OPERATIONAL STATUS OF THE POHANG LIGHT SOURCE

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Abstract

From the year 2000, the PLS storage ring stores 2.5GeV high-energy electron beam by ramping the energy from the 2.0GeV injection energy. The maximum stored current is presently 200mA at 2.5GeV, which is limited by the available RF energy. In May 2000, we succeeded in storing 300mA at 2.0GeV achieving the last design goal of the PLS. Further, the new record of the maximum stored beam current of 450mA at 2.0GeV was made in April 2001. Scheduled beam time to users in the PLS was 4,224 hours in 2000. The actual beam time available to users was 3,834 hours with a beam availability of 90.9%. The beam availability during operation in the first half of 2001 was improved to 93.6% that was the result of various improvements discussed here. At present, the PLS has 14 beamlines in operation and 9 beamlines under construction. A total of 237 experiments was carried out by 883 users in 2000.

1 INTRODUCTION

The Pohang Light Source (PLS) is a 2.0-2.5GeV, low-emittance light source that served to users since 1995 [1]. Until 1998, the PLS had been run only at 2.0GeV. After the successful demonstration of high energy (>2.4GeV) beam operation in 1998, the machine was fine tuned further in 1999 to accommodate better the high energy operation. In 2000, the overall operation energy was 2.5GeV with an average injection current of 170mA, which is well above the design value of 150mA at 2.5GeV. The maximum injection current is around 200mA being limited by total RF power, but all the beam instabilities were suppressed at this energy. At 2.0GeV mode, we succeeded in storing 300mA with a systematic control of the chromaticity and RF temperature in May 2000 [2], which was the last unachieved design goal of the PLS storage ring. Further, the new record of the maximum beam current of 450mA was made in April 2001 as shown in Fig.1. From early this year, we maintain a reference orbit chosen as a best empirical orbit during the machine-tuning period after the winter shutdown. At present, various machine upgrade projects are ongoing in the PLS, such as the precision beam diagnostic station, development of the new control system, cure of the closed orbit drift by thermal effects, global orbit feedback, beam based alignment, increasing the RF power for compensation of the energy loss by IDs, and the new RF control electronics, etc.

There are 14 beam lines in operation including the first insertion device (U7) beam line at the PLS. Also an EPU6 for an elliptically polarized beam is under commissioning, and a U10 has been installed in this summer. There was a total of 237 experiments out of 322 proposals submitted in 2000, and 134 experiments out of 147 proposals in the first half of 2001 indicating steady increase of the user participation [3]. In Table 1, total beam-time provided and user service time since 1995 are summarized.

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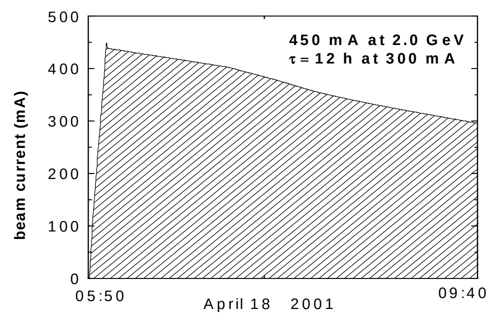

Fig. 1: Stored beam of 450mA at 2.0GeV.

Table 1: Beam-time and user service history

	'95	'96	'97	'98	'99	'00	'01,7
Beam-time provided(hr)	**1142**	**3034**	**3618**	**3784**	**3831**	**3834**	**2160**
Proposals submitted	**58**	**124**	**173**	**171**	**255**	**322**	**147**
Experiments carried out	**18**	**69**	**139**	**130**	**156**	**237**	**134**
Number of users	**78**	**283**	**577**	**646**	**659**	**883**	**506**

2 MACHINE OPERATION

2.1 Injector Linac

The linear accelerator operated 5,280 hours in 2000, with a 1-ns pulsed electron beam at 10 Hz repetition rate with beam energy of 2.045GeV. The operation time of the klystron and modulator system was 6,900 hours with the system availability of 95% in 2000 [4]. Fig. 2 shows the operational status of the PLS linac klystron-modulator system. Since the linac operation in 1993, three out of twelve klystrons has been failed. Based on the available failure data, klystron (Toshiba E3712) lifetime is anticipated as 110,600 hr. This lifetime is not yet realistic due to the lack of enough data. The anticipated lifetime will be constantly upgraded. An average accumulated run-time of the klyston is about 53,000-hr. Thyratrons (F-303) that are the most critical component in the PLS modulator has an anticipated lifetime of 36,500-hr. An average lifetime of failed thyratrons is 16,000-hr. Maximum accumulated run-time of the thyratron in the PLS is about 40,000-hr. Overall, the operation of the linear accelerator in 2000 was more stable than in previous years. Table 2 summarizes the yearly performance of klystron-modulator.

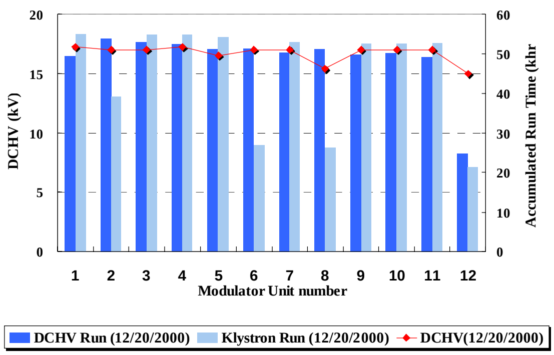

Fig. 2: Status of the PLS linac klystron-modulator.

Table 2: Linac Klystron-Modulator Availability

Year	1998	1999	2000
Operation Time (Hr.)	6,144	5,616	6,816
Failure Counts	283	39	103
Down Time (Hr.)	449	116	384
MTBF (Hr.)	22	144	66
MTTR (Hr./Failure)	1.58	2.97	3.73
Availability (%)	93.0	97.9	94.4

2.2 Storage Ring

The storage ring was operated for 4,834 hours in 2000. The beam time scheduled to users was 4,272 hours, divided into 18 ten-day periods. The actual time supplied to users was 3,884 hours with a beam availability of 90.9%. It is noteworthy that the beam energy was 2.5GeV for the whole operation period of 2000. The average injection current was 166.9mA, and the average beam lifetime was 37.7 hours in 2000 [3]. During the first half of year 2001, the average beam availability has been improved to 93.6%. We set a goal to improve the availability up to 95% by 2002. Table 3 summarizes the PLS beam availability and operation hours since 1996.

Table 3: Beam Availability

	1996	1997	1998	1999	2000	2001.7
Planned [hr]	3,236	3,960	4,272	4,224	4,272	2,160
Serviced [hr]	3,034	3,618	3,784	3,831	3,884	2,013
Availability [%]	93.8	91.4	88.6	90.7	90.9	93.2

3 PROGRESSES IN THE MACHINE OPERATION

After the last report on the PLS status [5], there have been fruitful progresses in the PLS operation.

3.1 Unification of the Control Room

Two independent control rooms of the linac and the storage ring were unified into the storage ring control room, beginning from March 2000. After the merging of the control room, a period of the shift-duty has become doubled for machine operators. Also injection time is much saved by removing the need of telephone calls between two remote control operators for adjusting various injection parameters. Now the beam injection is possible by clicking the command buttons on a single console screen. Online help menus will be implemented for more secure and easier operation.

3.2 Machine Operation at 2.5GeV

The PLS now regularly runs at 2.5GeV with the stable energy ramping control system. With this high energy, x-ray flux increased and the beam stability is improved. No beam instability is observed at the present operational beam current of 170mA. Beam lifetime at 100 mA is also increased from 20 hours at 2.0GeV to 40 hours at 2.5GeV. Shown in Fig. 3 is a beam current display for a successful ten-day 2.5 GeV operation.

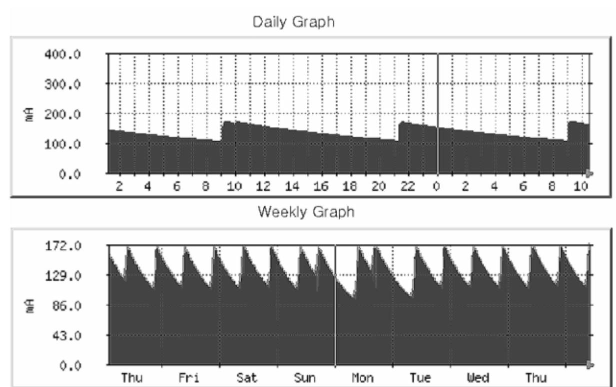

Fig. 3: Beam current display on the web page for daily and weekly operations (2.5GeV, 170 mA operation).

3.3 Operation of the First Insertion Device U7

From 2000, the first insertion device (ID) beamline U7 has been successfully running for the user service. The second ID in the PLS, EPU6, is installed and under commissioning now. The third ID, U10, is installed this summer shut-down and will be commissioned this year.

3.4 New Energy Ramping Control System

In old energy ramping control, the ramping is purely controlled by software. Thus, the synchronization between power supplies can not be maintained, causing serious tune shift during the ramping process and make difficult to finish the ramping in short time. Moreover, the complexity of software control algorithm often halts the system and eventually leads to frequent beam dumps. In the new energy ramping control, a control circuit is designed and installed at all uni-polar power supplies so that it can receive a synchronized ramping command [6]. The new controller is independent from the storage ring main controllers and is a Window based PC system. The new system greatly reduces ramping time, which is now less than two minutes. Moreover, the control system faults are also greatly reduced, and the beam availability is therefore highly improved. The present total injection time, which includes ID gap separation, 2.0 GeV injection, and ramping to 2.5 GeV, takes less than 10 minutes.

3.5 Improvement of BPM Performance

Beam position monitors (BPMs) are the key diagnostic tool in the PLS storage ring. BPM resolution is improved to ~4 µm by adopting AD boards with averaging function [7]. Fig. 4 shows the BPM signal that is compared with a laser displacement sensor signal. The laser displacement sensor has ~1 µm resolution. In Fig. 4, movement of 3~4 µm steps can be clearly seen. The BPMs in the storage ring tunnel is mounted on 10-m long single-piece sector chambers. Therefore, the chamber movement can affect the BPM output signals. The chamber movement is due mainly to temperature change, which is a function of cooling air, cooling water, magnet current, stored beam current amplitude, etc. The change produces some erroneous BPM output signals. We are in the process of minimizing various factors that affect the BPM performance. Preliminary test showed a significant reduction of the error by cooling the vacuum chamber, suggesting that all the vacuum chambers should be cooled eventually.

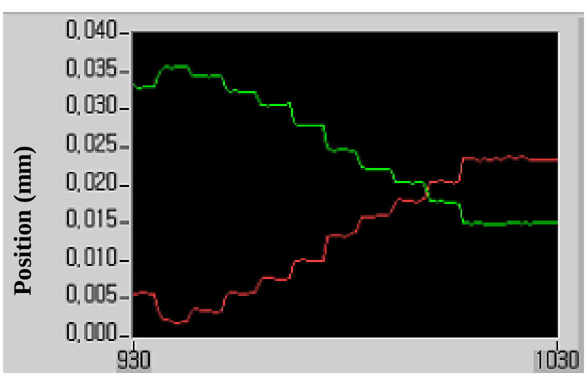

Fig. 4. Comparison of a BPM signal (bottom left) with a laser displacement sensor signal (top left), which are measured in a test set-up. The x-axis indicates sample number and the y-axis is position.

3.6 Access to the Experimental Hall

Experimental hall has been a restricted area during the beam injection until the end of 2000. This caused much inconvenience to the users because they must escape from their experimental stations. With a five-year accumulated radiation dose data for proof of the radiation safety, the PLS finally obtained permission of access to the experimental hall during the beam injection from March 2001.

3.7 Communication with Users

For effective communications between user side and machine operation side, we made several understandings. Most important was on the maintenance of the orbit with a reference orbit and the strategy for realignment of the ground motion. Several information-broadcasting services are also provided for effective communications. There are three CATV channels for broadcasting of the operation status and the pop-up messages. A ftp server supplies operational data to all machine and beamline users. Also we utilize the web page [8] for information-broadcasting and pop-up messaging.

4 ONGOING PROJECTS

4.1 Linac Modulator Control

Even though the linac modulator has its simple remote control function, most of its command and monitoring functions are controlled locally or manually. The most difficult points of remote monitoring are the pulse signals, such as 400 kV pulse output voltage, 500 A pulse current, the end of line clipper current, etc. Remote signal monitoring of those is necessary to check status and to protect modulator itself as well as klystrons. A signal processing board is developed so that it can monitor those pulse signals perfectly. The processed signals and other analog and digital signals are all integrated into an industrial PC and tested its monitoring functions. In addition, remote command signals such as input voltage, power on and off, etc. are also tested successfully with a prototype module. We will adopt the technique to all twelve modulators by the first quarter of 2002. The modulator controllers will be networked with the storage ring main control system so that operators in the control room can access the modulator remotely.

4.2 Closed Orbit Stabilization

In the PLS, long term orbit measurements show coherent drift of the orbit up to +/-150µm as shown in Fig. 5. With careful investigations, we find that there is a strong correlation between the orbit drift and the temperature changes of the magnet and air in the storage ring tunnel. Major source of the temperature change is attributed to the large change of the magnet current during the regular beam injection. The regular injection processes the following steps: dump the stored beam, degauss the magnets with the full swing of the magnet current up to saturation, fill the beam of 2.0GeV and raise the energy again to 2.5GeV. During the injection process, heat load changes around 200% of the normal operation.

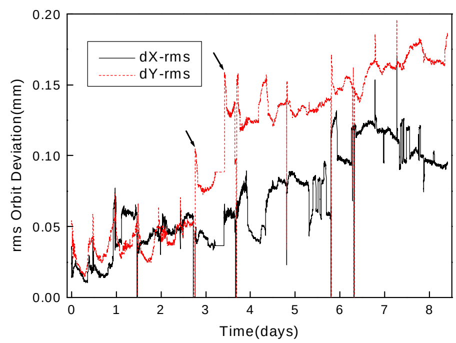

Fig. 5. RMS orbit deviation with operation time. Arrows indicate large increase of RMS values by the degaussing of magnets by unexpected beam dumps.

In contrary, when the machine is shutdown for several hours, it is over-cooled. Once heated up or cooled down, it takes around 4 hours for temperature to be stabilized in the vacuum chamber and supporting structures. To reduce the temperature shock, we applied de-ramping technique of the beam energy without dump the stored beam to refill. By this process, thermal shock on the magnets reduced significantly. Further, to make the air temperature uniform in the storage ring tunnel, all the air flows from the air ducts are redirected to tangential direction making the mass of air circulate along the tunnel circumference. As the result of those above efforts, the orbit change before and after injection is significantly reduced. In addition, long-term orbit drift is now reduced down to 50 μm peak-to-peak as shown in Fig. 6. In Fig. 6, the U7 gap change is also shown to check the effect on the orbit drift. As shown, the orbit is maintained stable regardless of the U7 gap.

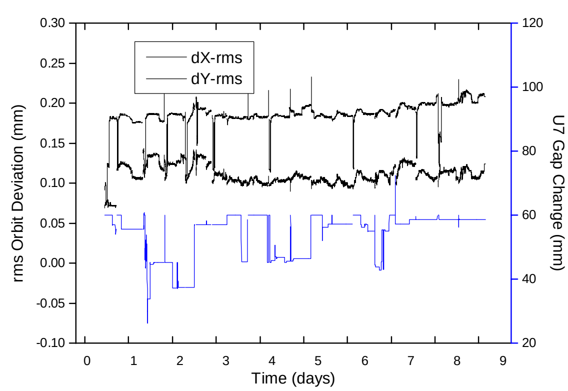

Fig. 6. RMS orbit deviation after the ramping-deramping and optimisation of air flow in the storage ring tunnel. x-orbit drift (middle line), y-orbit drift (top line), U7 gap change (bottom line).

4.3 Upgrade of the RF System

RF control electronics has been the major source of troubles, making frequent machine trips. All the RF control electronics are thus redesigned and in fabrication now. One of four control electronics has been assembled and successfully commissioned in this summer. Other three will be finished by the end of 2001 [9]. Further, since the present RF power budget (60kW x 4 klystrons) will become short as the number of IDs increase as shown in Fig. 7, we will replace 60kW klystrons with 75kW one by one and add one more cavity making total RF power 375kW [10]. Then, we will have operation capability of 200mA with 10 IDs at 2.5GeV energy [11].

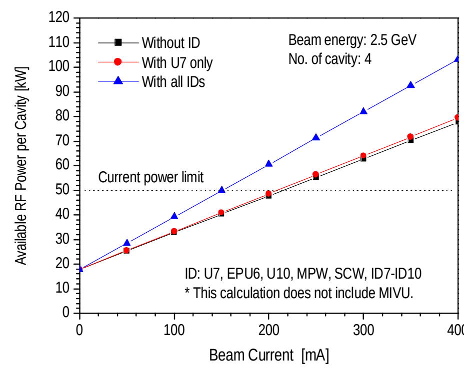

Fig. 7. Estimation of necessary RF power budget with all planned IDs.

4.4 Upgrade of Diagnostic Beamline

In beam diagnostics, there is a controversy in the estimation of the coupling coefficient between the one by the beam size measurement (>7%) and the other one by the tune approach method (0.7%) [12]. For measurement of beam size with less than 10 μm resolution, a new diagnostic beam line is under construction. The new beamline will be firstly equipped with a x-ray pinhole to measure beam size. A photon BPM with ~ 1μm resolution and a photon intensity monitor will be added in future to constantly check the stability of position and intensity of photon. For the measurement of bunch length, a streak camera is equipped in the present diagnostic beamline.

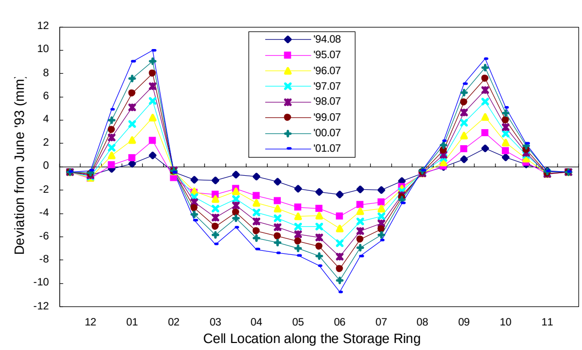

Fig. 8. Settlement of the storage ring floor after June 1993.

4.5 Storage Ring Deformation and Realignment

As shown in Fig. 8, the settlement of the storage ring tunnel continues at about 2.5mm (hill to valley) per a year in the PLS. The total deformation has reached presently 22mm compared to the reference elevation established in June 1993. Since the accumulated deformation still increases without slowdown, the smoothing technique [3] will not apply in the future. Thus we decided to realign all storage ring component toward the design orbit step by step in three years. Beamlines will also realign the elevation when it is necessary. As shown in Fig. 9, all the quadrupole magnets are realigned within 2 mm peak-to-peak deviation after 2001 summer shutdown.

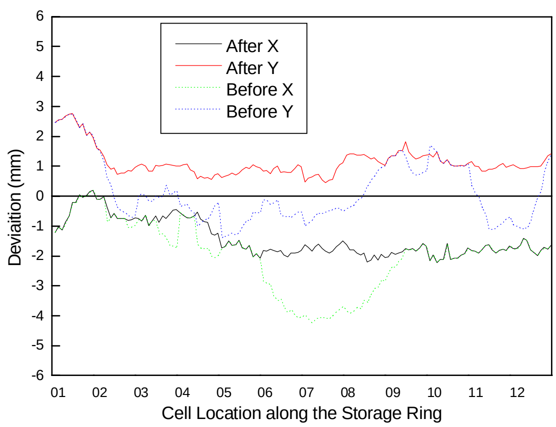

Fig. 9. Deviation of quadrupole-magnet alignment in the storage ring. The magnets are realigned during the summer shut-down period of 2001.

4.6 Other Issues

Various other efforts to improve the PLS performance are in progress, such as the storage ring vacuum control improvement [13], beam based alignment for BPM performance enhancement [14], global orbit feedback for improved orbit stability, longitudinal and transverse feedback system for having high quality and high stored current at 2.0 GeV [15, 16], injection system [17], and other physics issues [18, 19]. Finally, for the upgrade of the control system, we decided to apply EPICS for the PLS control system. Input-output controllers (IOC) will be implemented on VxWorks-based Motorola power PCs or on Windows-based PCs. Set up of the development system and the detailed proposal is in progress now. The new control system will be installed by the middle of 2003.

5 ACKNOWLEDGEMENTS

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