High Power Test of a 500 MHz RF Cavity

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Abstract

A prototype RF cavity for the Pohang Light Source (PLS) was manufactured and was tested with an input rf power up to 70 kW. The resonant frequency and the effective shunt impedance of the cavity are 500.082 MHz and 8.6 MΩ, respectively. At the end of the test, the vacuum pressure inside the cavity improved to $5x10^{-9}$ Torr with an input rf power of 60 kW. The performances of the cavity satisfied the requirements of the storage ring of the PLS.

I. INTRODUCTION

For the storage ring section of the PLS which is under construction [1], four single cell RF cavities will be applied. The power dissipation on the cavity wall is in excess of 60 kW for each cavity. A good vacuum condition of 10^{-9} Torr order is required at the maximum input power level. Toshiba Corp. manufactured a prototype cavity in 1992 at Keihin Product Operations and performed a high power test from November to December at Nasu Electron Tube Works [2]. The purpose of the test was aging and conditioning of the cavity and to confirm the cavity performances with a high input rf power. Another high power test was also carried out at POSTECH with their rf system in February, 1993. Other four cavities which will be installed in the storage ring are now being manufactured.

Design features, rf characteristics, setups of the high power test and test results are presented in this paper.

II. DESIGN AND PERFORMANCE

Figure 1 shows a cross section of the cavity. The shape of the inner surface is identical with RF cavities of the Photon Factory (PF) storage ring. The prototype cavity is made of OFHC-class1 and the inner surface is mechanically finished with a surface roughness of 1μm (Rmax). Water cooling channels are shaped on the outerwall of the cavity and the flow rate of the water is 100 l/min with a pressure drop of about 2 kg/cm^2.

The cavity is equipped with six ports which are an input coupler port, a tuner port, two higher order mode (HOM) damper ports and two beam ports. Herico flex type copper c-rings are used as rf contacts between equipments, such as an input coupler, and the port flanges. All the ports except for the beam ports are cooled directly by water channels formed in the port walls. Diffusion bonding techniques are applied for manufacturing the ports [3]. Experiences of improvements on the PF cavities indicated that an effective cooling for ports is one of the important factors to realize high power operations [4]. In addition to these main ports, two small ones for an rf monitor and a viewing window are provided.

To feed an rf power up to 100 kW (including a beam loading), an input coupler having an air cooled cylindrical ceramic window is applied. The vacuum side of the ceramic window is coated with TiN.

A plunger type tuner with a diameter of 70 mm is used for compensating a thermal detuning and a beam loading.

Two dummy blocks are prepared for the HOM damper ports because HOM dampers will not be adopted at the first stage of the ring operation. The dummy block length was adjusted to realize the designed resonant frequency.

The performances of the cavity as well as design values are listed in Table 1.

Table 1 Main parameters of the cavity

	Design	Achieved
Resonant frequency (MHz)	500.082	500.082
Input rf power (kW) :wall loss	60	70
Effective shunt impedance (MΩ)	≧8	8.6 (Qu=39100)
Unloaded Q-value :before aging	—	35700 (23°C)
. :after aging	≧37000	39100 (23°C)
Coupling coefficient of coupler	max. 3	max. 3.2
Tuning frequency range (MHz)	1.8	1.9
Base pressure (Torr) :before aging	$5X10^{-9}$	$5X10^{-9}$
. :after aging	—	$5X10^{-10}$
Pressure with 60 kW (Torr)	$2X10^{-9}$	$5X10^{-9}$;reducing

III. SETUP AND PROCEDURE OF HIGH POWER TEST

Figure 2 shows a schematic diagram of the setup of the high power test. A 400 l/sec ion pump (Varian) was used for pumping the cavity at Toshiba. In the test at

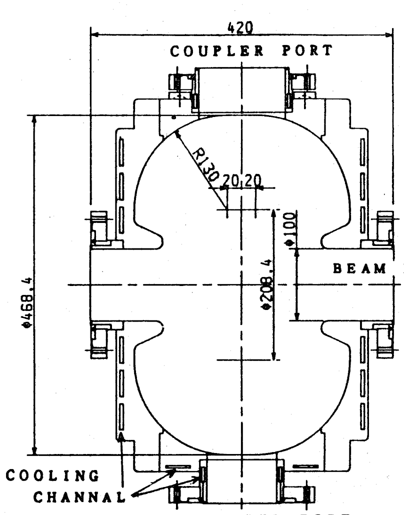

Figure 1. Cross section of the PLS prototype cavity.

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POSTECH, a 220 l/sec ion pump with NEG module (Perkin Elmer) was applied. An ionization gauge was located in a duct between the beam port and the ion pump. Interlock trigger levels were $1X10^{-6}$ Torr and 10 kW for the vacuum pressure and the reflected rf power, respectively. An arc sensor was also used at POSTECH.

Figure 3 shows the cavity under preparing the test.

Before starting the high power test at Toshiba, the cavity was baked at 150 °C for 15 hours (flat top period). We started the high power test (aging) with an input rf power of several hundreds watt and increased the power level gradually so that the vacuum pressure was kept below $1X10^{-7}$ Torr.

At POSTECH, a baking process was also performed at 150 °C for 20 hours and the high power test was very carefully progressed as keeping the vacuum pressure below $1X10^{-8}$ Torr.

The aging periods amount to 80 hours at Toshiba and 45 hours at POSTECH.

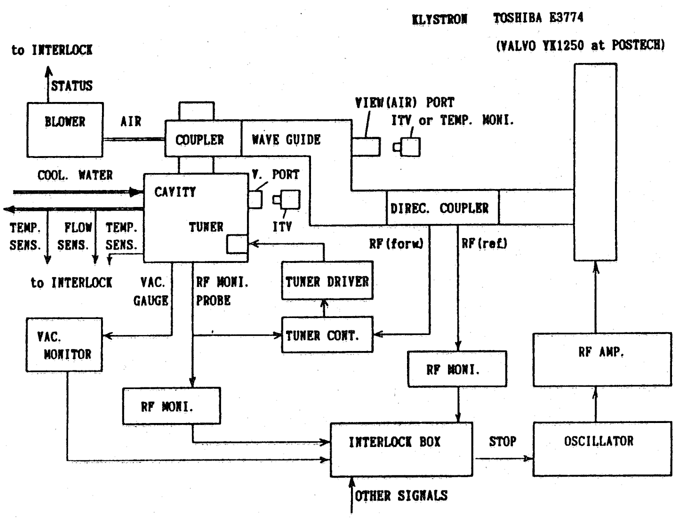

Figure 2. Setup of the high power test.

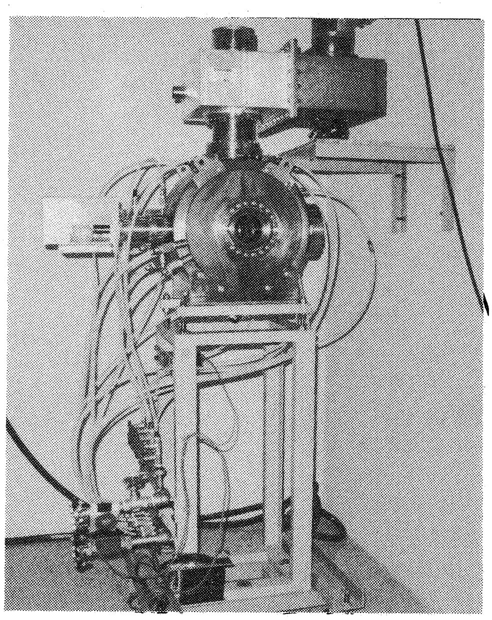

Figure 3. The prototype cavity preparing the high power test at POSTECH.

IV. TEST RESULT

A. Aging process

Figure 4 shows the input rf power over the test period. The rf power was occasionally turned off due to the vacuum pressure or the reflected power interlock during the first 30 hours at Toshiba. After then we could reach 60 kW. However, during the period from 32 to 40 hours, frequent arcing accompanied with pressure rise limited the input power. We could not identify the arcing positions due to a restricted viewing field of the ITV camera. After this period, aging progressed relatively easily with less arcing. During the last period of the test at Toshiba, the input rf power reached 70 kW and could be sustained at the power level for several hours. When the cavity was disassembled after the test, it was found out that two rf contacts inserted between the HOM damper ports and the dummy blocks were partially melted. The section diameter of the contacts was increased because we supposed that a poor pressures for the contacts could cause the abnormal arcing and the excessive temperature rise.

During the first 20 hours at POSTECH, the high power test was interrupted frequently due to the vacuum interlock. However, it turned out that this troublesome situation originated in noise problems. After modifying the grounding system, we could easily achieve the input rf power of 60 kW (the maximum power of the Valvo YK1250 klystron) without severe problems. Through the test period at POSTECH we detected only several times of arcing, some of which occurred at the ceramic window of the coupler. After the test, we confirmed that there were no damages on the rf contacts between the HOM damper ports and the dummy blocks.

The unloaded Q-value improved to 39100 which was 88 % of a Q-value calculated by using SUPERFISH.

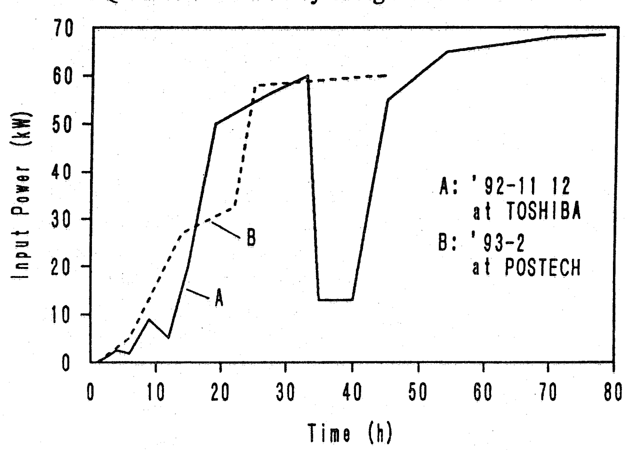

Figure 4. Input rf power over the test period.

B. Vacuum Pressure

During the first stage of the aging process, the vacuum pressure could rise to 10^{-7} Torr order even with a small input rf power around few kW. The vacuum condition was improved as more time was spent for aging.

Figure 5 shows the pressure rise (the pressure subtracted the base pressure) as a function of the input rf power for four different period (A～D) of the aging process. The

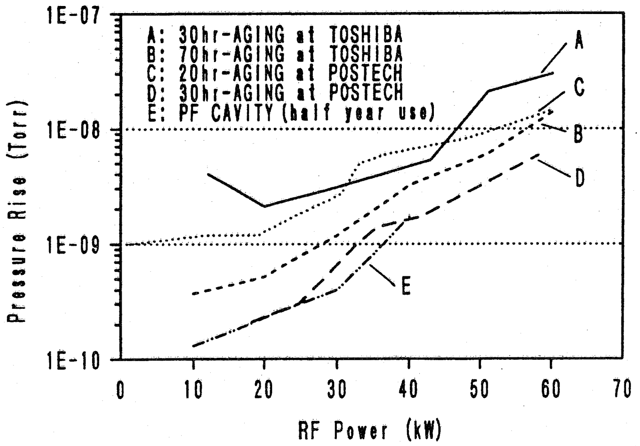

Figure 5. Pressure rise as a function of the rf power.

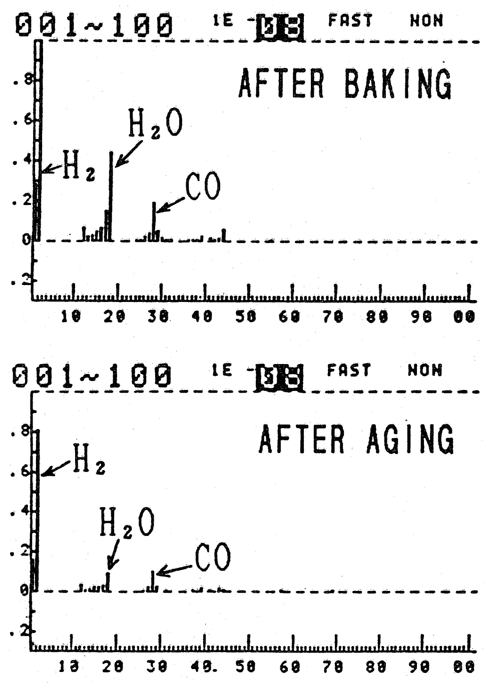

Figure 6. Results of residual gas analysis.

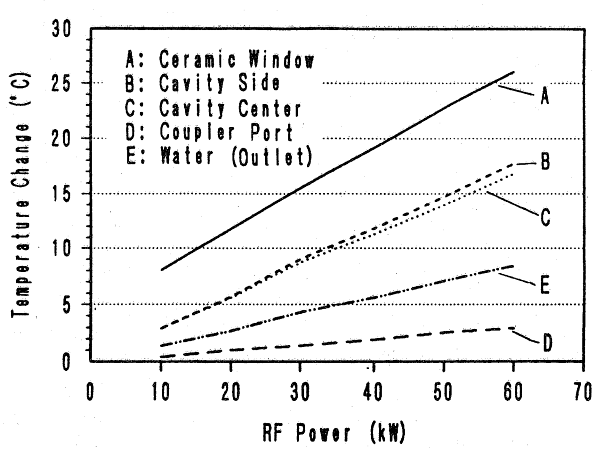

Figure 7. Temperature changes of the various parts.
A : subtracted the room temperature.
B-E : subtracted the water inlet temperature.

curve:C suggests that the effect of aging partially remained though the inner surface of the cavity was once exposed to the air after the test at Toshiba and was kept with dry N_2 gas for nearly two months. A data of the PF cavity is presented in the figure for reference (curve:E)[4]. This data was taken after a half year usage of the cavity in the PF storage ring and a pulse aging (peak :100 kW, duty :10 %) had been carried out for 24 hours [5].

At the end of the test at POSTECH, the vacuum pressure with an input rf power of 60 kW was $5X10^{-9}$ Torr and was still improving.

The results of the residual gas analysis during the test at Toshiba were presented in Fig.6. After the baking, the partial pressure of H_2O as well as the total pressure was reduced but still remained at higher level than that of CO. After the aging, the level of H_2O became lowest among the main three elements of the residual gas.

C. Temperature Rise and Frequency Change

Figure 7 shows the temperature changes (the temperature subtracted the base temperature) of the various cavity parts as a function of the input rf power. In addition to the parts shown in the figure, the temperature of many portions including the tuner port and the HOM damper ports were monitored. We observed no remarkable temperature rise which could disturb the high power operation.

The tuner position was recorded during the test. From the results, the frequency changing rate as a function of the input rf power was deduced to be about 3.2 kHz/kW with the cooling water flow late of 100 l/min. It agreed well with a result of a calculation performed by using SUPERFISH and COSMOS.

V. CONCLUSION

The prototype RF cavity for PLS had been tested with the input rf power up to 70 kW. The high power performance of the prototype cavity satisfied the requirements of the PLS storage ring. Now four RF cavities which will be installed in the storage ring are being manufactured. These cavities have the same design as the prototype one but a longer baking time shall be applied in order to reduce further the partial pressure of H_2O. The high power test is going to start from September in 1993 also at Nasu Electron Tube Works.

Acknowledgments

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VI. REFERENCES

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