DEVELOPMENT OF A HOM-DAMPED CAVITY FOR THE KEK B-FACTORY (KEKB)

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This paper describes a high-power test model of the normal conducting RF cavity for the KEK B Factory, KEKB. This cavity is loaded with a large coaxial waveguide for higher order mode (HOM) damping. The waveguide is equipped with a notch filter designed to block the TEM wave at the accelerating frequency of 509 MHz. Other waves coupled with the cavity HOMs are guided through the filter and absorbed by bullet-shape sintered SiC ceramics. This prototype model has been designed and built to demonstrate the performance in high power operation and the fabrication technologies involved. The results of the high-power test is reported together with the cavity structure and its RF properties.

I. INTRODUCTION

The KEK B-Factory (KEKB) is a two-ring asymmetric e^+e^- collider capable of producing B meson pairs at a luminosity of $10^{33\sim34}$ $cm^{-1}s^{-1}$. The collider consists of a 3.5-GeV positron ring and an 8-GeV electron ring. Both rings are required to store high-current beams with low emittances to achieve the design luminosity.

The key issue in the RF cavity design for KEKB is how to reduce the HOM impedances which will drive coupled-bunch instabilities limiting the stored beam current. A straightforward way to reduce the HOM impedances is to damp the HOMs in the cavity by guiding them out through dedicated waveguides. A number of HOM-damped cavity structures have been proposed and studied at accelerator laboratories around the world.

In addition, the operation of the RF cavities under the heavy beam loading in KEKB will give rise to another more serious problem. That is the longitudinal coupled bunch instability driven by the accelerating mode itself. The resonant frequency of the accelerating mode should be detuned from the RF frequency toward the lower side so as to compensate for the reactive component of the cavity voltage induced by the beam. In KEKB, the required detuning frequency for a conventional copper cavity will exceed the revolution frequency, leading to the large excitation of a coupled-bunch synchrotron oscillation.

A new RF structure named accelerator resonantly coupled with an energy storage (ARES) [1] is being expected as a breakthrough in the development of the KEKB normal conducting RF cavity system. In the ARES scheme, a HOM-damped accelerating cavity and a large energy storage cavity operated in a high-Q mode are coupled via a resonant coupling cavity, where these three coupled cavities are operated in the $\pi/2$ mode. The storage cavity is employed to reduce the required detuning frequency, which is inversely proportional to the amount of the electromagnetic stored energy with respect to the reactive part of the beam-field interaction energy.

A high-power test model of a HOM-damped structure for KEKB, which would be employed in the ARES scheme, has been designed and built [2], [3]. The high-power test was carried out in February, 1995.

II. CAVITY DESIGN

The prototype cavity is designed on the basis of the following HOM-damping scheme: the cavity is loaded with a large coaxial waveguide equipped with a notch filter. The filter blocks the TEM wave coupled with the accelerating mode while passing other waves coupled with the cavity HOMs. Damped structures with this scheme were devised by Shintake [4] and by Akai [5], independently of each other.

A. RF Design

A schematic drawing of the prototype cavity is shown in Fig. 1. RF parameters of the accelerating mode are listed in Table 1. The coaxial waveguide is equipped with a notch filter of a quarter-wavelength radial line. The gap dimensions of the waveguide and filter structures were carefully determined in order to avoid multipactoring discharge at the RF frequency of 509 MHz.

The cavity monopole and dipole modes are coupled with the TEM and TE11 waveguide modes, respectively. The first TEM stop frequency of the filter must be exactly tuned to the RF frequency. The bump structure in Fig. 1 can be lathe-machined for this purpose. The filter structure is deformed in order to raise the second TEM stop frequency from 1390 MHz to 1670 MHz. For the TE11 waveguide mode, the first and second stop frequencies are 530 MHz and 1680 MHz, respectively.

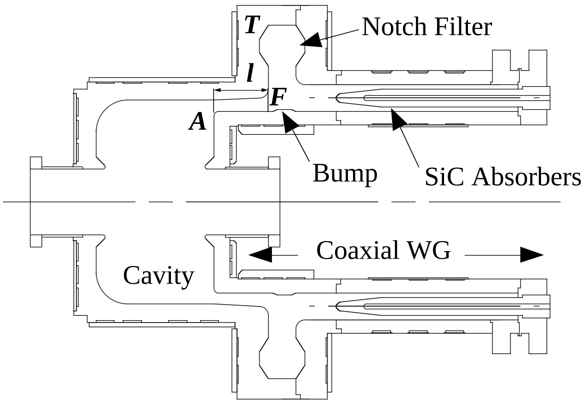

Figure 1: A schematic drawing of the test cavity

Table 1: RF parameters of the accelerating mode

f_{RF}	(MHz)	508.6	
Vc	(MV)	0.6	
Pc	(kW)	75 (*)	
R	(MΩ)	5.3	4.8 (*)
R/Q	(Ω)	150	
Q		3.5×10^4	3.2×10^4 (*)

(*) A degradation of ~10% due to copper surface imperfection and ports is taken into account.

Around the second TEM and TE11 stop frequencies, some cavity HOMs could be trapped. The beam bore diameter is enlarged to 145 mm in order to lower the cutoff frequencies of the beam pipe for the TM01 and TE11 circular waveguide modes below the second stop frequencies of the filter.

The filter position along the waveguide not only affects the accelerating mode Q value but also the HOM-damping properties. Waves propagating at HOM frequencies are partially reflected at the gap transition denoted by *F* in Fig. 1. Therefore, the distance from the waveguide aperture denoted by *A* to the gap transition should be carefully determined. This issue and the HOM characteristics are discussed in references [2] and [3].

Waves passing through the filter are guided toward sixteen SiC absorbers inserted from the waveguide end. Each absorber is a bullet-shape sintered SiC ceramics with dimensions of 40 mm in diameter and 400 mm in total effective length including a 100-mm nosecone section and directly cooled by water flowing in a circular channel inside. The high-power test of a bullet-shape prototype absorber was carried out using an L-band pulsed klystron. The prototype functioned without any vacuum, thermal, or discharge trouble up to an average RF power of ~2.5 kW. The R&D of the SiC absorber is reported in Ref. [6] at this conference.

B. Mechanical Structure and Assembly

The cavity parts with heat generation inside are made of oxygen-free copper (OFC). Stainless steel is used for the inner and outer cylindrical parts for the HOM damping coaxial waveguide to mechanically reinforce the whole cavity structure. Vacuum furnace brazing and electron-beam welding techniques are employed to assemble the cavity parts. Finally, the flanges (shown at the right end in Fig. 1) of the outer and inner cavity parts are tightly connected and vacuum-sealed by TIG welding. Both beam bores are aligned by using an optical alignment telescope. The alignment error for the test cavity was within 100 μm.

III. HIGH-POWER TEST

A. Setup

Figure 2 shows a photograph of the test cavity with an input coupler and a tuner installed. A TRISTAN-APS input coupler [7] capable of 300 kW transmission power was used for RF power feed. This coupler uses a loop coupling and has a cylindrical ceramic window at the rectangular-to-coaxial transition. The coupling factor to the test cavity was adjusted to 1.25 by rotating the loop.

A TRISTAN-APS tuner was used for tuning the cavity in high power operation. The tuner has a 7-cm-diameter plunger with about 6 cm of travel. This gives a tuning range of about 1.8 MHz.

The measured loaded Q value of the accelerating mode was 14000. With the coupling factor of 1.25, the unloaded Q

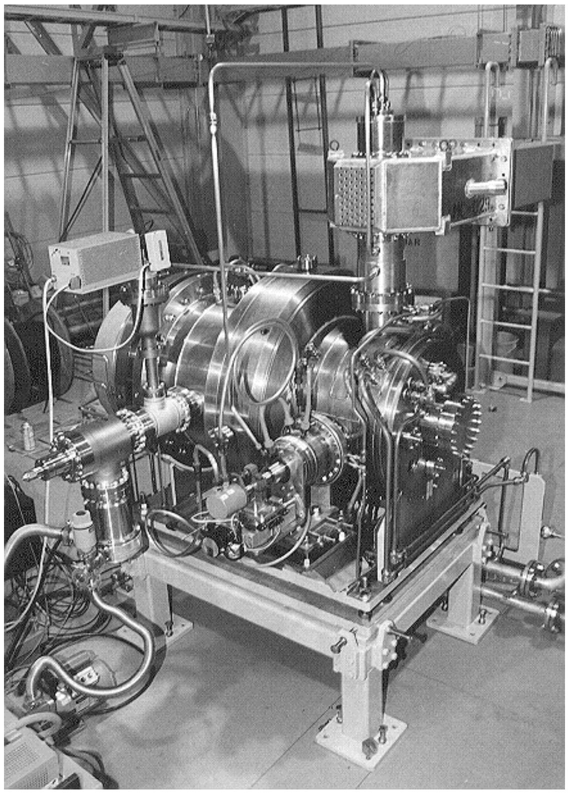

Figure 2: The test cavity with an input coupler and a tuner installed.

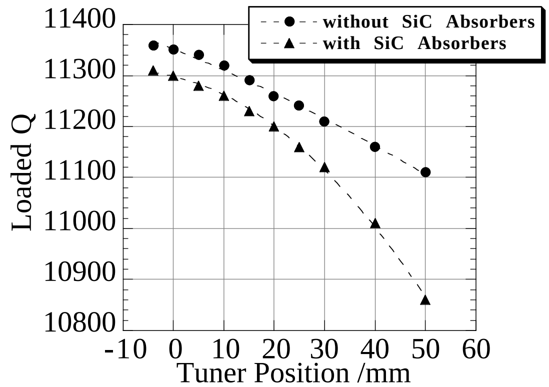

Figure 3: The loaded-Q responses to the tuner position for the cavity with/without the absorbers.

value was 31500, which is 90 % of the theoretical value (see Table 1) by SUPERFISH. The degradation of 10 % is probably due to the wall surface imperfection and the coupler and tuner ports.

Figure 3 shows the loaded-Q responses to the tuner position for the cavity with/without the SiC absorbers installed. The coupling factor is different from 1.25 for high-power test. The response for the cavity with the absorbers shows a more rapid decrease compared with that when no absorber is installed. This is due to distortion of the accelerating field by the tuning plunger. The distorted field will excite higher coaxial-waveguide modes even at the RF frequency. The higher-mode waves are not blocked by the notch filter and thus guided to the absorbers. Analysis of the field distortion using the numerical simulation code HFSS showed that the deformed accelerating mode leaks from the notch filter in the TE21 coaxial-waveguide mode. Further investigation is in progress in order to overcome the field deformation arising from the large coupling to a storage cavity in the ARES scheme.

B. RF Conditioning

RF power was supplied by a CW klystron Toshiba E3786. The whole cavity system was cooled by 100 l/min of water: 70 l/min for the cavity cooling circuits, 10 l/min for the input coupler and tuner, and 20 l/min for the SiC absorbers. The cavity was evacuated from two pumping ports at the HOM damping coaxial waveguide. The base pressure was 3×10^{-8} Torr before the high-power test.

RF conditioning of the cavity was continuously carried out keeping the vacuum pressure below $\sim5\times10^{-7}$ Torr. Figure 4 shows the conditioning history. It took about four hours to go above 0.5 kW of RF input power after the conditioning was started. That was probably due to multipactoring discharge in the coaxial waveguide aperture or in the notch filter although no light emission of discharge was observed. The cavity was conditioned up to 90 kW in about 33 hours and then the first high-power test was ended.

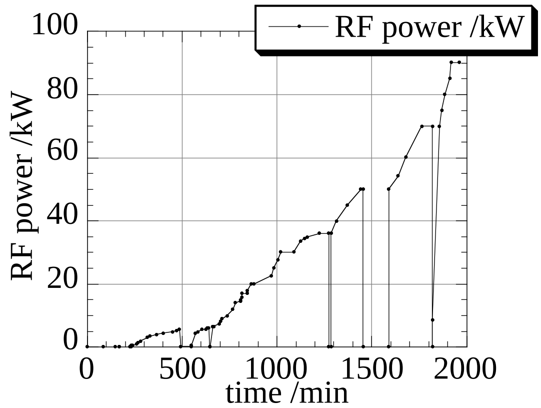

Figure 4: The history curve of the first RF conditioning.

Finally, the cavity was conditioned up to a peak RF input power of 110 kW. Subsequent high-power tests showed that the cavity was stably operated for long time up to 70 kW and the vacuum pressure was below 5×10^{-8} Torr. Small pressure rises due to gas bursts were frequently observed above 80 kW and similar events were sometimes observed at 40 kW. Further RF conditioning is planned for more stable high-power operation.

IV. SUMMARY

We have demonstrated the high-power performance of the HOM-damped accelerating structure for KEKB. However, further R&D work is required for more stable high-power operation and for an ARES scheme employing this damped structure.

V. REFERENCES

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