ISSUES FOR THE NEXT PHASE OPERATION IN PLS

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Abstract

Since September 1995, the Pohang Light Source (PLS) has been operated with 2-GeV electron beams in the range of 100 to 130 mA of the beam current. Beam lifetime is about 15 hours at 100 mA in normal cases. Next phase operation of PLS is aiming at the stable 2-GeV operation with higher beam current and at the higher beam energy operations. One of the major factors to limit the higher current operation is the coupled-bunch instabilities driven by the HOMs of RF cavities. Optimization of the cavity temperature and application of the feedback system have been actively pursued for curing instabilities. Increasing demand of the x-ray users forces operators to prepare for providing higher x-ray flux or for higher energy operation. The issues for the energy ramping from the 2-Gev electron beam and the direct injection from the full energy linac will be discussed.

1 INTRODUCTION

The Pohang Light Source (PLS) has been operated since September 1995 for users with over 90% of availability[1]. The nominal operating beam energy is 2-GeV and the maximum beam current used to be around 130 mA. The normal beam lifetime is 15 hours at 100 mA and the injection is performed three times a day. A major factor prohibiting PLS from higher current operation was found to be the higher-order-modes (HOM)-induced coupled-bunch instabilities. Several dangerous HOMs were identified[2]. A massive upgrade of the cavity cooling system was proved to be effective to reduce impedances of these dangerous modes to some extent and to increase the maximum operation current near 200 mA[3].

More demand for higher x-ray flux gives machine physicists a motivation to prepare for 2.5 GeV operation, which would be the upper limit of the beam energy capability of PLS. A ramping procedure from 2.0 GeV to 2.5 GeV was tested successfully. Some minor rendition of the control software are left to be done. A plan of the full-energy, direct-injection has been arranged by adding one more accelerating module to the linac, which gives extra 180 MeV to the electron beam. In this report, more attention will be paid to the storage ring injection system for accepting 2.5 GeV electron beams from the linac.

2 ISSUES FOR HIGHER CURRENT OPERATION

Two strong longitudinal and one vertical HOMs were identified in PLS as listed in Table 1.

Table 1. Resonant frequencies and loaded Q values of some strong higher order modes in PLS cavities.

Mode	Frequency (MHz)	Loaded Q
TM011	758	6610
TM013	1708	7900
TM111	1072	12100

To suppress these modes the cavity cooling temperature control system was massively upgraded[4] to expand the controllable range to 30 ^{0}C and to improve the stability to 0.1 ^{0}C. Control of the cavity temperature was very effective in Elettra to suppress harmful modes[5]. Unlike the Elettra, PLS cavities have plunge-type tuners to keep the resonant condition in any case. As the tuner moves in and out, HOM frequencies are varied accordingly.

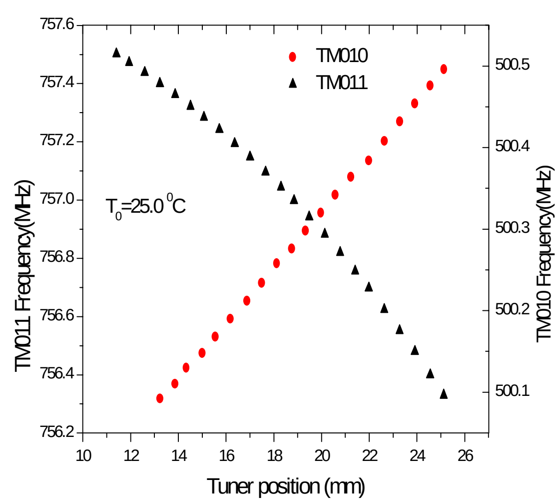

Figure 1. Variation of the resonant frequencies of the fundamental RF frequency, TM010 and the longitudinal HOM, TM011 mode as the tuner position changes. The cavity (C2) temperature was 25 ^{0}C.

Variation of the resonant frequencies of TM010 and TM011 modes according to the changes in the tuner position is illustrated in Fig. 1. At a thermally equillibrium state, there are three cases in which the tuner position changes; as there is certain changes in the cavity temperature, the fundamental frequency, and the beam current inducing a beam loading change. Since it is impossible to measure the exact resonant frequencies of a cavity during the normal operation, only an estimation could be made based on the low power measurements.

Following Elettra's appoach, the critical temperature, T_c for a longitudinal HOM of mode number l and n is derived as

$$T_c = \frac{1}{\chi}\left[\left(f_{HOM}^0 - f_{l,n}\right) - \left(\frac{f_{HOM}^0}{f_{RF}}\right)\varphi_{RF}\Delta l + \varphi_{HOM}\Delta l\right]\frac{1}{f_{HOM}^0} + T_0$$

---------------------------------- (1)

Here f_{HOM} is the measured frequency of the HOM, $f_{l,n}$ is the frequency of the coupled bunch mode expressed as $(lM+n+Q)f_{rev}$ with the mode number l, n as an integer, M number of bunches, Q synchrotron tune and f_{rev} the revolution frequency. And χ is the linear expansion coefficient of the copper, f_{RF} is the RF frequency, φ_{RF} is the derivative of the fundamental resonant frequency to the tuner position change (df_{RF}/dl), φ_{HOM} is the derivative of the HOM frequency to the tuner position change (df_{HOM}/dl), Δl is changes of the tuner position and T_0 is the reference temperature of the cavity, where a low power measurements are performed. The superscript 0 means that the value of the parameter is calculated or measured at T_0. The second term in the large bracket is the amount of the frequency shift of HOM due to the f_{RF} change induced by the tuner movements. The third term is the amount of the direct HOM frequency shift due to the tuner motion. It should be noted that the fundamental RF frequency dependence is not included. Since the HOM frequency with RF power on is difficult to measure, f_{HOM} is an expected value calculated from the measured one at low power as[6],

$$f_{HOM}^0 = -\frac{\bar{f}_{HOM}}{f_{RF}}\varphi_{RF}\Delta l + \varphi_{HOM}\Delta l \quad . \qquad (2)$$

Here the superscript '-` means that the value of the parameter is measured without RF power. The tuner movement here is the tuner displacement by applying RF power for nominal accelerating voltage. The Eq. (1) is a function of Δl, which is different from the case of Elettra. The amount of tuner position change is dependent of several parameters e.g. the beam current, cavity temperature and the cavity phase.

For the second cavity C2, the frequency of TM011 at 25^0C is 757.42 MHz, φ_{RF} is 36.3 kHz/mm and φ_{HOM} is -150 kHz/mm. The variation of the critical temperature according to the tuner position change is shown in Fig. 2. As the electron beam begin to be stored in the storage ring, the cavity tuners moves outward to keep the cavity phase constant. The amount of the tuner displacement becomes one to two mm for few hundreds mA of the electron beam current. Figure 2 shows that the critical temperature for this case still stays in the cavity temperature control system window. The measured amplitude of this HOM-induced instability as a function of the cavity temperature for C2 shown in Fig. 3, clearly

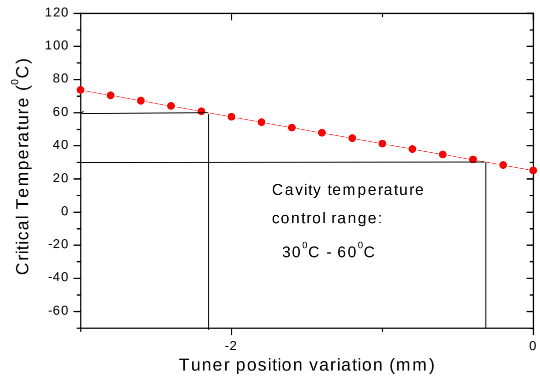

Figure 2. Critical temperature as a function of the tuner variation for C2 based on the Eq. (1).

displaying a peak in the controllable temperature range. Full analysis for all the modes should be done. The longitudinal-transverse mode coupling was also observed. In this case it has been proved to be effective sometime to change tunes and cavity voltages in small ranges.

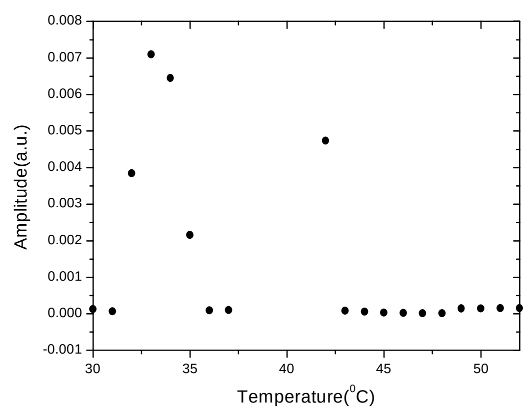

Figure 3. Measured amplitude of the instability induced by the mode TM011 as the cavity temperature was varied. Measurements was made by detecting amplitude of the corresponding synchrotron sideband.

Since the PLS cavities (same as the old PF cavities) were not optimized for the low-emittance, third-generation machines, other techniques would be required to achieve a stable, high current operation. If impedances for some strong HOMs are reduced substantially by the temperature optimization, the active feedback system could extend the stable operation window further. A damped cavity type kicker with nose-cone has been designed and fabricated. The DSP electronics is under fabrication in SLAC. This system will be installed in the coming summer.

3 ISSUES FOR HIGHER ENERGY OPERATION

The PLS was designed to store the electron beam up to 2.5 GeV of the beam energy. Two possible ways to increase the beam energy from the nominal value of 2.0 GeV are to ramp the energy in the storage ring and to use the full-energy direct-injection from the linac.

The ramping scenario was tested successfully in 1996. Each new lattice file was loaded at several different energies to correct the tune shift. A little works are required to optimize the control software to accelerate the ramping speed. Though this scheme is simple and easy to make it work, the injection procedure becomes little complex and takes longer time.

The direct, full-energy injection is quick and convenient during the injection, however, some important issues should be solved before realization. These include the stability and reliability of linac for 2.5 GeV operation, power capabilities of the storage ring injection kicker and septum magnet and power supplies and very importantly the leakage field effect of the septum magnet on the stored beam orbit. One more klystron-modulator and two accelerating columns were added in linac to provide 180 MeV of energy more to the electron beams. Linac already achieved 2.5 GeV beam energy by using full twelve accelerating modules. A reliable 2.5 GeV operation, however, will need more aging time.

The storage ring injection system consists of a Lambertson-type septum magnet and four kicker magnets. The septum was designed for 11 kG of gap flux with less than 10 G-m leakage field. However, for 2.5 GeV injection the gap flux should increase to 15 kG which will enormously increase the leakage field, too. With 2 mA of 2 GeV beams, as the current of the septum magnet was reset for 15 kG, the average rms value of the vertical closed orbit increased sixfold. The temperature change of the cooling water due to the coil current increase is still manageable. Attempts to correct the leakage field effect by the correct magnets is underway. The four kicker magnets are driven by single power modulator for local bump orbit. The current requirement for 2.5 GeV is 21.25 kA, while it is 17 kA for 2.0 GeV operations. The maximum capacity of the modulator is 24 kA. Above that level, a saturation occurs. Table 2 shows a required specification of the septum and kicker power supplies for higher energy operation.

Table 2. Required parameter specifications of the septum and kicker power supplies for different beam energy operations.

Energy (GeV)		2.0	2.3	2.5
Septum	Gap flux(kG)	12.0	13.8	15.0
	I(A)	157	192.5	222.5
	$\Delta T(^0C)$	8.03	12.14	16.2
Kicker	I(kA)	17	19.55	21.25

The 2.5 GeV operation could be possible with ramping after 2.0 GeV injection, but direct injection will be pursued in parallel. One more issue for this topic is to find a good way to compensate for the reduced, low energy photon flux, especially in vacuum-ultra-violet (vuv) region. A compromized energy level, 2.3 GeV looks very attractive in this sense. It will ease most of the technical difficulties in the storage ring injection system as well as it will increase reliability of the linac operation substantially.

4 SUMMARY

The PLS targets on the stable, high current operation with larger x-ray flux for the x-ray users without serious loss of vuv flux for the next phase of operations. A strategy to achieve these goals has been planned and several technical issues to overcome were reviewed. The PLS has now arranged one user run each for higher energy operation and for stable, high current operation in the second half of 1998. For achieving these goals successfully, the feedback system installation, the cavity temperature optimization and the storage ring injection system review and modification have been already started.

5 ACKNOWLEDGMENT

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