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RF system for SPring-8 storage ring at the commissioning

Takashi OHSHIMA, Hiroyasu EGO, Masahiro HARA, Naoyasu HOSODA, Yositaka KAWASHIMA,
Yuji OHASHI, Hiromitsu SUZUKI, Takeo TAKASHIMA, Hiroto YONEHARA
SPring-8, Kamigori, Ako-gun, Hyogo 678-12, Japan

Abstract

Three RF stations of the SPring-8 storage ring are in operation. We report the present status of the RF system of the ring and the performance of the cooling system. Some troubles occurred during the commissioning are also presented.

1 Introduction

SPring-8 is a third generation synchrotron radiation research facility. It consists of a 1 GeV injector linac, an 8GeV booster synchrotron and an 8GeV storage ring. There are four RF stations (A, B, C and D) in the storage ring. The installation of all apparatus at the B, C and D stations has been completed [1]. The A station will be installed near future.

The first phase of the commissioning of the storage ring was carried out from the middle of March to the middle of July '97. RF parameters at the commissioning are shown in Table 1.

Table 1
RF parameters

frequency	508.579343 MHz
harmonic number	2436
revolution frequency	207.78 kHz
number of RF stations in operation	3
number of RF cavities per RF station	8
energy loss per turn (without insertion devices)	9.2 MeV
total acceleration voltage	12 MV
synchrotron frequency	1.5 kHz

The RF acceleration system is composed of the following parts; a timing system which delivers a reference RF signal to three RF stations, a low level control system, a klystron and its power equipment, transmission lines, RF cavities and a computer control system.

The reference RF signal from a master oscillator is delivered to each RF station with a phase-stabilized optical fiber. The change in the transmission time of the fiber is within 5 ps/km/°C in the temperature range from 0°C to 30°C [2]. We use a cable which includes 6 fibers.

The low level control system keeps the RF phase and the acceleration voltage constant. A feedback loop is used to tune cavities at the fundamental acceleration mode. All cavities are initially detuned by -5 degrees of the RF phase to avoid Robinson instability.

The RF output power from the klystron is divided into eight using seven magic-Ts. The klystron is connected to the most upstream magic-T by the WR1800 waveguides. The cavities are connected to the magic-Ts with WR1500 waveguides. A circulator is inserted between the klystron and the first magic T to protect the klystron against the reflected RF power from the cavities.

The cavities have bell-shaped inner structures to avoid the beam instabilities caused by higher-order mode resonances of the cavities [3]. The cavities are evacuated by three sputter ion pumps and titanium getter pumps.

The RF system is operated from a central control room with networking computers. Using an RF main control panel working on a computer, we can set and monitor the RF frequency, the acceleration voltage, the station phase and so on.

The stored beam current can be reduced to a set value by changing the quantum lifetime. The lifetime is controlled by adjusting an RF phase of one RF station which results in decrease of the total acceleration voltage or the over voltage ratio.

2 Adjustment of RF parameters

2.1 Frequency of the reference RF signal

Before commissioning, the frequency of the reference RF signal was set to the design value of 508.580000 MHz. The frequency was adjusted to get the maximum turn number of the beam at the beginning of the commissioning. Now the frequency is adjusted to minimize the horizontal closed orbit distortion.

2.2 Phases between stations

It is necessary to adjust the station phases to gain a maximum acceleration voltage. Before the beam operation, the station phases were adjusted by the following procedure. Figure 1 shows the schematic drawing of the phase adjustment between the E station and the B station for example. The reference line 1 was used to deliver the reference RF signal from the E station to the B station. The signal from the master oscillator was sent by an electrical to optical transmitter (E/O) through the optical

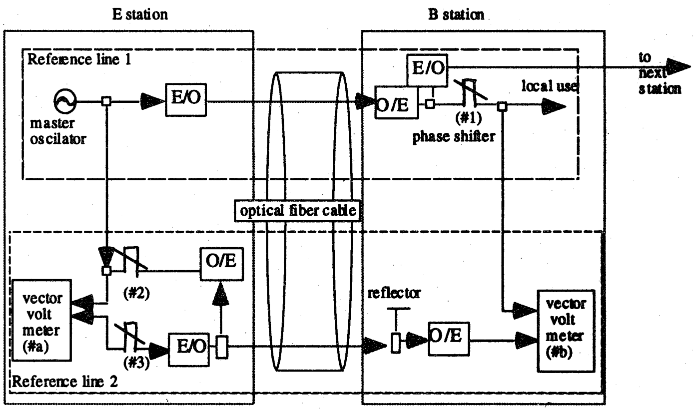

Fig. 1 Schematic drawing of the phase adjustment of the reference signal

fiber. The optical signal was transferred to the electrical signal by an optical to electrical receiver (E/O). The electrical signal is divided into two signals; one is used to send the signal to the next station and the other is used for the reference RF signal at the B station. To fix the phase of the B station, another reference line 2 was used. To fix the phase of the signal of the reference line 2 at the B station, two phase shifters (#2, #3) were changed with same amount so that the phase difference between the signal sent to the B station and the reflected signal from the reflector at the B station (#a) became zero. By this method there is an ambiguity in the phase by 180 degrees because an increase of the length of the fiber by one wavelength produces the same phase of the reflected signal. This ambiguity will be removed by adjusting the phases of reference line 2 with the signal of one half frequency of 508 MHz. The phase shifter of the reference line 1 (#1) was adjusted so that the phase difference between two reference lines (#b) became zero. Same procedures were carried out for the C and D stations.

At the beginning of the commissioning, the phase was adjusted to maximize the turn number of the injected beam with only one station. The phase of the D station was different from those of the B and C station by 180 degrees.

The phase relations between three stations were measured from the synchrotron frequency. The deviation of the phases between stations were less than 10 degrees except the 180 degrees deviation of the D station.

The phase between synchrotron and the storage ring was adjusted to maximize the injection efficiency and minimize the horizontal beam oscillation just after the injection.

2.3 Acceleration voltage

The total acceleration voltage was set to enough level taking account of the quantum lifetime. The acceleration voltage was measured by three methods. One was using a calibrated pickup signal. Second was using the wall loss of the cavity which was measured by a calorimetric method. Third was using measured synchrotron frequencies. Each result agrees within 10 %.

3 Cavity cooling system

The cavity temperature is stabilized by keeping the cooling water temperature constant. Figure 1 shows the schematic drawing of the temperature control system of the cavity cooling water. The temperature of the water is controlled in three steps. 1) The water flow fed from the utility to the heat exchanger is controlled. The cooling water after passing through the cavities is cooled down by the heat exchanger to 29.6±0.5 °C. 2) The heat moment of the water tank averages out the temperature to 29.6 ± 0.3°C. 3) The temperature is finally controlled to 30.0±0.2 °C by the heater installed between the tank and the cavities. The temperature of the water is measured by using with Platinum 200 Ω resistor. The accuracy of the temperature indication is 0.005 °C at 0 °C and 0.01 °C at 25 °C, 30 °C and 35 °C. The maximum heater power is 50 kW. The total water flow is 950 liters/min; a part of the flow (45 liters/min) is passing through the ion exchange resin to keep the water resistivity high. The temperature of the cavity can be changed by adjusting an angle of a valve the cavity. When one of the valve of a cavity is changed, a pressure control valve reduces the changes of the water flow of other cavities.

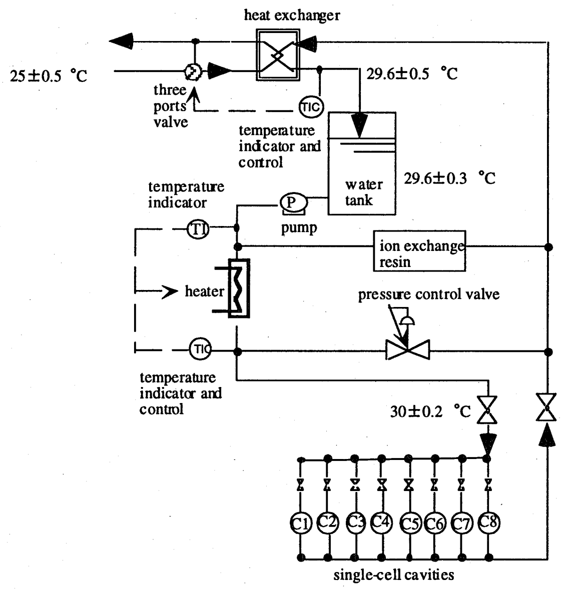

Fig. 2 Schematic drawing of the temperature control system of the cavity cooling water

Figure 3 shows the temperature deviation of the cooling water when the RF power up to 400 kW is fed to the cavities. The root mean square of the fluctuation of the cooling water temperature was ±0.02 °C which was one tenth of the specification value.

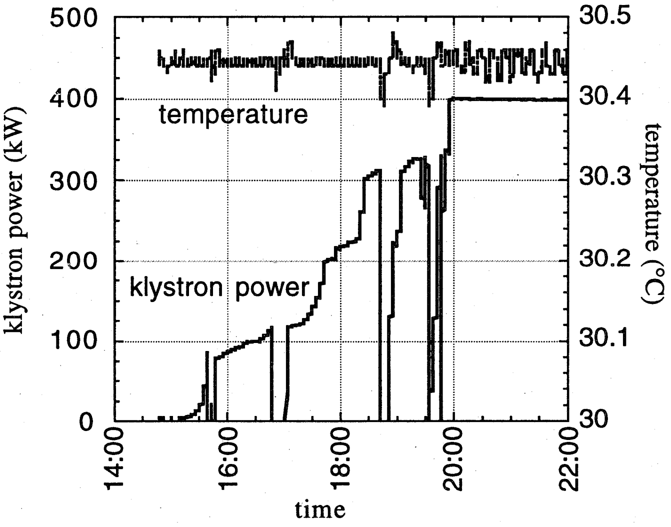

Fig. 3 The temperature deviation of the cavity cooling water and the klystron output power.

4 Troubles during the commissioning

4.1 Faults occurred during the commissioning

The beam commissioning of the storage ring was tripped by RF interlock signals. The sources of the interlock signals were a beam abort signal, low flow of cooling water for the klystron power supply, circulator

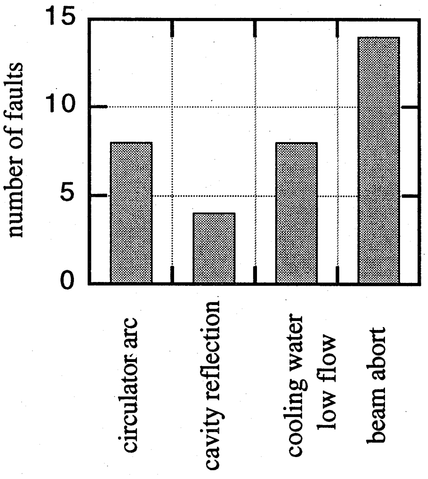

Fig. 4 Number of RF faults occurred during four months operation of the commissioning.

arc, an RF power reflection from cavities and so on. During the commissioning, about forty interlock signals were detected. Figure 4 shows the number of faults for each source. Beam abort signals mainly came from a raise of the vacuum pressure of the ring, a large deviation of the beam position and so on. Concerning the RF devices themselves, the circulator arc and cavity reflections happened at about 2 and 1 times/month, respectively. Failures in database system, interlock signals from communication errors of programmable logic control units of the safety system were also occurred. No beam instabilities due to higher-order mode resonances of the cavities have been observed at the beam current of 20 mA.

4.2 Vacuum leakage at a tuner

On May 27 in 1997, the vacuum pressure of the RF D station was degraded to 5×10^{-6} Pa at the beam current of about 18 mA. The value of the pressure was ten times worse than normal value. The pressure was changing with a period of a few minutes. Figure 5 shows the trend plot of the stored current and the vacuum pressure of the RF D station.

From the mass spectrum in the vacuum chamber, a large peak was detected in a mass number of 18. Possible leak points were a water channel of a cavity, a tuner, an RF coupler or a photon absorber. After we drained the water from the water channels, helium leak test was done for each cooling water channel. But frozen ice in the leak path prevented the helium gas from diffusing into the leak path. By pressurizing each cavity unit with nitrogen gas one by one, we could detect the increase of the vacuum pressure when the cooling water channels of the number 3 cavity unit was pressured. To remove the ice from the leak path, we baked the cavity to 150 °C for one hour and we blew the cooling water channel with a blower. We could find the leak point in the cooling water channel of a tuner. We replaced this tuner by a plunger with fixed length. The lost time due to the leakage was five days. The replacement of the plunger to a spare of the tuner was carried out during the summer shut-down period.

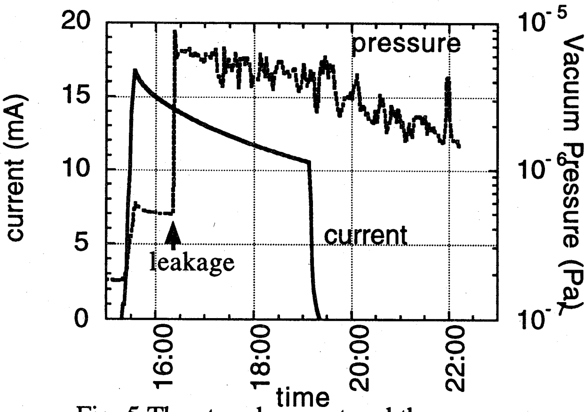

Fig. 5 The stored current and the vacuum pressure of the RF D station.

5 Conclusion

The RF system is stably operated. The temperature of the cavity cooling water was kept 30.44±0.02 °C at the klystron output of 400 kW.

Stored beam current was 20mA at present. No beam instabilities due to higher-order mode resonances of the cavities have been observed.

The beam commissioning of the storage ring was tripped by interlock signals of the arc of the circulator, large reflection from cavities and so on. The faults from RF devices occurred less than 3 times/month. A water leakage at a movable tuner was detected but it was recovered in five days. The faults will be decreased by improvement and maintenance of the RF system.

References

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[3] H. Ego et al., Nucl. Inst. and Meth. A383 (1996) 325