

ELBE.

Mg Photocathode in SRF Gun for medium current e^- - beam

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on behalf of the SRF Gun Crew at ELBE



hzdr

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Outline

1. Status of SRF Gun II & photocathodes
2. Laser cleaning for Mg photocathode
3. Metallic photocathode in SRF gun-II
4. Summary



EuCARD-2 3rd Annual WP12 Meeting
4-5 April 2015 at STFC Daresbury Laboratory



1. Status of ELBE - SRF Gun II & photocathodes

ELBE user requirements for SRF gun (simulation result @ 7MV/m)

user application	bunch charge	norm trans. emitt.	final bunch length	beam size at IP	average current
IR FELs (13 MHz)	77 pC	2.2 μm	< 1 ps		1 mA
Neutrons (100 kHz)	500 pC				50 μA
Positrons (500 kHz)	200 pC				100 μA
THz radiation (100 kHz)	350 pC		200 fs		35 μA
CBS x-rays (10 Hz)	450 pC		1 ps	30 μm	

J. Teichert, ERL2015

1. Status of ELBE - SRF Gun II & photocathodes

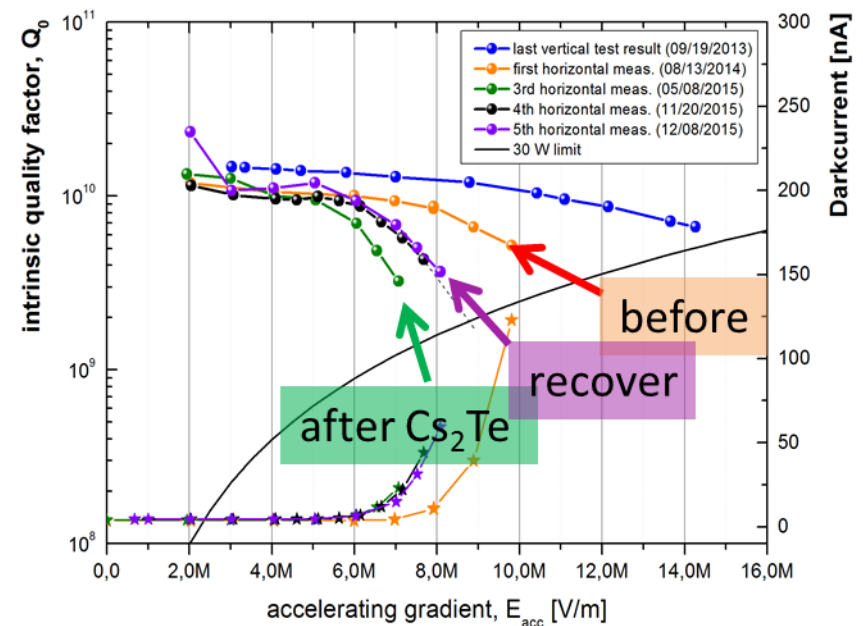
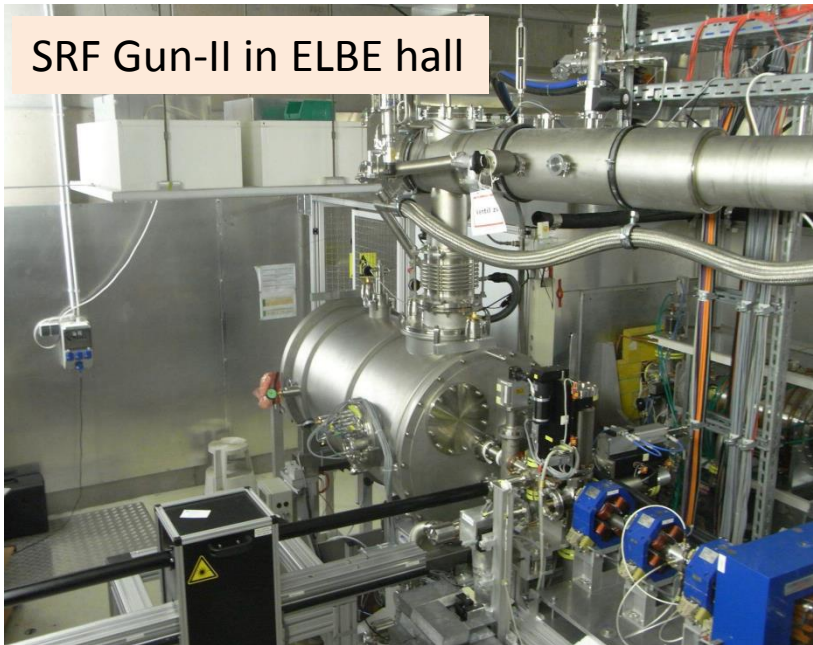
GUN

- $E_{\text{acc}} = 8 \text{ MV/m CW}$ (20.5 MV/m peak field)
- - 5 kV DC bias @ Cathode
- dark current in FC <100 nA @8 MV/m
- UV laser: 258 nm, 100 kHz, Gaussian

PHOTOCATHODE

- Cu cathode 2×10^{-5} @ 258 nm
- the 1st experiment of Cs₂Te in gun failed
- Mg cathode

SRF Gun-II in ELBE hall



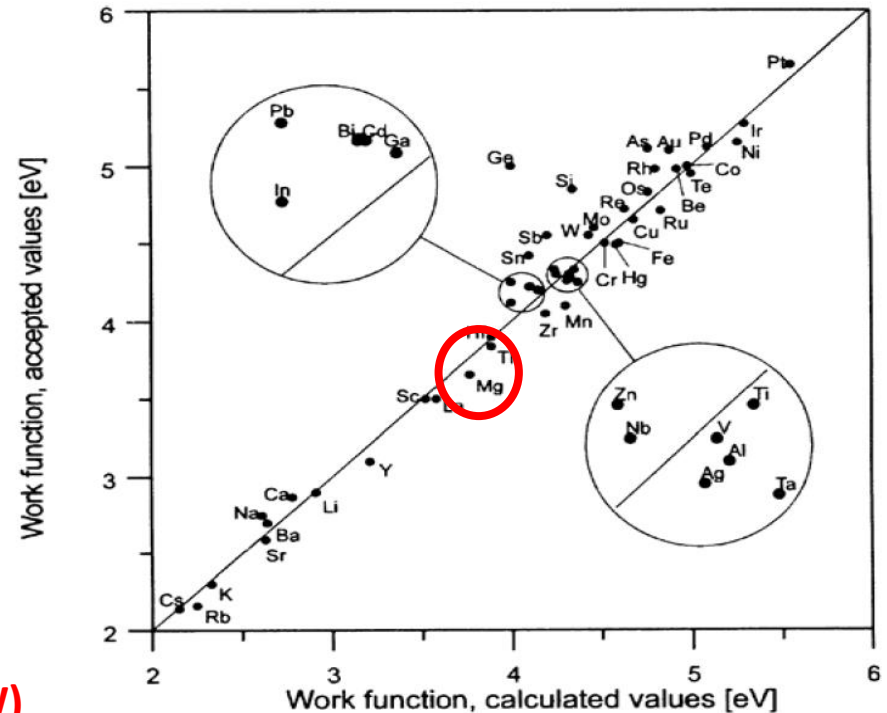
2. Laser cleaning for Mg photocathode

Motivation: to search for 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

Working plan:

- laser cleaning test with 200 mW UV laser (v)
- Ar⁺ ion beam cleaning
- heating cleaning



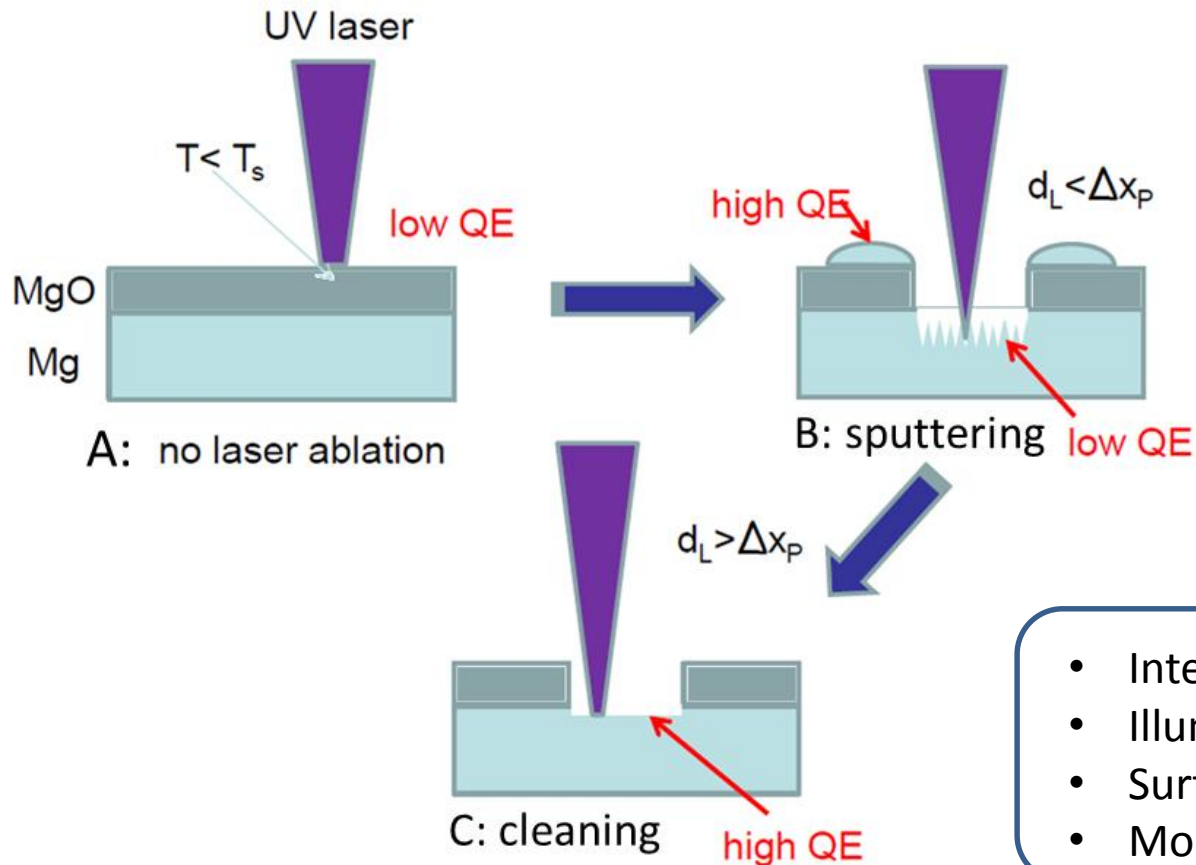
Lide, D. R.. Properties of Solids, in: *CRC Handbook of Chemistry and Physics, Internet Version 2005.*

Boca Raton, FL: CRC Press; 2005, P. 124

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

EuCard2. WP12

2. Laser cleaning for Mg photocathode



laser parameter:

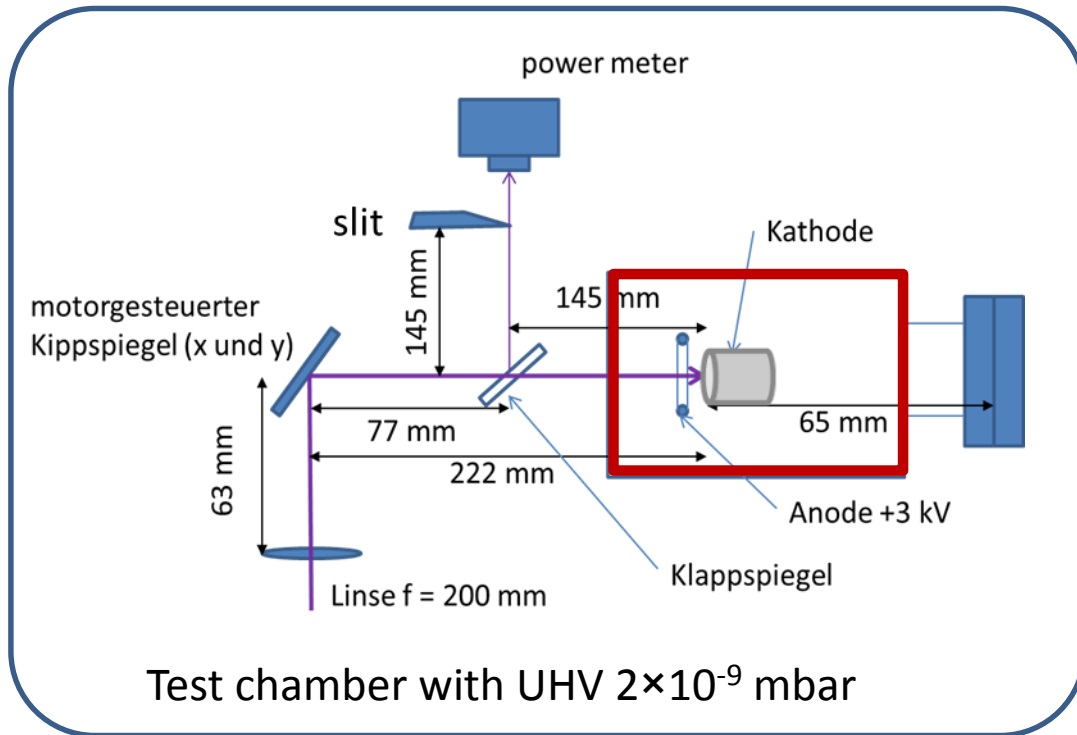
UV: 258 nm (4.8 eV)
rep. rate: 100 kHz
ultra short pulse: 10ps
mean power: 100 mW
min. spot: $r=30 \mu\text{m}$

- Intensity threshold *
- Illuminating duration
- Surface roughness of sample
- Mono-crystal or poly- Mg

* photoemission in gun 0.1-0.2 W/mm²

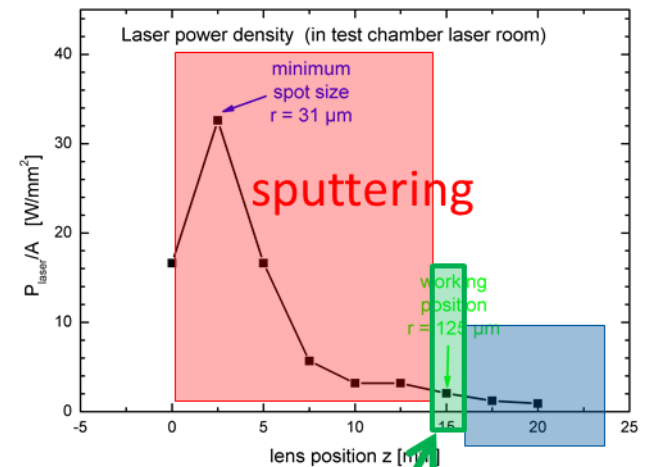
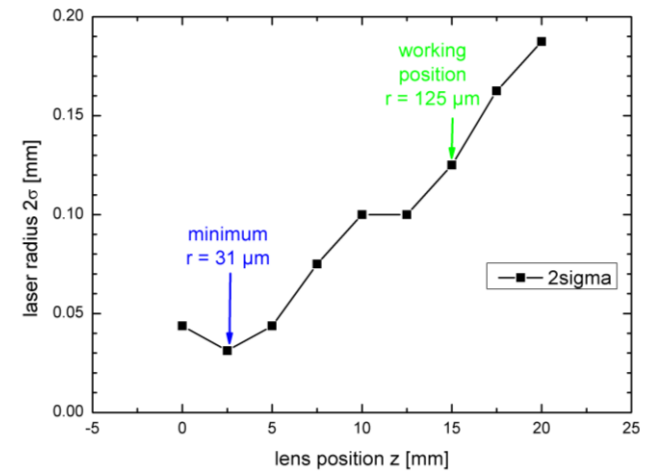
2. Laser cleaning for Mg photocathode

in test chamber



important:

adjust focusing lens position to search for the suitable power density



2.04 W/mm² cleaning

low intensity

* photoemission in gun 0.1-0.2 W/mm²

2. Laser cleaning for Mg photocathode

in test chamber

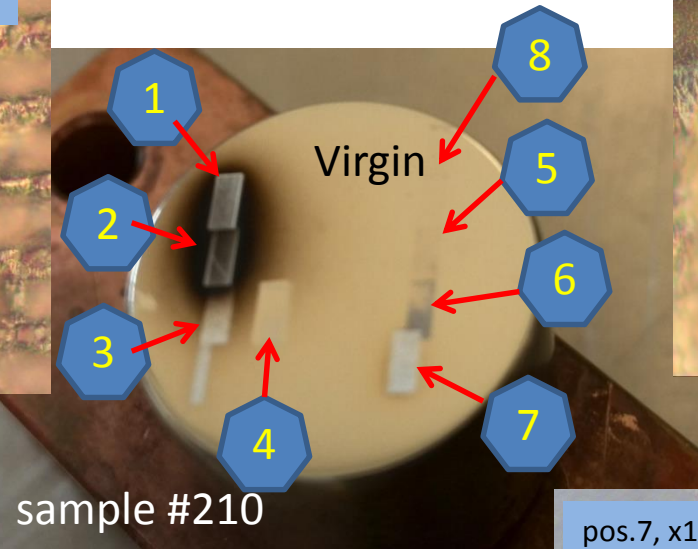
pos.1, x50, strong ablation, ~ 6 μm deep
low QE

1: sputtering

50 μm

x100, sputtered droplets, high
QE but very short life time

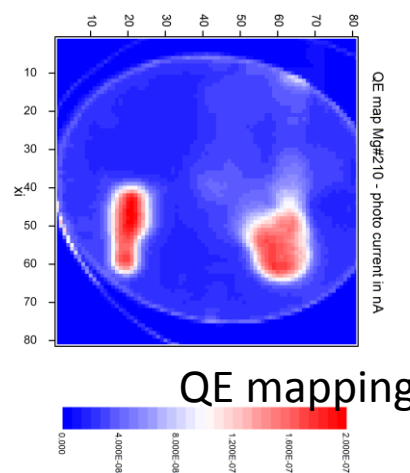
1: sputtering



sample #210

pos.4, x100
low QE

4: low intensity



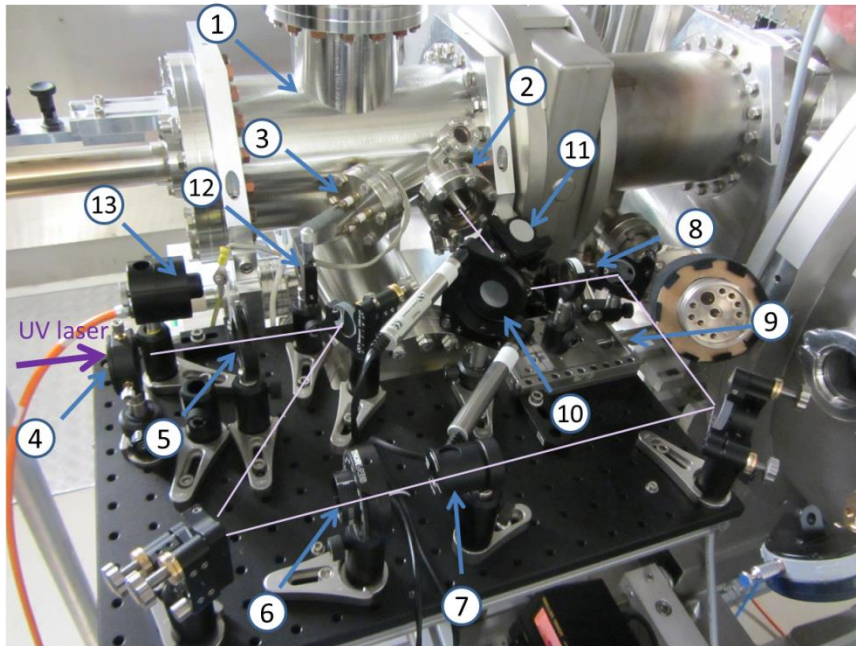
QE mapping

pos.7, x100, molten and recondense.
High QE.

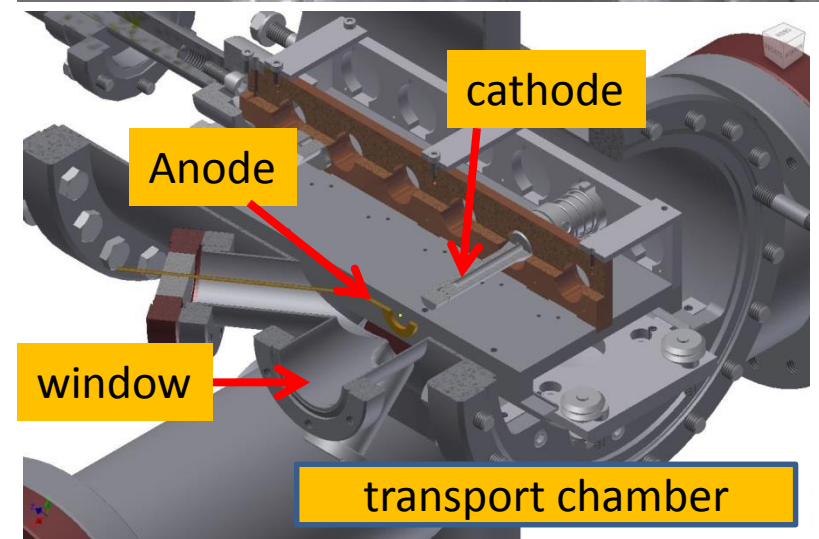
7: clean, 2.04 W/mm²

2. Laser cleaning for Mg photocathode

in transport chamber



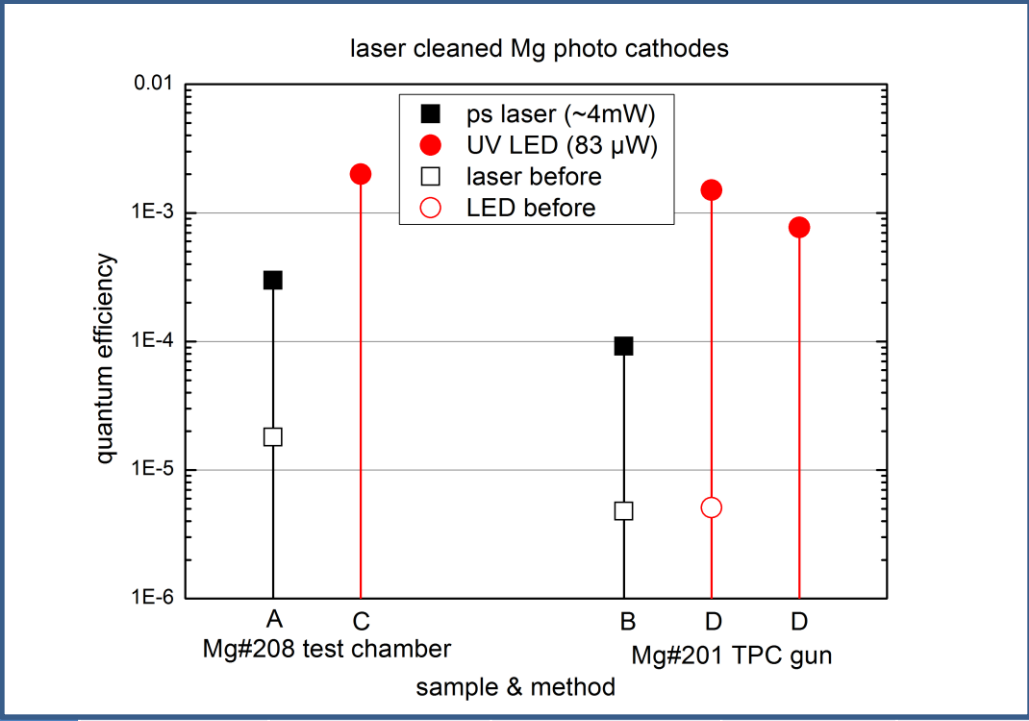
Photograph of laser cleaning setup



2. Laser cleaning for Mg photocathode

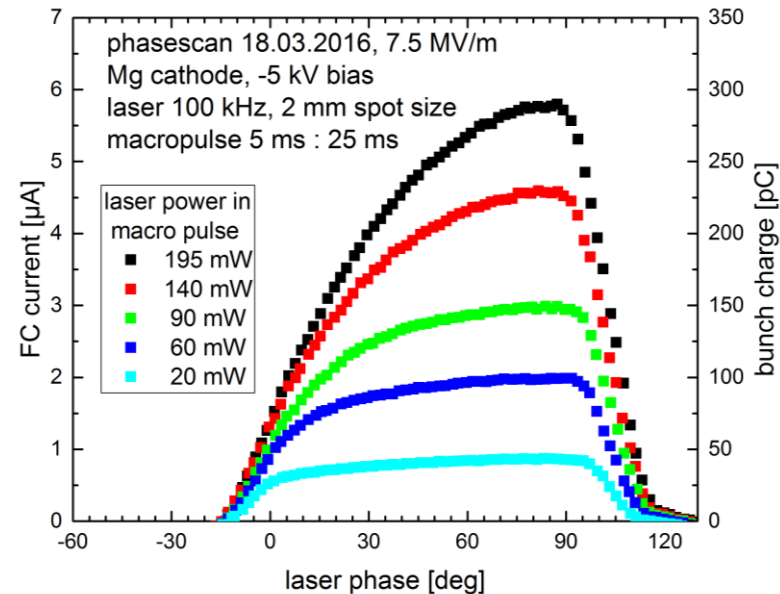
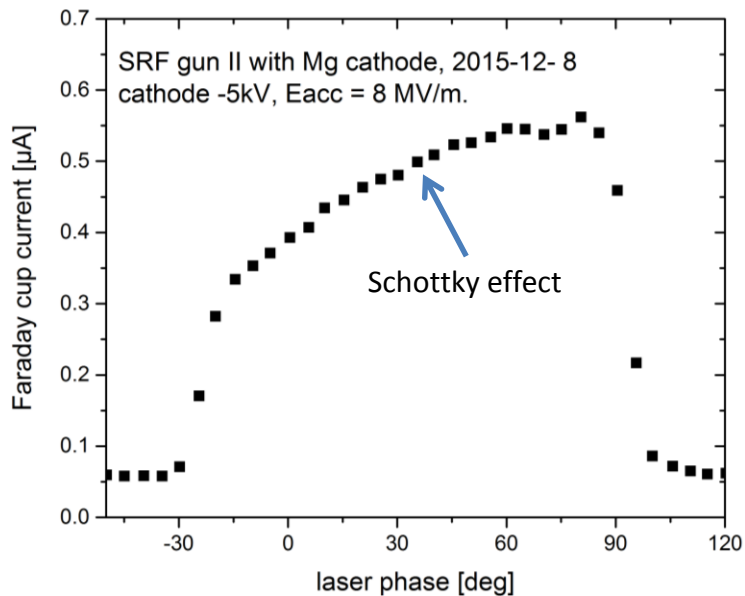
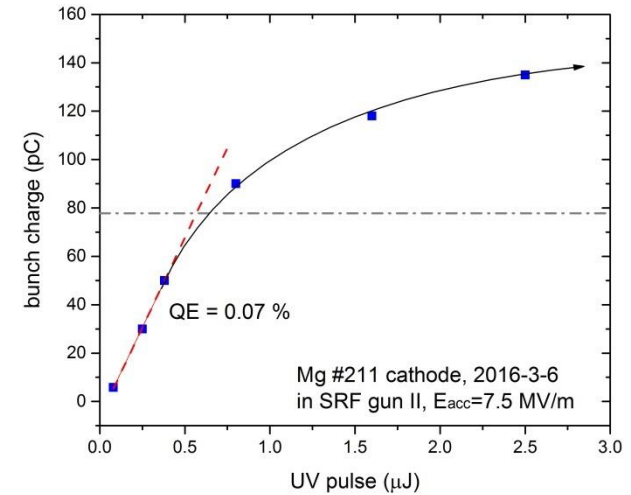
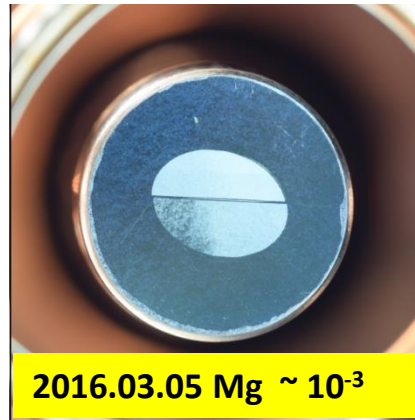
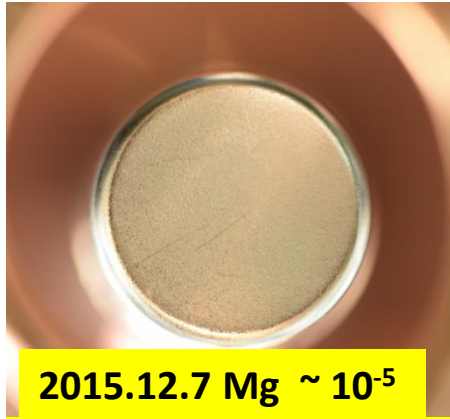
QE measurement

cathode	date	Methode	Place	power	current	QE	Bemerkung
Mg#210							
Mg#208						1.8 x 10 ⁻⁵	before laser cleaning
						0.0003	after
						0.20%	After
Mg#201						5.1x10 ⁻⁶	before laser cleaning
						4.8x10 ⁻⁶	before laser cleaning
						9.2 x 10 ⁻⁵	after
						0.15%	after
						0.077%	after
Mg#202							
Mg#207							
Mg#211						0.2 - 0.23%	
						0.06%	
Cu						3.2x10 ⁻⁶	Jörg



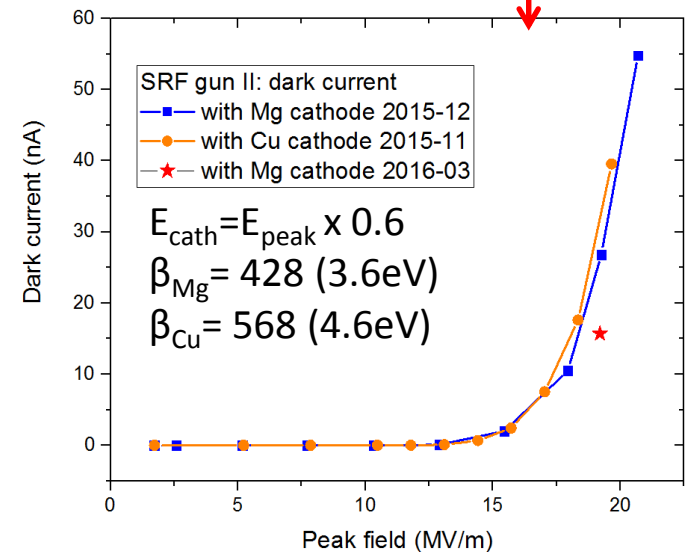
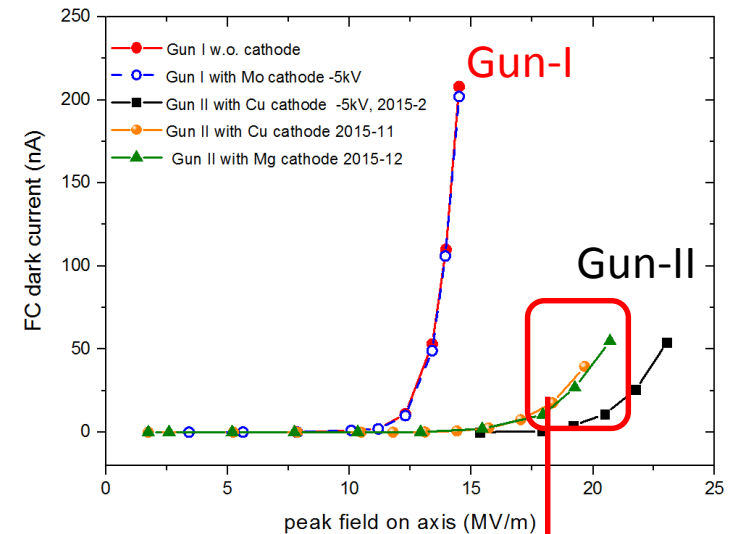
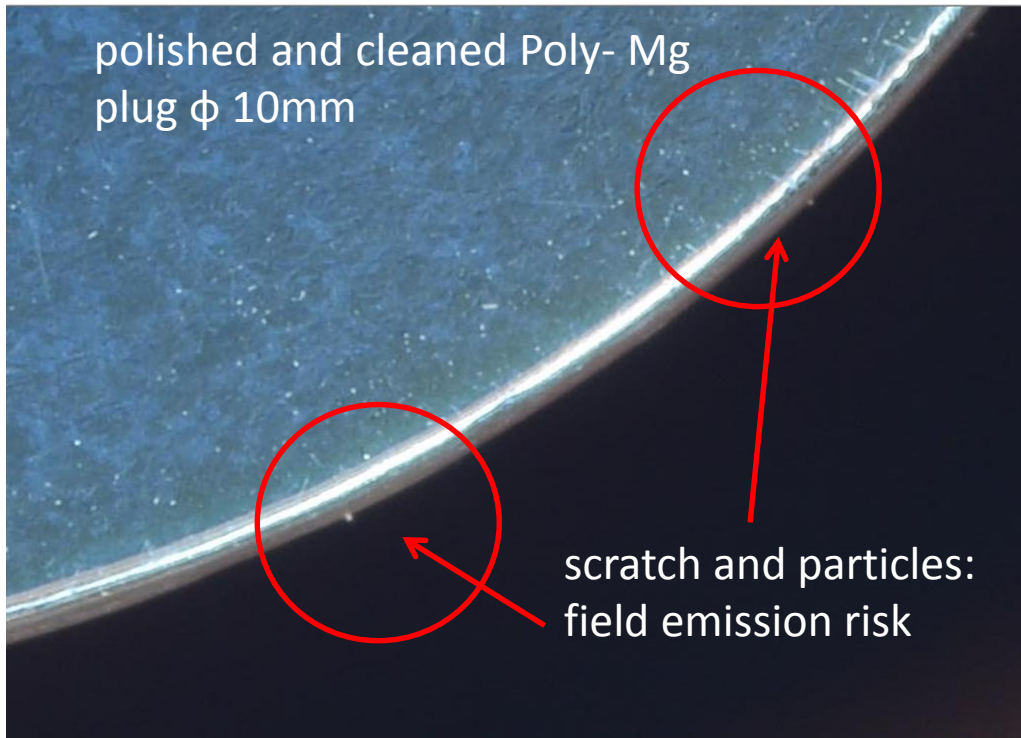
3. Mg photocathode in SRF gun-II

Laser phase scan and QE of Mg photo cathode in SRF gun



3. Mg photocathode in SRF gun-II

Dark current



3. Mg photocathode in SRF gun-II

QE increased **2 orders of magnitude**

- removal of the surface contamination (MgO, ϕ : 4.2eV)
- plasmon enhanced photoemission due to roughness (nm level)*

Experiment very well **repeatable**

Cleaned Mg is very **sensitive**

- stable in 10^{-9} mbar
- 10^{-8} mbar, loses 60% of QE in the 1st day

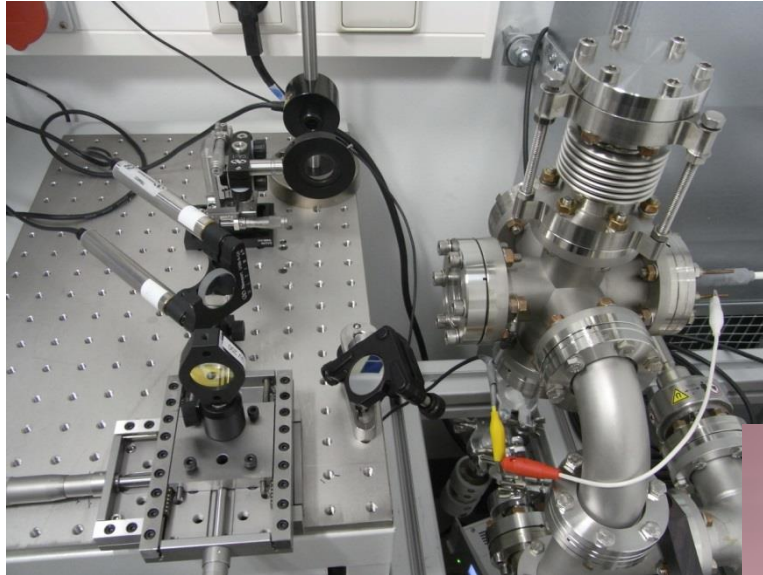
Effect of surface change

- reduced work function
- thermal emittance
- dark current

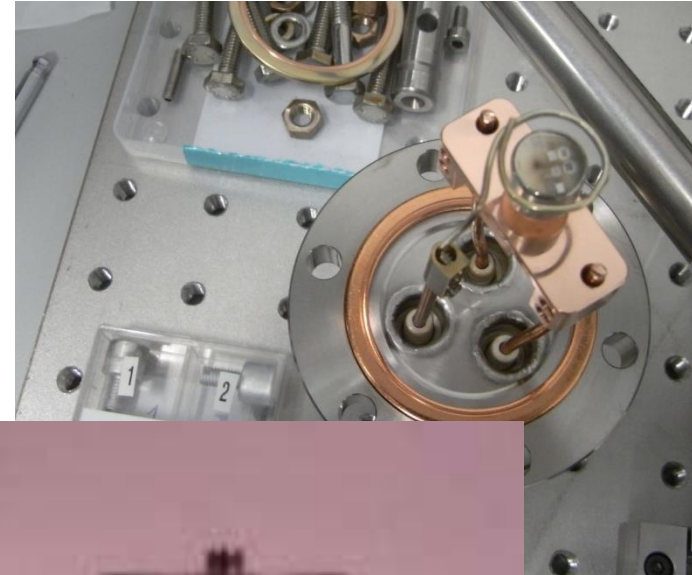


*Qian, H. J. et al., Applied Physics Letters, 97, 253504 (2010)

Long-term photo emission test of a Pb/Nb photo cathode at HZDR



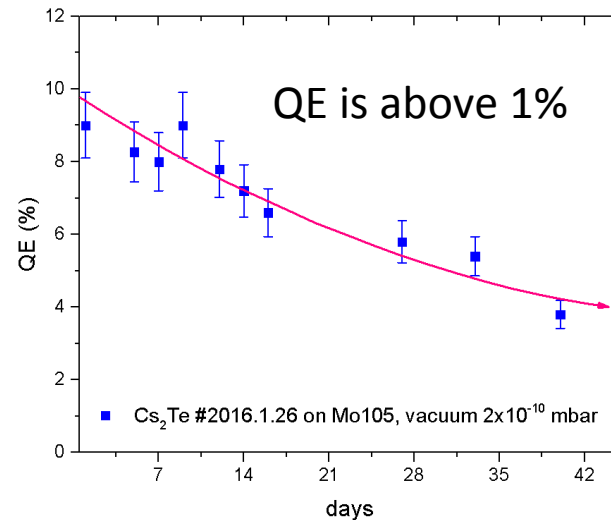
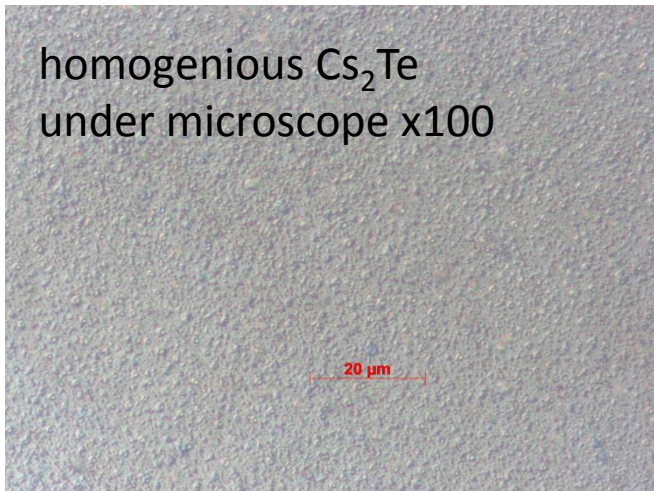
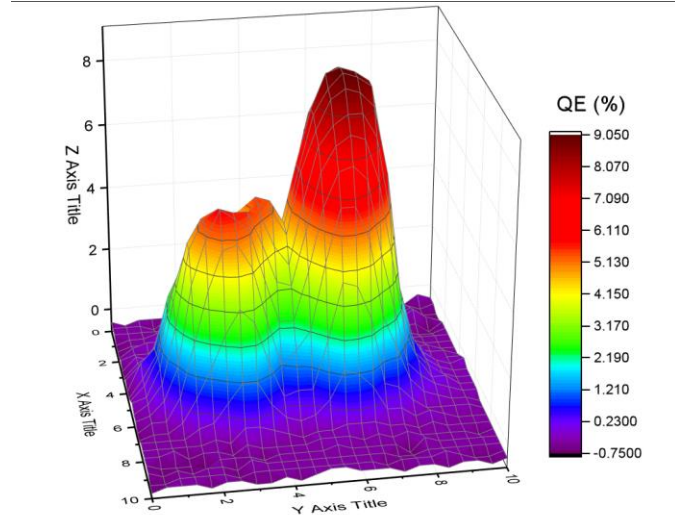
Test chamber for laser cleaning in the UV drive laser room



Pb/Nb plug of the SC gun cavity

- Nb plug from DESY for SC cavity
- Pb layer deposition at NCBJ Swierk
- at HZDR:
 - laser cleaning, QE measurements
 - performance test with several weeks laser irradiation @ 258 nm
 - using the ELBE SRF gun drive laser in the nights

Cs₂Te will be carefully going on... SRF Gun-II will run with Cs₂Te in 2016.



4. Summary

- SC RF gun with NC photocathode is promising but very challenging ...
- Metallic photocathodes are safe for SC cavity.
Cu for the gun commissioning and low bunch charge measurement
Mg can reach high QE of 10^{-3} , for medium current application.
- Semiconductor photocathodes for high bunch charge /high current
Cs₂Te will be back in SRF gun in 2016
GaAs (Cs,O), GaN(Cs) considered as candidates (proposed HOPE2)
Cs₂Ksb from HZB