STATUS AND DEVELOPMENT OF SUPERCONDUCTING CAVITY FOR KEKB

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Abstract

After successful test of 500 mA (Max 573 mA) electron beam at TRISTAN Accumulation ring (AR) using a prototype superconducting cavity, more than 4 superconducting cavities will be installed in high energy ring (HER) of KEK B-factory. The initial 4 superconducting cavities are almost same as the prototype one. The tests and results of the critical components of superconducting cavity system is described.

1 INTRODUCTION

The development of Superconducting cavity for KEK B-factory (KEKB) has started since 1991[1] on the basis of the experiences in the construction and 7 years operation of the 32 TRISTAN Superconducting cavities.

A single cell cavity with a cylindrical large beam pipe was designed to propagate HOMs toward the beam axis and damp them by ferrite absorbers bonded on inner surface of beam pipes[2].The absorber was made by HIP(Hot Isostatic Press) method and tested upto 15 kW RF power. For the feasibility study of the superconducting cavity for KEKB, a prototype module was constructed. This module was installed in AR and tested[3]. Fig 1 shows the prototype module installed in AR. Detailed discussion for high current beam test is presented on the other paper[4] in this conference

Fig.1 Prototype module for KEKB.

2 CAVITY

A single cell cavity was chosen to reduce the number of HOMs and to minimize the coupler power less than 500 kW. The diameter of aperture of 220 mm was chosen to provide the desired coupling of the lowest monopole modes of TM-011 and TM-020. A large cylindrical beam pipe(LBP) of 300mm diameter was connected on one side to obtain a sufficient coupling of the lowest dipole modes of TE-111 and TM-110. The same cavity shape is used for the AR prototype cavity and the HER superconducting cavity. The cavity parameters of the accelerating mode are summarized in Table 1.

Table 1: Cavity parameters of a HER Superconducting cavity.

Frequency	508.8	MHz
Gap length	243	mm
Dia.of aperture	220	mm
R/Q	93	Ohm
Loss factor	0.074	V/pC
Geometrical factor	251	Ohm
Esp/Eacc	1.84	
Hsp/Eacc	40.3	Gauss/(MV/m)

The prototype cavity was formed by spinning method of 2.5 mm thick Nb sheet of RRR 200. The surface treatment process using electropolishing is almost same as TRISTAN cavities. For high current application like as B factory, more stable surface is desired,so hydropreoxide rinsing was replace by ozonized ultrapure water rinsing(OUR)[5]. The OUR treatment removes completely the carbon contamination on electropolished Nb surface. The tested 508 MHz Nb cavities for KEKB showed high Q_0 values and the maximum accelerating field of 14.4 MV/m was obtained at 4.2K. Air exposures up to 4 days at 1 atm did not show degradations of cavity performances. The prototype cavity was rinsed by OUR and exposed to air for 2 days during full assembling in to the cryostat. In fully assembled cavity performance test,we call horizontal test, the field was improved by CW processing to 8 MV/m but standstill like a TRISTAN cavity. The pulse aging, in which the pulse power of 5% duty was added to the CW power[3] of just below the quench level, broke the deadlock and improved the field to 11.4 MV/m. In the high current beam test in AR, cavity

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performance was recovered by pulse aging from some degradation of field due to a large amount of condensed gas. The cavity performance was completely recovered by warming up to room temperature. One critical problem was frequent trips due to discharges in the superconducting cavity and the input coupler region. From the experience of TRISTAN operation, the trips were caursed by condensed gas on cold surface. In the first and second beam test at AR, the prototype cavity could not be operate stably due to frequent trips by arcing discharge interlock of the coupler. At that time vacuum condition was bad and a large amount gas condensed from both sides of the cavity. Before the third test (Oct.-Dec. 1996) the vacuum pump system of the beam ducts on both sides of the cavity were improved and the beam ducts were rinsed with OUR to reduce out gas rate. These were very effective to reduce the trip rate and the stable cavity operation continued for two weeks. The maximum beam current of 573 mA, which exceeded the world record of 220 mA set by a CESR superconducting cavity tested in CESR at Cornell university in 1994[6], was stored at 1.2 MV. A high current of 350 mA was also stored at 2.5 MV(10 MV/m) ,which is higher than the design voltage of 1.6 MV. The current limitations were not by cavity performances, but by the other things such as heating of ring components. For the beam ducts around the superconducting cavity of HER, we will use improved pump system like as improved AR one.

Additional loss of the cavity related to the beam current was observed[3]. In the third beam test, more detailed measurements of additional loss were done. The additional loss has seams like linear dependence on beam current. So higher current of two times more will not be too much additional loss in HER. The reason of additional loss is not clear now. We observed low energy (few electron volts) electrons at both side of the cavity using pick up probes of HOM power at taper transition beam ducts. The low energy electron current of up-stream side (LBP side) showed nonlinear dependence on the beam current and about one tenth intensity of the down stream one. The low energy electron current of down stream side(SBP side) depend on the beam current linearly. The direct synchrotron light could not hit the pick up probes and the cavity, and the electron produced by direct synchrotron light was swept out by magnet, but scattered photons might hit both, and have linear dependence on beam current. The vacuum pressure of the cavity dependent on beam current nonlinearly. So up stream side might be shade of scatted photon and only collect ionized electron. These electrons may increase electron loading in superconducting cavity and this type electron loading is one of the candidate reason for the additional loss.

3 HOM DAMPER

The loss parameter of the prototype module is 2.9V/pC for the designed bunch length of 4 mm. The main part of the loss comes from the tapers between the cell and beam ducts. Therefore, the loss parameters can be reduced to 1.6 V/pC in HER of KEKB by using the beam ducts of larger diameter and longer tapers. The expected power dumped to the HOM load for HER is 5 kW per module. The HOM dampers were made by IB-004 ferrite using HIP method. The power test of the damper were made using coaxial line with 508 MHz klystron. The maximum power of 11.7 kW and 14.8 kW were given to the 220 mm diameter and the 300 mm diameter damper. In the high current beam test in AR, the maximum HOM power of 4.2 kW was absorbed by the HOM dampers without any damage.

4 INPUT COUPLER

The input coupler for KEKB superconducting cavity has almost same design as that used for TRISTAN superconducting cavities. The gap of 3 mm of choke structure was changed to 4 mm to reduce the field strength at ceramic disk. Three monitoring ports were set near the ceramic window to monitor vacuum pressure, electron and discharge light(arc sensor) for protection and diagnosis. The couplers tested up to 800 kW[7] by the traveling wave and 300 kW totally reflected standing wave, changing phase up to half wave (in short time 500 kW which equivalently corresponding 2 MW traveling wave). In the second beam test, frequent discharge around the coupler occurred and temperature changed by cool gas flow rate affect to this trip rate. So condensed gas affected the surface condition and multipacting of the coupler occurred. Before the third test we prepared a biased type doorknob transition which can supply a bias voltage to the inner conductor of the coaxial input coupler. The biased type doorknob transition was tested at the test bench up to 300 kW standing wave changing phase of half wave length and traveling wave. Fig 2 shows the biased type doorknob transition for KEKB superconducting cavity.

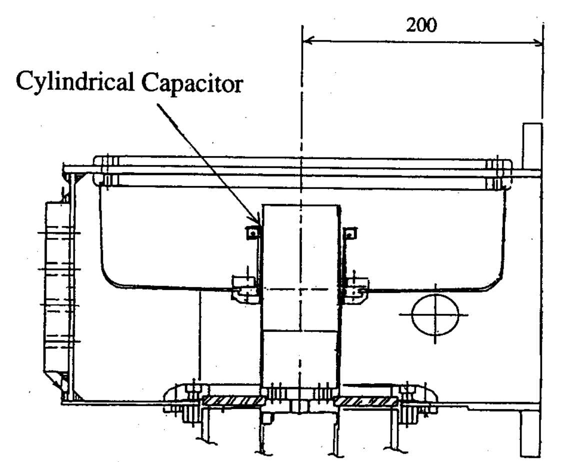

Fig.2 Biased type doorknob transition for KEKB.

Between the inner conductor and the doorknob, a capacitance of 1520 pF was inserted. The insulating

material was two layer of polyimide(like as Kapton) films of 0.125 mm thick each.
At the test bench ,the bias voltage of +/- 2000 volts range was tested. The bias voltage of around -700 V is most stable.(Fig.3)

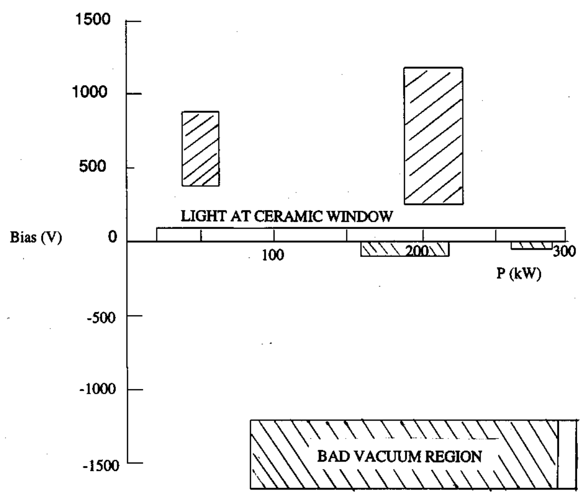

Fig. 3 Mapping of bias voltage for input coupler.

At third beam test the effect of the bias voltage was tested in short time of 2 hours to apply -700 V after frequent trip. After this test the cavity warmed up to room temperature for out gasing,and cool down again. The cavity was operated stably with and without the bias voltage in good vacuum condition for two weeks.

5 SUMMARY

Development of the critical components required for KEKB have been continued. The test results of the critical components of superconducting cavity for KEKB are summarized in Table 2.

Table 2: Design and test results of the critical components of superconducting cavity for KEKB.

	design	Bench test	Beam test
Cavity Max Vc	1.6 MV	3.3 MV	2.5 MV (2.9MV)
Coupler	500 kW	800 kW (300 kW)	160 kW (280 kW)
HOM load	5 kW	15 kW	4.2 kW

We reached the design requirement but should continue detailed test for critical components.
The improvement of the vacuum pumps and the surface treatment of vacuum ducts nearest to the superconducting cavity is essential for stable operation of superconducting cavity. For HER we will add NEG pumps on usual ion pumps and the OUR rinse will be used to clean up vacuum ducts.

To apply bias voltage for the inner conductor of input coupler is effective to reduce multipacting and to improve the aging process precisely. The biased type doorknob transition will be used for HER modules.
The construction of 4 superconducting cavities for HER have been started and they will be installed in next year.

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REFERENCES

[1] S.Mitsunobu, et al.,Proc.5th SC-RF Workshop, DESY,1991
[2] T.Takahashi, et al.,Proc.9th Symposium on Accelerator Scie. and Tech.,Tukuba,Japan,p327,1993
[3] T.Furuya,et al.,Proc. 5th European Particle Accelerator Conference,Sitges,Spain,June 10-14,1996.
[4] T.Furuya,et al., This conference
[5] K.Asano,et al.,Proc. 7th SC-RF Workshop,CEA-Saclay,France,
[6] H.Padamsee,et al.,Proc.of the 1995 Part. Accel. Conf., Vol 3,P 1515.
[7] S.Mitunobu,et al.,Proc. 7th SC-RF Workshop CEA-Saclay,France,P.735,1995