THE PROGRESS REPORT ON RF SUPERCONDUCTIVITY AT PEKING UNIVERSITY*

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Abstract

Peking University Superconducting Accelerator Facility (PKU-SCAF) is under construction at Peking University. It will include a DC-SC photo-injector with 1+1/2, 1.3 GHz Nb cavity, the main accelerator which is a superconducting 1.3 GHz linac module with two TESLA-type Nb cavities. As the most important subsystem, the 2 K cryogenic plant was approved by Peking University and 2 K cryogenic system will be designed in this year. The fundamental research on RF superconductivity is being carried on at Peking University, and such as a 3+1/2 Nb cavity for DC-SC photo-injector is designed and a two cell Nb cavity was fabricated simultaneous. The R&D of high purity Nb sheets with RRR > 400 and large grain Nb sheets are also reported in this paper.

INTRODUCTION

PKU-SCAF will be an ideal compact scientific experimental platform for universities [1]. The layout of PKU-SCAF is shown in figure 1. The high quality electron beam accelerated by PKU-SCAF will be tested to generate IR FEL (5-10 μm) and THz radiation (100-3000 μm) which could be used for nonlinear transient physical process, chemical kinetics, molecular biology, material science and so on. PKU-SCAF project has several sub-systems, includes 1+1/2 cell 1.3 GHz DC-SC photoinjector, a superconducting 1.3 GHz linac with two 9-cell TESLA-type Nb cavities and the cryogenic system. As the core devices, the R&D on superconducting cavity is carried on in our group. The research on high purity Nb material for superconducting accelerators is performed by Peking University and progresses have been obtained.

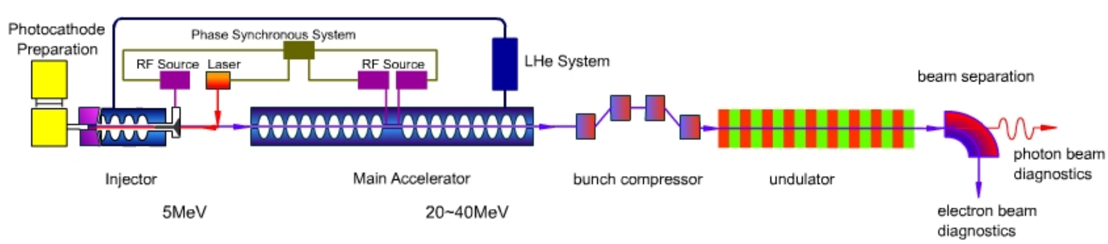

Figure 1: Schematic Layout of PKU-SCAF

THE PROGRESS OF DC-SC PHOTOINJECTOR

The DC-SC photoinjector test facility is a compact system, integrating a DC Pierce gun with a SC 1+1/2-cell niobium cavity. Figure 2 gives an overview of the facility, including the cathode preparation chamber, the cryostat housing the DC gun and the SC cavity, the 100 kV high voltage source for the cathode of DC gun, the RF main coupler, the 4.5 kW solid-state power amplifier, the driving laser system, and the beam diagnostic system [2].

Figure 2: Overview of the DC-SC photoinjector.

Core elements of this electron gun are the DC Pierce gun and the 1+1/2-cell SC cavity. The photocathode is

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placed at the cathode of the Pierce structure, and the anode makes up the bottom of the 1+1/2-cell cavity. A draft is shown in Figure 3.

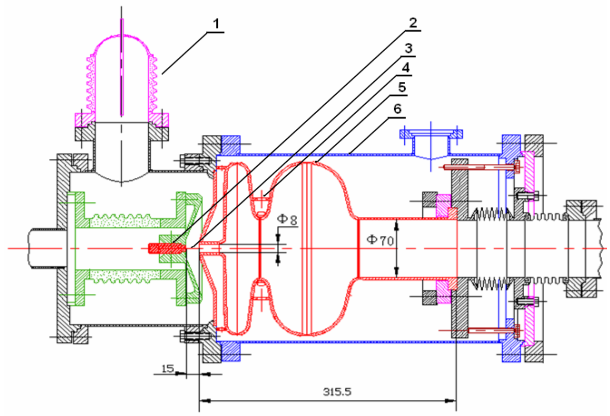

Figure 3: Draft of the 1+1/2 cell cavity.
(1) Ceramic insulation (2) Photocathode (3) Pierce DC gun (4) Stiffening ring (5) Niobium cavity (6) LHe tank

The feasibility of DC-SC photoinjector has been validated through experiment on the test facility [3]. The advantages are: (1) simple and compact structure, (2) separate photocathode from superconducting cavity. (3)It is easy to operate in CW mode. The beam loading test at 4.4 K has been performed and the results are shown in table 1. The maximum energy gain is 1.1 MeV at 4.4 K. Energy spread and emittance are measured at the moderate energy gain. The upgrade of injector is a pierce DC gun plus 3+1/2, 1.3 GHz Nb cavity with tuning structure and new cryostat.

Table 1. The measured results of DC-SC injector

Average Currunt	Energy Gain	Emittance
200 μ A	0.5 MeV	5.4 mm.mrad
70 μ A	0.59 MeV	2.8 mm.mrad

MAIN ACCELERATOR

The design of the main accelerator is finished. Two TESLA-type 1.3 GHz cavities are chosen for the main accelerator, which will be housed in a Rossendorf-type cryostat (figure 4). Parameters of the main accelerator are listed in Table 2.

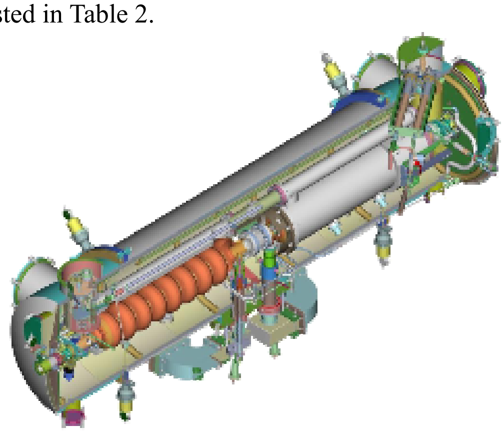

Figure 4: ELBE Module for the main accelerator

Table2: Parameters of the main accelerator

RF frequency (cavity at 2.0 K)	1300 MHz
Accelerating voltage	15~20MV/m
Q0 @15 MV/m	8×109
Electron Beam Peak Current	20~50 A
Bunch Charge	About 20~50 pC
Electron Beam Ave. Current	1.625~4.0 mA
External Q of Power Coupler	5×106
Cryogenic losses (stand-by)	12W at 2K

ELBE Module can run in CW mode and provide electron beams with high average current. In order to minimize the scale of LHe machine, the main accelerator will operate in long pulse mode. At present, the macro pulse length is set to 1.5 ms with a repetition rate of 10 Hz.

CRYOGENICS SYSTEM

Cryogenics system will supply superfluid helium (2 K) to the photo-injector and the main accelerator. A LHe plant has been designed and TCF 20 compressor will be selected. The evaluated heat load is listed in table 3.

Table 3. The heat load evaluation

	Long pulse mode (W)	CW mode (W)
Static heat loss of main accelerator	12	12
Dynamic heat loss of main accelerator	4.4	88
Static heat loss of injector	6	6
Dynamic heat loss of injector	1	20
Heat loss of transfer line	10	10
Total heat losses without contingency	33.4	136
Total static heat losses with 50% contingency	42	42
Total heat load with 50% contingency	50.1	204

For CW mode, the total heat is over the capacity of compressor TF20. In this case, the cryogenic system will be operated 3 or 4 hours per day and 2 day per week or in long pulse mode, 5 ms of duration, 10 Hz of repetition and 5% of duty factor.

FUNDAMENTAL RESEARCH ON SUPERCONDUCTIVITY

It is essential to do the R&D of high purity niobium material for superconducting accelerators. In the past two years, great progresses have been obtained. The Nb sheets of high RRR (>300), Nb sheets of very large grain size with diameter 300mm (figure5) and seamless Nb tubes (RRR > 250) have been made successfully. The comparison with specification of DESY is listed in table 4. A two cell cavity was fabricated with Nb sheets from China and the performance will be got soon.

Table 4. comparison of measured results with specification of DESY

	Content	standard value	test value	impurity/（ppm）		
1	RRR	≥300	333	element	standard	ingot
2	grain size ASTM（level）	≥6 (Local 4~4.5)	6.5	C	≤ 10	10
3	Yield strength （MPa）	＜100	110.8	N	≤ 10	5
4	tensile strength （MPa）	＞140	165.6	O	≤ 10	5
5	Elongation at break （%）	≥ 30	55.8	H	≤ 2	3
6	HV/9.8N	＜ 50	59.0	Ta	≤ 500	＜100
7	thick（mm）	2.8±0.10	2.81~2.89	W	≤ 70	16
8	width（mm）	265±1.0	265.5~265.6	Ti	≤ 50	＜5
9	Length（mm）	265±1.0	265.5~265. 6	Fe	≤ 30	5
10	weight（kg/block）	1.63~1.76	1.71~1.72	Si	≤ 30	＜10
11	Rt （mm）	≤ 15	2.4~5.6	Mo	≤ 50	＜10
12	Plane tolerance（mm）	0.56	0.14~0.36	Ni	≤ 30	＜5
13	Non-Nb Penetrating Cluster	≤ 30μm	none			
14	Burr & Scratch（μm）	≤30	＜10			

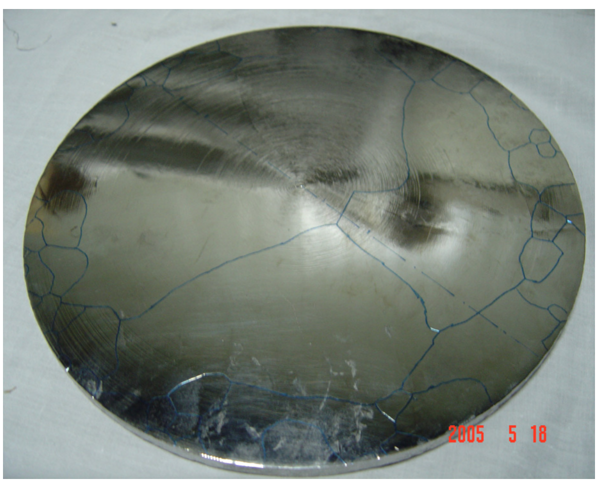

Figure 5. large crystal Nb sheet with diameter 245 mm

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REFERENCES

[1] Zhao Kui, et al., Nucl. Instr. and Meth. A483(2002)125.

[2] Jia'er Chen, et al., Proceedings of PAC 2003, Portland, Oregon, USA, p2580.

[3] Jiankui Hao et al, ThP24, this workshop.