Status on the SPring-8 Storage Ring RF System

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Abstract

Tests of some RF components, a 1.2 MW circulator and a 300 kW and 50 kW dummy loads, have been carried out under high power and successfully completed. The procedure and obtained results are described. As to higher order modes induced in a bell-shaped cavity, detuning method from resonance points at an instability condition has been done by changing a plunger position and temperature of a prototype cavity under RF low power, and the method was verified to be effective.

1 INTRODUCTION

All buildings including a linac, a booster synchrotron and a storage ring of the SPring-8 are still under construction. In December 1992, one tenth of the storage ring building was completed and one of the RF stations which are distributed in four places over the circumference is included in it. Installation of a klystron and its high power equipment began in November 1993.

Tests of most RF components have been finished under high power [1]. However, there were still a few components which have not yet been tested. A 1.2 MW circulator for 508.58 MHz which is Y-type and produced by ANT company in Germany was newly developed. First, two 1.2 MW circulators were imported last year in March and their performances were tested under RF high power. There was an another issue on a 300 kW and a 50 kW dummy loads. Main problem was an RF leakage from them. We should suppress RF leakage under the level permitted by the related law and regulations.

Higher order modes (HOM) induced in a bell-shaped cavity [2] which is to be adopted in the SPring-8 storage ring have been investigated from various points of view. We have three methods to suppress coupled bunch instability. One is to change the flow rate of cooling water supplied into a cavity. Second is to use a variable plunger and third is to change the cavity shape. The temperature of the cavity, thus, goes up or down depending upon the flow rate of water which well changes the inside shape of a cavity. All frequencies of HOMs except a fundamental mode which is tuned by a variable plunger must be shifted, too. We mention about only frequency shifts of HOMs as a function of temperature in a cavity and a plunger position.

Concerning above subjects, we describe the results obtained experimentally.

2 A 1.2 MW CIRCULATOR

The structure of a circulator is shown in Fig.1. It has ferrite disks cooled by water at the junction of three wave guide. A static magnetic field is applied to the ferrite for its premagnetization. This field is generated by two permanent magnets, mounted top and bottom of the wave guide of the circulator. Each permanent magnet is surrounded by a coil which is used for compensating the effects of the fluctuation of temperatures of the cooling water and/or the ambience. The specification of the circulator is shown in table 1.

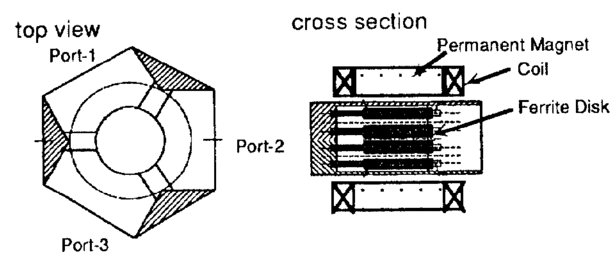

Fig.1 A top view and a cross section of the circulator

Table 1 The specification of the circulator

frequency	508.58MHz
20dB bandwidth	±2%
insertion loss	<0.15dB
forward power(CW)	max.1.2MW
backward power(CW)	max.600kW
VSWR	<1.2
flange	WR1800

The RF characteristic of the circulator was measured with a calibrated network analyzer. The results were as follows: The insertion loss was less than 0.1dB, the isolation was better than -25dB and the reflection was less than -25dB, i.e. VSWR was less than 1.12.

The high power tests were done under a set- up as shown in Fig.2. The 1.2MW klystron was connected to the circulator port-1 through a directional coupler (D.C.1). The port-2 was shorted with a short plate. The port-3 was terminated by a 1.2MW dummy load. Another directional coupler (D.C.2) was inserted between the port-3 and the dummy load. The worst phase condition is that the H-field of the forward 1.2MW wave and reflected 600kW wave are summed up in phase, which results in the largest energy loss at the ferrites. We tested in a condition of the total reflection of 875kW at the port-2, which is equivalent to the forward 1.2MW and reflected 600kW.The insertion loss was measured as a function of the distance between the short plate and the port-2. The step size was 10cm which corresponds to about 40 degree of the RF phase. The insertion loss was determined by measuring dissipated energy in the circulator, i.e. a temperature rise of its cooling water.

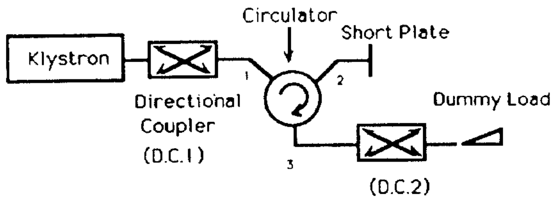

Fig.2 A setup for the high power experiment.

Figure 3 shows the ratio of the dissipated power in the circulator and the input power as a function of the position of the short plate. The maximum power loss at the circulator was observed when the short plate was set at a distance of 24cm from the port-2. The insertion loss was less than 2.5%, i.e. 0.11dB.

In conclusion, performance of the two circulators satisfied our requirements.

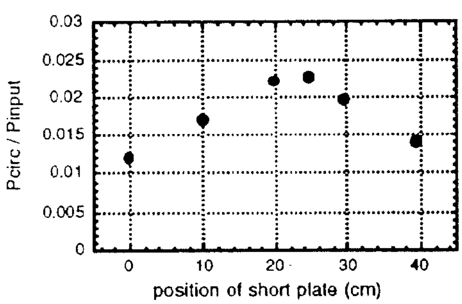

Fig.3 The ratio of the input power (Pinput) and the dissipated power at the circulator (Pcirc) as a function of the short plate.

3 DUMMY LOADS

Figure 4 shows a schematic diagram of the RF transmission system. The RF power from a klystron is fed to the eight bell-shape single-cell cavities through circulator and three stage magic-tees. Reflected RF power is absorbed in two types of dummy loads, 300 kW and 50 kW ones. We estimate the RF powers absorbed in these loads by considering only stationary reflection in the following two cases. Suppose we set a coupling coefficient β corresponding to the designed stored beam current of 100 mA. The reflected power is about 4 kW from each cavity without beam loading. This reflected power decreases with increasing beam current up to 100 mA. In another case, if the klystron power is not fed to a particular cavity which is inoperable, the reflected power induced by the beam loading becomes about 14kW. We chose 50 kW loads at the magic-tees and 300 kW one at the circulator in consideration of above cases. They are operational even for the beam current up to 200 mA. These loads should stand, of course, for much higher transient reflected power.

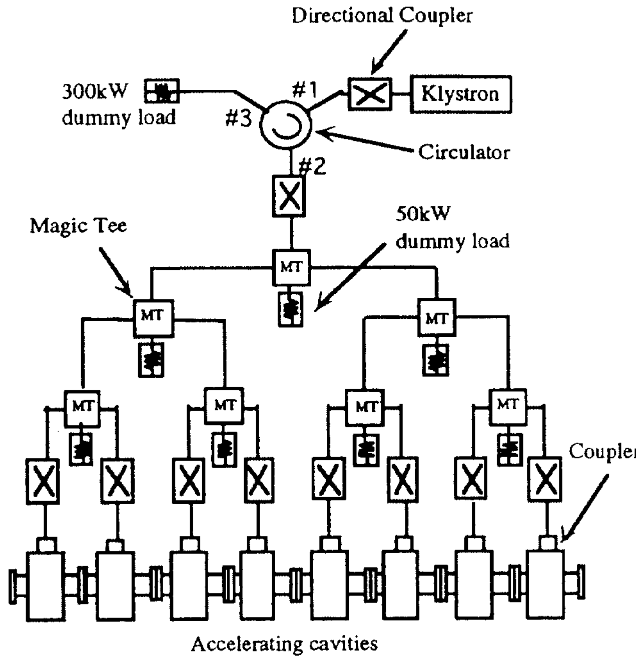

Fig.4 RF transmission system

We regards the RF leakage as the most important criterion in the selection process. In consideration of reliability and good shielding against RF leakage of the 300 kW loads, we selected them uniquely from the Premier Microwave of California, U.S.A. In order to examine performance, we purchased three different 50 kW loads from Premier, Bird Electronic corp., U.S.A., and Nihon Koshuha corp.

Preceding to the installation, we examined all the loads. Tests include low power measurements of VSWR and high power measurements of temperature distribution, power reflection, and RF leakage. The reflected power from cavities has higher frequencies, so VSWR should be good not only at 508 MHz but also at higher ones. Since a low power measurement was done with a network analyzer through a coaxial-to-waveguide transition, it provided the characteristics of only two transitions near 508 MHz. Obtained VSWR of all the loads are less than 1.1. The result of high power measurements is listed in table 2.

The 50 kW load from Premier shows very high temperature rise on the outer case. This is because water flows inside the resistor but not between the resistor and the outer case. Since this particular load has 10 flanges, a chance of RF leaking might be high because of the uneven tightening. A regulation on the RF leakage requires that leakage electric field is to be 40 dBμV/m or below on the site boundary. A measurement should be done to map the electric field with an antenna and a spectrum analyzer. In this measurement we used a close-field probe (Hewlett Packard 11940A) to get a reasonable estimate. Leakage was observed fairly locally, so the active area ($1.9cm^2$) of the probe is a good measure to estimate the field strength at a certain distance. We expect about 20 dB below the limit in the worst case with all the loads installed.

One practical problem arose in the 300 kW load that we could supply only 200 l/min in the test stand because of a big pressure loss in the water line. This is avoided by enlarging a diameter of the water connectors. Care also must be paid in the design of water lines to minimize the pressure loss.

In conclusion all the tested loads satisfied our requirements in the short term test. A long term operation for a reliability check is to be done next.

Table 2 Result of high power measurement

Parameter /company	Premier	Premier	Bird	N. K.
Power (kW)	300	50	50	50
Max temp rise (℃)	36(load),61 (transition)	80	18	13
Reflected power (kW)	.1	<.025	<.025	<.025
RF leak (dB μV/m)	132	152	152	142

4 TEMPERATURE DEPENDENCE OF HOM FREQUENCIES IN A BELL-SHAPED CAVITY

Quality and current value of the beam in the storage ring of the SPring-8 depend on beam instabilities. Intrinsic higher order modes (HOMs) in a cavity excited by the beam are likely to cause coupled-bunch instabilities [3]. Then characteristics of HOMs in a bell-shaped cavity were measured and their field distributions have been obtained with the bead perturbation technique [4]. Detuning HOM resonances from the instability conditions is one of the methods for suppressing the instabilities. HOMs with high coupling impedances have the high Q-value and the frequency shift by more than 100 kHz is needed. Figure 5 shows a schematic diagram of controlling HOM frequencies with two movable plungers. The plunger 1 on the side of the cavity is used for shifting HOM frequencies and the plunger 2 tunes the cavity to the accelerating frequency, 508.58MHz, within ±0.5KHz.

The temperature of the cavity increased by about 20℃ in operation of 100kW RF power. HOM frequencies change in accordance with the temperature. The two-plunger system was tested for a prototype cavity at various temperatures. We heated up the cavity with mantle heaters instead of RF power, since it is difficult to measure HOM frequencies while feeding the RF power into the cavity. The temperature of the cavity was set to 30,40,50 and 60℃ and controlled within ± 0.5 ℃. The cavity was evacuated to about 10^{-5} Pa to prevent oxidation. Figure 6 shows frequency shifts of the TM110 mode as a function of the position of the plunger 1, since those of other HOMs are similar to each other. The frequency of TM110 mode changed at the rate of 12KHz/℃ when the position of the plunger 1 was fixed. Then the frequency was very sensitive to the position of the plunger 1 and the shift at the rate of about 50KHz /mm was attained. The amount of frequency shift was independent of the cavity temperature in this measurement. Similar data were obtained when the roles of two plungers were exchanged with each other.

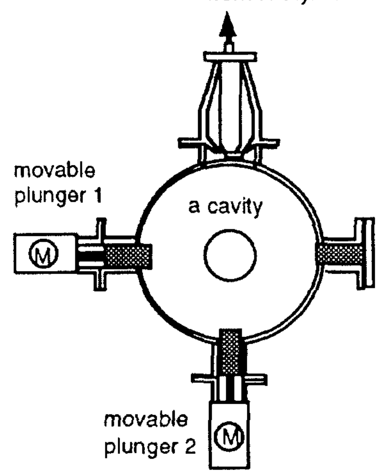

Fig.5 A schematic diagram of the two-plunger system.

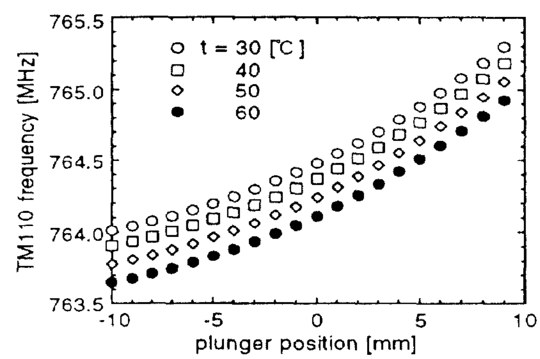

Fig.6 Frequency shifts of TM110 mode as a function of the position of the plunger 1. The accelerating frequency was tuned to 508.580MHz within ± 0.5KHz by the plunger 2. The origin of the abscissa shows the position of the inner surface of the cavity.

References

[1] H.Ego et al., "High Power Test of RF System for SPring-8", XVth International conference on high energy accelerators, vol.II, July,1992 pp. 712-714.

[2] H.Ego et al., "Status of the SPring-8 RF System", XVth International conference on high energy accelerators, vol.II, July,1992 pp. 709-711.

[3] Y.Yamazaki, K.Takata and S.Tokumoto, "DAMPING TEST OF THE HIGHER-ORDER MODES OF THE RE-ENTRANT ACCELERATING CAVITY", IEEE Trans. Nucl. Sci., 28, (1981) pp. 2915-2917.

[4] H.Ego et al., "Higher Order Modes of the Single Cell Cavity for the SPring-8", Proc. of the 9th Symp. Accel. Sci. Tec., (1993) pp. 249-251