COMMISSIONING OF THE PLS-II

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Abstract

The Pohang Light Source (PLS) has operated for 14 years successfully. To meet the request of the increasing user community, the PLS-II that is the upgrade project of PLS has been completed. Main goals of the PLS-II are to increase beam energy to 3 GeV, to increase number of insertion devices by the factor of two (20 IDs), to increase beam current to 400 mA and to reduce beam emittance below 10 nm with existing PLS tunnel and injection system. The PLS-II had been commissioned over the six months. During commissioning, we achieved 14 insertion devices operation and top-up operation with 100 mA beam current and 5.8 nm beam emittance. In this paper, we report the experimental results from the PLS-II commissioning.

INTRODUCTION

The past Pohang Light Source (PLS) was painfully short of magnet free straight sections for the installation of insertion devices. Unfortunately, the circumference of the PLS did not allow all ID sections to be comparable to 5.8 m long straight sections. In addition, one such long section needed to be reserved for injection and two more for a full RF system comprising four RF cavities. Therefore, the PLS-II incorporates almost twice as many straight sections for the installation of insertion devices. In addition to the doubling number of insertion device, The performance will be improved from '18.9 nm-rad, 2.5 GeV, and 200 mA' to '5.8 nm-rad, 3 GeV, and 400 mA'. The PLS storage ring (SR) had been completely dismantled and the new DBA structure SR had been re-installed in the same tunnel within 6 months, and commissioning had been completed within another 6 months. The unique feature of PLS-II is the compact employment of 20 insertion-devices in the storage ring of 280 m-long circumference including 14 in-vacuum-undulators. After introducing PLS-II machine characteristics shortly, we will describe the experimental result during commissioning in this proceeding.

3 GeV Linear Accelerator

3 GeV linear accelerator in PLS-II is used as full energy injector to storage ring. PLS-II linear accelerator consists of thermionic DC gun, S-band linear accelerator and 86 m beam transport line. 46 Accelerating sections installed along 164 m. 16 Pulse modulators (200 MW and 7.5 us for each modulator) and 16 klystrons (80 MW and 4 us for each klystron) feed energy to beam up to 3 GeV.

Storage Ring

Fig. 1 shows the lattice functions while in Table 1 the main beam parameters for the PLS-II are compiled. The lattice of the PLS-II have a gradient dipole double bend achromat structure with 12 superperiods. Each of the 12 superperiods contains two dipole magnets embedded in a FODO cell arrangement. The critical photon energy from bending magnets is 8.97 keV. The lattice provides 6.88 m straight and 3.69 m straight sections per cell for installation of insertion device. The figure shows how the compact lattice can accommodate twenty insertion devices throughout 280 m circumference.

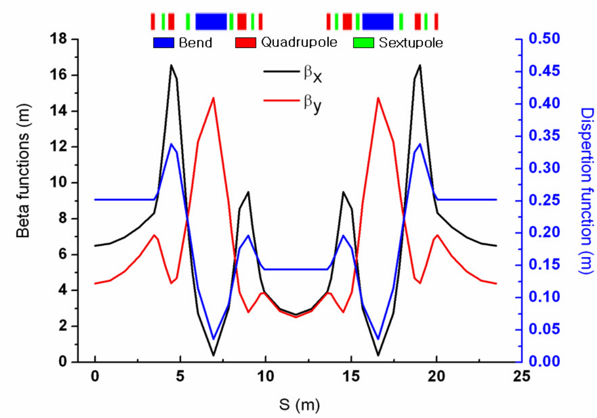

Figure 1: Superperiod in a designed lattice for the 3.0 GeV ring and its optical functions.

Table 1: The Main Parameter of the PLS-II.

Parameter	Unit	Value
Beam energy	GeV	3
Beam current	mA	400
Lattice structure		DBA
Superperiods		12
Emittance	nmrad	5.8
Tune		15.245 / 9.18
RF Frequency	MHz	499.97
Energy spread	%	0.1

EXPERIMENTAL RESULT

Commissioning Overview

The following is PLS-II commissioning milestones:

- 2011. 25 January, PLS-II installation begins
- 23 May, Linac commissioning begins
- 13 June, 3 GeV beam
- 25 June, SR installation finished and BTL commissioning begins
- 1 July, First beam to SR
- 5 July, Kicker PS accident
- 5 August, First accumulation
- September, Shutdown for installating insertion device

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- 7 October, 100 mA stored
- 24 October, First photons to beamline
- December, Shutdown for installating insertion device
- 2012. 14 February, Commissioning with users
- 21 March, Start of operations

During commissioning, we did shutdown PLS-II machine in order to install 6 insertion devices for two months (September and December). 30 days were allocated for linear accelerator commissioning. After we did storage ring commissioning, we provided photon beam to beam line for their commissioning. Overall process was going similarly to recent commissioning trend [1][2][3]. However, one big accident and event should be remarked for PLS-II commissioning. There was a fire on kicker power supply due to mal function of capacitor within power supply. Fortunately, the recovery of injection region including kicker power supply had been performed with one month. We planned special event for PLS-II commissioning. That was beam line commissioning with user. Supposed user for PLS-II could share the experience, estimated beam quality and gave their feedback to us during commissioning.

Linear Accelerator

During installation of storage ring, parallelly, we had performed commissioning of linear accelerator for full 3 GeV injection. Fig. 2 shows the trend of RF conditioning. We did commissioning of linear accelerator with RF conditioning in order to save commissioning time. However, we could achieved 3 GeV beam at the end of linear accelerator without any problem. Obtained beam parameters after commissioning of linear accelerator are summarized in Table 2.

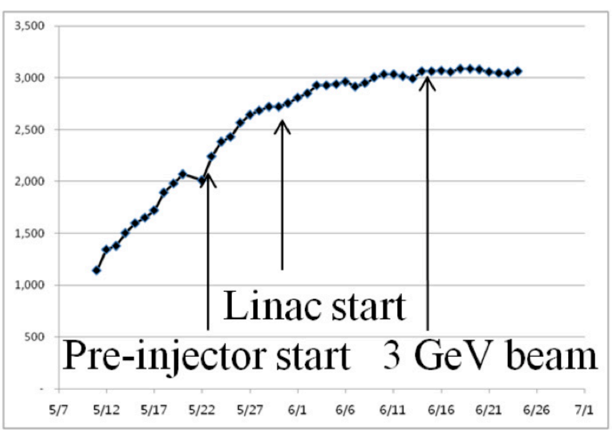

Figure 2: Linac RF conditioning. Horizontal axis is for date and vertical axis is for estimated energy with MeV unit.

Table 2: Achieved Beam Parameter for Linear Accelerator

Parameter	Preinjector	Linac	BTL
Charge [nC]	0.4	0.3	0.2
Emittance [nmrad]	~ 800		~ 30
Energy jitter [%]		~ 0.12	

Storage ring

After setting bending, quadrupole and sextupole magnet power supple according to 3 GeV value, we tried to inject the beam into storage ring. But there was limit to make beam going further than 3 cell of whole 12 cell storage ring. Therefore, we scanned bending magnet power supply set value since energy measurement system in linear accelerator seem to have 80 MeV ambiguity and also there must be an error in storage ring magnet power supply. At the 3.04 GeV set value of bending magnet power supply with small change of quadrupole set value, the first turn was achieved. It token one month to store beam after first turn due to a fire on kicker power supply. By adjusting RF phasing and kicker magnet power supply strength properly, we could achieved 20 mA beam storage with 400 multibunch.

Since beam storage, every ring setup had processed straight forward. Orbit correction, beam based alignment, lattice analysis and restoration of periodicity were applied on PLS-II storage ring by using matlab middle layer tool [4]. The result of orbit correction is shown in Fig. 3. In PLS-II storage ring, 96 BPMs and 96 correctors are implemented for each plane. With 93 singular values, we can easily achieved corrected orbit below rms 1 μm in vertical plane. In horizontal plane, we observed a spike at BPM 7-5. After removing BPM 7-5, we were able to use all singular values. After correcting with all singular values the orbit at BPM 7-5 was 0.238 mm. This is assumed to be the offset for the BPM. This offset was applied on the BPM and the orbit correction with all singular values was performed again. Finally the distorted rms orbit is below 1 μm.

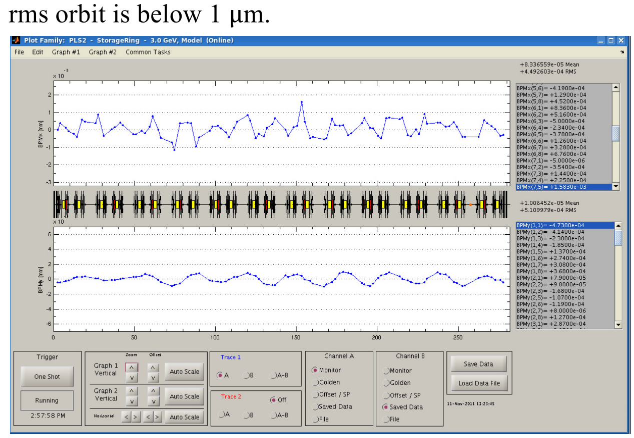

Figure 3: Residual orbit distortion after orbit correction.

LOCO [5] analysis reveals focusing error by fitting the measured orbit response matrix to the model orbit response mtrix. By readjusting currents of quadrupole magnet power supplies to eliminate focusing error component on the ring, lattice periodicity of the ring was restored. Fig. 4 and 5 show beta-functions and dispersion function, respectively. The rms values of horizontal and vertical beta-beats, 10.7 % and 4.2 % are corrected to 0.69 % and 0.68 % after LOCO. Dispersion functions was also corrected and model dispersion functions are

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compared with measured dispersion functions before and after LOCO.

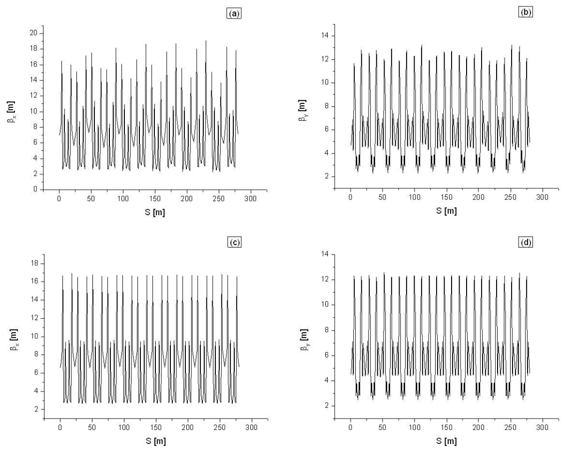

Figure 4: Estimated beta functions. (a) and (b) : Horizontal and vertical beta functions before correction. (c) and (d) : Horizontal and vertical beta functions after correction.

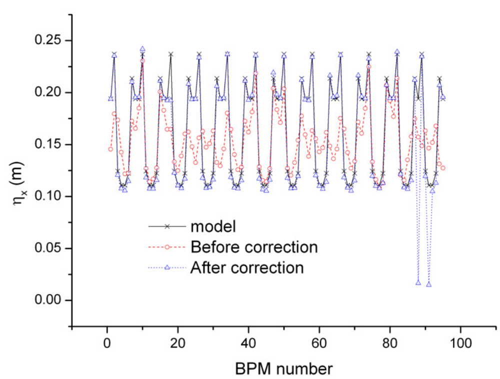

Figure 5: Horizontal dispersion functions before and after correction are compared to the model.

Beam Line Commissioning

Total 30 beam lines including 14 insertion device beam lines were commissioned with 100 mA beam current. All beam lines are categorized as X-ray scattering, macromolecular crystallography, XAFS, SAXS, Lithography and imaging. They all did their commissioning successfully and operated from the beginning of PLS-II user run. Some collected results from beam line commissioning are introduced from Fig. 6 to 8.

Table 3: Commissioning Summary.

Parameter	Goal	Achieved value
Energy [GeV]	3	3.04
Current [mA]	100	150
Lifetime [hr]	> 10	> 10.5
Beam dose [AH]	70	135

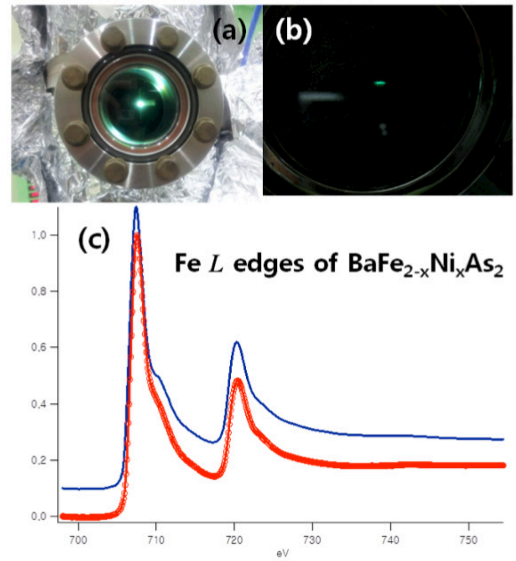

Figure 6: (a) Focused beam before entrance slit. (b) photon beam after experimental chamber. (c) XAS result for Fe pnicide.

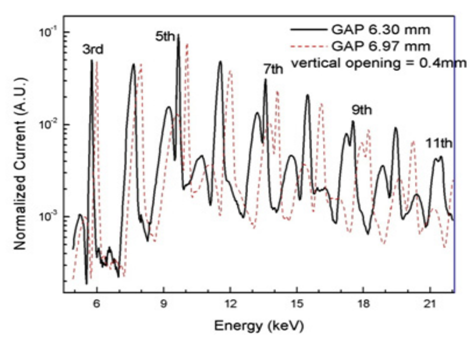

Figure 7: Energy spectrum from SFA invacuum undulator.

SUMMARY AND ACKNOWLEDGMENT

Our commissioning results are summarized in Table 3. It token 1 year from machine installation to completion of 30 beam line tunings. These tight works could be done by the help from accelerator society worldwide.

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