FABRICATION AND TEST OF THE 500 MHZ SC MODULES FOR THE BEPCII

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Abstract

Two KEKB type HOM damped SC cavities were constructed during past three years. These SC modules were re-designed to meet the RF frequency of 500 MHz of the BEPCII, the upgrade project of the Beijing Electron and Positron Collider, and have already been operated smoothly. It is a product of the successful collaboration among Mitsubishi Electric Co. (MELCO), KEK and IHEP of China. The cavity modules were fabricated and surface-treated by MELCO with the help and support of KEK. The vertical test of niobium cell, and the high power test of couplers and dampers were carried out in KEK, and the final acceptance tests were done in IHEP.

INTRODUCTION

An upgrade project for the Beijing Electron and Positron Collider was been proposed since it had already been operated for fifteen years since 1988. By adopting the double ring and multi-bunch colliding scheme, the beam intensity of one ampere can be expected, but the coupled bunch instability induced by HOMs becomes an outstanding issue. As a reasonable solution, application of a commercially available 500 MHz HOMs-damped SC cavity is a preferable choice for the BEPCII. But it was truly difficult to make a decision to choose a manufacturer between MELCO and ACCEL, who could construct the 500 MHz HOMs-damped SC cavity module.

Table 1: Comparison of the design parameters of the BEPC and the BEPCII

	BEPC	BEPCII
Ring No.	single	double
Beam energy	1.89 GeV	1.89 GeV
Design beam current	35 mA * 2 bunches	9.8 mA * 93 bunches
RF freq.	199.526 MHz	499.8 MHz
Cavity type	NC	SC
Cavity No.	4 /per ring	1 /per ring
RF voltage	0.3MV/per cavity	1.5 MV/per cavity
Beam power	10 kW/per cavity	130 kW/per cavity

After a deliberate consideration, the KEKB-type HOMs heavily damped structure SC cavity was chosen. According to the requirements of the BEPCII, the original KEKB SC cavity should be adapted in two aspects. By increasing the cell equator length of 23.6 mm, the resonant frequency of the niobium cell shift from 508.887 MHz to 499.8 MHz to meet the frequency requirement of the BEPCII, Also according to the beam loading of the BEPCII, the coupling coefficient of input coupler against the cell should be optimized, by using the code of microwave studio, the insert depth of the inner conductor of the input coupler was calculated. A test model cavity was been built in a lab of KEK to confirm whether the HOMs were suppressed enough or not by the dampers after taking those modifications, especially one should take care of the mode of TM011. Also the external quality factor of the input coupler was measured on this device; the measuring result shows a good consistent with the calculated one.

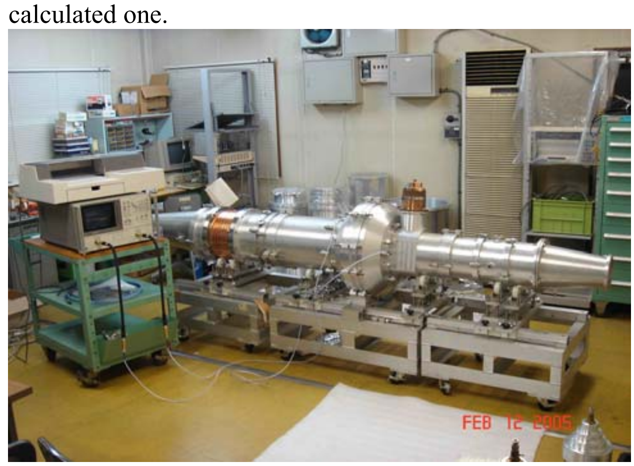

Figure 1: Aluminium model cavity in a test room.

TREATMENT OF NIOBIUM CELL

The SC modules were constructed from March 2004. The niobium sheets and blocks were bought from Tokyo Denkai Co. by MELCO, a moderate value of RRR from 170 to230 was required. Cell forming, mechanic polishing and electron beam welding were done in the Kobe factory

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of MELCO. Electropolishing for Niobium (Nb) cells were done at Nomura plating factory, which was near KEK. The cavity surface of 80 micrometer was removed in average aiming to eliminate the surface layer that was damaged in the forming process. After electropolishing, we found a dark contamination of 1mm on the inner surface of IHEP No.1 SC cavity, see figure 2. By grinding off using a handy polishing tool and giving the slight electropolishing, this spot could be perfectly eliminated and no effect was observed in the vertical performance test.

Figure 2: Before and after the mechanical local grinding.

In order to take out the hydrogen gas from the Nb surface, the Nb cavities were put into a Ti-box and annealed up to 700 °C in a vacuum furnace. And then a set of pre-tuning device was used to give a permanent deformation to the cavity length so as to make the cavity resonant frequency reaching to the design value. Finally Nb cells were electropolished again to remove 20 micrometer in average. After electropolising, the cavity was immediately rinsed by pure ozone water and ultra pure water in turn.

OTHER KEY COMPONENTS

Coupler

Because of adopting a choke structure around ceramic window and applying of bias aging, the KEKB-type input coupler can handle the RF power of more than 500 kW that keeps enough margin for the BEPCII. A problem, which bothers us, is how to transport it from Japan to China, because the length of the antenna of input coupler is more than 0.9 meter, and a mechanical simulation showed that the acceleration should keep lower than 5 m/s2 during the long-distance transportation, otherwise it had a risk to damage ceramic window. For this reason, an air-suspended supporting system is designed to prevent the strong shock during moving.

HOMs damper

Ferrite HOM dampers on both sides of the cavity were just same as that of KEKB SC cavities. Each damper was high power tested at KEK before delivering. They showed almost same microwave absorbing spectrum.

Frequency tuner

The tuner device including power supply, motor drivers and piezo elements were provided by KEK which were the retired components from the TRISTAN SC cavity.

After cooling down, the resonant frequency of IHEP No.1 SC module reached higher than the target one, as shown in table 2. Thus a pair of compensation springs was mounted on the cryostat to press back the tuner arm until the resonant frequency of the cavity decreased to the desired point, so that the tuner could obtain the enough regressing force for tuning. Figure 3 shows the tuner mechanism. This additional mechanism works well, however, the compensation springs have to be detached from tuner arm before every cooling down or warming up the cavity.

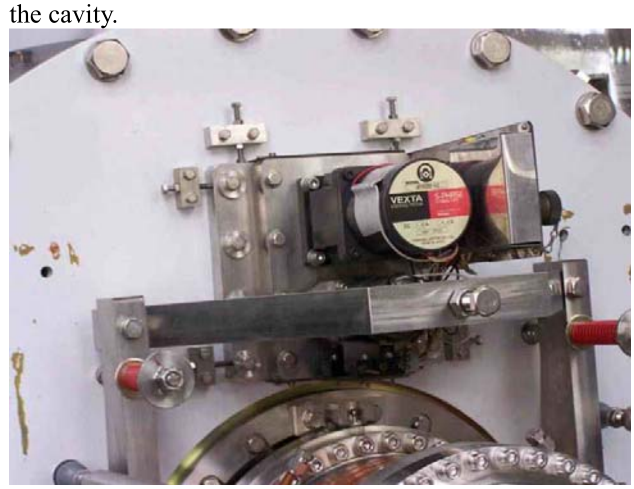

Figure 3: Mount a pair of compensation springs (red) on the tuner arm.

VERTICAL AND HORIZONTAL TEST

The vertical tests had carried out in KEK, first IHEP No.1 cavity was measured, its accelerating voltage reached to 3.6MV smoothly, no any limitation occurs. On the other hand, the performance of IHEP No.2 SC cavity did not reach the specification at the first cold test. Then this Nb cell was electropolished and rinsed again. Just before assembly in a clean room, we took a sample of rinsing water left in the cavity, and found some tiny fiber suspend in the water. By checking the water system, we found that a filter of the pure nitrogen gas line had damaged and some fiber fragments penetrated into the cavity during a slow feed of nitrogen gas into the cavity. Thus the cavity was rinsed by ultra pure water again in clean room, and its performance recovered basically. See chart 1, green line.

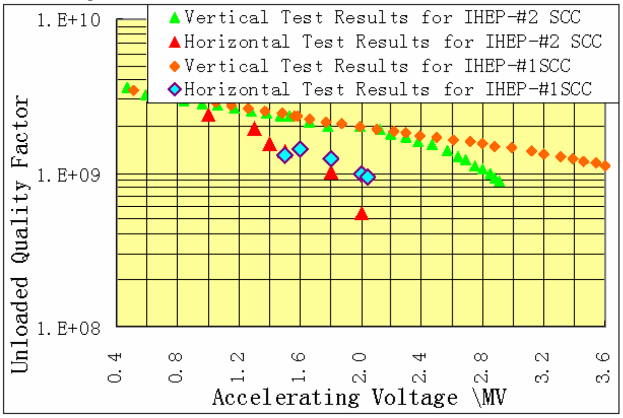

Chart 1: Unloaded quality factor vs. accelerating voltage.

After finishing the vertical test, cryostat, niobium cavity and coupler was assembled together and cooled to the helium temperature at KEK. Before the middle of May in 2005, two sets of the cryomodules including cryostat and the Nb cavity, input couplers, HOM dampers and tuners were transported to IHEP on time separately. It spent another year to assemble those parts including cavity, coupler, damper, tuner, gate valve, ion pump, vacuum gauge and other peripheral parts together. The horizontal tests were carried out from June to August of 2006 in IHEP, refer to table 2. Fortunately, both SC modules passed through the final acceptance test at the first cooling.

Table 2: Performance of both SC modules at the acceptance test

	Specification /Condition	IHEP-#1 (West SC)	IHEP-#2 (East SC)
Frequency	(4.5K) /[MHz]	499.977	499.700
Tuning sensitivity		139kHz /100kg	123kHz /100kg
Spring constant		0.38mm /100kg	0.36mm /100kg
Vc max	2.0 /MV [MV]	2.0 /2.3 (2007/04)	2.0 /2.2 (2007/04)
Field limitation		not limited	Thermal B.D
Q_0 (2MV)	0.5E+9	0.99E+9 /1.6E+9(2007/10)	0.55E+9 /0.53E+9(2007/10)
Qext (Coupler)	1.9E+05	1.9E+05	2.1E+05
Cryostat static loss	35 [W]	27.2	29

SUMMARY

Because this is the first time for MELCO and KEK to transport SC cavity to abroad, and is also the first experience for IHEP to deal with a SC cavity, the risk of failing was foreseen. Fortunately, all of the components had passed through the acceptance test at the first try.

BEPCII has commissioned since last November. The SR running mode operated successfully at 2.5 GeV with the beam current up to 200mA, and the beam accumulation of 500 mA has also tested at 1.89GeV in outside storage ring. However, in the double ring scheme of the physics operation mode, the bending magnets at the second interaction point are very close to the SC cavities, so that the outgas of the beam chambers due to the synchrotron light strongly influence to the increasing of beam current.

Now the spare SC module construction for BEPCII has already started up, and RF group of KEKB, SSRF (Shanghai Synchrotron Radiation Facility), and IHEP are to collaborate very tightly for the future SRF technology development, especially in the aspects of Nb cavity construction and test, high power coupler research and HOM damper manufacture.

ACKNOWLEDGEMENT

During the past several years, experts of KEK had visited IHEP many times to instruct IHEP person to do the module assembling, horizontal test and RF commissioning. Furthermore supervisors from MELCO helped IHEP for checking the auxiliary equipments and tools, and delivered the necessary technical document to IHEP.

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