# Development of Superconducting Cavity for KEK B-Factory

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*Abstract*

Our first B-Factory superconducting prototype cavity was fabricated and tested at 4.2°K in KEK. We achieved the maximum acceleration field of 11.6 MV/m. In the test, temperature-rise maps and X-ray maps on the outside surface of the cavity were taken, and we obtained information of the state of the cavity. Parallel to this, Higher Order Mode (HOM) damping has being measured by using an Al model cavity. This paper reports the present status of the development of the superconducting cavity for B-Factory in KEK.

## I. INTRODUCTION

The beam current of 2.6 A for low energy ring of B-Factory is 100 times higher than that of TRISTAN in KEK [1]. For such a high current accelerator, it is a severe problem for RF cavities to absorb HOM power because of the beam instability. In the case of superconducting cavity, the cavity shape is optimized to propagates out the HOM power to the beam pipes and damp it by absorbers located inside the pipes. Then how much HOM power propagate out to the beam pipes and can be absorbed by ferrite dampers is the key of the use of superconducting cavities. In Cornell university, a cavity with a "fluted" beam pipe has been studied to achieve that requirements[2]. In KEK we adopted a large diameter beam pipe because of the ease of manufacturing. The performance of this beam pipe has been tested by an Al-model cavity and a prototype Nb cavity has been fabricated. Parallel to the development of the superconducting cavity with such a beam pipe, R & D of HOM absorbers has been studied

## II. HOM MEASUREMENT OF Al-MODEL CAVITY

We adopted a single cell superconducting cavity to reduce the input coupler load and HOM load. The geometry of the cavity is in Fig. 1. One of the beam pipes has a large diameter of 30cm (large beam pipe LBP) which is optimized so as to lower the cut off frequency than that of HOM's. The diameter of the other beam pipe is 22cm (small beam pipe SBP). HOM power is damped by ferrite tiles which are located on the inner surface of the beam pipes. The geometry of superconducting cavity is designed so that the external Q's of HOM's become as small as possible [3]. The input coupler of the B-Factory cavity is the same type coaxial coupler that was used for the TRISTAN 5-cell cavity. The main parameters for the designed superconducting cavity are described in Table 1.

An aluminum model cavity was manufactured to check the design properties. Measured frequency and $Q_L$ of HOM's are listed in Table 2 as well as R/Q and Qext calculated by URMEL. The powers of dangerous HOM modes could be damped sufficiently by ferrite tiles which were located on the beam pipes. The $Q_L$ was measured with 64 ferrite tiles in the large beam pipe and 44 in the small beam pipe. TDK ferrite IB-004 was selected as the absorber, and the size of one ferrite tiles is 60mm x 60mm x 3.8mm.

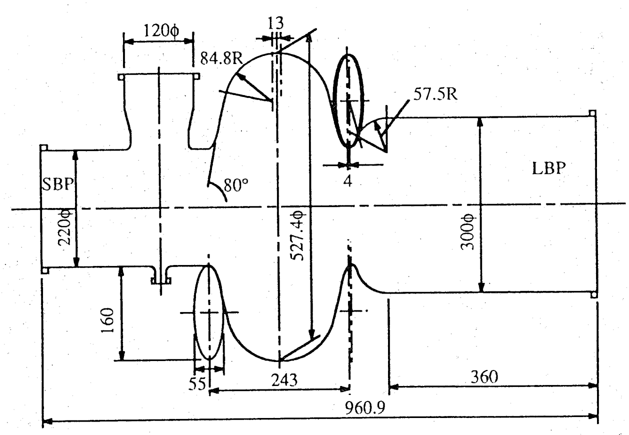


Fig. 1. The geometry of the prototype cavity for KEK B-Factory .

Table 1. The main parameters of the cavity

| | |
|---|---|
| Accelerating Frequency | 508.6MHz |
| R/Q | 93.3 Ω/cavity |
| Hsp/Eacc | 40.0 G/(MV/m) |
| Esp/Eacc | 1.83 |

Table 2. Frequency, R/Q and Qext of major HOM's.

| Mode | Freq.(MHz) | R/Q | Qext(URMEL) | $Q_L$(meas.) |
|---|---|---|---|---|
| $TM_{011}$ | 1011 | 8.7 | 121-131 | 110 |
| $TM_{020}$ | 1071 | 0.4 | - | 80 |
| $TM_{110}$ | 693 | 21* | 94-138 | 115 |

*R/Q was defined by $(R/Q)/(R_0\omega/c)^2$, $R_0$=5cm.

## III. FABRICATION AND SURFACE TREATMENTS OF Nb-CAVITY

About 80 μm of the cavity inside surface was removed by pre-electropolishing (pre-EP) and first electropolishing (EP1) prior to annealing of 700°C x 90 minutes at $1.1 \times 10^{-5}$ Torr. After annealing an additional 15μm was removed by the final electropolishing (EP2). The processes of the final surface treatments are listed in Table 3. These fabrication and surface treatment processes are the same as that of 5-cell superconducting cavities in TRISTAN.

Table 3. Final surface treatments.

| | |
|---|---|
| EP2 (37min) | 15 μm with $N_2$ gas flow |
| 1st rinse (40min) | pure water |
| 2nd rinse (30min) | shower rinse with pure water |
| $H_2O_2$ rinse (60min) | $H_2O_2$ rinse in the ultra sonic (U.S.) water bath |
| 3rd rinse (120min) | pure water overflow in the U.S.water bath |
| 4th rinse (30min) | $N_2$-gas flow & ultra pure water three times of overflow |

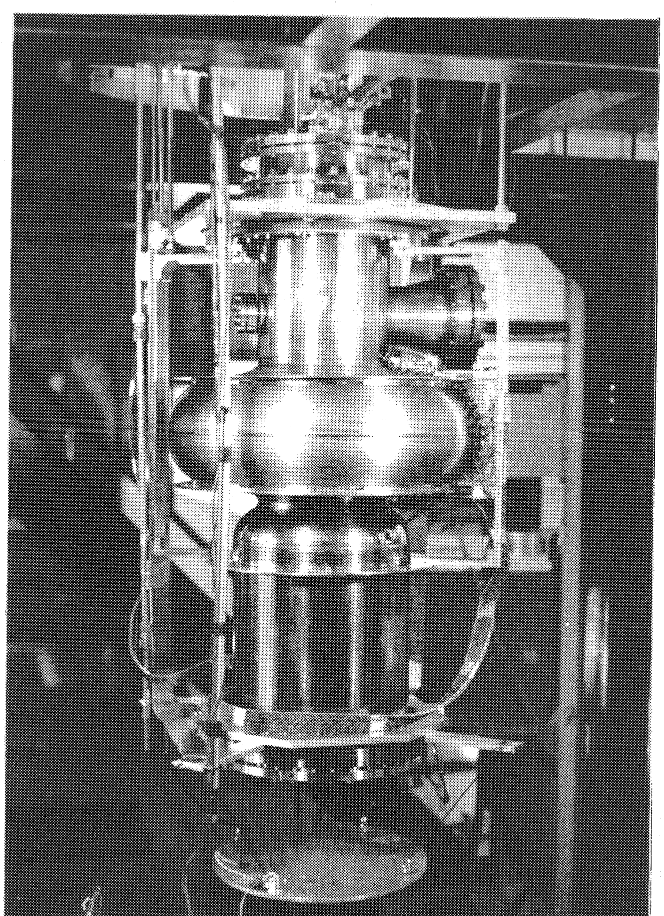

Fig. 2. The superconducting cavity prepared for vertical testing.

## IV. 4.2°K VERTICAL TESTS OF Nb-CAVITY

Two vertical tests have been made to date. Fig. 2. shows the Nb-cavity prepared for vertical testing. An extension beam pipe was installed at the end of the small beam pipe. Inner surfaces of the extension beam pipe and two endplates were made of stainless steal plated with copper to reduce the RF loss at the surface. Powers loss of these inner surfaces was estimated less than 2.6 % of that of Nb-cavity at $Q_0=10^9$. 19 X-ray sensors and 25 carbon resisters were distributed on a frame along one meridian of the outer surface between the lower and upper irises. Carbon resisters which were used as thermometers to measure the temperature-rise were pressed by plate spring against the cavity wall [4]. S1722 PIN photodiodes (Hamamatsu Photonics) were used as photon intensity monitors to measure the X-ray. Rotating speed of the frame was controlled by the sensor position controller in 2~6 minutes per turn, and it took about 2 seconds to scan all channels of the sensor arrays. The data were taken at every 6°~2°.

$Q_0$-$E_{acc}$ curves of the two test are presented in Fig. 3. Fig. 4(a)-(d) show the temperature-rise maps and X-ray maps of the first measurement at each field level. The sensitivity of the temperature map is 0.054 °K/mV. In X-ray maps, 1 V corresponds to $\sim 1 \times 10^9$ photons/cm$^2$·sec. In the first measurement, $Q_0$ dropped suddenly from $1.22 \times 10^9$ to $5.42 \times 10^8$ at $E_{acc}$=10 MV/m after a heavy discharging. For recovering the $Q_0$, we tried RF-processing of about 75 minutes, but the cavity performance did not change. At this field, X-ray map showed the large peak near the lower iris on the meridian of 45° and temperature map also showed the heating spot at the same position(Fig. 4(a)). Next we tried pulse aging (~200W x several msec) for 120 min. and the performance of the cavity could be recovered. During the pulse aging, temperature map showed the large heating spot on the 150° meridian instead of the spot on the 45°. Fig. 4(b) shows the maps during the pulse aging process and the maps just after the aging is in Fig. 4(c) at the field of 9.4 MV/m. This

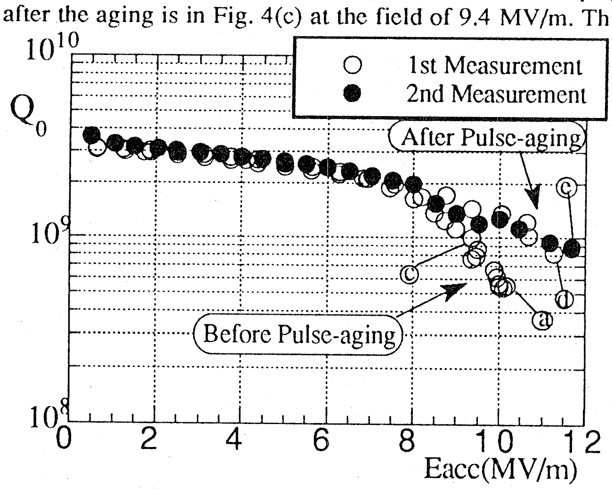


Fig. 3. $Q_0$ vs $E_{acc}$ for the cavity test at 4.2°K. The indexes of a,c,d,e are corresponding to Fig. 4 (a),(c),(d),(e) respectively.

means that the degradation of the $Q_0$ was caused by the electron emission on the meridian of 45° which could be eliminated by the pulse aging. After the pulse aging, the new emission site on the 150° became dominant. The maximum field of 11.3 MV/m was achieved after the pulse aging. The $Q_0$ at the field level was $8.19 \times 10^8$. The maps at the maximum field shows the X-ray peaks on the 150° and 320° meridians (Fig. 4(d)). But no heating spot was observed.

After one month later, the cavity was cooled again without any surface treatment. The cavity performance and the maps showed the same results as that of final state at the 1st cold test. The maximum $E_{acc}$ and $Q_0$ were 11.69 MV/m and $8.8 \times 10^8$ respectively. The field was limited by the electron emission on the 150° and 320° (Fig. 4(e)), but the emission on the 45° did not appeared. Warming up the cavity to room temperature did not affect to these emission sites This suggests that the cause of the emission sites is not the gas condensation during cooling down but some defects on the surface.

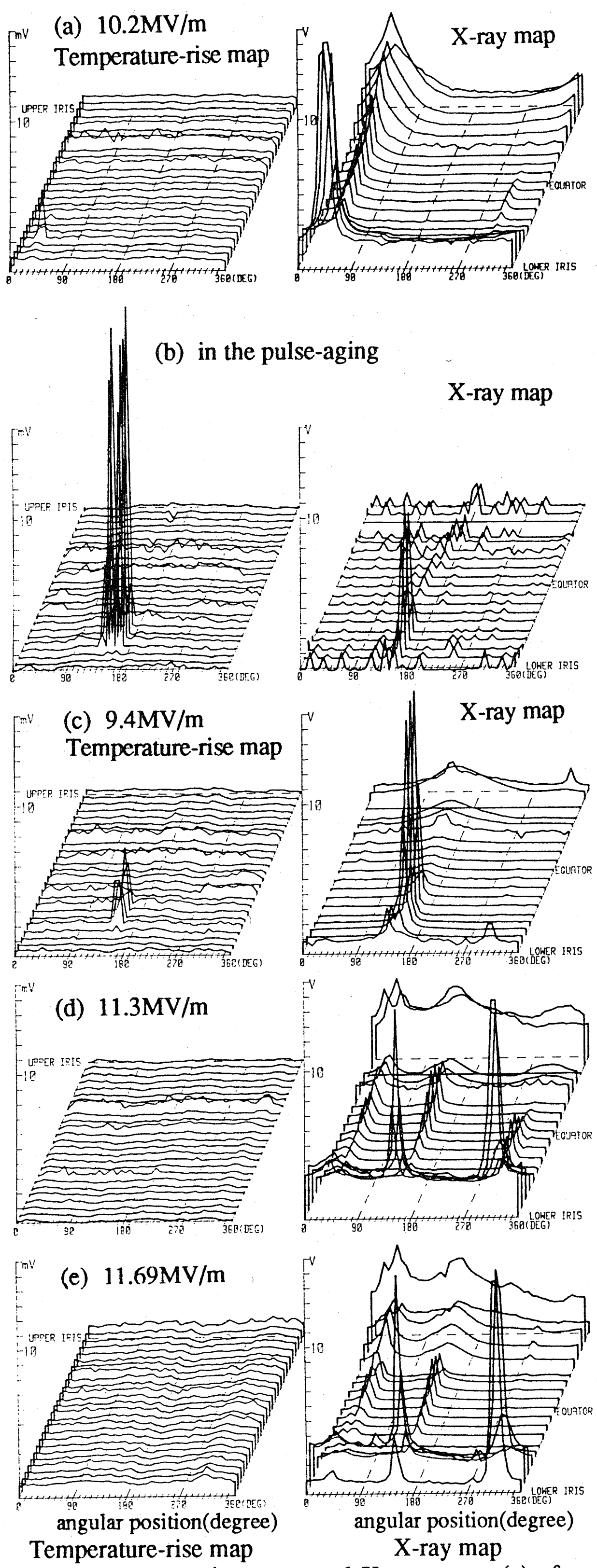


Fig. 4. Temperature-rise maps and X-ray maps, (a) after discharge, (b) in the pulse-aging, (c) after pulse-aging, (d) at just below $E_{acc}$ max. of 1st measurement, (e) at just below $E_{acc}$ max. of 2nd measurement.

## CONCLUSION

We designed the new shape for KEK B-Factory and tested the shape by using Al-model and Nb cavities. In the Al-model test, Q of HOM's could be damped enough by Ferrite tiles located on the beam pipes. Nb-cavity showed the field of 11.7 MV/m, which is a little lower than that required in B-Factory. But our mapping system made clear the limitation of the cavity field, that is, electron emission near the iris. The mapping system will be a useful diagnostic method to understand the field limitation mechanism, if more data are accumulated. Further, at the whole area near the irises, X-ray emission is observed like as background. These background electrons should be reduced for operating at higher field gradient.

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