IHEP 1.3 GHz SRF TECHNOLOGY R&D PROGRESS

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Abstract

1.3 GHz superconducting radio-frequency (SRF) technology is one of the key technologies for the ILC and future XFEL / ERL projects of China. With the aim to develop this technology, IHEP has started a program to build an SRF Accelerating Unit in the frame of ILC collaboration. The SRF Accelerating Unit contains a 9-cell 1.3 GHz superconducting cavity, a short cryomodule, a high power input coupler, a tuner, a low level RF system and a high power RF source, etc. The unit can undergo beam test and used as the booster for any SRF linac based test facility. Recent progress of the components R&D is presented.

INTRODUCTION

IHEP has started the "1.3 GHz SRF Accelerating Unit and Horizontal Test Stand Project" since 2009 [1, 2]. The SRF Accelerating Unit can undergo beam test and used as the booster for the SRF linac based test facility in the future. The key components under development are:

- 1.3 GHz high gradient 9-cell cavity
- 1.3 GHz high power input coupler
- Cavity frequency tuner and LLRF system
- Cryomodule and cryogenic system

Recent progress of the components R&D is presented.

R&D PROGRESS

Low Loss Large Grain 9-cell Cavity

A low-loss shape 9-cell cavity using Ningxia large grain niobium was fabricated and processed at IHEP [3, 4]. The cavity has no HOM couplers, but with one input coupler port for evacuation during vertical tests. The cavity EBW was finished in the mid of April 2010 at BIAM (Beijing Institute of Aviation Materials), Beijing.



Figure 1: IHEP low-loss large grain 9-cell cavity

Then the cavity was processed at IHEP. The processing recipe was:

- CBP (centrifugal barrel polishing) 190 μm
- BCP (buffered chemical polishing) 110 μm
- Annealing (750 °C, 3 hours at OTIC, Ningxia)
- Pre-tuning
- BCP 20 µm and Ultrasonic cleaning

The cavity was then sealed and shipped to STF of KEK. After HPR and baking, the cavity will be tested at STF in the end of June. For more details of the cavity fabrication and processing as well as the SRF facilities commissioning and operation, please refer to [3, 4].

The low-loss shape 9-cell cavity with full end groups is also under development. The end cell shape, the HOM couplers and the end plate were optimized to damp higher order modes and reduce high field Lorentz force detuning.

The copper model of the HOM coupler was made and the passpand performance was tested (Fig. 2). A compact tuning fixture was attached to the top plate of the HOM coupler cylinder to adjust the notch filter.



Figure 2: Components of the HOM coupler copper model, the bench test and the measured frequency passpand

High Power Input Coupler

Considering the design and fabrication technologies developed in the construction of the high power input coupler for the BEPCII 500 MHz superconducting cavity, the high power input coupler for the IHEP 1.3 GHz SCRF Accelerating Unit has been designed based on the STF baseline coupler with two TRISTAN type windows. Table 1 lists the general specifications of the input coupler.

Table 1: General specifications of the input coupler

Frequency	1.3 GHz
Power	Test: 1 MW, 1.5 ms,5 Hz
	(average: 7.5 kW)
	Oper: 300 kW,1.5 ms,5 Hz
	(average: 2.25 kW)
Two TRISTAN windows	safe operation
	clean cavity assembly for
	high gradients
2 K heat load	0.06 W
5 K heat load	1 W

Up to now, the design of the input coupler has been completed through careful RF, thermal and mechanical

simulation. Fig. 3 shows the CAD model of the whole coupler. The fabrication has just been started recently.



Figure 3: CAD model of the input coupler

Tuner and LLRF

The STF type tuner will be developed at IHEP. The mechanical simulation and design have been made for the fabrication of a prototype tuner. The tuner will be set in the middle of the cavity Ti helium vessel. A special motor to drive the tuner will be installed inside the cryomodule. The LLRF loops based on FPGA is under test (Fig. 4 and Fig. 5).



Figure 4: 1.3 GHz LLRF system



Figure 5: LLRF system model test

Two control loops are included in the LLRF loops: one is for frequency tuning and the other is for the cavity field. The intermediate frequency is 3 MHz from the analog front ends, by mixing the RF signal (1.3 GHz) with a 1303 MHz signal.

There are 8 RF signals for down-conversion. Four signals will be used for the control loops (the cavity reflect signal, forward signal, pick up signal, and

07 Accelerator Technology T07 Superconducting RF reference signal) and the other 4 signals for diagnostics of the RF system (klystron, load etc).

Amp & Phase modulator is employed for upconversion. The amplitude and phase information will be carried in the RF signal after this modulator, then the adjustment signal will be fed into the cavity through the klystron and waveguide.

Cryomodule

As the single 9-cell superconducting cavity cryostat, its structure is almost the same with the Euro-XFEL cryomodule:

- Single 9-cell cavity horizontal test cryostat with the length of 2683 mm and diameter of 966 mm;
- A 300 mm He Gas-Return-Pipe (GRP) acting as the support structure. Two adjustable posts are on the top of the vacuum vessel. One post is the fixed-point, and the other post can slide in the longitudinal direction;
- A 2 K forward line transferring single phase helium; a 2 K two phase line connected to the cavity helium vessels; a 4-8 K forward and return line; a 40 / 80 K forward and return line; and a warm-up / cool-down line with capillary to the bottom of cavity vessel;
- Aluminium thermal shields with stiff upper parts for 4 / 8 K and 40 / 80 K are attached to the support structure, with 10 layers and 30 layers of superinsulation (MLI) for 4 / 8 K and 40 / 80 K respectively;
- At the end of the cryostat, there is a small helium vessel with a liquid level meter inside, which is connected with He GRP and 2 K supplying line of the 9-cell cavity. The cavity can be kept in the 2 K LHe by monitoring the liquid level meter. Working flow chart is shown in Fig. 6.

The first edition of the drawings has been finished (Fig. 7). It is expected that the cryomodule can be put into machining this year.



Figure 6: Flow chart of the cryomodule



Figure 7: Mechanical drawings of the cryomodule

2 K cryogenic system

According to the requirement of the 1.3 GHz 9-cell cavity, the preliminary design of the 2 K cryogenic system has been finished (Fig. 8). This cryogenic system includes a 500 W @ 4.5 K refrigerator, a 3000 L liquid helium Dewar, a 4.5 K / 2 K cryogenic distribution valve box, the vertical test and horizontal test cryostats of the 9-cell cavity, the vertical test cryostat of the single cell cavity, the decompression vacuum pump for 2 K superfluid helium and purification system etc.



Figure 8: Cryogenic system of the 1.3 GHz SRF Project

Vertical test cryostat

The main design of the vertical test cryostat is referred to Fermilab: vertical test cryostat with low pressure heat exchanger and phase separator inside, which is equivalent to setting conventional cryogenic distribution valve box in the vertical test Dewar's vacuum jacket. 2 K helium will have high liquefaction rate and low transmission loss, but it also makes the internal structure more complicated, such as the cryogenic pipes layout, phase separators and cryogenic heat exchangers installation and vacuum insulation etc.

The preliminary process design was made (Fig. 9). At the beginning stage, 4.5 K liquid helium from the refrigerator or the liquid helium Dewar goes through the phase separator and then goes in directly from the Dewar's bottom. When the liquid helium's height meets test requirements, decompression and cooling will be started. 4.5 K liquid helium from the phase separator goes through the low pressure heat exchanger to form 2.5 K of the super cooled liquid helium, through J-T valve to form 2 K super flow liquid helium. The 2 K return gas goes through the cryogenic heat exchanger to reach about 3.5 K, and the remained can be further used or heated directly to normal temperature in the decompression and cooling vacuum system.

The mechanical design of the vertical test cryostat is nearly finished. For the dynamic heat load calculation, we take TESLA type cavity as example, Assume $R / Q = 1036 \Omega$, L = 1.038 m, $E_{\rm acc} = 35$ MV / m, $Q_0 = 8 \times 10^9$, the dynamic heat load of vertical test is 160 W, and the corresponding 2 K super flow helium mass rate is about 7 g / s. Considering the static heat load etc, we select 10 g / s as the design mass flow rate of the low temperature heat exchanger.



Figure 9: Flow chart of the vertical test cryostat



Figure 10: 3D model of the vertical test cryostat

SUMMARY

IHEP 1.3 GHz SCRF R&D is ongoing well. Most of the components will be fabricated this year. The whole accelerating unit will be integrated and horizontally tested in 2011.

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