

# Current Status of RF System for the SPring-8

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## Abstract

The RF system for the SPring-8 storage ring has been determined to adopt four 1-MW klystrons and thirty-two single-cell cavities. The electron energy loss per turn has been estimated to 12.9 MeV. An overvoltage ratio of 1.31 gives a sufficient quantum lifetime. A single-cell cavity with low higher order mode impedances has been designed by using the computer codes. The measured RF characteristics of the aluminum alloy model cavity agree well with calculated values. A single-cell cavity for high power test has been newly designed and fabricated. A test stand for the 1-MW klystron has been constructed. The threshold current limited by cavities themselves due to coupled-bunch instabilities was estimated to be 140 mA.

## 1 Introduction

The design of the SPring-8 synchrotron radiation facility which consists of a storage ring, a booster synchrotron, and a linac is in progress. The role of the RF system in a storage ring is to provide sufficient accelerating voltage for an adequate beam lifetime and power to compensate beam energy losses due to synchrotron radiation. Moreover, the instability caused by cavities on the beam must be minimized to attain a low-emittance and high current beam.

## 2 RF Parameters and Power System

The RF parameters are listed in Table 1. The energy loss per turn due to synchrotron radiation in bending magnets is 9.2 MeV. The energy loss due to insertion devices depends on the final distribution characteristics of undulators and wigglers. It is estimated to be 3.2 MeV for the typical insertion device configuration. Remaining loss due to cavities and vacuum chambers is estimated to be 0.5 MeV. The total energy loss amounts to 12.9 MeV per turn. An overvoltage is required for a long quantum lifetime. The growth rate of instabilities due to RF cavities must be significantly lower than the radiation damping rate.

Table 1. RF parameters of the storage ring.

Beam energy	8 GeV
Circumference	1436 m
Revolution frequency	208.78 kHz
Radio frequency	508.58 MHz
Harmonic number	2436
Total loss in the arcs	9.2 MeV
Loss in insertion devices	3.2 MeV
Parasitic mode losses	0.5 MeV
Maximum RF voltage	17 MV
Over voltage ratio	1.31
Quantum lifetime	1 day
Number of 1-MW klystrons	4

Four 1-MW klystrons are used to drive thirty-two single-cell cavities. Eight cavities are arranged on one straight section and the power from a klystron is divided equally to the eight cavities by seven magic tees. A 1-MW circulator with water load is used to protect the klystron from the reflected power. The phase of the cavity voltage can be adjusted by changing waveguide length between the circulator and the cavity. The RF power requirements are listed in Table 2.

Table 2. RF power requirements in the storage ring.

Power transferred to the beam at 100 mA	1.3 MW
Power dissipated in the cavities	1.6 MW
Total power	2.9 MW
Input power per cavity	90 kW
Power dissipated per cavity	50 kW

## 3 Accelerating Cavity Structure

A single-cell cavity for the SPring-8 storage ring has been designed. The design principles are as follows;

1) since the desired beam emittance is quite low and the beam current required is more than 100 mA, the threshold current of coupled-bunch instabilities due to cavities

must be sufficiently high. Therefore, the impedances for higher order mode's (HOM's) must be minimized as small as possible;

2) a simple cavity structure is desirable for easy fabrication. Consequently cavity-cooling mechanism is refined and, furthermore, phenomena induced by the bunched beam in the cavity must be understandable;

3) high shunt impedance in an accelerating mode generally conflicts with minimizing HOM impedances. Thus the accelerating shunt impedance is set as large as  $5.5 \text{ M}\Omega/\text{cell}$  in order to suppress excessive thermal load in the cavity and stabilize operation.

High transverse impedance was measured by using a prototype re-entrant cavity[1] and a single-cell cavity without re-entrant nose cones. The RF characteristics about them have been studied by comparing with the calculation using the computer codes SUPERFISH[2] and MAX3D[3]. Furthermore the dependence of resonant mode impedances upon the design parameters was also investigated.

A prototype cavity was fabricated to examine its RF characteristics. Figure 1 shows the cross-section of this cavity. The fabrication process was divided into 2 steps, since in order to check an interferences of several ports in construction. The prototype cavity was machined out of aluminum alloy with an overall tolerance of within  $\pm 0.1 \text{ mm}$ . The principal field mode distributions on a beam axis were measured by a perturbation method[4] on the prototype cavity, and compared with results obtained using a three-dimensional code MAX3D. The results agree well with the computed ones. The details on RF characteristics are presented in Ref.[5].

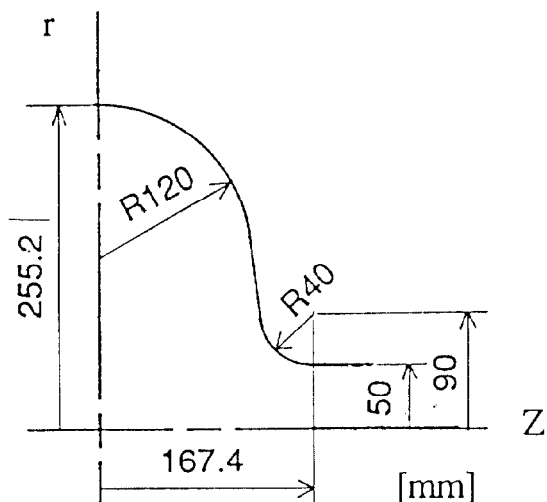


Fig.1. Cross-section of the model cavity.

Based on the former studies, a prototype cavity for high power tests was newly designed. The conceptional structure of this cavity is shown in Fig.2. The cavity is made of Oxygen free high conductivity(OFHC) copper and has

several ports for such as frequency tuners, HOM damping couplers, an input coupler, and a pick-up probe.

The input coupler consists of a coupling loop, a cylindrical ceramic window for the vacuum seal, and a rectangular WR1500 waveguide. A plunger type of tuner is used to correct deviations from the resonant frequency arising from the fabrication error, the thermal effects of power dissipation, and the phase difference between the generator and accelerating voltages. During the initial operation, blank flanges are used instead of the HOM damping couplers. By adjusting the length of these flanges, it is possible to control the distribution of HOM frequencies in a cavity. Damping couplers can be mounted later to avoid coupled-bunch instabilities if necessary. In order to control the amplitude and phase of the low-level signal generated by the high-stability oscillator, a pick-up probe is equipped to monitor the accelerating voltage.

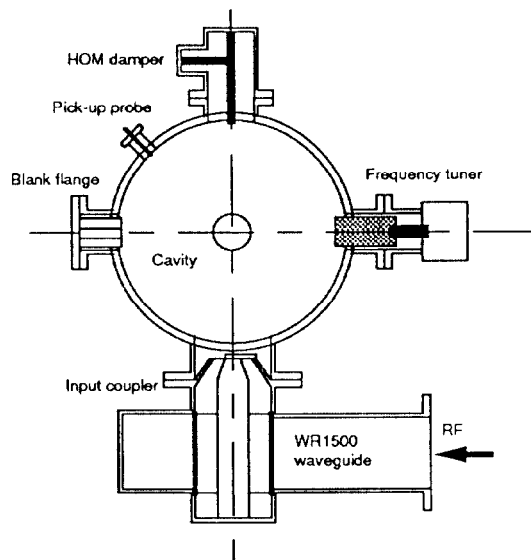


Fig.2. Schematic cross-section of a 508.58 MHz cavity.

The design principles of the prototype cavity for high power tests are listed below.

1) Two plungers for a frequency tuner are mounted at opposite sides to each other to minimize the symmetry breaking for the distribution of an electro-magnetic field in the cavity. Their offset lengths from the inside surface of the cavity is 10 mm, and one of them is movable and the other is fixed.

2) A coupling coefficient for an input coupler should be 1 because the prototype cavity has no beam loading.

3) Even if a shift from the resonant frequency happens by thermal deformation due to the energy loss on the surface of the cavity wall, which is estimated to 100 kW, a frequency tuner can recover 508.58 MHz automatically. The temperature in the wall of the cavity, of which structure

permits easy cooling, must be kept constant everywhere. The shunt impedance in the accelerating mode is estimated to be  $5.5 \text{ M}\Omega$ . When the accelerating voltage per cavity is 530 kV, the dissipated power in the cavity wall is calculated to be about 50 kW.

Two cavities were made to examine the effect through the different fabrication processes for joining two copper plates in constructing a cavity by diffusion-bonding and electron beam welding. As an input coupler, a cylindrical ceramic window type used for the TRISTAN MR[6] at KEK is adopted.

## 4 Test Stand for RF System

A test stand consisting of a klystron, waveguides and dummy load for RF cavities was constructed to examine their RF characteristics under high power. The klystron supplies about 1 MW RF power in continuous wave (CW mode). This is the same model as that to be installed in the storage ring of the SPring-8. In order to investigate characteristics of the klystron and, furthermore, take various data for the final design work of RF cavities, various studies are carried out. The block diagram of the test stand is shown in Fig.3. The specifications of the klystron are listed in Table 3.

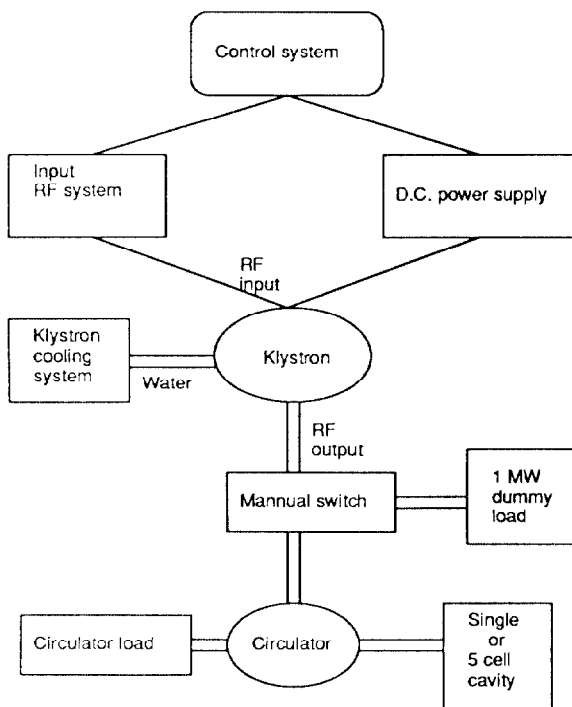


Fig.3. Block diagram of the test stand for the klystron and the RF cavity.

The klystron unit has three operation modes; storage-ring, synchrotron, and pulse modes. The first one is a constant amplitude and continuous wave mode. In the second one, the output power level is modulated in accordance

with a pattern required for a synchrotron acceleration at a repetition of 1 Hz. The pulse one generates a pulsed RF power of a  $10\mu\text{sec} - 1 \text{ msec}$  width and is used for aging cavities.

In the first stage, the studies on the performance of the klystron and the waveguide system propagating RF power of more than 1-MW from the klystron are examined by using a water cooled dummy load of 1-MW rating. Then RF cavities are installed. There are two type RF cavities. One is single-cell for a storage ring and the other consists of 5 cells for a synchrotron. Their input couplers and tuners are tested with or without RF power from the klystron.

Table 3. Relevant parameters of the klystron.

Company	Toshiba
Type	E3786
Frequency	508.58 MHz
Heater power	$23.0\text{A} \times 11.2\text{V}$
Anode vol.	64.5 kV
/current	2.2 mA
Cathode vol.	95 kV
/beam current	19.95 A
Drive power	3.8 W
RF power	1.2 MW
Efficiency	63.4%

## 5 Conclusion

A single-cell RF cavity without re-entrant nose cones has been studied. The actual RF characteristics of the model cavity was measured and the results agree well with the computed results obtained using a 3-dimensional code MAX3D. A test stand consisting of 1-MW klystron and RF cavity was constructed to investigate the characteristics of the klystron, single-cell and five-cell cavities under a high power of RF up to 250 kW.

## References

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