UPGRADE STATUS OF THE RF SYSTEM FOR THE PLS STORAGE RING*

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Abstract

The RF system for the Pohang Light Source (PLS) storage ring consists of four independent RF stations. We have been gradually upgraded up to total maximum RF power of 270kW so far, and can operate the stored currents of 180mA at 2.5GeV. Because of adding the insertion devices and increasing the storage current up to 250mA, more RF power is required. Therefore, two more 60kW klystrons will be replaced with 75kW klystrons this year, and one more RF station with fifth RF cavity will be installed in the next year. This paper describes the progress and plan about the upgrade of the RF system.

INTRODUCTION

The PLS is a 2.0 to 2.5GeV, third generation synchrotron radiation source, which has a full energy Linac and a storage ring. The PLS RF system at the initial phase in 1994 consisted of three stations of total 180kW. Each station was consisted with a 60kW CW klystron amplifier as a power source, a circulator, a single-cell cavity with cooling system, all connected by 6-1/8" coaxial transmission lines and low level RF system. After one more station was added in 1996, total RF power of 240kW can provide enough power to store up to 400mA with 1.6MV of the RF voltage at 2.0GeV and 200mA at 2.5GeV[1]. And two klystron amplifiers of 60kW klystrons were modified with 75kW klystrons for increasing the storage currents so far.

Table 1 shows characteristics of the present status of major components of the PLS RF system [2].

Table 1: Characteristics of the PLS RF System

Klystron amplifier Klystron tubes	60 & 75kW (CW max.) Philips YK1265 (2 EA) E2V K3773 (2 EA)
Transmission line High power Circulator	6-1/8" Coaxial lines AFT 80 kW, Coaxial
Cavities Shunt Impedance Unloaded Q Coupling Coefficient Gap Voltage	Single-cell (PF-type) >8 MΩ >35,000 ~1.8 to 2.0 400 kV/cell (Pc=20kW)

PRESENT OPERATION STATUS

In 2003, the PLS has been operating into the ninth year of the user operation. One of the operational targets of the year is to provide 180mA at 2.5GeV to users regularly with more than 95% beam availability. Two 60kW RF stations and two 75kW RF stations can support the stored currents of about 400mA at 2.0GeV and 220mA at 2.5GeV with six insertion devices operation. Optimizing the cavity temperature control system had been performed to cure the beam instabilities [3]. The new upgraded low level RF(LLRF) system has been operated very well[4, 5].

So far four 60 kW Philips YK1265 klystron tubes were replaced with new 60kW or 75kW klystrons after using about 32,000 hours lifetime for the PLS RF system.

The high power RF test stand has been operated with a spare cavity, in-house made klystron amplifier, and so on. Input couplers, klystrons, LLRF control electronics and prototype components have been tested in this high power RF test stand of the teat lab. Table 2 shows major parameters of present status of the RF system for the PLS storage ring.

Table 2: Parameters of present RF system

RF Frequency	500.076 MHz
Harmonic Number	468
No of Cavities & Klystrons	4 EA
RF Power (total)	270 kW(max.)
RF Voltage (total)	1.6 MV
Radiation Loss (@2.0/2.5GeV)	243 / 592 keV
RF Power Loss(@180mA) (@2.0/2.5GeV)	119 / 182 kW
Available Storage Currents (max.) (@2.0/2.5GeV)	~500 / 220 mA

Figure 1 shows the present RF system layout with four independent stations with klystron amplifiers, circulators, coaxial switches, RF cavities, 6-1/8" coaxial lines.

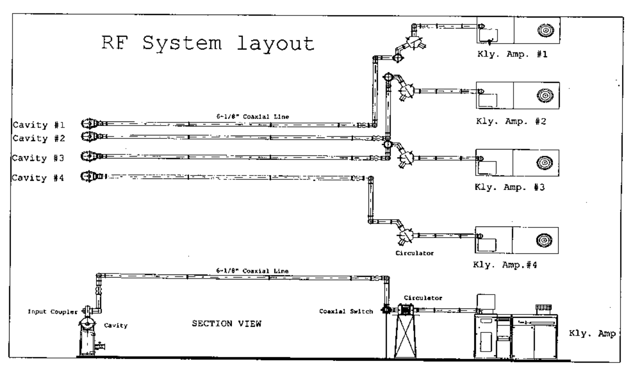

Figure 1: Layout of the present PLS RF system

KLYSTRON AMPLIFIER

The klystron amplifier system was a little modified the 60kW(CW) UHF TV transmitter made by Harris Allied. The normal klystron beam voltage of 25kV and the beam current of 6A have been operated within 0.5% by an automatic voltage regulator and a high-tension regulator.

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Four klystron amplifiers were operated between 20kW and 50kW level during normal operation at 2.5GeV of 180mA. Klystron amplifier performances were decreased until 45kW from 60kW of maximum output power. After replaced the klystrons due to lifetime and trouble, two YK1265 60kW klystrons and two K3773 75kW klystrons were installed and operated. Therefore, the available maximum total RF power is 270kW. So far, six klystrons were replaced including two failed klystrons. Average lifetime is 32,069 hours except two failed klystrons, and 21,607 hours including two failed klystrons.

We purchased six 75kW klystrons from the E2V technologies (former Marconi), and the klystrons have operated successfully at the PLS RF system. Table 3 shows the specification of the 75kW E2V K3773 klystron.

Table 3: Specification of the 75kW klystrons

Model	E2V K3773BCD
Maximum RF power	76 kW(CW)
Gain	40 dB
Saturated efficiency	45.3 %
Beam voltage	27.5 kV
Beam current	6.1 A
Drive power	7.5 W
Micro-perveance	~1.95

For operating the 75kW klystrons at the 60kW UHF transmitter, some mechanical modifications such as additional cooling, coaxial lines, and adjusting of the electrical specification have been performed. The beam voltage was able to increase for the 75kW klystron operation, even though the mould-type high voltage transformer has a little power margin. The 75kW klystrons have been operated a little bit low voltage for the safe operation of the power supplies as compared with the specification.

Figure 2 shows the 60kW and 75kW klystron assembly. The two klystrons have almost same mechanical dimension and four external adjustable cavities, but the magnet assembly of the 75kW klystron has the higher power and better cooling performances.

RF CAVITIES AND COOLING

The upgraded Photon Factory (PF) type single cell cavities were installed and have been showed good electrical and mechanical performances so far. The cylindrical-shape ceramic window is used for input coupler, which has a transition from WR-1500 waveguide to 6-1/8” coaxial line structure.

Four PF nose-cone type RF cavities are operated with temperature controlled cooling system. Only one input coupler was replaced due to a vacuum leakage of the ceramic window after maintained with vacuum sealing, and four input couplers were maintained with vacuum sealing to keep the ultra high vacuum condition since operated in 1994,.

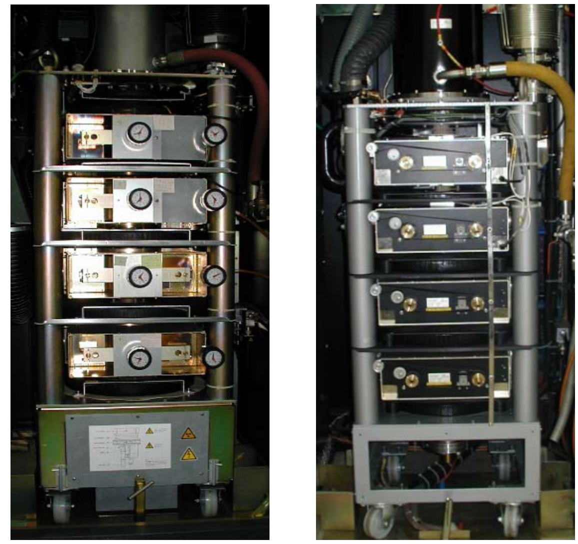

Figure 2: 60kW & 75kW klystron assembly

Efforts to identify the HOMs causing the collective instabilities were performed, and a trial to reduce HOMs instability was established. The RF cavity cooling water control system was massively upgraded in 1997 to shift the harmful HOMs and to regulate the operation temperatures of cavities at the stable condition. Upgraded temperature control system can be operated to closed loop from 27°C to 55°C and have better stability within 0.2°C at each set value. And then the temperature control system for four RF cavities was upgraded again to make it possible to remotely control by personal computer in the operation control room. Additional temperature controlled cooling system for the fifth RF cavity was installed at the separated cooling room. Also present RF cooling system will be moved to the new-built cooling room and upgrade the performance better stability of 0.1°C for more stable operation with EPICS control environments. As moving the cooling system from the RF building, the LLRF system and automatic voltage regulators for the klystron amplifiers will be re-arranged for installing the fifth RF station.

One module of HOM tuner was fabricated and tested at the low power to cure the coupled bunch instability excited by the higher order modes of RF cavities. It changes the resonance frequency of HOM by changing the volume of cavity inside through the movement of plunger. It will be installed into the fifth RF cavity after testing with high power at the RF test lab.

LOW LEVEL RF SYSTEM

After new low level RF (LLRF) system was designed, tested, and commissioned in 2001, the LLRF system has been operated without any serious troubles [5]. Since the old LLRF appeared to be the major causes of beam loss at the storage ring, we developed the new LLRF system with different control algorithms, more precise electronics design and advanced RF technology. In the new design, we incorporated NIM-type modules to enable the easy maintenance of each module. The old LLRF had an amplitude control loop, a phase control loop, and a cavity tuning control loop as usual. But the new LLRF system employs two pairs of amplitude and phase control loops. One is for controlling the variation of the klystron power supply, called the inner fast loop with the 1 kHz bandwidth. The other is for controlling the RF cavity variation due to the beam loading and current change, called the outer slow loop with the 100 Hz bandwidth [6]. In addition, the new LLRF was added some RF and control signal monitoring points at every important paths in the system so that we can easily diagnose and maintenance a system. Also Mechanical phase shifters were added to the LLRF to get the easy phase controllability and better stability. The new LLRF has good reliability and stability. As a result, beam availability was improved up to more than 95% from 91% during the former two years.

FUTURE PLAN

Two more 60 kW klystrons will be replaced with 75 kW klystrons for increasing the storage currents and RF power margin this year. Therefore, the high power RF system with four klystron amplifiers with total power of 300kW can support the stored currents of about 400mA at 2.0GeV and 250mA at 2.5GeV. We can get more 60 kW RF power as only replacing four 60kW klystrons with 75 kW klystrons. We are going to install the fifth RF station to the storage ring with a 75kW klystron and an RF cavity for increasing the storage current at 2.5GeV with ten insertion devices. For this station, an in-house made klystron amplifier will be installed, and a new low level RF system will be prepared with a minimum budget. After investigating and comparing of the klystron and IOT, we finally decided to choose the klystron for more easy maintenances and operations even though the UHF klystrons are disappeared at the commercial broadcasting market. When installing the fifth 75kW RF station, the RF system will be had total 375kW RF power capacity. Even though all ten insertion devices will be operated in the future, the RF power budget for compensating the radiation loss can have a much margins up to 300mA at 2.5GeV operation [7].

SUMMARY

Upgrade status of the RF system for PLS storage ring is introduced with present operation status. The high power RF system with four klystron amplifiers, circulators, and 6-1/8" coaxial components can supply the maximum 270kW of RF power to the four RF cavities independently. Therefore, the storage ring can be stored beam current of about 400mA at 2.0GeV and 220mA at 2.5GeV. And the new LLRF system has been operated with good reliability and stability. Also additional temperature controlled cooling system for the fifth RF cavity was installed and present RF cooling system will be moved to the new-built cooling room with upgraded performances for more stable operation with EPICS control environments.

We are increasing the RF power by replacing another two 60 kW klystrons with two 75 kW klystrons this year, and manufacturing a klystron amplifier system with domestic company for adding one more RF station according to installing insertion devices and increasing the storage ring beam current.

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