PROPOSAL OF PEKING UNIVERSITY SUPERCONDUCTING ACCELERATOR FACILITY (PKU-SCAF)*

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Abstract

A proposal of Peking University Accelerator Facility (PKU-SCAF) is described briefly in this paper. PKU-SCAF is to produce high quality electron beams with high average current. It will have a wide opportunity of applications. PKU-SCAF is mainly composed of a DC-SC photocathode injector and a superconducting accelerator module with two TESLA 9-cell cavities. It will work at CW mode. The energy of electron beam is 20~35 MeV and the current is about 1mA. This project will be accomplished with cooperation of DESY. The PKU-SCAF project has obtained supports of NSFC (National Natural Science Foundation of China), Ministry of Education of China and Peking University.

1 INTRODUCTION

The high average power FEL has a lot of potential applications in scientific researches and industry[1]. PKU-SCAF can generate a 20~35 MeV electron beam of high quality and stability, which will be used for Free Electron Laser of Peking University to produce infrared laser beams with wavelength from 10 to 30 μm. The wavelength stability is 10^{-4} and micro-pulse length is from 1 ps to 8 ps at a repetition rate of 40.5 MHz. If re-circulate system adopted, the beam re-passing through the accelerator section for the further acceleration can go up to about 45 MeV and the laser wavelength will be shortened to 3 μm. The fields of fundamental and applied research could be opened in Chemistry, Biology, Material Physics science. For example, the studies of structure dynamics, research of X-ray source applications (LCSS)[2] , etc.

2 PKU-SCAF

PKU-SCAF is mainly composed of a DC-SC photocathode injector[3], the superconducting accelerator and the driven laser system[4]. Figure 1 shows the Sketch of this facility, but the beam diagnostic system is not included. The laser driven DC-SC photocathode injector can produce low emittance and short bunched electron beam. Acceleration after the injector is provided by a superconducting accelerator module with two TESLA 9-cell cavities[5][6]. The cavity also provides a longitudinal position-momentum correlation for subsequent bunch length compression. Two CW RF power amplifiers are used. One is a 1.3 GHz, 5 kW solid state power amplifier for DC-SC photocathode injector. The other is a 1.3 GHz, 20 kW CW mode klystron for the main RF power supply to the two 9-cell cavities. At the first stage of our project, the expected average beam current is less than 1 mA and the electron energy is 20-35 MeV. The sketch and main parameters of PKU-SCAF are shown respectively in Fig.1and table 1.

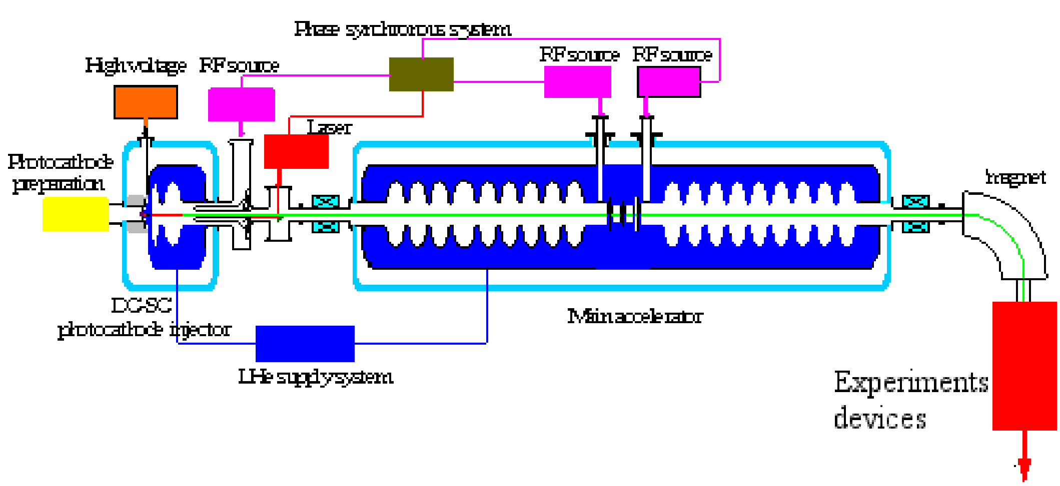

Fig. 1 Sketch of the PKU-SCAF (Peking University Superconducting Accelerator Facility

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Table 1 Main parameters of PKU-SCAF

SC Accelerator	Parameters
Frequency	1.3 GHz
Electron energy	20-35 MeV
Bunch repetition freq.	25-40 MHz
Charge/bunch	60 pC
Bunch length	3 ps
Peak current	20 A
Average current	< 1 mA
Normalized emittance (εN)	<15 π-mm-mrad
Energy spread (σe)	< 1%

3 INJECTOR

PKU-SCAF will adopt DC-SC photocathode injector which is designed by Peking University. The DC-SC injector consists of a pierce gun and a 1+1/2 cell superconducting cavity. The configuration of DC-SC photocathode injector is shown in Fig. 2. It solves the compatibility problem between the superconducting cavity and the photocathode. Code SUPERFISH is used to optimise the shape of the 1+1/2 cell cavity and code PARMELA is used to calculate the performance of beam dynamics[7]. The initial conditions and the optimised results of the beam quality at the exit of the injector are listed in Table 2. Calculated results of the equipotential lines in Pierce gun and the electric field distribution of 1+1/2 cell cavity are shown in Fig. 3 and Fig. 4 respectively.

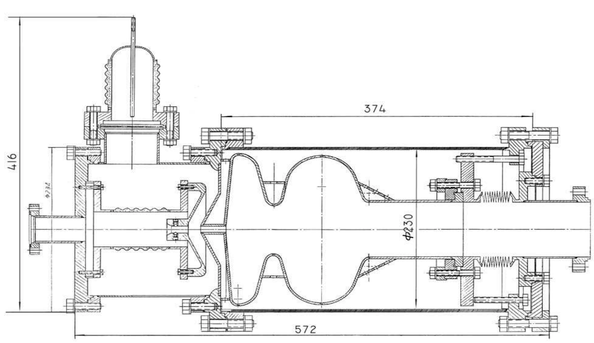

Fig. 2 Configuration of DC-SC photocathode injector

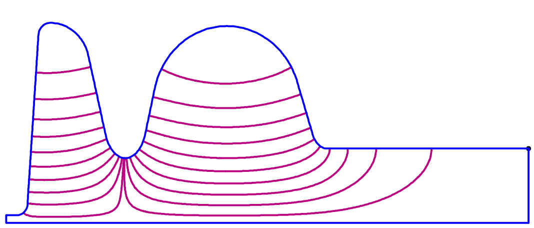

Fig. 3 Equipotential Lines in the Pierce Gun

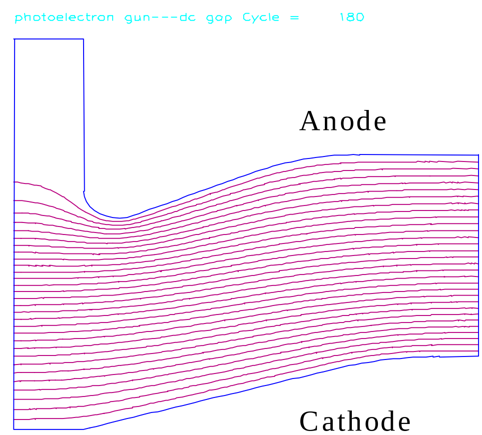

Fig. 4 Electric Field Distribution in 1+1/2 Cell Cavity

The injector will be operated in CW mode, with micro-pulse frequency of tens of MHz. The photocathode will be fixed in the pierce gun of injector. The photocathdes of GaAs (+Cs) or Cs_2Te will be selected because they have high quantum efficiency at roughly 400~800 nm and 266 nm respectively[8]. Mg cathode has attracted most of the RF gun laboratories, because the quantum efficiency of Mg shows a dramatic improvement upon laser cleaning, increasing from 10^{-5} to 4×10^{-4} after two hours of cleaning, and to 0.2% after systematic cleaning[9]. Therefore, Mg cathode is also one of candidates. The drive laser for electron beam source is crux of the matter. The laser system has not been decided yet, because it should be very carefully consider according to our selected photocathode. The 1+1/2 cell cavity will work at 2 K. A set of die for forming the cavity has been designed and manufactured. Nb sheet of 2.5 mm thickness and RRR 250 will be used for 1+1/2 cell cavity. The cryostat is being designed.

Table 2 The initial conditions and optimised results of the DC-RF injector

Initial conditions			**Simulation results**	
Electron bunch	Radius	3.0 mm	Anode inclination	65°
	Length	10 ps	Synchronous phase	-50°
	Charge	60 pC	Energy	2.61 MeV
	Emittance	0 mm-mrad	Radius	2.8 mm
SC cavity	Average gradient	15 MV/m	$\Delta E_k/E_k$ (rms)	1.16 %
Pierce gun	Distance between cathode and anode	15 mm	Bunch Length	9.6 ps
			ε_x (90%, n)	12.4 mm-mrad
	Cathode voltage	-70 kV	ε_y (90%, n)	12.7 mm-mrad
	Anode voltage	0 kV	ε_z (90%, n)	51.4 keV-ps

4 MAIN ACCELERATOR

The main superconducting accelerator is one of the critical equipments in PKU-SCAF. The main accelerator module includes two 9-cell TESLA type 1.3 GHz superconducting cavities. Since TESLA represents the one of the most advanced superconducting technology in the world, we choose the 9-cell cavities[6] of TESLA as our main accelerator. Each of cavities is excited by its own coaxial power coupler. The two cavities are in one cryomodule, which is similar to that of the superconducting linear accelerator of ELBE-project at Rossendorf[10].

In order to find out whether the injector can match the main accelerator, code PARMELA is used to estimate the properties of beam dynamics at the exit of the main accelerator. The simulation results under different accelerating gradients are listed in table 1. The simulation results show that combination of DC-SC photocathode injector with the main accelerator is feasible and PKU-SCAF can provide good electron beams. The main accelerator will operate at CW mode and at 2 K. The maximum accelerating gradient can reach 15~20 MV/m. The energy gain of the electron bunches from the main accelerator is 20~35 MeV and the average current of the electron beam is about 1 mA. Since two cavities and two main couplers are used, each coupler only needs to deliver about 10 kW power to each of the cavity in the first step. In the future, energy recovery system will be used to increase the average current, thus a new coupler is needed. The new coupler will be improved by using HERA technology in order to transfer much more RF power. This project will be accomplished with cooperation of DESY. When finished manufacturing, the cavities and cryostat will be delivered to DESY for testing. After that, the whole system will be shipped to Peking University for installation.

Table 2 Simulation results of the beam at the exit of the main accelerator

E_{acc} (MV/m)	E_k (MeV)	$\Delta E_k/E_k$ (rms)(%)	ε_x(90%,n) (mm-mrad)	ε_y(90%,n) (mm-mrad)	ε_z(90%,n) (deg-keV)
10	20.41	0.08	10.62	10.48	64.86
12.5	25.09	0.07	9.62	9.51	62.49
15	29.60	0.06	9.56	9.48	63.38

5 RF POWER SYSTEM

Two CW RF power sources will be used. One of them is a solid-state power source of 1.3 GHz, 5 kW, CW for DC-SC photocathode injector. The other power source is provided by a klystron of 1.3 GHz, 20 kW for the main accelerator. The power provided by the solid state of 5 kW power source is coupled into the 1+1/2 cavity through a coaxial coupler. The power provided by klystron of 20 kW will be coupled into the two 9-cell cavities through a power splitter. The klystron of 20 kW, CW will be designed and manufactured in China. A low level RF control system will be also used to ensure the stability of synchronized phase and amplitude in the injector and main accelerator.

6 CONCLUSION

A new project--PKU-SCAF is proposed at Peking University. It can generate high average current electron beams with energy of 20-35 MeV. The beam dynamics analysis has been completed and the manufacturing of DC-SC injector is in process. The main accelerator will be constructed in collaboration between Peking University and DESY in the next two years.

7 ACKNOWLEDGMENT

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8 REFERENCE

[1] UV demo FEL Design Team, Free-Electron Lasers For Industry, Volume 2: UV Demo Conceptual Design, Laser Processing Consortium, CEBAF, May 1995.

[2] J. Chen et al., Nucl. Instr. Meth. A341(1994)346.

[3] Kui Zhao, Jiankui Hao, Yanle Hu, et al., Research on DC-RF superconducting photocathode injector for high average power FELs, to be published in Nuclear Instruments and Methods in Physics Research A, 2001.

[4] K. Zhao et al., Research on Peking University Superconducting Accelerator Facility (PKU-SCAF), to be published in Proceedings of the 2001 Particle Accelerator Conference, Chicago, 2001.

[5] D. Edwards, 1995 TESLA Test Facility LINAC - Design Report, DESY-TESLA-Report 95-01.

[6] R. Brinkmann et al., TESLA Technical Design Report, Part II: The Accelerator, March 2001

[7] James H Billen. PARMELA Documentation. LANL, 1997.

[8] T. Srinivasan-Rao, et al., Photocathode and laser for PERL, NSLA Review.

[9] T. Srinivasan-Rao, et al., performance of magnesium cathode in the S-band rf gun, 0-7803-4376-X/98/$10.00 © 1998 IEEE.

[10]A. Buchner, F. Gabriel, P. Michel, et al., The ELBE-Project at Dresden-Rossendorf, Proceedings of EPAC 2000, p732