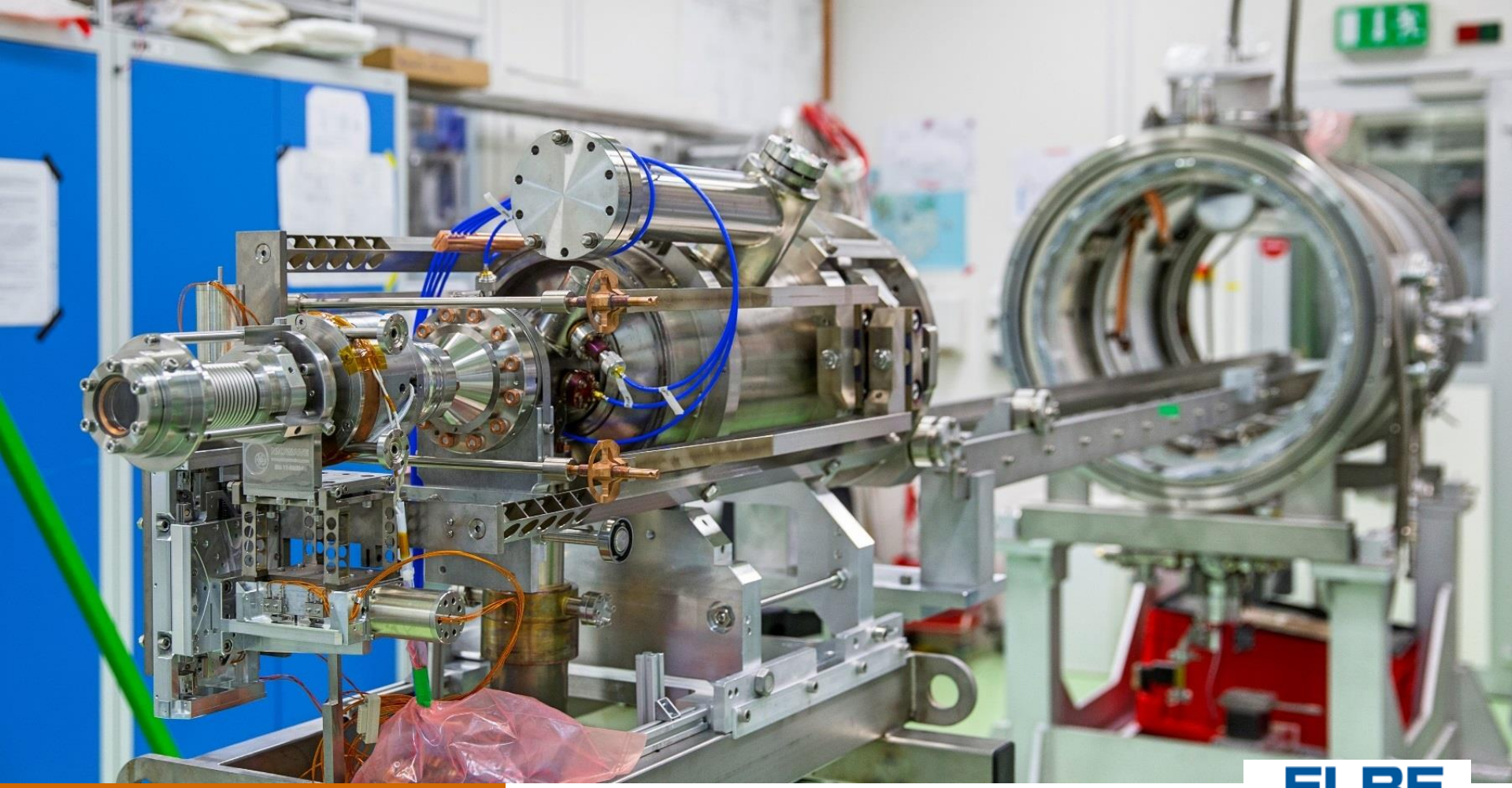

Robust Mg cathodes in SRF gun-II

Rong Xiang on behalf of the SRF Gun Group

 EWPAA 2019, 11 Sep. - 13 Sep. 2019, PSI

Outline

1. Status of ELBE SRF gun-II
2. Mg photocathodes in SRF gun-II
3. ps UV laser cleaning of Mg photocathodes
4. Alternative preparation methods of Mg
5. Summary and outlook

ELBE.

HZDR

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ELBE.

HZDR

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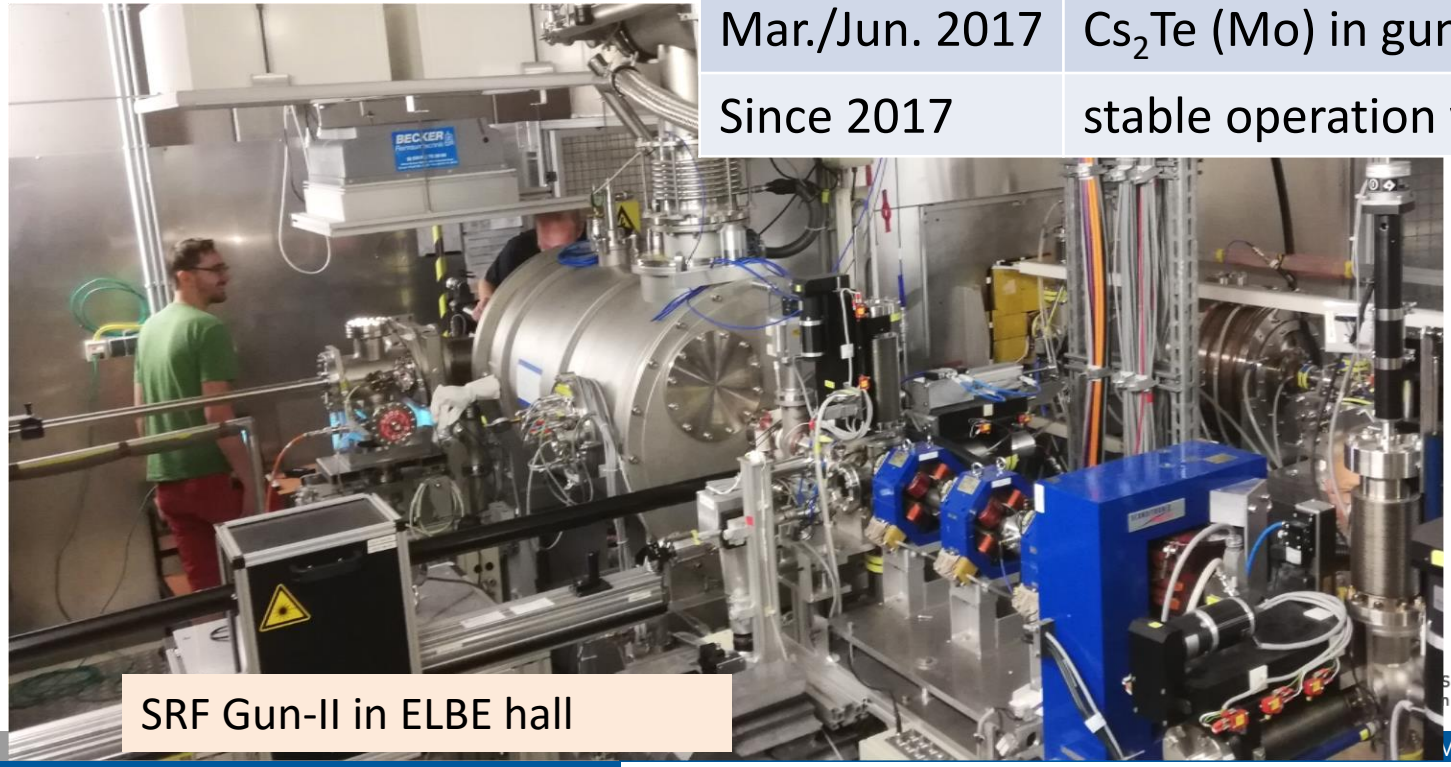
1. Status of ELBE SRF gun-II

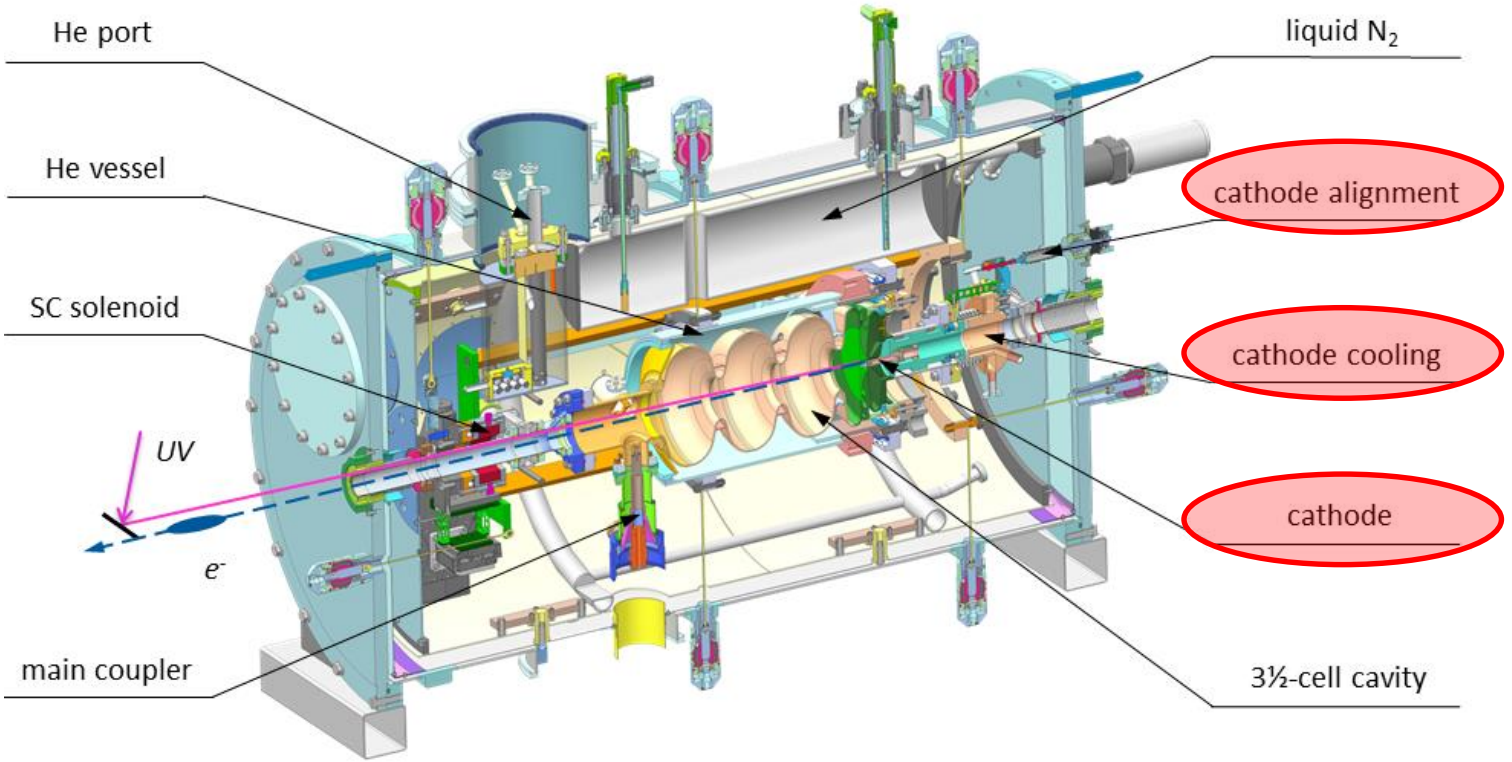
	Milestone of cathode in gun
Jun. 2010	cavity manufacture finish in Jlab
Aug. 2014	commissioning at HZDR
Feb. 2015	first CW beam with Cu cathode
Nov. 2016	Mg cathode in operation
Mar./Jun. 2017	Cs_2Te (Mo) in gun
Since 2017	stable operation with Mg



SRF Gun-II in ELBE hall

1. Status of ELBE SRF gun-II

Jochen Teichert, presentation on 11.09

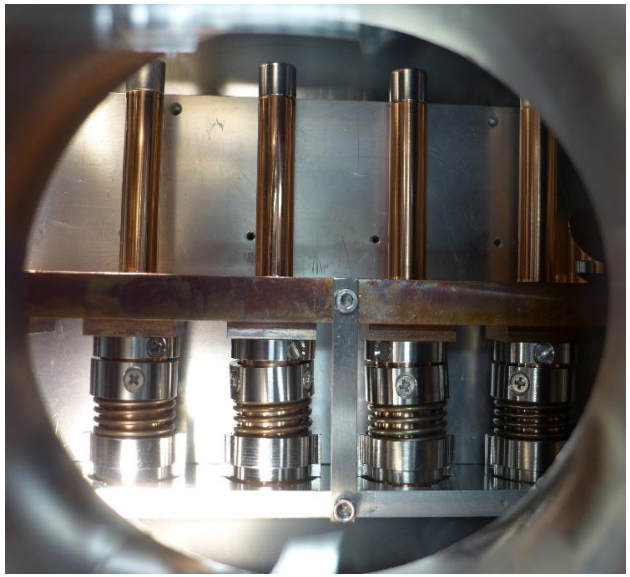


parameters of SRF gun II in operation

E_{acc} = 8 MV/m CW (20 MV/m peak field on axis)
$E_{cathode}$=12 MV/m (field on cathode)
I_{dark} ~ 30 nA @8 MV/m
4 MeV kinetic energy, bunch charge < 0.4 nC

1. Status of ELBE SRF gun-II

Keyword: NC cathode for SC cavity



Semiconductor photocathodes

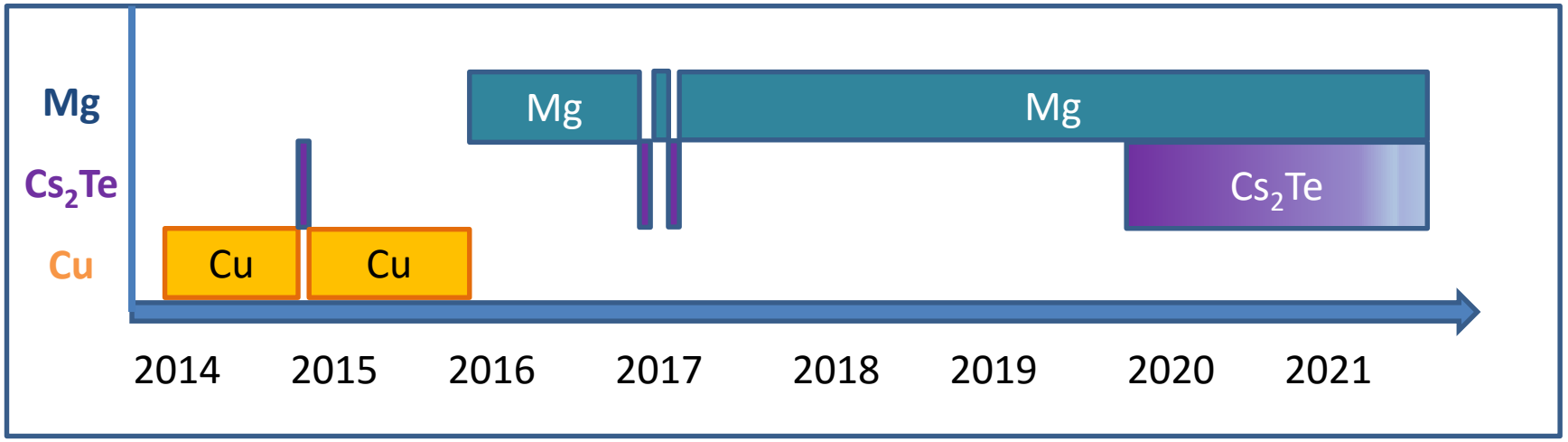
- high risk of contamination
- vacuum demanding
- preparation system
- high quantum efficiency (QE)
- less laser power required

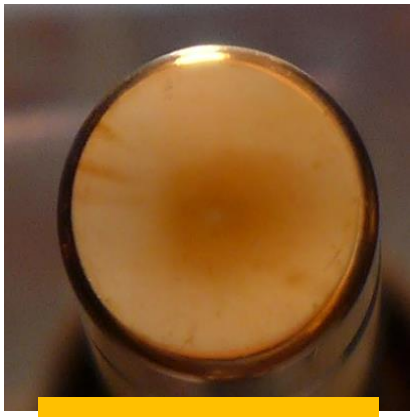
Metallic photocathodes

- good compatibility with Nb cavity
- robust, long lifetime
- fast response
- low QE
- high UV laser power required

1. Status of ELBE SRF gun-II

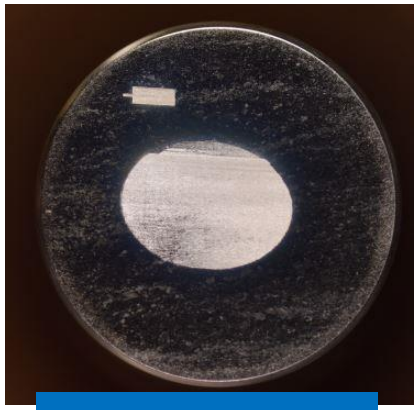
Cathodes applied in SRF Gun-II





Cu plug (used)

Cs_2Te on Mo plug

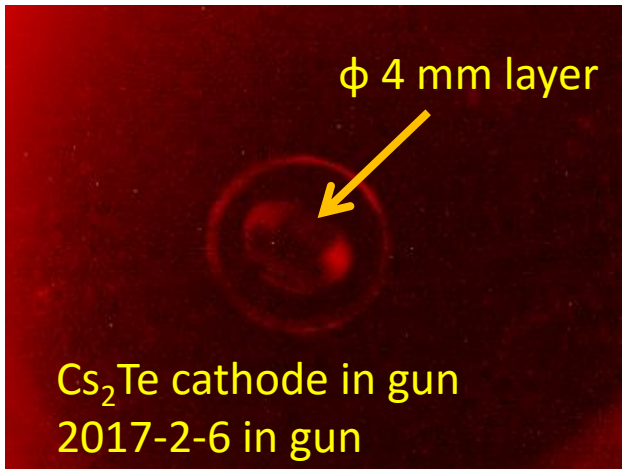


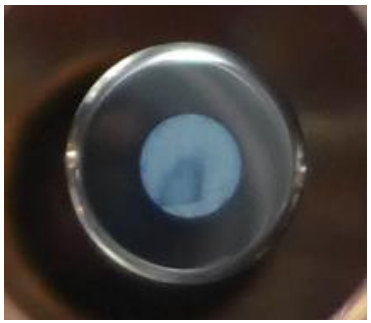
Mg pug #216

1. Status of ELBE SRF gun-II

Problem: cathode overheating in SRF gun II

in 2017, Cs_2Te cathodes #2016.03, #2017.03 disappeared in SRF gun II, cavity is recovered by warming up - cooling down cycle.

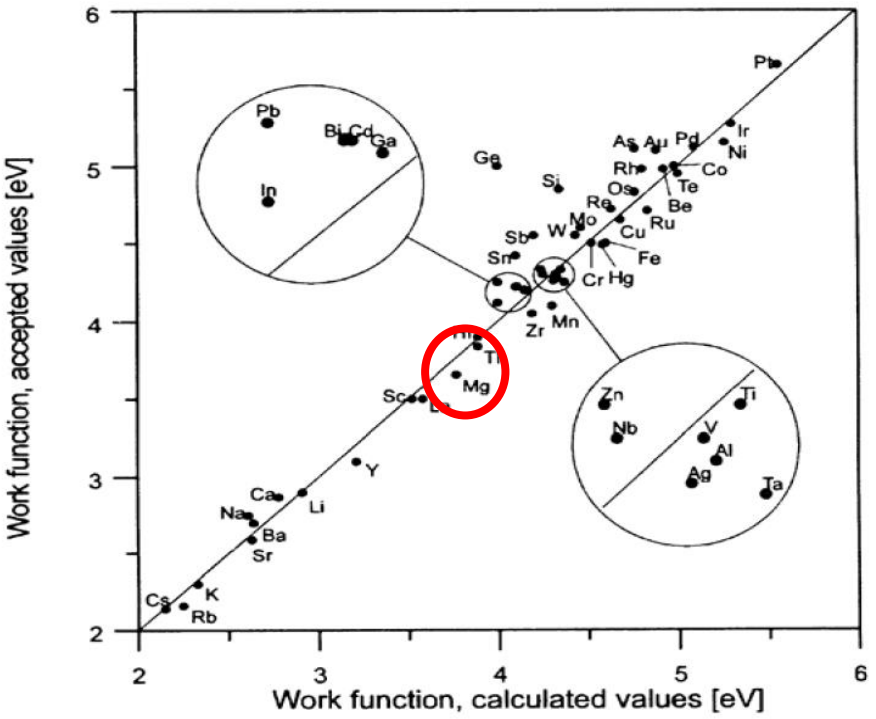




2. Mg photocathodes in SRF gun-II

a „Clean“ (Cs-free) cathode for SRF gun

Metal (polycrystalline)	QE (%)	ϕ (eV)
Cu	10^{-6} - 10^{-5}	4.6
Mg	10^{-6} - 10^{-4}	3.6
Mo	10^{-6}	4.5
Nb	10^{-6}	4.3
Pb	10^{-6}	4.25

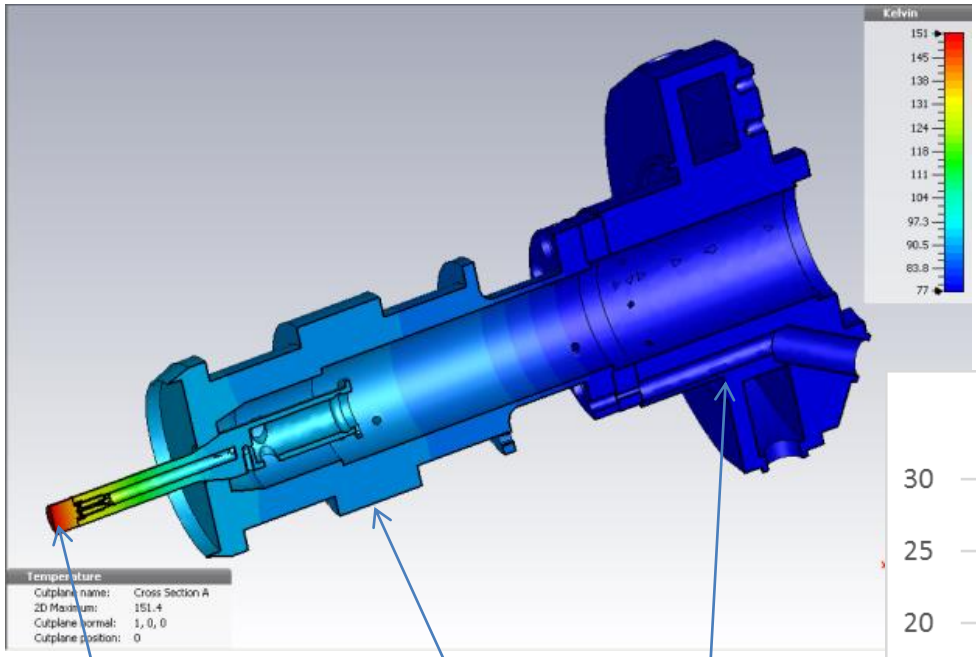


Lide, D. R.. Properties of Solids, in: *CRC Handbook of Chemistry and Physic, Internet Version 2005*. Boca Raton, FL: CRC Press; 2005, P. 124

S. Halas, Materials Science-Poland, Vol. 24, No. 4, 2006

2. Mg photocathodes in SRF gun-II

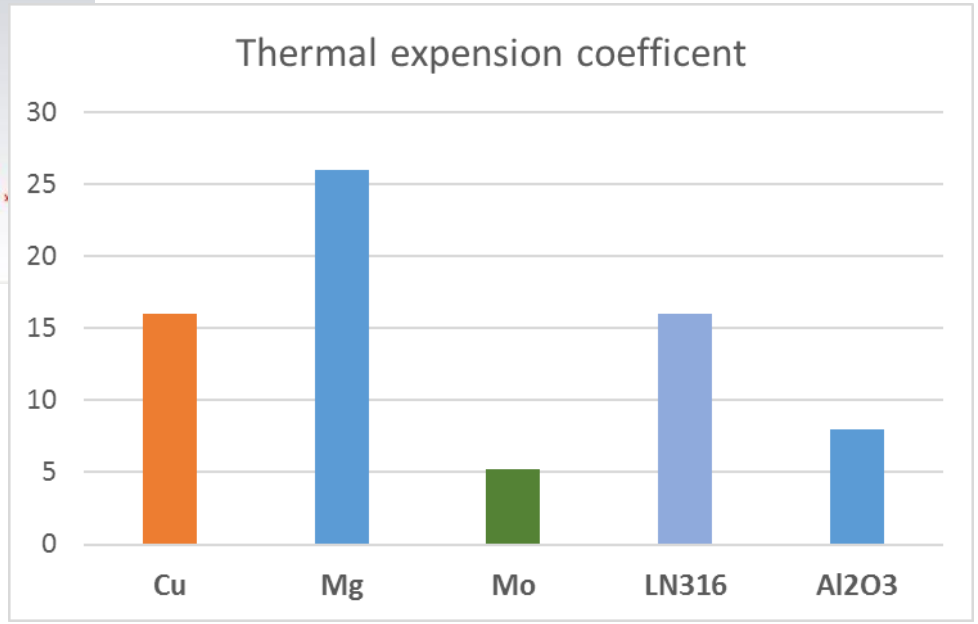
avoid overheating of cathode



T1 T2 T3

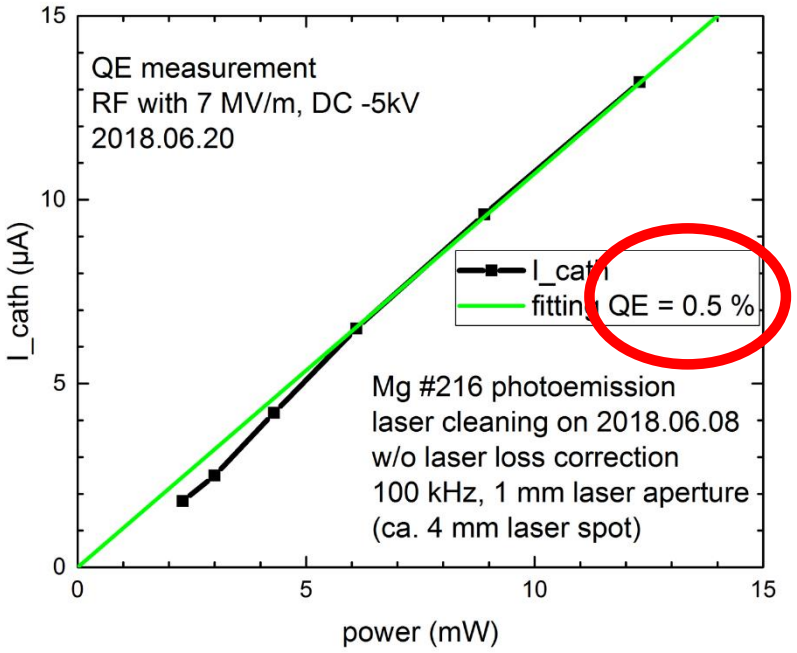
thermal transition coefficient

(W/m.K)	@ room temperature	@ LN temperature
Cu	401	~ 500
Mo	138	~ 220
Mg	156	~ 200
Al_2O_3	30	~ 200

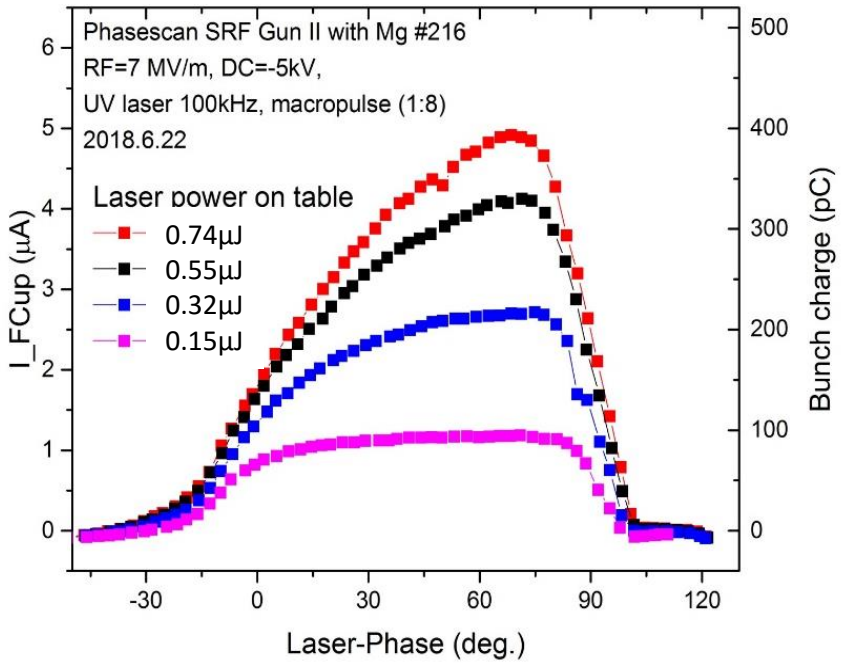


2. Mg photocathodes in SRF gun-II

- ✓ High QE @ 258nm after laser cleaning



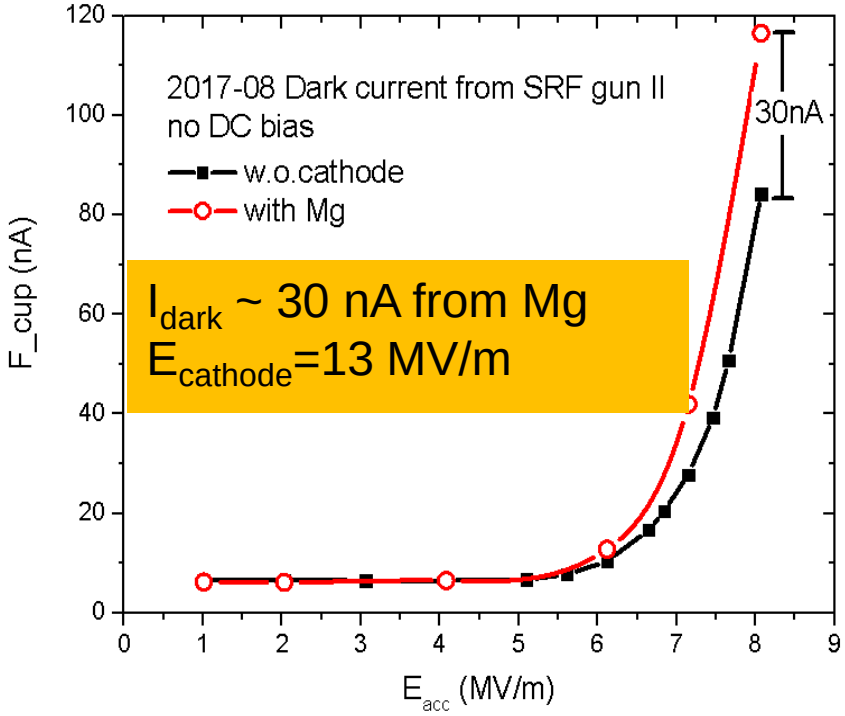
- ✓ Bunch charge ~ 0.3 nC

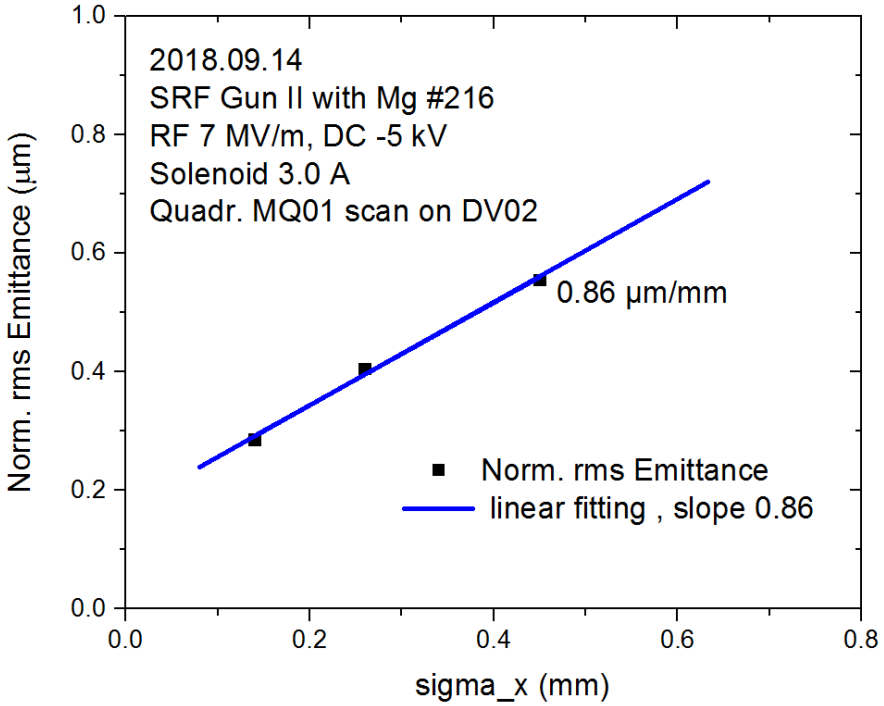


2. Mg photocathodes in SRF gun-II

- ✓ No multipacting problem
- ✓ acceptable dark current

? Thermal emittance

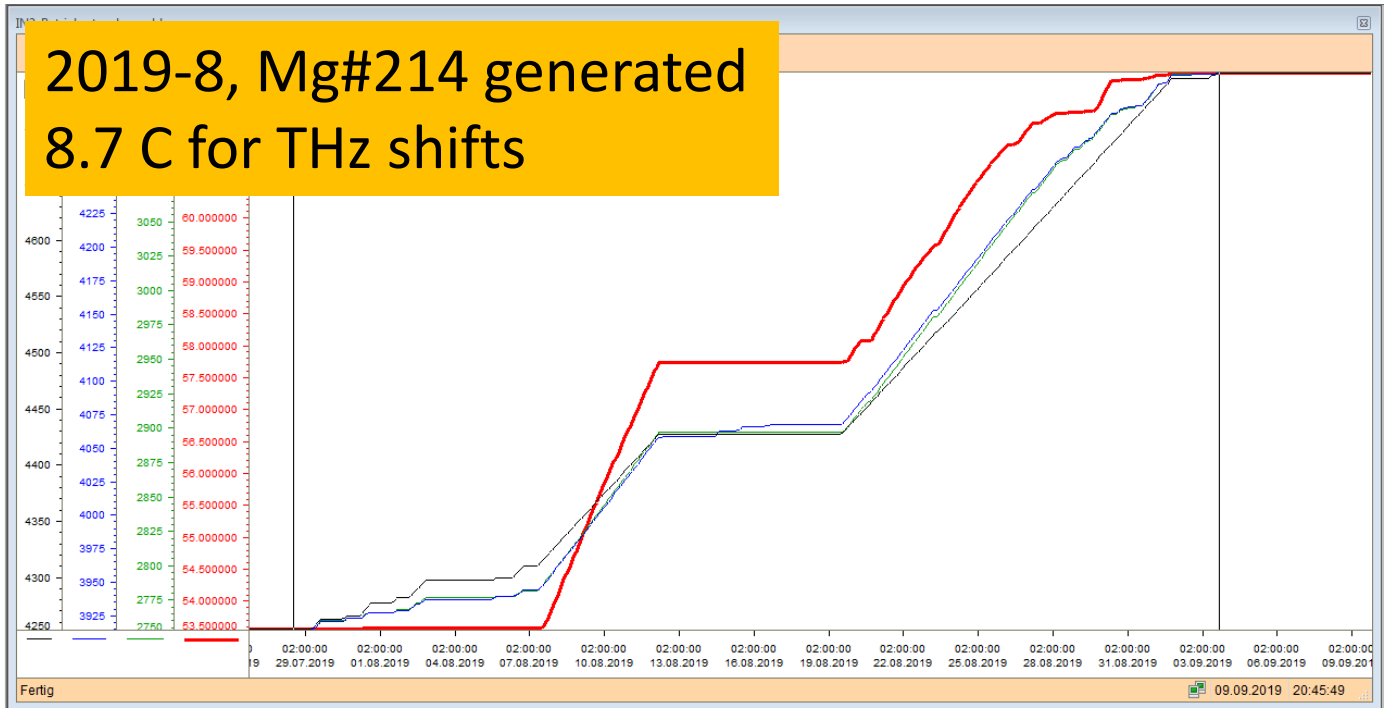




H.J.Qian et al., Appl. Phys. Lett. **97**, 253504 (2010)

2. Mg photocathodes in SRF gun-II

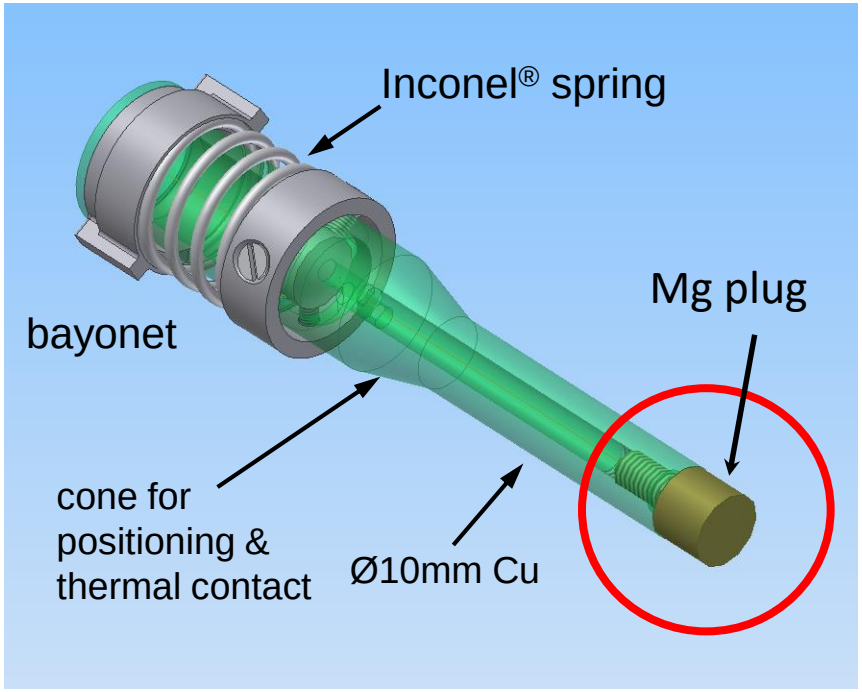
- ✓ Robust in SRF gun
- ✓ Replaced only due to vacuum issue in injector

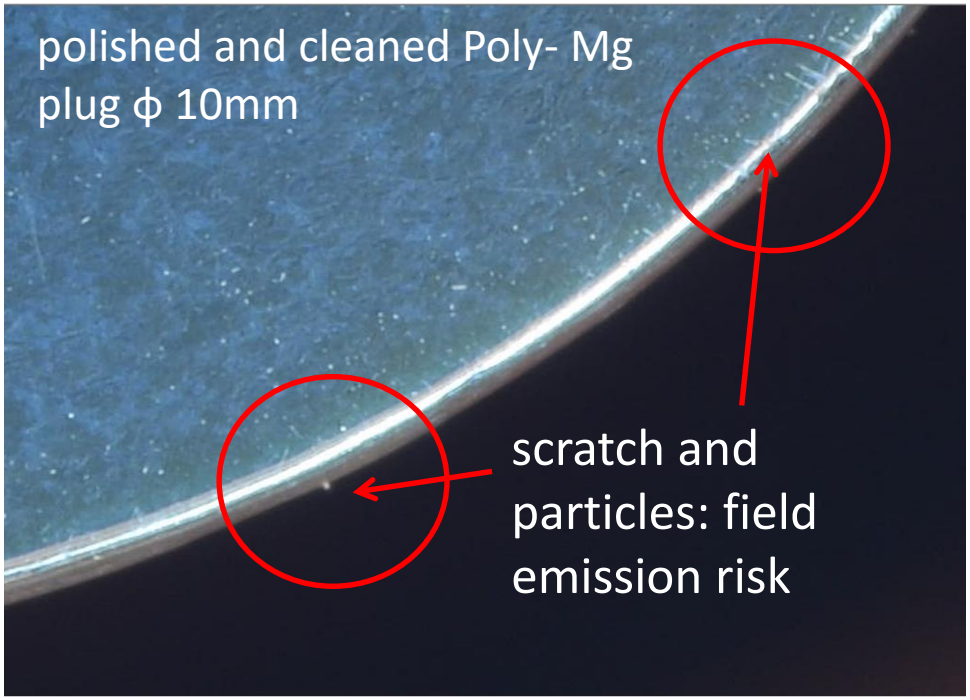


3. ps UV laser cleaning of Mg phtocathodes

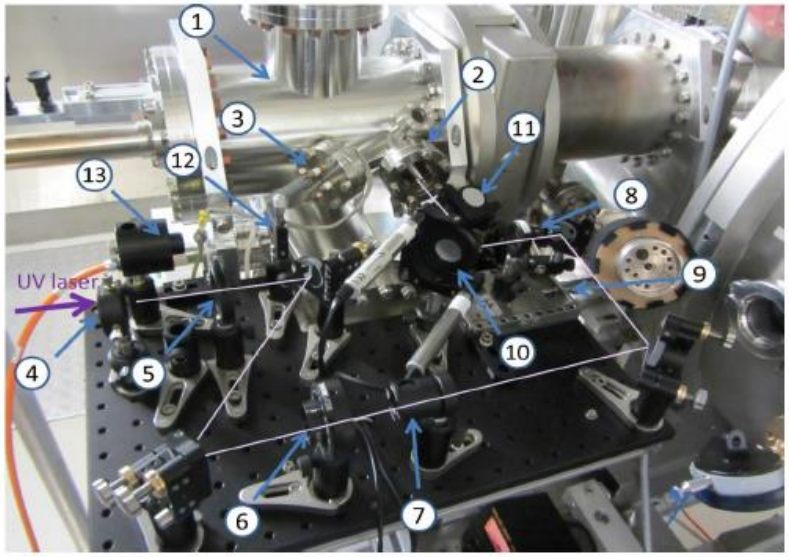
Steps:

- Machine bulk plug of Mg (Goodfellow & MaTecK)
- Optical polishing
- Remove oxide layer & clean in cleanroom
- Install in transport chamber and check quality
- Laser cleaning

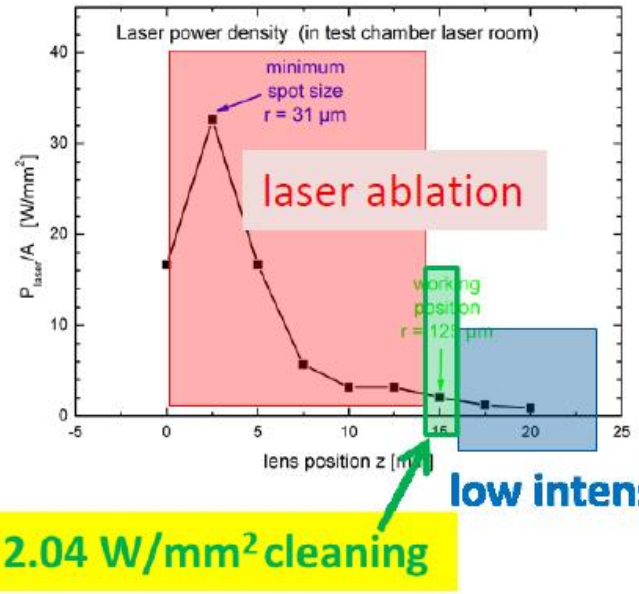


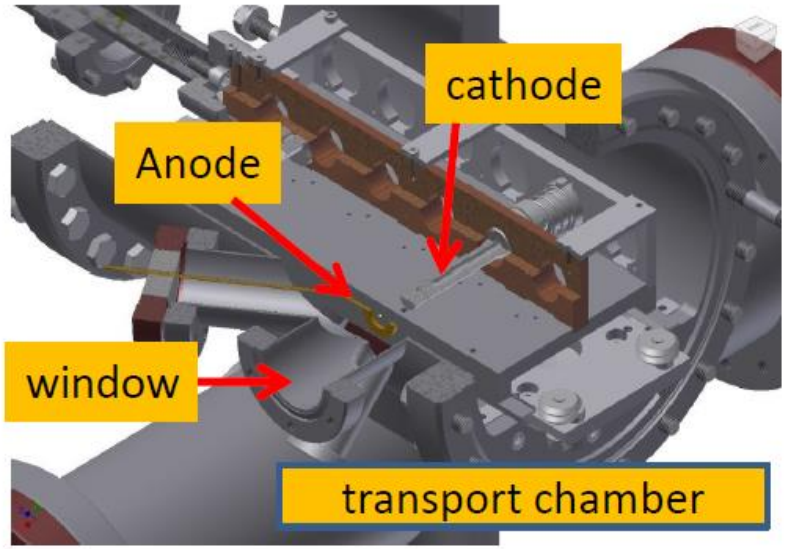


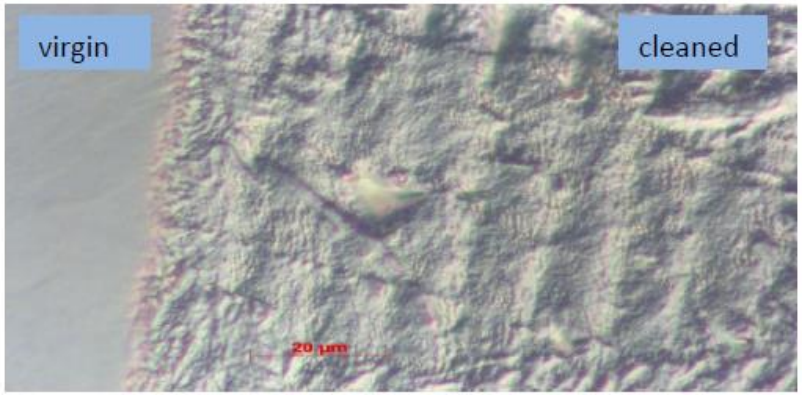
3. ps UV laser cleaning of Mg phtocathodes



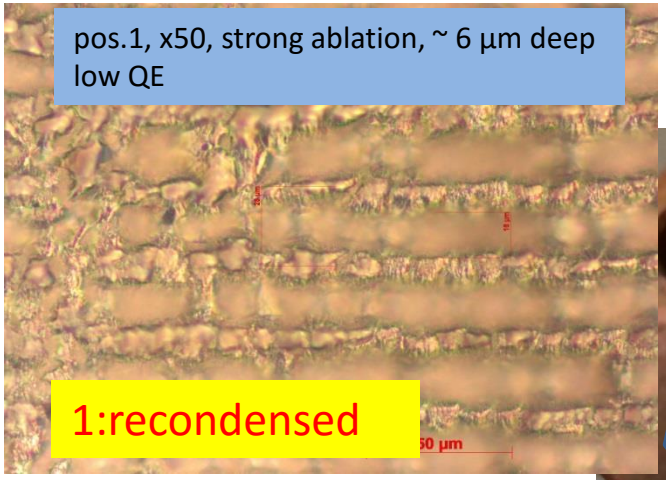
Laser cleaning set-up at transport chamber at SRF gun
using the UV drive laser (100 mW, 100 kHz CW)



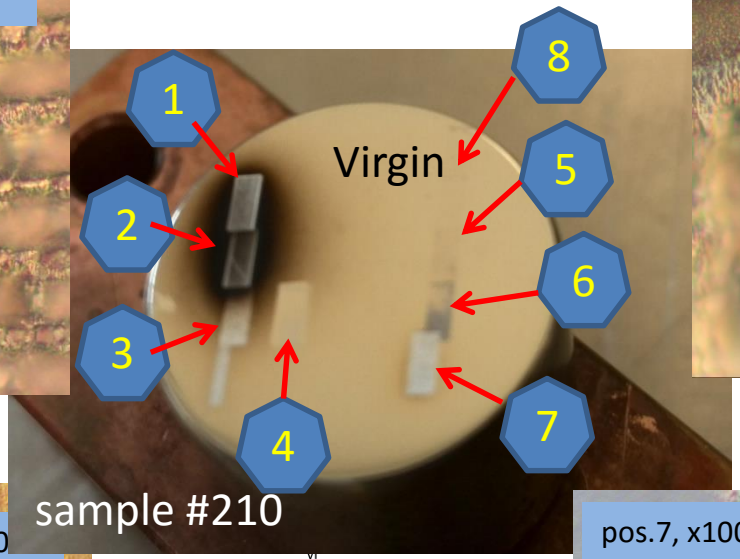


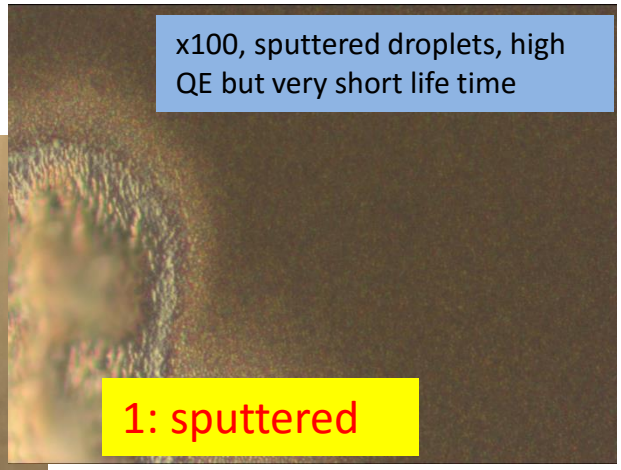


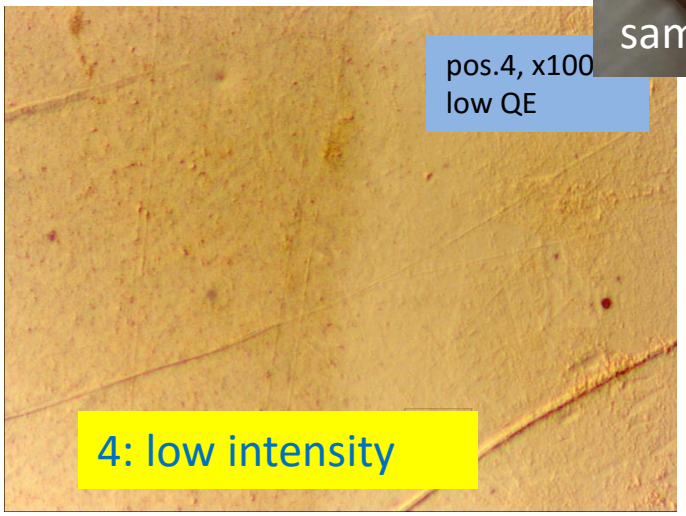
3. ps UV laser cleaning of Mg phtocathodes

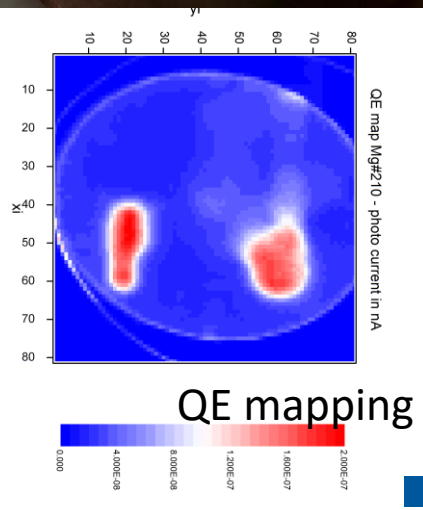


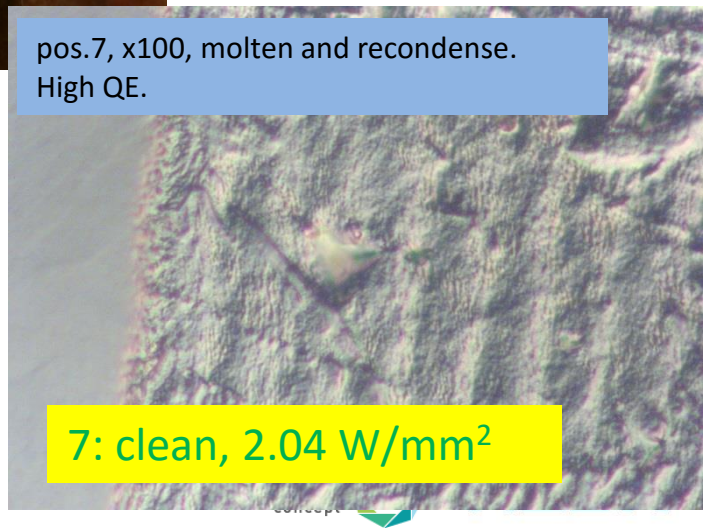
in test chamber



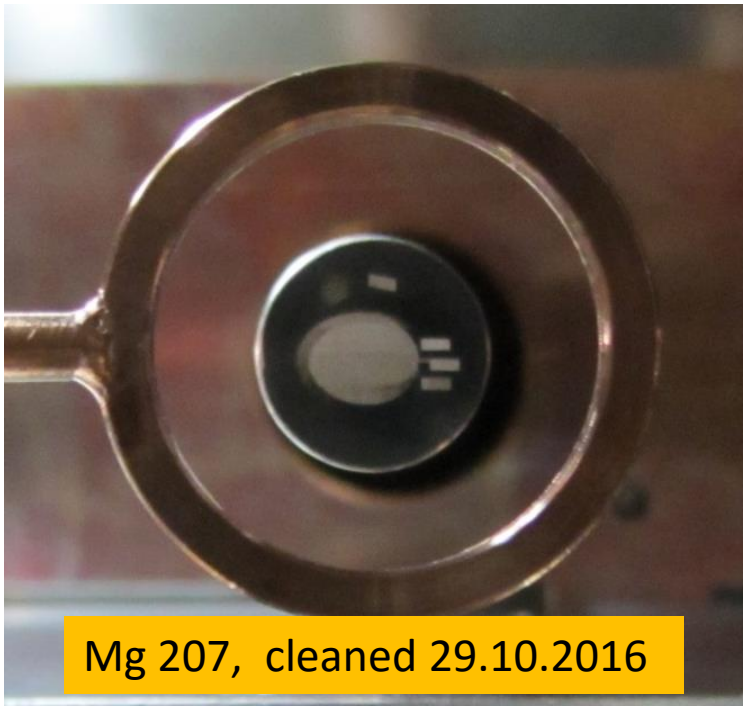




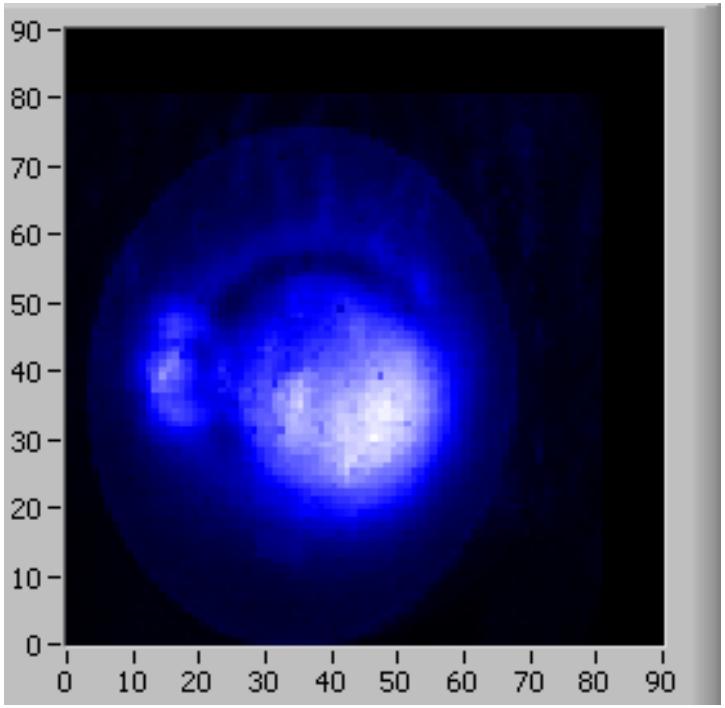




3. ps UV laser cleaning of Mg phtocathodes

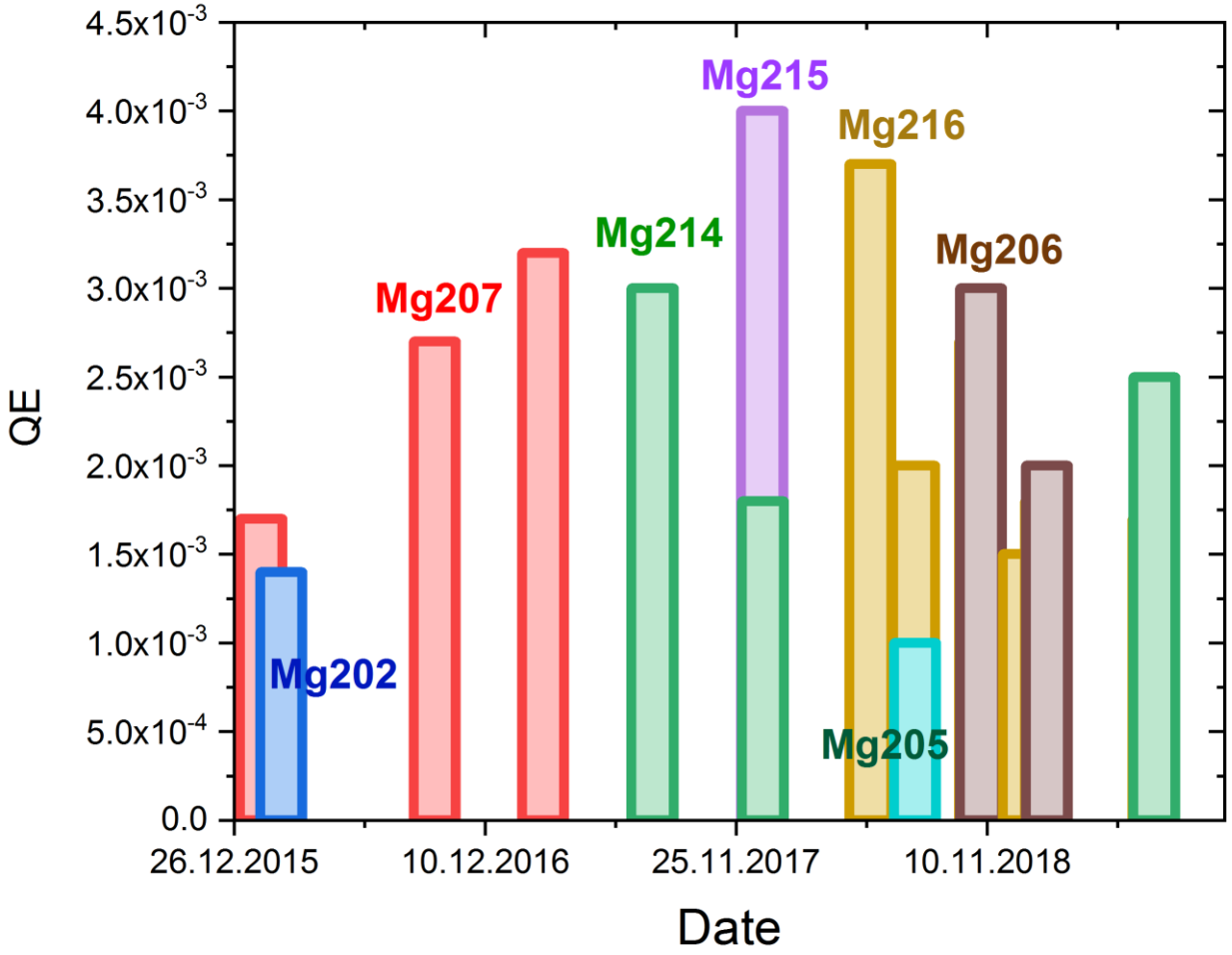


cleaning time: about 2 hours
12 µm x 12 µm step size,
100 ms dwell time



QE mapping
with low laser power

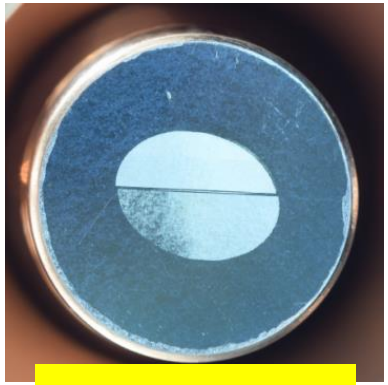
3. ps UV laser cleaning of Mg phtocathodes



QE measured in transport chamber with DC bias

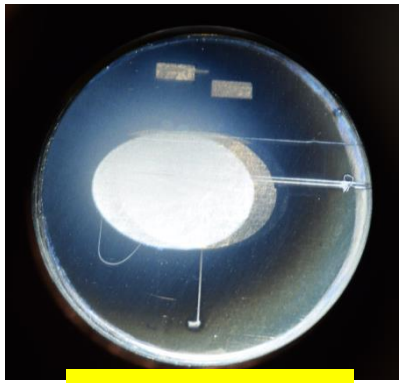
3. ps UV laser cleaning of Mg phtocathodes

Part of examples



2016.03 **Mg #201**

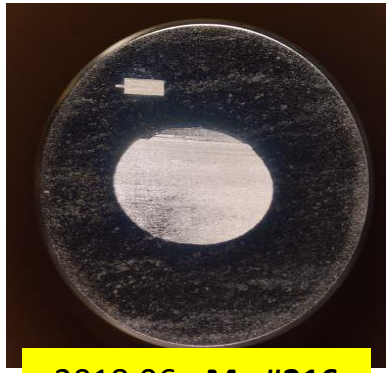
2016.11 **Mg #207**



2017.8 – **Mg #214**

2018.1 – **Mg #214**

2018.01 - **Mg #215**

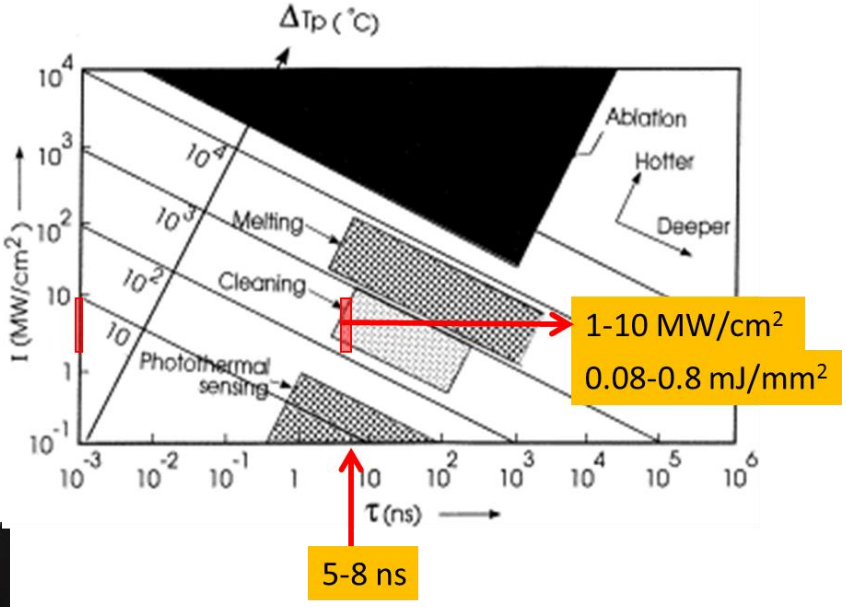


2018.06 - **Mg #216**

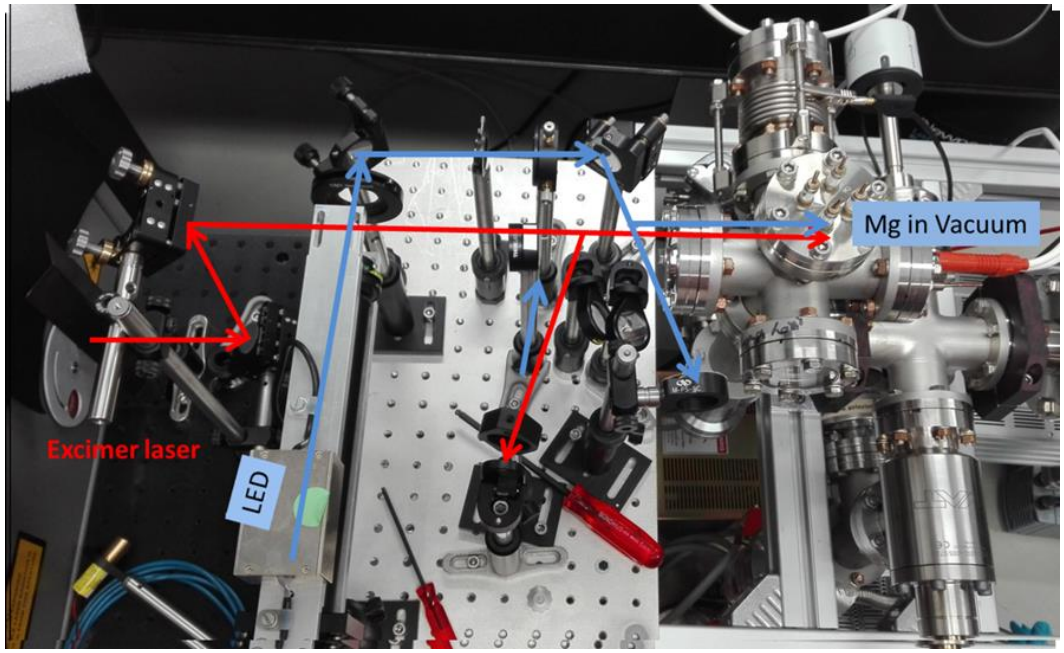
4. Alternative preparation of Mg phtocathodes

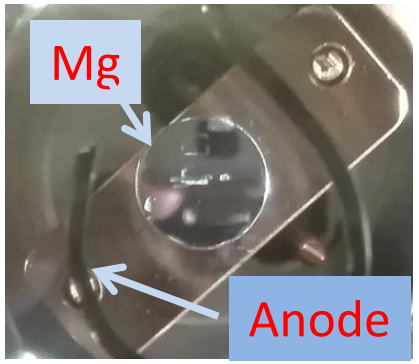
- *Cleaning with excimer laser*

krF laser, 248nm, 5-8 ns, energy intensity 0.25 -2.5 mJ/mm^2



A. C.Tam et al., Applied Surface Science 127-129 (1998) 721-725



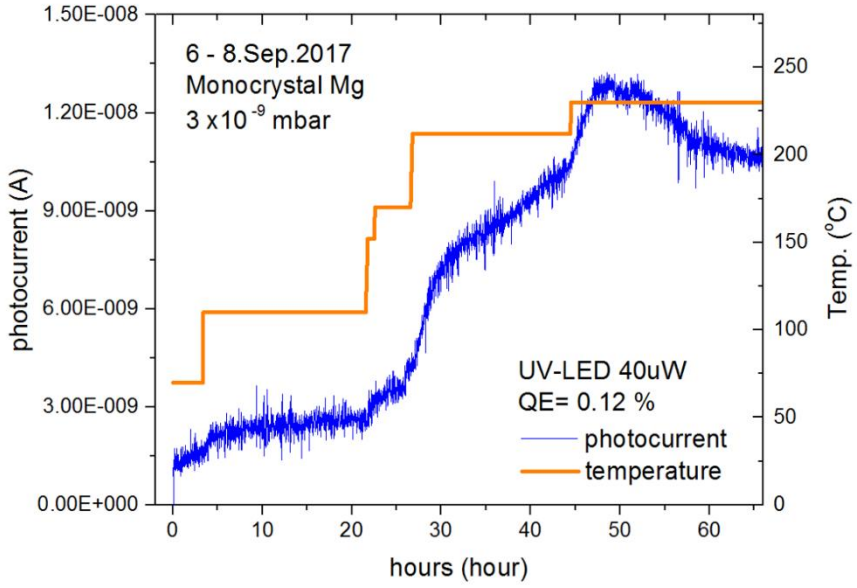


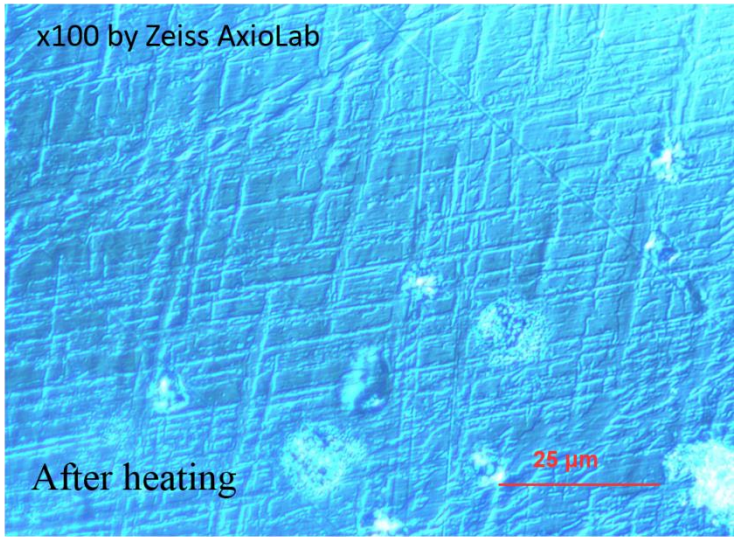
going on …

4. Alternative preparation of Mg phtocathodes

- *Thermal treatment of Mono-crystal Mg*

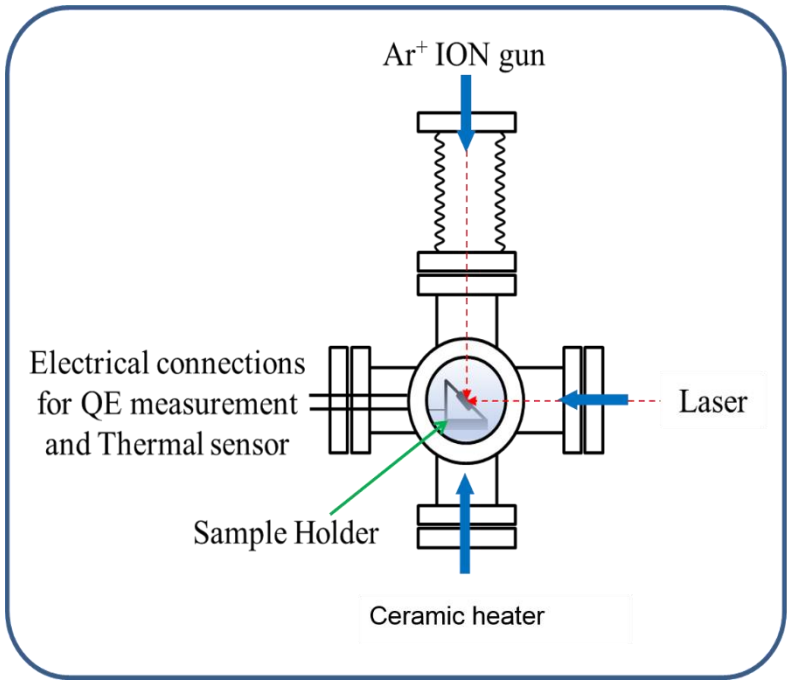
- QE reaches 0.12 %, smooth surface
- Repeatable, independent on heating speed
- Optimal working temperature 220 °C
- Working mechanism ? Poly-Mg?

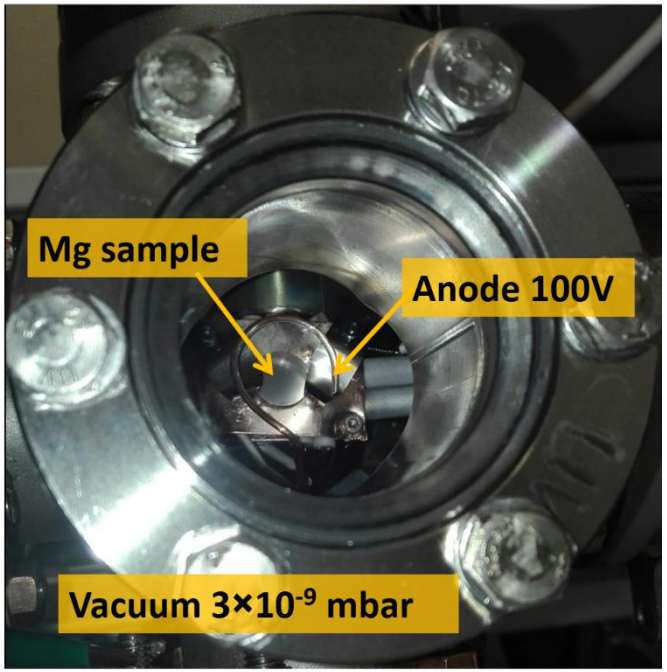




4. Alternative preparation of Mg phtocathodes

- *Ar+ ion bombardment*





5. Summary and outlook

- **Mg photocathodes operate successfully in SRF gun**
  - Mg can reach high QE of $1\sim4\times10^{-3}$
  - no multipacting and low dark current (<30 nA)
  - robust

- **Photocathode manipulation is a high risk**
  - careful quality check of cathodes
  - mechanics to avoid particle production

- **Medium / high currents require semiconductor photocathodes**
  - Cs_2Te is still the choice for medium currents (1 mA)
  - suitable substratum
  - new material (GaN)

Thank you for your attention!

Thanks to the ELBE team and our cooperators!

Influence of Cs_2Te tests to cavity

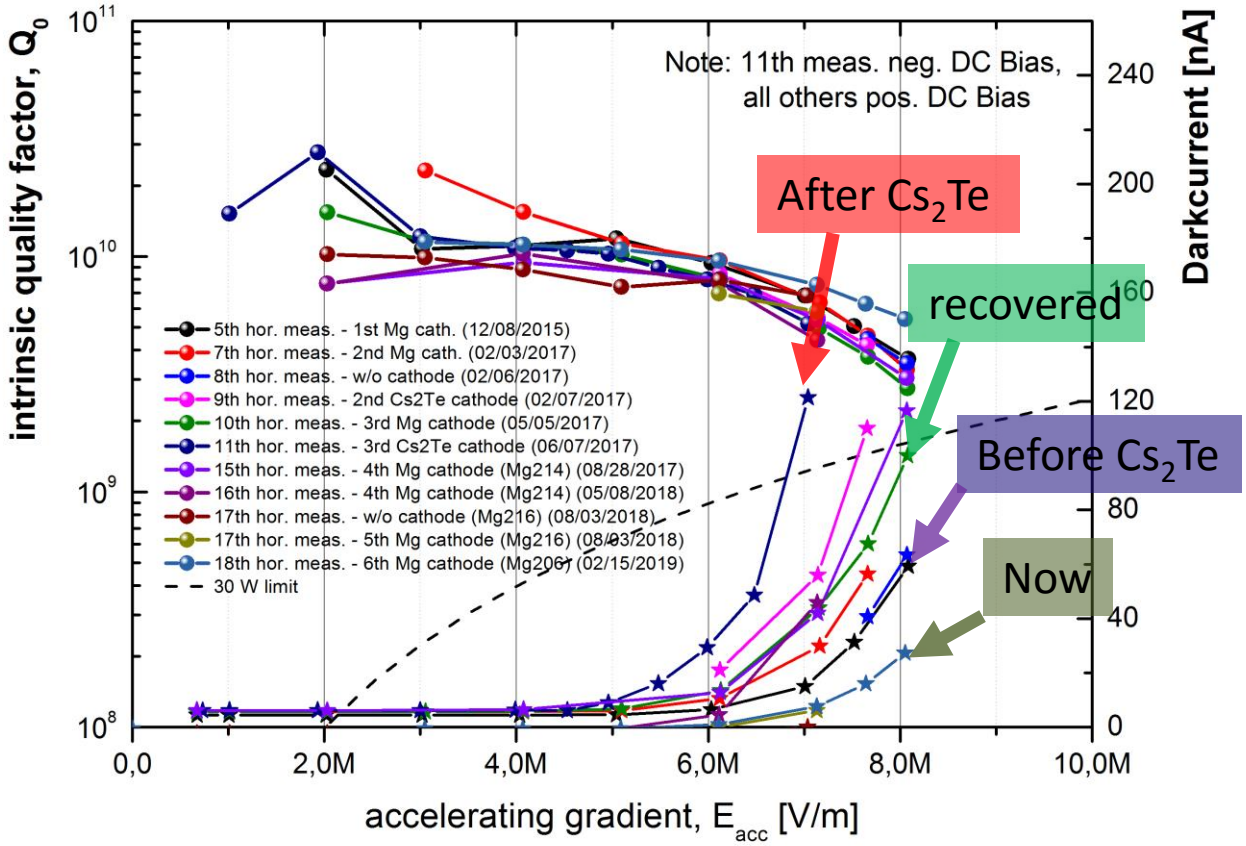


TABLE 3.—VAPOUR PRESSURE OF MAGNESIUM, ZINC AND CADMIUM

temp. °K	vapour pressure, atm		
	MAGNESIUM	ZINC	CADMIUM
298·15	$8{\cdot}32\times10^{-20}$	$4{\cdot}14\times10^{-17}$	$3{\cdot}92\times10^{-14}$
400	$2{\cdot}03\times10^{-13}$	$2{\cdot}32\times10^{-11}$	$3{\cdot}45\times10^{-9}$
500	$1{\cdot}08\times10^{-9}$	$5{\cdot}19\times10^{-8}$	$2{\cdot}60\times10^{-6}$
594	—	—	$1{\cdot}67\times10^{-4}$
600	$3{\cdot}23\times10^{-7}$	$8{\cdot}64\times10^{-6}$	$2{\cdot}05\times10^{-4}$
692·7	—	$2{\cdot}60\times10^{-4}$	—
700	$1{\cdot}84\times10^{-5}$	$3{\cdot}23\times10^{-4}$	—
800	$3{\cdot}74\times10^{-4}$	—	—
900	$3{\cdot}89\times10^{-3}$	—	—
923	$6{\cdot}15\times10^{-3}$	—	—
assumed value of $\Delta H_{v,\,st}$, cal mole^{-1}	34,290	30,850	26,540

New project: SRF Gun Lab (start from 2019)