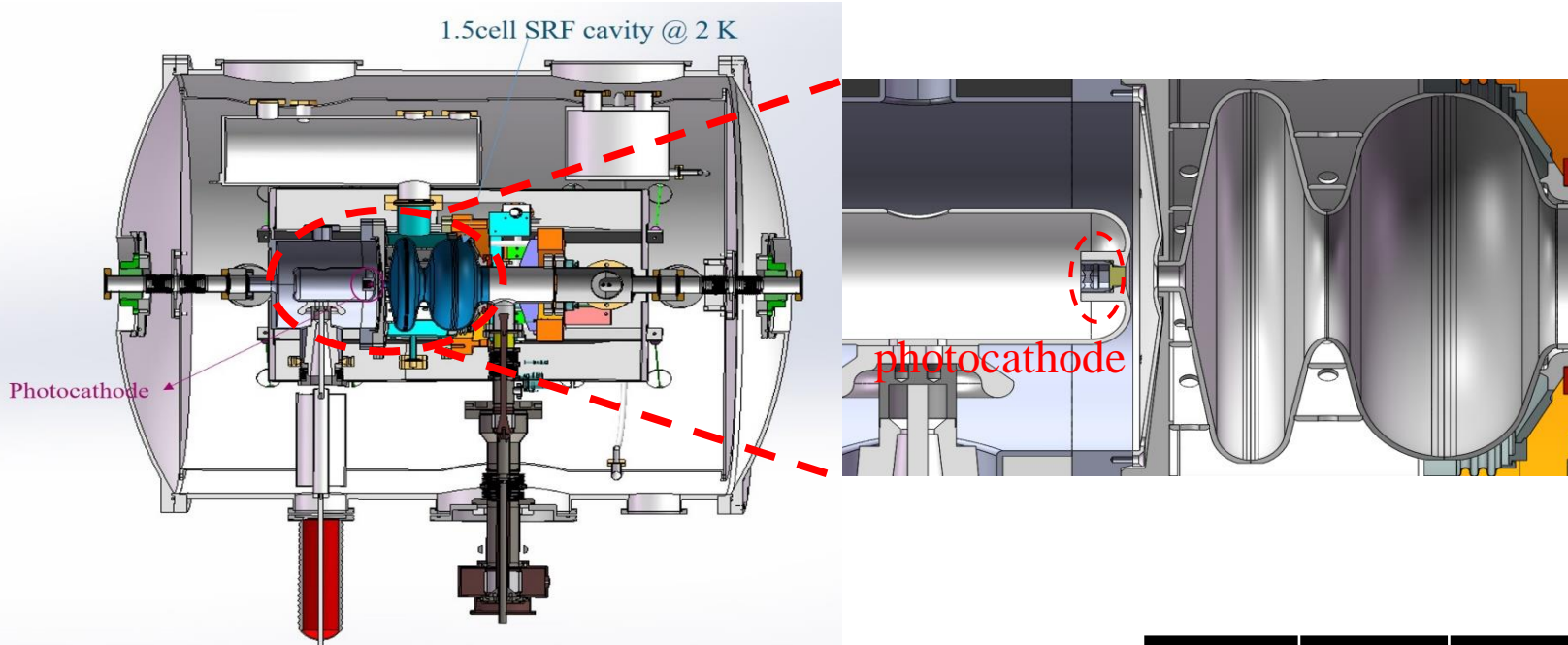


First CW Operation





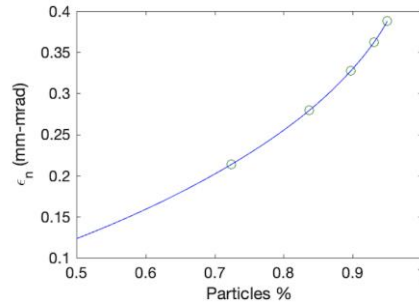
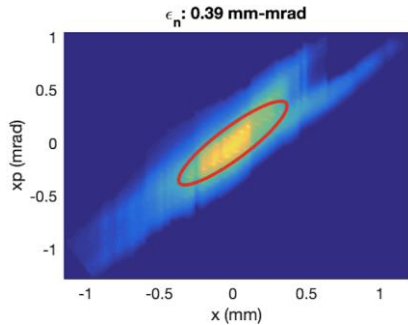
Cryogenic performance



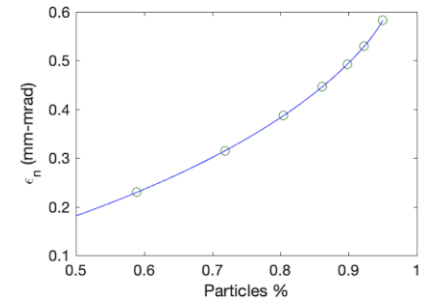
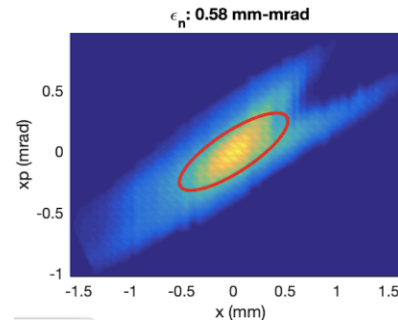
Simulation results of temperature distribution

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

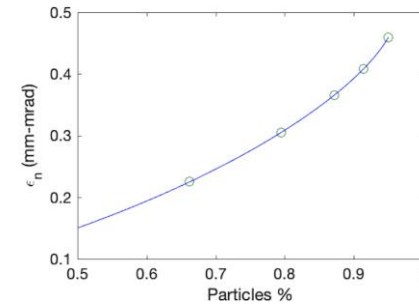
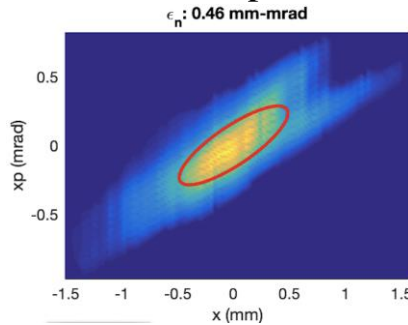
Emittance Measurement



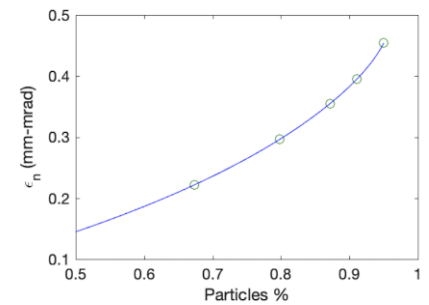
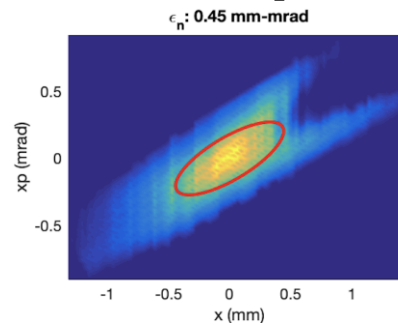
RF phase 36°, S1 current 2.40 A



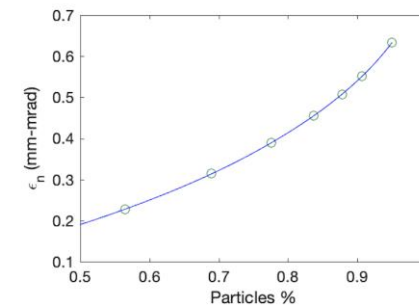
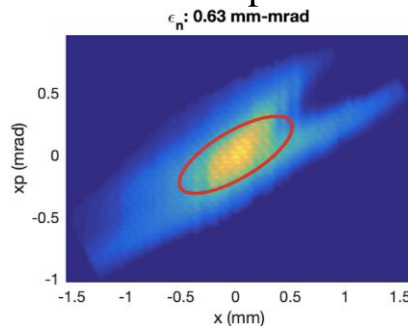
RF phase 31°, S1 current 2.40 A



RF phase 36°, S1 current 2.45 A



RF phase 26°, S1 current 2.40 A



RF phase 36°, S1 current 2.35 A

Normalized rms emittance, 95% particles:
0.4~0.6 mm-mrad @ 22 pC

Experiments on May 29, 2021
Preliminary results



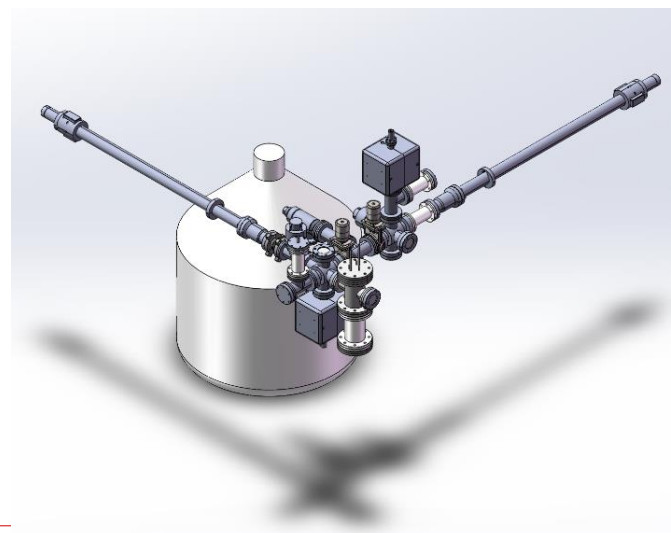
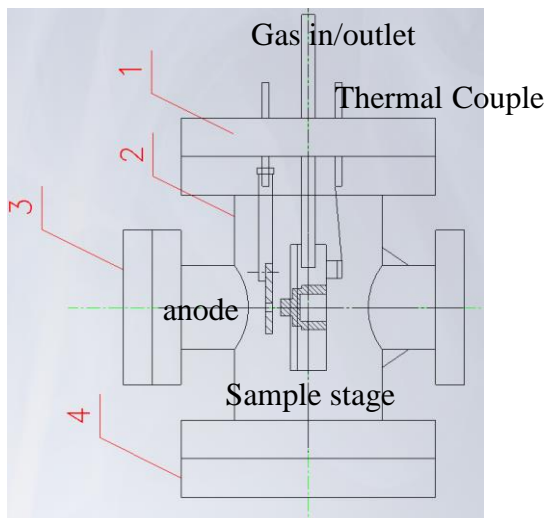


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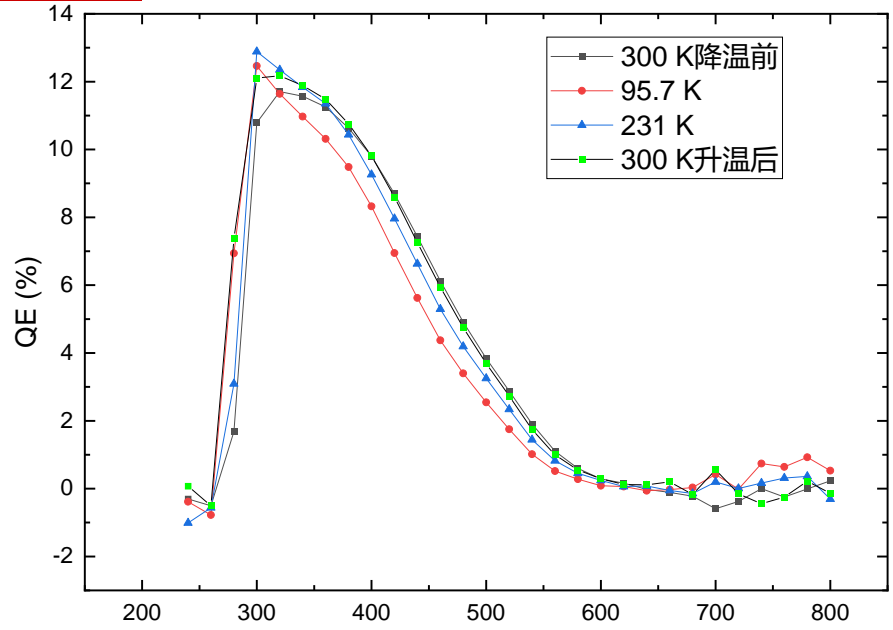
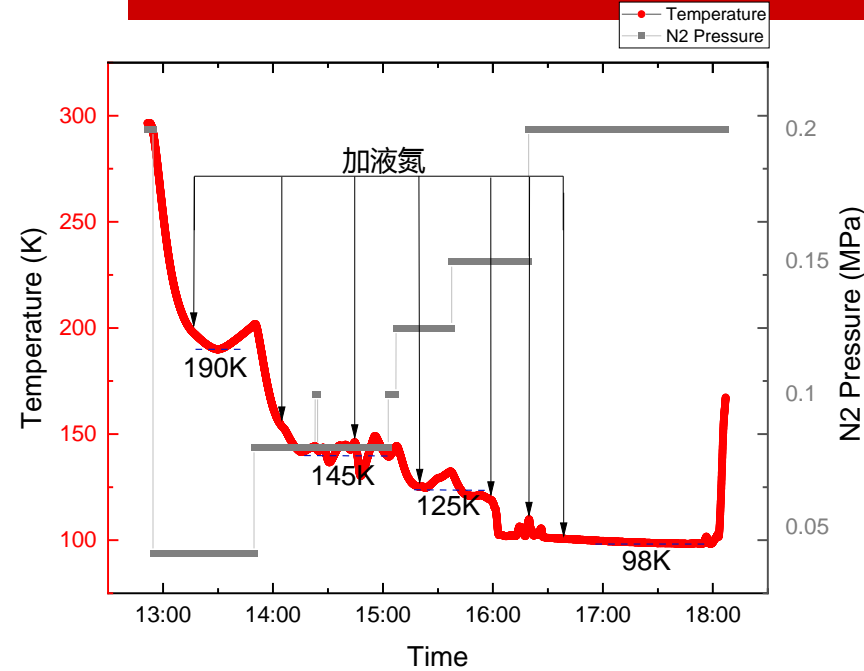


Cryogenic performance





Cryogenic performance

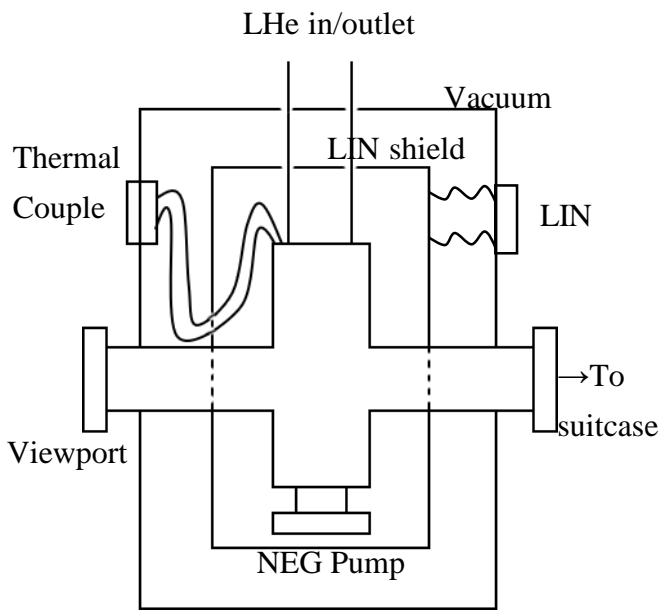


Temperature/K	White light source QE@520nm	Laser QE@520nm	Spectral response QE@520nm
95.7	1.73%	1.71%	1.75%
231K	2.25%	2.3%-2.43%	2.34%
300K	2.69%	2.69%	2.73%

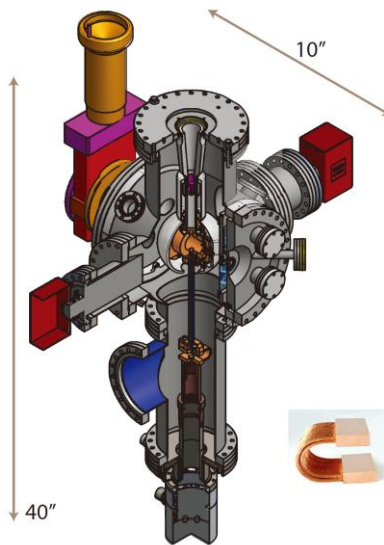
Lab	Temp Range	QE@RT (%)	QE Drop	ϕ @RT (eV)	$\Delta\phi$ (eV)
BNL	300K-166K	10	20%	1.81	0.03
JLab	275K-77K	11.2	~50%	1.66	0.1
PKU	300K-95.7K	2.7	~40%	1.90	0.0455
PKU	300K-36K	4.3	~90%		



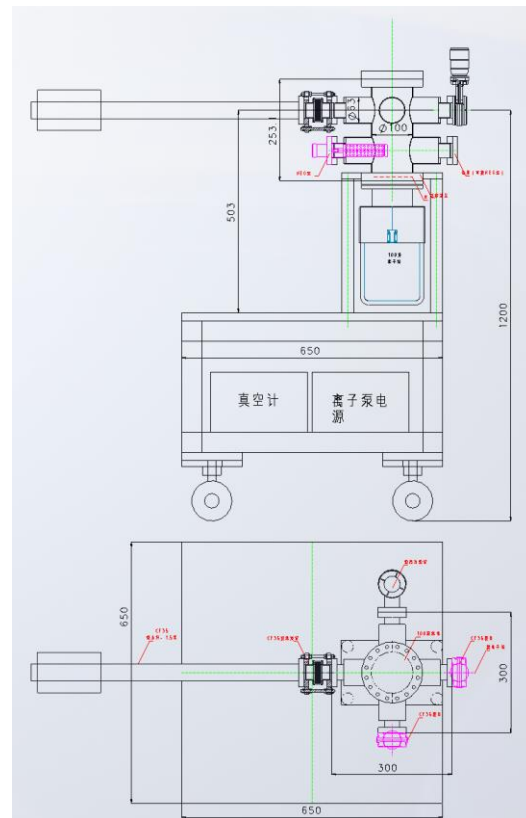
To control the QE decay at cryogenic temperature



LHe cooled sample stage



Cornell Cryo-DCgun



For lower temperature to measure the QE of photocathode at around 36 K

Heating the photocathode by back illuminating with IR laser.



Future work

- The intrinsic emittance of the K_2CsSb photocathode at 36 K will be measured in the following beam experiments from the DC-SRF photoinjector.
 - Estimated intrinsic emittance at 36 K: 0.1~0.2 mm.mrad/mm
 - The cryo-photocathode delivered ultra-low emittance electron beam from the DC-SRF photoinjector with ultralow intrinsic emittance photocathode
 - We need to find new application of the Cryo-DC/SRF hybrid-gun
-



Conclusion

1. High QE K_2CsSb photocathode with repeatable recipe is fabricated at PKU
2. The K_2CsSb photocathode in DC-SRF-II photoinjector delivered required 100-250 pC bunch charge beam
3. The cryogenic K_2CsSb photocathode in the gun has the potential to deliver ultralow emittance electron beam for XFEL and UED, for the intrinsic emittance of K_2CsSb photocathode at 36 K is very small, which will be measured in next beam experiment.
4. The cryogenic performance of the K_2CsSb photocathode has been investigated in a cryogenic sample stage. The spectral response at 90 k and RT are compared, and will be measured at 20-30 K