INSTABILITY STUDIES OF THE POHANG LIGHT SOURCE

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ABSTRACT

The Pohang Light Source(PLS) is routinely operated for the beamline users at about 120 mA with over twelve hours of beam lifetime. Unstable beam conditions have been reported for certain operation setting and an attempt of a systematic study for the beam instabilities has been made. The coupled bunch instabilities, mostly induced by the higher order modes(HOMs) of the RF cavities, and the ion trapping are the major subject in this campaign. Couple of methods to cure these unstable conditions have been applied and the fast feedback system is also being designed and tested. This paper will present the approaches and results of the measurements.

1 INTRODUCTION

The PLS is the full-energy injected, the 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 three beamlines(VUV, X-ray scattering, NIM) are operational and three more beamlines are under commissioning. The first undulator is being assembled and aligned and it will be installed early next year with the dedicated beamline. A typical operation parameters of PLS are shown in Table 1. The RF system consists of three cavities independently powered by three TV-klystrons. The fourth station will be added this summer. The accelerating voltage is maintained at 1.2 MV and the required klystron power is 60 kW total.

Table 1: Parameters of the PLS Storage Ring

Beam Energy	2.0 GeV
Nominal Beam Current	120 mA
Momentum Compaction Factor	0.00181
RF Frequency	500.082 MHz
Revolution Frequency	1.068 MHz
Harmonic Number	468
Accelerating Voltage	1.2 MV
Synchrotron Frequency	9.8 kHz
Tune(υ_x/υ_y)	14.28/8.18

During the commissioning phase and the user shifts at certain setting, unstable beam conditions were observed. At the level of beam current of 150 mA, collective effects can predominantly limit the maximum stored beam current in the storage ring and the photon beam quality is also deteriorated if no effort for suppression is made. The HOMs in the cavities are considered as the prime candidate for the source to invoke the collective instabilities. Preliminarily these problems in PLS have been treated in two ways: measure the RF characteristics effective to the single bunch, and characterize the multi-bunch instabilities in terms of rf-related parameters. The first topic will be presented in the separate papers[1,2].

Longitudinal instabilities have been studied to examine the characteristics and to estimate the effect on the photon beam quality. Since the emittance measurement diagnostics has not been set up yet, complete understanding and analysis are not possible. However, mode identification and an attempt to suppress instabilities has been made. HOM-induced transverse multi-bunch instabilities are not strong at the present level of operation beam current. Instead, there exists strong, low frequency transverse oscillations. Transverse beam instabilities mentioned below without a comment means the latter one. These are speculated to be invoked mainly by the ion trapping even though there are no direct evidences. Power supply ripple, ground and other mechanical vibrations turned out to make a negligible effect on the transverse beam motion. Some indirect evidences for the ion trapping are the sudden change in beam lifetime, tune, and low frequency oscillations. Experimental results will be shown in the subsequent section.

2 OBSERVATIONS

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). Figure 1 shows the current dependence of the oscillation amplitude.

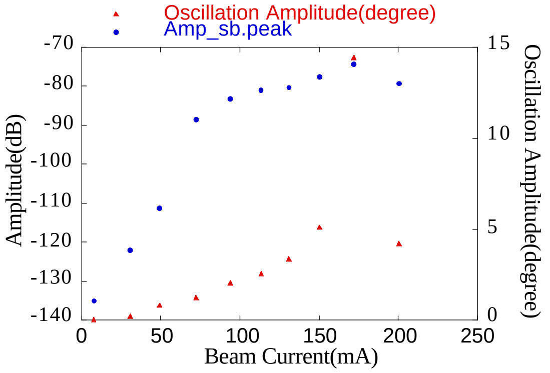

Figure 1: Measured amplitude of a single coupled bunch mode as a function of beam current.

Transverse oscillation is normally slow and not appeared frequently. Since it is slow, it can be easily observed in the stripline signal and BPM signal monitor. The source is not identified, but the ion trapping is most suspicious. The horizontal and the vertical beam signal from a set of four BPM buttons are displayed in X-Y mode which shows a slow beam motion in the transverse plane. Since there has not been a diagnostic beamline this has been used most of time during this study. Several indirect evidences of ion trapping are observed, such as the sudden changes in lifetime, betatron tune and the beam position at a fix location of the ring.

3 EXPERIMENTS AND RESULTS

3.1 Longitudinal Mode Identification

For studying longitudinal instabilities, mode identification experiments have been performed. Using the normal mode method[3] 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. Figure 2 is a typical result of this measurement. For this case, one in every four buckets(117 bunches total) was filled and the total beam current was 100 mA. The most dangerous two modes appeared are 758MHz, and 1707MHz HOMs, identified by comparing with the calculation.

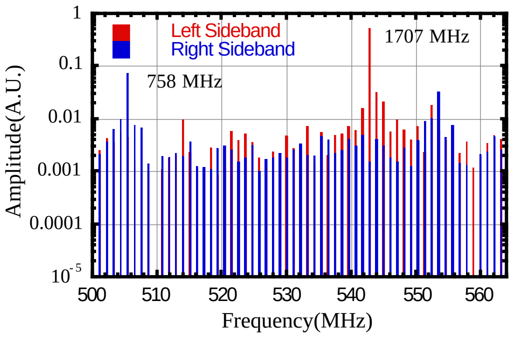

Figure 2: Measured amplitudes of the synchrotron sidebands showing two strong longitudinal HOMs aliased into the measured frequency window.

3.2 Transverse Oscillation

Transverse oscillation has been observed from BPM signals and stripline monitor signal. The characteristics are that the oscillation frequency is low(from few Hz to 100 Hz) and that the frequency is not still. Various possible sources were scrutinized such as the power supply ripple and stability, ground and mechanical vibration and LCW temperature oscillations. The power supply ripple was measured[4] to be less than 0.05% in all power supplies and the ripple frequencies were fixed. Operational stability was also kept lower than 0.005%. Mechanical and ground vibrations were measured simultaneously with the BPM signal. The measurement showed no significant correlated frequency signal between vibration and beam oscillation in low frequency band as shown in Fig. 3. LCW temperature oscillation did not made any contribution, either.

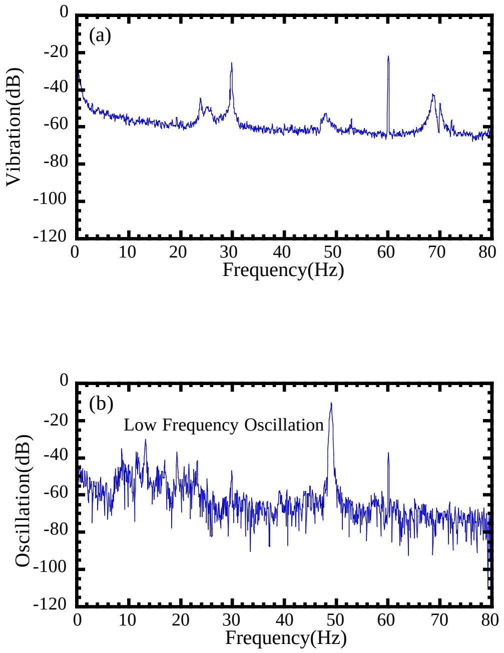

Figure 3: Measured frequency spectrum of (a) the mechnical vibration and (b)the beam oscillation in the PLS storage ring.

3.3 Ion Trapping

As in other electron machines, the ion trapping was suspected to be the source of the transverse oscillation. The PLS, the third generation light source with low emittance, is intrinsically weak to the two-beam instability. A simple linearized calculation shows that between 60 to 180 mA, PLS is very susceptible to the instability with only 0.1% of ion density. The critical ion mass above which can be captured in the electron bunches in PLS, is less than two at 100 mA, which means that all the ions including hydrogen atom could be captured. To test the ion effects, the dependence of the oscillation amplitude on the beam current is measured. The threshold current above which the oscillation appears increases as the gap width increases. This is an indirect evidence of the ion effects. The tune change also has a dependence on the gap width. The smaller the gap width is, the more the tune changes.

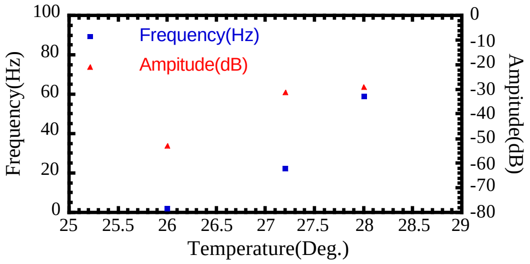

Figure 4: The dependence of the transverse oscillation frequency and amplitude on the cavity cooling temperature in the PLS storage ring.

A typical frequency spectrum of the low frequency oscillation is shown in Fig. 3. The frequency and the amplitude are changing as the cavity temperature changes as well as the beam current(Fig. 4).

Sometimes the lifetime suddenly drops. Sudden drop in lifetime coincided with the emission of the gamma ray from a location of the storage ring was observed once.

3.4 *Suppression*

To suppress the transverse oscillation, a prototype feedback system[5] with 30 MHz bandwidth using a correlator filter was installed and tested. Table 2 shows an example of damping by this system measured from the BPM monitor and from the low frequency spectrum analyzer.

Table 2: Damping effect in terms of oscillation amplitude

	BPM Monitor	Low Frequency Amp.
Before Damping	~450 µ	-51dB
After Damping	~20 µ	-74dB

The transverse and longitudinal feedback system are in the design stage at present. It is planned that these feedback systems will be operated in 1997. For longitudinal instabilities, cavity temperatures setting is controlled for shifting the dangerous HOMs. Since contrillable temperature range is only 5 degrees in Celsius, an optimum setting has not been obtained, where both longitudinal and transverse oscillations damp substantially. The cavity cooling temperature is set for the longitudinal mode to be damped effectively during normal operation. Studies for seeking other techniques to shift HOM frequencies is underway.

4 SUMMARY

Longitudinal and transverse coupled bunch instabilities were observed and some strong modes were identified by the normal mode method. Cavity temperature change is effective to some extent for suppressing these modes and an active fast feedback system is under development.

Low frequency transverse oscillation were observed and the ion trapping is suspected for the source. Some indirect evidences of ion trapping were obtained and gap between bunches and a slow transverse feedback system appeared to be effective for suppression. An active clearing and damping technique is being tested. Up to 120 mA of beam current, the PLS storage ring can provide stable beam to users within 0.05% of intensity variation. To improve the beam quality in high current operation and in operations with the undulator and wiggler, a dedicated beam study with the diagnostic beamline for characterizing various beam oscillations and for estimating the effectiveness of the suppression techniques, is required and being planned.

5 REFERENCES

1. D.-H. Han, M. Kwon, and Y. S. Kim, In these proceedings.
2. M. Yoon, S. S. Chang, J. Y. Huang, C. K. Kim, M. Kwon, T. Lee, S. H. Nam, and T. -N. Lee, In these proceedings.
3. J. Leclare, Proceedings of the 11th Int. Conf. on High Energy Accelerators, (Basel:Birkhauser Verlag, 1980, ed. W. S. Newman).
4. S. H. Nam, S. H. Jeong, S. H. Han, J. H. Suh, K. M. Ha, M. Yoon, In these proceedings.
5. J. Y. Huang, M. K. Park, M. Kwon, S. S. Chang, M. Yoon, In these proceedings.