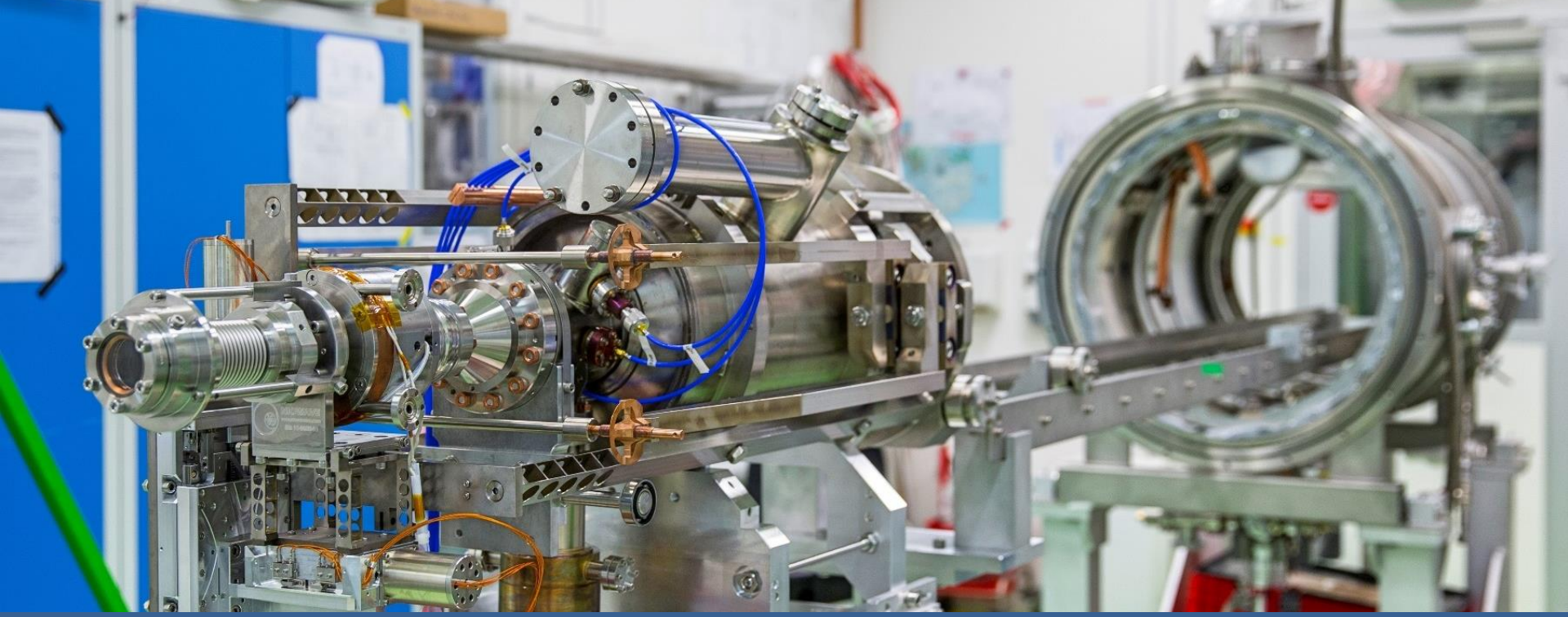


Metallic Photocathodes for Superconducting RF Photo Guns

Jochen Teichert & Rong Xiang

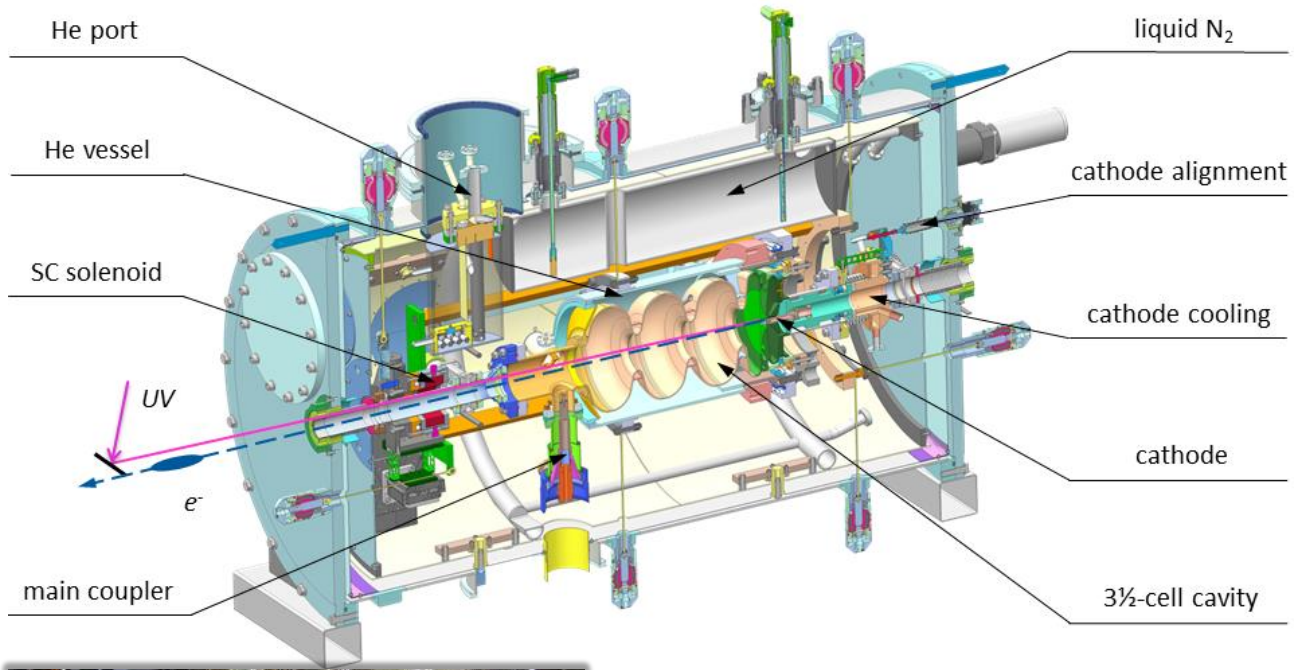
on behalf of the SRF Gun Crew at ELBE

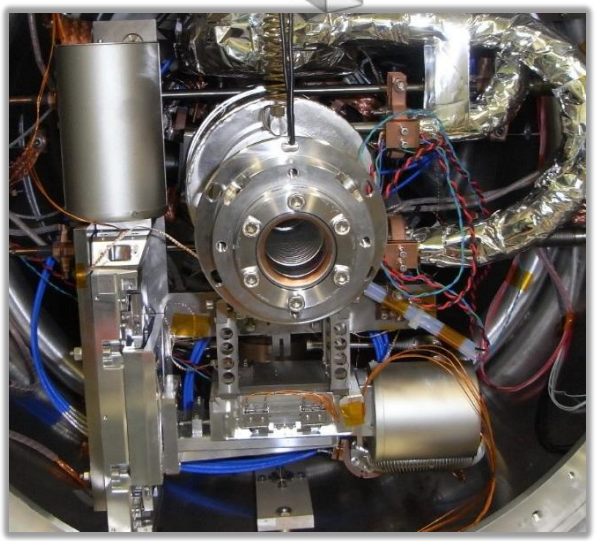
EuCARD2 WP12 Annual Review Meeting NCBJ Swierk

Outline

1. Introduction
2. Preparation, laser cleaning and application of Mg cathodes
3. Laser cleaning and long-term test of Pb/Nb cathodes
4. Summary

ELBE SRF Gun II - Cryomodule

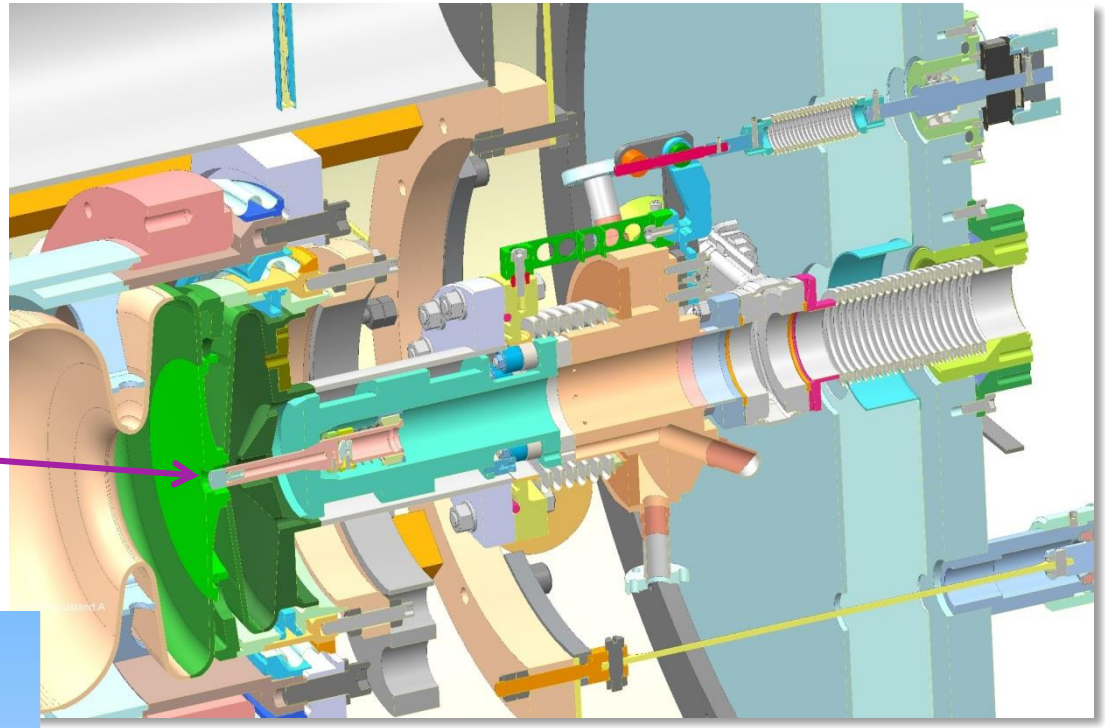


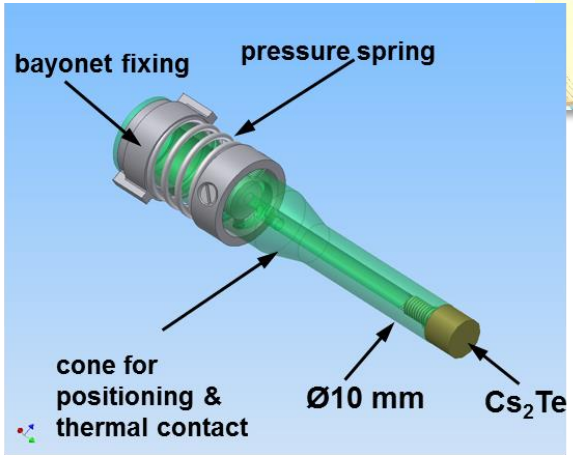


- New cavity - fine grain Nb, produced, treated, tested at JLab
- New cryomodule
  10 cm longer, fabricated and assembled at HZDR
- Integration of a superconducting solenoid

ELBE SRF Gun II – Photocathode

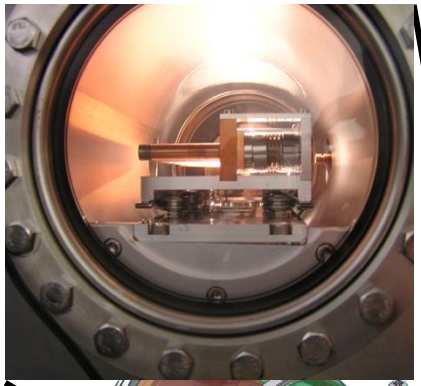
UV laser @ 258 nm
0.5 W CW
100 kHz, ≤ 5 µJ
Gaussian 12 ps FWHM



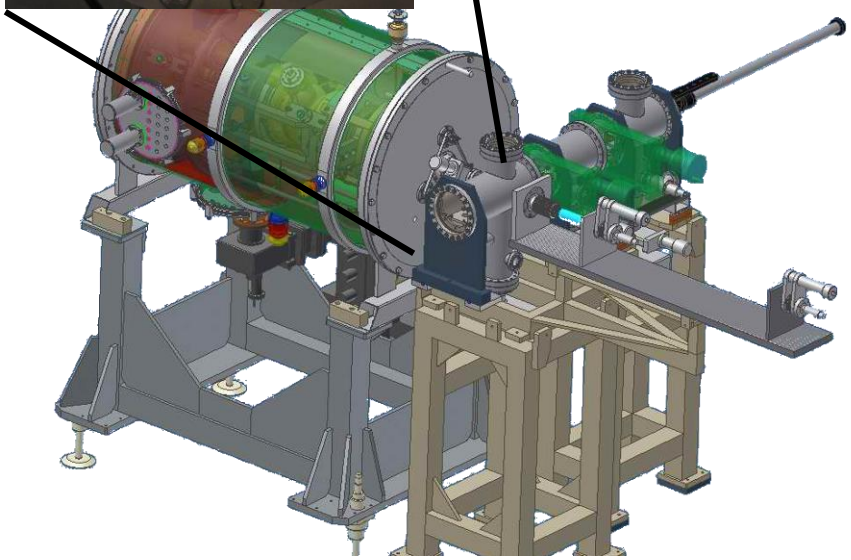


- normal conducting - low RF losses on axis
- vacuum gap - thermally and electrically isolated
- axis alignment (by hand)
- remote controlled positioning +- 0.6 mm range
- retracted RF focussing
- cathode exchange in cold gun

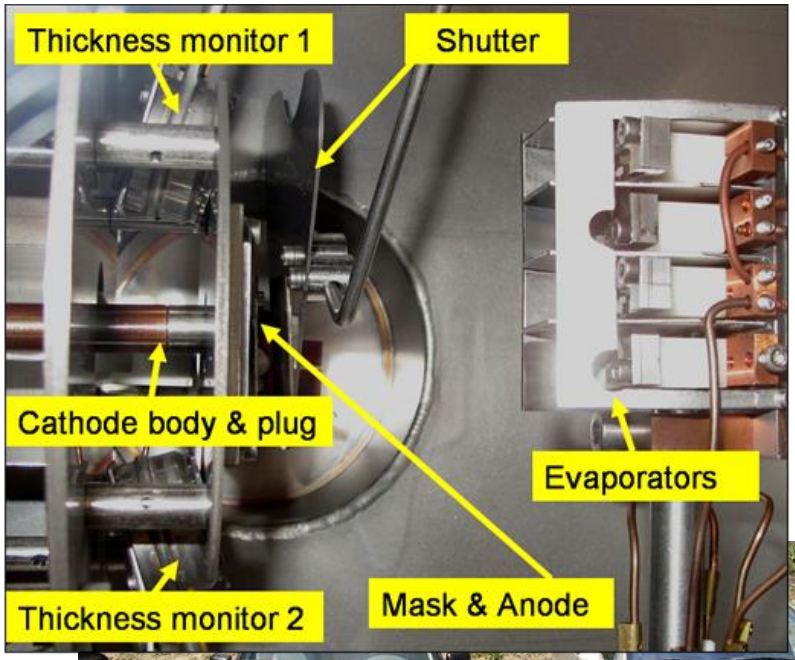
ELBE SRF Gun II – Photocathode



refurbished
cathode exchange
system of SRF Gun I

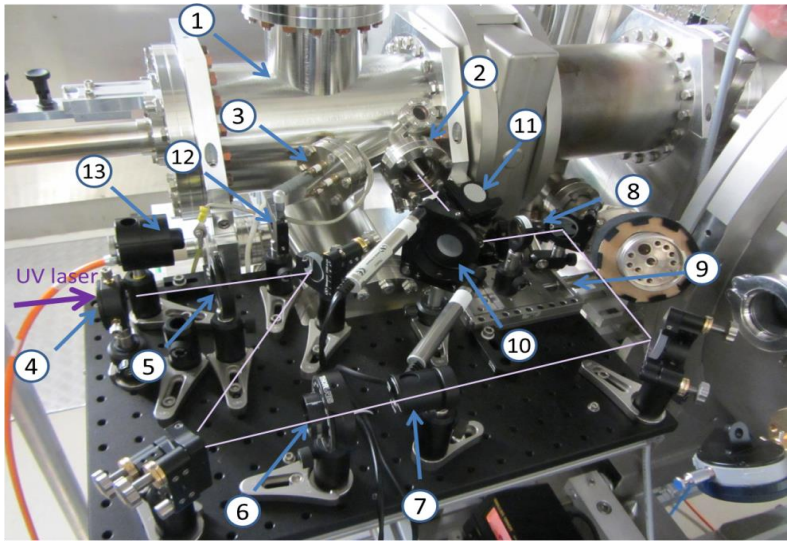


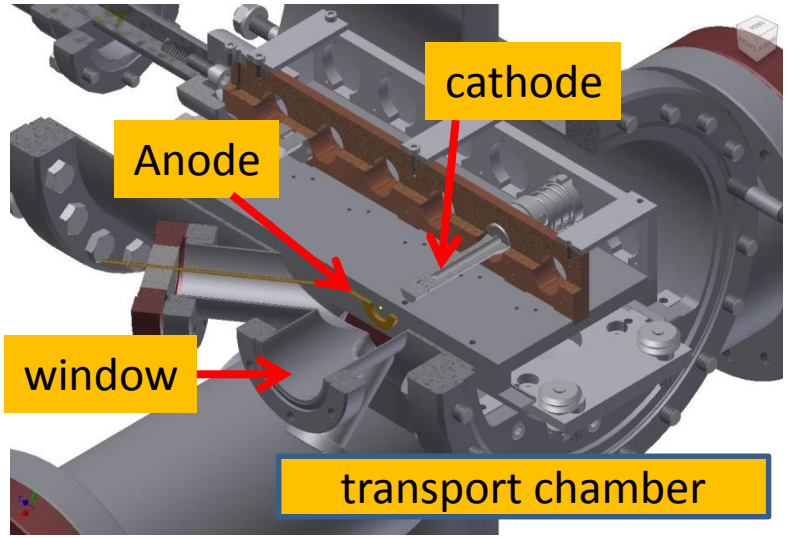
Cs_2Te preparation system



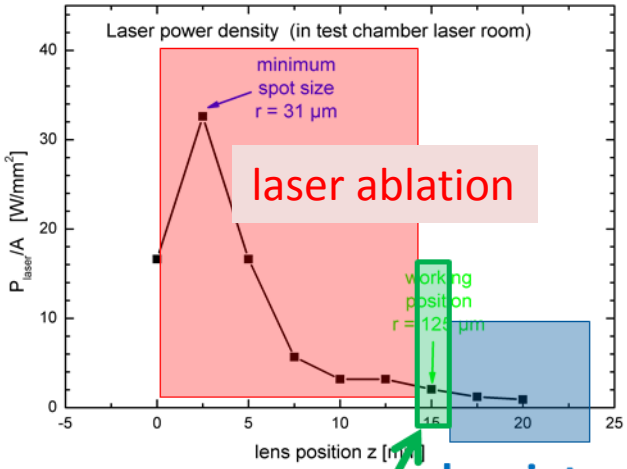
- Gun installation finished in May 2014
- Photo cathode exchange system ready in January 2015

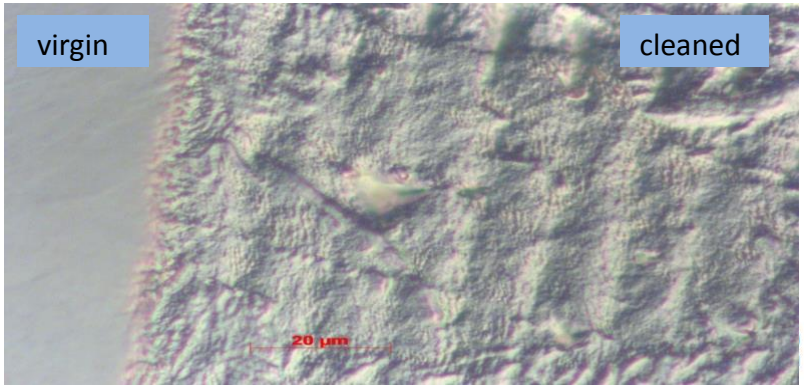
Mg Photocathodes – Laser Cleaning





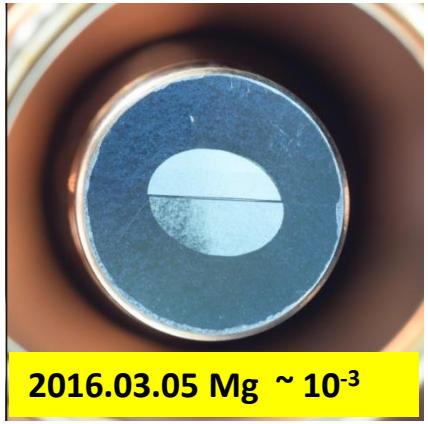
Laser cleaning set-up at transport chamber at SRF gun
using the UV drive laser (100 mW, 100 kHz CW)

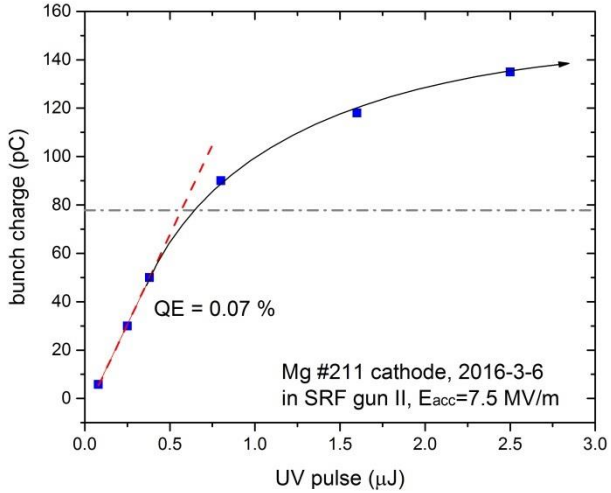


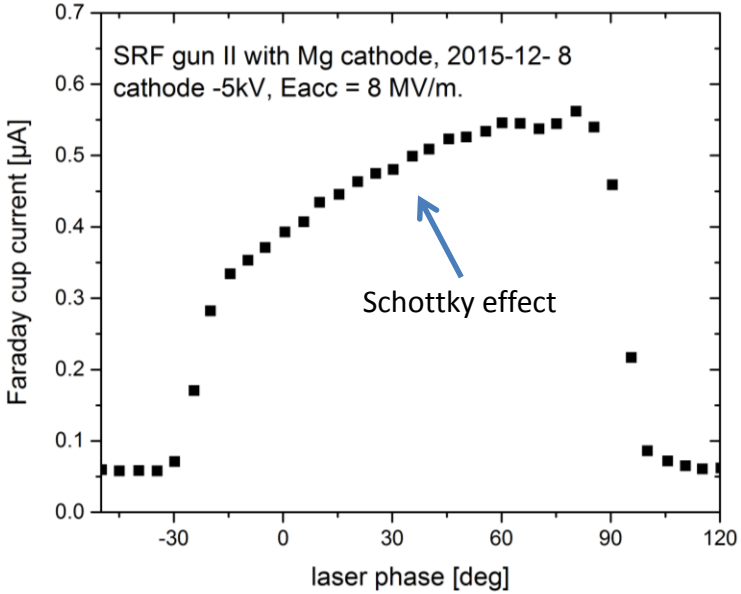


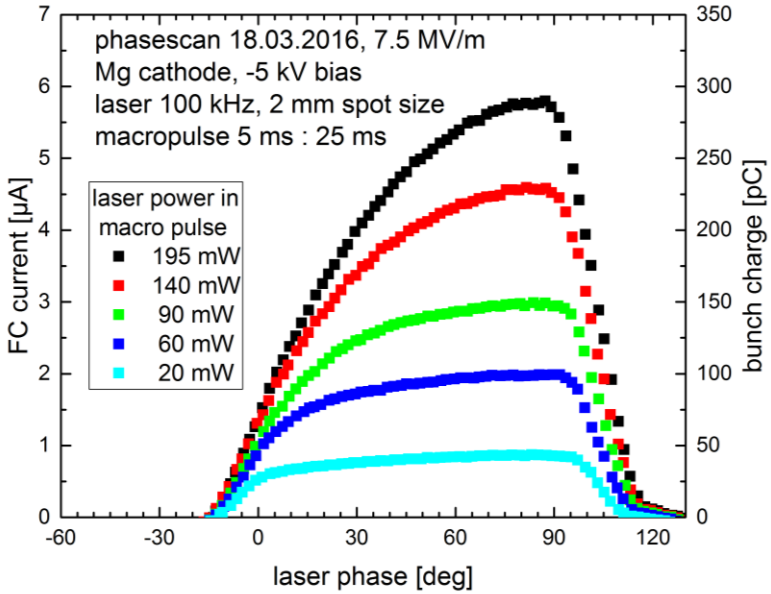
Mg photocathodes - in SRF gun II

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







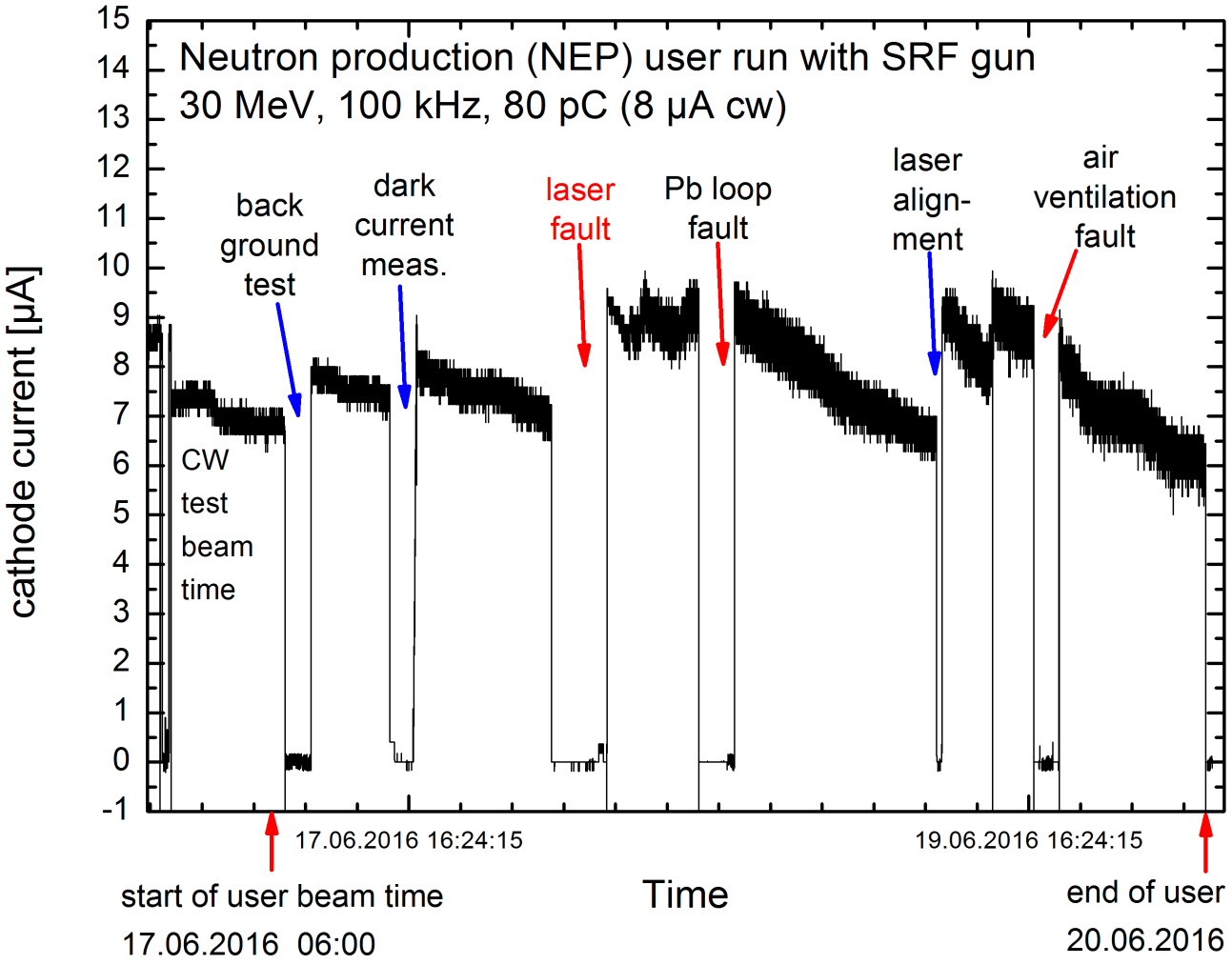


concept

HZDR

SRF gun for neutron production beam time in ELBE

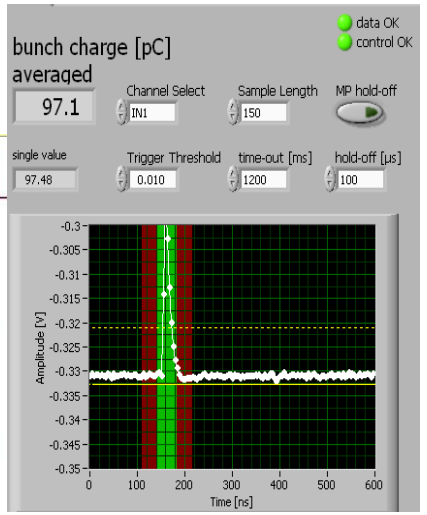
June 2016: successful 6 x 12 hours user shifts
limited by diagnose mode <10 µA for SRF gun in ELBE

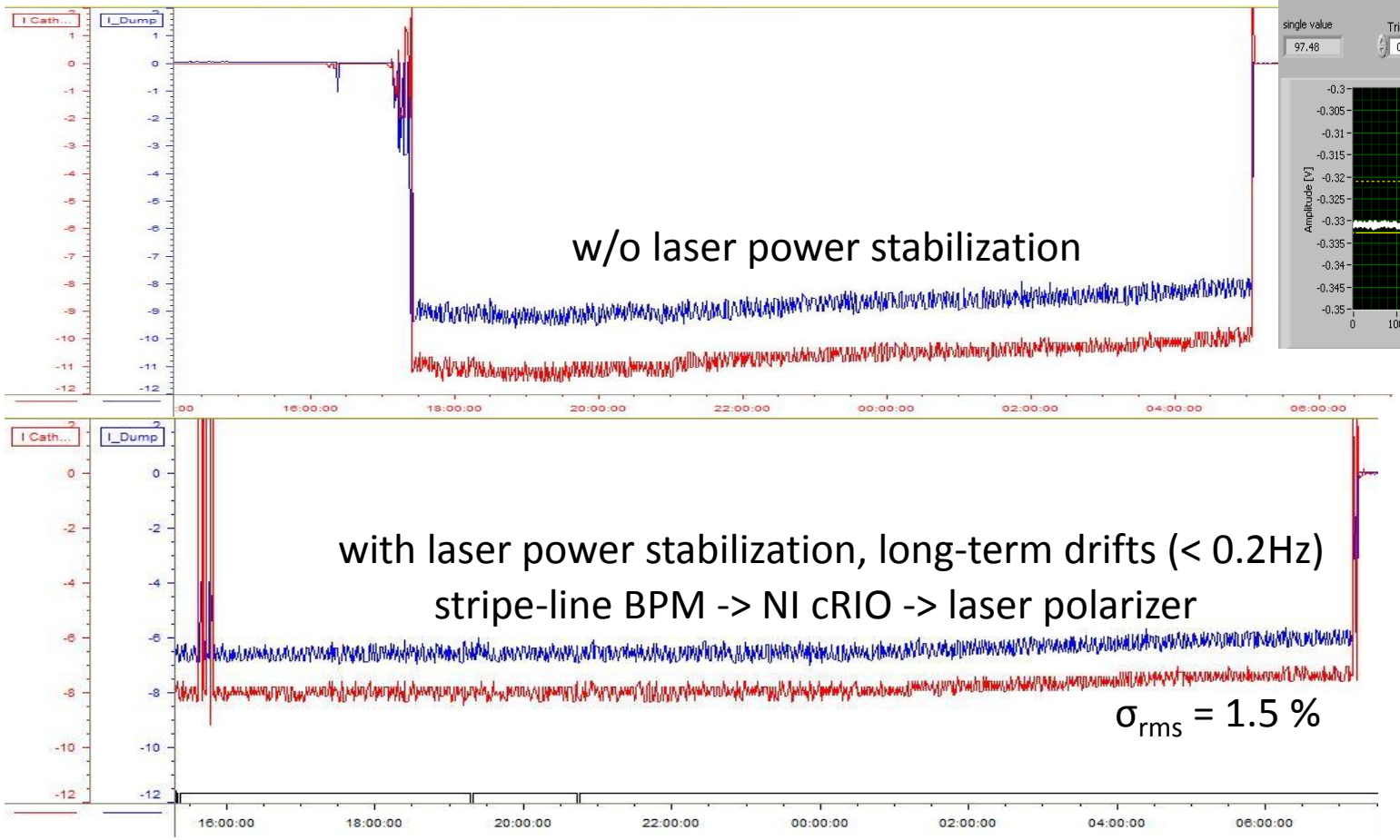


Mg photocathodes - in SRF gun II

Beam for the ELBE accelerator:
several 12h-shifts for user setting preparation, test, and measurement
with 100 kHz CW, 80 -100 pC

ICT in ELBE





w/o laser power stabilization

with laser power stabilization, long-term drifts (< 0.2Hz)
stripe-line BPM -> NI cRIO -> laser polarizer

σ_{rms} = 1.5 %

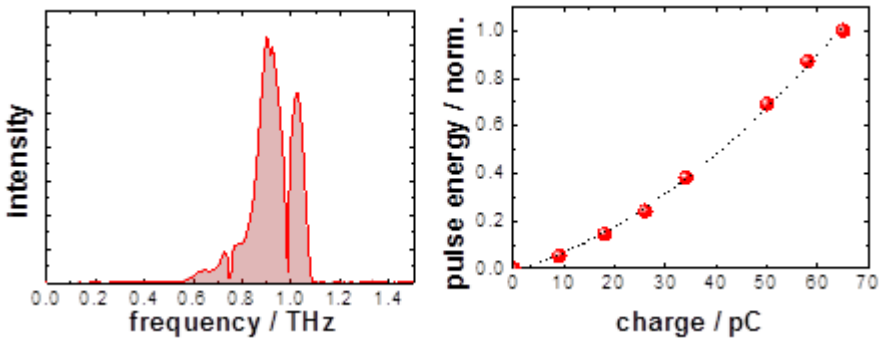
Mg cathode in gun since March 3rd, 2016, 270 h beam time, no QE decrease

4. SRF gun for THz beam time

4 x 12 h user shifts for THz radiation production

- 80 – 100 pC, E_{kin} = 4 MeV, 100 kHz
- 10 mW @ 1 THz
  32 mW@ 0.5 THz
- next: shorter bunches wanted

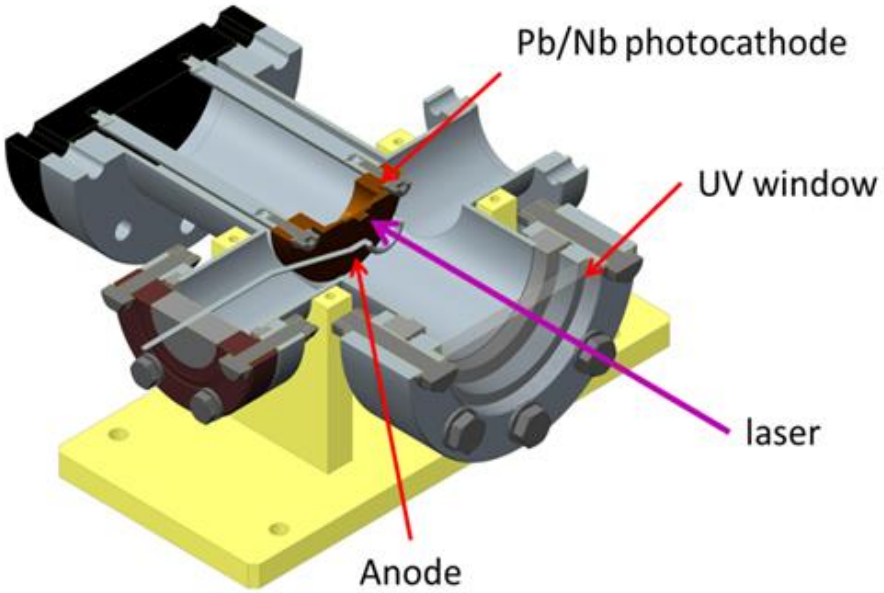
THz spectrum and charge dependence



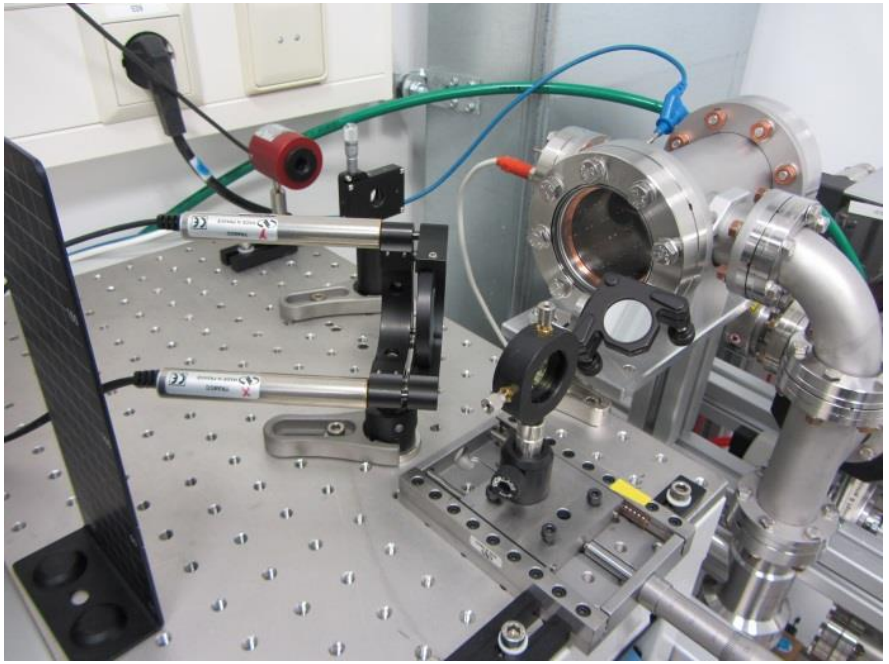
first beam 3.12.2016!

MuT /ARD Subtopics ST1 „SRF“ & ST3 „ps-fs“

Measurement of Pb/Nb photo cathodes

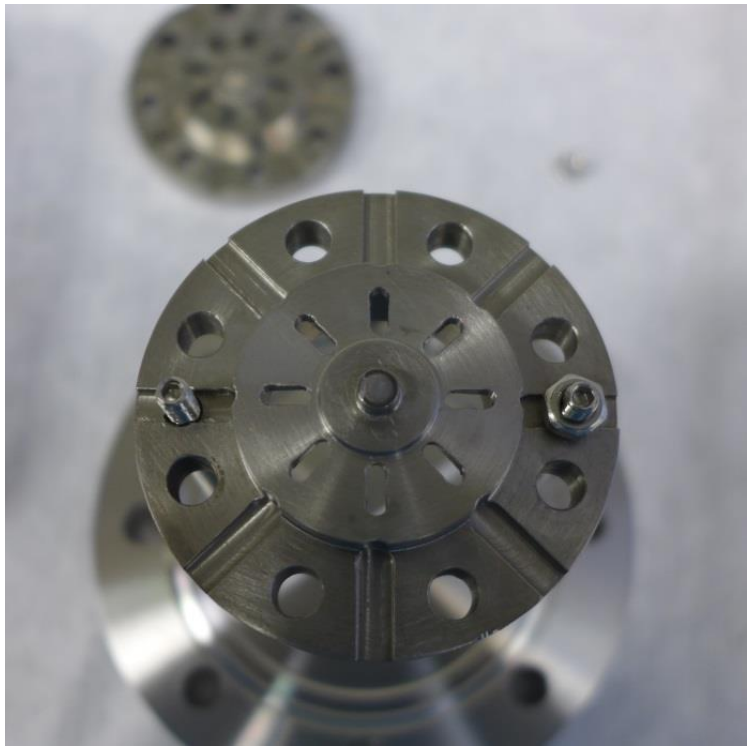


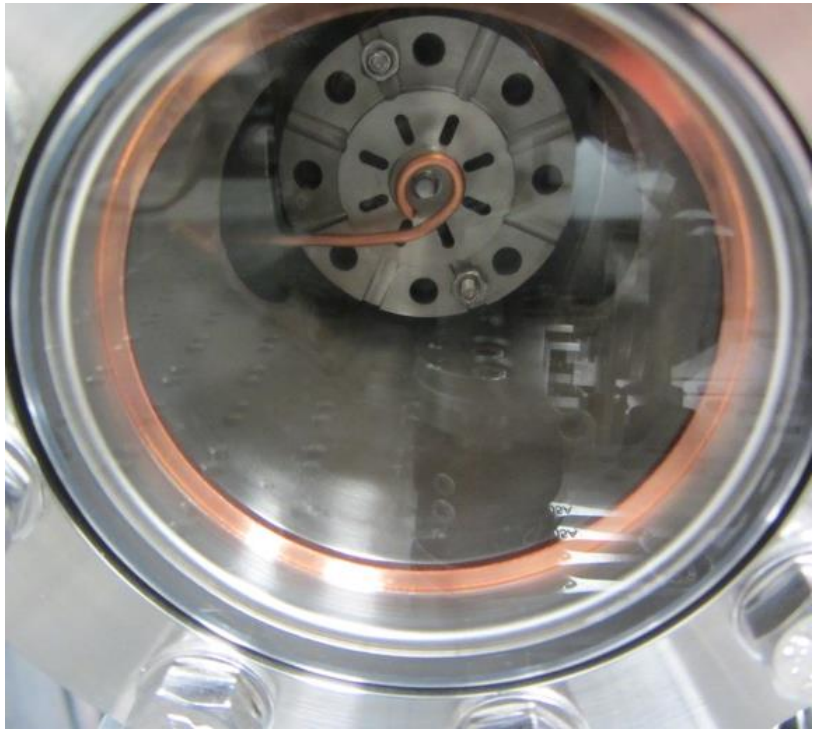
Test chamber for DESY-type cathodes



Cleaning and irradiation set-up

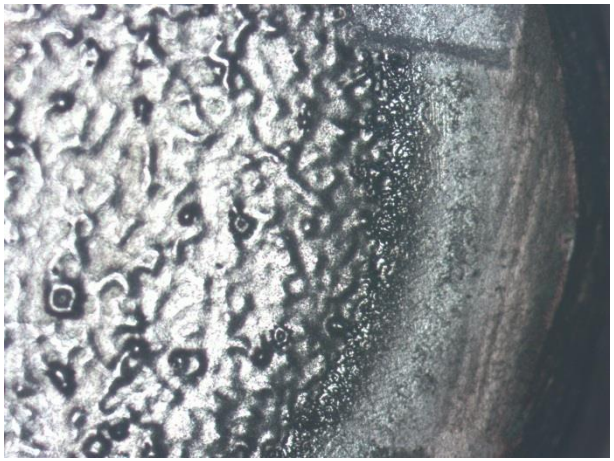
Measurement of Pb/Nb photo cathodes



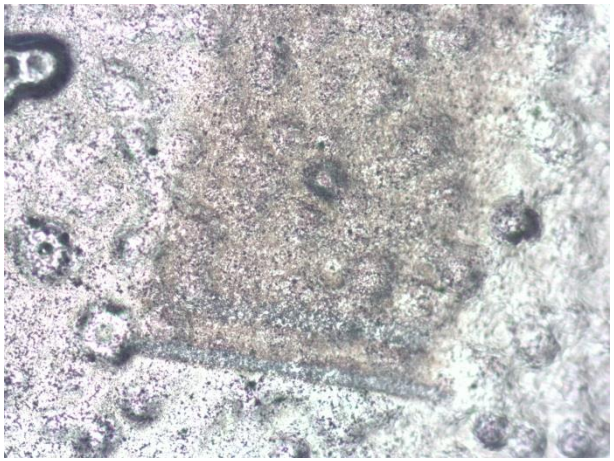


DESY Pb/Nb photo cathode deposited at NCBJ Swierk

Measurement of Pb/Nb photo cathodes



optical microscope view of depositedPb layer



laser cleaned test field

parameter	value
Power	100 mW
Pulse length	16 ps FWHM
Repetition rate	100 kHz
Pulse energy	1 µJ
Spot size (radius)	125 µm
Power density	2 W/mm^2
Pixel dwell time	100 ms
Pulse number per pixel	10 000
Pulse energy density	20 µJ/mm^2

UV laser (263 nm) parameters for Pb/Nb cathode

cleaning by scanning the focused laser spot across the cathode

Measurement of Pb/Nb photo cathodes

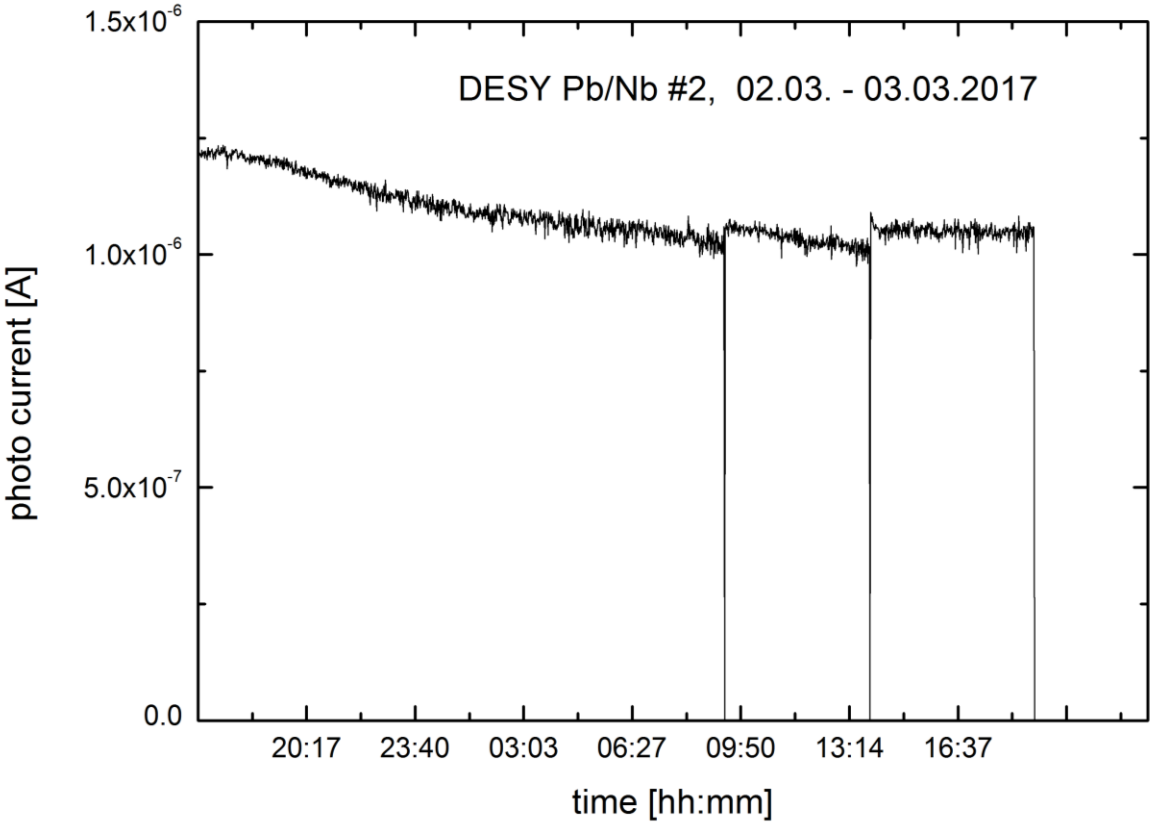
Results for quantum efficiency QE

Sample	Quantum efficiency QE @ 263 nm		References
	before cleaning	after cleaning	
J. Smedley et al. /BNL	-	3.8×10^{-4}	[5]
R. Barday et al. /HZB [1)]	3.6×10^{-5}	9.2×10^{-5}	[11]
HZDR Pb/Nb #1 [2)]	2.0×10^{-5}	1.0×10^{-4}	this report & [17]
HZDR Pb/Nb #2 [2)]	2.7×10^{-5}	6.0×10^{-5}	this report & [17]
DESY Pb/Nb #1 [3)]	-	1.8×10^{-4}	this report
DESY Pb/Nb #2 [3)]	$<1 \times 10^{-5}$	1.7×10^{-4}	this report

[5] J. Smedley, et al., Physical Review Special Topics - AB 11, 2008, 013502.
[11] R. Barday, et al., Proceedings of IPAC13, Shanghai, China, p. 279
[17] R. Xiang, et al., Proceedings of FEL2014, Basel, Switzerland, p. 836

Pb/Nb cathode operational lifetime

long-term testing of Pb/Nb photocathode in test-chamber with UV photo gun laser



laser irradiation

2016: 40 h (report)

2017: 108 h up to now

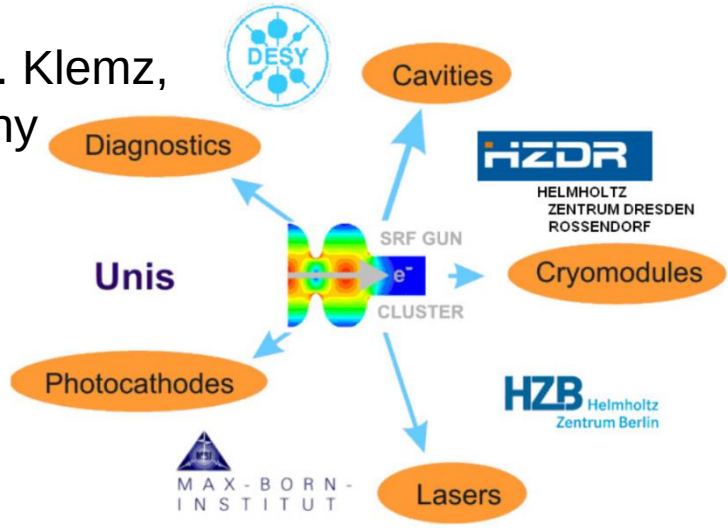
will be continued

Summary

- Normal contacting photo cathodes operate successfully in SC cavities
- Photocathode exchange and operation are a high risk for cavity contamination
  - careful quality check of cathodes
  - improved mechanics to avoid particle production
- Metallic photocathodes can easily be used in SC cavity
  - Mg can reach high QE of 10^{-3} , suitable for current application < 100 µA
  - no multipacting and low dark current (<10 nA)
  - Cs2Te + UV light is still the choice for medium currents (1 mA)
- Superconducting Pb/Nb photo cathodes
  - SC photo cathodes can be integrated in SC cavity
  - successful laser cleaning with standard UV photocathode laser
  - long-term operational life-time are ongoing

Thank you for your attention!

Thanks to the ELBE team
A. Arnold, S. Hartstock, P. Lu, P. Murcek, H. Vennekate, R. Xiang, H. Büttig, M. Freitag, M. Gensch, M. Justus, M. Kuntzsch, U. Lehnert, P. Michel, C. Schneider, G. Staats, R. Steinbrück,
and our co-workers
P. Kneisel, G. Ciovati JLAB, Newport News, USA
I. Will MBI, Berlin, Germany
T. Kamps, J. Rudolph, M. Schenck, M. Schmeißer, G. Klemz, J. Voelker, E. Panofski, J. Kühn, HZB, Berlin, Germany
J. Sekutowicz, DESY, Hamburg, Germany
K. Aulenbacher, JGU, Mainz, Germany
R. Nietubyć NCBJ, Świerk/Otwock, Poland
U. van Rienen, Uni Rostock, Germany



EuCARD² LA³NET Bundesministerium für Bildung und Forschung

We acknowledge the support of the European Community under the FP7 programme since 2009 (EuCARD, EuCARD2, LA3NET) as well as the support of the German Federal Ministry of Education and Research, grants 05 ES4BR1/8 and 05K2012.

ELBE SRF Gun II – Photo cathode history

Type	Time	QE	Q / I_{cw}	Remarks
Cu	June 14 – Feb. 15	$2x10^{-5}$	3 pC / 300 nA	Inserted during clean-room assembly of the gun
Cs_2Te	Feb. 15	2 % ↓ 0 %		strong multipacting & field emission cavity polution
Cu	Mar. 15 – Feb. 16	$2x10^{-5}$	3 pC / 300 nA	high dark current from cavity, no multipacting
Mg (#201)	Mar. 16 – Aug. 16	0.2 %	200 pC / 20 µA	no multipacting, no dark current from Mg, stable (user) operation, no QE decrease
Mg (#207)	Nov. 16 – Dec. 16	0.1 %	80 pC / 8 µA	no multipacting, no dark current from Mg, stable (user) operation, no QE decrease
Cs_2Te	Feb. 17	1.7 %	300 pC / 30 µA	no multipacting, no dark current from cathode, QE drop down
Mg (#207)	Mar. 17 – April 17	0.2 %		Not yet tested
Cs_2Te	May 17 ->			