

OPERATION RESULTS OF UPGRADED COOLING WATER SYSTEM FOR THE PLS STORAGE RING RF CAVITIES

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Abstract

The RF cavities of the PLS storage ring have already used in normal operating mode. Multi-bunch beam instabilities driven by HOM in the cavity have been occurred, damaging the beam quality such as energy spread and horizontal beam size. Therefore a study of suppressing the HOM such as the longitudinal feedback system is currently being progressed at PAL. In parallel, a different method to avoid unfavorable excitation of the HOM has been implemented. A cooling system as a mean of thermal tuning of the cavities was used with a controllable range of 5°C from 25°C to 30°C, with a stability of $\pm 0.5^\circ\text{C}$. However, with a limited range of temperature control over the cavities, it was not possible to have a good control of the HOM. We constructed an improved cooling system of a wide controllable range of about 30°C, with a stability of $\pm 0.2^\circ\text{C}$. A detailed description of the RF cooling system is given, and the initial operation results on the beam quality is presented here.

1 INTRODUCTION

The Pohang Light Source (PLS) with operating energy of 2 GeV has provided stable beam to the users during the normal operation periods. It is optimized with four 500 MHz single cell cavities which provide the power necessary for compensating the beam loading, and the power for restoring the energy lost in form of synchrotron radiation. However, it was found that beam oscillations were occurred and occasionally they led to beam loss in the storage ring. This feature was identified as the cavity high order mode (HOM) induced multi-bunch instabilities[1]. Therefore an extensive study of the beam instability has been performed to avoid dangerous HOM excitation in the cavities.

The maximum power of 60 kW is dissipated in the cavity walls. This power should be carried away by a cooling water system. Since we wanted to maintain very precisely a control over a number of higher order mode (HOM) in the cavity, the temperature tuning of the cavity with cooling system is contemplated as one of curing multi-bunch instabilities of electron beam. In fact, the cooling system with a temperature range of from 25 to 30°C, with a thermal stability of $\pm 0.5^\circ\text{C}$, has been operated to dissipate the power from the cavities. However, it only provides cooling water for each cavity, and it was not obtained a good control over the HOM due to limitation of temperature range and stability. So, an

improved cooling water system to reflect thermal tuning precisely has been constructed, and is performed with more reliable and operational stability.

2 SYSTEM DESCRIPTION

The improved cooling water system for the RF cavities was designed[2] based on the requirements of temperature variation for a range of 30°C to 60°C and temperature stability within $\pm 0.2^\circ\text{C}$ at a given set value during the normal operation mode. And it should be constructed in an economical way by modifying the existing cooling system, and separated from the main utility cooling system except the supply of secondary cooling line.

2.1 Design of cooling water system

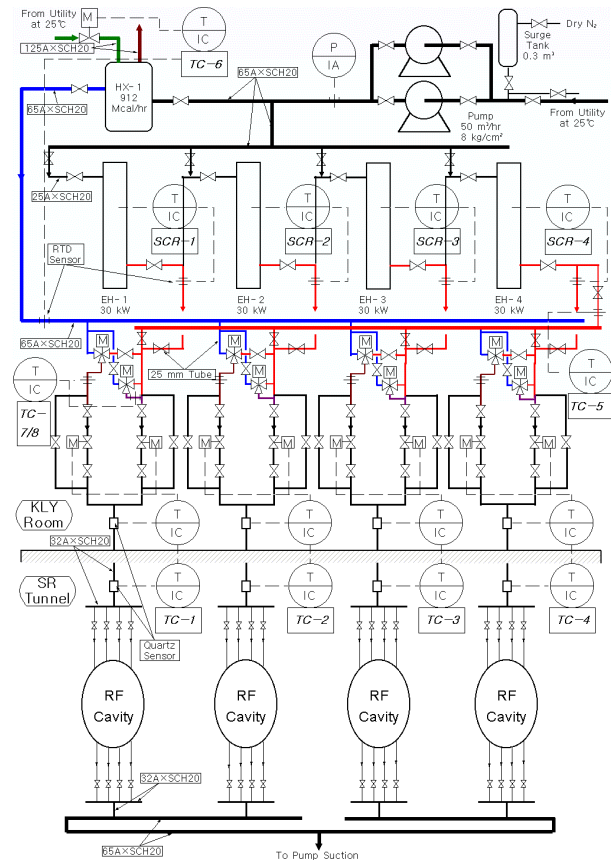


Figure 1: Flow diagram of rf cavity cooling water system

The total water flow rate per each cavity assembly is about 6 m³/hr. So, the total design flow rate of cooling water system for the cavities is 24 m³/hr, and the input pressure to circulate the water is about 8 kg/cm².

We designed the cooling system as two loops; the primary and the secondary loop. The primary loop has two circuits; one for cold water from the heat exchanger and the other for hot water from the electric heaters. The temperature of cold circuit will be maintained at about 27°C and the temperature of hot circuit at about 30 to 65°C, depending on the operation temperature of each cavity systems after thermal tuning. The secondary loop is interconnected with main utility system through the heat exchanger, and the low conductivity water of 1MΩ•cm about 25°C should be circulated into heat exchanger to dissipate the rf power. The final temperature control of incoming water into each cavity was achieved by regulating control valves at each cold and hot water line.

2.2 Cooling water temperature control schemes

In the cooling water temperature control system is accomplished a rough temperature control by ±0.5°C and a fine temperature control by ±0.2°C. The rough control is obtained by three-way electric motor-driven control valve with linear characteristics, for a full operation range, provided by a proportional-integral-derivative (PID) temperature controller. We select the process parameters depending on the heat balancing between the rf power and the cooling water. During the thermal tuning of cavity, the temperature will be determined by adjusting input water temperature. The fine control of input water temperature within ±0.2°C is carried out by regulating two-way valves installed downstream at each cold and hot circuits with computer controllers. As the temperature sensor, we adopted the linear-coefficient (LC) type quartz crystal with oscillator circuit. This sensor shows high resolution of 0.0001°C, excellent linear feature of frequency to temperature, and strong anti-EMI and anti-radiation performance.

The temperature control algorithm as shown in Fig. 2 was designed with PI combination, and the Smith predictive scheme to compensate for the time delay, originated from a transit time difference in cooling loop, and to prevent the process from the disturbance as in pressure fluctuation.

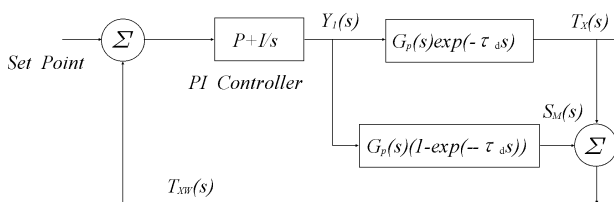


Figure 2: Smith predictive compensation algorithm for the cascade control applied in the cavity precision temperature control.

3 CAVITY OPERATING TEMPERATURE AND THERMAL TUNING

The temperature difference between the cold circuit and the hot circuit was selected from about 1.0 to 4.0°C through controlling the 3-way and 2-way control valves. After process tuning, the temperature was stabilized in 10 minutes with a opening range of control valves about from 45.0 to 55.0%, for the rf loading conditions. Figure 3 and 4 show an example of the temperature control trend during rf powering in the storage ring rf cavity.

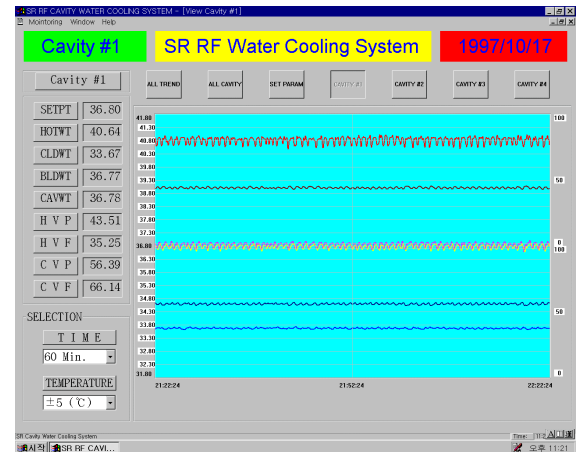


Figure 3: An example of 36.8°C temperature control of #1 cavity during rf loading

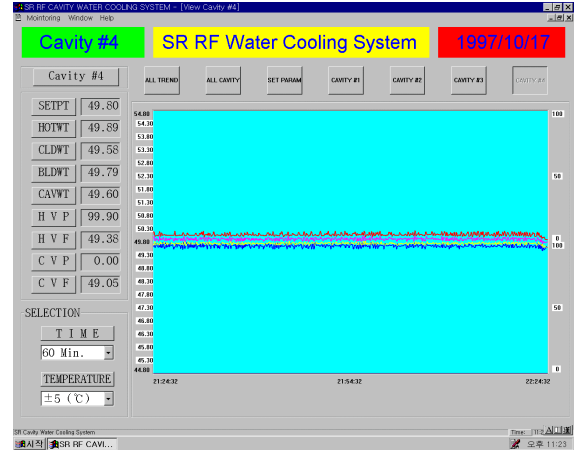


Figure 4: An example of 49.8°C temperature control of #4 cavity during rf loading

4 IMPROVEMENT OF BEAM QUALITY

After installing the cavity temperature control system, the photon beam quality has been greatly improved. Figure 6 shows the suppression of a longitudinal instability induced by TM₀₁₁ mode of the cavity 2 after changing temperature from 48°C to 45°C. We also achieved a minimum emittance of 11.3 nm-rad by utilizing this new system. The maximum stored current with stable condition extended to 200 mA. We expect to reach 250 mA by optimizing all four cavity temperatures soon.

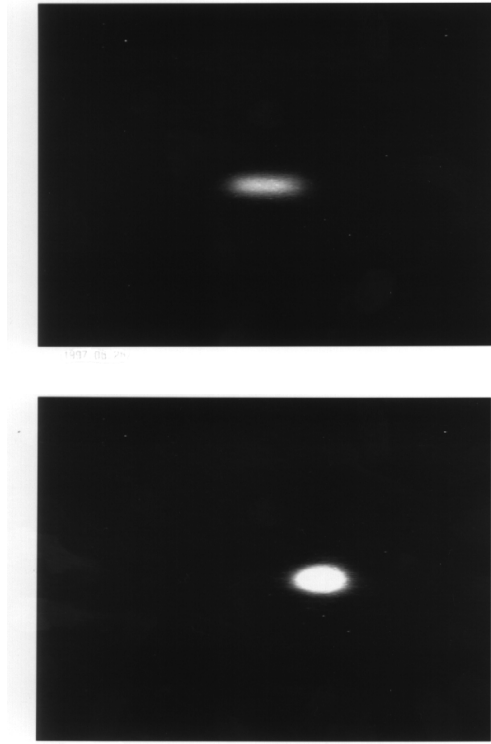


Figure 5: Reduction of a longitudinal instability by variation of cooling water temperature of the #2 cavity from 48°C to 45°C.

5 SUMMARY AND FUTURE WORKS

We have designed an improved cooling water system for the SR RF cavity assembly. The computer control system with Smith predicative algorithm was utilized, and it was also verified the possibility of a good performance of rf cooling water system. We will continue to perform the optimization of the stability cooling water temperature for beam instability.

6 REFERENCES

- [1] M.Kwon, et al., 'Instability studies of the Pohang Light Source', Proc. of EPAC96, Sitges, Spain (1996).
- [2] K.R.Kim, et al., 'Design Report on Precision Temperature Controlled Cooling Water System for SR RF Cavity', Pohang Accelerator Laboratory, PAL-PUB-97-004,(1997).