HIGH POWER TEST OF THE RF DAMPED CAVITY

Tadashi Koseki, Masaaki Izawa*, Kenji Shinoe, Syuichi Tokumoto*,Yukihide Kamiya ,
Toshi Miura** and Kiyokazu Satoh**

Synchrotron Radiation Laboratory, Institute for Solid State Physics (ISSP),
The University of Tokyo, Tanashi, Tokyo 188, Japan
* Photon Factory, High Energy Accelerator Research Organization (KEK),
Tsukuba, Ibaraki 305, Japan
** Toshiba Corporation, Tsurumi, Yokohama 230, Japan

Abstract

This paper describes the recent results of high power test of the damped cavity which has been developed at ISSP, the University of Tokyo and KEK-PF. We have fabricated four damped cavities to install at the Photon Factory (PF) storage ring with high brilliance configuration. High power conditioning of all four cavities has been carried out successfully. The temperature rise and thermal deformation of the cavity were understood by the thermal structure analysis.

1 INTRODUCTION

We have developed an RF cavity which has SiC beam ducts for damping the higher-order mode (HOM's) [1, 2]. Figure 1 shows the cross sectional view of the cavity. The cavity aims at being installed in two low emittance electron/positron storage rings. One is a third-generation VUV and SX synchrotron radiation source, the VSX storage ring, and the other is a high brilliance configuration of the Photon Factory storage ring at KEK.

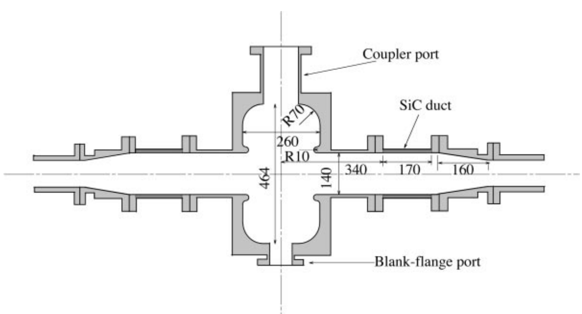

Figure 1: The cross sectional view of the damped cavity

The VSX storage ring is a future project of the University of Tokyo. The ring has a beam energy of 2.0 GeV, a circumference of about 400 m, an emittance less than 5 nm·rad, four 14-m long straight sections and twelve 7-m semi-long straight sections for extensive use of insertion devices [3,4]. Three RF cavities will be installed at one of the semi-long straight sections. The proposal for constructing the VSX facility was submitted to Japanese government in 1996, and the government decided to give a budget for preliminary study of the facility in the fiscal year 1997.

The reconstruction for the emittance upgrade of the PF storage ring is now in progress. The beam emittance will be reduced from 130 nm·rad to 27 nm·rad by doubling the number of the quadrupole magnets in the FODO cells [5]. All of existing four cavities will be replaced with the new damped cavities described here. The commissioning with high brilliance configuration of the PF ring will be started in October 1997.

2 DAMPED CAVITY

The design parameters of the damped cavity are summarized in Table 1. The nominal RF voltage of the cavity system is 1.7 MV for the PF ring and 1.5 MV for the VSX ring. The numbers of the cavities to be installed are four (PF) and three (VSX). For the VSX ring, the nominal RF voltage per cavity is 0.5 MV which requires the power of about 33 kW to be dissipated in the cavity. Therefore, the design of 150 kW wall loss has large safety margin and operational flexibility.

Table 1: Parameters of the cavity.

RF frequency	500.1 MHz
Shunt impedance	7.68 MΩ
Unloaded Q	44000
RF voltage / cavity	0.50 (VSX), 0.43 (PF)
Maximum wall loss	150 kW
Coupling coefficient	1.9 (VSX), 2.3 (PF)
Number of cavities	3 (VSX), 4 (PF)

The high power model of the cavity was fabricated in 1995. The high power test of the cavity was carried out successfully. The input power of 150 kW was achieved without any severe problem [6].

From 1996 to 1997, we have fabricated four cavities for the PF ring. The design of the cavities are same as the model fabricated in 1995. They were manufactured at Keihin Product Operations of Toshiba Corporation. The main parts of the cavities are made of class1-OFHC copper which has been treated with Hot Isostatic Press (HIP) before. After fabrications, the cavities were prebaked at 150 ˚C for 24 hours at Keihin Product Operations.

3 HIGH POWER TEST

3.1 setup

The high power conditioning has been performed on the high power test bench at the Photon Factory (Fig. 2). An RF power was supplied by 500.1 MHz, 180 kW klystron (Toshiba E3774). A 250 kW circulator of Y-junction type was used to protect the klystron against the reflection wave from the cavity. Reflected power was dissipated in a 50 kW dummy load.

The cavity was cooled by water; the flow of cooling water was about 150 *l*/min and the inlet temperature was kept at 23±1˚C. A 300 *l*/sec turbo molecular pump was attached to the cavity, and an ionization gauge and a quadrupole mass filter were placed between the beam port and the turbo pump.

The reflected power signal was used as an interlock trigger. A thermal detuning of the cavity was compensated by the tuning plunger. The conditioning data, input power, vacuum pressure and residual gas spectrum were recorded every 20 seconds by a personal computer. The temperature distribution of the outside wall of the cavity was monitored by eight thermocouples.

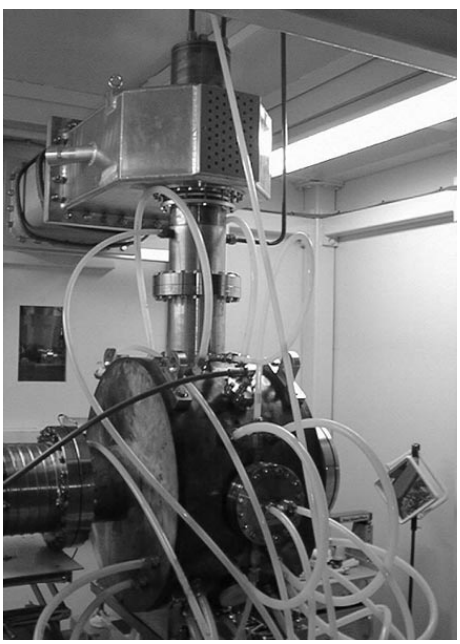

Figure 2: The cavity on the test bench.

3.2 High Power Conditioning

We have carried out conditioning for all four cavities. In order to generate the nominal gap voltage of 0.43 MV/cavity, a dissipated power of about 24 kW is needed. On the other hand, if the PF ring is operated with three cavities, the required RF voltage and the dissipated power per cavity are 0.57 MV and 42 kW, respectively. In general, large safety margin for the RF system is necessary to secure a stable operation of the ring and to avoid a long shutdown caused by a trouble of RF power source. The goal of the conditioning was, then, set to achieve the input power of 80 kW, about two times higher than 42 kW.

Figure 3 shows a whole process of the conditioning for one cavity. In this case, the vacuum pressure of the cavity before applying RF power was less than 1×10^{-7} Torr. The conditioning started with an input power of a few hundreds watt. The power level was slowly increased, so that the vacuum pressure was kept below 5×10^{-6} Torr. The input power of 80 kW was attained after 4.2 hours without any severe trouble.

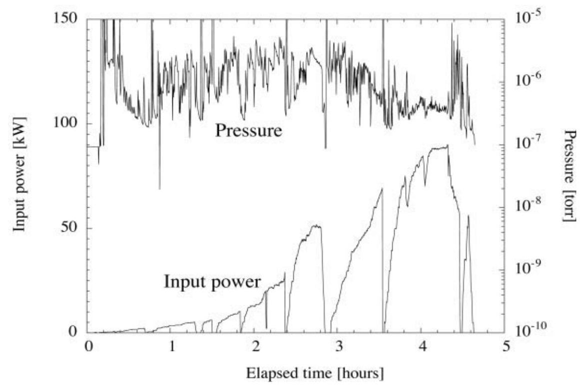

Figure 3: An example of cavity conditioning.

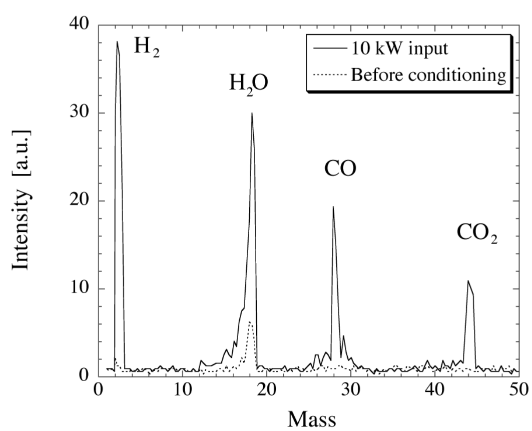

Figure 4: Residual gas spectrum.

The residual gas spectrum measured by the quadrupole mass filter is shown in Fig. 4. The dotted line and the solid line are the mass spectra before conditioning and during conditioning, respectively. The data of solid line was taken for an input power of 10 kW after about 1 hour conditioning. Before the conditioning, partial pressure of H_2O was much higher than those of the other gases. On the other hand, during the conditioning, the main components of outgas from cavity wall were not only H_2O but also H_2 ,CO and CO_2. At the beginning, the levels of CO and CO_2 were higher than that of H_2. After the conditioning progressed, however, H_2 became most dominant among all components of outgases from cavity wall.

3.3 Thermal analysis

We carried out the thermal structure analysis of a two-dimensional cavity model using the ANSYS code. The analysis assumed the water flow of 140 *l*/min and the inlet water temperature 22 ˚C. For 80 kW total power dissipation, the peak power density around the nose cone is calculated to be 15 W/cm^2 by the SUPERFISH code. Figure 5 shows the temperature distribution calculated by ANSYS. The inner surface of the cavity becomes 37 - 50 ˚C and the edge of the nose cone has the maximum temperature. The calculated temperature of the outer wall is 27 - 34 ˚C, while the measured one is 33 - 37 ˚C.

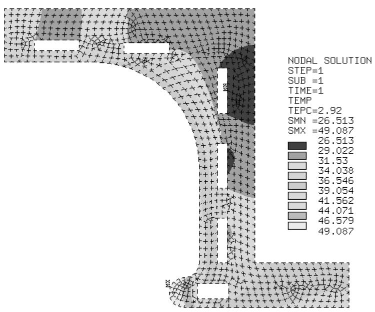

Figure 5: Temperature distribution of the cavity for 80 kW total power dissipation.

Thermal deformation of the cavity was also calculated by ANSYS. The thermal deformation for 80 kW total power dissipation is shown in Figure 6. From the result, the frequency shift caused by the thermal expansion is found to be -130 kHz for the fundamental mode.

In the high power conditioning, the frequency shift due to thermal expansion can be estimated by measuring the position movement of the tuning plunger. The frequency shift was about -150 kHz for input power of 80 kW.

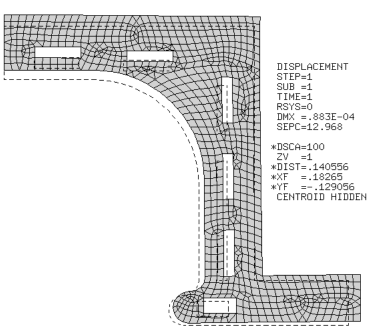

Figure 6: Thermal deformation of the cavity for 80 kW total power dissipation.

4 SUMMARY

We have fabricated four damped cavities for the PF ring with high brilliance configuration. High power conditioning of all four cavities has been already carried out. The temperature rise and thermal deformation were well understood by the thermal structure analysis with a two-dimensional model.

In 1996 summer, the two damped cavities were installed in the PF ring to replace two of four old cavities. The beam test of the new cavities was carried out successfully [7]. The remaining two cavities were then replaced by new ones in 1997 spring.

5 REFERENCES

[1] T. Koseki, M. Izawa and Y. Kamiya, Proc. 4th European Particle Accelerator Conference, London, 1994, p. 2152.
[2] T. Koseki, M. Izawa and Y. Kamiya, Rev. Sci. Instrum., 66 (1995) 1892.
[3] Y.Kamiya *et al*., Proc. 4th European Particle Accelerator Conference, London, 1994, p. 639.
[4] H. Takaki *et al.*, “A Lattice for the Future Project of VUV and Soft X-ray High Brilliant Light Source“ in these proceedings.
[5] M. Katoh and Y. Hori, Proc. 5th European Particle Accelerator Conference, Barcelona, 1996, p. 650.
[6] T. Koseki *et al.*, Proc. 5th European Particle Accelerator Conference, Barcelona, 1996, p. 1988.
[7] M. Izawa, “Beam Test of an RF Damped Cavity at the Photon Factory Storage Ring” in these proceedings.