RF System

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At the occasion of the first edition of the annual report of SPring-8, it is natural to review the progress of research and development of the RF system of SPring-8. First, RF system is briefly introduced and then the progress is reviewed.

RF system design [1]

The RF parameters are listed in Table 1. There are four RF stations named A, B, C, and D-stations, symmetrically arranged around the storage ring. Each station has 1.0 MW klystron and 8 single cell cavities at a straight section with low betatron functions. The RF power from a klystron is divided equally into 8 cavities by seven magic-T splitters. A 1.2 MW circulator is inserted between the klystron and the first magic-T to protect the klystron from RF power reflection. The reference 508.58 MHz signal is distributed by optical fiber with phase lock loop to all the RF stations including injectors. At the commissioning phase, only 3 RF stations (B, C, D) are scheduled to be constructed.

The review of the development

The design of SPring-8 was started in 1986. The conceptual design of the RF system was done and main parameters were evaluated [2]. For the high power klystron, we decided to purchase an already developed one, not developing by ourselves. For an accelerating cavity, the structure was designed in considering acceleration efficiency, HOM (higher order modes) and instabilities, discharge, and fabrication. Single-cell cavities were investigated for storage ring and multi-cell cavities for synchrotron.

At first, a 1/6 scale model cavity was designed and manufactured. Single cell and 3-cell cavities could be assembled using these parts, and RF characteristics were measured with a network analyzer. Based on these models, full size aluminum models were constructed and RF characteristics were measured [3]. In 1988, the storage ring design was changed from 6 GeV to 8 GeV. RF parameters were also revised accordingly. These parameters are listed in Table 1.

Through model test and calculation, RF component design was progressed [3]. Cavity structure was investigated using several computer codes such as H2DB, HAX, SUPERFISH, URMEL, MAX3D and so on. The bell-shape cavity structure was selected to reduce the higher order mode impedance, with a little deterioration of acceleration efficiency. Full scale aluminum model was constructed and RF characteristics of fundamental mode and higher order modes were investigated [4]. The cross sectional view of the cavity is illustrated in Fig. 1.

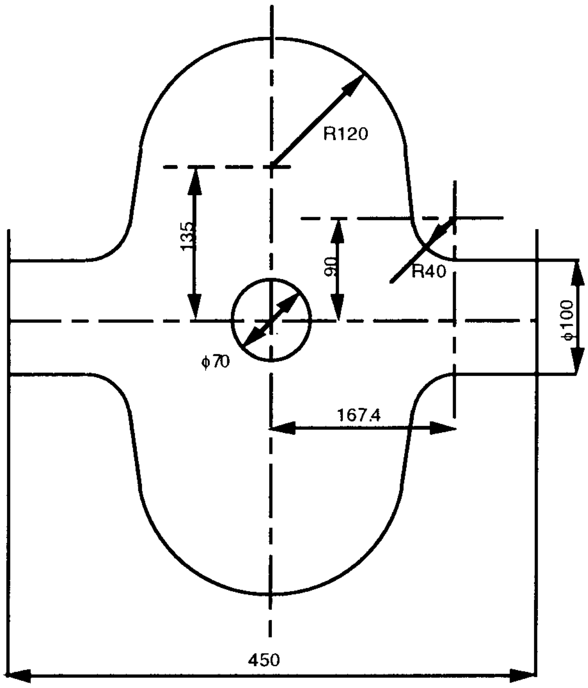

Fig. 1 Bell-shape single cell cavity of the storage ring.

Other components such as an input coupler and a tuner were also designed and full scale models were constructed. An RF test stand consisting of 1 MW klystron and its power supply was constructed in Wako campus and was put into operation [5]. At the same time, two prototype bell-shape single cell cavities were fabricated by different methods for comparison. One was fabricated by the diffusion bonding and the other by the electron beam welding [7,8]. At that time, the design of the RF system of the SPring-8 storage ring was fixed. In 1991, high power test up to 250 kW was performed for prototype input coupler and prototype 5-cell cavity of the booster synchrotron both with good result [9]. Based on the experiences of the klystron operation, low power system was designed for the SPring-8 storage ring. Temperature dependence of the optical fiber for the timing system was measured [10]. After low power test of the prototype single cell cavity for the storage ring, high power test was performed up to 150 kW with success [8]. HOM characteristics were investigated for the bell-shape cavity in detail and plural plunger system was designed in order to avoid coupled bunch instability by controlling the HOM frequencies [11]. High power test for 300 kW and 50 kW dummy loads were also performed and RF leakage was measured [12]. In 1993, 1.2 MW circulators were purchased from AFT in Germany and tested on the most severe condition of total reflection at 875 kW. Phase lock system for the 508.58 MHz reference line was designed and tested. Timing signal transmission test was also performed [9]. In 1993, klystron and its power supplies for an RF station were constructed. In the test run, higher harmonics noise of fundamental 60 Hz was generated from the klystron power supply with more than allowable level. One year later a transformer equipped with harmonics filters, was installed and the noise level was reduced. The klystron test stand was transported from Wako to the SPring-8 site and now the power test for several RF components such as 5 cell cavities are to start. Eight single-cell cavities among 32 were ordered and would be delivered in July 1995.

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
Momentum compaction factor	1.460×10^{-4}
Natural energy spread	1.094×10^{-3}
Synchrotron radiation loss	
in bending magnets	9.23 MeV
Energy loss in Insertion device	3.2 MeV
Parasitic energy loss	0.5 MeV
Radiation damping time	
longitudinal	4.2 msec
transverse	8.3 msec
Synchrotron frequency	2.13 kHz
Klystron power	1 MW
Number of 1-MW klystrons	4
Cavity	
Aperture	100 mm
R/Q (includ. trans. time fact)	155 Ω
Shunt impedance per cavity	5.5 MΩ
Multi-bunch operation	
Beam current	100 mA
Peak voltage	13.9 MV/turn
Overvoltage ratio	1.12
Bunch length (s)	3.63 mm
	12.1 psec
Wall loss	34.3 kW/cavity
Total klystron power	2.4 MW
Single-bunch operation	
Beam current	5 mA
Peak voltage	17 MV/turn
Overvoltage ratio	1.31
Bunch length	10.9 mm
	36.3 psec
Wall loss	50 kW/cavity
Total klystron power	1.7 MW

References

[1] SPring-8 Project Part I, Facility Design 1991 [revised], August 1991, JAERI-RIKEN SPring-8 Project Team.

[2] Conceptual Design Report of STA SR Project, June 1988.

[3] T. Kusaka, K. Inoue and M. Hara, RIKEN Houkoku 68, 28-34 (1992) in Japanese.

[4] T. Kusaka, T. Yoshiyuki, K. Inoue, I. Takeshita, and M. Hara, RIKEN-Houkoku 68,35-43 (1992) in Japanese.[1] SPring-8 Project Part I Facility Design

[5] M. Hara, T. Kusaka, T. Yoshiyuki and I. Takeshita, Proc. of the 1st Korea-Japan Synchrotron Radiation Symposium, Pohang Korea 1990, 283-304 (1990).

[6] K. Inoue, Y. Kawashima, T. Nakamura, and M. Hara, Proc. IEEE Particle Accelerator Conference, San Francisco, Vol. 1, 667-669 (1991).

[7] H. Ego, M. Hara, K. Inoue, Y. Kawashima, Y. Ohashi, H. Suzuki, I. Takeshita, and H. Yonehara, Int. J. Mod. Phys. A(Proc. Suppl.) 2A, 709-711(1993).
[8] H. Ego, M. Hara, K. Inoue, Y. Kawashima, Y. Ohashi, H. Suzuki, I. Takeshita, and H. Yonehara, Int. J. Mod. Phys. A(Proc. Suppl.) 2A, 712-714(1993).
[9] H. Suzuki, T. Kojo, H. Yonehara, T. Harami, Y. Miyahara, Y. Kawashima, Y. Ohashi, K. Inoue, and M. Hara, Proc. of the 8th Symp. on Accel. Science and Technology, 1991 Saitama, Japan, 113-115 (1991).
[10] H. Suzuki, Y. Kawashima, Y. Ohashi, H. Yonehara, H. Ego, N. Tani, T. Nagafuchi, T. Hori, T. Ohshima and M. Hara, Proc. of the 9th Symp. on Accel. Science and Technology, Tsukuba, Japan, 1993, 252-254 (1993).
[11] H. Ego, M. Hara, Y. Kawashima, Y. Ohashi, T. Ohshima, H. Suzuki, I. Takeshita, and H. Yonehara, Proc. of the 9th Symp. on Accel. Science and Technology, Tsukuba, Japan, 1993, 249-251 (1993).
[12] H. Ego, M. Hara, Y. Kawashima, Y. Ohashi, T. Ohshima, H. Suzuki, I. Takeshita, N. Tani, and H. Yonehara, Proc. of the 4th European Particle Accel. Conf., London, 1994, 1865-1867 (1994).