

## STATUS OF 3½ CELL SUPERCONDUCTING RF GUN PROJECT IN ROSSENDORF

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### Abstract

In the paper, we report on the status and progress of the superconducting RF gun project in Rossendorf. The gun is designed for cw operation mode with 1 mA current and 9.5 MeV electron energy, and it will be installed at the ELBE superconducting electron linear accelerator. The gun will have a 3½ cell niobium cavity operating at 1.3 GHz. The cavity consists of three cells with TESLA geometry and a specially designed half-cell in which the photocathode will be placed. The production of two Nb cavities, with RRR 300 and 40 respectively, has been finished at the beginning of 2005. After delivery, the RF tests will be performed and the preparation of the cavities will be started. At the same time, the design of the cryostat and the fabrication of its components are already finished. Further activities are the design of the diagnostic beam line, the testing of the new photocathode preparation system, and the upgrade of the 262 nm driver laser system.

### INTRODUCTION

In the research center of Rossendorf (FZR) a superconducting RF photo-injector (SRF gun) is under development. This gun allows continuous wave operation with energy of 9.5 MeV and average current of 1 mA. The goals of this project are to build a new

electron source with high average current and low emittance for the ELBE superconducting linear accelerator and to demonstrate the capability for the future applications in FEL light sources and energy recovery linacs. This new gun can generate short pulses and high-brightness electron beams, as known from the conventional photo-injectors. Moreover, the use of the superconducting cavity allows the cw-mode operation and thus high average currents. In the proof-of-principle experiment, the operation of such a photo-injector with a half-cell cavity was successfully demonstrated [1]. During about 200 hours of operation, no phenomenon of quality factor depression was observed.

### SRF GUN PARAMETERS

The SRF gun was mainly designed as the source for the ELBE superconducting linac, which runs in continuous wave operation with the pulse repetition rate of 13 MHz and the bunch charge of 77 pC. A 10 kW klystron, the RF low-level control and power couplers will be adopted for this new SRF gun. By using the full RF-power capacity a beam energy of 9.5 MeV is intended. These values determine the basic parameters of the SRF gun as presented in Tab. 1. Besides this ELBE operation mode, the gun will be

Table 1: Parameters of SRF gun in different modes.

Parameter	ELBE mode	High charge mode	BESSY-FEL mode
RF frequency	1.3 GHz		
nominal beam energy	9.5 MeV		
operation mode	CW		
driver laser wavelength	262 nm		
photocathode	Cs <sub>2</sub> Te		
quantum efficiency	≥1 %		≥2.5 %
average current	1 mA		2.5 μA
laser pulse length	5 ps	20 ps	~30 ps
repetition rate	13 MHz	1 MHz	1 kHz
bunch charge	77 pC	1 nC	2.5 nC
transverse emittance	1 μm	2.5 μm	~3 μm

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operated with high bunch charges mode and BESSY-FEL mode. The high bunch charges mode will produce the beams with such a high bunch charge as 1 nC charge, which will be a great challenge for photocathodes and the transverse emittance of beam. The beam parameter measurements and the long term behavior are important for the future use of the high charge mode. The BESSY-FEL mode is a new plan. Rossendorf and BESSY are cooperating to develop the high peak current injector, which will be a brand new trial for SRF gun. Now the simulation and design are on going [2].

### 3.5 CELL CAVITY

The main part of the current SRF gun is the 3.5 cell TESLA type superconducting cavity instead of the previous half-cell SRF gun in 2002 [1]. The back wall of the half-cell has a slightly conical shape and a centered hole for the photocathode. The photocathode itself is normal conducting and cooled with liquid nitrogen. A circular vacuum gap ensures thermal insulation between the cavity and the photocathode. Therefore the heat loaded in the cathode does not burden the helium bath. On the other hand, to prevent RF power loss caused by this coaxial line geometry, an additional superconducting niobium choke filter attached to the coaxial line has been designed.

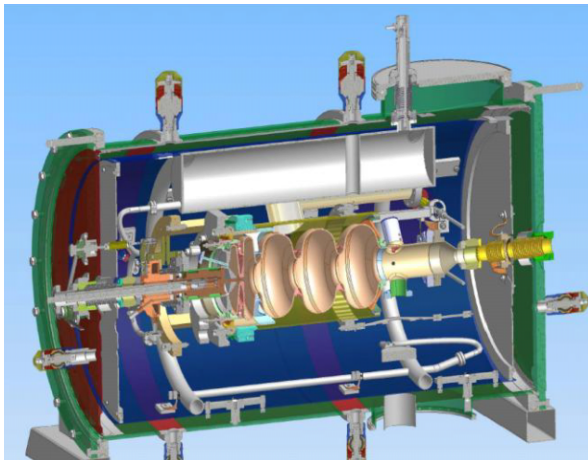


Figure 1: 3-D view of the cavity design with cryomodule, cathode cooler, photocathode, and transfer rod.

The three full cells have TESLA shapes [3] with exception of the cell adjacent to the special half-cell, where the left cup has been shortened in order to obtain a better phase match of the electron bunch. In the cavity optimization, the main considerations were, that the electric and magnetic surface field strengths in the gun half-cell do not exceed the corresponding values in the TESLA cell and that the electric field in front of the cathode has its maximum at the launching phase. In the Reference 4 and 5 the design and the corresponding parameters of cavity have been detailed presented.

The cavity has the RF power coupler, two higher-order mode couplers, and a pick-up adopted from the

TESLA cavity [3] and one extra pick-up especially for the cathode half-cell (fig 2).



Figure 2: Two 3.5 cell cavities with the RF choke, the pick-up, the power couplers and the HOM coupler.

The production of two Nb cavities (RRR 300 and 40 respectively) has been already finished and shipped back to Rossendorf in March 2005. The RF tests and the warm tuning are now under way, and the preparation of the cavities and the cold tuning will then be performed at DESY. At the same time, the design and the fabrication of the cryostat and its components have been finished.

### PHOTOCATHODE

Among the known cathode materials, cesium telluride is the best candidate for SRF gun because of its relatively high efficiency and long life time as well.  $\text{Cs}_2\text{Te}$  requires an UV driver laser system with 262 nm wave length. For the purpose of 1mA average current, the cw-mode laser power will be about 1 W, and the cathode's QE is required at least 1%. The  $\text{Cs}_2\text{Te}$  photolayers will be produced in a separate preparation chamber and then transferred to the SRF gun in an UHV storage chamber. Fig. 3 presents the photocathode designed for installation and transportation. The stem has a diameter of 10 mm, and the total length of the cathode is 130 mm. The stem and conical part of the cathode are made of Cu. It is possible to exchange the head of the stem part and to test different substrata material.

The assembling and test of the main preparation chamber are going on, and its control system is still in building. Before the end of 2005, the preparation system will finish the first test. The new system has two pairs of evaporators and they can be changed without the breaking of main vacuum. Two quartz oscillators are used to measure the deposition rate of the two sources separately, and the rate resolution is 0.1 angstrom per second. There exists the system of a scan laser and a fine mesh anode to inspect the uniformity of the  $\text{Cs}_2\text{Te}$  layer.



Figure 3: Photocathode design for the SRF gun.

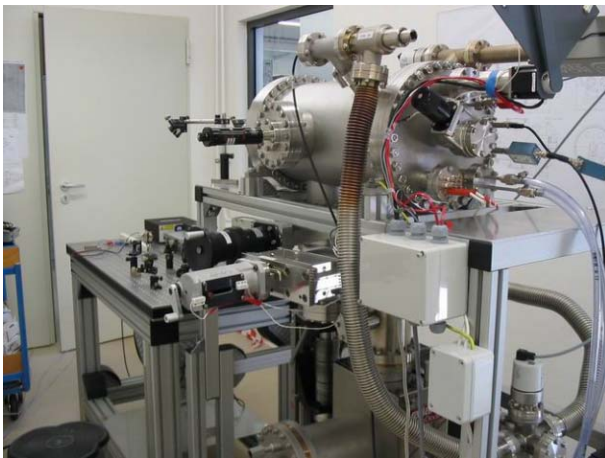


Figure 4: New photocathode preparation system.

The standard method and co-evaporation will be adopted to fabricate  $\text{Cs}_2\text{Te}$  film. The former means two steps, at first evaporate tellurium about 20 nm, and then activate tellurium with cesium till the maximum photocurrent. According to the experience of CERN, by using co-evaporation dramatic improvement of QE and lifetime can be attained [6]. The open question is the technology of stoichiometric rate control.

### CATHODE COOLER

This cathode cooling system is a special point for the SRF gun system. The niobium cavity with the He tank and the cathode cooling system is shown in fig. 1. Also

the photocathode and the transfer rod for cathode exchange are visible. The cooler, made of Cu, holds the photocathode and provides the thermal connection to the liquid  $\text{N}_2$  tank. They are separated by an electric insulator which allows to measure the cathode emission current as well as to apply a DC voltage for suppressing multipacting and simultaneously producing an additional focusing effect.

### SUMMARY AND OUTLOOK

The project of SRF photo-injector is going well for cw-mode operation in the ELBE electron linear accelerator laboratory. The design and the fabrication of the two Nb cavities and the surrounding components like cryomodule, cathode cooling system, and tuners have been finished. The photocathode preparation system and cathode cooler has been in the first test. Further activities are the design of the diagnostic beam line and the upgrade of the 262 nm driver laser system.

### ACKNOWLEDGEMENT

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