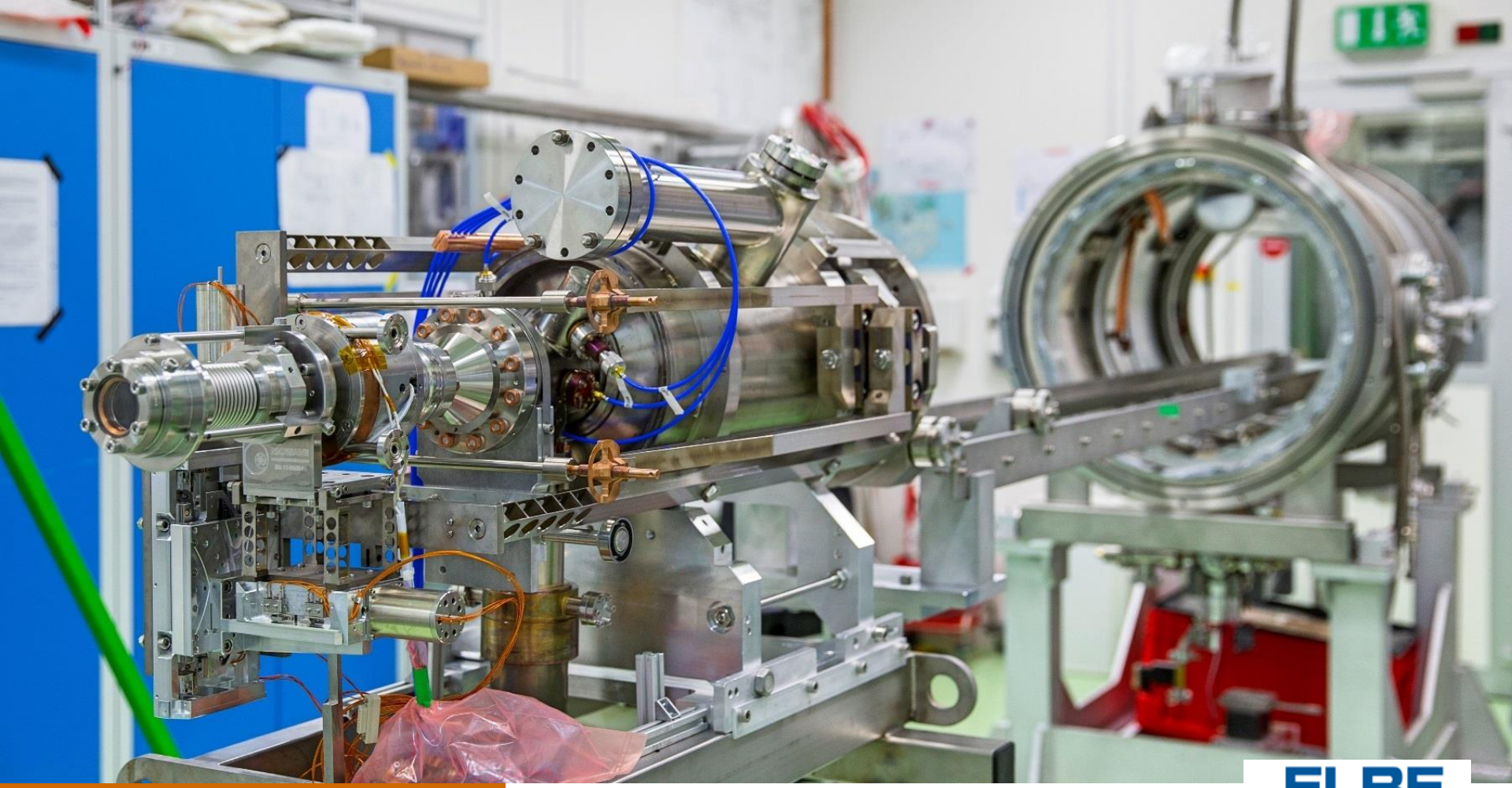


Long term operation of Cs_2Te in SRF-gun for TELBE user facility

Rong Xiang on behalf of the SRF Gun Group

3-6. Oct. 2022, ERL 2022

ELBE.

HZDR

HELMHOLTZ ZENTRUM DRESDEN ROSSENDORF

Outline

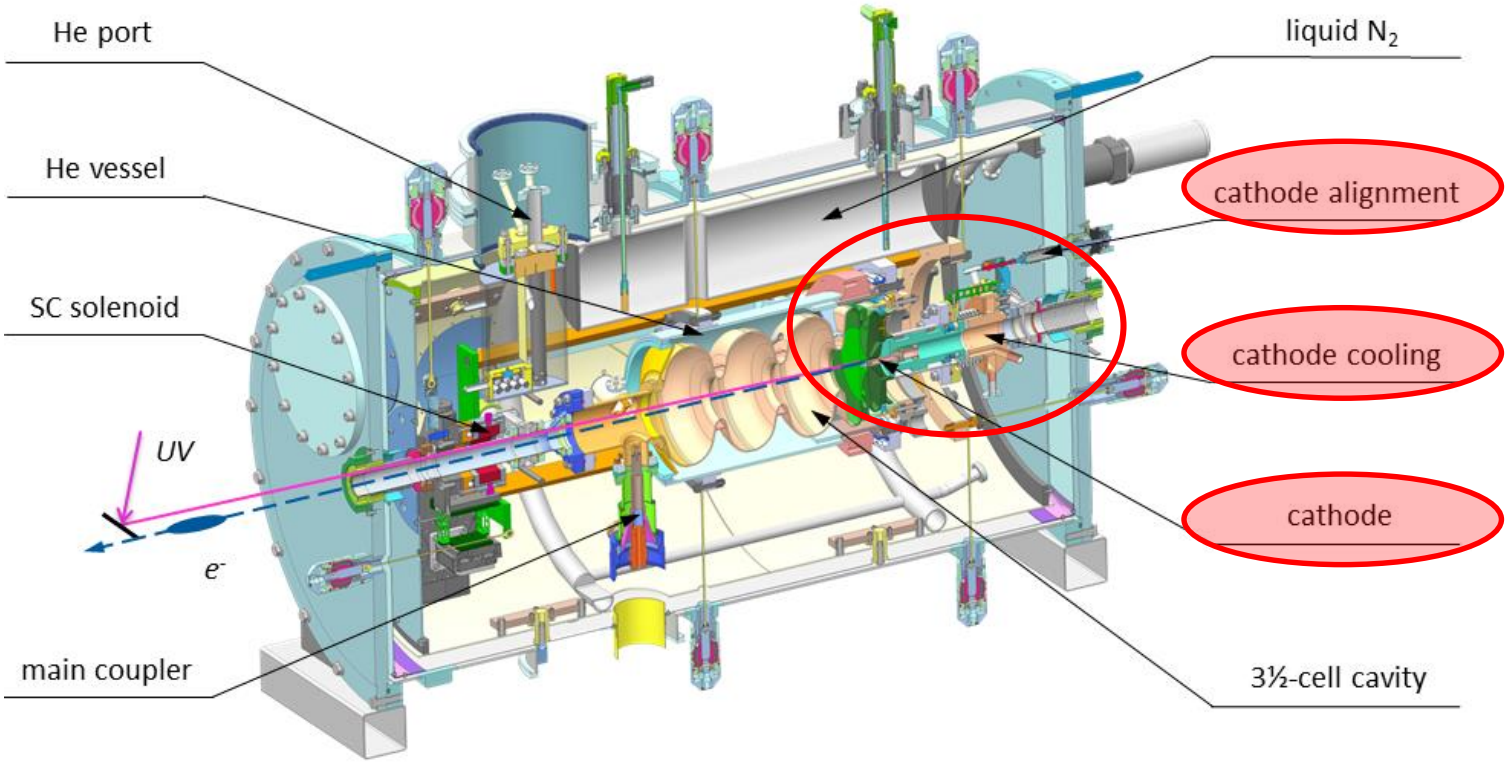
1. Introduction of SRF gun-II and ELBE
2. Cs_2Te photocathodes for SRF gun-II
3. Cathode QE evolution during operation
4. Summary and outlook

ELBE.

HZDR

HELMHOLTZ ZENTRUM DRESDEN ROSSENDORF

1. Introduction of SRF gun-II and ELBE



parameters of SRF Gun-II in operation

E_{acc} = 8 MV/m CW (20 MV/m peak field on axis)
$E_{cathode}$=12 MV/m (field on cathode)
I_{dark} ~ 120 nA @8 MV/m
4 MeV kinetic energy, bunch charge < 0.4 nC

1. Introduction of SRF gun-II and TELBE

	Milestones of SRF Gun-II
Jun. 2010	cavity manufacture finish in JLab
Aug. 2014	commissioning at HZDR
Feb. 2015	first CW beam with Cu cathode
Mar./Jun. 2017	Cs_2Te (Mo) cathodes overheated in gun
Since 2017	User operation with Mg
Since May 2020	User operation with Cs_2Te (on Cu plug)

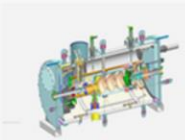
HIGHLIGHTED ARTICLES

Editors' Suggestion

Successful user operation of a superconducting radio-frequency photoelectron gun with Mg cathodes

J. Teichert, A. Arnold, G. Ciovati, J.-C. Deinert, P. Evtushenko, M. Justus, J. M. Klopf, P. Kneisel, S. Kovalev, M. Kuntzsch, U. Lehnert, P. Lu, S. Ma, P. Murcek, P. Michel, A. Ryzhov, J. Schaber, C. Schneider, R. Schurig, R. Steinbrück, H. Vennekate, I. Will, and R. Xiang

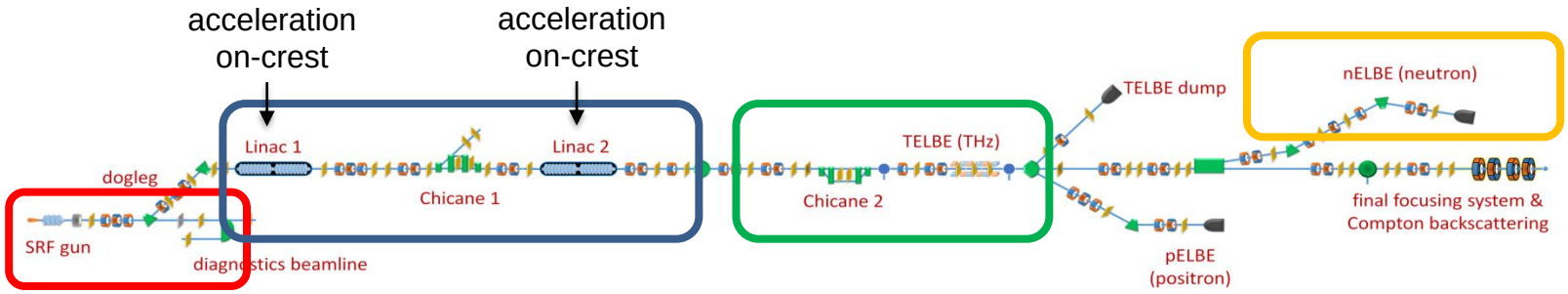
Phys. Rev. Accel. Beams **24**, 033401 (2021) – Published 4 March 2021



The first superconducting rf electron source to be operated in a free electron laser.

Show Abstract +

1. Introduction of SRF gun-II and TELBE

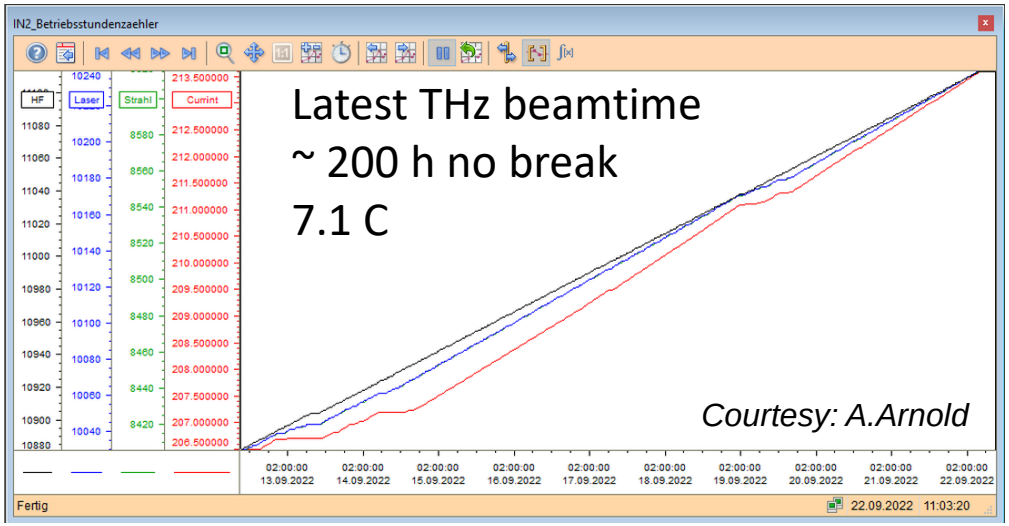


SRF-Gun **SC-LINAC** **THz @ ELBE** **neutron @ ELBE**

100% of THz shifts and up to 40% of ELBE user shifts (4500h w/o MD) are served by SRF gun-II.

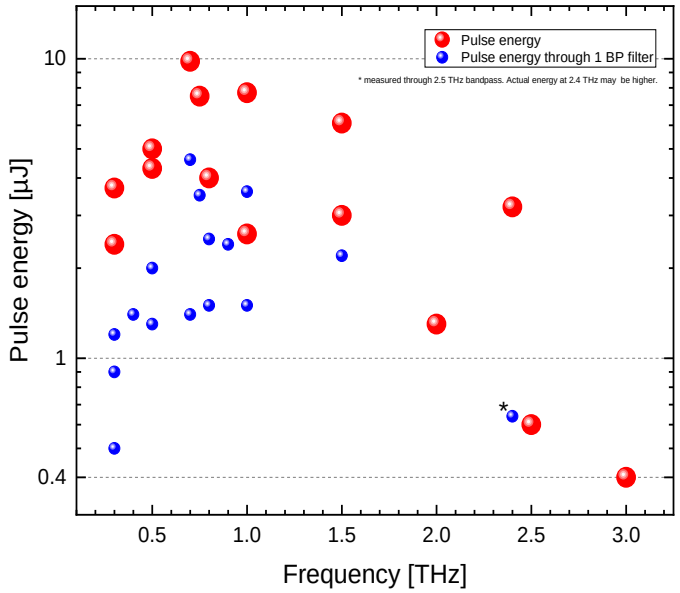
E_{gun} = 4 MeV, E_{ELBE} = 30 MeV

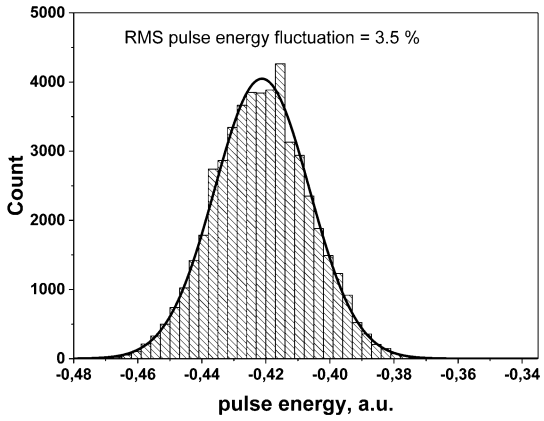
200 - 250 pC @ 100 kHz CW

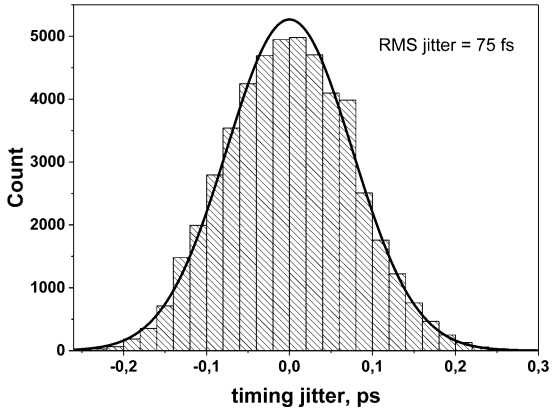


1. Introduction of SRF gun-II and TELBE

- stable and reliable CW operation with 10, 50, 100, 250 kHz rep.-rate
- E-beam after linac and compression ~300 fs
- THz radiation with frequencies 0.05 – 2.5 THz
- pulse energies ≤10µJ (≤1 THz), few µJ (≤2.5 THz)
- pulse energy fluctuations are typ. 3.5 %
- synchronization to external systems typ. 75 fs
  (including the laser jitter, w/o feedback)
- stable and very reliable SRF gun operation



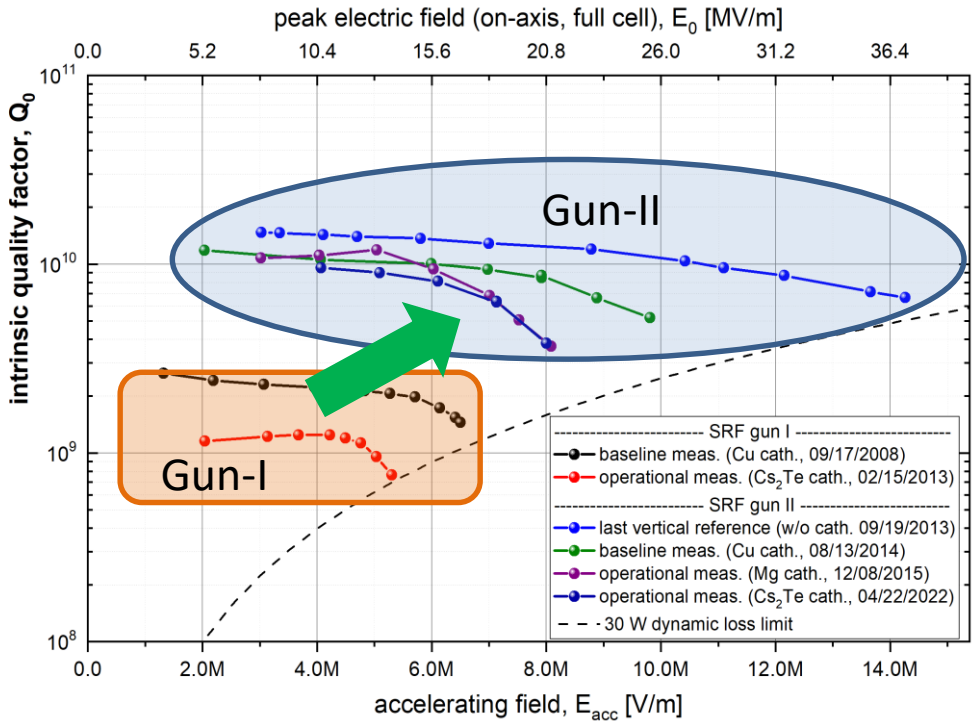




Courtesy: J. Deinert

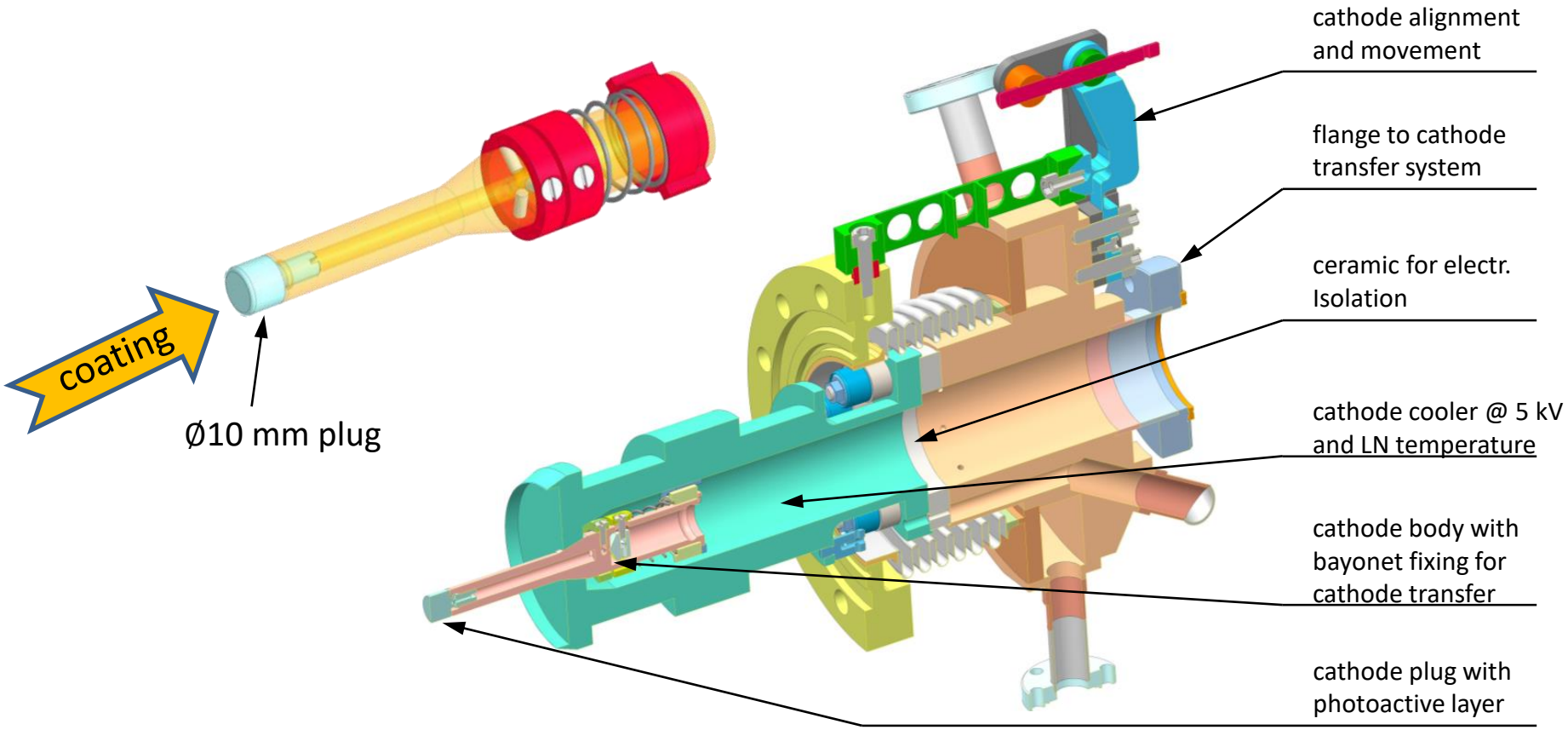
1. Introduction of SRF gun-II and TELBE

- Jun. 2010 cavity manufacture finish in Jlab.
- Aug. 2014 commissioning at HZDR.
- Comtaminated due to cathode failure in 2017.
- Warming up process helped to recover cavity.
- Stable quality after 2018.



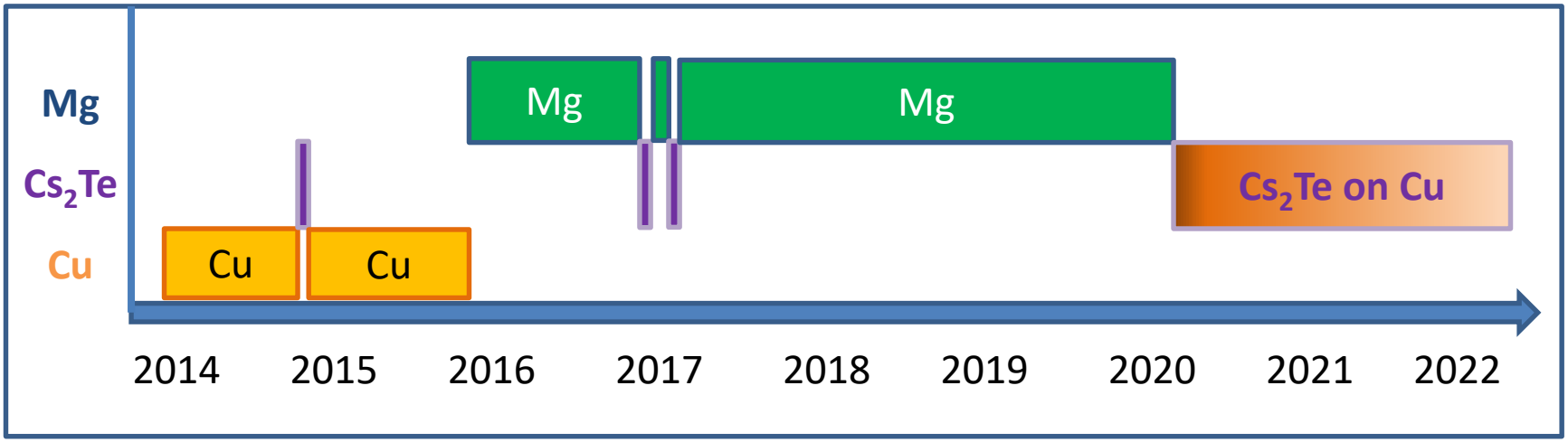
Courtesy : A. Arnold

1. Introduction of SRF gun-II and TELBE

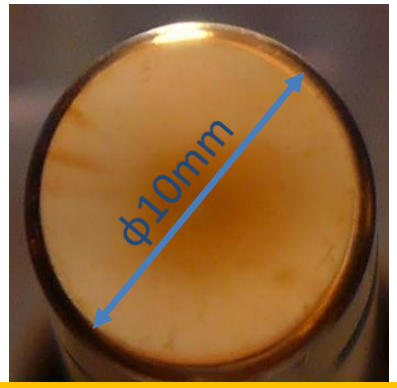


- metallic cathodes or semicondcutor cathodes
- cathode cooling by LN2 to 77 K
- particle free transfer into the cold gun
- therm. and electrical isolation, DC bias 0 - 5 kV to suppress MP
- moveable (±0.6 mm) by remote stepper

1. Introduction of SRF gun-II and TELBE

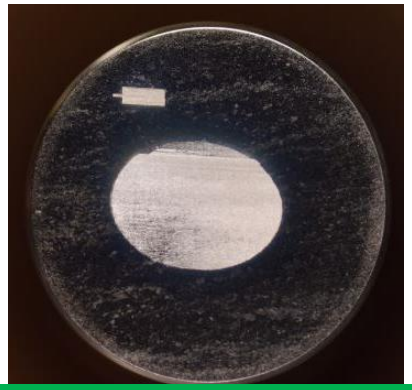


Cathodes applied in SRF Gun-II



Cu plug (used in gun)

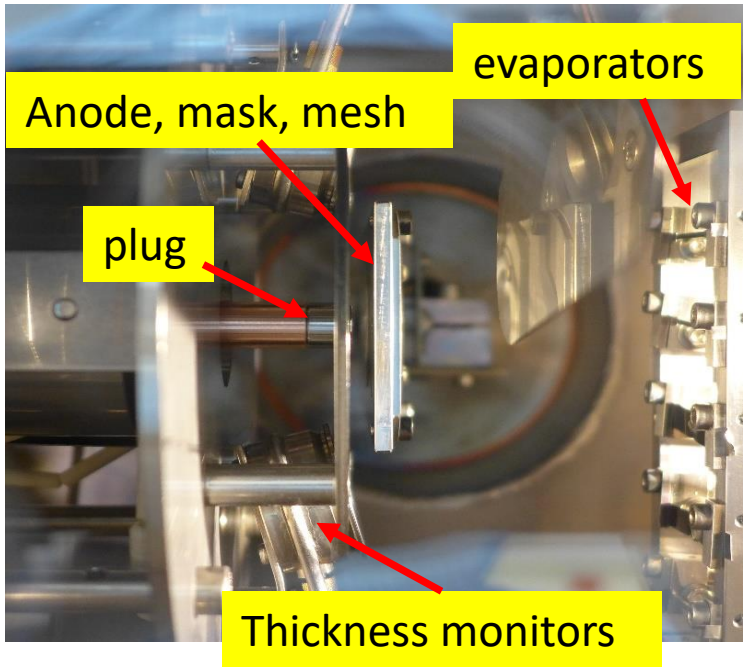
Cs_2Te on Mo plug

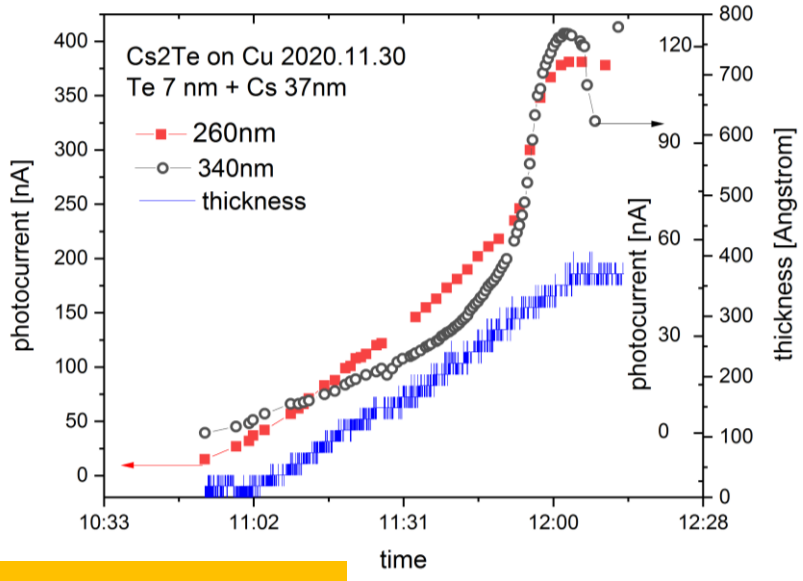


Mg (ps laser clean)

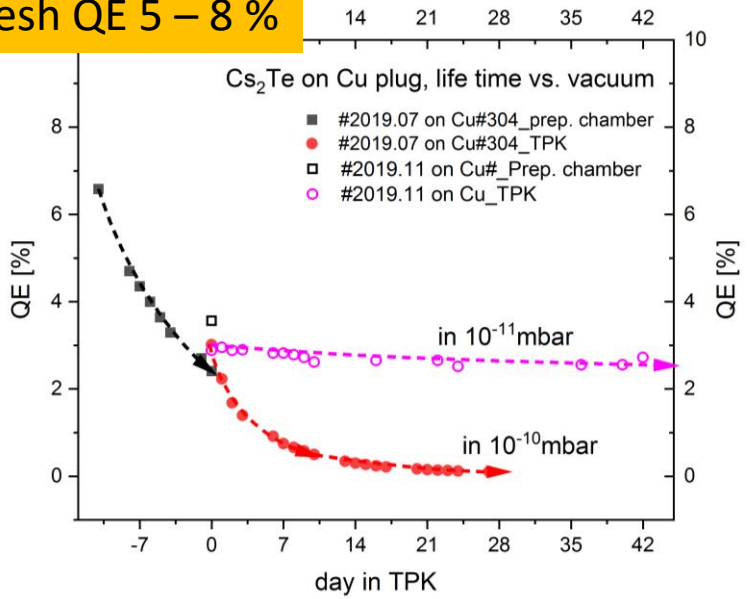
Cs_2Te on Cu plug

2. Cs_2Te photocathodes for SRF gun-II





Typical fresh QE 5 – 8 %

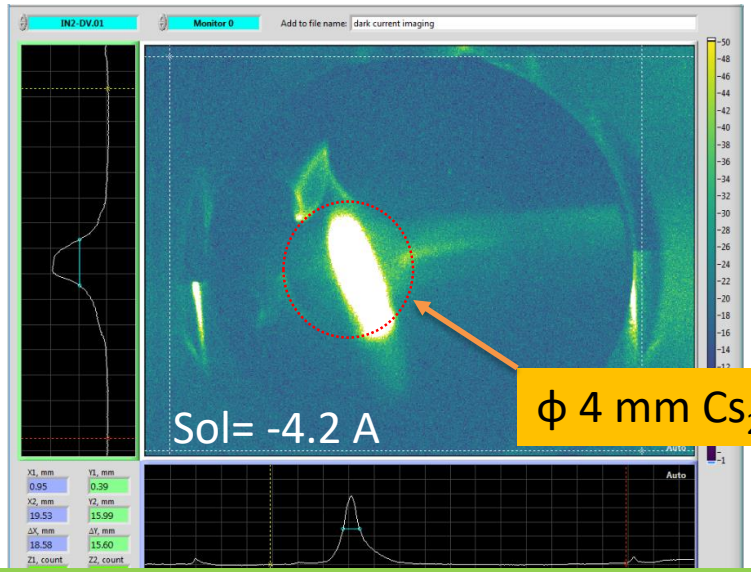


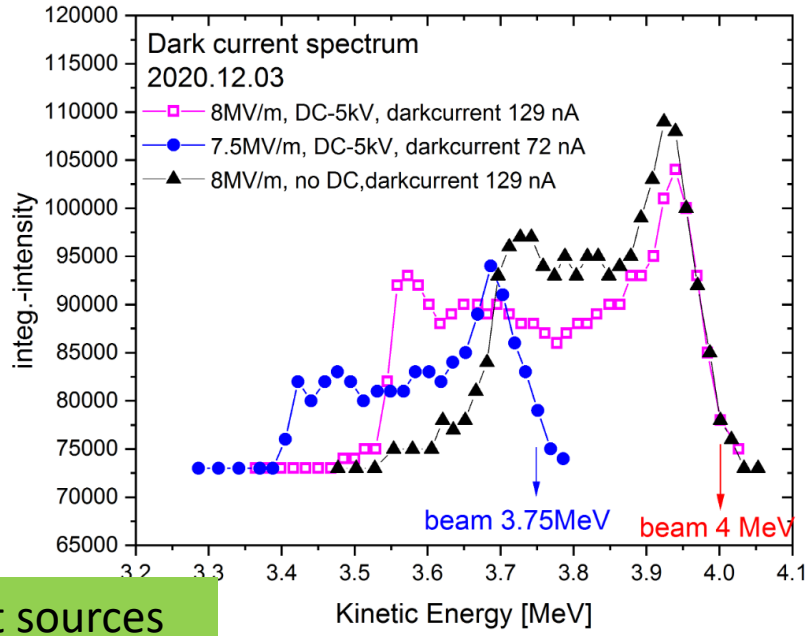
- Polished or diamond turned Cu plug
- baking 350°C before preparation
- Te deposition + Cs activation @ 120° C
- till max photocurrent with 260/340nm LEDs
- storage/ transport chamber 10^{-11}mbar

PhysRevSpecialTopics_13_043501

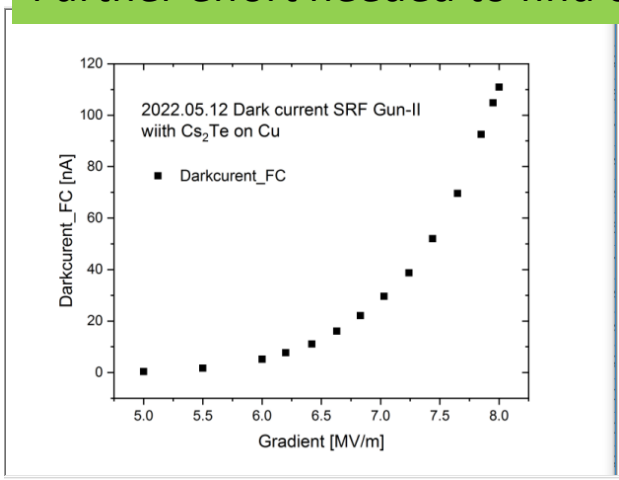
2. Cs_2Te photocathodes for SRF gun-II

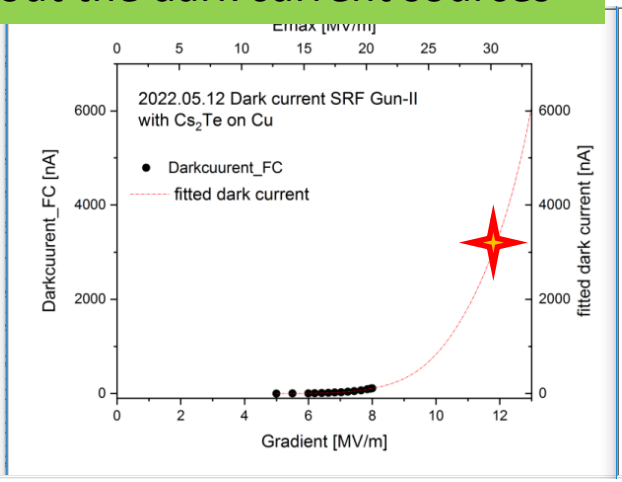
Dark current ~ 120 nA @ 8 MV/m (Screen/FC 1 m from cavity exit)

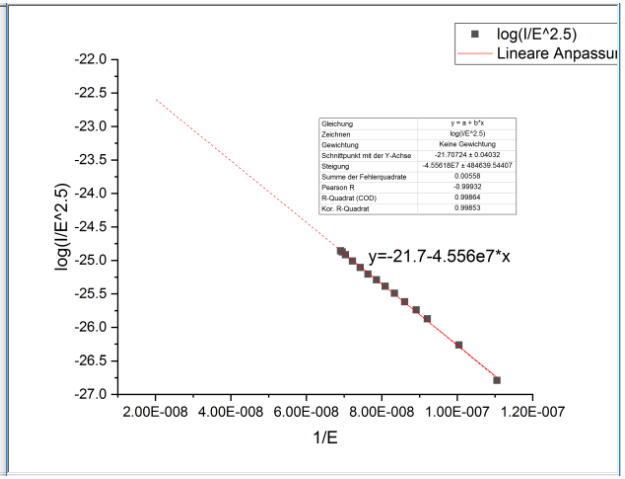




Further effort needed to find out the dark current sources







3. Cathode QE evolution during operation

Cathode No.	Time in gun	Beam time	Extract Charge
Cs_2Te #2021.06.11_7nm	2021.07 ~ 2021.09	492 h	15.3 C
Cs_2Te #2021.06.09_10nm*	2021.09 ~ 2021.12	529 h	16.9 C
Cs_2Te #2021.06.07_8nm	2022.01 ~ 2022.03	262 h	7.1 C
Cs_2Te #2021.10.05_6nm	*2022. 03 ~ 2022.09*	*~ 840 h*	*~ 29 C*

* diamond turned plug

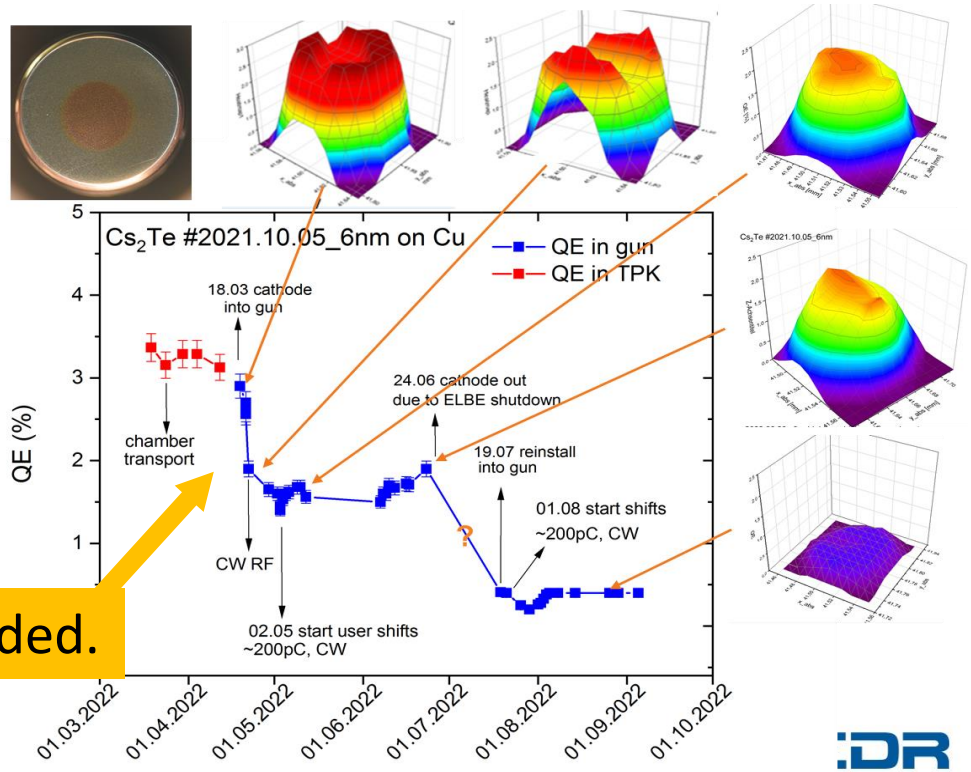
Status: stable operation

3-6 months operation time

The latest Cs_2Te in gun

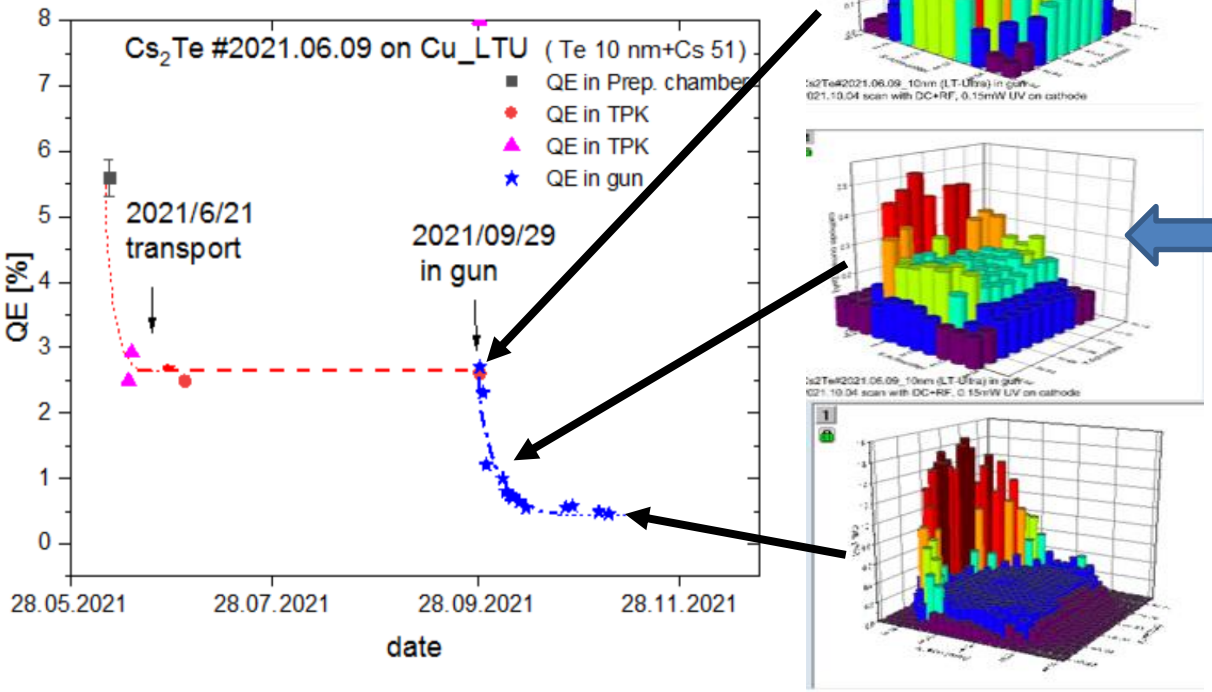
6 nm Te+ 37 nm Cs
fresh QE 7 %
1st operation in gun 1.6%
after 2nd insertion 0.4%

QE dropped when CW RF was loaded.

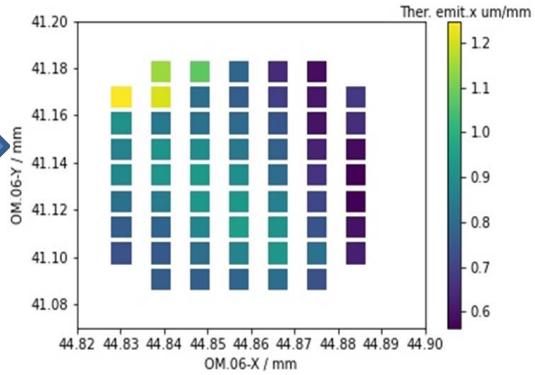


3. Cathode QE evolution during operation

Another problem: several cathodes showed inhomogenous QE distribution during operation.

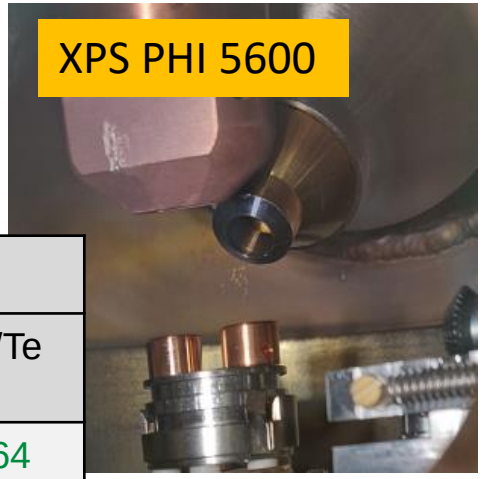


Inhomogeneous thermal emittance 0.6-1.2 µm



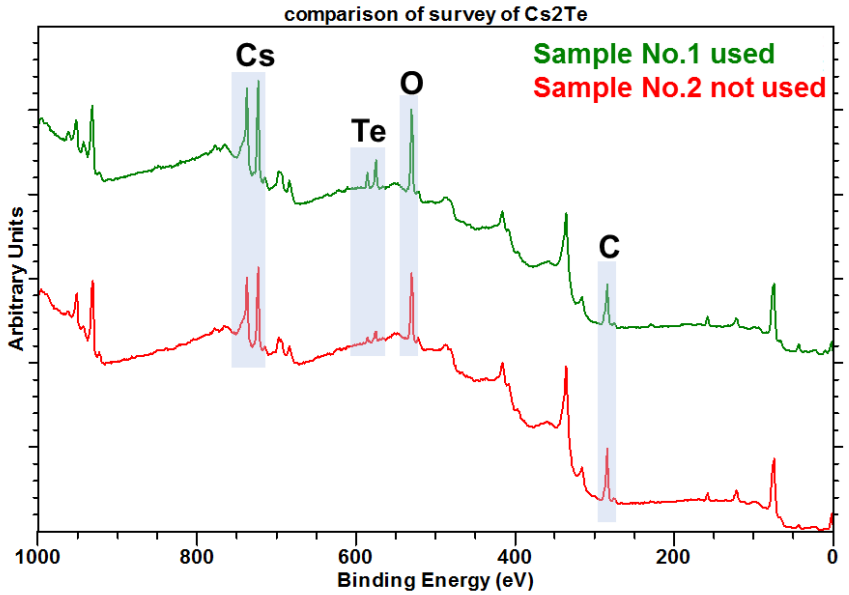
Courtesy: Shuai Ma

3. Cathode QE evolution during operation



Courtesy: Jana Schaber

	Thickness Monitor			XPS survey		
No.	Te	Cs	Cs/Te	Te peak area (%)	Cs peak area (%)	Cs/Te
#1. 2021.06.07 used in gun	8.2 nm	40.3 nm	4.91	7.70 %	28.01 %	3.64
#2. 2021.06.15 not used in gun	6.0 nm	32.1 nm	5.35	3.04 %	25.48 %	8.38



Lessons from XPS measurement:

1. **Cathode #1 (**used in the gun) has less Cs on surface.
2. In vacuum tranport is necessary:
   - All Te oxidize to Te 6+ & 4+.
   - All Cs exist as Cs 1+

4. Summary and outlook

✓ **Cs_2Te on Cu is working well in HZDR SRF gun**

- QE ~1%, charge life time > 10 C
- no thermal contact problem during operation
- acceptable dark current

❖ **Dedicated RF starting up process** is important to avoid MP and to preserve cathode.

❖ **Possible reasons for degradation in gun:**

1. Photoelectrons & unwanted beam hit cavity wall, release gases, which contaminate the cathode surface.
2. Released gas molecules are ionized by photoelectrons & unwanted beam, and ions back bombard cathode.
3. RF heats the dielectric Cs_2Te layer.

Thank you!

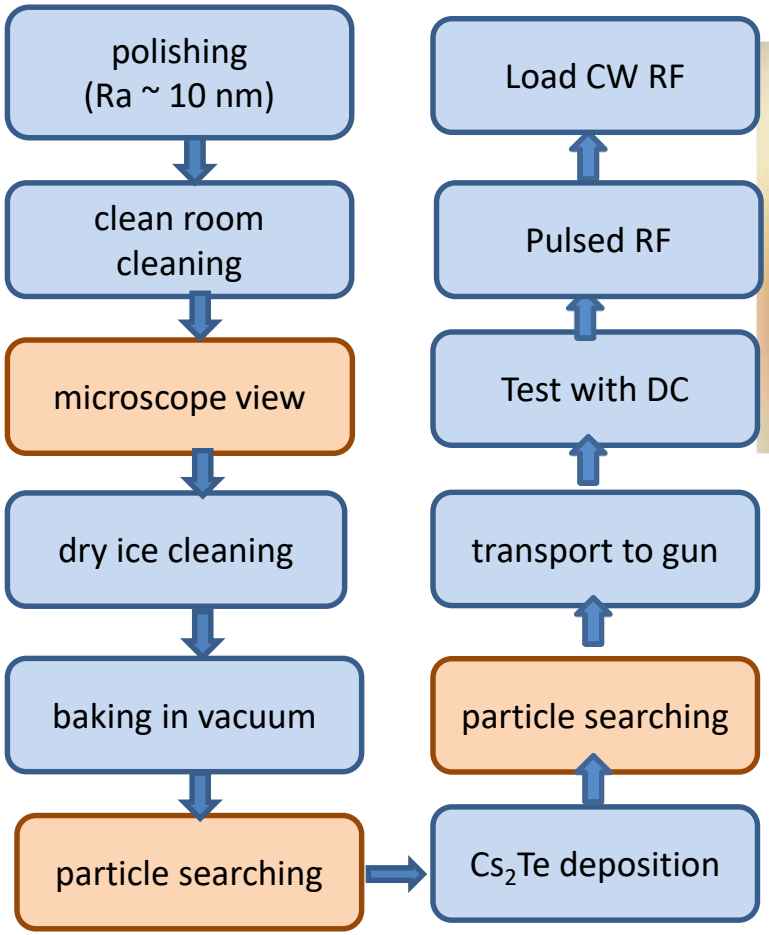
Many thanks to the ELBE team and our cooperators!

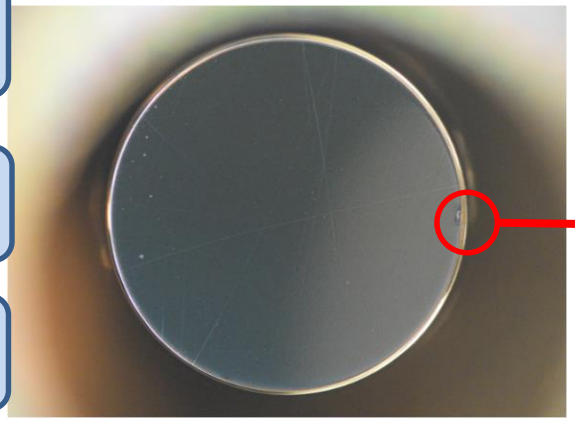
Bundesministerium für Bildung und Forschung

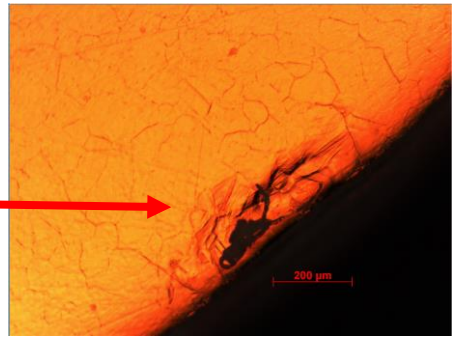
HZDR

Backup slides

2. Cs_2Te photocathodes for SRF gun-II







Before/after coating, high resolution photos are taken for particel counting.

No contamination to cavity after 2018