STATUS OF THE IHEP 1.3 GHz SUPERCONDUCTING RF PROGRAM FOR THE ILC*

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Abstract

The 1.3 GHz superconducting radio-frequency (SRF) technology is one of the key technologies for the ILC. IHEP is building an SRF Accelerating Unit, named the IHEP ILC Test Cryomodule (IHEP ILC-TC1), for the ILC SRF system integration study, high power horizontal test and possible beam test in the future. In this paper, we report the components test results and the assembly preparation of this cryomodule. Processing and vertical test of the large grain low-loss shape 9-cell cavity is done. Performance of the in-house made high power input coupler and tuner at room temperature reaches the ILC specification.

INTRODUCTION

1.3 GHz superconducting radio-frequency (SRF) technology is one of the key technologies for the International Linear Collider (ILC) and future XFEL and ERL projects of China. With the aim to develop this technology, IHEP has started a program to build an SRF Accelerating Unit within ILC collaboration [1].

The SRF Accelerating Unit contains a 9-cell 1.3 GHz superconducting cavity, a short cryomodule, a high power input coupler, a tuner, and a low level RF (LLRF) system. The unit can undergo beam tests and can be used as the booster for an SRF linac.

LL LG CAVITY PROCESS AND TEST

IHEP's first low-loss shape (LL) large grain (LG) 9-cell cavity with full end groups (IHEP-02, Fig. 1) is fabricated in-house in 2012. The HOM characteristics of this low-loss shape cavity are measured [2].

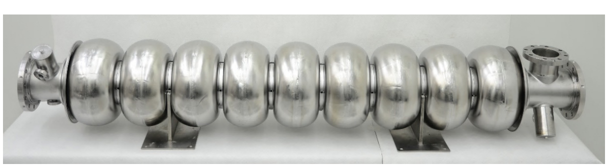

Figure 1: IHEP-01 low-loss large grain 9-cell cavity.

The cavity is processed and tested in FNAL in March to April 2013. The main processing procedures are: 200 µm CBP (tumbling) to mirror surface, 40 µm EP, heat treatment 800 °C 3 hr, pre-tuning, 20 µm EP, ultrasonic clean, HPR, 120 °C bake 24 hr. In the vertical test, thermal sensors and OST system are used. Tumbling removed most of the defects near equators, but several big ones remained. By optical inspection with Kyoto camera system, all the defects are in the joint points of grain boundaries and welds.

The cavity quenches at 20 MV/m with $Q_0 = 1.4\times10^{10}$ at 2 K (Fig. 2), 298 degree in cell#9, 2 mm from the equator (Fig. 3). The quench location has sharp and deep grain boundary step made during half cell pressing (Fig. 3). We didn't make intensive manual grinding. By passband mode test, all the other cells reach around 40 MV/m except cell#1 symmetrically limited by cell#9.

The cavity frequency under vacuum after vertical test is 1297.439 MHz, within the tuner range to reach 1300.000 MHz after cooling down. We will weld the helium vessel, assemble the magnetic shield and install the cavity to IHEP ILC-TC1 cryomodule.

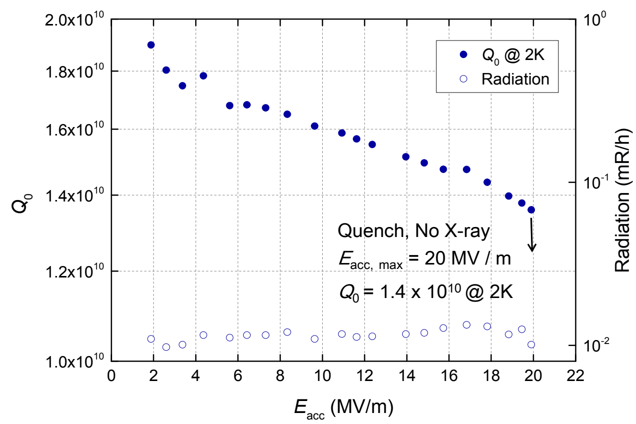

Figure 2: Test result of the IHEP-02 LL LG cavity.

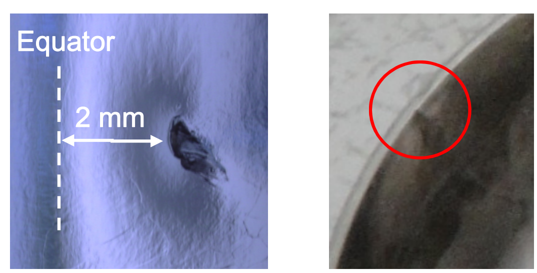

Figure 3: Quench defect in cell#9 (left), grain boundary step of the half cell after pressing and trimming (right).

HIGH POWER INPUT COUPLER FABRICATION AND CONDITIONING

The STF baseline cavity coupler is chosen as the coupler design reference. Two input coupler prototypes have been manufactured, assembled and vacuum checked in the end of 2012. Technical problems occurred during copper plating of thee RF surfaces of the stainless steel bellows, resulting in bubbles or copper layer disappeared after heat treatment. Solutions to avoid these failures have been found after numerous experiments in different

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manufactures. However, the copper plating procedure should be improved to increase the success rate, reduce the thickness of the copper layer and get a better uniform in the future. In addition, the bellows structure should be improved for better copper plating and brazing. We also suffered from the unreasonable sealing structure design of the inner conductors between the warm part and cold part. The sealing structure was modified based on a sealing experiment; four M5 bolts instead of three and thicker flange were adopted in the new sealing structure. Figure 4 shows the fabricated input couplers.

Figure 4: Two fabricated IHEP 1.3GHz input couplers.

High power test at room temperature was done at KEK in March 2013. The two couplers were mounted on a test stand. The test stand consists of a pair of back-to-back couplers, one connected waveguide, vacuum system and monitoring system, as shown in Fig. 5. An arc sensor is attached near each warm window and two monitor cameras are added at the bottom side of the connected waveguide to detect discharging. An ionization vacuum gauge is installed in each pumping system of the cold side and the warm side to observe outgasing and to realize vacuum interlock control further. One electron pick-up probes in each coupler are attached close to both sides of the cold window to identify multipacting positions and intensity. Several thermocouples are placed on the doorknob, the outer conductor and the connected waveguide to measure the temperatures. The input coupler system was baked out at 120°C for 72 hours prior to RF conditioning.

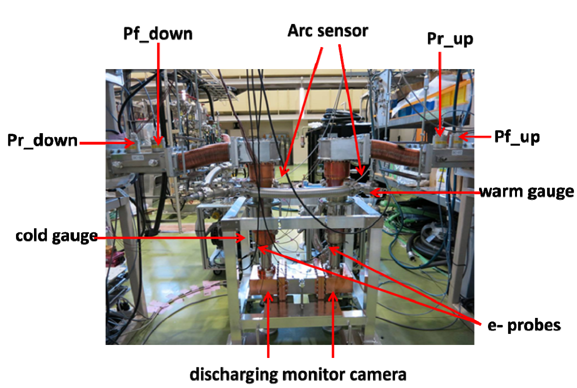

Figure 5: High power test stand.

The RF conditioning was started with 10 μs, 5 Hz pulse mode. The first outgassing and discharging were observed at 30 kW and 80 kW respectively. It took about 43 hours to reach the maximum RF power of 1200 kW in this pulse mode. Then the pulse width was increased gradually. i.e. the pulse modes of (30 μs, 5 Hz, 1200 kW), (100 μs, 5 Hz, 1200 kW), (500 μs, 5 Hz, 1200 kW), (1500 μs, 5 Hz, 1000 kW) were processed in turn. Figure 6 gives a summary of the conditioning time in each modes. We can see that after the initial pulse mode, the conditioning became faster. Outgassing, multipacting and discharging happened mainly in the initial conditioning. Finally, the two input coupler prototypes had been successfully tested up to 1000 kW with pulse mode of 1500 μs and 5 Hz after about 72 hour conditioning, which is the ILC specification. The operation stability was confirmed in further by keeping the couplers operated at 800 kW, 1500 μs, 5 Hz for 3 hours. It can be seen from Fig.7 the vacuum pressures and temperatures are stable.

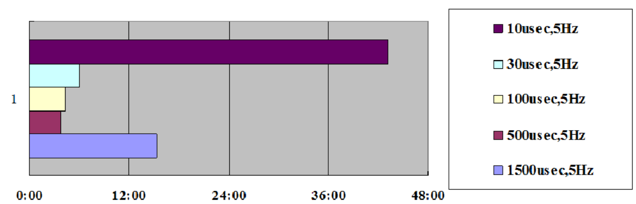

Figure 6: Summary of the conditioning time (in hr).

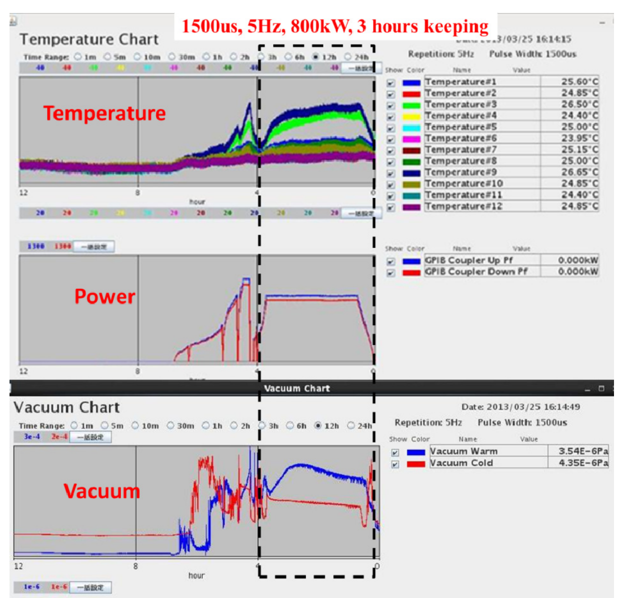

Figure 7: Vacuum pressure and temperature.

TUNER ROOM TEMPERATURE TEST

A slide jack tuner similar as KEK STF has been fabricated for the IHEP-02 9-cell cavity. In order to measure the performance of the tuner, we test it on a room temperature test stand with a dummy load (spring) of the same stiffness as the cavity.

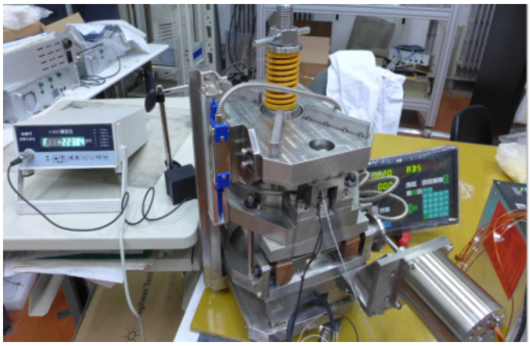

Figure 8: Tuner in the room temperature test stand.

The test curves and parameters are shown in Fig. 9, Fig. 10 and Table 1. Most of the parameters reach the design value at room temperature. We will make tuner test with LLRF system and the cavity in the cryomodule at cryogenic temperature.

Table 1: Designed and Measured Tuner Performance

Parameter	Design	Measured
Cavity tuning sensitivity	300 kHz/mm	/
Cavity stiffness	300 kgf/mm	/
Stroke of motor tuner	3 mm	1.5 mm
Motor step angle	/	0.09°
Coarse resolution	0.1 μm	0.012 μm @ free load 0.007 μm @120 kg
Stroke of piezo @300K	40 μm	48.8 μm（free load）
Stroke of piezo@2K	4 μm	/
Fine resolution@300 K	/	46 nm
The max load	1000 kg	> 1000 kg
Backlash	/	< 3.6°

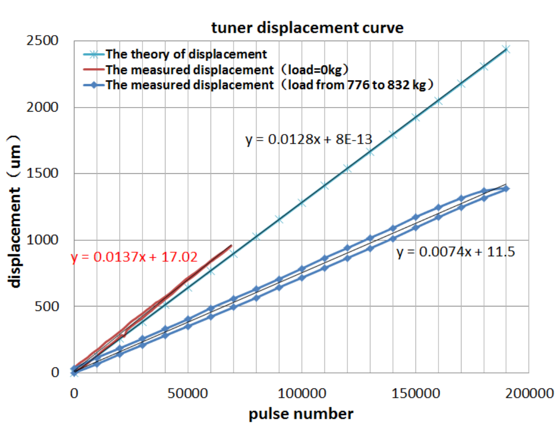

Figure 9: Motor tuner test curve.

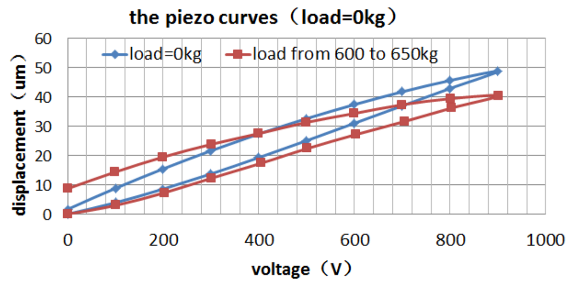

Figure 10: Piezo tuner test curve.

CRYOMODULE FABRICATION

Fabrication of the IHEP ILC-TC1 cryomodule is finished. The assembly toolings for the cold mass and the vacuum vessel are ready to use. Magnetic shielding of the 9-cell cavity in the module is fabricated [3].

Figure 11: Cryomodule components and tooling.

SUMMARY

Most key components of the IHEP 1.3 GHz SRF Program's accelerating unit have finished fabrication and performance test. The whole accelerating unit will be integrated in late 2013. The corresponding multi-beam klystron and Marx modulator as well as the 2K cryogenic system are also in preparation. The horizontal test will take place in the year of 2014 at IHEP.

ACKNOWLEDGEMENT

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