OPERATION EXPERIENCE OF SUPERCONDUCTING CAVITIES FOR KEKB

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Abstract

Eight superconducting cavities for KEKB have been installed in KEKB tunnel. The superconducting cavities have large diameter beam pipe of 300 mm to damp beam induced HOM power. The superconducting cavities are stably operating for physics experiment of CP violation, and the world highest maximum current of 872 mA was successfully stored using the superconducting cavities. Experience of cavity operation and many troubles will also be described.

1 INTRODUCTION

KEKB, an asymmetric energy double-ring electron-positron collider for B-physics, was commissioned in December 1998. Two types of heavily-damped cavities are used in KEKB. A normal conducting cavity system (ARES) is used in both the low energy ring (LER) and the high energy ring (HER); 4 superconducting cavities were initially used in the HER. [1] Four additional superconducting cavities were installed in the HER at the summer shutdown of 2000. This increased the beam current of the HER up to 872 mA. The current was not limited by the superconducting cavities but rather by HOM heating of vacuum components such as masks. High current application of superconducting cavities needs high field damped structure type cavities, high power input couplers, HOM loads and powerful cryogenic systems of 6.5kW He refrigerators. We experience many troubles like as metal gasket and indium seal, shortage of low temperature cable, one ceramic window breaking during horizontal test, and another one damaged during beam operation and coupler processing due to long shutting off time of 10 m second, and burning of bias cable in doorknob transition at test bench.

2 SUPERCONDUCTING CAVITY

Based on the long-term operation of 32 superconducting cavities in TRISTAN and the successful beam test of the prototype cavity at the TRISTAN Accumulation Ring (AR) reaching a maximum current of 0.57 A in 1996, we started construction of 4 superconducting cavity modules for the KEKB HER. Figure 1 shows the whole module. The superconducting cavity has a single cell structure with large aperture beam pipes on both ends so that higher order modes (HOM) can propagate out of the cavity and be damped by ferrite absorbers bonded on the inner surface of the beam pipe

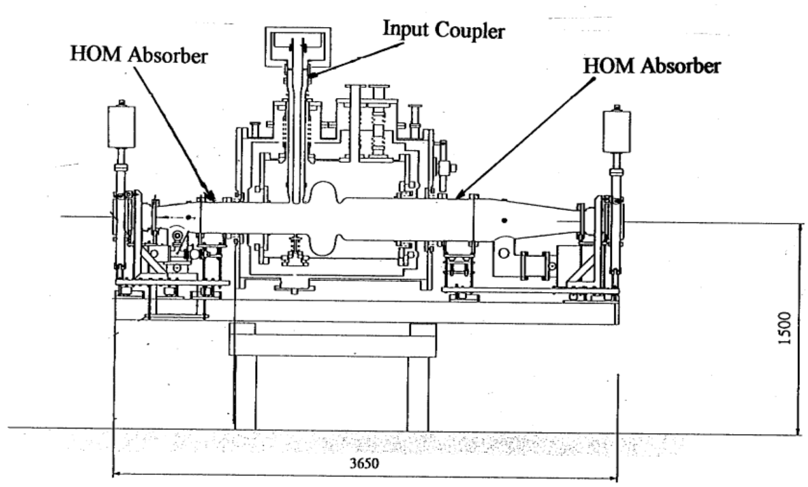

Fig. 1 Superconducting cavity of KEKB

The accelerating fields attainable in the cavities were first measured using a vertical cryostat. The results were higher than 15 MV/m as shown in Fig. 2. The accelerating fields decreased to 10-11 MV/m after full assembling but exceed the necessary operating field of 6-8 MV/m.

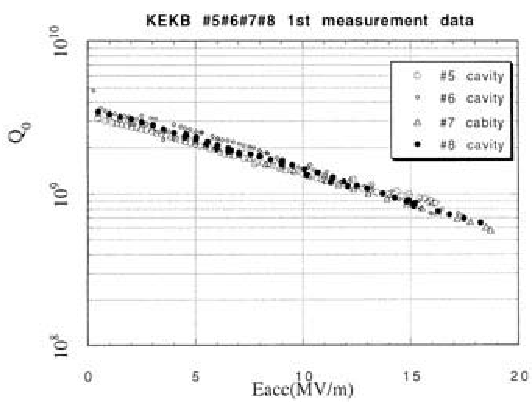

Fig. 2 Performance of vertical test for recent four SC cavities.

2 KEKB INPUT COUPLER

The input coupler for the KEKB superconducting cavity is almost the same design as that used for the TRISTAN superconducting cavities. The 3 mm choke structure gap was changed to 4 mm to reduce the field strength at the ceramic disk. One of authors suggested the use of water-cooling for the inner conductor of the TRISTAN coupler. The calculated heat transfer by radiation is 0.6 W for the electro-polished Cu inner conductor. This heat transfer is small and is expected to have almost no effect on cavity performance in the case of high fields of more than 10 MV/m for KEKB. The cooling water system has enough cooling capacity up to 1 MW power transmission. The window of the coupler is almost same as those in the 1MW klystrons used at TRISTAN, which have a long lifetime of more than 50000 hours. So the TRISTAN coupler can be operated at 1 MW in principle but were used only up to 200 kW in TRISTAN. So for higher power operation, the KEKB couplers need more diagnostics for precise RF processing and interlock operation.

Before cooling down the cavities, we condition the input couplers up to 300 kW with perfect reflection condition, and up to 200 kW with dc bias voltages applied on the inner conductor up to +- 2kV.[2] The developed high power door knob transition with capacitor for applying bias voltage works well up to 300 kW perfect reflection condition (corresponding to 1.2 MW of forward power). The insulating material is two layer of 0.125 mm thick polyimide film, shown in Fig 3. At test bench, some cable burned due to RF heating of standing wave of leaked RF from cylindrical capacitor. We are trying absorbing material of ferrite tiles to reduce standing waves.

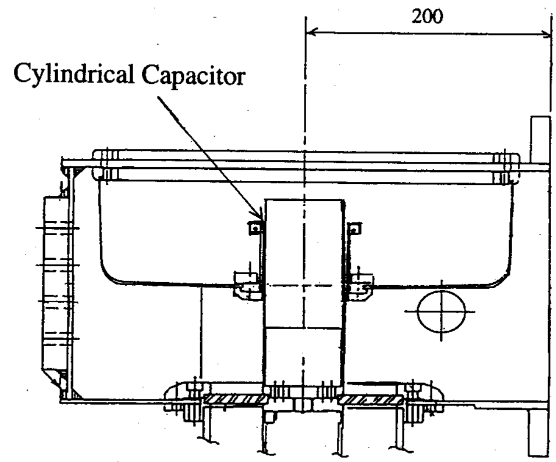

Fig 3 Bias type door knob transition for SC cavity.

3 HOM DAMPERS

HOM dampers are made of ferrite and tested up to 5 kW and 7 kW for the SBP and LBP, respectively, with a 508 MHz coaxial line, then baked at 150°C for about one month to reduce the outgassing rate. Considering the importance of making the amount of gas flowing into the cavity as small as possible for stable operation, we installed five 400 liter/s NEG pumps and one 300 liter/s ion pump on the duct between each module.

4 BEAM OPERATION

The initial four cavities were operated stably with gradually increasing beam current.[1] Four new cavities were operated from start-up with high current of more than 500 mA. The cavity vacuum pressure was worse than $7x10^{-6}$ Pa, about one order worse pressure than the initial cavities.

We experienced rather a high trip rate of a few times per week due to superconducting cavity breakdown. Sometimes, processing with bias voltage of -700 volt during cavity excitation was effective in improving the poor vacuum condition. Trips did not occur for more than two weeks after this processing. With the beam current limited by heating of masks, the maximum current reached is 780 mA for the HER with superconducting cavities. Two cavities have bud RF-monitoring cables, preventing feedback cavity frequency tuning. So two cavities were detuned at liquid helium temperature. At the New Year shut down, the shorted cables were replaced with new anchor type cables to prevent shorting between inner and outer conductors by caused thermal cycling. Another cavity leaked at the indium seal at the LBP and is now being repaired. During repairing indium seal, large metal gasket of U-tight seal show another type leaks of clacking at welding part of copper outer shell.

The high beam current operation of these cavities depends on the high power capabilities of our coupler-380 kW at maximum, though 200-300 kW is sufficient for normal operation.

The cavity performances have shown no degradation during more than two years with high current operation.

Higher current test have been tried at July 2001, and maximum current of 872 mA was stored and the limitation is not due to SCC.

Table 1

	Design	Bench test	Beam test
Cavity Max Vc	1.6 MV	4.5 MV	2.5 MV
Coupler	270 kW	800 kW	380 kW
HOM load	5 kW	15 kW	7.4 kW

5 FAILURES BEFORE AND AFTER INSTALLATION

We experienced many failures as following,

- One coupler ceramic break during horizontal cavity test.
- One coupler damaged during operation of bud vacuum with 10 msec field decreasing time.
- One coupler port break during installation and repaired using ultra-sonic solder.
- Tow piezo element break and exchanged by properly made crystal one.
- Ferrite burned in doorknob transition.
- RF monitor semi rigid cable made short after cooling down.
- Metal gasket leaked by crack at copper weld.
- One indium seal of LBP leaked.

All these failures were fixed, and no degradation of the cavity performance observed.

6 SUMMARY

- High current application of superconducting cavities successfully performed at KEKB.
- Many failures show more study needed for more higher current.
- The limitation of current is not due to superconducting cavity, we will try more than 1 A soon.

REFERENCES

[1] T. Tajima et al, PAC99 March29-April 2, 1999, New York City.
[2] Y. Kijima et al, This conference