HOM ABSORBERS OF SUPERCONDUCTING CAVITIES FOR KEKB

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Abstract

Superconducting Cavities (SCC) being developed for KEKB adopted ferrite HOM absorbers. The way of making full size absorbers was established and the feasibility of the absorber in accelerators have been tested. An SCC fully equipped with two full size absorbers was tested in TRISTAN Accumulation Ring. The result showed no problems up to 110 mA with single bunch and max absorbed power of 760 W.

1 INTRODUCTION

Extraction of HOMs or higher order modes is essential to the success of high current machines such as B-factories (called KEKB at KEK) [1]. Use of SCC in KEKB has been considered, especially in High Energy Ring (HER). The requirements for HOM dampers or absorbers of SCC in HER are 1) desired mode damping characteristics, 2) ultra high vacuum compatibility (1 x 10^{-9} Torr >) and 3) power handling capability (5-10 kW). So far, we have established a process to make full size absorber based on Hot Isostatic Press (HIP) technique, and low power test using aluminum model, high power test on full size absorbers and outgas measurements were performed [2]. As a final stage of the test, we have been doing beam tests. This paper presents the status of the material development and the results of recent tests on full size absorbers.

2 MATERIAL AND MANUFACTURING

2.1 Presently used material

When we started this study in 1992, we found some ferrite that has a good absorbing characteristics. We measured its mode damping capability using a number of flat tiles and we concluded that it can be used concerning the damping performance. Then the question was how to make full size absorber. We tested blazing and soldering flat pieces to copper and stainless steel plate. Unfortunately, however, there was not an excellent bonding without cracking due to low bending strength of ferrite tile. During struggling about bonding, an idea of HIPping ferrite powder came up to our mind. HIP stands for hot isostatic press. We studied about the optimum conditions of temperature and pressure patterns as well as electromagnetic properties. The finally decided HIP conditions are 1500 atm, 900˚C x 5h using ~1 µm pre-sintered powder of IB-004, TDK Co. With this method, we have been able to make full size absorbers, as shown in Fig. 1, that have less porous surface and no voids at the interface. The detail of the process can be seen in [2].

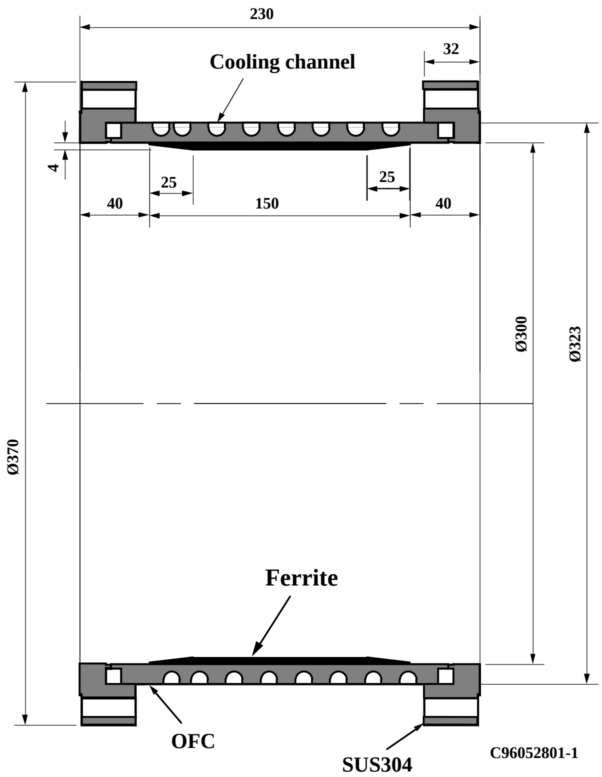

Fig. 1 : Present design of HOM absorber for KEKB.

2.2 R & D on new material

According to the previous tests, the only problem that could arise in the future using present material seems to be excessive outgas when a few 10 kW or more power is absorbed due to the temperature rise of ferrite. To solve this problem, an R & D on a new material has been done. What we are presently doing is to add copper powder with ferrite powder aiming at increasing thermal conductivity of the material to reduce the temperature rise, and decreasing the porosity so gases are not trapped. Unfortunately, though thermal conductivity rose about a factor of 4 when 23 vol% of copper powder was added, the calculation with SEAFISH using measured ε and μ showed that Q_{ext} for TM011 mode increases from ~100 to ~1400. Further study is needed to find the key factor to increase thermal conductivity without sacrificing Q_{ext}.

3 BENCH TESTS

3.1 Low power test

Using an aluminum model with full size absorbers, mode damping characteristics were measured with a network analyzer and confirmed the calculated design values [2,3].

3.2 High power test

Prior to the beam tests, the full size absorbers were high power tested with 508 MHz coaxial line in air [2]. Up to 11.7 and 14.8 kW, and average power density of 14.6 and 10.8 W/cm^2 were tested for small and large absorbers, respectively. No damage was observed except surface temperature went up to 140 - 149˚C.

Recently, to know the vacuum characteristics in feeding high power, 1.3 GHz Klystron with ceramic window plus TM01 mode converter were introduced. Nominal power of the Klystron output is 5 kW and about 13 % of the input power is reflected from the absorber and window to the circulator. A temperature distribution of 40 - 65 ˚C was observed in the preliminary test before evacuation when the absorbed power was 2 kW. Tests in vacuum will start soon.

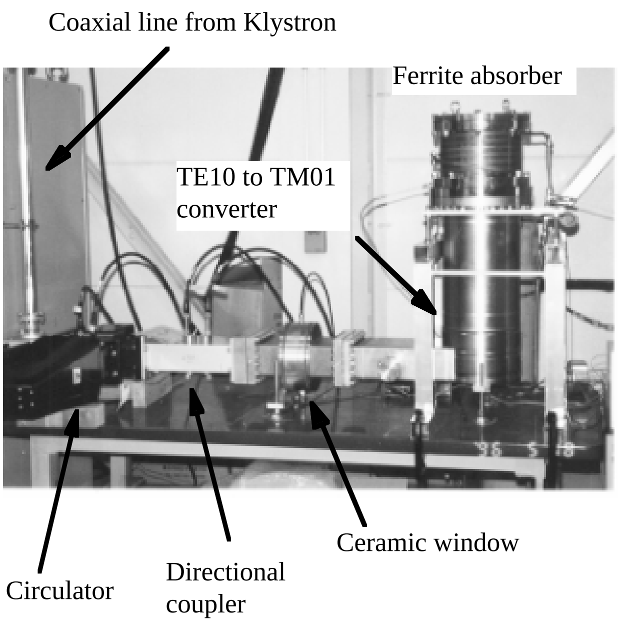

Fig. 2 : 1.3 GHz high power test set-up.

3.3 Outgas measurement

Figure 3 shows a typical outgassing rate at different temperatures including the pressure trend in baking. Since pre-degassing of ferrite powder was introduced, outgassing rate decreased by about an order of magnitude. Also, the data suggests that longer baking will reduce the outgassing rate significantly, e.g. one month of baking can reduce the outgassing rate another order of magnitude. Considering the total ferrite area of ~2200 cm^2, the total outgas becomes ~2 x 10^{-7} Torr l/s at 20 ˚C and ~2 x 10^{-6} Torr l/s at 90 ˚C. The fully assembled superconducting cavity shows 2 x 10^{-9} Torr at room temperature with ion pumps that have effective total evacuation speed of 150 l/s, which confirms this prediction, which is similar to the outgas rate of TRISTAN SCC. To maintain this outgas level during high power absorption, further baking should be required.

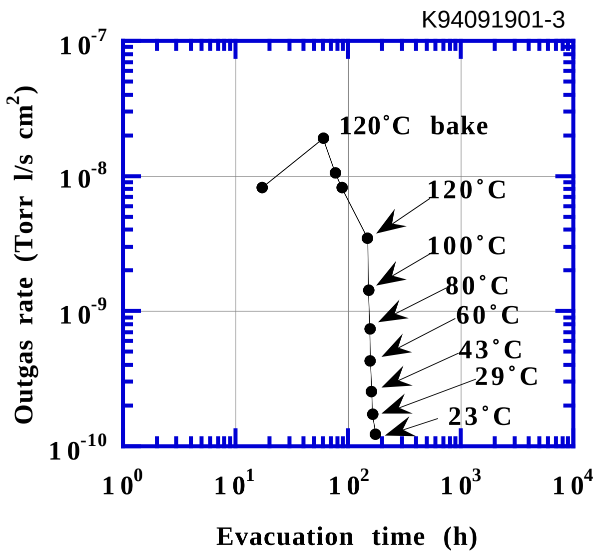

Fig. 3 : Outgas rate as a function of evacuation time.

4 BEAM TESTS

4.1 Test in TRISTAN MR

One of the full size absorbers whose dimension is shown in Fig. 1 was tested in the TRISTAN Main Ring from May 31 through June 1 in 1995 [4]. The major objectives were 1) to check if any damage can occur on the absorber due to the beam induced field, 2) to find the things we did not consider but can be important for the future and 3) to measure the loss factor and compare it with calculation.

Briefly, the test results are 1) no damage on the ferrite by the induced field of 8.5 times KEKB LER, 2) we found that the tapers adjacent to the damper heat up and water cooling will be necessary in the future and 3) loss factor becomes ~40 % higher than the calculated value at 4 mm, which is the design bunch length for KEKB as shown in Fig. 4.

In the test, the max power absorbed in the ferrite was 273 W and was not sufficient to see the effect of the outgas from ferrite.

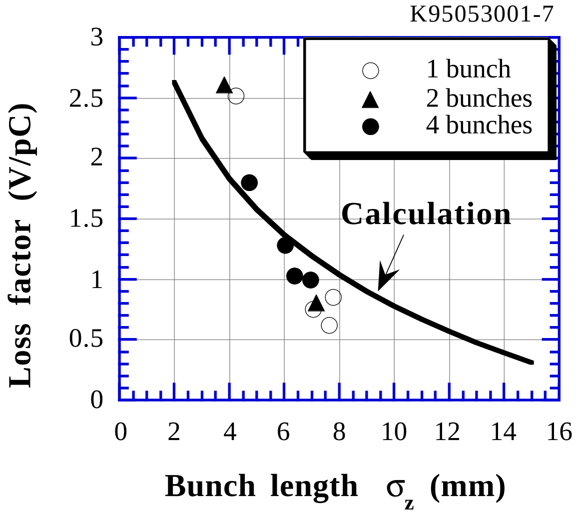

Fig. 4 : Loss factor as a function of bunch length. Calculation is the addition of ABCI for structure and analytic calculation for ferrite itself.

4.2 Test in TRISTAN AR

The first beam test with a superconducting cavity was held from Mar. 28 through April 2, 1996, in the TRISTAN Accumulation Ring [5]. Two full size absorbers, which were previously high power tested, were set at both ends of the cavity. As for the absorber or HOM damper, the objectives of this test were 1) to confirm the mode damping, 2) to know if there is any serious problem on vacuum and operation of the cavity with the absorber, 3) to see the effect of relatively high power absorption (a few kW), and 4) to measure the loss factor as a function of bunch length and compare it with calculation.

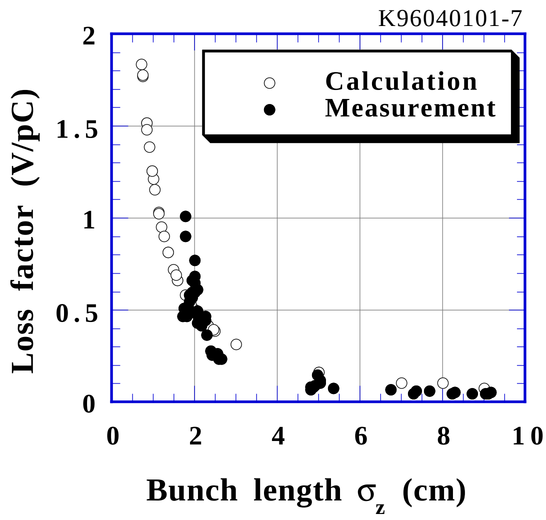

Fig. 5 : Loss factor as a function of bunch length measured at Accumulation Ring (AR). Note that the bunch length is in cm. At AR, bunch was much longer than that of MR. Calculation was made using the same method as above.

A summary of the test is as follows, 1) mode damping was confirmed, 2) no problems up to the max current of 110 mA with single bunch or 8.6 x 10^{11} particles/bunch, which is 26 times that of KEKB LER, 3) the max absorbed power was 760 W in total, thus we could not see much of the effect relating to high power absorption, and 4) as shown in Fig. 5, measured loss factor seemed to be higher than that of calculation when bunch length was shorter than approximately 2 cm, although the measurement accuracy became low with short bunches due to small loss.

5 SUMMARY AND FUTURE PLAN

HOM absorbers made of HIPped ferrite have been developed for superconducting cavities. A couple of full size absorbers were manufactured and mode damping characteristics, high power handling capability, outgas measurement have been performed as bench tests. Moreover, beam tests using TRISTAN Main Ring and Accumulation Ring have been conducted. So far, there have been no problems up to a total power of 760 W and single bunch current of 110 mA in AR. From July, 1996, beam tests in AR will be starting again and hopefully we will get higher absorption in the absorber and we can check the outgas properties with beams.

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REFERENCES

[1] KEKB B-Factory Design Report, KEK Report 95-7 (1995).
[2] T.Tajima et al. ; 1995 Particle Accelerator Conference, Dallas, U.S.A. (1995), KEK Preprint 95-77.
[3] T.Tajima et al. ; Proc. 6th Workshop on RF Superconductivity 2 , pp. 962-980 (1993).
[4] T.Tajima et al. ; to be published as KEK Report.
[5] T.Furuya et al. ; in this conference.