Upgrade of Accelerator Complex at Pohang Light Source Facility (PLS-II)

Kyung-Ryul Kim
PAL/POSTECH

On behalf of PAL Staffs Joined in the PLS-II Project
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  - Beam Diagnostics and Control
  - SR Sources: Magnet and ID Systems
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Aerial View of PAL/POSTECH Campus

PAL/PLS
Aerial View of PAL/POSTECH Campus
Aerial View of PAL/POSTECH Campus
Aerial View of PAL/POSTECH Campus
Aerial View of PAL/POSTECH Campus
### PLS Operation Issues and User’s Demands

| Nation’s Reliable and Mature Multi-user Large-Scale Light Source Facility |

| Elaborate Cutting-Edge Scientific Needs from User Community |

#### More Fine Beam Orbit Stability and Reliability
- Need more correlated analysis between e-beam performance and photon beam stability
- Need well-established orbit control scheme to be adaptable into the proper PLS operation environment
- Fine beam control requirements, especially ID users

#### High Flux and Brilliance Beam
- Meet advanced user’s research demands
- More ID beamlines at lower operation and construction costs through PLS upgrade (PLS-II)
## Overview of PLS-II Project

- **PLS-II Project Schedule**: FY 2009 – FY 2011 (3 years)
- **Project Organization**: PAL PLS-II Project Team (including domestic and abroad expertise joined) with a support of KOSUA Systems

### Project Cost Breakdown (only machine upgrade) (US M$)

<table>
<thead>
<tr>
<th>Systems</th>
<th>Fiscal Year</th>
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### Key Milestones of PLS-II Project

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Status of PLS-II Accelerator System
Established PLS-II design work with a great help from Prof. Helmut Wiedemann in October 2008.

- Justification of the PLS Upgrade (lower beam emittance, higher photon energies as well as more straight sections for insertion devices in the PLS-II)
- Outlined the scope of upgrade (storage ring lattice, hardware systems, beam monitoring/diagnostics, top-up operation and linac energy upgrade in the PLS-II)
- ID and photon source calculation (photon beam performance in the short and long straight sections)
## Classification of PLS-II System Upgrade Structures

<table>
<thead>
<tr>
<th>Scope of PLS-II Upgrade</th>
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<tbody>
<tr>
<td><strong>Magnetic Lattice</strong>: low emittance of 5-7 nm at 3 GeV with a number of 20 ID sections (TBA→DBA)</td>
</tr>
<tr>
<td><strong>Bending Magnets</strong>: small pole gap of 34 mm compared to 56 mm in PLS</td>
</tr>
<tr>
<td><strong>Quadrupoles and Sextupoles</strong>: new more sextupoles for much stronger focusing</td>
</tr>
<tr>
<td><strong>Vacuum Chamber</strong>: newly designed and constructed</td>
</tr>
<tr>
<td><strong>Beam Position Monitors</strong>: more stable support from the girder</td>
</tr>
<tr>
<td><strong>Magnet Power Supplies</strong>: depending on the number of magnets and adjustment of beam dynamics</td>
</tr>
<tr>
<td><strong>RF System</strong>: sustain the 400 mA at 3 GeV, HOM-damped style (NC, SC) cavity be implemented</td>
</tr>
<tr>
<td><strong>Linac Upgrade for Top-up</strong>: upgrade to 3 GeV and sustain stable beam condition</td>
</tr>
<tr>
<td><strong>Photon Beamline-Relocation and Heat Load Issue</strong>: newly designed for high heat load components such as photon mask, shutter</td>
</tr>
<tr>
<td><strong>R&amp;D on Key Components</strong>: In-vac Undulator and DCM, Microwave Components, Others</td>
</tr>
</tbody>
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**Upgrade of PLS-II Linac Full Energy Injector**

**PLS-II Linear Accelerator of 3.0 GeV**

<table>
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<tr>
<th>Parameters</th>
<th>PLS</th>
<th>PLS-II</th>
</tr>
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<tbody>
<tr>
<td><strong>Energy</strong></td>
<td>2.5 GeV</td>
<td>3.0 GeV</td>
</tr>
<tr>
<td><strong>Repetition Rate</strong></td>
<td>10 Hz</td>
<td>10 - 30 Hz</td>
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<tr>
<td><strong>Energy Stability</strong></td>
<td>0.5% rms</td>
<td>0.1% rms</td>
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<tr>
<td><strong>Energy Spread</strong></td>
<td>0.6% rms</td>
<td>&lt; 0.2% rms</td>
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<tr>
<td><strong>Emittance (normalized, rms)</strong></td>
<td>150 mm mrad</td>
<td>&lt; 20 mm mrad</td>
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<tr>
<td><strong>Gun Pulse Length</strong></td>
<td>1.5 ns FWHM</td>
<td>&lt; 1 ns FWHM  or 0.5 us</td>
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<tr>
<td><strong>Klystron Power (Operating Levels)</strong></td>
<td>50 – 60 MW</td>
<td>70 – 80 MW</td>
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<td><strong>SLED Gain</strong></td>
<td>1.5 – 1.6</td>
<td>1.6 – 1.7</td>
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<tr>
<td><strong>Diagnostics</strong></td>
<td>BCMs, BASs, BPRMs</td>
<td>+ BPMs, Slits, Wire Scanners</td>
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</table>
Upgrade of PLS-II Linac Full Energy Injector (cont.)

Preinjector Layout and Bunch Train

80 KeV @ Gun
Peak current : 1 A
Pulse width : 0.2 ns
Beam size : 10 mm
Beam transmission : 54 %
Preinjector Layout and Bunch Train

- Parameter of bunching system has been optimally adjusted into Bunch Length of 12 psec.
Upgrade of PLS-II Linac Full Energy Injector (cont.)

Linac Layout and Energy Upgrade to 3.0 GeV

- Number of klystrons: 16
- Klystron power (MW): 80
- SLED Gain: 1.5
- No. of accelerating columns: 46
- Total length (m): 160
## Upgrade of PLS-II Linac Full Energy Injector (cont.)

<table>
<thead>
<tr>
<th></th>
<th>MK1(1set)</th>
<th>MK2 – MK08(7set)</th>
<th>MK09-MK14(6set)</th>
<th>MK15-MK16(2set)</th>
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<td>Toshiba E3712</td>
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<td>A/C</td>
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<td>IHEP</td>
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<tr>
<td>SLED Gain</td>
<td>w/o</td>
<td>1.5</td>
<td>1.5</td>
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<tr>
<td>Gradient</td>
<td>18.3 MeV/m</td>
<td>20.9 MeV/m</td>
<td>29.6 MeV/m</td>
<td>29.6 MeV/m</td>
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<tr>
<td>Energy</td>
<td>105.8 MeV</td>
<td>251.0 MeV</td>
<td>177.5 MeV</td>
<td>177.5 MeV</td>
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<tr>
<td>Number of A/C</td>
<td>2</td>
<td>28</td>
<td>12</td>
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\[ E = 3.286 \text{ GeV} \]

![Diagram](https://via.placeholder.com/150)

- **MK1(1set)**
  - 70 MW
  - 20.9 MV/m, 251.0 MeV

- **MK2 – MK08(7set)**
  - 70 MW

- **MK09-MK14(6set)**
  - 70 MW
  - 29.6 MV/m, 177.5 MeV

- **MK15-MK16(2set)**
  - 70 MW
  - 29.6 MV/m, 177.5 MeV
### Upgrade of PLS-II Linac Full Energy Injector (cont.)

<table>
<thead>
<tr>
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<th>MK1(1set)</th>
<th>MK2–MK08(7set)</th>
<th>MK14(6set)</th>
<th>MK15-MK16(2set)</th>
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<td><strong>SLED Gain</strong></td>
<td>w/o 1.5</td>
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<tr>
<td><strong>Gradient</strong></td>
<td>18.3 MeV/m</td>
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<td><strong>Energy</strong></td>
<td>105.8 MeV</td>
<td>251.0 MeV</td>
<td>177.5 MeV</td>
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<tr>
<td><strong>Number of A/C</strong></td>
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*Note: All values are approximate and subject to change.*

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$E = 3.286 \text{ GeV}$
Upgrade of PLS-II Linac Full Energy Injector (cont.)

RF Synchronization of SR and Linac

SR-Linac RF Synchronization for Top-up

PAL

2009. 11. 12. / M.H. Chun (ver. 3.2)
Upgrade of PLS-II Linac Full Energy Injector (cont.)

Linac Beam Energy Stabilization

Fluctuation: ±0.5 mm
Resolution: 10 MeV/mm

Feed back on Beam Position #12 RF Phase

PLS-II Linac requirement: 0.2% energy spread:
3 GeV x ±0.2% = ± 6 MeV => ± 0.6 mm @ BPM
Upgrade of PLS-II Beam Injection

**Horizontal Plane**

- **Kicker 1- Kicker 2 distance** (center-to-center): 1.24 m → 1.590 m (+0.35 m)
- **Septum length (longitudinal)**: 1.068 m → 1.335 m (+25%)
- **Expected bump height**: ~12 mm → ~15 mm (+3 mm)

**Vacuum pumps**

- Before: 3 x 240 l/s
- After: 6 x 120 l/s

**Vertical Plane**

- **Additional BM : HM**
  - Effective Length: 0.2 m
  - Rotation Angle: 1.5°

- **VB3 : Rotation Angle**: 7.17° Downward
- **SEP : Rotation Angle**: 8.23° Downward
Upgrade of PLS-II Beam Injection
Upgrade of PLS-II Beam Injection

Beta Function (m) vs Distance (m)

- betax
- betay
- Bending
- Quad
- alphax
- alphay

Beam Size (m) vs Distance (m)

- Sx
- Sy
- Bending
- Quad
Upgrade of PLS-II Beam Injection

Layout of Injection Straight Section

- Kicker Magnet
- Photon Mask
- Septum Magnet
- Ion Pump
- Girder and Support System
Upgrade of PLS-II Beam Injection

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<th>Distance D (mm)</th>
<th>Field (T)</th>
<th>Angle (rad)</th>
<th>Energy (GeV)</th>
<th>Bump H (mm)</th>
<th>Length (m)</th>
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<td>0.009889</td>
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<td>15.7</td>
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Kicker voltage

0 turn
1 turn
2 turn
3 turn

Distance D (mm)
Field (T)
Angle (rad)
Energy (GeV)
Bump H (mm)
Length (m)

Kicker voltage

0 turn
1 turn
2 turn
3 turn

3 µsec
# Magnet Lattice and Beam Dynamics

## Electron Beam

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<td>Current</td>
<td>400 mA</td>
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## Lattice

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<td>Tune (h/v)</td>
<td>15.24 / 9.17</td>
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<td>Natural chromaticity (h/v)</td>
<td>-32.88 / -15.49</td>
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## Straight Section

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<td>Long length, #</td>
<td>6.86 m × 9</td>
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<td>( \beta_x / \beta_y / \eta_x )</td>
<td>6.46 m / 4.32 m / 0.25 m</td>
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<td>Effective emittance</td>
<td>9.5 nm</td>
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<td>Short length, #</td>
<td>3.10 m × 11</td>
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<tr>
<td>( \beta_x / \beta_y / \eta_x )</td>
<td>2.95 m / 2.86 m / 0.14 m</td>
</tr>
<tr>
<td>Effective emittance</td>
<td>8.5 nm</td>
</tr>
</tbody>
</table>

## Magnet

<table>
<thead>
<tr>
<th>Type</th>
<th>Parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bending</td>
<td>24 units, length 1.8 m</td>
</tr>
<tr>
<td>Rectangular</td>
<td>Bending radius 6.875m</td>
</tr>
<tr>
<td></td>
<td>field gradient (-0.4\ T/m)</td>
</tr>
<tr>
<td>Quadrupole</td>
<td>96 units, length 0.24~0.53m</td>
</tr>
<tr>
<td></td>
<td>field gradient (~22\ T/m)</td>
</tr>
<tr>
<td>Sextupole</td>
<td>144 units, length 0.1~0.2m</td>
</tr>
<tr>
<td></td>
<td>2\textsuperscript{nd} field derivative (~600\ T/m^2)</td>
</tr>
</tbody>
</table>
Magnet Lattice and Beam Dynamics (cont.)

Magnetic Lattice Design of PLS-II Storage Ring

Electron Beam Parameters

- **Energy**: 3.0 GeV
- **Current**: 400 mA
- **Emittance**: 5.8 nm·rad
- **Emittance coupling**: < 1%
- **Energy spread**: 0.1%
The vertical BSC is limited by the vertical aperture of 13 mm in the bending magnet vacuum chamber. The horizontal limit of BSC is given by the standard chamber with an aperture of 36 mm in quadrupoles.
### Magnet Lattice and Beam Dynamics (cont.)

#### Alignment error (rms)

- Bending magnet: 150 μm
- Quadrupole / Sextupole: 100 μm
- Roll for all magnets: 200 μrad
- Main magnet field error: $2 \cdot 10^{-4}$

#### Multipole contents

<table>
<thead>
<tr>
<th>Multipole</th>
<th>Systematic errors</th>
<th>Random errors</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dipole</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 (b3/b1)</td>
<td>-1.88e-4</td>
<td>2.0e-4</td>
</tr>
<tr>
<td>4</td>
<td>2.55e-4</td>
<td>2.0e-4</td>
</tr>
<tr>
<td><strong>Quadrupoles</strong></td>
<td>Systematic errors</td>
<td>Random errors</td>
</tr>
<tr>
<td>3</td>
<td>0</td>
<td>0.00013</td>
</tr>
<tr>
<td>4</td>
<td>0</td>
<td>7.20e-5</td>
</tr>
<tr>
<td>5</td>
<td>0</td>
<td>1.26e-5</td>
</tr>
<tr>
<td>6</td>
<td>4.57e-4</td>
<td>2.34e-5</td>
</tr>
<tr>
<td>7</td>
<td>0</td>
<td>2.34e-5</td>
</tr>
<tr>
<td>8</td>
<td>0</td>
<td>2.34e-5</td>
</tr>
<tr>
<td>9</td>
<td>0</td>
<td>2.34e-5</td>
</tr>
<tr>
<td>10</td>
<td>2.50e-5</td>
<td>2.34e-5</td>
</tr>
<tr>
<td>14</td>
<td>2.52e-4</td>
<td>2.34e-5</td>
</tr>
<tr>
<td><strong>Sextupole</strong></td>
<td>Systematic errors</td>
<td>Random errors</td>
</tr>
<tr>
<td>4</td>
<td>0</td>
<td>0.00075</td>
</tr>
<tr>
<td>5</td>
<td>0</td>
<td>0.00075</td>
</tr>
<tr>
<td>6</td>
<td>0</td>
<td>0.00075</td>
</tr>
<tr>
<td>7</td>
<td>0</td>
<td>0.00075</td>
</tr>
<tr>
<td>8</td>
<td>0</td>
<td>0.00075</td>
</tr>
<tr>
<td>9</td>
<td>0.003</td>
<td>0.00075</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>0.00075</td>
</tr>
</tbody>
</table>
Magnet Lattice and Beam Dynamics (cont.)

Corrected chromaticity: \( \sim 0.2 \)

Corrected chromaticity: \( \sim 5 \)

ID tracking

ELEGANT
(Ying Wu’s canonical integration code)

\[
B_y = -|B_0| \sum_{m,n} C_{mn} \cos(k_{x,m}x) \cosh(k_{y,m}y) \cos(k_{z,n}z + \theta_{z,n}) \\

k_{y,mn}^2 = k_{x,m}^2 + k_{z,n}^2, \quad k_{z,n} = 2\pi n / \lambda_w
\]
Beam Diagnostics and Control

Beam Diagnostics System

Design Requirements of Beam Diagnostics

- Satisfy the requirements of commissioning, machine study, routine operation and the performance upgrade
- Provide beam intensity, orbit information, transverse and longitudinal profiles, energy and many beam parameters
- Distribute the diagnostics tools around the accelerator, incorporating signal-processing electronics in analogue or digital way for data acquisition and further analysis

<table>
<thead>
<tr>
<th>Electron Beam Parameters</th>
<th>Instruments</th>
<th>Description</th>
<th>Quantity</th>
</tr>
</thead>
</table>
| Beam position meas. (first-turn, turn-by-turn, closed orbit feedback) | Digital BPM | - Machine tuning and beam studies  
- Closed orbit meas. Orbit control and feedback | 12×8=96 |
| Average beam current | DC Current Transformer | - Built-in magnetic field shielding, low temperature coefficient, 1 μA resolution | 2 |
| Betatron tune and beam damping | Stripline Electrode | - Beam spectrum and observation of instability  
- Used as transverse kickers for a transverse bunch-by-bunch feedback | 2 |
| Beam profile for commissioning | Screen Monitor | - Destructive position measurement | 1 |
| Beam trimming, dynamic aperture | Scraper | - To define the physical dynamic aperture | 1 |
Beam Diagnostics and Control (cont.)

Beam Position Monitor Distributions in PLS-II

Position offset: $X_0 = -0.1107 \text{ mm}$, $Y_0 = 0.1599 \text{ mm}$
**Beam Diagnostics and Control (cont.)**

**Orbit Control and Monitoring System**

### Orbit Stability Requirements

<table>
<thead>
<tr>
<th>Source</th>
<th>Beam Size (μm)</th>
<th>Orbit Stability (μm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Horizontal</td>
<td>Vertical</td>
</tr>
<tr>
<td>Bending Magnet</td>
<td>53</td>
<td>30</td>
</tr>
<tr>
<td>IDs at Long Straight Section</td>
<td>241</td>
<td>17</td>
</tr>
<tr>
<td>IDs at Short Straight Section</td>
<td>160</td>
<td>11</td>
</tr>
</tbody>
</table>

### Orbit Feedback System

- MPSs (4ea)
- BPMs (8ea)
- VME
- Liberas (8ea)
- RS422 Pick-ups
- GbE
- Sync Triggers
- RFM

Cell#1

Cell#12
Beam Diagnostics and Control (cont.)

- Feedback Type
  - Hybrid Type (Fast + Slow Orbit Feedback)
  - Download + Interaction (Soleil Type)
- BPM, Corrector Number
  - Number of BPM: 96 (8 per cell)
  - Corrector: 48 (4 per cell, insertion device area)
- Feedback Bandwidth
  - BPM Sampling Rate > 4 kHz
  - Corrector Magnet Risetime < 1 ms
  - Feedback bandwidth > 100 Hz
- Corrector Strength
  - Corrector Magnet Strength: ±20 μrad
SR Sources: Magnet and ID Systems

Magnet Layout in Half Cell of PLS-II

- Blue: Dipole Magnet - 2ea
- Magent: Quadrupole Magnet - 8ea
- Black: Sextupole Magnet - 8ea

Gradient Magnet coils and 3D Drawings
Bus structure with two parallel conductors
SR Sources: Magnet and ID Systems

Central Field Distribution of Gradient BM

By [Tesla]

Z [m]

-1.0 -0.5 0.0 0.5 1.0

0.0 0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6

X=-8mm
X= 0mm
X= 8mm
### Magnet Systems for PLS-II

<table>
<thead>
<tr>
<th>Type</th>
<th>Number</th>
<th>Key Parameters</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gradient</td>
<td>2×12</td>
<td>1.4555 T, 4.0028 T/m, Gap=34 mm, L_{eff}=1.800 m</td>
<td>All powered in series</td>
</tr>
<tr>
<td>Quadrupoles</td>
<td>8×12</td>
<td>4 types, Max Gradient 22T/m, R_c=36 mm</td>
<td>Powered in family series with independent aux coils.</td>
</tr>
<tr>
<td>Sextupoles</td>
<td>8×12</td>
<td>Max B”=550 T/m², R_c=39 mm, 2 types</td>
<td>SkewQ, V-corrector, H-corrector, combined function</td>
</tr>
<tr>
<td>Kicker Magnet</td>
<td>4</td>
<td></td>
<td>Recycle existing one</td>
</tr>
<tr>
<td>Lambertson Septum</td>
<td>1</td>
<td>3.0 GeV, 8.8 degree vertical bending,</td>
<td></td>
</tr>
</tbody>
</table>

| Energy, $E$         | 3.0    | GeV                                   |
| Bending radius, $r$ | 6.87549| m                                     |
| Full aperture in bending magnet, $G$ | 34 | mm                                   |
| Aperture radius in quadrupole, $R_Q$ | 36 | mm                                   |
| Aperture radius in sextupole, $R_S$ | 39 | mm                                   |
### ID Installation Plan of PLS-II

Vacuum pipe cross-section: 22 x 66 (mm)

<table>
<thead>
<tr>
<th>Name</th>
<th>#</th>
<th>Pole-gap (mm)</th>
<th>Length (m)</th>
<th>Radius&lt;sup&gt;1&lt;/sup&gt; (mm)</th>
<th>Total length&lt;sup&gt;2&lt;/sup&gt; (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>EPU</td>
<td>1</td>
<td>18</td>
<td>4</td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td>EPU</td>
<td>1</td>
<td>18</td>
<td>3.6</td>
<td>7</td>
<td>5.6</td>
</tr>
<tr>
<td>NanoScopy</td>
<td>1</td>
<td>18</td>
<td>3.6</td>
<td>7</td>
<td>5.6</td>
</tr>
<tr>
<td>U10</td>
<td>1</td>
<td>16</td>
<td>1.6</td>
<td>6</td>
<td>3.6</td>
</tr>
<tr>
<td>U6</td>
<td>1</td>
<td>18</td>
<td>2</td>
<td>7</td>
<td>4</td>
</tr>
<tr>
<td>MPW10</td>
<td>1</td>
<td>12</td>
<td>2</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>MPW10</td>
<td>1</td>
<td>12</td>
<td>1.1</td>
<td>4</td>
<td>3.1</td>
</tr>
<tr>
<td>MPW14</td>
<td>1</td>
<td>14</td>
<td>1.2</td>
<td>5</td>
<td>3.2</td>
</tr>
<tr>
<td>IVU</td>
<td>2</td>
<td>5</td>
<td>1.8</td>
<td>3&lt;sup&gt;3&lt;/sup&gt;</td>
<td>1.8 x 2</td>
</tr>
<tr>
<td>IVU</td>
<td>9</td>
<td>5</td>
<td>1.35</td>
<td>3&lt;sup&gt;3&lt;/sup&gt;</td>
<td>1.35 x 9</td>
</tr>
<tr>
<td>Rev.</td>
<td>1</td>
<td>4</td>
<td>1.02</td>
<td>3&lt;sup&gt;3&lt;/sup&gt;</td>
<td>3.2</td>
</tr>
</tbody>
</table>

1. If out-vac, (pole-gap – 4mm) /2
2. If out-vac, +2m
3. Nominal operation @ 6mm full gap
1. If out-vac, (pole-gap – 4mm) /2
2. If out-vac, +2m
3. Nominal operation @ 6mm full gap
# Magnet Power Supply System

## Design Parameters of Magnet Power Supply

<table>
<thead>
<tr>
<th></th>
<th>BD</th>
<th>Main-quadrupole</th>
<th>Sextupole</th>
<th>Sept.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>MQ1</td>
<td>MQ2</td>
<td>MQ3</td>
</tr>
<tr>
<td>INPUT(3Φ, Y/Δ, V)</td>
<td></td>
<td>470</td>
<td>400</td>
<td>400</td>
</tr>
<tr>
<td>OUTPUT(A)</td>
<td></td>
<td>1000</td>
<td>1000</td>
<td>1000</td>
</tr>
<tr>
<td>Power conversion</td>
<td></td>
<td>4-paralleled buck converter</td>
<td>2-paralleled buck converter</td>
<td>single buck</td>
</tr>
<tr>
<td>Stability Short: &lt;1 hour</td>
<td>+/- 5 ppm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stability Long: &gt;8 hour</td>
<td>+/- 10 ppm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Controller</td>
<td></td>
<td>Full digital controller</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Resolution</td>
<td></td>
<td>20 bit</td>
<td></td>
<td></td>
</tr>
<tr>
<td>cooling</td>
<td></td>
<td>water</td>
<td></td>
<td></td>
</tr>
<tr>
<td>protection</td>
<td></td>
<td>OC, OT, OV, cooling water, Ext.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
# Magnet Power Supply System

## Design Parameters of Magnet Power Supply

<table>
<thead>
<tr>
<th></th>
<th>Aux. Quad.</th>
<th>Skew</th>
<th>Slow corrector</th>
<th>Fast corrector</th>
<th>Trim coil (Gradient magnet)</th>
<th>ID corrector (ID no: 20)</th>
</tr>
</thead>
<tbody>
<tr>
<td>INPUT(3Φ, Δ, V)</td>
<td>23</td>
<td>15</td>
<td>23</td>
<td>15</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>OUTPUT(A)</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>15</td>
<td>15</td>
<td>10</td>
</tr>
</tbody>
</table>

- **Power conversion**: H-bridge type
- **Stability Short**: <1 hour +/- 5 ppm
- **Stability Long**: >8 hour +/- 10 ppm
- **Regulation**: Line: +/-10 ppm for +/-10%, Load: +/-10 ppm for +/-10%
- **Controller**: Full digital controller
- **Resolution**: 20 bit
- **Cooling**: Water
- **Protection**: OC, OT, OV, cooling water, Ext.
Magnet Power Supply System

Arrangement of Magnet Power Supply in Typical Cell

Main quadrupole MPS

Current[A]
Magnet Power Supply System

Installation Layout of Magnet Power Supply

- Main Substation: 154kV
- Storage Ring Substation: TR6 1MVA
- PLS MPS Location: Bending, Q1, Q2, Q3, Q4
- MPS ROOM
- Control Shed: Sextupole, Septum, Corrector, Skew

PLS-II MPS system is nicely under progress on the scheduled time.

More detailed status is given by S. -Ch. Kim.
Sector Girder and Alignment System

**Mechanical Girder System**

**System Design Criteria**
- Hold magnet center of 1,400 mm from the SR tunnel floor
- Rigid enough to sustain higher natural frequency
- Absorb the deformation coming from the ground movement
- Allow the active adjustment in vertical direction
- Install several diagnostic instruments to measure the deformation and get more flexible alignment (HLS, HPS, LVDT)

**BM Girder**
- Screw Jack : 3 set
- Stepping Motor : 3 set
- Linear Absolute Encoder : 3 set
- Total weight : 2.0 ton

**QM/SM Girder**
- Screw Jack : 6 set
- Stepping Motor : 3 set
- Linear Absolute Encoder : 3 set
- Total weight : 3.0 ton
 Vacuum System

**Configuration of Magnet Vacuum Chambers**

**Gradient bending magnet**
- Diff. Pressure: 0.1 MPa
- Support: Fixed (2point)
- Material: Al 5083-H321
- Deformation (Max): 0.196 mm

**Multipole magnet vacuum chambers**
- Diff. Pressure: 0.1 MPa
- Support: Fixed (2point)
- Material: Al 5083-H321
- Deformation (Max): 0.106 mm

- Diff. Pressure: 0.1 MPa
- Support: Fixed (2point)
- Material: Al 5083-H321
- Deformation (Max): 0.107 mm

- Diff. Pressure: 0.1 MPa
- Support: Fixed (2point)
- Material: Al 5083-H321
- Deformation (Max): 0.196 mm
Vacuum System

Configuration of Magnet Vacuum Chambers
Vacuum System (cont.)

Stiffner – shunt structure

Increases cutoff frequency

Mode 1
457.45 MHz

Mode 2
539.377 MHz

Mode 7
487.811 MHz

Mode 8
501.568 MHz

Mode 9
510.069 MHz
Vacuum System (cont.)

Vacuum Chamber Fabrication Process

- Machining
- Delivery/Inspection
- Moving
- Measurement
- TE mode test
- Cleaning
- Alignment
- Weld
- Assembly/Vacuum test
### Design Parameters of Superconducting RF System

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>RF cavity</td>
<td>SC</td>
</tr>
<tr>
<td>Number of cryomodule</td>
<td>3</td>
</tr>
<tr>
<td>RF voltage per cavity</td>
<td>1200 kV</td>
</tr>
<tr>
<td>RF power per cavity</td>
<td>232 kW</td>
</tr>
<tr>
<td>Wall loss power $(P_{\text{wall}})$</td>
<td>23 W</td>
</tr>
<tr>
<td>Beam Loading power $(P_{\text{beam}})$</td>
<td>232 kW</td>
</tr>
<tr>
<td>Number of power amplifier</td>
<td>$300 \text{ kW} \times 3$</td>
</tr>
<tr>
<td>SR tunnel space</td>
<td>1 and half -SS</td>
</tr>
</tbody>
</table>

![Diagram of RF System](image-url)
RF System

Design Parameters of Superconducting RF System

- He Refrigerator system in Experimental Room
- Compressor ~100 m apart from SR
### Parameters | PLS | PLS-II
--- | --- | ---
Energy [GeV] | 2.5 | 3.0
Current [mA] | 200 | 400
Emittance [nm-rad] | 18.9 | 5.8
Circumference [m] | 280.56 | 281.82
Revolution frequency [MHz] | 1.068 | 1.0638
Harmonic number | 468 | 470
No. of Insertion Devices | 10 | 20
Electron energy loss / turn from dipoles [keV] | 548.4 | 1042
and insertion devices [keV] | 160 | 250
Beam loss power by synchrotron radiation [kW] | 142 | 517.0
RF frequency [MHz] | 500.082 | 499.973
Cavity type | NC | SC
No. of RF cavities | 5 | 3 (2)
Accelerating Voltage [MV] | 2.0 | 4.5 (3.3)
RF Voltage per cavity [MV] | 0.4 | 1.5 (1.65)
Klystron amplifier | Five 75 kW amplifiers | Three 300 kW amp.
Cryogenic Cooling Capacity @4.5 K [w] | 700 | - Baseline design: Three Cryomodules
- Two Cryomodules will be installed in Phase II commissioning periods.
RF System (cont.)

Digital Low Level RF System and Klystron System

- Cavity Field Control (Amplitude & Phase)
- Cavity Tuning & Beam Loading Compensation
- Beam Instability Suppression
- RF Reference Generation & Distribution
- High-power protection

- Analog + Digital Technology
- RF Signal Generation & Precision Clock Synchronization
- RF & Digital Board Development with JLAB Collaboration
- PC/104 Based Single Board Computer with EPICS IOC with JLAB Collaboration
- High Power Amplification: 2-75kW and 2-300kW Klystron

**Prototype**
- ~ February 2011

**Production Type**
- ~ April 2011

**Overall Field Test & Commissioning**
- ~ July 2011
### Design Parameters of PLS-II RF System

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>RF cavity</td>
<td>SC</td>
</tr>
<tr>
<td>Number of cryomodule</td>
<td>2</td>
</tr>
<tr>
<td>RF voltage per cavity</td>
<td>1200 kV</td>
</tr>
<tr>
<td>RF power per cavity</td>
<td>232 kW</td>
</tr>
<tr>
<td>Wall loss power (P_wall)</td>
<td>23 W</td>
</tr>
<tr>
<td>Beam Loading power (P_beam)</td>
<td>232 kW</td>
</tr>
<tr>
<td>Number of power amplifier</td>
<td>300 kW x 3</td>
</tr>
<tr>
<td>SR tunnel space</td>
<td>1 and half -SS</td>
</tr>
</tbody>
</table>

- **# of Amplifier/HVPS**: 3
- **Waveguide**: WR1800
- **Circulator**: ~350kW
- **Amplifier**: 300kW klystron
- **HVPS**: 55kV/10A
### RF System (cont.)

<table>
<thead>
<tr>
<th>Item</th>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resonant frequency</td>
<td>MHz</td>
<td>499.765</td>
</tr>
<tr>
<td>RF Voltage per cavity [MV]</td>
<td>MV</td>
<td>1.65 (1.5)</td>
</tr>
<tr>
<td>Accelerating voltage [MV]</td>
<td>MV</td>
<td>3.3 (4.5)</td>
</tr>
<tr>
<td>Operating temperature</td>
<td>K</td>
<td>4.5</td>
</tr>
<tr>
<td>Operating pressure</td>
<td>mbar</td>
<td>1.3</td>
</tr>
<tr>
<td>Pressure stability of LHe tank</td>
<td>mbar</td>
<td>± 3 @2.0 MV</td>
</tr>
<tr>
<td>Cryomodule helium level stability</td>
<td>%</td>
<td>± 1</td>
</tr>
<tr>
<td>LN2 pressure stability</td>
<td>mbar</td>
<td>± 50</td>
</tr>
</tbody>
</table>
Magnet Girder and Alignment System

Mechanical Girder and Supporting Structures

System Design Criteria

- Hold magnet center of 1,400 mm from the SR tunnel floor
- Rigid enough to sustain higher natural frequency
- Absorb the deformation coming from the ground movement
- Allow the active adjustment in vertical direction
- Install several diagnostic instruments to measure the deformation and get more flexible alignment (HLS, HPS, LVDT)

DM Girder
- Screw Jack : 3 set
- Stepping Motor : 3 set
- Linear Absolute Encoder : 3 set
- Total weight : 8.0 ton (w/magnet)

MM Girder
- Screw Jack : 6 set
- Stepping Motor : 3 set
- Linear Absolute Encoder : 3 set
- Total weight : 7.5 ton (w/magnet)
Magnet Girder and Alignment System

Multipole Magnet Girder

Dipole Magnet Girder
Magnet Girder and Alignment System

[Magnet Error Tolerance with respect to Girder]
- QM, SM : 50 μm
- BM : 150 μm
Storage Ring Total : 100 μm (rms)

[Alignment System]
- HLS : Monitoring the Girder Movement
- Stepping Motor : Adjusting the Vertical Position
- Absolute Linear Encoder, Digital Probe : Recording the Position
Upgrade of PLS-II Utility/Infrastructures

Infrastructures for More Stable Beam of PLS-II

- **Building and Ground Movement**
  - Monitor ground displacement using the HLS in real time and countermeasure mechanically the movement with a active girder system

- **Thermal Deformation**
  - Prevent structural thermal deformation using isolating materials and low thermal expansion structures
  - Water temperature control, air-conditioning and dissipation of heat from electric power devices

- **Mechanical Vibration**
  - Increasing the resonance frequency of the mechanical structures, using damping materials and isolating vibration sources

- **Electrical Power and Grounding System**
PLS-II SR and Infrastructure Dismantling, Installation and Commissioning
Basic Strategy of PLS-II Installation and Commissioning

- Define Key Milestones
- Analyze System Integration
- Establish Dismantling and Installation Plan
- Safety Issue and Radiation Shielding
- High Heat Load Components (Vacuum)
- Communication (Risk Management)
- Experienced Experts (Manpower)
- Planned Commissioning Scenario
Basic Strategy of PLS-II Installation and Commissioning

Concepts of Three Phase Construction Programs

- Separation of the construction activities into Three Phases to meet the overall dismantling/installation schedules based on the work duties

<table>
<thead>
<tr>
<th>Installation Phases</th>
<th>Periods (Not Fixed)</th>
<th>Main Activities*</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Phase I</strong></td>
<td>Dec. 15, 2010 – Jan. 15, 2011</td>
<td>Dismantling of PLS SR Components</td>
</tr>
<tr>
<td><strong>Phase II</strong></td>
<td>Jan. 16, 2011 – Feb. 11, 2011</td>
<td>Preparation of tunnel floor, ground marking, cable tray</td>
</tr>
</tbody>
</table>

* The beamlines with front-end components should be interfaced with SR installation activities.
Procedures of Dismantling Program

Dismantling Procedures to Meet PLS-II Needs

1. Preparation of tug transport system for moving heavy-weight structures, chain blocks and jigs, etc
2. Three gates (doors) open to transfer from SR tunnel to outside (#5, 11 cell - shielding wall blocked)
3. Dismantling the HLS, power/signal cables, cooling pipes/tubes, cable trays, air/gas lines, vacuum vent/valve closing, sector by sector
4. Disassemble the re-cycled components in the SR tunnel and move out the components to outside building (reserved for final removal after radiation safety check)
5. Anchor removal, ground grouting/painting, ground floor survey/monument and marking, cable tray re-arrangement
6. Review and check the dismantling of the SR tunnel for PLS-II needs
Storage Ring Layout of PLS SR Tunnel
Demolition Status of PLS Storage Ring/Beamlines

Dec. 16, 2010

Dec. 20, 2010

Dec. 22, 2010

Dec. 24, 2010
Demolition Status of PLS Storage Ring/Beamlines

Dec. 26, 2010

Dec. 29, 2010

Jan. 10, 2011

Jan. 07, 2011
Demolition Status of PLS Storage Ring/Beamlines

Dec. 10, 2010

Dec. 23, 2010

Feb. 10, 2011
Installation Strategy of SR Components

- Detailed analysis and planning of manpower and resource distribution for intensive system integration on the scheduled time
  - Identification of equipment and systems – hardware readiness
  - Identification of assembly sequence between the main components and ancillary systems – interface procedure readiness
- Safety process depending on the rules and regulations for no accidents
- Installation crew training and coordination
- Review of the readiness to verify the PLS-II start-up
Procedures of Installation Program

- Demonstration of Typical Cell of PLS-II for Identifying Installation Activities and Component Interfaces
Installation Procedures of both Magnets and Girder Assembly

In the Workshop (Assembly Room)

- Set and lay out the girders to the imaginary orbit center line on the ground.
- Install the magnets and adjust the position locally.
- The magnet-girder assemblies will be transported independently in the tunnel by a tug transporter.

In Storage Ring Tunnel

- Check the ground level and grout the floor.
- Drill and insert the anchor nut into the ground with a precision less than 1 mm.
- Move and pre-install the magnet-girder assembly.
- Install the base plate and screw jack.
- Install the magnet-girder assembly on the screw jacks.
- Remove the upper part of the Quadrupole and Sextupole Magnets.
- Install the vacuum chamber.
- Set up the upper part of the Quadrupole and Sextupole Magnets.
- Install the dipole magnet.
- Survey and align the magnet and vacuum chamber cell by cell
- Whole ring survey and adjust the positions of the magnets.
Installation Status of PLS-II Storage Ring/Beamlines
Start-up and Commissioning Plan of PLS-II

Tentative Machine Start-up and Commissioning Plan

PLS and PLS-II Operation Plan

Phase I
- 3.0 GeV
- Open to users

Phase II
- Project Overview

Phase III

Shutdown
- Disassembly
- Tunnel repair
- Survey/Marking
- RF Bridg
- Insertion device
- NC Installation

PLS-II Comm.
- Phase-I
- Phase-II
- Phase-III

Linac
- Storage Ring

RP
- SC Cavity
- HV power supply
- Klystron
- Cryogenics
- LLRF, others
- NC removal

Vacuum
- Installation

*) Existing NO : 66 mWCavity at 3 GeV
*) SC : 133 mWCavity at 3 GeV
On-going Activities and Outlook

Be done an actual installation program of PLS-II accelerator systems including the dismantlement of current PLS SR and beamline components, including the modification of ancillary infrastructures to meet PLS-II requirements.

Be defined key milestones depending on the system levels more clearly from construction to start-up or commissioning to achieve the technical goals of a complex projects.

Be confirmed on-time delivery of components with an accepted performance to prevent an interruption of the installation program of PLS-II within 6 months.
On-going Activities and Outlook

Readiness of PLS-II Main Accelerator Components

- **Magnetic Lattice**: Completion of Linear/Nonlinear Beam Dynamics including error budget analysis and optimization (tune, DA, etc.)
- **Bending Magnets**: IHEP manufacturing (BM) prototype finished and under field measurement delivered on Jan., 2011
- **Quadrupoles and Sextupoles**: For aux coil, IHEP manufacturing (QM) and refurbished with PLS QM, domestic company manufacturing (SM) - on schedule (delivered on Dec. 2010)
- **Vacuum Chamber**: Domestic company manufacturing (Sector Chamber) - on schedule (delivered on Dec. 2010)
- **Beam Position Monitors**: IT (Libera) manufacturing (2nd procurement) and pick-up button (domestic) - on schedule (delivered on Jan. 2011)
- **Magnet Power Supplies**: domestic company manufacturing - on schedule (delivered on Dec. 2011)
- **RF System**: Cryomodule system (RI-contracted), Cryogenics (AL-contracted), Klystron amplifier (Thales), Waveguide and others - on schedule
- **Linac Upgrade**: Klystron (Toshiba-contracted), Acc. Section (Mitsubishi-contracted, Modulator (domestic) and others - on and advanced schedule
- **R&D on Key Components**: In-vac Undulator (domestic)
- **Utilities and Safety**: Water, Electricity, Radiation Safety (domestic) -on schedule
- **SR Dismantling and Installation**: Under preparation of detailed work duties (domestic) - on schedule
The upgrade program (PLS-II) has been officially launched with a project period of three years from 2009 to 2011. The main goals of PLS-II are the increase of straight sections for more insertion devices, the energy increase from 2.5 GeV to 3.0 GeV, a stored beam current from 200 mA to 400 mA, a relatively low emittance of 5.9 nm-rad, and more stable beam conditions. During last year (2011) of project periods, the current PLS facility will be shutdown and components be built, and then the first stage commissioning of 100 mA with 3.0 GeV be finalized. New beamlines and experimental stations will be also relocated with newly established insertion devices (undulators and wigglers), while the existing insertion device beamlines may be preserved. The PLS-II is to open for user experiments in 2012 after the international review for assessment of the PLS-II performance and readiness.

Cited from TPS CDR, 2008
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Thank you very much for your kind attention