OPERATIONAL CHARACTERISTICS OF RF SYSTEM AFFECTING PLS BEAM STABILITY

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Abstract

The fourth RF station was installed to the Pohang Light Source (PLS), whereas its station consists of a 60 kW klystron amplifier and a nose cone type cavity connected by a coaxial transmission line. Total 240 kW RF power is available for storing electrons up to 400-mA at 2-GeV and 200-mA at 2.5-GeV of beam energy. During the normal operation, some dangerous higher order modes (HOMs) induced by cavities have been identified. Making an effort to suppress instabilities caused by HOMs has been started by enhancing the capability of cavity cooling temperature control and adding the transverse and longitudinal feedback systems. Besides these efforts, characterizations of the beam loss transient due to RF have been underway. A modulation experiment of the accelerating voltage is also planned using the fourth cavity. We present performance test results with newly installed low level system.

1 INTRODUCTION

The PLS is a third generation storage ring which has twelve-period TBA lattice with 5 meter long straight sections. The nominal operation beam current during the user shift is 120 - 150 mA with over twelve hours of lifetime. Currently six beamlines (VUV, X-ray scattering, NIM, EXAFS, Lithography, and Microprobe) are operational and two more beamlines are under construction. The first undulator, U7, is ready for installation this summer and the dedicated beamline by the end of next year. A typical operation parameters of PLS RF system are shown in Table 1. The RF system consists of four cavities independently powered by four TV-klystrons. The fourth station was added last summer. The accelerating voltage is maintained at 0.4 MV/cavity and the required RF power is 20 kW each[1].

Table 1: Parameters of the PLS RF System

Beam Energy	2.0 GeV
Number of Station	4
Momentum Compaction Factor	0.00181
RF Frequency	500.082 MHz
Revolution Frequency	1.068 MHz
Harmonic Number	468
Accelerating Voltage	1.6 MV
Synchrotron Frequency	11.5 kHz
Tune(n_x/ n_y /n_z)	14.28/8.18/0.013

2 PERFORMANCE WITH FOUR SYSTEMS

During the summer shut down period in 1996, the fourth RF station was added to the PLS storage ring. The total available RF power increases to 240 kW and total accelerating voltage becomes 1.6 MV, which increases the RF bucket height to 2.2%. For 2 GeV operation, 400 mA of beam current can be stored with enough margin, while it would be around 200 mA at 2.5 GeV. The maximum current achieved so far is 375 mA at 2 GeV, and 100 mA at 2.5 GeV. Fig. 1 shows the operation window of the PLS RF system in terms of the stored beam current for different beam energies and accelerating voltages. The newly installed cavity is located at the

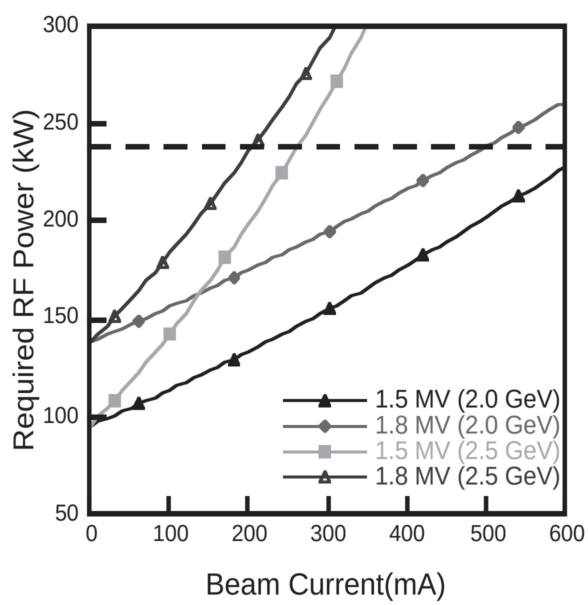

Figure 1: PLS operation window as a function of the beam energy and the current.

upstream in the RF straight section, 43 cm away from the next one. A refurbished version of the low level system was also installed. In the new system, various new and enhanced features are included. For higher reliability and stable operation, filter stages are added and dynamic ranges of the RF detection circuits are extended. For better isolation from outer noise, housings for RF parts are separated and multi-shot circuit is added to the trip signal processor. Also system installation and wiring are simplified to ease the maintenance, test and measurements.

During the normal beam operation of the ring, beam losses with unknown causes occurred and RF system trips were accompanied in most time. To monitor these transients, a relatively fast data acquisition system was installed to monitor RF parameters with pre-triggering. RF system trip signal triggers the acquisition system with preset pre-triggering time. It is observed that most of the beam loss with unknown causes force the RF system to be tripped by high reflection power or high vacuum pressure. However, what causes to increase the reflect power or the vacuum pressure is still not clear. Sometimes beam is lost owing to the instabilities. In Fig. 2, a periodic oscillation of the reflected power signal is observed just before the beam loss. The frequency of the periodic oscillation happens to be similar to the one of the low frequency oscillation[2].

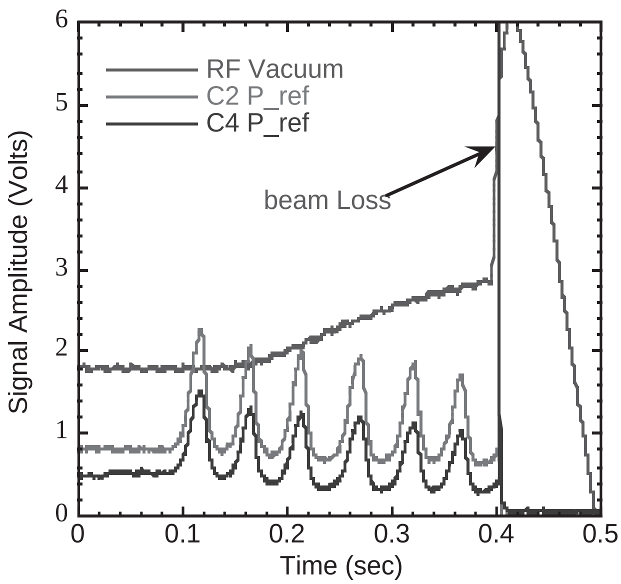

Figure 2: Behaviors of the vacuum pressure and RF reflected power signals at a beam loss transient.

3 EFFECTS ON THE BEAM STABILITY

With three cavities, at the level of beam current of 120 mA, collective effects can predominantly limit the maximum stored beam current in the storage ring for the user opeartions. The HOMs in the cavity #2 was found to be the major source to invoke the collective instabilities.

For studying longitudinal instabilities, mode identification experiments have been performed[2]. Using the normal mode method with a uniform fill pattern, HOMs invoking coupled bunch instabilities can be identified. Using the sum signal from the four BPM buttons, the beam current spectrum has frequency components at multiples of the bunch frequency and the oscillations of individual unstable modes appear as sidebands about the bunch harmonics. The oscillation amplitude of unstable modes can be determined from the ratio of the sideband to the carrier. By changing fill pattern, since HOMs appeared at different aliased frequencies, the reliability of a specific mode identification increases. The most dangerous two modes were found to be 758 MHz, and 1,707 MHz HOMs, identified by comparing with the calculation.

To check the stability of the photon beam, a photodiode is placed at the focal point of the VUV beamline, measuring the oscillation frequency of the photon beam. At certain condition, the time signal shows a discrete frequency component, which is turned out to be the synchrotron oscillation frequency. By changing conditions such as cavity temperature, this apparent oscillation has disappeared. A sampling data from the stripline signal shows that the phase between bunches are oscillating(phase jittering).

The limit was relieved somehow as the cooling path of the cavity #2 was modified. With a narrow controllable range (~4^o) of the cavity temeperature control system, the maximum quiescently stored current is extended to 180 mA. Adding one more station, however, a severe dipole mode was observed at 62 mA, which is not possible to remove by the present cavity temperature control system. Fig. 3 shows the beam shape just before and after the threshold current.

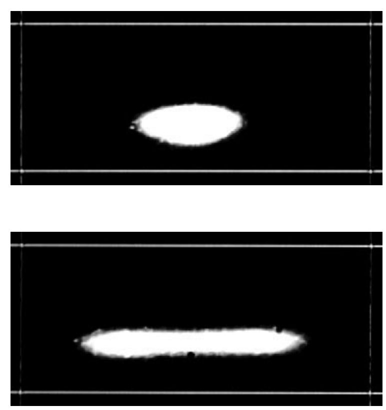

Figure 3 : The electron beam cross section monitored from the diagnostic beam line before (top) and after (bottom) when the stored beam passes the threshold current for the cavity 1.

In Fig. 4, it is illustrated how the cavity temperature sensitively affects the beam qualities. A small variation of the cavity temperature forces to change the lifetime when it is set near a 'critical' temperature. As the temperature decreases below this 'critical' value, a dipole longitudinal mode is invoked, forcing the beam unstable to reduce the lifetime. The stored beam current was above the threshold. When the beam current is above the threshold for a transverse mode, however, the lifetime increases as the temperature passes the 'critical' range invoking the instability. This reverse phenomenon occurs owing to the emittance growth, which

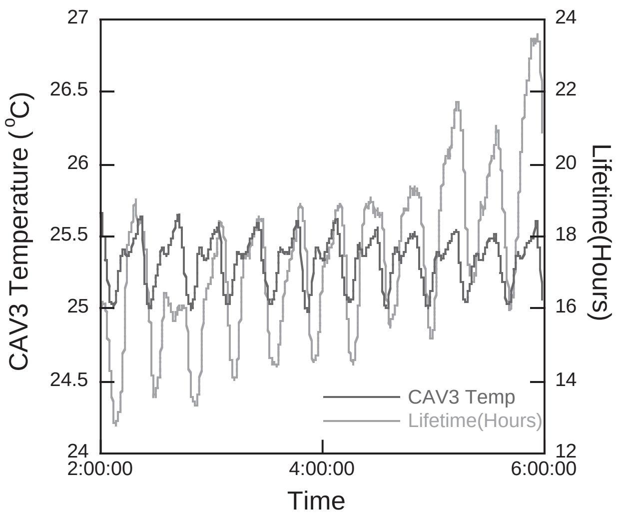

Figure 4: The correlation of the stored beam lifetime with the variation of the cavity cooling temperature in the PLS storage ring

increases the damping time.

4 EFFORTS TO PROVIDE HIGH CURRENT QUIESCENT PHOTON BEAM

In the previous section, it is shown that the cavity temperature affects the beam stability sensitively, and the present temperature control system has very limited capability, not suitable for wide varieties of temperature setting. Now a plan for upgrading the cavity temperature control system is underway, in which a wide range of temperature variation (30 ^{o}) and precise regulation (0.2^o) will be achieved. When this will be finished, it is expected to lower the impedances of the HOMs substantially, which will also save the power requirement of the longitudinal feedback system to be mentioned below.

The gap voltage modulation technique was also performed using the cavity 1. Without modulation, as mentioned before, above 62 mA the beam size increased with a strong dipole instability mode. This limit was extended to 90 mA when a modulation was given to the input RF signal of cavity 1. The modulation frequency was varied and it was observed that a best result was obtained with harmonics of the synchrotron oscillation frequency. The modulation amplitude of the RF level was kept less than 10% of the total input power.

The most important effort of all should be the development of the longitudinal and transverse feedback systems. The transverse feedback system is installed and being tested[3]. A PEP-II-type longitudinal feedback system was being ordered and a kicker for this is under development. All these systems should be working by the middle of the year 1998.

A new disk type input coupler is developed which inherently has better damping capability of HOMs than the present tube-type one. Upon using this coupler with proper HOM absorbing technique, it will also help lessen the harmful effects of HOMs.

5 SUMMARY

Longitudinal and transverse coupled bunch instabilities were observed and some strong modes were identified by the normal mode method. Though cavity temperature change is effective to some extent to suppress these modes, with the present narrow range system it is difficult to remove all the dangerous HOMs. A plan for upgrade is underway.

The fourth RF station was added to the PLS RF system. It will improve the power requirement for high current operation. However, to utilize its full function, the cavity temperature control system should be improved. In the mean time, the cavity 1 is used as a modulating Landau cavity.

Unknown beam loss transient was closely monitored by fast sampling, which provides informations how RF parameters are altering during the transient and clues what causes the beam loss.

6 ACKNOWLEDGMENT

This work has been supported by the Korean Ministry of the Science and Technology (MOST) and the Pohang Iron and Steel Company (POSCO).

7 REFERENCES

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