HZB Helmholtz Zentrum Berlin
bERLinPro

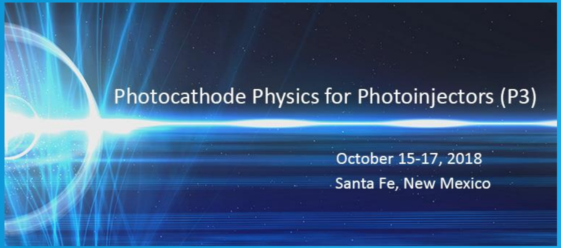
Overcoming challenges related to the operation of photocathodes in SRF photoinjectors

Julius Kühn

High Brightness Electron Beams

Institute for Accelerator Physics (FG-IA)

16.10.2018



Photocathode Laboratory

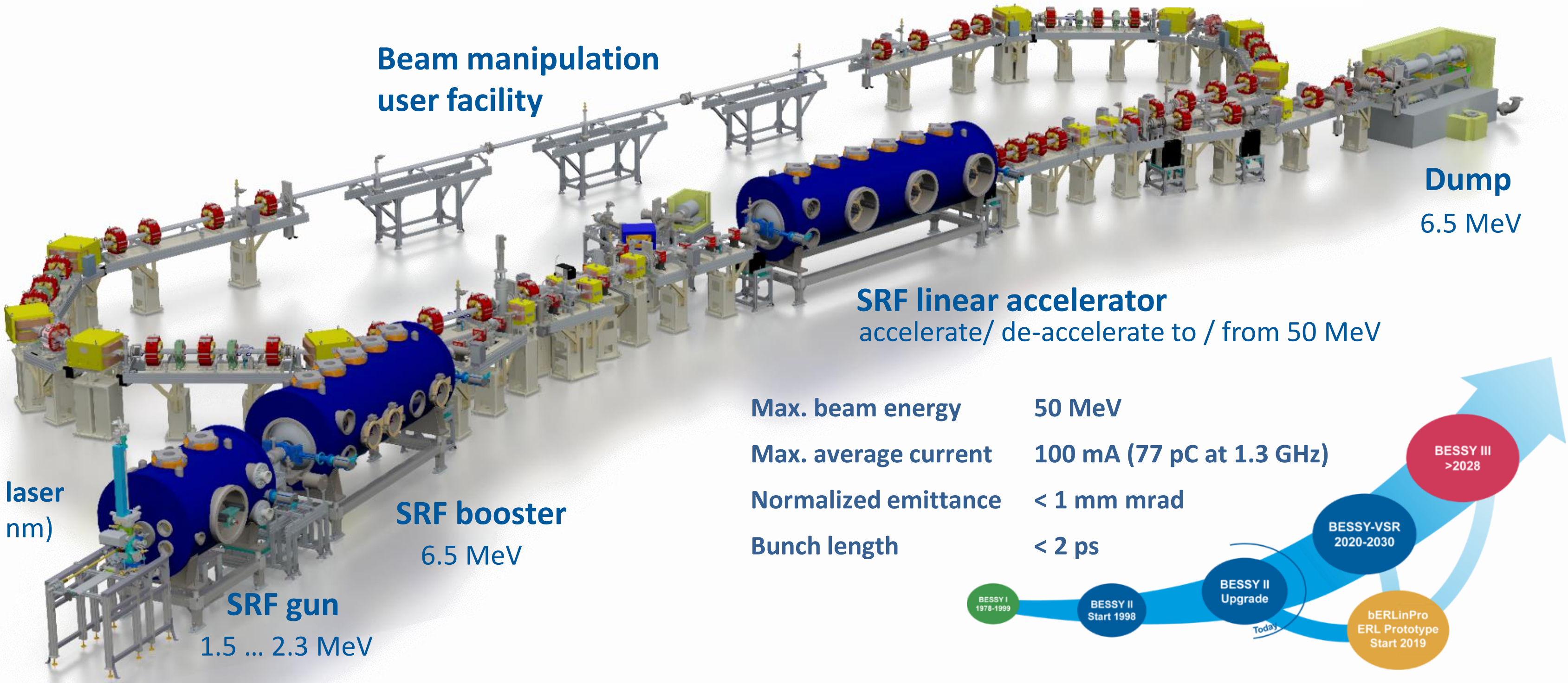
GunLab@Hobicat

Thermal Contact eXperiment

bERLinPro

HZB Helmholtz Zentrum Berlin WCRC

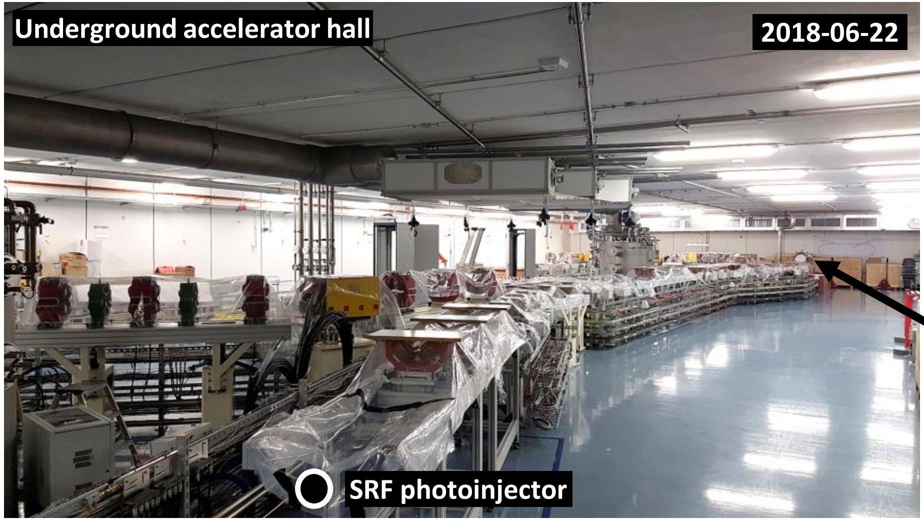
BERLIN ENERGY RECOVERY LINAC PROTOTYPE: bERLinPro



Max. beam energy	50 MeV
Max. average current	100 mA (77 pC at 1.3 GHz)
Normalized emittance	< 1 mm mrad
Bunch length	< 2 ps

- Goal: Build and operate a 100 mA, low emittance technology demonstrator
- Target parameters flexible and geared towards light source application

bERLinPro

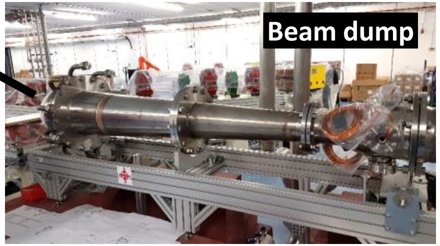


9th International Particle Accelerator Conference IPAC2018, Vancouver, BC, Canada JACoW Publishing
ISBN: 978-3-95450-184-7 doi:10.18429/JACoW-IPAC2018-THPMF034

STATUS REPORT OF THE BERLIN ENERGY RECOVERY LINAC PROJECT bERLinPro*

M. Abo-Bakr†, W. Anders, A. Büchel, K. Bürkmann-Gehrlein, A. Bundels, Y. Bergmann, P. Echevarria, A. Frahm, H.-W. Glock, F. Glöckner, F. Göbel, B. Hall, S. Heling, H.-G. Hoberg, A. Jankowiak, C. Kalus, T. Kamps, G. Klemz, J. Knobloch, J. Kolbe, G. Kourkafas, J. Kühn, B. Kuske, J. Kuszynski, A. Matveenko, M. McAteer, A. Meseck, R. Müller, A. Neumann, N. Ohm-Krafft, K. Ott, E. Panofski, L. Pichl, F. Pflocksch, J. Rahn, M. Schmeißer, O. Schüler, M. Schuster, J. Ullrich, A. Ushakov, J. Völker,
Helmholtz-Zentrum Berlin für Materialien und Energie GmbH, Berlin, Germany

Start of operation in 2019!



PHOTOCATHODE *CHALLENGES* FOR bERLinPro

I

High quantum efficiency Cs-K-Sb photocathodes

- high bunch charge and current up to 100 mA

II

Smooth substrate and photocathode

- low field emission and low emittance

III

Reproducible growth procedure & *robust* lifetime

- necessary for accelerator operation

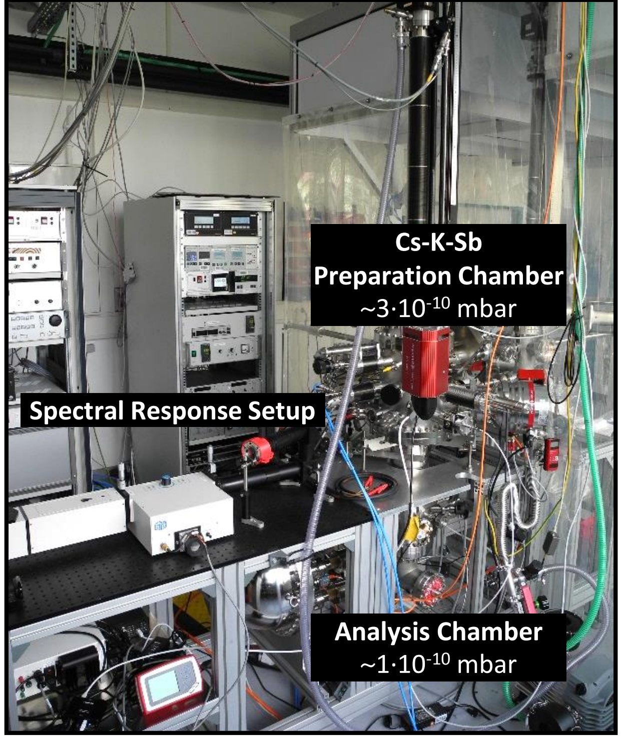
IV

Photocathode transfer into *superconducting* RF photoinjector

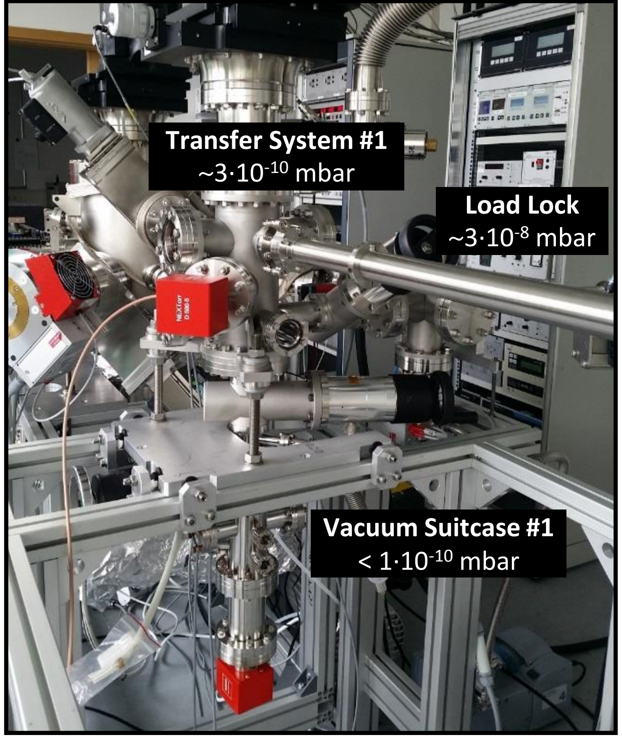
- permanent UHV conditions during Cs-K-Sb photocathode transfer
- avoiding contamination of superconducting Nb-cavity

PHOTOCATHODE INFRASTRUCTURE

Preparation & Analysis System (PAS) w/ spectral response setup



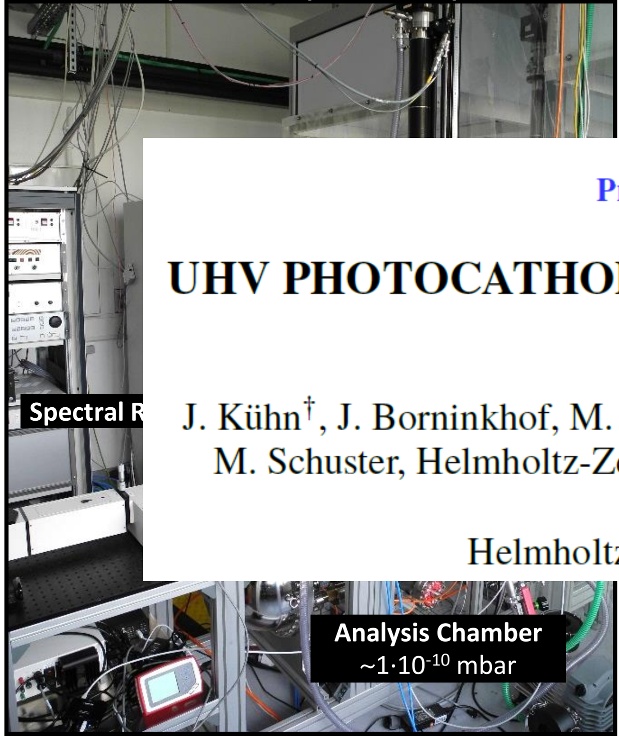
Transfer system #1 at the PAS w/ vacuum suitcase



Transfer system #2 at the SRF-photoinjector module

PHOTOCATHODE INFRASTRUCTURE

Preparation & Analysis System (PAS) w/ spectral response setup



Transfer system #1 at the PAS w/ vacuum suitcase

Transfer system #2 at the SRF-photoinjector module

Proceedings of IPAC2017, Copenhagen, Denmark TUPAB029

UHV PHOTOCATHODE PLUG TRANSFER CHAIN FOR THE bERLinPro SRF-PHOTOINJECTOR*

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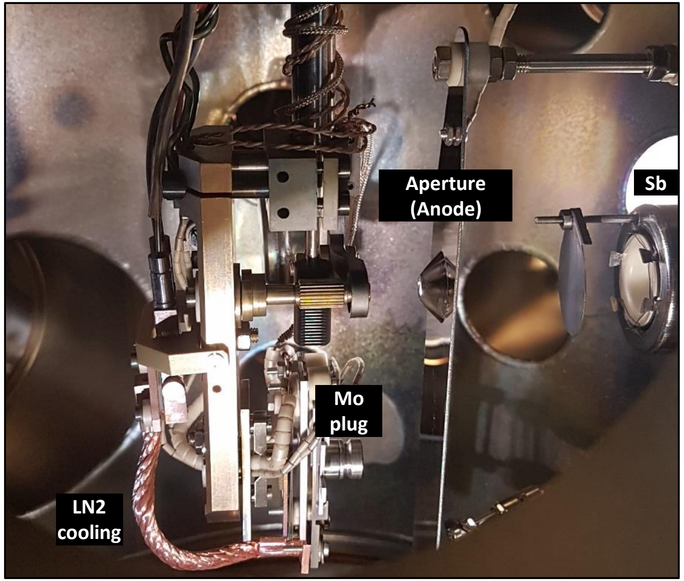
P. Murcek, J. Teichert, R. Xiang
Helmholtz-Zentrum Dresden-Rossendorf (HZDR), Germany

PHOTOCATHODE PRERARATION AND ANALAYSIS SYSTEM

Cs-K-Sb preparation chamber:



Preparation system:

- Sample heating and cooling, argon sputtering
- Aperture to cover sample and measure photocurrent
- Sb-effusion cell
- Load lock for SAES alkali metal dispensers (17 mm)

Analysis methods:

- Spectral response from 370 - 700 nm
- X-ray photoelectron spectroscopy

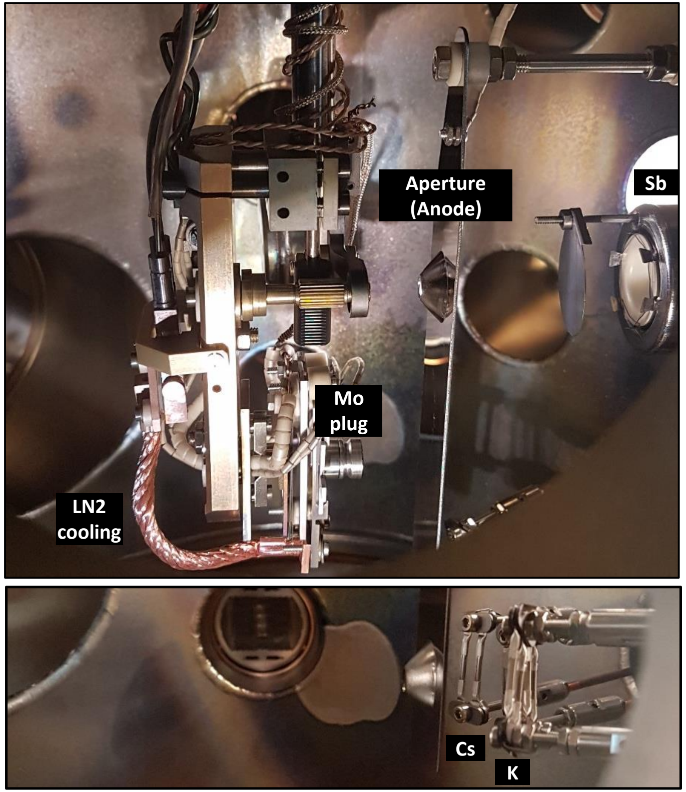
Plans for the future:

- More reliable customized manipulator
- “Momentatron 2.0“ for emittance studies
- Study of optcial properties of the photocathode

M. A. H. Schmeisser, Ph.D.-Thesis, HU Berlin, to be submitted
N. Al-Saokal, L. Bedau, Research interns, 2018.
H. Kirschner, Master-Thesis, HU Berlin, 2017.

PHOTOCATHODE PRERARATION AND ANALAYSIS SYSTEM

Cs-K-Sb preparation chamber:



Proceedings of ERL2015, Stony Brook, NY, USA THPTHL072

CsK_2Sb PHOTOCATHODE DEVELOPMENT FOR bERLinPro*

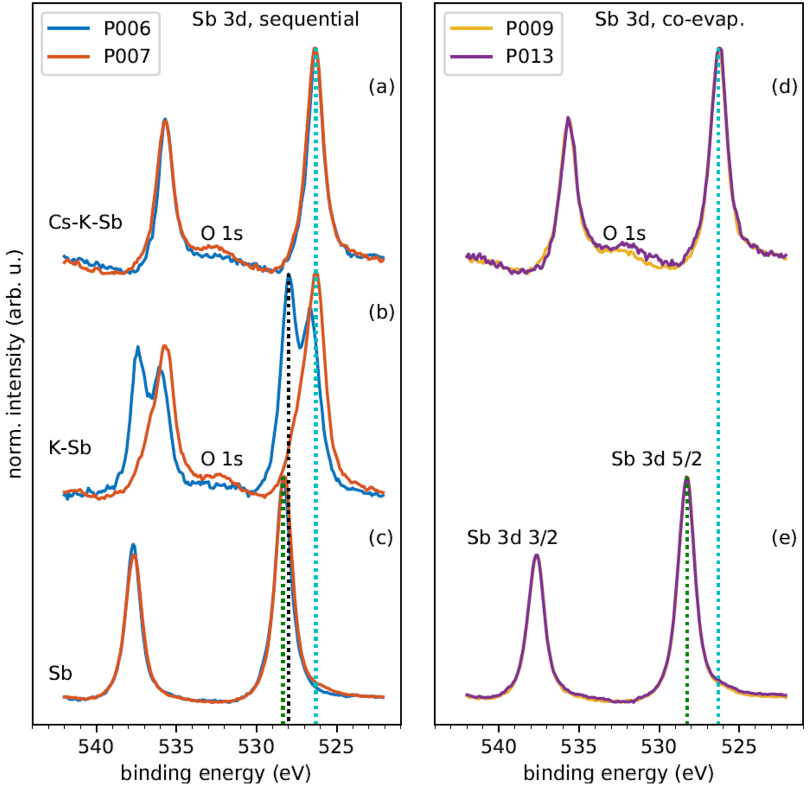
M.A.H. Schmeißer#, A. Jankowiak, T. Kamps, J. Kühn, Helmholtz-Zentrum Berlin, Germany

TUPAB028 Proceedings of IPAC2017, Copenhagen, Denmark

MEASURING THE SPECTRAL RESPONSE OF Cs-K-Sb PHOTOCATHODES FOR bERLinPro*

H. Kirschner, A. Jankowiak, T. Kamps, J. Kuehn†, M. A. H. Schmeißer
Helmholtz-Zentrum Berlin für Materialien und Energie GmbH, Berlin, Germany

DEVELOPMENT OF A HIGH QE PHOTOCATHODE GROWTH PROCEDURE



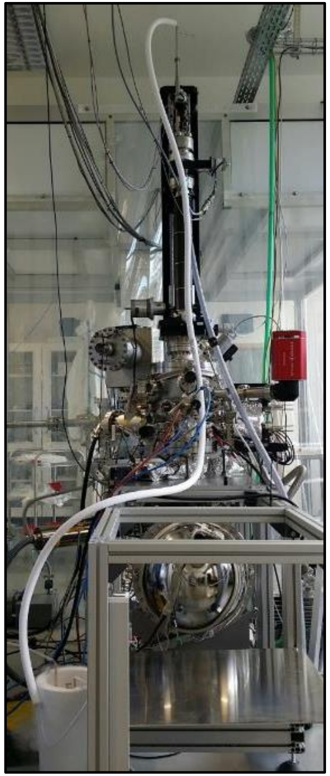
- Studied sequential growth recipe
- Developed a Cs + K co-deposition recipe
  - No complete reaction of K and Sb
  - No extra Cs deposition saves time
  - Smoother photocathodes
  - Substrate temperature critical parameter
  - Sb layer thickness influence QE and lifetime

TABLE I. Chemical composition, thickness of the initial Sb layer, and final QE of the sequentially and co-deposited samples. The QE is measured at 2.33 eV, as-prepared.

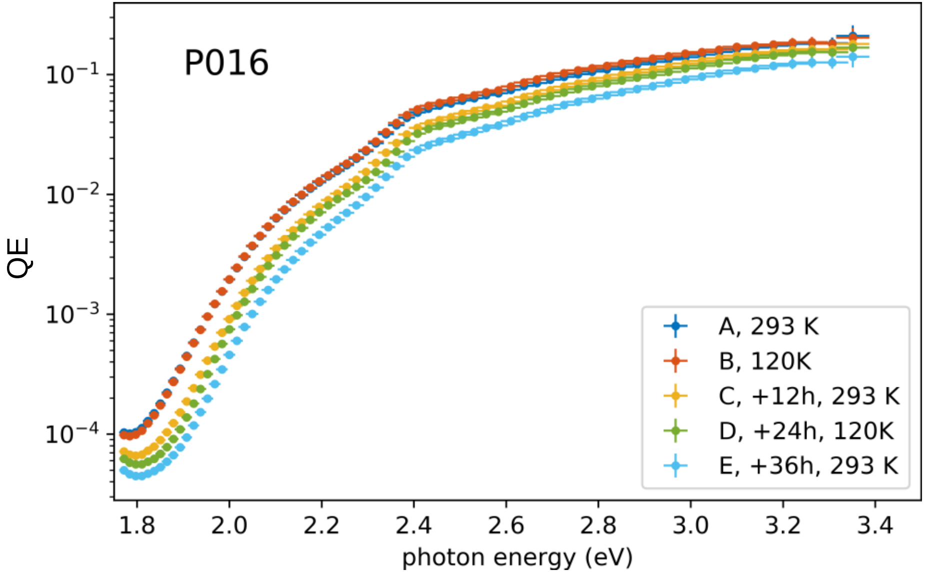
Sample		Sb layer (nm)	Sb	K	Cs	QE (%)
P006	K-Sb	10	1	2.3		
	Cs-K-Sb		1	1.8	1.4	4.8
P007	K-Sb	10	1	2.7		
	Cs-K-Sb		1	2.4	0.8	1.6
P009	Cs-K-Sb	10	1	1.9	1.4	2.6
P013	Cs-K-Sb	30	1	1.5	2.3	5.6
P014	Cs-K-Sb	30	1	0.5	1.8	7.7
P015	Cs-K-Sb	30	1	1.0	2.3	7.2

Cs_2KSb has higher QE than CsK_2Sb

PHOTOCATHODE PERFORMANCE AT LOW TEMPERATURES (LN2)

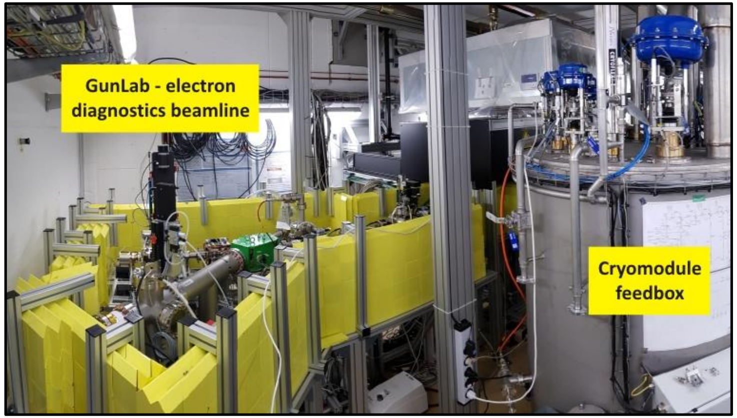


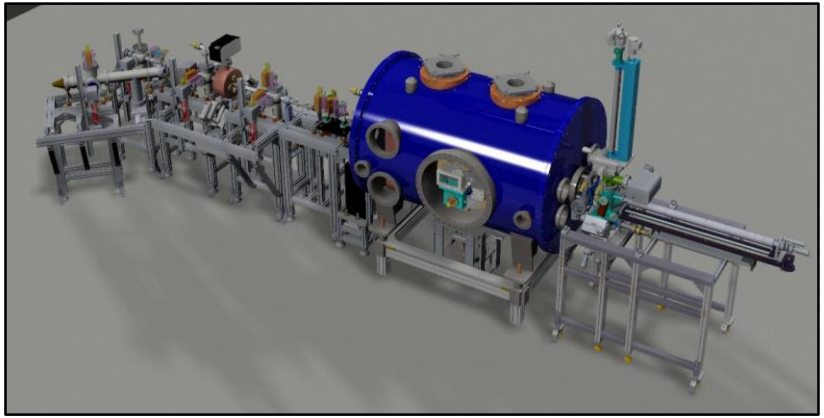
- Photocathodes operated at 80 K in the SRF Photoinjector
- Decrease of the QE at low temperatures was reported

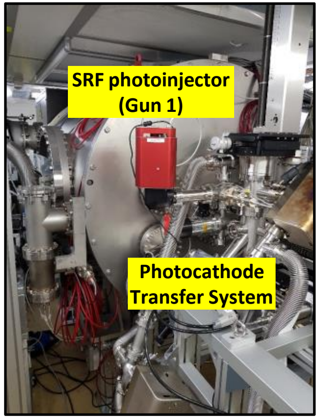


No significant change in QE observed at low temperatures under excellent vacuum conditions

THE BERLINPRO SRF PHOTOINJECTOR TEST FACILITY AT HOBICAT







+ Drive Laser System | **GunLab + SRF Photoinjector + Transfer System** | **+ Photocathode Lab**

9th International Particle Accelerator Conference IPAC2018, Vancouver, BC, Canada JACoW Publishing
ISBN: 978-3-95450-184-7 doi:10.18429/JACoW-IPAC2018-TUPML053

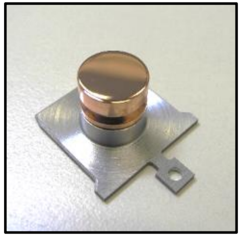
THE bERLinPro SRF PHOTOINJECTOR SYSTEM - FROM FIRST RF COMMISSIONING TO FIRST BEAM *

A. Neumann†, D. Böhlick, M. Bürger, P. Echevarria, A. Frahm, H.-W. Glock, F. Göbel,
S. Heling, K. Janke, A. Jankowiak, T. Kamps, S. Klauke, G. Klemz, J. Knobloch,
G. Kourkafas, J. Kühn, O. Kugeler, N. Leuschner, N. Ohm, E. Panofski, H. Plötz,
S. Rotterdam, H. Stein, M.A.H. Schmeißer,
M. Schuster, Y. Tamashevich, J. Ullrich, A. Ushakov, J. Völker
Helmholtz Zentrum Berlin, 12489 Berlin, Germany

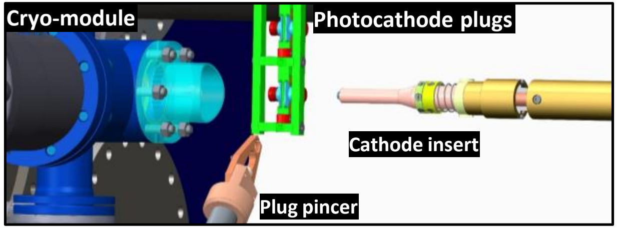
COPPER PHOTOCATHODE PREPARATION AND TRANSFER

Plug preparation → **Transfer** → **Insertion**

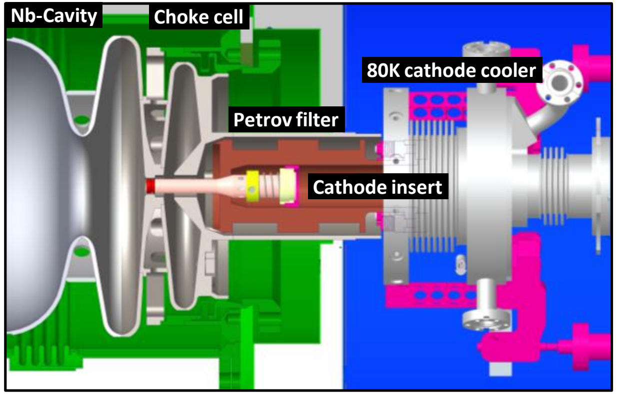
Plug selection and cleaning:



- Plug design developed in-house
- Snap-fastener mechanism on modified omicron sample holder
- Surface cleaning in UHV
- Transfer via vacuum suitcase to transfer system at the SRF photoinjector



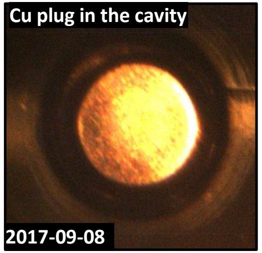
Cathode / Cavity Interface:

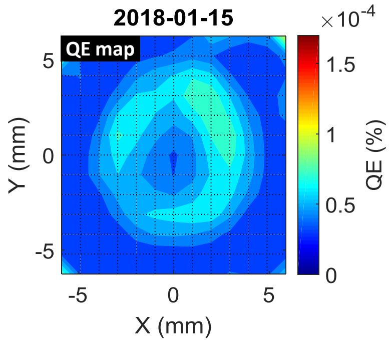


9th International Particle Accelerator Conference IPAC2018, Vancouver, BC, Canada JACoW Publishing
ISBN: 978-3-95450-184-7 doi:10.18429/JACoW-IPAC2018-TUPMF002

A Cu PHOTOCATHODE FOR THE SUPERCONDUCTING RF PHOTOINJECTOR OF bERLinPro *

J. Kuehn†, N. Al-Saokal, M. Buerger, A. Frahm, A. Jankowiak, T. Kamps, G. Klemz, G. Kourkafas, S. Mistry, A. Neumann, N. Ohm-Krafft, M. A. H. Schmeisser, M. Schuster, J. Voelker
Helmholtz-Zentrum Berlin fuer Materialien und Energie GmbH (HZB), Germany
P. Murcek, J. Teichert
Helmholtz-Zentrum Dresden-Rossendorf (HZDR), Germany



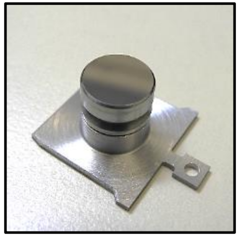


G. Kourkafas et al., *in preparation*

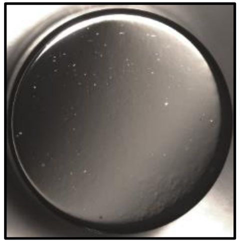
SEMICONDUCTOR PHOTOCATHODE PREPARATION AND TRANSFER

Plug preparation → Cs-K-Sb growth → Transfer → Plug exchange → Insertion

Plug selection and cleaning:



Mo Plug in UHV:

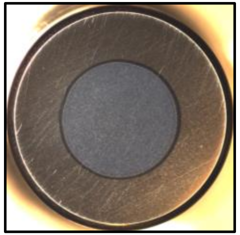


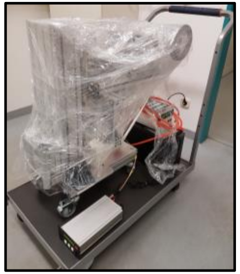
1. Sb-layer
2. Cs-K-co-deposition

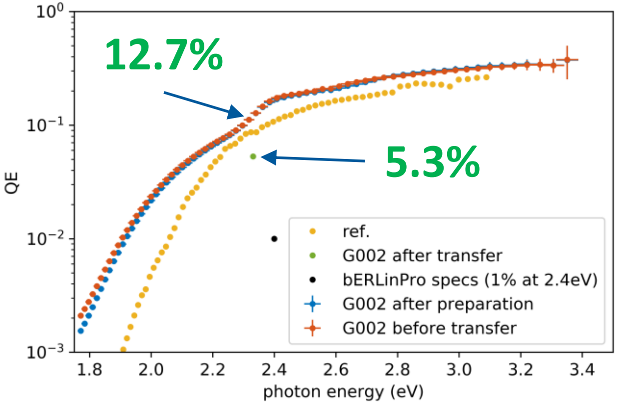
+ photocurrent
+ spectral response

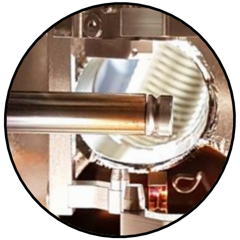
Keep in darkness!

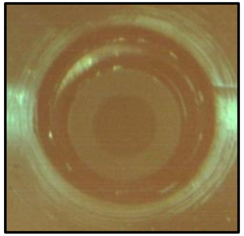
Cs-K-Sb/Mo:







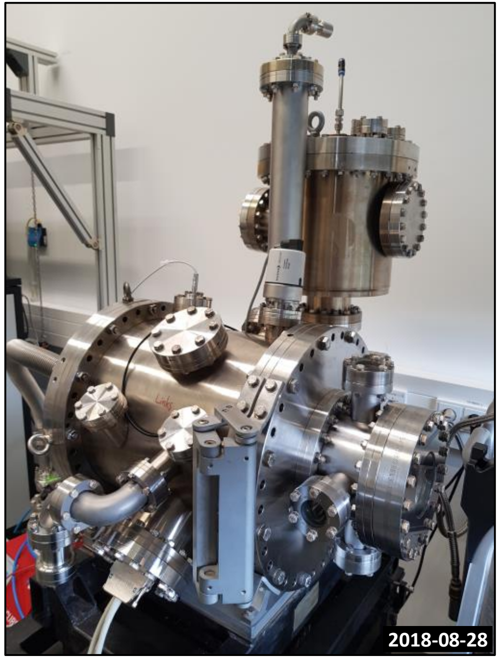


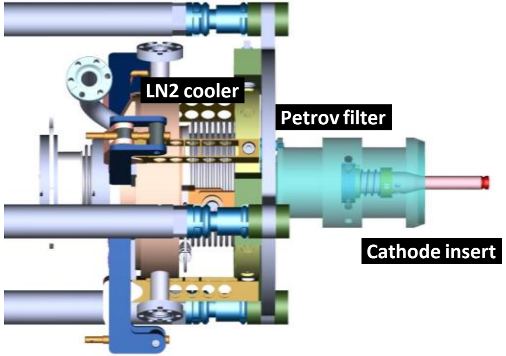


From a thin film in the lab to a functional device in the SRF photoinjector.

Operation failed due to malfunction of the cathode insert. To be continued in bERLinPro…

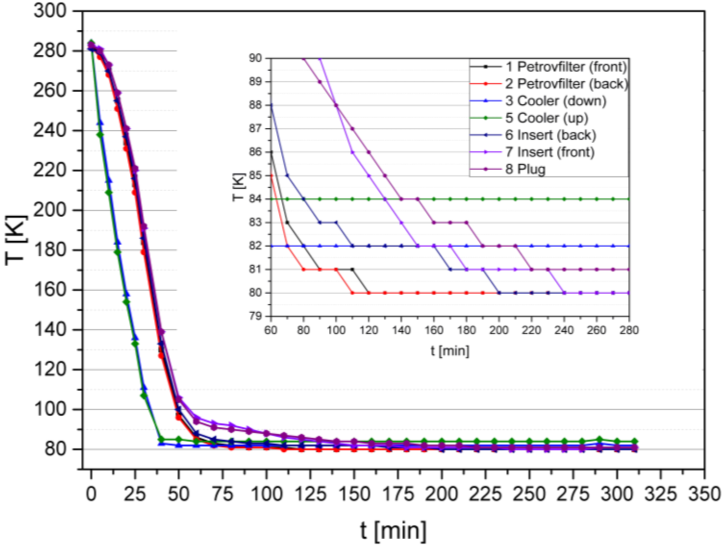
CATHODE INSERT THERMAL CONTACT TEST STAND 2.0





- UHV
- LN2 cooling
- 8 Temperature sensors
- 100 W Heater
- Control system

Cooling performance w/o heating:



N. Al-Saokal, Master-Thesis, ongoing
S. Ovsyannikov, HZB summer student program 2018

Mechanical and thermal stress tests of the cathode insert: avoid overheating in the gun!

SUMMARY AND OUTLOOK

- photocathode preparation system
- high QE photocathodes
- operation with Cu cathode (hobicat)

- photocathode production system
- increase lifetime
- operation of Cs-K-Sb photocathodes (bERLinPro)

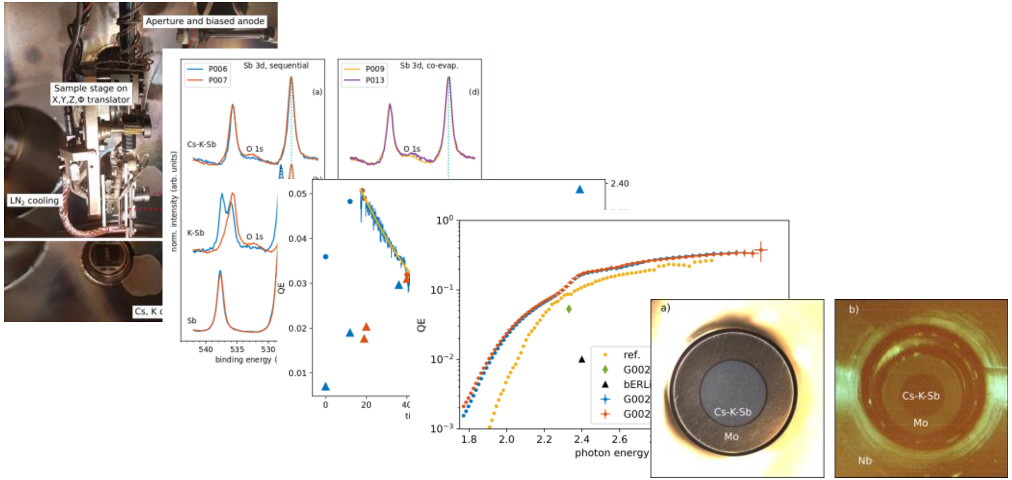
Addressing challenges related to the operation of Cs-K-Sb photocathodes in SRF photoinjectors

Martin A. H. Schmeißer, Sonal Mistry, Hans Kirschner, Susanne Schubert, Andreas Jankowiak, Thorsten Kamps, and Julius Kühn*

Helmholtz-Zentrum Berlin, Albert-Einstein Strasse 15, Berlin 12489, Germany

(Dated: July 12, 2018)

2018-10-11: re-submitted to Phys. Rev. AB



ACKNOWLEDGEMENTS

Team-Photocathode:
Martin Schmeißer (PhD-Student), Nawar Al-Saokal (Master Student),
Sonal Mistry (Postdoc), Andreas Jankowiak, Thorsten Kamps

Photocathode-Alumni:
S. Ovsyannikov (Summer student 2018), Leonard Bedau (Research intern 2018),
Hans Kirschner (Master Thesis 2017), Zihao Ding (DAAD rise professional 2015) Susanne Schubert (Postdoc 2012-2014)

High brightness electron beam group members:
Guido Klemz, Georgios Kourkafas, Jens Völker

Engineering:
Markus Bürger, Daniel Böhlick, Kerstin Martin

SRF-group:
Michael Schuster, Jan Ullrich, Henry Plötz, André Frahm, Jens Knobloch, Axel Neumann

THANK YOU FOR YOUR ATTENTION!