Status and Future of Taiwan Light Source

by

Keng S. Liang, G.H. Luo, C.C. Kuo, J.R. Chen,
D.J. Wang and Y.W. Yang

APAC 2007

Indore, India
Outline

- Overview of Taiwan Light Source
- Performance and Upgrade
  - Superconducting RF cavity and cryogenic system
  - Superconducting wigglers
  - Top-up injection
- Statistics of TLS Operation
- Taiwan Photon Source
Schematic Layout and Timeline of TLS

- Commission on Apr. open to users on Oct. ‘93
- 1.3 to 1.5 GeV ramping in operation in ‘96
- 240 mA operation beam current in ‘96
- Upgrade booster from 1.3 GeV to 1.5 GeV full energy injection in ’00
- Sc. wavelength shifter in operation in ‘02.
- Cryogenic system and SW6 available in ‘04
- SRF cavity in operation on Feb. ‘05.
- Top-up injection implemented on Oct. ‘05.
Facility Development

- Light Source: 1.3 → 1.5 GeV
- Insertion Device: 0 → 8
- Beamline: 3 → 27
- End Station: 3 → 55

Taiwan Contract Beamlines at SPring-8
**Superconducting RF (SRF) project**

**Goals:**
- To double the maximum stored beam current of the storage ring
- To eliminate beam instabilities caused by the strong higher-order-modes (HOMs) of Doris RF cavities
Superconducting Insertion Devices

Superconducting Wavelength Shifter (6 T, SWLS)

Superconducting Wiggler (3.2T, SW6)
IASW Construction Project

(a) vacuum chamber for straight section
(b) girder
(c) vacuum chamber for arc section

IASW under construction
Top up injection

Threshold dose for interlock (4 μSv)

Fluctuation of photon intensity $\delta I/I_0$ (%)
• Software gating
  BL01 B  IMAGE
  BL03 Absorption
  BL05 XAS,PEEM
  BL09A XAS
  BL20 XAS
  BL21B Absorption
  BL24 XAS

• Real time gating
  BL11 MCD
  BL15 XAS

• Non-gating
  BL01 C  EXAFS
  BL09A SPEM
  BL14 FTIR
  BL17 B,C Scattering, EXAFS

Injection beam pulses
  e-pulse: 70~150 ns
  Kicker pulse: 3 μs

Real time gating

Software gating

100 ms

~ 400 ms

2 ms

- **2006/11/14** Tue:Merit: 214.84%
  - Chart showing data with annotations for "Reset pre-injector".

- **2006/11/15** Wed:Merit: 191.86%
  - Chart showing data with annotations for "DCCT not updating".

- **2006/11/16** Thu:Merit: 183.39%
  - Chart showing data with annotations for "DCCT not updating".

- **2006/11/17** Fri:Merit: 193.49%
  - Chart showing data with annotations for "DCCT not updating".

- **2006/11/18** Sat:Merit: 194.71%
  - Chart showing data with annotations for "DCCT not updating".

- **2006/11/19** Sun:Merit: 187.06%
  - Chart showing data with annotations for "DCCT not updating".

- **2006/11/20** Mon:Merit: 183.06%
  - Chart showing data with annotations for "DCCT not updating".
Accumulated dosage per 4 hours (Nov. 14~20)

Decay mode threshold line 4 μSv/4 hrs.

Machine development

Maintenance

<table>
<thead>
<tr>
<th>Signal Name</th>
<th>Max</th>
<th>Min</th>
<th>Dif</th>
<th>Avg</th>
<th>Sum</th>
</tr>
</thead>
<tbody>
<tr>
<td>gS1.1 (uSv/h)</td>
<td>0.310</td>
<td>0.001</td>
<td>0.309</td>
<td>0.109</td>
<td>6597.339</td>
</tr>
<tr>
<td>gS2.2 (uSv/h)</td>
<td>0.170</td>
<td>0.001</td>
<td>0.169</td>
<td>0.042</td>
<td>2570.930</td>
</tr>
<tr>
<td>gS3.3 (uSv/h)</td>
<td>0.270</td>
<td>0.001</td>
<td>0.269</td>
<td>0.097</td>
<td>5889.946</td>
</tr>
<tr>
<td>gS4.4 (uSv/h)</td>
<td>0.100</td>
<td>0.001</td>
<td>0.099</td>
<td>0.031</td>
<td>3862.947</td>
</tr>
<tr>
<td>gS5.5 (uSv/h)</td>
<td>0.210</td>
<td>0.001</td>
<td>0.209</td>
<td>0.096</td>
<td>5780.251</td>
</tr>
<tr>
<td>gS6.6 (uSv/h)</td>
<td>2.050</td>
<td>0.001</td>
<td>2.049</td>
<td>0.714</td>
<td>6924.782</td>
</tr>
</tbody>
</table>
Top-up Injection

Top-up mode injection has no negative effect on the data quality.
Annual scheduled and delivered machine time
Statistics of unexpected beam loss

Beam loss comparison between decay mode and top-up operation.

Total number of beam loss per month

SRF in operation

Top-up in operation

IASW installed

# of beam loss due to injection

Number of beam loss

2005

2006

1 2 3 4 5 6 7 8 9 10 11 12

0 5 10 15 20 25
Statistics of SCI Publication

![Chart showing the number of publications from 1994 to 2008 across different years. The chart is divided into years: 1994, 1996, 1998, 2000, 2002, 2004, and 2006. The chart highlights the number of publications in relation to the impact factor (I.F.) criteria: I.F. > 6, I.F. > 2, and Total. The chart indicates a significant increase in publications, particularly in the years 2000 to 2006.]

- **I.F. > 6:** Shows a steady increase from 1994 to 2006, with a notable spike in 2006.
- **I.F. > 2:** Demonstrates a gradual increase from 1994 to 2006, with a significant rise in the latter years.
- **Total:** Displays a consistent growth trend from 1994 to 2006, with the highest increase observed in the last few years.
Distribution and Growth of Users Research Area

1. Atomic and Molecular Science
2. Surface, Interface and Thin Films
3. Condensed Matter Physics
4. Materials Science
5. Chemistry
6. Nanofabrication
7. Soft Matter
8. Protein Crystallography
9. Environmental and Earth Science
10. Applied and Industrial Research
11. Methodology and Instrumentation
12. Others
The Feature of TPS

- Taiwan Photon Source
  - Beam energy: 3 ~ 3.3 GeV
  - Circumference: ~ 486 m to accommodate in current site
  - Beam current: 400 ~ 300 mA
  - Beam emittance: ~ 2 nm-rad.
  - Number of straight sections: 24
  - Top-up operation by single bunch injection
  - Adopting superconducting technology in IDs and cavities
Taiwan Photon Source (TPS)

- The estimated hardware budget and time for constructing accelerator are NTD 6.88 billions and 7 years, respectively.
- The lattice design has reached an emittance of 1.7 nm \cdot \text{rad} and a dynamical aperture of \pm 25 \text{ mm}
- Conceptual design of sub-systems has begun.
- TPS will reach $10^{21}$ photons/s/0.1\%BW/mm$^2$/mr$^2$ brilliance and become one of the brightest synchrotron X-ray sources in the world.
## Basic Parameters of DBA, QBA Lattices

<table>
<thead>
<tr>
<th></th>
<th>DBA_27E1 Non-achromat</th>
<th>DBA_27F1 Achromat</th>
<th>QBA_27Q1 Hybrid</th>
<th>QBA_27R2 Hybrid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy (GeV)</td>
<td></td>
<td></td>
<td>3.0</td>
<td></td>
</tr>
<tr>
<td>Beam current (mA)</td>
<td></td>
<td></td>
<td>400</td>
<td></td>
</tr>
<tr>
<td>Circumference (m)</td>
<td></td>
<td></td>
<td>486</td>
<td></td>
</tr>
<tr>
<td>Nat. emittance $\varepsilon (\text{nm-rad})$</td>
<td>1.7</td>
<td>5.2</td>
<td>2.7</td>
<td>2.7</td>
</tr>
<tr>
<td>Cell / symmetry / structure</td>
<td>24 / 6 / DBA</td>
<td></td>
<td>24 / 6 / QBA</td>
<td></td>
</tr>
<tr>
<td>Straights</td>
<td>10.9m<em>6+5.7m</em>18</td>
<td>10.9m<em>6+5.3m</em>18</td>
<td>10m<em>6+6m</em>12+4.8m*6</td>
<td></td>
</tr>
<tr>
<td>$\beta_x / \beta_y / \eta_x$ (m) LS middle</td>
<td>11.1 / 7.14 / 0.15</td>
<td>11.3 / 7.1 / 0.0</td>
<td>11.2 / 8.6 / 0.018</td>
<td>10.8 / 7.4 / 0.016</td>
</tr>
<tr>
<td>$\beta_x / \beta_y / \eta_x$ (m) MS middle</td>
<td>3.8 / 1.3 / 0.12</td>
<td>4.2 / 1.4 / 0.0</td>
<td>2.5 / 1.2 / 0.1</td>
<td>2.7 / 1.5 / 0.1</td>
</tr>
<tr>
<td>$\beta_x / \beta_y / \eta_x$ (m) SS middle</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>4.1 / 1.4 / 0.01</td>
</tr>
<tr>
<td>Betatron tune $\nu_x/\nu_y$</td>
<td>26.22 / 12.30</td>
<td>26.22 / 12.30</td>
<td>26.28 / 12.25</td>
<td>26.28 / 12.25</td>
</tr>
<tr>
<td>Mom. comp. ($\alpha_1$, $\alpha_2$)</td>
<td>$2.4\times10^{-4}$, $2.4\times10^{-3}$</td>
<td>$3.1\times10^{-4}$, $2.0\times10^{-3}$</td>
<td>$2.6\times10^{-4}$, $2.2\times10^{-3}$</td>
<td>$2.6\times10^{-4}$, $2.1\times10^{-3}$</td>
</tr>
<tr>
<td>Nat. energy spread $\sigma_E$</td>
<td>$8.86\times10^{-4}$</td>
<td></td>
<td>$8.31\times10^{-4}$</td>
<td></td>
</tr>
<tr>
<td>Damping time (ms) ( $\tau_x / \tau_y / \tau_s$)</td>
<td>11.4 / 11.4 / 5.7</td>
<td></td>
<td>13.0 / 13.0 / 6.5</td>
<td></td>
</tr>
<tr>
<td>Dipole B/L (Tesla)/(m)</td>
<td>1.1908 / 1.1</td>
<td></td>
<td>1.0479 / 1.0 and 1.5</td>
<td></td>
</tr>
<tr>
<td>Critical energy dipole (keV)</td>
<td>7.12</td>
<td></td>
<td>6.26</td>
<td></td>
</tr>
<tr>
<td>Nat. chromaticity $\xi_x / \xi_y$</td>
<td>-68 / -30</td>
<td>-73 / -29</td>
<td>-63 / -31</td>
<td>-62 / -29</td>
</tr>
</tbody>
</table>
## Effective Emittance of ID Effects (3GeV)

<table>
<thead>
<tr>
<th># of SW6</th>
<th>Configuration</th>
<th>U0 (MeV)</th>
<th>sigE/E</th>
<th>Natural emittance (nm-rad)</th>
<th>2D effective emittance (nm-rad)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Long Straight</td>
</tr>
<tr>
<td>24P27E</td>
<td>bare x 000 x 000 x 000 x 000 x 000</td>
<td>0.85269</td>
<td>8.8598E-04</td>
<td>1.6748</td>
<td>2.1731</td>
</tr>
<tr>
<td></td>
<td>1 x fef C fef H adf H bdf H bff H gff</td>
<td>1.4383</td>
<td>9.1251E-04</td>
<td>2.1518</td>
<td>2.6914</td>
</tr>
<tr>
<td>24P27F</td>
<td>bare x 000 x 000 x 000 x 000 x 000</td>
<td>0.85269</td>
<td>8.8584E-04</td>
<td>5.2681</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1 x fef C fef H adf H bdf H bff H gff</td>
<td>1.4383</td>
<td>9.1243E-04</td>
<td>3.1306</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3 x fef C fef H adf H bdf B cff G cff</td>
<td>1.6388</td>
<td>1.0107E-03</td>
<td>2.7497</td>
<td></td>
</tr>
<tr>
<td>24P27Q</td>
<td>bare x 000 x 000 x 000 x 000 x 000</td>
<td>0.75037</td>
<td>8.3115E-04</td>
<td>2.6973</td>
<td>2.7068</td>
</tr>
<tr>
<td></td>
<td>1 x fcf A fhf B fhf B fhf D fhf D ege</td>
<td>1.3360</td>
<td>8.8512E-04</td>
<td>2.1097</td>
<td>2.1204</td>
</tr>
<tr>
<td></td>
<td>3 x fcf A fcf B fcf B fhf D fhf D ege</td>
<td>1.5365</td>
<td>9.9574E-04</td>
<td>1.8638</td>
<td>1.8774</td>
</tr>
<tr>
<td>24P27R</td>
<td>bare x 000 x 000 x 000 x 000 x 000</td>
<td>0.75037</td>
<td>8.3115E-04</td>
<td>2.7275</td>
<td>2.7361</td>
</tr>
<tr>
<td></td>
<td>1 x fkf A fqf B fqf B fqf D fqf D epe</td>
<td>1.3360</td>
<td>8.8512E-04</td>
<td>2.1243</td>
<td>2.1340</td>
</tr>
<tr>
<td></td>
<td>3 x fkf A fkf B fkf B fqf D fqf D epe</td>
<td>1.5365</td>
<td>9.9573E-04</td>
<td>1.8682</td>
<td>1.8805</td>
</tr>
</tbody>
</table>
Linear Optics Functions of DBA Lattices

OPTICAL FUNCTIONS

C = 486 m
Emittance = 1.7 nm-rad
DBA-24P27E1

C = 486 m
Emittance = 5.2 nm-rad
DBA-24P27F1
Linear Optics Functions of QBA Lattices
Nonlinear Tracking-Frequency Map Analysis

FMA (DBA_24P27E1)

FMA (DBA_24P27F1)
Nonlinear Tracking-Frequency Map Analysis

FMA QBA_24P27Q1

FMA QBA_24P27R2
Brilliance of 486 m (486m-24P27E1)

3 GeV (486m-24P27E1), 400mA
Injection scheme

In a long straight K-t-K: 9.2m

Another option: Thick and Thin septa scheme

TPS septum and kicker parameters

<table>
<thead>
<tr>
<th></th>
<th>septum</th>
<th>kicker</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length (m)</td>
<td>1.8</td>
<td>0.80</td>
</tr>
<tr>
<td>Field (T)</td>
<td>0.97</td>
<td>0.0898</td>
</tr>
<tr>
<td>Bend Angle (mrad)</td>
<td>174.5</td>
<td>7.18</td>
</tr>
</tbody>
</table>
# Budget and schedule of proposed TPS

Funding source of the TPS construction (total 6.88 BNT or ~ 200 MUS):

<table>
<thead>
<tr>
<th>Year</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
</tr>
</thead>
<tbody>
<tr>
<td>NSC funding</td>
<td>0.1</td>
<td>0.35</td>
<td>0.7</td>
<td>0.7</td>
<td>0.7</td>
<td>1.05</td>
<td>1.08</td>
<td>0.45</td>
</tr>
<tr>
<td>EPC funding</td>
<td>-</td>
<td>0.5</td>
<td>0.6</td>
<td>0.5</td>
<td>0.15</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>

- (5.13 BNT)
- (1.75 BNT)
Cryogenics platform
SRF cavity 2x2
Power rack (RF)
Transmitter
Trenches for Piping and cables
RF Straight Section and Liquid Helium Supply System
Cryogenics platform
Prospects

- To become one of the world's brightest synchrotron X-ray sources
- To develop cutting-edge experimental facility and new areas of scientific research
- To help high-tech industry conduct product R&D and process optimization
- To attract more international scientists to perform experiments or build dedicated beamlines at NSRRC
- To recruit worldwide outstanding scientists to establish long-term leading-edge research in Taiwan
- To attract young generation to advanced scientific research and plant the seeds great future scientific discoveries
Summary

- 7 insertion devices installed in a 6-fold symmetric TLS
- 300 mA top-up injection mode operated with SCRF cavity and three SCIDs successfully at TLS
- DBA- and QBA-type lattices are studied for the proposed 3 GeV storage ring with its circumference 486 m.
- Nonlinear beam dynamics are studied. Both QBA and DBA deliver promising working lattices
- ID effects on the emittance are compared.
- Further studies on the nonlinear effects and error analysis are in progress.
Thank you for your attention
Flux of 486 m (486m-24P27E1)

3 GeV (486m-24P27E1), 400mA

Flux (Photons/s/0.1%bw) vs. Photon Energy (eV)
The Planning of TLS

- Taiwan Light Source
  - Increasing the top-up of store beam current to 360 mA
  - Installation of two more In-Archromat Sc. Wigglers
  - Implement fast orbit feedback system in vertical plan
  - Putting the second set cryogenic system into operation
  - Testing hybrid filling pattern
  - Research on low-emittance and high peak current electron gun
  - Strengthen the communication with users -Weekly Users and Operation Meeting
    [http://srrcidd01.nsrrc.org.tw/iddA/operation.htm](http://srrcidd01.nsrrc.org.tw/iddA/operation.htm)
  - Web site of Operation Group