The First 3 Years of Operation of PLS-II Vacuum System

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On behalf of Vacuum Group
Pohang Accelerator Laboratory
Contents

• Brief description of PLS-II
• PLS-II vacuum system
  – Tight space (20 IDs / 280 m)
  – BPM stability (< 1 um)
  – TE mode suppression
  – High current operation (Photon absorber, RF finger)
• Some experiences
  – Leak induced from injection kicker accident
  – Beam interruption by TC wire
  – Beam dump due to TC malfunction
  – Beam dump due to gauge controller malfunction by instantaneous sag
Pohang Accelerator Laboratory

3 GeV full energy Linac

280 m Storage ring
## Main parameters of PLS-II

<table>
<thead>
<tr>
<th>Parameter</th>
<th>PLS</th>
<th>PLS-II</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Beam energy</strong></td>
<td>2.5</td>
<td>3</td>
<td>GeV</td>
</tr>
<tr>
<td><strong>Beam current</strong></td>
<td>190</td>
<td>400</td>
<td>mA</td>
</tr>
<tr>
<td>Revolution freq.</td>
<td>1.06855</td>
<td>1.06377</td>
<td>MHz</td>
</tr>
<tr>
<td>No of bunches</td>
<td>300</td>
<td>400</td>
<td>Plan</td>
</tr>
<tr>
<td>Bunch Charge</td>
<td>0.59</td>
<td>0.94</td>
<td>nC (Calculated)</td>
</tr>
<tr>
<td>Bunch length</td>
<td>30</td>
<td>20</td>
<td>ps (Designed)</td>
</tr>
<tr>
<td>Bunch current</td>
<td>8.86</td>
<td>18.74</td>
<td>A (Peak value)</td>
</tr>
<tr>
<td><strong>Emittance</strong></td>
<td>18.9</td>
<td>5.8</td>
<td>nm mrad</td>
</tr>
<tr>
<td><strong>Lattice</strong></td>
<td>TBA</td>
<td>DBA</td>
<td>20 IDs (10 IDs in PLS)</td>
</tr>
<tr>
<td>Circumference</td>
<td>280</td>
<td>280</td>
<td>m</td>
</tr>
</tbody>
</table>
Challenges of PLS-II

Challenges
- Bright (5.8 nm.rad)
- Compact (20 IDs/ 280m)
- IVU X-ray (12 IVUs +)
- Top-Up (w/Linac)

Number of ID sections vs Emittance (nm rad) diagram showing PLS-II and other synchrotrons and free-electron lasers.
Re-installation of PLS-II storage ring

PLS

Dismantling

DEC. ‘10

Re-installation

JAN. ‘11

Jun. ‘11

PLS-II
PLS-II timeline

O 2011
- 25 January, PLS-II installation begins
- 23 May, Linac commissioning begins
- 13 June, 3 GeV beam
- 25 June, SR installation finished
- 1 July, First turn
- 5 July, Kicker PS accident
- 5 August, First accumulation
- 7 October, 100 mA stored
- 24 October, First photons to beamline

O 2012
- 14 February, Commissioning with users
- 21 March, Start of operations

O 2013
- 18, Jun, 200 mA top-up operation
Plan of beam current increase

- **Current**: 400 mA
- **SRF #1, #2 installation**
- **SRF #3 installation**
- **Achievement**
- **User service current**

<table>
<thead>
<tr>
<th>Quarter/Year</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 mA</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>200 mA</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>300 mA</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>400 mA</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
• 30 vacuum pumps
  • Sputter ion pumps (30 l/s + 60 l/s): 7 ea
  • Lumped NEG (ST707 + D-400-2): 9 ea
  • NEG +SIP combination pump: 8 ea
  • Strip NEG: 5 ea

• 2 Ion gauges

• 2 RGAs
Arc-section vacuum chamber

• Cross section

• Vacuum seals
  - Al/SUS hybrid Conflat system

STS Conflat

Al Conflat (A2219-T87)
TiC coated

Al gasket (A1050-H24)
Cu (<100°C Bakeout)

STS bolt/nuts
Silver coated

A5083-H321
Dynamic pressure and lifetime in early stage

○ Dynamic pressure reached to $<10^{-11}$ mbar/mA after integrated beam current of 50 Ah which is our target value.

○ Beam-gas scattering lifetime dominates at the early stage of commissioning. After ~50 Ah, Touscheck effect mainly limits beam lifetime.
Chamber supports (Arc section)
Chamber supports (Short straight section)
Mechanical stability of BPMs

BPMs are mechanically separated by bellows.

Long straight

Reference plane

Short straight

Arc section-I

Arc section-II

Ground
Mechanical stability of BPMs

Can bellows absorb chamber deformation?

Chamber motion (vertical) vs. time (24 h)

Beam current vs. time (24 h)
TE mode excited in PLS SR chamber
Shunt structure to avoid TE mode in PLS-II Vacuum chamber

Design Goal

→ No resonance mode in the frequency band of 500 ± 5 MHz

How to?

Find resonance mode Using CST Microwave Studio (MWS)
Shunt structure (stiffener)
→ Reduce effective width
→ Control of frequency of TE modes

Val seal for RF contact
Holes for vacuum pumping
Bolt connection to plate
SR vacuum chamber assembled

- To control the resonance mode frequency
  - Slotted stiffeners are installed to minimize conductance reduction
No peak is found.

Pickup antenna on BPM electrode

Setup and Results

TE mode measurement results

No TE mode found in PLS-II operation mode until now!
Photon absorbers in PLS-II
## Parameters for PA design

<table>
<thead>
<tr>
<th>Item</th>
<th>Magnitude</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beam energy ((E))</td>
<td>3</td>
<td>GeV</td>
</tr>
<tr>
<td>Beam current ((I))</td>
<td>400</td>
<td>mA</td>
</tr>
<tr>
<td>Bending radius ((\rho))</td>
<td>6.8775</td>
<td>m</td>
</tr>
<tr>
<td>Bending magnet field ((B))</td>
<td>1.4557</td>
<td>T</td>
</tr>
<tr>
<td>Total power</td>
<td>417</td>
<td>kW</td>
</tr>
<tr>
<td>Beam divergence ((1/\gamma))</td>
<td>0.17</td>
<td>mrad</td>
</tr>
</tbody>
</table>

## Input Parameters

<table>
<thead>
<tr>
<th>Input Parameters</th>
<th>Magnitude</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source distance</td>
<td>1520</td>
<td>mm</td>
</tr>
<tr>
<td>Incident peak power density</td>
<td>12.23</td>
<td>W/mm(^2)</td>
</tr>
<tr>
<td>Rectangular approximation width</td>
<td>0.405</td>
<td>mm</td>
</tr>
<tr>
<td>Convection film coefficient</td>
<td>1</td>
<td>W/cm(^2)K</td>
</tr>
<tr>
<td>Vertical miss-steering</td>
<td>±1.5 mm offset</td>
<td></td>
</tr>
</tbody>
</table>
The yield strength of the cold forged OFHC is enhanced up to 240 MPa.
Materials for PA (cold forged OFHC)

- Number of cycles to failure for total strain of 0.115 % (most severe point) in air is measured to be larger than 10,000 cycles.
- Fatigue lifetime in vacuum is 10 times longer than that in air, typically.
- The lifetime of the PLS-II photon absorber is expected to be longer than 100,000 cycles.
• Operating temperature of the most severe photon absorber at the sensor position is measured to be 50°C at 400 mA.
• Most severe point ~ 150°C at 400 mA (much lower than the thermal analysis result)
• photon absorbers will endure 400 mA top-up operation
RF shielded bellows

- BeCu finger
- Thermocouple Line
- Feedthrough for thermocouple
- Upper thermocouple
- STS guide
- Lower thermocouple
RF shielded bellows in operation

Rf finger inside bellows

Beam current

Upper sensor

lower sensor

Outside of bellows

More than 70°C, is it O.K.?
RF shielded bellows in operation

- Beam induced power $\propto$ bunch current$^2$

- Sudden change, why?
Some vacuum related events during PLS-II operation
Leakage in injection section (after fire)

(2011.10)

Kicker power supply fire in tunnel (2011.07)

Weld join of bellows was corroded by particles produced during fire

Pressure change

Leak sealed

Leaked 3 months after fire
Abnormal pressure in an IVU

Pressure high at 7A IVU

- Interruption by TC wire
- Changed with the spare IVU
Beam was dumped due to the malfunction of a thermocouple interlock.

Any recommendation to prevent this?
Gauge controller malfunction due to sag

Instantaneous voltage sag ➔ gauge controller emission off ➔

Analog output sent 10 V signal ➔ Machine Interlock System triggered

➔ Gate valve closed ➔ beam dump

(The controller being in trouble was changed then it became O.K.)
THANK YOU FOR YOUR ATTENTION