MAJOR UPGRADE ACTIVITY OF THE PLS IN PAL: PLS-II*

S.H. Nam# on behalf of the PLS-II Project Team
PAL, Pohang, KungBuk 790-784, Korea

Abstract

The Pohang Light Source (PLS) has started its operation with 2.0 GeV operating energy in 1995. The first major upgrade of the PLS had been done from 2000 to 2002, in where operation energy of the PLS was increased to 2.5 GeV. The Pohang Accelerator Laboratory (PAL) is pursuing the second major upgrade plan, called PLS-II. With this project, energy, stored current, and emittance of the PLS will be respectively improved to 3.0 GeV, 400 mA, and about 5 nm•rad. The operation will be top-up mode. It will be possible to construct more than twenty insertion devices. The brightness and energy of the PLS-II photons will be highly increased compared to the current PLS. The project is scheduled to complete its commissioning at the end of 2011.

INTRODUCTION

The PLS is the first third generation light source in Korea. The PLS is consisted of a 2.5GeV linac and a 2.5 GeV storage ring (SR). After commissioning in 1994, the PLS had been operated with 2.0 GeV energy [1]. From 2000 to 2002, the PLS had been upgraded by increasing its energy from 2.0 GeV to 2.5 GeV. Since then, high quality scientific results and number of users have been increased remarkably. With recent requests to increase the number of insertion devices and improve the beam quality from scientific communities in Korea, the PAL started from this year the new project called PLS-II. With this project, energy, stored current, and emittance of the PLS will be respectively improved to 3.0 GeV, 400 mA, and about 5 nm•rad. The operation will be top-up mode. More importantly, the total number of insertion devices will increase from ten to more than twenty. The project is scheduled to complete its commissioning at the end of 2011. Total budget of the project is about US 100M$.

Table 1: Main Specifications of the PLS-II

Parameter	**PLS**	**PLS-II**
Beam Energy [GeV]	2.5	3.0
Beam Emittance [nm•rad]	18.9	~5 – 10
Stored Beam Current [mA]	200	400
Total Number of IDs	10	>20
Lattice	TBA	DBA
Operation Mode	Decay	Top-up
Brightness	~2 x 10^{18}	~ 10^{20}

*Work supported by POSCO and MEST
#nsh@postech.ac.kr

PLS-II GOAL

Main specifications of the PLS-II are shown in Table 1 and compared with the existing PLS.

LINAC UPGRADE

The 2.5 GeV PLS linac is consisted of 12 klystron-modulator (MK) systems, 11 pulse compressors, and 44 accelerating columns. The linac has a 1.5 ns, 80kV, 1A thermionic electron gun. Operation frequency of the linac is 2,856MHz. A SLAC 5045 klystron is installed in the preinjector section, and Toshiba E3712 klystrons are used in other eleven stations. Average operating power of the Toshiba klystrons in the PLS is between 50 to 60 MW.

Table 2: Performance Goal of the PLS-II Linac

	PLS	PLS-II
Energy	2.5 GeV	3 GeV
Repetition Rate	10 Hz	10 - 30 Hz
Energy Stability	0.5% rms	0.1% rms
Energy Spread	0.6% rms	< 0.2% rms
Emittance (normalized, rms)	150 mm mrad	< 20 mm mrad
Gun Pulse Length	1.5 ns FWHM	< 1 ns FWHM
Klystron Power (Operating Levels)	50 – 60 MW	70 – 80 MW
SLED Gain	1.5 – 1.6	1.6 – 1.7
Diagnostics	BCMs, BASs, BPRMs	+ BPMs, Slits, Wire Scanners

For the PLS-II, the PLS linac also need to be upgraded. The major task is of course to increase its energy from 2.5 GeV to 3.0GeV. Moreover, the linac energy stability and spread, and time structure of the electron beam need to be improved to ensure high injection efficiency to the SR that is a must for top-up operation of the PLS-II. Table 2 shows major performance goal of the PLS-II linac and also compares the PLS-II with the current PLS linac. The linac gun needs improvement for especially top-up operation and higher injection efficiency. For top-up operation, we are designing a new gun system to improve mean-time-to-repair of the gun. As indicated in Table 2, major efforts of the PLS-II linac will be focused on energy stability and spread improvement. The total energy of the linac will of course be increased to 3.0 GeV. The average klystron power in the PLS operation is currently 50 to 60 MW, while the peak operable power of the Toshiba E3712 is 80 MW. To gain additional 0.5 GeV for the PLS-II, we will increase the klystron operation power to more than 70 MW as summarized in Table 3.

Table 3: PLS-II Linac Microwave System Layout

Parameter	**MK 1 (1 set)**	**MK 2 to 10 (9set)**	**MK 11 to 14 (4 set)**
Klystron Output Power [MW]	60	72	70
Klystron Model	5045	Toshiba E3712	
No. of Accelerating Column (A/C)	2	4 x 9 = 36	2 x 4 = 8
A/C Manufacturer	IHEP		Commercial
SLED Gain	NA	1.6 ~ 1.7	
Gradient [MV/m]	-	22.6	31.6

✓ MK: Modulator and Klystron Unit

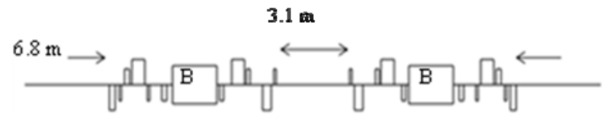
As explained in Table 3, the power of klystrons from MS2 to MK10 will be simply increased to 72 MW to achieve 22.6 MV/m in the PLS-II. The IHEP accelerating columns in those units have maximum gradient of 25 MV/m. However, it has not been tested at the PAL and thus the field tests of those columns are under progress. The eleventh MK unit of the PLS linac is currently connected to four IHEP columns. These columns will be replaced with high gradient commercial columns. The eleventh unit will be split into two MK units, in which each unit will be connected to two high gradient columns. The units will be renumbered as MK 11 and 12. The twelveth unit of the PLS linac is currently in connection with two high gradient columns. This will be maintained and renumbered as MK 13. One unit with two high gradient columns will be added at the end of linac and numbered as MK 14. The klystron power will be 70 MW for MK 11 to MK 14 in order to have 31.6 MV/m gradients. Estimated total PLS-II linac energy is 3.278 GeV. With one idle MK unit, the linac can still inject 3.0 GeV beam to the storage ring. Additional beam diagnostics, energy feedback system, energy slit, and others are under consideration to achieve the required energy stability and spread.

STORAGE RING UPGRADE

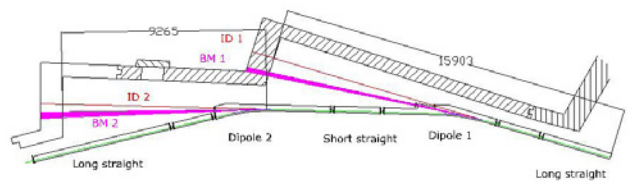
PLS-II Storage Ring Lattice

In Fig. 1, storage ring (SR) layout schematics of the PLS and PLS-II are presented. The current 2.5 GeV PLS storage ring (SR) lattice is a Triple Bend Achromat (TBA) structure with 12 superperiods and 280.56 m circumference. Each superperiod has a mirror symmetric configuration. In order to accommodate more IDs and low beam emittance, the Double Bend Achromat (DBA) lattice is selected for the PLS-II. The PLS-II ring structure maintains 12 superperiods. New short straight sections are placed in place of the center bending magnet of the TBA lattice. From this new arrangement, the full SR has 12 long and 12 short straight sections for installation of IDs.

(a) PLS SR layout: 12 long straight (6.8 m) sections available



(b) PLS-II SR layout: 12 long (6.8 m) and 12 short (3.1 m) straight sections available.



(c) Physical arrangement of the PLS-II SR layout.

Figure 1: Storage Ring Layout.

One long section is required for injection, and one or two long section will be used for the RF system. One short section, which is obstructed by shielding wall structure at the injection area, cannot be used for ID. That results in 9 or 10 available long straight sections and 11 short straight sections. Base conditions for the design of the PLS-II SR are to use the existing SR tunnel, shielding walls and experimental floor. Therefore, a serious design constraint appears from the existing shielding walls. New photon beam lines should be at or close to existing exit locations through the shielding wall. By radially expanding the ring by 20 cm and rotating by 1.5 deg against injection it is possible to accommodate all 24 ID and 24 bending magnets beam lines to aim at the exit face of the shielding wall. Injection angle needs to be corrected to accept the new ring layout. Fig. 2 shows the PLS-II DBA lattice functions. In Table 4, the main photon beam parameters for the PLS-II design are summarized.

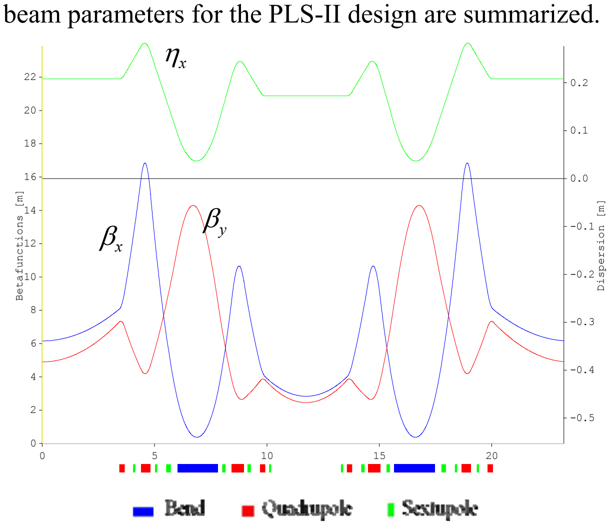


Figure 2: PLS-II Storage Ring Lattice.

Table 4: Photon Source Parameters

	Long SS	Short SS	Bending magnet
Number	9 or 10	11	24
Length or Bending R (m)	6.8	3.1	6.875
β_x (m)	6.16	2.84	0.38
β_y (m)	4.90	2.46	14.14
η_x (m)	0.21	0.17	0.037
$\sigma_x \times \sigma_y$ (μm^2)	234 x 17	167 x 12	47 x 28

Magnets

We made an effort to reuse most of existing PLS magnets in the PLS-II lattice. However, the bending magnets will be new since those require a field gradient and must operate at 3 GeV. On the other hand, quadrupoles and sextupoles can be reused with minimum modifications. The existing sextupoles have combined horizontal and vertical correctors as well as rotated quadrupole fields. This will be reused in the PLS-II. In Table 5, key parameters of the PLS-II magnets are summarized. Optimization of the lattice may bring some minor changes in the magnet specifications in Table 5.

Table 5: Key Magnet Parameters

Type	No.	Parameters	Remarks
Gradient Dipole	24 (2 x 12)	1.4555 T, 4.0828 T/m, Gap = 34 mm, L_{eff}=1.80 m	All powered in series
Quad.	96 (8 x12)	4 types, Max Gradient 22T/m, R_c=36 mm	Powered in family series with independent aux coils.
Sextu-poles	144 (12 x12)	Max B' = 550 T/m2, R_c = 39 mm, 6 types	Skew Q, V-corrector, H-corrector, combined function

Vacuum System

The existing vacuum chamber will be replaced with new chambers. The material will be aluminium. Points with low-conductivity metals where dynamic magnetic fields up to 300 Hz can be applied to the beam will be available for the dynamic feedback system. Length of the vacuum chamber will be reduced as short as possible to reduce stored beam current dependent thermal expansion. This will reduce the temperature dependence drift of beam position monitors that will be attached to the vacuum chambers. The chamber and vacuum system designs are under progress.

Girders

Active mover system will be used in the PLS-II SR. The system will be consisted of cam movers and screw jacks. The cam movers will cover ±5 mm girder alignment range with remote control capability and five degrees of freedom. The screw jack will have ±50 mm manual adjustable range. Movement of the PLS tunnel floor has been about 2.5 mm per year, mainly occurred in the PLS injection area where the linac and SR are joined. With the new girder system, the floor movement can be remotely and then manually compensated. Real time monitoring of floor and girder surfaces is planned with HLS, HPS, and LVDT.

RF System

The RF system for the PLS-II requires a major upgrade. In Table 6, major PLS-II RF parameters are summarized and compared with the PLS. Twenty IDs, which include fifteen undulators, four multipole wigglers, and one super-conducting wriggler, as well as the bending magnets are considered in the radiation loss calculation. The accelerating voltage is increased to 3.3 MV to have enough beam lifetime for top-up operation.

Table 6: Main Specifications of the PLS-II RF

Parameter	PLS	PLS-II
Circumference [m]	280	281.82
RF Frequency [MHz]	500.082	499.66
Radiation Loss [kW]	124	670
Acceleration Voltage [MV]	1.6	3.3

The selection of cavity type is under progress. The new PLS-II RF system is not expected to be ready within the project period. Thus, the existing PLS NC cavities will be firstly used for initial commissioning of the PLS-II, with reduced beam current and number of IDs. The new cavities will be installed in a stepwise passion to ensure the operation reliability.

Survey Network

In order to survey and monitor the whole PLS site ground motion, survey bench mark points will be increased from four to twelve. The data will be compared with floor monitoring devices such as HLS so that precise movement of SR and experimental floors and SR and beamline girder surfaces.

SUMMARY

Base designs of the PLS-II are completed and detail designs are under progress. Components purchases for long lead items have already started. Major purchase will be started from August 2009 when the international advisory committee (IAC) finishes the design review in July 2009. Technical design report will be ready after the IAC meeting. The PLS-II is scheduled to finish its commissioning at the end of 2011 with the existing NC RF cavities.

REFERENCES

[1] PLS Design Report (revised ed.), Pohang Accelerator Laboratory, 1992.
[2] PLS-II Conceptual Design Report, Pohang Accelerator Laboratory, 2008.