# THE FIRST EXPERIENCE OF PLS-II OPERATION*

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*Abstract*

Design parameters of the PLS-II, upgrade of Pohang Light Source, are 5.8 nm-rad emittance, 3.0GeV beam energy, and 400mA beam current with top-up injection. The PLS-II has 20 insertion-device spaces in a compact DBA storage ring of 281.82m circumference. The first year operation in 2012 was completed with 100 mA and mostly decay mode. Two SC RF modules were installed in 2012. Total 30 beamlines are in operation including 16 ID beamlines. From 2013, top-up mode operation has been in service with up to 150 mA current. Scheduled user service time and reliability in 2012 were respectively 3014 hours and 93.8%. The low reliability was largely due to immature operation of SC RF system. Scheduled user service time in 2013 is 4080 hours that is 35 % increase from 2012.

## INTRODUCTION

The PLS-II is a Korea's only and brand new 3rd generation synchrotron radiation source that was upgraded from the 16-year-old PLS in 2011. The old PLS started user service from 1995 and shutdown on Dec. 10, 2010. The PLS-II has been open to users from March 2012 with upgraded performance.

## PLS-II INJECTOR

The PLS-II has a 3 GeV full energy injector that consists of a thermionic DC gun, a S-band linear accelerator (linac) and a 86-m beam transport line (BTL). 16 pulsed klystron-modulator modules and 15 SLEDs are used in the linac. The peak power and width of the klystron RF output are 80 MW and 4 us. The BTL has three isochromatic systems for guiding the 3 GeV beam. In Table 1, major parameters of the PLS-II linac is listed.

Table 1: Major Paremeters of the PLS-II Linac

| | PLS-II |
|---|---|
| Energy | 3 GeV |
| Repetition Rate | 10 Hz |
| Energy Stability | ~ 0.1% rms |
| Energy Spread | 0.2 ~ 0.3 % rms |
| Emittance (normalized) | ~ 120 μm rad rms |
| Gun Pulse Length (FWHM) | ~ 1 ns or 0.25 ns |
| SLED Gain | 1.5 |

## PLS-II STORAGE RING

### *PLS-II Storage Ring*

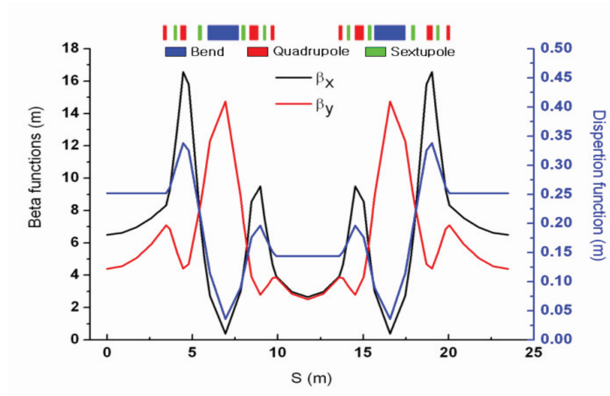


Figure 1: PLS-II Storage Ring Lattice.

Table 2: Main Design Specifications of the PLS-II

| Parameter | PLS-II |
|---|---|
| Beam Energy [GeV] | 3.0 |
| Beam Emittance [nm•rad] | 5.8 |
| Stored Beam Current [mA] | 400 |
| Total Number of ID Straights | 20 |
| Lattice Structure | DBA |
| Superperiods | 12 |
| Operation Mode | Top-up & Decay |
| Circumference | 281.82 m |
| Tune | 15.28/9.18 |
| Coupling | 0.2 % |
| Lifetime @ 400mA | 10 hours |
| RF Frequency | 499.97 MHz |
| Energy Spread | 0.1 % |
| Brightness | ~ $10^{20}$ |

The 3.0 GeV PLS-II SR lattice has DBA structure with 12 superperiods and 281.82 m circumference. The PLS-II SR has 12 long (6.88 m) and 12 short (3.69 m) straight sections, and 20 out of those 24 straights are for insertion devices. In Fig. 1, PLS-II storage ring (SR) lattice functions are shown. In Table 2, major SR design parameters are summarized.

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### *PLS-II RF System*

Since the delivery of PLS-II SC RF cavities could not meet the operation schedule in March 2012, the PLS-II started its user operation with five normal conducting (NC) RF cavities that had been used for the old PLS. The first SC RF cavity module was installed during summer shut-down in 2012 and started user operation from October 2012. The second SC RF module was again installed during the winter scheduled shut-down in 2012, and started user operation from March 2013. The last and third SC RF module will be installed during the summer shut down in 2014. In Table 3, the SC RF main parameters are listed [4]. In Fig. 2, a picture of the installed SC RF modules in the PLS-II SR is shown.

Table 3: Main Design Specifications of the PLS-II SC RF

| Parameter | PLS-II RF |
|---|---|
| Harmonic Number | 470 |
| RF Frequency [MHz] | 499.66 |
| Radiation Loss [kW] | 500 |
| Acceleration Voltage w/ 3 modules [MV] | 4.5 |
| Cooling Capacity @ 4.5 K [W] | 700 |


Figure 2: PLS-II SC RF cavities installed in the SR tunnel.

## PLS-II BEAMLINE

In PLS-II, one wriggler, three out-vacuum undulators (OVUs), and ten in-vacuum undulators (IVUs) are installed for user service. Current routine minimum operational full gap of IVUs is 6 mm. Three IDs are under construction and three ID spaces are reserved for future use. Total thirty PLS-II beamlines are under user service, which include sixteen insertion device (ID), thirteen bending (BD) magnet, and one fs-THz beamlines. The fs-THz is an independent beamline facility that is separately installed from the SR. Two diagnostic beamlines are also under operation. The OVUs have two branch beamlines. Details of PLS-II beamline information can be found in reference [3].

## FIRST YEAR USER SERVICE OF PLS-II

PLS-II has been opened to users since 21st March 2012. Total scheduled user operation in the first year 2012 was 3024 hours. 13 user-runs in 2012 were serviced with average 218.4 hours per user-run. Total serviced user operation in 2012 was 2839.83 hours. The first year reliability of the PLS-II is thus 93.8 %. In Fig. 3, the PLS-II reliability statistics of each user-run are plotted. The user-runs up to 10th were serviced with NC RF cavities. From 11th run, SC RF modules started to use for operation that significantly affected the PLS-II reliability due mostly to immature cryogenic system operation.

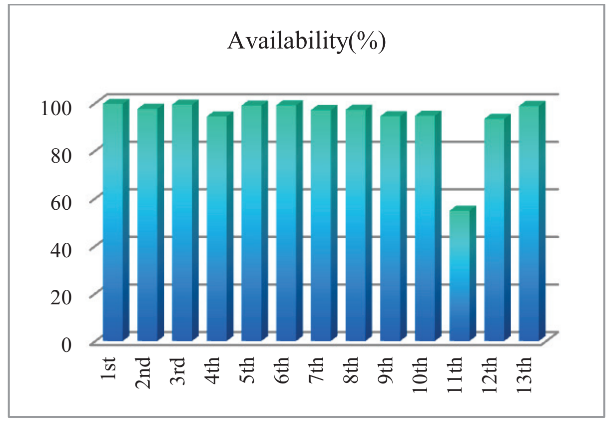

Figure 3: The year 2012 availability of the PLS-II.

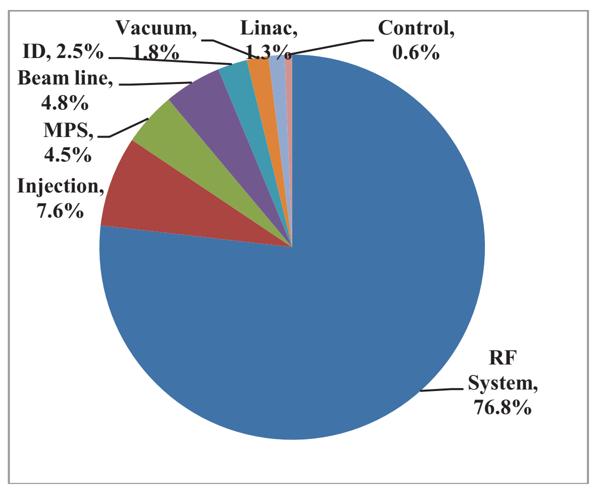

Figure 4: PLS-II fault statistics of in 2012.

Total accumulated fault time in PLS-II was 189.13 hours that corresponds to 14.6 hours in average fault time per user-run. MTTR and MTBF of the PLS-II in 2012 were respectively 3.2 and 61.4 hours. Total number of faults and average faults per run were respectively 72 and 5.5. A cryogenic system fault occurred during the 11th run was the one affected the operation availability most. The MTTR in the 11th run was 27.15 hours. In Fig. 4, a chart of PLS-II system fault statistics in 2012 is shown. As indicated, the RF system occupies the largest area of 76.8% or 145.3 hours. As the SC RF modules and cryogenic system operation become mature, we expect that the machine reliability will be much improved.


ISBN 978-3-95450-122-9

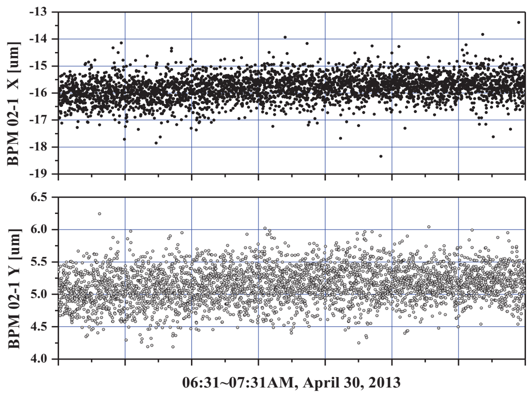


Figure 5: Orbit variation for 24 hours during top-up user run in April 30, 2013.

A slow orbit feedback (SOFB) with Libera brilliance BPM electronics is running at 2Hz for orbit stability. The BPM system updates orbit every 10 Hz with sub-micro resolution. As shown in Fig. 5, the rms values of horizontal and vertical stabilities at an ID source point are respectively 0.4 μm and 0.3 μm. However, very long term stabilities such as 10-day shows horizontal and vertical stabilities of 3.6 μm and 24 μm, which were largely caused by random loss of SOFB mainly from MPS malfunctions and no implementation of ID feed-forward. ID feed-forward as well as 100 Hz bandwidth fast orbit feedback system implementation are ongoing activities of the PLS-II.

The PLS-II was commissioned in 2011. The user service from March 2012 started with 100 mA stored current with decay mode. The top-up operation was serviced to users for two days in July 2012 after getting top-up operation authorization from Korea Institute of Nuclear Safety (KINS). The maximum stored current tested in the PLS-II was 230 mA in December 2012. From 2013, top-up with 125 mA became a standard mode of user service operation. The stored current for top-up has been increased to 150 mA from April 2013. The top-up stored current will be further increased up to 200 mA in 2013. Design performance test of 400 mA stored current is also scheduled in 2013. Scheduled total user service time in 2013 is 4080 hours that is 35 % increase from 3014 hours in 2012. The reliability goal is more than 95 %.

There are several conditions for top-up interlock, in which case the top-up mode shifts to decay mode for six hours. During these six hours, the causes of interlock need to be cured to recover the top-up mode again. Some of important top-up interlocks are low bending magnet current, low injection efficiency, high radiation level, and low stored beam current. An example of 150 mA top-up operation is shown in Fig. 6 that was recorded in April 30, 2013 user-run. As seen, there were one top-up interlock incident and one system fault. In Fig. 7, peak stored current area is expanded to see current fluctuations. In the top-up mode operation, beam is injected every three minutes and stopped injection either the desired current of 150 mA is reached or the injection time becomes 30 seconds. The peak-to-peak stored current fluctuation is maintained within 0.4% that is less than 1 % current goal. This fluctuation will be reduced further by changing the top-up mode injection control from time to current level.


Figure 6: Stored beam current recorded during top-up mode in 2013 (April 30 ~ May 03, 2013). There were one fault and one top-up interlock. The interlock converted to decay mode for six hours during the user-run.

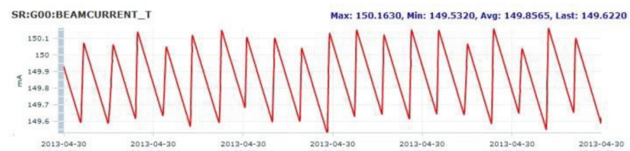


Figure 7: Expanded plot of Fig. 6 that shows the stored beam current fluctuations recorded for an hour in April 30. 0.4 % peak-to-peak fluctuations can be observed.

## SUMMARY

The PLS-II started its first year user service from March 2012 with 100 mA decay mode, and with NC RF cavities. Two SC RF modules were installed in 2012. From 2013, top-up mode operation became a standard mode of user service operation. The stored current for top-up has been increased to 150 mA from April 2013. Scheduled total user service time in 2013 is 4080 hours that is 35 % increase from 3014 hours in 2012. The reliability in 2012 was 93.8% that was largely due to the immature operation of SC RF system. The reliability goal in 2013 is more than 95 %.

## ACKNOWLEDGEMENT

The work outlined in this paper was accomplished with efforts of PAL staffs in the accelerator as well as beamline divisions.

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