RECENT RESEARCHES ON RF SUPERCONDUCTIVITY IN PEKING UNIVERSITY*

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Abstract

Researches on RF superconductivity are carried out in Peking University in the recent years. A niobium-sputtered copper QWR was successfully fabricated and tested. Accelerating gradient of 5-6 MV/m without beam loading was obtained at 4.2 K. New type of niobium films were prepared and tested. Peking University Superconducting Accelerator Facility (PKU-SCAF) is proposed and will be constructed in collaboration with DESY. PKU-SCAF consists of a novel DC-SC photocathode injector, a superconducting accelerator, high quality laser system, RF power supply and diagnostic system. It will provide CW electron beams of 20-35 MeV with high average current.

1 INTRODUCTION

Quarter wave resonators (QWRs) are extensively used in heavy ion LINACs. Niobium sputter-coated copper QWRs are developed for many years[1,2]. Niobium-sputtered copper QWRs are selected as the first choice for the accelerating structure of the booster of Beijing Radioactive Nuclear Beam Facility (BRNBF).

A lot of progress has been made in the Institute of Heavy Ion Physics of Peking University on niobium-copper sputtered QWRs. A lot of technologies were developed, including the surface cleaning, uniformity of niobium films, morphology and superconducting performance, etc. After the QWR was coated with niobium, low temperature experiments were processed without beam loading and with proton beam loading.

At the same time, in order to get high average current electron beams for Free Electron Lasers, a new project—Peking University Superconducting Accelerator Facility (PKU-SCAF) is proposed. PKU-SCAF will be operated at CW mode and is a compact facility. TESLA technology will be used in PKU-SCAF in collaboration with DESY.

In this paper the researches on niobium-sputtered copper QWR and PKU-SCAF at Peking University are introduced.

2 R&D ON NB-CU QWR IN PKU

2.1 Sputtering Technology in PKU

A lot of researches have been done on niobium-sputtered QWRs in Peking University. A DC diode sputtering system was developed[3]. Sputtering technologies have been developed. Simulations have been done to optimize the field distribution in the resonator and to optimize the niobium target. Optimized parameters were obtained by niobium sample experiments. OFHC copper surface was treated by electro-polishing, high pressure water rinsing, ethanol dehydrating and vacuum argon ion cleaning technologies[4].

2.2 Niobium Coating of the OFHC QWR

With the critical technologies for niobium-sputtered superconducting cavities, the QWR was coated with niobium films. Due to the pre-treatments, the niobium film adhered to the surface of QWR tightly. The Nb-Cu QWR was successfully finished sputtering in October 1999. This is the first Nb-Cu QWR in China. Fig. 1 showed the QWR after electro-polishing and after niobium coating.

(a) (b)

Fig. 1 QWR after electro-polishing (a) and after niobium coating (b)

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2.3 Superconducting Performance of Niobium-Copper QWR

Liquid helium experiments have been done to test the performance of the niobium-sputtered superconducting QWR. A new cryostat has been designed and installed. The base vacuum in the cryostat can be maintained better than 10^{-6} Pa in room temperature.

Low temperature experiments were done from November 1999 to September 2000. The obtained E_{acc} is more than 5 MV/m.

The Q value is under 10^{9}, this is because the brazing seam on the outer conductor of the QWR. The QWR is brazed with two parts, see Fig. 2(a). The film near the seam is not so good, see Fig. 2(b). The brazing seam must be modified to improve the performance of niobium film on QWR.

(a) (b)

Fig. 2 Brazing seam on QWR (a) and niobium film near the seam (b)

2.4 Proton beam test with Nb-Cu QWR

After the low temperature experiments, we installed the QWR to the terminal of the 2×6 MV tandem at the Institute of Heavy Ion Physics to do some beam tests with proton beams to verify its performance. Fig. 3 is the layout of the accelerator beam line. The proton beam energy gain curves at different E_{acc} were obtained by magnetic filed scanning, see Fig. 4. In CW mode, 500 keV energy was obtained when the input RF power is 6 W.

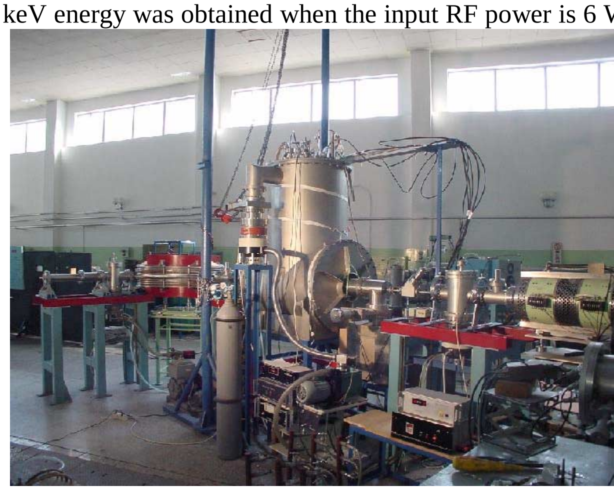

Fig. 3 Layout of proton beam accelerating structure

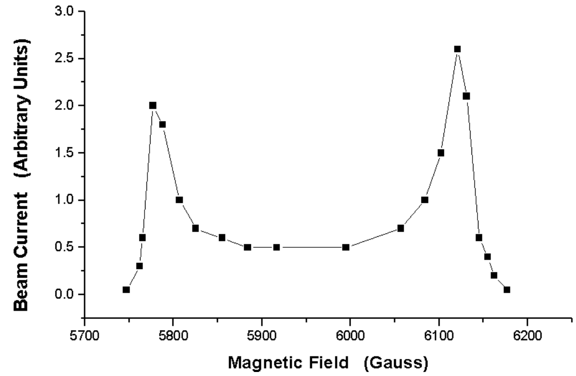

Fig. 4 Energy spectrum by magnet filed scanning

2.5 Researches on new niobium films

To improve the properties of the niobium films, researches on new type of niobium films were done. The prepared niobium film samples were sent to Cornell University to test the performances. The measured results showed that the T_c of the new niobium film got to 9.7 K. Fig. 5 showed the T_c figure measured in Cornell University.

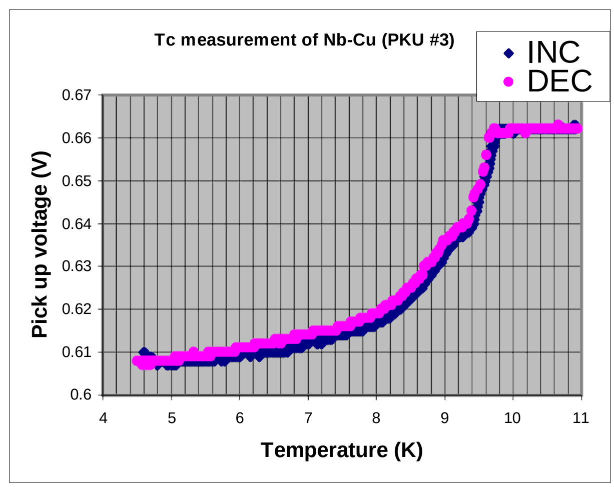

Fig. 5 T_c measurement of new niobium film (at Cornell University)

3 RESEARCH ON PEKING UNIVERSITY SUPERCONDUCTING ACCELERATOR FACILITY (PKU-SCAF)

3.1 Why to Build PKU-SCAF

The purpose of PKU-SCAF is to provide high quality electron beams with high average current. It will be operated at continuous wave mode. PKU-SCAF will supply a lot of research opportunity to related research fields at Peking University, such as learning most advanced superconducting technology, providing a user facility for various scientific or industrial applications, theoretical researches and principle-proof experiments of the interaction between the high power laser and the ultrashort electron bunch, etc.

3.2 PKU-SCAF

Peking University Superconducting Accelerator Facility PKU-SCAF consists of the DC-SC photocathode injector[5,6], the superconducting accelerator, the RF-power system, and the laser driver system. Fig. 6 shows the sketch of PKU-SCAF. Since superconducting technology is used, the whole facility will be a compact one.

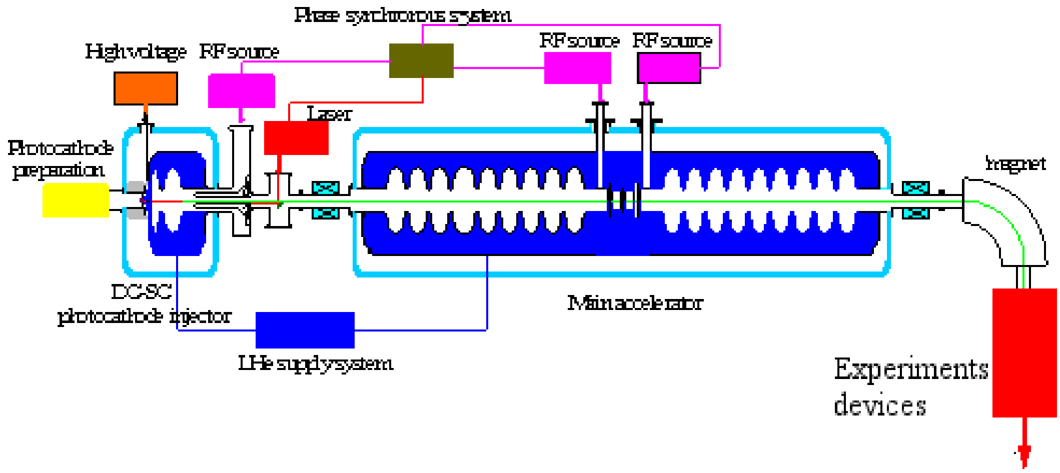

Fig. 6 The sketch of PKU-SCAF

The DC-SC photocathode injector consists of a pierce gun and a 1+1/2 cell superconducting cavity[6]. It solves the compatibility problem between the superconducting cavity and the photocathode. The injector will be operated in CW mode, with micropulse frequency of tens of MHz. The injector will use a p-type GaAs(Cs) photocathode in the pierce gun. The cavity will work below 2 K. The injector is under construction now and will be finished in 2002.

As to the main accelerator, we will use two 9-cell TESLA type cavities and TESLA technologies[7,8]. It will work at continuous wave mode. The energy of the electron bunches got from the main accelerator is about 20-35 MeV and the current of the electron beam is about below 1mA in the first step.

The RF power system consists of two RF sources. One is a 1.3 GHz, 5 kW, CW mode solid-state power source for the DC-SC injector. The other is a 1.3 GHz, 20 kW, CW mode klystron for 9-cell superconducting cavities.

The drive laser is used to deliver IR light pulses (800nm) to the cathode. We will use a Ti:Sapphire laser pumped by a semiconductor laser. It can provide laser pulse of 6~8 ps and work at 700~800 nm. The energy of laser pulse is about 10 nJ.

3.3 Simulation of Beam Dynamics

Code POISSION, SUPERFISH and PARMELA are used to optimize the structure of the pierce gun and the 1+1/2 cell cavity. Table 1 lists the simulation results. The results show that the injector can meet our requirements.

The electron beam from the DC-SC injector will be injected into the main superconducting accelerator. Code PARMELA is used to obtain the beam properties at the exit of the main accelerator. The simulation results under different accelerating gradients are listed in table 2. From the table, we can see that the combination of DC-SC photocathode injector with the main superconducting accelerator can provide high quality electron beams.

Table 1 Simulation results of the DC-RF injector

E_k (MeV)	**R (mm)**	**$\Delta E_k/E_k$ (rms)(%)**	**Bunch length(ps)**	**ε_x(90%,n) (mm-mrad)**	**ε_y(90%,n) (mm-mrad)**	**ε_z(90%,n) (Deg-keV)**
2.61	2.2	1.16	9.6	12.42	12.67	51.36

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

4 CONCLUSION

Researches and experiments have been done on niobium-sputter coated copper QWR in Peking University. Crucial techniques are developed on making good niobium films. High quality niobium films are coated on OFHC QWR. Accelerating gradient of 5 MV/m with no beam and 500 keV energy gain of proton beam can be obtained. The improvements of niobium films are in processing at the present.

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.

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6 REFERENCES

[1] V. Palmieri et al., Proc. of the 6th Workshop on RF Superconductivity, CEBAF, USA, 1993, p868-885.

[2] S. Stark et. al., Proc. of the 8th Workshop on RF Superconductivity, Abano Terme (Padova), Italy, 1997, p1156-1163.

[3] Jiankui Hao et al., Proc. of the first Asian particle accelerator conference (APAC98), p304-306, KEK, Tsukuba, Japan, March 23-27, 1998.

[4] Kui Zhao et al., R&D on the copper-niobium superconducting cavity, Proc. of the 9th Workshop on RF Superconductivity, Santa Fe, New Mexico, U.S.A., Oct. 31-Nov. 5, 1999.

[5] K. Zhao, R.L. Geng, L.F. Wang et al. Nucl. Instr. & Meth. in Phys. Res., 1996, A375:147-149

[6] K. Zhao, J.K. Hao, Y.L.Hu, et al. Research on DC-RF photocathode injector for high average power FEL. To be published in Nucl. Instru. & Meth. in Phys., 2001.

[7] D. Proch, Superconducting cavities for accelerators, Rep. Prog. Phys. 61 (1998) 431-482.

[8] Conceptual Design of a 500 GeV e+e- Linear Collider with Integrated X-ray Laser Facility, DESY, Vol1: 298-320, 1997