STATUS OF 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 and its total power of 255kW can support the stored currents of about 400mA at 2.0GeV and 220mA at 2.5GeV with three insertion devices operation. The RF system has been operated for a large number of hours with relatively good efficiency since 1995. Major improvements such as the RF cavity cooling, low level RF system, and the stable operation of the high power RF system have been completed since the start of commissioning in 1994. This paper reports status of the major RF system of the storage ring such as klystron amplifiers, RF cavities, low level RF system, and so on.

1 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 storage ring RF system should provide enough energy for compensating synchrotron radiation loss and the beam loading.

The PLS RF system at the initial phase consisted of three stations, in which each station has a 60 kW CW klystron amplifier as a power source, a circulator and a single-cell cavity, all connected by 6-1/8" coaxial transmission lines. The total 180 kW RF power capacity could afford to store the beam current up to 300mA at 2.0GeV with 1.2MV of the accelerating voltage. After one more station was added in 1996, total RF power of 240 kW can provide enough power to store up to 400mA with 1.6 MV of the RF voltage at 2.0GeV and 200mA at 2.5GeV[1]. And one 60 kW klystron was replaced with 75 kW klystron for increasing the storage currents at the beginning of this year.

Table 1: Characteristics of the PLS RF System

Klystron amplifier Klystron tubes	60 to 75 kW (CW) Philips YK1265 (2 EA) Marconi EEV K3672 (1 EA) Marconi EEV K3773 (1 EA)
Transmission line High power Circulator	6-1/8" Coaxial line AFT 80 kW, Coaxial
Cavities Shunt Impedance Unloaded Q Coupling Coefficient. Gap Voltage	Single-cell (PF-type) >8 MΩ >35,000 ~1.8 400 kV/cell

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

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2 PRESENT OPERATION STATUS

In 2002, the PLS has been operating into the eighth year of the user operation. One of the operational targets of this year is to provide 180mA at 2.5GeV to users regularly with more than 95% beam availability. Three 60kW RF stations and one 75kW RF station can support the stored currents of about 400mA at 2.0GeV and 220mA at 2.5GeV with three insertion devices operation. Optimizing the cavity temperature control system had been performed to cure beam instabilities[3]. The old low level RF system was replaced with the new upgraded system[4,7].

In 2001, the RF system was operated about 5,600 hours for the user services and machine studies. Four klystron amplifiers were operated for 22,427 hours in total with four klystrons, and about 689MWh of RF power was consumed in four cavities for storing electron beams. The 2.5GeV operations were carried out up to 170mA storage currents with total 172kW RF power, i.e. 43kW per cavity. User service operation in 2001, the total number of the RF system faults was 99 times, that were classified into 5 times of cavity tuner problem, 4 times of gap voltage instability, 7 times of control system fault, 7 times of circulator arc trip, 23 times of klystron amplifier fault, and 53 times of low level RF system fault. The RF system faults had a 37% of the total storage ring faults.

So far three 60 kW Philips YK1265 klystron tubes were replaced with new one after using about 30,000 hours lifetime for the high power RF system.

Using a spare cavity and a newly domestic assembled klystron amplifier, the high power RF test stand has been operated. Input coupler, klystrons, control electronics and prototype components have been tested in this high power RF test stand. 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)	255 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 Beam Current (max.) (@2.0/2.5GeV)	~500 / 200 mA

3 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. 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 maximum output power from 60kW. So the No.4 and No.3 YK1265 klystron tubes were replaced with new one. The tubes each have been operated 28,466 and 33,537 hours. But the replaced No.3 K3672 klystron was failed with breaking of the 2nd drift ceramic during RF test after installation. Also the second replaced No.3 K3672 klystron was failed again with cracking of the 4th drift ceramic after 1,337 operating hours. Finally the 75kW klystron K3773 was installed and operated. Therefore, the available maximum total RF power is 255kW. The klystron manufacturer is under inspection and warranty for the failed klystrons. So far five klystrons were replaced including two failed klystrons. Average lifetime, which is decreased about 75% of maximum output RF power, is 30,030 hours except two failed klystrons, and 18,290 hours including two failed klystrons.

At first, we purchased one 75 kW klystron from the Marconi and tested successfully at the factory and site acceptance tests. Table 3 shows the test results of the 75 kW EEV K3773 klystron.

Table 3: Test results of the 75kW klystron

Model	EEV 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

After the 75 kW klystron tested at the RF test stand with mechanical modifications such as additional cooling, coaxial lines, and adjusting of the electrical specification, we replaced the 60 kW klystron of the No.1 RF station.

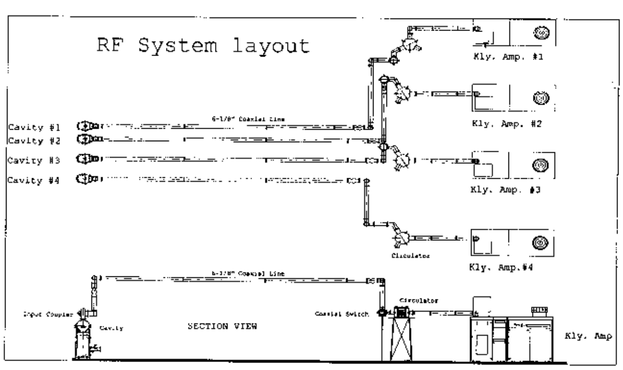

Figure1: PLS RF system layout

Figure.1 shows the RF system layout with klystron amplifiers, circulators, coaxial switches, RF cavities, 6-1/8” coaxial lines, and so on.

4 RF CAVITIES AND COOLING

The upgraded Photon Factory(PF) type single cell cavities are installed and showed good electrical and mechanical performances up to 60 kW. 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. A disk-type input coupler for the RF cavity has been developed, fabricated and tested up to 60 kW in the RF test stand[5]. Good performance and better response to the cavity higher order modes (HOMs) are tested. Also since this input coupler can extract HOMs better than cylindrical-shape one out of cavity, a specially designed HOM absorber was designed and fabricated with HFSS code of Ansoft[6].

Four PF nose-cone type RF cavities are operated with temperature controlled cooling system. Since operated in 1994, 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.

Efforts to identify the HOMs causing the collective instabilities were made and a strategy to reduce their effects were 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℃ to 55℃ and have better stability within 0.2℃ at each set value. And 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.

One module of HOM tuner was fabricated 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 one of the RF cavities after the high power RF test.

5 LOW LEVEL RF SYSTEM

The new low level RF system (LRS) was designed, tested, and commissioned in 2001[7]. Since the LRS appeared to be the major cause of beam loss, the new LRS was developed with different control algorithms and monitor functions from the old system. In the new design, we incorporated NIM-type modules to enable the easy maintenance of each module. The old LRS had an amplitude control loop, a phase control loop, and a cavity tuning control loop. But the new 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[8]. In addition, the new LRS was added some RF and control signal monitoring points at every important paths in the system so that we can easily diagnose a system performance. Mechanical phase shifters were added to the LRS to gain easy phase controllability and better stability. The new LRS has good reliability and stability. As a result, beam availability was improved to more than 95% from 91% in this year.

6 FUTURE PLAN

6.1 Replacing 60 kW klystrons with 75 kW

One 60 kW klystron was replaced with 75 kW klystron for increasing the storage currents and RF power margin. Therefore, the high power RF system with four klystron amplifiers with power of 255 kW can support the stored currents of about 400mA at 2.0GeV and 220mA at 2.5GeV. According to the installation plan of the insertion devices such as multi-pole wigglers and undulators in the near future, more RF power will be required to support the present current storage capability. Therefore, a plan to increase the RF power by replacing 60 kW klystrons with 75 kW klystrons and adding one more RF station in the storage ring are examined. When replacing three more 60 kW klystrons with 75 kW klystrons, we can get more 45 kW RF power, i.e. total 300 kW that means the storage ring beam current will be increased more than 100mA, up to 300mA of 2.5GeV at present operation condition with three insertion devices.

6.2 Addition of the fifth RF station

We have a plan to install the fifth RF station to the storage ring after replacing four 60 kW klystrons with 75 kW klystrons for increasing the storage current at 2.5GeV with ten insertion devices. For this station, an in-house assembled klystron amplifier will be installed and a new low level RF system will be prepared with a minimum budget. Another option of the 75 kW solid-state RF amplifier will be examined, because the high power RF amplifier for commercial television application has been developed with a economic price. So far a maximum of combined 60 kW solid-state RF amplifiers have been developed and using for broadcast transmitters instead of the klystron. When installing the fifth 75kW RF station, we will have total 375 kW RF power. Even though ten insertion devices will be operated, the RF power budget for radiation loss can compensate up to 300mA at 2.5GeV operation.

6.3 Joint research with KEK for RF cavity

We are cooperating a joint research program with the PF of KEK in Japan. The PLS RF system employed the upgraded RF cavities that were used in the PF storage ring before its upgrade to the low emittance ring. During this joint research, one more RF cavity will be added for the fifth RF station. By installing an additional RF cavity, the RF system will have five single-cell cavities. An important purpose of the joint research is to investigate the effect of the PLS RF system on various beam interactions, dynamic features, and HOM instabilities in the RF cavities. Since the basic beam parameters of the PLS and the old PF storage ring are different, various new results will be expected.

7 SUMMARY

Status of RF system for the 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 255kW 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 LRS is operating with good reliability and stability.

We are going to increase the RF power by replacing another 60 kW klystron with a 75 kW klystron this year, and have the upgrade plan of adding one more RF station according to installing insertion devices and increasing the storage ring beam current.

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