

# High-Power Conditioning of an RF Cavity for High Brilliant Synchrotron Radiation Source

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## Abstract

Presented in this paper is a recent status of the R&D on a damped-cavity being developed at ISSP and Photon Factory (PF). A high-power model cavity made from solid copper was fabricated and tested. The input power of 150 kW was obtained without any severe problems.

## 1 INTRODUCTION

We have developed the damped-structure RF cavity for two low emittance electron/positron storage rings. One is a third-generation VUV and SX synchrotron radiation source (VSX Light Source in short) which is a future project of the University of Tokyo. The storage ring has a beam energy of 2.0 GeV, a circumference of about 400 m, an emittance of less than 5 nm-rad [1,2]. The other is a high brilliance configuration of the PF storage ring [3]. For these storage rings, coupled-bunch instability due to higher-order modes (HOM's) in RF cavity is a serious problem when a stable beam with high current is required. The damped cavity has large beam duct, a part of which is made of a SiC microwave absorber. The HOM's propagating out from the cavity through the beam duct are expected to be damped by the SiC part.

We fabricated two cold models of the cavity and measured their RF characteristics in low power level. As the SiC absorber, we chose CERASIC-B (made by Toshiba Ceramics Co. Ltd.) which was fabricated by sintering in an argon atmosphere under normal pressure. The low power measurement showed the SiC beam ducts strongly reduce the Q-values of HOM's in the cavity [4, 5, 6]. The design parameters of the damped-cavity are summarized in Table 1. The nominal operating voltage of the cavity system is 1.5 MV for both the PF ring and the VSX ring. The number of the cavity to be installed in the storage rings is four for the PF ring and three for the VSX ring. For the VSX ring, the nominal gap 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

140 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 M $\Omega$
Unloaded Q	44000
Coupling coefficient ( $\beta$ )	> 2
Maximum wall loss	140 kW

## 2 HIGH POWER MODEL

The high power model cavity was manufactured at Keihin Product Operations of Toshiba Corporation [7]. Figure 1 shows the cross-sectional view of the high power model.

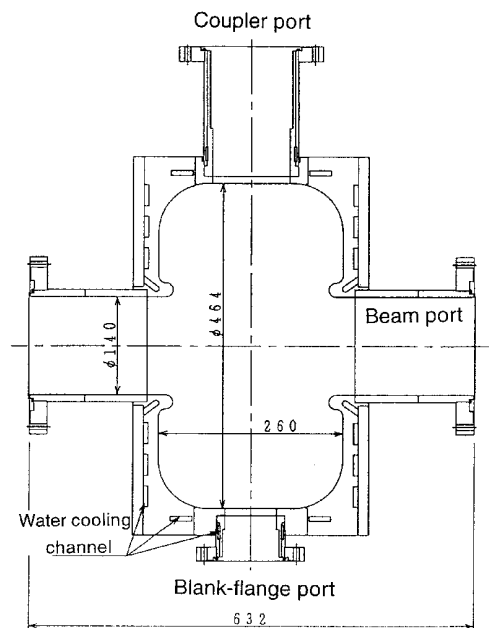


Figure 1 : Cross section of the high power model.

The main part of the cavity was made of class1-OFHC copper which had been treated with Hot Isostatic Press (HIP) before. The layout of water cooling channel is also shown in Fig. 1. The water flow of 200 *l/min* is available with a pressure drop of 4 kgf/cm<sup>2</sup>. The cavity has two beam ports and four side ports for an input coupler, a tuning plunger and two blank-flanges. U-tight seal gaskets are adopted as RF contacts between the port flanges and the attached equipments.

A thermal structure calculation with two dimensional mesh was carried out [7]. The analysis assumed a water flow of 140 *l/min* and inlet water temperature of 20 °C. For 160kW total power dissipation, peak power density around the nose cone that gives the highest power density in the cavity is calculated to be 30 W/cm<sup>2</sup>. The calculation showed that the inner wall of the cavity becomes 50 - 60 °C and the edge of the nose corn about 70 °C. The frequency shift caused by the thermal deformation was expected to be -250 kHz for the fundamental mode.

Figure 2 shows the input coupler of the cavity. The coupler was newly designed being based on that for the 508 MHz APS cavity of TRISTAN ring. We changed the shape of the end of coaxial line and optimized the positions of the short plates of rectangular waveguide and coaxial line in order to obtain low reflection for 500 MHz microwave [8].

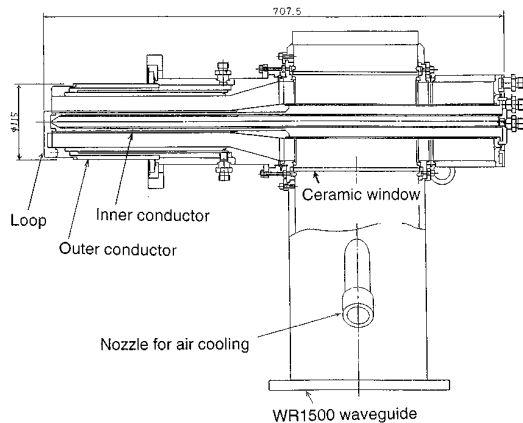


Figure 2 : The newly designed input coupler.

The tuning plunger of the cavity is the same type as used in the PF cavity. The blank-flange, also called fixed tuner, is a flange with cylindrical block to pad the port of the cavity. The cavity has two blank-flanges (horizontal and vertical ). The blocks of the blank-flanges are projecting 10 mm from inner surface of the cavity.

After fabrication, the cavity was pre-baked at 150 °C for 24 hours at Keihin Product Operations of Toshiba Corporation.

### 3 HIGH POWER CONDITIONING

The high power test has been carried out at the high power test bench of the Photon Factory. Figure 3 shows

the high power model set in the test bench. SiC beam-duct was not attached to the cavity for this test. Before the high-power test, RF characteristics of the cavity was measured in low power level. The unloaded Q value of the accelerating mode was measured to be 39000 at 500.1 MHz. The coupling coefficient  $\beta$  was 2.35, while the value expected from the low-power measurement was 2.27 [6].

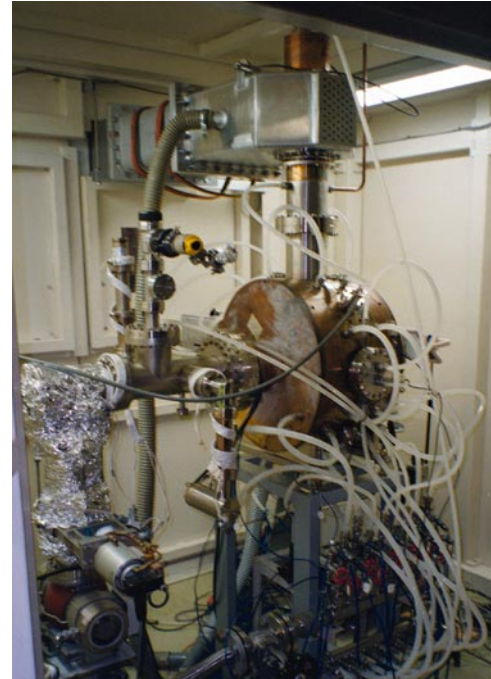


Figure 3 : The high power model.

In the high power test, a 300 *l/sec* turbo molecular pump was attached to the cavity and an ionization gauge was placed between the beam port and the turbo pump. The vacuum pressure without input RF power was  $5 \times 10^{-8}$  Torr. The high power conditioning started with an input power of a few hundreds watt and the power level was slowly increased in order to keep the vacuum pressure below  $5 \times 10^{-6}$  Torr. The reflected RF power signal was used as an interlock trigger. The tuning plunger was adjusted to compensate for a thermal detuning of the cavity.

After 20 hours conditioning, the input power reached up to 60 kW. The vacuum pressure became  $5 \times 10^{-8}$  Torr without RF power. In order to try higher power conditioning under the lower vacuum pressure, the cavity was baked at 150 °C for 24 hours. After the baking, the pressure was down to  $3 \times 10^{-9}$  Torr, and then pulse conditioning at 100 kW with 10% duty was carried out for 12 hours. After that, cw conditioning was restarted. Elapsed time of conditioning vs. maximum input power is summarized in Fig. 4. Total conditioning time has been 60 hours. The input power of more than 150 kW was obtained without any severe problems.

The cavity has three viewing ports to observe discharge phenomena around input coupler, tuning plunger and nose cone. Small glowing points and occasional arcing grew with increasing input power. However, as the high power conditioning progressed, the number of these glowing points decreased.

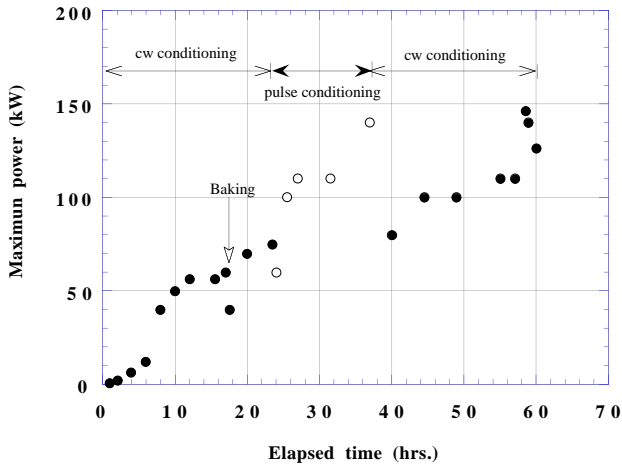


Figure 4 : Elapsed time vs maximum input power. Closed and open circles are conditioning with cw and pulse, respectively.

Figure 5 shows an example of input power, vacuum pressure and reflection power. At an input power of 140 kW, the maximum temperature of cavity wall was measured to be 47 °C with the cooling water of 200 l/min and 22 °C (inlet temperature). When 140kW is applied, the reflection power of 23 kW is expected from the value of coupling coefficient,  $\beta = 2.35$ . However, the measured reflection power was lower than the expected value. The reason of this discrepancy would be that Q-value of the cavity decreases due to temperature rise of inner surface with increasing input power.

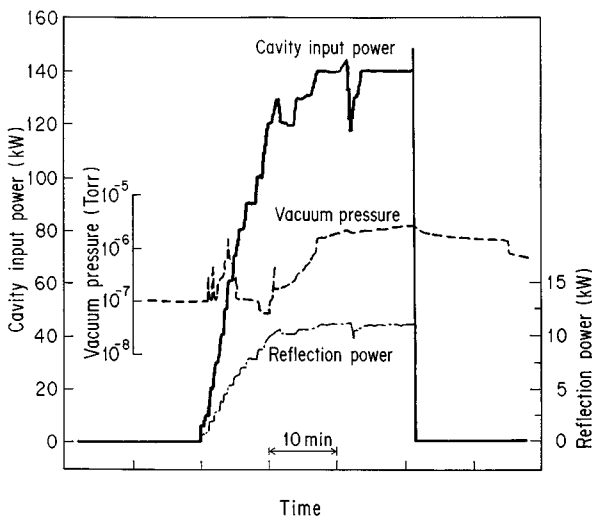


Figure 5 : An example of high power test.

## 4 HIGH POWER TEST OF THE SiC BEAM-DUCT

We have also fabricated the SiC beam-duct for high power test. The duct is composed of Al duct with ICF253 flanges and CERASIC-B duct which is inserted in the Al duct by the method of shrink fit. The high power test of the SiC beam-duct has been successfully carried out as described in Ref. [9].

Recently, the SiC beam-duct was installed in the PF ring and tested by the real beam. Either out-gassing from SiC surface or resistive wall instability due to the SiC-duct was not observed. A detailed description of this beam test is reported elsewhere [10].

## 5 FUTURE PLAN

In this summer shutdown of the PF storage ring, two of four PF cavities will be replaced by the damped-cavity presented here. Operation with the damped-cavities will be started in this autumn.

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