RF STATIONS OF THE SPRING-8 STORAGE RING

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Abstract

Construction of three RF stations in the SPring-8 storage ring was completed. Twenty-four single-cell cavities were installed in the storage ring. Three klystrons and their power equipments were also installed. Low power control system such as tuner control, feedback control for phase lock loop and cavity voltage control was assembled and operated. High power test up to 800 kW was carried out in each RF station and verified to satisfy the designed specification.

1 INTRODUCTION

Low power and high power tests for twenty-four bell-shaped single cell cavities and input couplers were carried out at a test stand from January and completed in the end of September, 1996. There are three RF stations in the storage ring, named B, C, D stations. Installation of cavities, couplers, waveguides, vacuum components etc. was started in parallel with high power test from April in D-station and completed in November '96 in C-station.

A klystron and its power equipment were installed in each RF station. Various kind of tests, in particular, interlock test for protection of a klystron were carefully done. After installation of waveguides, low power control system was assembled by using NIM modules. Then phase difference between each cavity was measured and adjusted with phase shifters of the waveguides. A measurement of attenuation of co-axial cables from pick-up ports on cavities and from directional couplers was done using a network analyzer.

To check total system under high power operation, a program for computer control was prepared based on a prototype program which had been developed to test a cavity [1]. A final version in beam operation was developed through high power test. The high power test was started from July and completed in December. During high power test, water temperature of cavity inlet was stable within ±0.15˚C in the range of zero to 800 kW. Beam was injected into the storage ring in March, 1997. Three RF stations are being operated stably. Here, processes and results mentioned above are reported.

2 INSTALLATION OF CAVITIES

Figure 1 shows the cavity assembly in one of the stations. The assembly consists of the cavities, the vacuum equipments, waveguides, input couplers and frequency tuners and so on. The cavities are connected to each other with special vacuum vessels; three vacuum manifolds and four bellows made of stainless steel. Two cavities at both sides of one vacuum vessel are connected smoothly by the slit copper pipe fixed in the vessel so as

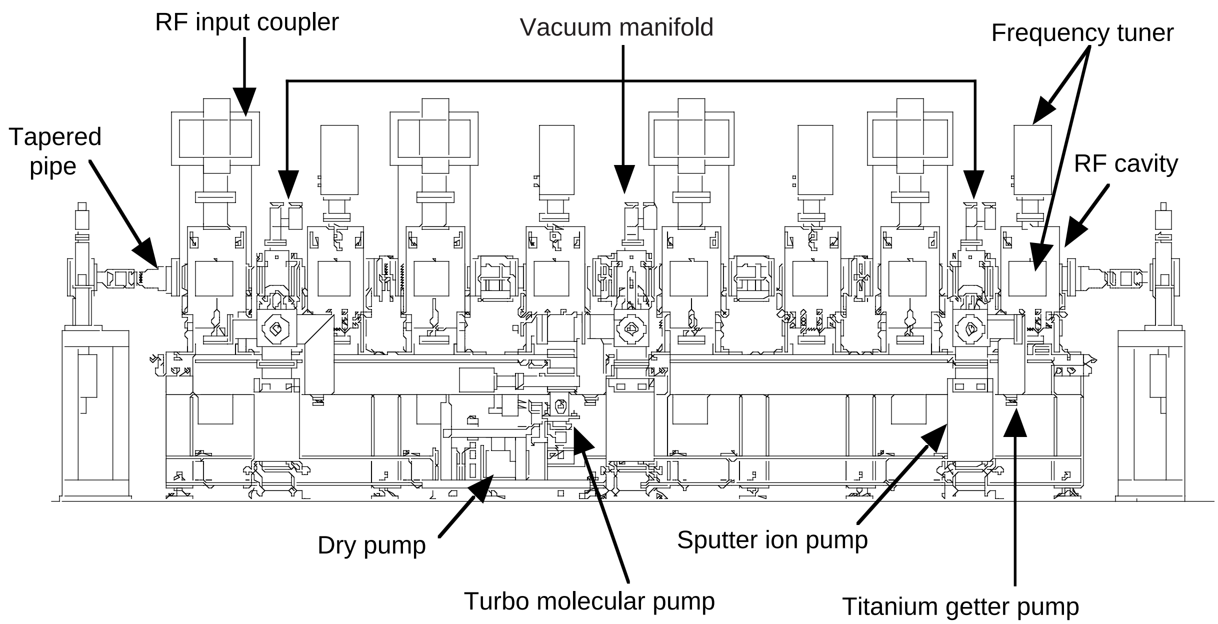

Fig. 1 Cavity assembly of the SPring-8 storage ring.

to reduce the parasitic impedance. Rings made of beryllium-copper alloy or silver with a diameter of 100 mm are used as an RF contact between a cavity and a vacuum vessel. The cavities at both ends of the assembly are connected to the vacuum chambers which are mounted in the quadrupole magnets with tapered ducts made of stainless steel and transforming the shape of cut-view with a diameter of 100 mm to the elliptical one with a semi-major radius of 50 mm and a semi-minor radius of 20 mm. The cavities are evacuated through beam ports with a diameter of 100 mm connected to the manifolds. Cold cathode gauges, main vacuum pumps, sputter ion pumps (pumping speed of 400 litters per second for N_2 gas) and titanium getter pumps (pumping speed of 800 litters per second for N_2 gas), are attached to the ports of each manifold. A thermocouple gauge, an extractor ion gauge, a mass-spectrometer and a roughly pumping system are connected to the manifold in the center position of the assembly. The roughly pumping system consists of a turbo molecular pump (pumping speed of 285 litters per second for N_2 gas) and a dry pump (pumping speed of 450 litters per second for N_2 gas).

After the success of a helium-leak test, the assembly was evacuated to less than 1×10^{-5} Pa by the roughly pumping system and was baked at 150 ˚C for more than 100 hours. After completion of baking, we started to operate the main pumps. The attained value of pressure in the assembly was about 1×10^{-7} Pa. The mass-spectrometer showed that there was only H_2 gas in the assembly after baking.

3 LOW POWER CONTROL

Reference RF signal of 508.58 MHz is distributed to three RF stations located at the storage ring and the synchrotron ring through optical fiber cables. The phase of a reference line is kept constant with the accuracy of ±0.1˚ when phase lock loop (PLL) is on. Even if PLL is off, the phase difference is ±1˚. This error is mainly due to temperature dependence of electric circuits and due not to the optical fiber cable [2].

Low power RF system in an RF station consists of (a) an automatic level control (ALC) and phase lock loop (PLL) of RF power, (b) a cavity tuning, (c) an anode modulation, (d) an interlock, and (e) various monitorings. Low power RF control diagram is shown in Fig. 2. A part (a) has a function to level klystron-out power and cavity voltage, and to lock klystron-out and cavity phase, respectively. A part (b) is to keep cavity resonating at 508.58 MHz with slight detuning offset by using a movable tuner. A part (c) makes klystron power handling stable compared with cathode modulation (independent anode power supply is installed in two RF stations out of three). A part (d) is for protecting equipments from break down, beam abort, and radiation safety. A part (e) is to check running condition and to respond to system failure.

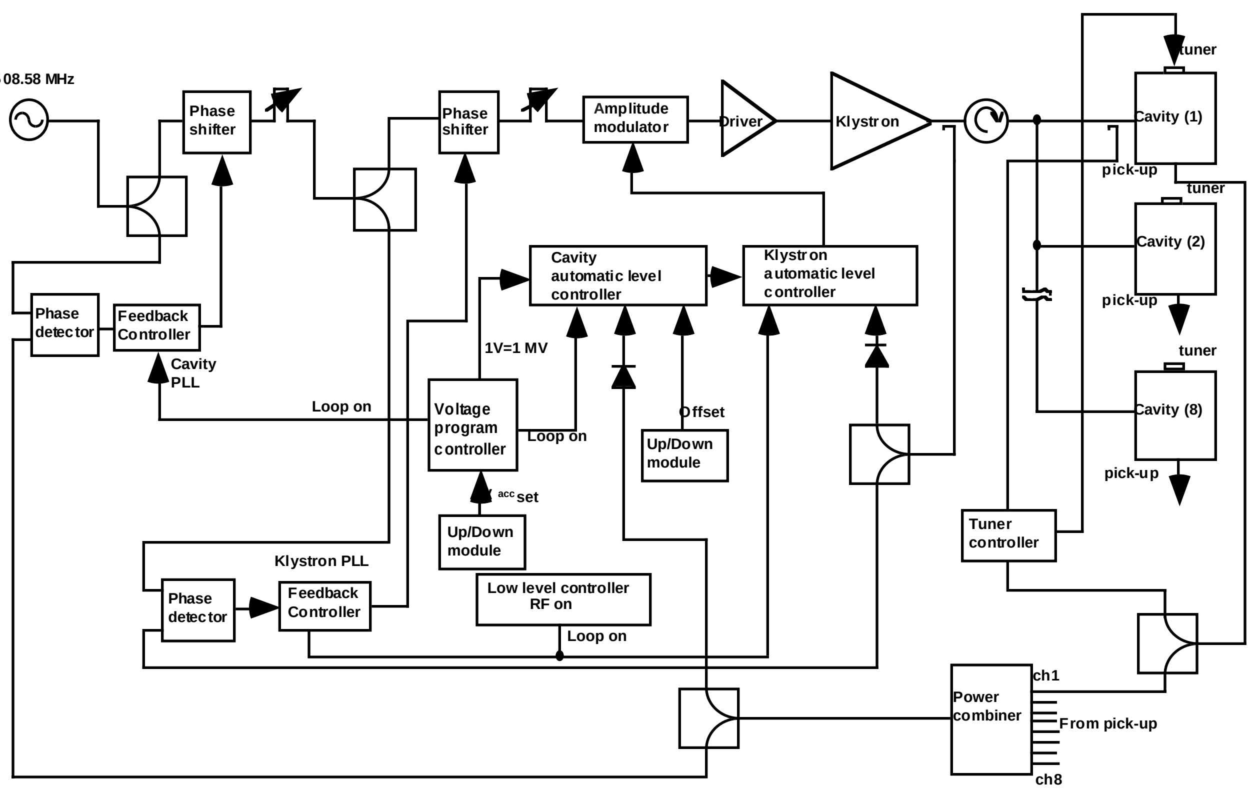

Fig. 2 Block diagram of low power system.

4 COMPUTER CONTROL OF RF SYSTEM

We developed a control program for cavity conditioning based on a personal computer system [1]. Based on this experience, a computer control program has been developed for the operation of RF system of the storage ring under the frame of the SPring-8 control system.

An operator uses a graphical user interface (GUI) to control RF system. A command is sent to a message server (MS) from GUI, then is sent to an access server (AS), and finally is reached to an equipment manager (EM) working on a VME. There the command is interpreted and is executed to control RF equipments through VME I/O modules. Control commands are sent in a text format. For example, to turn on the RF switch in B-station, a command of "put/sr_rf_rfsw_b/on" is sent to EM, then a digital pulse signal is sent to turn on the RF switch. As another example, to get the vacuum pressure in C-station, the command of "get/sr_rf_ccg_1_c/pressure" is sent to the EM, then an analog data of a cold cathode gauge is taken from an analog input board. The voltage is converted to the vacuum pressure using a conversion coefficient and the result is sent back to the GUI program.

The RF control system consists of three kind of panels; a main panel, a control panel for klystron power equipments and a low level control panel for each RF station. Functions on a main panel are to set following data; total acceleration voltage, a phase of each RF station, frequency of a master synthesizer, present values of the acceleration voltage, phase and vacuum pressure in cavities of each RF station. The control panel for klystron power equipments is used to start up, to shut down and to monitor power supplies. The main roll of the low level control panel is to change the acceleration voltage and station phase. These values are stored in the parameter database written on the main panel. They are manually input on a low level control panel, too. Another roll of the panel is monitoring the status of each klystron and cavities such as sensing an occasional arcs in wageguides, reflection power from the cavities and vacuum pressure. These control panels are working well now. Updating of the program is continued.

5 HIGH POWER TEST AS A TOTAL SYSTEM

We conditioned the assembly in high and continuous wave RF power operation. RF power up to 90 kW was successfully put into each cavity with the power control system aided by a computer mentioned in section 4. Figure 3 shows the time chart of the output power from a klystron and the pressure in the assembly. The left vertical axis shows the RF power from the klystron. About 89 % of the power is consumed in the eight cavities. The rest of the power is reflected from the cavities because coupling coefficient between a cavity and an input coupler is 2.0. The right vertical axis shows the pressure in the manifold between the first cavity and the second cavity at the right-hand side shown in Fig. 1. In the beginning of feeding RF power into the cavities, the vacuum pressure increased over 1×10^{-5} Pa at small RF power by the outgas from the inner surface of the cavities exposed to the excited electric field. The outgas was gradually reduced by the continuous exposure of the surface to the electric field. Finally the value of pressure reached to about 5×10^{-7} Pa while the RF input power of 90 kW was put into all cavities. The value of pressure without feeding RF power was also improved to about 6×10^{-8} Pa. Now, three RF stations are stably operated.

6 REFERENCES

[1] T. Ohshima et al., Proc. of the 5th European Particle Accelerator Conf., SITGES (Barcelona), 2047 (1996).

[2] H. Suzuki et al., 9th Symp. on Accel. and tech., 252 (1993)

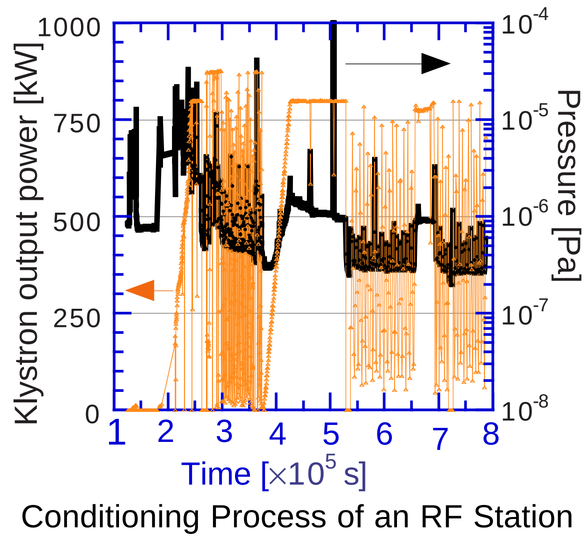

Fig. 3 Result of the conditioning by feeding the RF power into the cavities. The thin dotted line shows the output power from a klystron. The thick solid line shows the pressure in the manifold at the right-hand side in Fig. 1.