Review of the Status of SRF Photo-Injectors


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Motivation

4TH GENERATION LIGHT SOURCES
• high photon brightness
• short pulses
• high coherence

Energy recovery superconducting LINACs can provide the high quality e-beams with high average current

Photo-injectors $\varepsilon_{t,n}[2 \text{ mm mrad}$ with cw – operation SRF-PI?

SOME PROJECTS:
4GLS, Daresbury, ERLSYN, Erlangen, MARS, Novosibirsk, PERL, BNL

Radiation source ELBE
Superconducting Photo-Injectors

Main Advantage:

- low RF power losses & cw operation

Problems and Open Questions:

- Cavity contamination by particles sputtered from cathode (fast Q degradation, low gradient).
- Specific geometry of the SC cavity (cathode insert). Can we reach the high gradient?
- Operation of the photo cathode itself at cryogenic temperature.
- Not possible to do the emittance compensation like in a NC RF gun.
SRF-PI: Peking Univ. DC-SC Photo-Injector

Photocathode outside the cavity

No compatibility problems
SRF-PI: Peking Univ. DC-SC Photo-Injector

1.5 cell, 1.3 GHz
Field: 15 MV/m (5 kW)
DC voltage: 70 kV
DC gap: 15 mm
Charge: 60 pC
Simulation:
Energy: 2.6 MeV
Trans. emittance: 12.5 mm mrad

DC field at cathode causes high emittance

B.C. Zhang et al., SRF Workshop 2001
SRF-PI: BNL All-Niobium SC Gun

1/2 cell, 1.3 GHz
Maximum Field: 45 MV/m

Q.E. of Niobium @ 248 nm
with laser cleaning
before: $2 \times 10^{-7}$
after: $5 \times 10^{-5}$

Thermal analysis:
maximum laser power of 1 W/cm$^2$
& low Q.E. limit current

No contamination from cathode particles

T. Srinivasan-Rao et al., PAC 2003

Radiation source ELBE
SRF-PI: Rossendorf SC ½ Cell Gun

normal-conducting cathode inside SC cavity

Cavity:
Niobium ½ cell, TESLA Geometry
1.3 GHz

Cathode:
Cs$_2$Te (262 nm, 1 W laser)
thermally insulated, LN$_2$ cooled


Radiation source ELBE
SRF-PI: Rossendorf ½ Cell SRF Gun

Cool down to 4 K and operation of the SRF gun over 7 weeks in 2002

He cryostat data

13.03.02 18:00 bis 18.03.02 18:00 (SRF-data11.dat)
SRF-PI: Rossendorf ½ Cell SC Gun

Q measured at 4 K

Radiation source ELBE
SRF-PI: Rossendorf ½ Cell SC Gun

Electron beam parameters

- SRF-Gun, 39 W, 08.+10.06.02
- emission current
- beam dump current
- energy

Radiation source ELBE
Stable operation of the SRF Gun over 7 weeks 5h/day was demonstrated.

Maximum beam energy was 900 keV, corresponds to $E_{z,\text{max}} = 22$ MV/m.

No significant change of $Q$ without and with cathode.

Proof-of-Principle Experiment

For low bunch charge the beam parameters were measured.

At 4.2 K, we did not find any changes of $Q = 2 \times 10^8$ during the whole operation.
SRF-PI: Rossendorf 3½ Cell Gun Project

Cavity design
1. 3 GHz, 10 kW
optimized half cell & 3 TESLA
$E_{z,\text{max}} = 50 \text{ MV/m (T cells)}$
$= 33 \text{ MV/m (1/2 cell)}$

<table>
<thead>
<tr>
<th>77 pC</th>
<th>1 nC</th>
</tr>
</thead>
<tbody>
<tr>
<td>$I_{av} = 1 \text{ mA}$</td>
<td></td>
</tr>
<tr>
<td>$E = 9.5 \text{ MeV}$</td>
<td></td>
</tr>
<tr>
<td>0.5 mm mrad</td>
<td>2.5 mm mrad</td>
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</tbody>
</table>

RF focusing in SC gun cavities
SRF-PI: Rossendorf 3½ Cell Gun Project

J. Stephan, D. Janssen, FZR, S. Kruchkov BINP
## Radiation source ELBE

**Summary**

### Overview of the SRF-PI Projects

<table>
<thead>
<tr>
<th>Type</th>
<th>Peking Univ.</th>
<th>BNL</th>
<th>Rossendorf</th>
</tr>
</thead>
<tbody>
<tr>
<td>DC-SC Gun</td>
<td>All Niobium</td>
<td>NC Cathode in SC Cavity</td>
<td></td>
</tr>
<tr>
<td>Cell</td>
<td>1+1/2</td>
<td>1/2</td>
<td>3+1/2</td>
</tr>
<tr>
<td>Cathode</td>
<td>Cs₂Te</td>
<td>Laser-cleaned Nb</td>
<td>Cs₂Te</td>
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<tr>
<td>Q.E. @262 nm</td>
<td>0.01</td>
<td>5x10⁻⁵</td>
<td>0.0025</td>
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<tr>
<td>Contamination</td>
<td>no</td>
<td>no</td>
<td>not found</td>
</tr>
<tr>
<td>transv. emittance</td>
<td>bad</td>
<td>good</td>
<td>good</td>
</tr>
<tr>
<td>Status</td>
<td>cool down to 4 K</td>
<td>Q measured at 4 K</td>
<td><strong>operated at 4 K</strong></td>
</tr>
</tbody>
</table>
Collaboration:
BESSY, Berlin
Max-Born-Institut, Berlin
TJNAF, Newport News
University of Peking
BINP, Novosibirsk
DESY, Hamburg
ACCEL, Bergisch Gladbach
Technische Universität, Dresden

The ELBE crew
(visiting the cool-down of the ELBE river source,
Spindleruv Mlyn, Czech Republic, April 2003)