TESLA TECHNOLOGY IN CHINA

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Abstract

Great efforts have been made in China for developing TESLA technology since SRF 2007. As a mid-term goal, Peking University is striving for constructing a SRF ERL test facility to provide coherent radiations. A cryomodule of an upgraded DC-SRF injector with a 3.5 cell cavity of large grain niobium was designed and constructed for this purpose. The field gradient of the 3.5 cell cavity in the vertical test at J-Lab is reported as 23.5MV/m. A cryomodule consisting of a China made 9-cell TESLA type cavity is also presented. As the helium liquefier system produced by the Linde Company is being commissioned, it is expected that the PKU test facility will be able to provide 15-20 MeV high quality e-beam at an operating temperature of 2K early next year. Apart from PKU, IHEP started a program to build a short cryomodule consisting of a 1.3GHz 9-cell low loss cavity and related components to serve as a horizontal test stand under the frame of ILC collaboration. The R&D of 500MHz single-cell Nb cavity module as a spare SRF component of BEPCII is also in progress. In order to manipulate the beam bunch length on the SSRF ring, 1.5 GHz single cell SRF cavities are being developed at SINAP.

INTRODUCTION

Great efforts have been made in China for constructing superconducting cavities since the last SRF conference. To provide coherent radiations a SRF ERL (Energy Recovery Linac) test facility (PKU-SETF) was initiated by the PKU-SRF group as a mid-term goal [1]. The PKU-SETF consists of mainly a 5 MeV DC-SRF injector and a cryomodule of 9-cell TESLA cavity working at 2k for accelerating electrons to 15-20 MeV. An energy recovery beam transport loop with two arcs is designed to match with the main accelerator. An undulator and a chicane are inserted in the loop to produce 4-8 micron laser light.

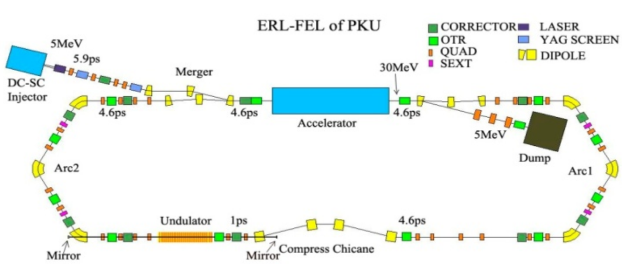

Figure 1: The PKU Energy Recovery Linac Test Facility.

The PKU-SETF will be implemented in about 3 steps. For the first step, the 5 MeV beam from the DC-SRF injector will be injected directly to an undulator to produce THz radiation. After the main accelerator and the energy recovery loop being commissioned, an ERL-CBS (Compton Backscattering) device will be constructed to produce high flux X-ray of ~10 keV. Finally with an 11.5 m long optical cavity, the IR laser light can be produced so that PKU-SETF can provide users with various kinds of radiations according to their needs. To realize these goals, 2-cell, 3.5-cell and 9-cell TESLA type cavities, made of both large and fine grain Nb, have been developed at PKU. Accordingly cryomodule of DC-SRF injector and the main accelerator have been constructed. Meanwhile, SRF group at IHEP started a program to build a short cryomodule consisting of a 1.3GHz 9-cell low loss type Nb cavity and related components to serve as a horizontal test stand and an accelerating unit under the frame of ILC collaboration. The R&D of a 500MHz single-cell Nb cavity, as a spare SRF component of BEPCII is also in progress. [2] At SINAP, Shanghai, three 500MHz CESR type SRF cavities are running steadily on the SR ring to provide the cycling beam with 600KW RF power. Besides, 1.5 GHz single cell SRF cavities are being developed to manipulate the beam bunch length on the SSRF ring.[3] A further growing phase on SRF is well getting on in China.

EFFORTS ON MULTI-CELL SRF CAVITIES AT PKU

Encouraged by the high gradient performance of the first single cell cavity with large grain Nb[4], the PKU SRF Group started a series of efforts to develop 1.3 GHz 2-cell, 3.5-cell and 9-cell cavities with both large and fine grain Nb sheets. All these cavities are fabricated in China using sheets produced by Ningxia OTIC. Primary cavity profiling, surface treatments and field flatness tuning of these cavities are completed at PKU. With the help of Dr. Kneisel, Prof. Proch and Geng, they are transported to J-Lab or DESY for further BCP, HPR and heat treatments as well as vertical test at 2K.

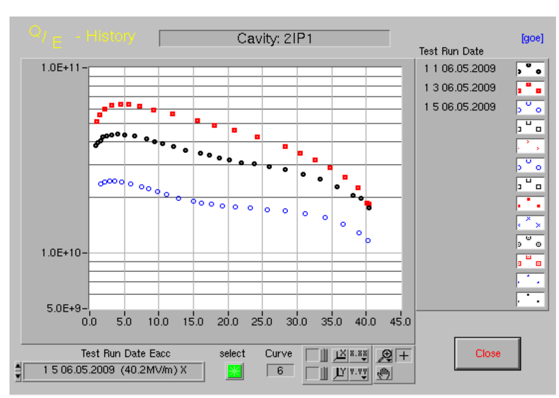

Figure 2: Pi modes of 2-cell cavity at 1.6, 1.8 and 2.0K.

Thanks to the help of ACCEL, the 2-cell cavity with large grain Nb was treated and tested at DESY and the field gradient reached higher than 40MV/m @ Q_0 of 1.2E10 (Fig.2) as reported by DR. Krzysztof Twarowski. The cavity went through a series of preparations before the test including 80 µm BCP (Accel), 800^{0}C HT, 100 µm EP (Henkel), 4 x HPR, 1200^{0}C HT in Ar atmosphere, kept at 90-140 K for 24 hours. No Q disease was observed and the residual resistance of the material at 1.5 K is 4 nano ohms. The conclusion is "Very good cavity made of good Nb material"[5].

To meet the practical applications, PKU Group carried out fabrications of multi-cell cavities with end groups consisting of the input power coupler, HOM couplers, signal pick-up and etc. A fine grain Nb 2-cell cavity with end group was made up first (Fig.3) and was tested at J-Lab. With the treatment by Dr. Kneisel, the field gradient was raised from 20 to 28 MV/m @ Q_0=1E10 after BCP and baking; it was quenched at 30 MV/m. [6]

Figure 3: A 2-cell cavity of fine grain Nb with end-group.

Before the construction of a 9-cell Nb cavity, a Cu cavity with same geometry and a 5-cell Nb cavity were fabricated and tested as reported at the last workshop.[4] Based on these technological studies a fine grain 9-cell Nb cavity without end group was first manufactured and tuned. With the help of Dr. P. Kneisel this cavity was first treated by HT & BCP 150 µm and after further BCP 50 µm, the field gradient turned out to be 23 MV/m@Q_0=6E9 without quenching [7] which was just meet the least specification of our needs (Table 1).

Table 1: Designed Specifications of 9-cell Cavity

RF frequency (cavity at 2.0 K)	1.3 GHz
Accelerating voltage	~ 20 MV/m
Q_0 @20 MV/m	1×10^{10}
Electron Beam Peak Current	20~50 A
Bunch Charge	About 20~50 pC
Electron Beam Average Current	1.6~4.0 mA
External Q of Power Coupler	$2\times10^6 \sim 1\times10^7$
Cryogenic losses (stand-by)	12W at 2K

Based on the above efforts, a 9-cell fine grain Nb cavity with end groups was constructed (Fig. 4) and was assembled into a LHe tank as a core component of the main accelerating cryomodule, which is to be tested with beam at 2K.

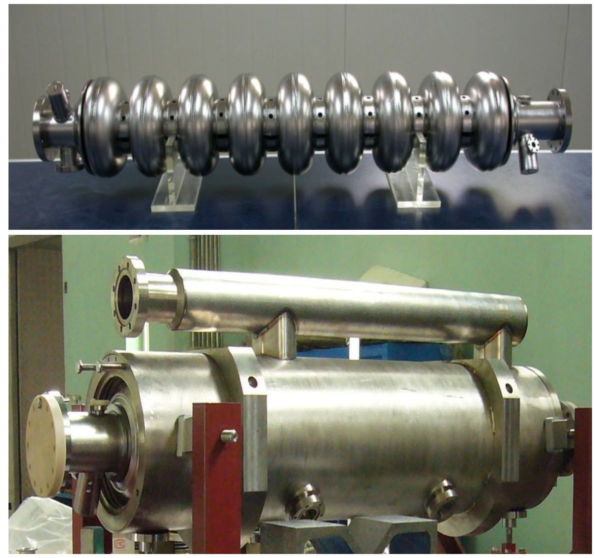

Figure 4: The 9-cell cavity of fine Nb grain with end groups in a Liquid He tank.

More 9-cell fine and large grain cavities with end groups have been fabricated; they are going to be further processed and tested at 2K.

PROGRESS ON DC-SRF INJECTOR WITH A 3.5-CELL CAVITY

One of most critical and delicate elements of the PKU SETF is the DC-SRF electron beam injector. It is essentially an integration of a photo-cathode Pierce gun with a 3+1/2 SRF accelerating cavity of 1.3 GHz [8].

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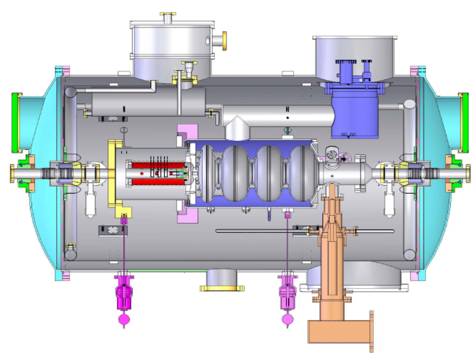

Figure 5: Schematic design of DC-SC Photo-injector.

Table 2: Main Parameters of the 3.5-cell SRF Cavity

Working frequency	1300 MHz , π-mode
Q_0	1×10^{10}
E_{acc}	13 MV/m
Effective Length	0.417 m
G-factor	242 Ω
E_{peak}/E_{acc}	2.12
B_{peak}/E_{acc}	4.95 mT/(MV/m)
Shunt Impedance r/Q	417 Ω

To obtain high quality electron beam of ~5 MeV, the geometrical structure of the Pierce electrode and the first half of the SRF cavity are carefully designed so that there will be no crossover inside the cavity. The transverse beam waist will be around the exit of the injector cryomodule. To compensate the deformation caused by Lorentz force and manual tuning, special reinforced stiffening rings are applied to the first cavity, especially the first half cell so that the field flatness change within the±200KHz tuning range is less than 3%. Simulations of various parameters have also been made to see the possible field of multipacting in the first cavity so as to ensure that no multipacting would occur at the operating field gradient (Fig.6). Because of the compact structure of the special end group, the possible cross talk between main coupler and pick up was also examined and it can be neglected at the SRF state.

The specially designed 3.5-cell cavity is made of large grain Nb. It has been constructed under strict quality control. Before the field gradient test, the cavity was prepared with BCP 100 µm and 12500C HT at OTIC. The HPR and tuning was done at PKU. The field flatness was tune to 94%. Further treatment was done in J-Lab by Dr. Geng with BCP 30µm and HPR×3. At first, the field gradient was limited by multipacting to less than 10 MV/m. After 8000C HT to release residual contaminates between the grain boundaries, finally the MP barriers were conditioned through and the gradient raised up to 23.5 MV/m. [9] (Fig.7) The field in the first half cell is still the limiting factor of the field gradient.

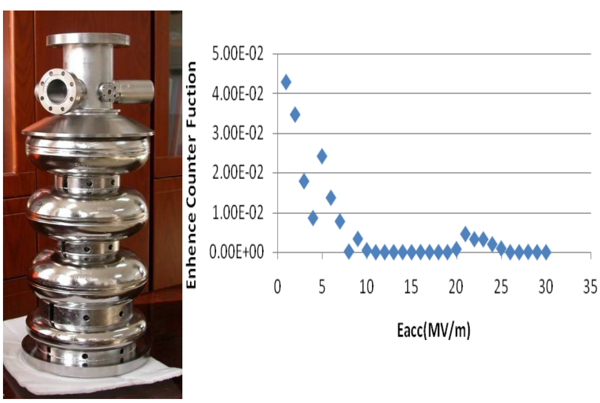

Figure 6: Simulation on multipacting of 3.5-cell cavity.

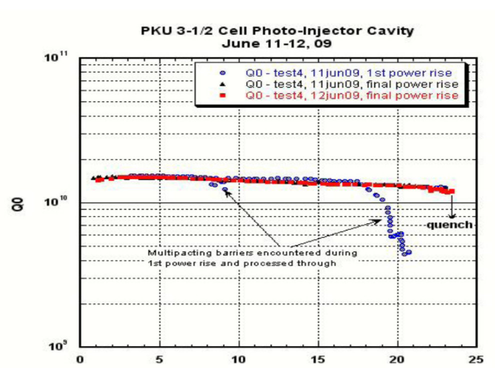

Figure 7: RF Test of 3.5 cell cavity at J-Lab.

RECONSTRUCTION OF NEW SRF EXPERIMENTAL HALL

Great efforts have been made to reconstruct the old building into a new SRF Experimental Hall to house the PKU-SETF and related beam lines, control room, laser room, cleaning rooms for processing, assembling and tuning of SRF cavities as well as the whole cryogenic system so as to enable the DC-SRF injector and the accelerating cryomodule working under 2K for a number of applications. For this purpose the L-140 Helium liquefier and related cryogenic facility produced by the Linde Company have just been installed in the new SRF Hall. It can provide 120l/hr liquid He [10]. The acceptance test of the system will be completed by the end of this year.

SRF ACTIVITIES AND RECENT PROGRESS AT IHEP, CAS

So far IHEP has two 500 MHz SRF (Fig. 8) cavities running steadily on upgraded BEPCII. Beam current up to

Figure 8: 500 MHz KEKB type SRF cavity for IHEP.

500mA per ring have been achieved. Both high power & LLRF interlock were developed to prevent SRF from damage. To prepare for spare parts a home made power coupler was successfully tested up to 270 KW. In addition R&D on spare SRF cavity is also progressing well. [11]

Under the frame of ILC collaboration, The SRF group at IHEP started a program to build a short cryomodule consisting of a 1.3GHz 9-cell low loss Nb cavity to serve as a SRF accelerating unit and a horizontal test stand [12].

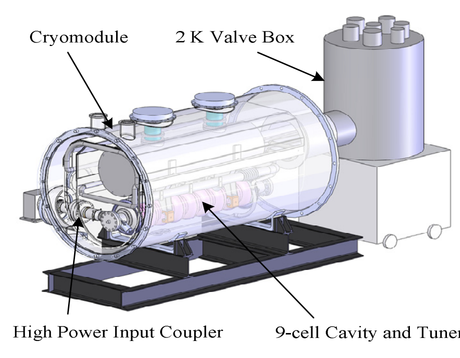

Figure 9: The cryomodule of 1.3 GHz 9-cell Nb as test stand.

For this purpose two 9-cell cavities are in construction. Fabrication of related components including dumbbells, input couplers, tuner as well as cavity surface treatment equipments and etc are well in progress. A new cryogenic system is to be installed. RF power source and LLRF control system also progress well.

PROGRESS ON SRF AT SINAP

Shanghai Synchrotron Radiation Facility (SSRF) is a 3.5GeV 3rd generation synchrotron light source. Three CESR type single cell SRF cavities of ACCEL are working steadily on the SSRF storage ring providing 3-6MV accelerating voltage and transferring up to 600kW RF power to the stored beam. [13] Correspondingly, three 310 KW Klystron RF power amplifiers, a 650W Helium liquefier and related components have been working well.

Table 3: Parameters of the SRF Module of SSRF

Frequency	499.654 MHz
Operating temperature	4.2K
V_{acc}	>2.4MV
Q_0 @2MV	$1X10^9$
Standby losses	<35W
Dynamic heat load at 2MV	<65W
Q_{ext} of input coupler	$1.8 \times 10^5 \pm 0.2 \times 10^5$
Power transferable to beam	>250 kW

In order to manipulate the bunch length and to suppress beam instabilities, a CW passive SRF system with a frequency of ~ 1.5GHz is being developed at SINAP to provide 1.8-2.0 MV RF voltage. For this purpose, R&D efforts are being made on the construction of single and multi-cell SRF cavities (Fig. 10). Meanwhile, infrastructures for cavity processing and performance tests are being built. [14]

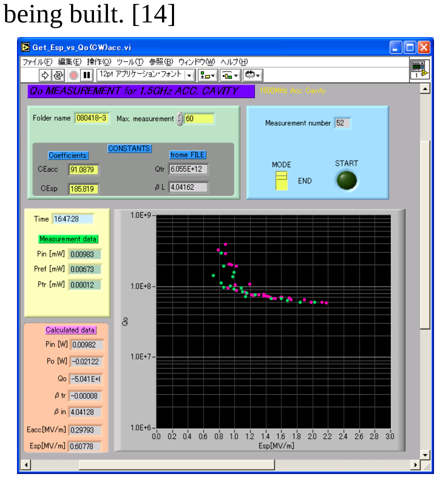

Figure 10: Vertical test result of SINAP single cell cavities.

CONCLUSIONS

It has been 20 years since PKU SRF group started to develop the TESLA Technology in China. With the help and encouragement from the international community, the group managed to establish the capability to construct single cell & multi-cell TESLA type SRF cavities and related cryomodule for various applications. During these days the large grain Nb material jointly developed by OTIC and PKU in 2005 with its own merits is interested by a number of labs in the world. While the new SRF experimental hall equipped with 2k cryogenic system will enable the group to have SRF cavities treated and tested in situ. Collaborating with the world SRF community, high power SRF cavities has been working successfully on the colliding rings of BEPCII and also on the SSRF ring by transferring hundreds KW of RF power to the cycling e-beam. Under the frame of ILC collaboration, SRF group of IHEP started to build a short cryomodule consisting of a 1.3GHz 9-cell low loss Nb cavity and related components to serve as a horizontal test stand and an accelerating unit. Meanwhile 1.5GHz cavities are also being developed for SSRF. A further growing phase of TESLA technology is emerging in China.

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