



# SRF GUN CHARACTERIZATION - PHASE SPACE AND DARK CURRENT MEASUREMENTS AT ELBE

## **Motivation**

RF photoelectron sources with superconducting cavities provide the potential to generate high quality, high brightness electron beams for future accelerator applications. Helmholtz-Zentrum Dresden-Rossendorf provides a test stand for SRF gun technology. The SRF Gun can also be used as an electron source for the two-stage super-

## Longitudinal Phase Space



#### Phase scan technique

- Bunch of finite length receives energy chirp in RF cavity module
- Passing a dipole the energy spectrum is projected in the transverse plane

conducting linear accelerator ELBE.

Future applications, such as driving X-Ray FEL facilities, require a good understanding of the longitudinal phase space distribution of the photoelectron source. Furthermore, in order to provide a stable, high quality electron beam sources of dark current as well as unwanted beam transport from the SRF gun to the linear accelerator must be investigated.



- Measuring the rms energy spread for different RF phases of linac cavity
- Fitting the measured rms energy spread for several linac phases with parabola function

Longitudinal Parameters at cavity entrance



6,0E-6 -



Field	E <sub>acc</sub>	7 MV/m
Beam energy	E <sub>kin</sub>	3.6 MeV

Longitudinal phase space of the SRF Gun II

#### **Diagnostic beamline with 180° dipole**

Measurement for two different laser phases 49.4° and 56.6°

 $\rightarrow$  Beam **Energy**: E<sub>kin</sub> = 3.59 Mev

→ Energy Spread:  $\sigma_E (49.4^\circ) = 23.04 \pm 0.96 \text{ keV}$  $\sigma_E (56.6^\circ) = 13.44 \pm 0.96 \text{ keV}$ 





- Correlated energy spread represents the two energy spread minima from SRF gun at low laser phase and 57°
- Vertex shift at both minima is zero
- Vertex shift correlation with the gun laser phase
- Uncorrelated energy spread nearly constant at 8 keV dominated by thermal and RF contributions
- Bunch length shorter than laser pulse length of 6 ps due to RF compression
- Bunch length and long. emittance grow linearly with laser phase and therefore with bunch charge



0.2

 $sin(\phi)$ 

0.4

 Dark Current and Energy Acceptance of the Dogleg

 1,256

 1,256

1.00E6



#### Dark current

Laserphase [deg]

#### Schottky Scan

Measurement for two different DC bias voltages 0 kV and - 5 kV at photocathode

- $\rightarrow$  Dark current offset: 20 nA
- $\rightarrow$  Whole bunch accelerated at 10°
- $\rightarrow$  Further increase of the beam current due to Schottky effect
- $\rightarrow$  Extract emission time from the slope:
  - Assume a Gaussian longitudinal bunch distribution
  - Fit the slope with a Gauss error function  $F(x) = \frac{1}{2}(1 + \operatorname{erf}(\frac{x \mu}{\sqrt{2\sigma^2}}))$

**Emission time**  $\sigma_t = 10.7 \pm 2.6 \text{ ps}$ 

 $\leftrightarrow$  Laser pulse length 6 ps

Overestimated due to rising Schottky effect, beam dynamics, fit quality and accuracy of the displayed laser phase  $(\pm 0.5^{\circ})$ 



- Dark current: 18±2 nA (Faraday-Cup)
- One significant dark current peak at 2.3 MeV
  - $\rightarrow$  Field emission at the cavity walls



- Unwanted beam transport to ELBE determined by energy acceptance of the dogleg
- Measurement: Variation of gun gradient between
   6.8 MV/m and 7.5 MV/m (i.e. energy [3.2 MeV, 3.6 MeV])

Dark current peak at 2.3 MeV does not match the energy acceptance of the dogleg

J. Teichert et al., "Commissioning of an Improved Superconducting RF Photoinjector at ELBE", THP061, Proceedings of FEL'14, Basel, Switzerland (2014)\_J. Teichert et al., "Evaluation of Critical R&D Issues of SRF Guns", EuCARD SRF Review 2011\_T. Kamps et al., Rev. Sci. Instrum., 79 (2008) p. 093301\_J. Rudolph, "Bunch Length Measurements and Status of the Slice Diagnostics System for ELBE/SCRF Gun", EuCARD SRF Review 2010\_D.H.. Dowell et al., Nucl. Instr. and Meth. A 507 (2003) 331\_S. Kashiwagi et al., "Photo-electron beam longitudinal phase space tomography studies at the ATF", Proceedings of LINAC'00, Monterey, California (2000)

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