Operation of TLS and Progress of TPS

Gwo-Huei Luo on behalf of Accelerator Divisions

EPICS Collaboration Meeting
June 13-17, 2011
TLS accelerator layout and key milestones

The most densely-packed SR ring with the highest number of superconducting IDs!

- Commission in Apr. & open to users in Oct. 1993
- 1.3 to 1.5 GeV ramping in operation in 1996
- 240 mA operation beam current in 1996
- Booster full energy injection in 2000
- Sc. wavelength shifter in operation in 2002
- Cryogenic system & SW6 available in 2004
- SRF cavity in operation in Feb. 2005
- Top-up injection implemented in Oct. 2005
- 1st IASW installed in 2006 & 2nd IASW in 2009
- 360 mA top-up & 3rd IASW in 2010
Weekly report and accumulated dosage

Threshold of dose-rate for top-up OP : 4 μSv/4hrs

Annual dosage limit for NSRRC staff < 2 mSv/yr.
Atomic Energy Council annual dosage < 50 mSv/yr. (rad. worker)
Operation statistics during user shifts

Availability of TLS user time

- Scheduled
- Delivered
- Percentage

Percentage of availability:

- 0%
- 10%
- 20%
- 30%
- 40%
- 50%
- 60%
- 70%
- 80%
- 90%
- 100%

Hours:

- 0
- 100
- 200
- 300
- 400
- 500
- 600

Year:

2009 2010 2011

Linac Kly. failure
IASW installation
TPS ground break

Operation statistics during user shifts

Linac Kly. failure
Users Distribution

Distribution of users' proposals in 2010

- Materials Science, 23%
- Soft Matter, 12%
- Chemistry, 9%
- Condensed Matter Physics, 14%
- Surface, Interface and Thin Films, 13%
- Environment & Earth Science, 8%
- Protein Crystallography, 12%
- Methodology & Instrumentation, 2%
- Nanofabrication, 2%
- Applied and Industrial Research, 3%
- Others, 2%
- Atomic and Molecular Science, 4%

6.5% international proposals

3% international users

No. of User-runs

Experimental Runs
SCI Publication Statistics

Remark:
1. Top 5%、10% and 15% include SCI paper in the field of natural science and life science.
2. Top 5%: IF ≥ 6.0 in natural science, and IF ≥ 9.0 in life science.
3. Top 10%: IF ≥ 4.5 in natural science, IF ≥ 6.0 in life science.
4. Top 15%: IF ≥ 3.5 in natural science, IF ≥ 4.8 in life science.
5. 92年(含)前所有年度之IF值皆以93年之IF值為統計標準，其餘年度皆依據該年度之IF值為統計標準。
6. 以上為截至100年6月上旬之資料。相關統計仍持續進行中。
Status and Progress of TPS
## Major Parameters of Taiwan Photon Source

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Energy</strong></td>
<td>3 GeV (maximum 3.3 GeV)</td>
</tr>
<tr>
<td><strong>Current</strong></td>
<td>500 mA at 3 GeV (Top-up injection)</td>
</tr>
<tr>
<td><strong>SR circumference</strong></td>
<td>518.4 m ( (h = 864 = 2^5 \cdot 3^3 ), \ dia. = 165.0 m)</td>
</tr>
<tr>
<td><strong>BR circumference</strong></td>
<td>496.8 m ( (h = 828 = 2^3 \cdot 3^2 \cdot 23, \ dia. = 158.1 m)</td>
</tr>
<tr>
<td><strong>Lattice</strong></td>
<td>24-cell DBA</td>
</tr>
<tr>
<td><strong>Straight sections</strong></td>
<td>12 m x 6 ( (\sigma_v = 12 \ \mu m, \ \sigma_h = 160 \ \mu m)</td>
</tr>
<tr>
<td></td>
<td>7 m x 18 ( (\sigma_v = 5 \ \mu m, \ \sigma_h = 120 \ \mu m)</td>
</tr>
<tr>
<td><strong>Bending magnets</strong></td>
<td>48</td>
</tr>
<tr>
<td><strong>Emittance</strong></td>
<td>1.6 nm·rad at 3 GeV (Distributed dispersion)</td>
</tr>
<tr>
<td><strong>Coupling</strong></td>
<td>1 %</td>
</tr>
<tr>
<td><strong>RF frequency</strong></td>
<td>500 MHz</td>
</tr>
<tr>
<td><strong>RF gap voltage</strong></td>
<td>2.8~3.5 MV ( (3 \text{ SRF cavities})</td>
</tr>
<tr>
<td><strong>RF power</strong></td>
<td>750 kW ( (3 \text{ SRF cavities})</td>
</tr>
<tr>
<td><strong>Location</strong></td>
<td>No. 101, Hsin-Ann Road, Hsinchu, Taiwan</td>
</tr>
<tr>
<td><strong>Building</strong></td>
<td>Outer diameter 210 m ; Inner diameter 129 m</td>
</tr>
</tbody>
</table>
Taiwan Photon Source (TPS)
3 GeV, 518.4 m, 500 mA

Natural emittance: 1.6 nm-rad
Straight sections: 7 m (x 18); 12 m (x 6)

3D Aerial View of NSRRC
The largest investment for scientific research program in this country in history.

Concentric booster and storage ring

Distributed utility and control instrumentation
Utility, control and instrumentation for one cell lattice
Comparison of brightness between TLS and TPS

The X-ray spectrum (photon energy 8 keV ~ 70 keV):
- the brightness of bending magnet \( >10^2 \).
- the brightness of IDs: 4~6 orders of mag.
## Major parameters of TPS storage ring

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Circumference $C$ (m)</td>
<td>518.4</td>
</tr>
<tr>
<td>Energy $E$ (GeV)</td>
<td>3.0</td>
</tr>
<tr>
<td>Beam current (mA)</td>
<td>400</td>
</tr>
<tr>
<td>Natural emittance $\varepsilon_{x0}$ (nm-rad)</td>
<td>1.6</td>
</tr>
<tr>
<td>Straight sections (m)</td>
<td>12 (x6) + 7 (x18)</td>
</tr>
<tr>
<td>Radiofrequency (MHz)</td>
<td>499.654</td>
</tr>
<tr>
<td>Harmonic number $h$</td>
<td>864</td>
</tr>
<tr>
<td>RF voltage (MV)</td>
<td>3.5</td>
</tr>
<tr>
<td>Energy loss per turn (dipole) (MeV)</td>
<td>0.85269</td>
</tr>
<tr>
<td>Betatron tune $\nu_x/\nu_y$</td>
<td>26.18 / 13.28</td>
</tr>
<tr>
<td>Momentum compaction $(\alpha_1, \alpha_2)$</td>
<td>$2.4\times10^{-4}, 2.1\times10^{-3}$</td>
</tr>
<tr>
<td>Natural energy spread $\sigma_E$</td>
<td>$8.86\times10^{-4}$</td>
</tr>
<tr>
<td>Damping time $\tau_x/\tau_y/\tau_s$ (ms)</td>
<td>12.20 / 12.17 / 6.08</td>
</tr>
<tr>
<td>Natural chromaticity $\xi_x/\xi_y$</td>
<td>-75 / -26</td>
</tr>
<tr>
<td>Synchrotron tune $\nu_s$</td>
<td>0.00609</td>
</tr>
<tr>
<td>Bunch length (mm) $\sigma_l$</td>
<td>2.86</td>
</tr>
</tbody>
</table>
TPS storage ring lattice functions

1.6 nm-rad

2.5 nm-rad

4.9 nm-rad

24 DBA cells
Alternative lattice configurations

• Low $\alpha$ short bunch -- reduce 1st –order $\alpha$ so that bunch length can be reduced by a factor of 5 (a few ps).

• High/low $\beta_x$ in the straight -- provide tuning flexibility for optimizing photon beam properties for the experiments.

• Double mini- $\beta_y$ in the long straight – accommodate two mini-gap insertion devices in a long straight.

$\alpha_1 = 7.3e-6$
$\varepsilon_x = 2.8 \text{ nm-rad.}$

$\varepsilon_x = 1.6 \text{ nm-rad}$
Accelerator application tools for beam commissioning and operation

Beam Based Alignment

Dispersion Function Measurement

Beta Function Measurement

Tune Control

P. Chang et al
**TPS Sub-system design and prototype**

### 二極、四極與六極磁鐵

- **A-type**
- **B-type**
- **C-type**
- **Extended type**
- **Cutting type**
- **Standard type**

### 真空系統設計與射束診斷安排

#### A-type

- **S1**
- **S7**

### 四極磁鐵原型及量測平臺

#### Specification

- Max. voltage: ±500V/510A
- Current ripple: 10 ppm
- Short term stability: 5 ppm
- Long-term stability: 10 ppm

Total 750 units to be fabricated by local company

### 修正磁鐵電源供應器原型

(與工研院合作開發)

- **Hall量測系統**
- **Hall量測支架**

### 700 W液氦低溫系統配置

- **BPM1**
- **BPM2**
- **BPM3**
- **BPM4**
- **BPM5**
- **BPM6**
- **BPM7**

### 潔淨室無油加工鋁質二極真空腔

- **IG3**
- **IG4**
- **IG5**
- **IG6**

### 修正磁鐵電源供應器原型

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- **Hall量測系統**
- **Hall量測支架**

### 超導高頻共振腔

**KEKB Type SRF Module**

- Installed at
  - KEKB (508 MHz)
  - BECPI-II/IHEP (500 MHz)

### 淨潔室無油加工鋁質二極真空腔

- **S3**
- **S4**
- **B1**
- **S5**
- **B2**
- **S6**
- **B3**
- **S7**
- **B4**

### 四極磁鐵原型及量測平臺

- **BPM1**
- **BPM2**
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- **BPM6**
- **BPM7**

### 潔淨室無油加工鋁質二極真空腔

- **IP1**
- **NEG1**
- **NEG2**
- **IP2**
- **NEG3**
- **NEG4**
- **IP3**
- **NEG5**
- **NEG6**
- **IP4**
- **NEG7**
- **IP5**
- **NEG8**
- **IP6**
- **NEG9**
- **IP7**

### TPS儲存環1/24段實體照片

- **S2**
- **S8**

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- **IP3**
- **NEG5**
- **NEG6**
- **IP4**
- **NEG7**
- **IP5**
- **NEG8**
- **IP6**
- **NEG9**
Software development for the accelerator control

To enable early testing of applications through the control system, a virtual accelerator has been implemented to give simulation of the accelerators through the intended EPICS PV interface. Prototype was set up by the help from DLS.

- Current version is AT/MML version.
- Virtual booster and linac are also possible near future!
- Many facility have such kinds activities: SNS, KEK, J-PARC, DLS, ... many others!
# Parameters of GHe tanks (completed)

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Base Value (TPS)</th>
<th>Unit</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cold box</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximum refrigeration capacity</td>
<td>700</td>
<td>W</td>
<td>at 4.5K</td>
</tr>
<tr>
<td>Inlet GHe temperature</td>
<td>300</td>
<td>K</td>
<td></td>
</tr>
<tr>
<td>No. of turbines</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. of heat exchangers</td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. of 80K absorbers</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>O2 impurities</td>
<td>0.01</td>
<td>ppm</td>
<td></td>
</tr>
<tr>
<td>N2 impurities</td>
<td>3.6</td>
<td>ppm</td>
<td></td>
</tr>
<tr>
<td>No. of 20K absorbers</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pressure drop of return gas thru HEXs</td>
<td>&lt;120</td>
<td>mbar</td>
<td>at 700W</td>
</tr>
<tr>
<td><strong>Helium storage tanks</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. of tanks</td>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Volume</td>
<td>100</td>
<td>m³</td>
<td></td>
</tr>
<tr>
<td>Design pressure</td>
<td>20</td>
<td>barg</td>
<td></td>
</tr>
<tr>
<td>Operation pressure</td>
<td>2~9.5</td>
<td>barg</td>
<td></td>
</tr>
</tbody>
</table>

---

**TPS 日語**

1. Welding
2. He leakage rate test at 18 barg mixing gas (3 barg He and 15 barg N₂)
3. Sand Blasting
Basic parameters of 700 W LHe cold box (delivery in July, 2011)

<table>
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<tr>
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</tr>
</tbody>
</table>

Turbines Cooler
Electrical Junction Box
1st Heat Exchanger
Refrigerator/Liquefier for TPS
RF system

KEK type SRF module :
Contracted to MHI
DDR review on Dec. 2010
Petra Cavity module :
High power processing

300kW RF transmitter :
1. 2 sets of transmitter and 2 spare klystrons pass acceptance test
2. Re-assembly for all modules
3. Waveguide, ferrite load and cooling units ready
4. high power and acceptance test – 305 kW reached
Process welding of BC in Chu-Tung

Upper and lower leaf of BC
Welding pumping port
Alignment for the bending chamber
Bending chamber in auto-welding stage
Assembly of vacuum system and storage in Chu-Tung
Assembly and acceptance test of 150 MeV linac

Linac

Bunching section

Network and control rack

35 MW Modulator
Beam parameters of 150 MeV linac

Single-bunch Mode

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification-SBM</th>
<th>Measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bunch train length (μs)</td>
<td>≤ 1 ns</td>
<td>0.7</td>
</tr>
<tr>
<td>Charge in bunch train (nC)</td>
<td>≥ 1.5 nC</td>
<td>1.5</td>
</tr>
<tr>
<td>Energy (MeV)</td>
<td>≥ 150</td>
<td>153</td>
</tr>
<tr>
<td>Pulse to pulse energy variation (%)</td>
<td>≤ 0.25 (rms)</td>
<td>0.08</td>
</tr>
<tr>
<td>Relative energy spread (%)</td>
<td>≤ 0.5 (rms)</td>
<td>0.2</td>
</tr>
<tr>
<td>Normalised emittance (1σ) (μm mrad)</td>
<td>≤ 50 (x plane)</td>
<td>41</td>
</tr>
<tr>
<td></td>
<td>≤ 50 (y plane)</td>
<td>36</td>
</tr>
<tr>
<td>Repetition rate (Hz)</td>
<td>1 to 5, adjustable</td>
<td>1.2 to 5</td>
</tr>
<tr>
<td>Pulse to pulse time jitter (ps)</td>
<td>≤ 100</td>
<td>29</td>
</tr>
<tr>
<td>Single bunch purity (1%)</td>
<td>better than 1</td>
<td>0.7%</td>
</tr>
</tbody>
</table>

Emittance-vertical (SBM)

- K=0
- K=0.54 (4 A)
- K=1.09 (8 A)
- K=1.63 (12 A)

Vertical emittance analysis:
$\varepsilon_{y,\text{rms,norm}} = 38 \, \text{π mm mrad}$

Emittance-horizontal (SBM)

- K=0
- K=0.54 (4 A)
- K=1.09 (8 A)
- K=1.63 (12 A)

Horizontal emittance analysis:
$\varepsilon_{x,\text{rms,norm}} = 41 \, \text{π mm mrad}$

Energy and Energy Spread-SBM

Spec.: >150 MeV; spread < 0.5%

$l=46A, E=153 \, \text{MeV}$

$\Sigma = \sigma_x^2 + D_x^2 (\Delta E/E)^2 + D_y^2 (\Delta E/E)^2$

$1.9^2 > 1000^2 ((\Delta E/E)^2)$

$0.2\% > \Delta E/E$
Shielding design for BL and end-station

GB: Gas Bremsstrahlung
SR: Synchrotron Radiation
TPS phase space tracking for top-up injection

Forward and backward tracking in phase space for bending magnet’s beamline

Forward and backward tracking in phase space for insertion device’s beamline
The First-Phase BL’s Proposals for TPS

- $\mu$-focus macromolecular crystallography (2013)
  (微聚焦巨分子結晶學光束線)

- High resolution Inelastic soft-x-ray scattering (2013)
  (高解析非彈性軟X光散射學光束線)

- Sub-$\mu$ soft x-ray photoelectron & fluorescence emission (2013)
  (次微米軟X光能譜學光束線)

- Soft matter small angle scattering (2014)
  (軟物質小角度散射學光束線)

- Sub-$\mu$ x-ray diffraction (2014)
  (次微米繞射光束線光束線)

- Nano-probe x-ray diffraction (2014)
  (奈米探針光束線)

- Multi-purpose coherence x-ray scattering (2014)
  (多用途同調性散射光束線)
Conceptual design of first-phase beamlines

- Micro-focus macromolecular crystallography
- High resolution Inelastic soft-x-ray scattering
- Sub-μ soft-x-ray photoelectron & fluorescence emission
- Soft matter small angle scattering
- Sub-μ x-ray diffraction
- Nano-probe x-ray diffraction
- Multi-purpose coherence x-ray scattering
NSRRC site image from satellite (by National Space Center)
Long beam lines
Linac area
Space for utilities and accelerator lab.
Experimental Area for 50 m beamlines and five 70 m beamlines

TPS Storage ring
(beneficial occupancy plan in Q2, 2012)
# TPS construction schedule

<table>
<thead>
<tr>
<th>計畫項目</th>
<th>年度</th>
<th>‘07</th>
<th>‘08</th>
<th>‘09</th>
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<tr>
<td>1. Acc. Design</td>
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<td>2. Prototype &amp; long lead item</td>
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<td>3. Accelerator Construction</td>
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<td>4. Installation</td>
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<td>5. Commission</td>
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Installation pedestal and girder in Q2, 2012
Booster and storage ring commissioning in Q4, 2013.
Summary

• **Taiwan Light Source**
  – 1.5 GeV beam energy provides more than 5500 hrs with 360 mA top-up to users. Photon energy can be up to ~30 keV by SC wigglers.
  – Beamlines in SPring-8 provide hard x-ray to users.

• **Taiwan Photon Source**
  – 3 GeV storage ring with 500 mA as design goal. Seven beamlines are under design for Phase-I operation.
  – Subsystems of accelerator are delivering to NSRRC for acceptance test and installation.
  – The installation will start in the 2\textsuperscript{nd} quarter of 2012.
  – Booster and storage ring commission are planned before the end of 2013.
Taiwan Photon Source (TPS)

Thank you for your attention!