Overcoming challenges related to the operation of photocathodes in SRF photoinjectors

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Goal: Build and operate a 100 mA, low emittance technology demonstrator
• Target parameters flexible and geared towards light source application
STATUS REPORT OF THE BERLIN ENERGY RECOVERY LINAC PROJECT bERLinPro®


Start of operation in 2019!
PHOTOCATHODE CHALLENGES FOR ubERLinPro

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

Cs-K-Sb Preparation Chamber
~3·10⁻¹⁰ mbar

Analysis Chamber
~1·10⁻¹⁰ mbar

Spectral Response Setup

Transfer System #1
~3·10⁻¹⁰ mbar

Load Lock
~3·10⁻⁸ mbar

Vacuum Suitcase #1
< 1·10⁻¹⁰ mbar

SRF-Photoinjector

Transfer System #2
~3·10⁻¹⁰ mbar
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

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

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PHOTOCATHODE PREPARATION AND ANALYSIS 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 optical properties of the photocathode

M. A. H. Schmeisser, Ph.D.-Thesis, HU Berlin, to be submitted
PHOTOCATHODE PREPARATION AND ANALYSIS SYSTEM

Cs-K-Sb preparation chamber:
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.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Sb layer (nm)</th>
<th>Sb</th>
<th>K</th>
<th>Cs</th>
<th>QE (%)</th>
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<tbody>
<tr>
<td>P006</td>
<td>K-Sb</td>
<td>10</td>
<td>1</td>
<td>2.3</td>
<td>4.8</td>
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<tr>
<td></td>
<td>Cs-K-Sb</td>
<td></td>
<td>1</td>
<td>1.8</td>
<td>1.4</td>
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<tr>
<td>P007</td>
<td>K-Sb</td>
<td>10</td>
<td>1</td>
<td>2.7</td>
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</tr>
<tr>
<td></td>
<td>Cs-K-Sb</td>
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<tr>
<td>P009</td>
<td>Cs-K-Sb</td>
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<td>1</td>
<td>1.9</td>
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<tr>
<td>P013</td>
<td>Cs-K-Sb</td>
<td>30</td>
<td>1</td>
<td>1.5</td>
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<td>P015</td>
<td>Cs-K-Sb</td>
<td>30</td>
<td>1</td>
<td>1.0</td>
<td>2.3</td>
</tr>
</tbody>
</table>

Cs$_2$KSb has higher QE than CsK$_2$Sb
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 PHOTINOJECTOR TEST FACILITY AT HOBIGACAT

GunLab - electron diagnostics beamline

Cryomodule feedback

+ Drive Laser System

GunLab + SRF Photoinjector + Transfer System

SRF photoinjector (Gun 1)

Photocathode Transfer System

+ Photocathode Lab

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


HZB Helmholtz Zentrum Berlin, 12489 Berlin, Germany


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COPPER PHOTOCATHODE PREPARATION AND TRANSFER

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:
- Nb-Cavity
- Choke cell
- 80K cathode cooler
- Petrov filter
- Cathode insert
- Cu plug on insert
- Cu plug in the cavity

First beam

QE map

G. Kourkafas et al., in preparation
Plug preparation

Plug selection and cleaning:
1. Sb-layer
2. Cs-K-co-deposition
   + photocurrent
   + spectral response

Mo Plug in UHV:

Cs-K-Sb/Mo:

SEMICONDUCTOR PHOTOCATHODE PREPARATION AND TRANSFER

Transfer

Plug exchange

Insertion

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

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

- 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
SUMMARY AND OUTLOOK

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

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

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THANK YOU FOR YOUR ATTENTION!