The 10th Continuous Wave and High Average Power RF Workshop

Status of Taiwan Light Source (TLS) and Progress of Taiwan Photon Source (TPS)

Kuo-Tung Hsu

On behalf of the Accelerator Team
June 26, 2018
Outlines

- TLS and TPS are in operation simultaneously since 2016.

- Taiwan Light Source (TLS)
  - Operational Status

- Taiwan Photon Source (TPS)
  - Machine parameters and strategy of TPS development
  - Operational statistics
  - Reliability and stability improvement
  - TPS development in progress

- Summary
Why We Gather Here?

- You power the accelerator world! Thank you!
- All accelerator facility need powerful, reliability RF system.

Together Everyone Achieves More!

A Great Dream Requires A Great Team!
**Activity Center**

**Utility**

**- III & Guest Hose II**

**Administration Building**

**TLS Storage Ring**
- 25 beamlines

**TPS Storage Ring**
- 7 beamlines in operation
- 3 beamlines available in late 2018
- 7 new beamlines in construction ~ 2020
- 9 beamlines in planning ~ 2023

**Guest House I**

**1.1 MWp Solar Panel**

**Machine Shop**

**Utility-I & II**

**Utility-III & Guest Hose II**

**Office & Labs**

**Bird’d-eye View of the NSRRC Campus**

*CWRF 2018, June 25 - 29, 2018, Hsinchu, Taiwan*
Routine Operation of TLS and TPS

<table>
<thead>
<tr>
<th>User Beam Time</th>
<th>Taiwan Photon Source</th>
<th>Taiwan Light Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy</td>
<td>3.00 GeV</td>
<td>W200 g</td>
</tr>
<tr>
<td>Current</td>
<td>400.64 mA</td>
<td>U50 g</td>
</tr>
<tr>
<td>Lifetime</td>
<td>9 hr 5 min</td>
<td>U90 g</td>
</tr>
<tr>
<td>Size X</td>
<td>63 μm</td>
<td>EPU56 g</td>
</tr>
<tr>
<td>Size Y</td>
<td>40 μm</td>
<td>EPU56 p</td>
</tr>
<tr>
<td>User Beam Time</td>
<td>7.28 mm</td>
<td>SW60</td>
</tr>
<tr>
<td>Energy</td>
<td>1.50 GeV</td>
<td>SWLS</td>
</tr>
<tr>
<td>Current</td>
<td>361.79 mA</td>
<td>IASW-R2</td>
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<tr>
<td>Lifetime</td>
<td>6 hr 54 min</td>
<td>IASW-R4</td>
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<tr>
<td>Size X</td>
<td>7.00 mm</td>
<td>IASW-R6</td>
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<tr>
<td>Size Y</td>
<td>7.00 mm</td>
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<tr>
<td>ΔIo/Io</td>
<td>0.048 %</td>
<td></td>
</tr>
<tr>
<td>User Beam Time</td>
<td>7.00 mm</td>
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<tr>
<td>Energy</td>
<td>65.00 mm</td>
<td></td>
</tr>
<tr>
<td>Current</td>
<td>0.00 mm</td>
<td></td>
</tr>
<tr>
<td>Lifetime</td>
<td>40.00 mm</td>
<td></td>
</tr>
<tr>
<td>Size X</td>
<td>0.00 mm</td>
<td></td>
</tr>
<tr>
<td>Size Y</td>
<td>27.30 mm</td>
<td></td>
</tr>
<tr>
<td>ΔIo/Io</td>
<td>25.52 mm</td>
<td></td>
</tr>
<tr>
<td>Energy</td>
<td>0.00 mm</td>
<td></td>
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<tr>
<td>Current</td>
<td>45A (EPU46) g</td>
<td></td>
</tr>
<tr>
<td>Lifetime</td>
<td>45A (EPU46) p</td>
<td></td>
</tr>
<tr>
<td>Size X</td>
<td>25.52 mm</td>
<td></td>
</tr>
<tr>
<td>Size Y</td>
<td>0.00 mm</td>
<td></td>
</tr>
<tr>
<td>ΔIo/Io</td>
<td>0.048 %</td>
<td></td>
</tr>
</tbody>
</table>

TPS Beam Current

TLS Beam Current

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## Operation Schedule

**Weekly (before 2018) => Biweekly (2018)**

| Mar. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 |
|------|---|---|---|---|---|---|---|---|---|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 1-9  | T | S | S | S | S | S | S | S | U | U | U | U | U | U | U | U | U | U | U | U | U | U | U | U | U | U | U |
| 9-17 | S | S | U | U | U | U | U | U | U | U | U | U | U | U | U | U | U | U | U | U | U | U | U | U | U | U | U |
| 17-01| S | S | S | S | U | U | U | U | U | U | U | U | U | U | U | U | U | U | U | U | U | U | U | U | U | U | U |

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

| May  | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 |
|------|---|---|---|---|---|---|---|---|---|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 1-9  | U | U | U | U | U | U | U | U | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S |
| 9-17 | U | U | U | U | U | U | U | U | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S |
| 17-01| U | U | U | U | U | U | U | U | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S |

**Note:**
- **U**: User shift (36 weeks, 5184 hrs)
- **M**: Machine maintenance
- **S**: Machine study

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CWRF 2018, June 25 - 29, 2018  Hsinchu, Taiwan
Bi-weekly Operation Schedule

- 6 shifts reserved for machine study and accelerator system maintenance:
  - 5 shifts for accelerator test.
    - Machine study.
    - RF conditioning.
  - 1 shift for accelerator system maintenance.
    - Visual inspection.
    - Necessary maintenance.

Pros:
- More efficient in operation (half of the machine preparation time).
- Maintenance load of accelerator team reduced.
- Offsetting machine maintenance of TLS and TPS by one week.
- No sensible increase rate of the machine problem.

Cons:
- If non-critical problems happened, it requires one-week waiting for the action.
- If crane is needed for new beamline construction, it is essential to synchronize with user beam time.
- Increase loading of beamline supports.

(8 hours/shift)
Status of the TLS
TLS Accelerator Layout and Key Milestones

- The 1st 3rd generation LS in Asia (1993)
- The 2nd LS using the SRF cavity (2005)
- The 3rd LS running full time with top-up injection (2005)
- The most densely-packed SR with the highest number of superconducting IDs!

- Commissioned in Apr. & opened to users in Oct. 1993
- 1.3 to 1.5 GeV ramping in operation in 1996
- Operational beam current at 240 mA in 1996
- Booster in full energy injection in 2000
- SC-wavelength shifter in operation in 2002
- Cryogenic system & SW60 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 in top-up mode & 3rd IASW installed in 2010
TLS Beamlines

Taiwan Light Source

1.5 GeV, 300 mA, Top-up Superconducting RF

IR, VUV: 5
Soft X-ray: 7
X-ray: 13

Taiwan BL @ SP8: 2

24A WR-SGM
23A SAXS
CGM (ARPES)
21A White Light
20A H-SGM
19A EUV
17C EXAFS
17B Scattering
17A Powder XRD
16A Tender X-ray
15A Biopharmaceuticals PX
14A IR Microscopy

White X-ray 01A
TX Microscopy 01B
EXAFS/Powder XRD 01C
High Flux CGM 03A
SRCD 04B
Scattering; PEEM 05B
Scattering 07A
L-SGM 08A
Soft X-ray AGM 08B
SPEM 09A
Dragon 11A
X-ray Scattering 13A; PX 13B, 13C
2016: Delivered: 5,526 hrs; Availability: 98.2%; MTBF: 100.5 hrs

2017: Scheduled user time ~ 4,680 hrs (36 weeks); Delivered user time 4,669 hrs (Jan. ~ Dec.);
Availability: 98.5%; MTBF: 259.4 hrs

2018: Scheduled user time ~ 5,184 hrs; Delivered user time 2,032 hrs (Jan. ~ May)
TLS Operational Status

- Near 25 years user service since late 1993.
- Deliver high availability and high beam stability for users.
- Maintain a smooth operation for user service.
- Upgrade subsystems gradually which are difficult to maintain or least reliable.
Status of the TPS
Major Parameters of Taiwan Photon Source

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy (GeV)</td>
<td>3.0 (maximum 3.3 GeV)</td>
</tr>
<tr>
<td>Beam current (mA)</td>
<td>500 mA at 3 GeV (Top-up injection)</td>
</tr>
<tr>
<td>SR circumference (m)</td>
<td>518.4 m (h = 864 = 2^5\cdot3^3, dia. = 165.0 m)</td>
</tr>
<tr>
<td>BR circumference (m)</td>
<td>496.8 m (h = 828 = 2^2\cdot3^2\cdot23, dia. = 158.1 m)</td>
</tr>
<tr>
<td>Lattice</td>
<td>24-cell DBA</td>
</tr>
<tr>
<td>Straight sections (m)</td>
<td>12 m x 6 (σ_v = 12 μm, σ_h = 160 μm)</td>
</tr>
<tr>
<td></td>
<td>7 m x 18 (σ_v = 5 μm, σ_h = 120 μm)</td>
</tr>
<tr>
<td>Storage Ring Circumference (m)</td>
<td>518.4</td>
</tr>
<tr>
<td>Energy (GeV)</td>
<td>3.0</td>
</tr>
<tr>
<td>Beam current (mA)</td>
<td>500</td>
</tr>
<tr>
<td>Natural emittance (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</td>
<td>864</td>
</tr>
<tr>
<td>RF voltage (MV)</td>
<td>3.5</td>
</tr>
<tr>
<td>Energy loss per turn (dipole) (keV)</td>
<td>852.7</td>
</tr>
<tr>
<td>Betatron tune</td>
<td>26.18 / 13.28</td>
</tr>
<tr>
<td>Momentum compaction (α_1, α_2)</td>
<td>2.4\times10^{-4}, 2.1\times10^{-3}</td>
</tr>
<tr>
<td>Natural energy spread</td>
<td>8.86\times10^{-4}</td>
</tr>
<tr>
<td>Damping time (ms)</td>
<td>12.20 / 12.17 / 6.08</td>
</tr>
<tr>
<td>Natural chromaticity</td>
<td>-75 / -26</td>
</tr>
<tr>
<td>Synchrotron tune</td>
<td>0.00609</td>
</tr>
<tr>
<td>Bunch length (mm)</td>
<td>2.86</td>
</tr>
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Storage Ring

Booster Ring

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First light delivered to the experimental station (port 5A) on Nov. 19, 2015

Install 2 SRF cavity and 10 IDs

Available for users

1\textsuperscript{st} SR from the TPS (3 GeV, 1 mA)

Phase I Commissioning up to 100 mA (with two 5-cell PETRA Cavity)

Phase II Commissioning (with two SRF Cavity)

300 mA Top-up

Vacuum Improvement

400 mA Top-up

400 mA Long-term Test Run

SRF #3 Project

TPS Milestone

Design

Construction

2007

2010

Q4 2014 - Q1 2015

Q3/Q4 2015

Q4 2015

Mar. 2016

May 2016

Q3 2016

Feb. 2017

Nov. 2017

2018

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Hsinchu, Taiwan

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Strategies for TPS Accelerator System Development

• **Short-term: Improvements**
  - Increase stored beam current: 300 mA (May 2016) => 400 mA (late 2017) for routine operation, further test for 500 mA in future.
  - Improve reliability:
    Software bug elimination, improvement of the latest reliable subsystem, post-mortem diagnostics, minimized trip rate.
  - Improve stability: Noise source identification, reduce, remove and active feedbacks, Injection transient minimization.
  - Improve compatibility of storage ring and beamlines/end-stations.
    Orbit reproducibility, stability, long-term drift, … etc.
  - Explore methods for energy saving without the sacrifice of accelerator operation performance.

• **Mid-term: SRF #3, Phase-II and Phase-III beamlines projects**
  - Various subsystem enhancement and development:
    Solid-state pulser, digital LLRF, solid-state RF power amplifier, novel IDs R&D, …
  - 3rd SRF system to support Phase-III ID project.
  - Phase-II and Phase-III ID construction.
  - Explore feasibility for short bunch mode.
  - Investigation methods of how to reduce emittance to less than 1000 pm-rad.
TPS Operation Statistics

1,595 hrs
1,615 hrs

Delivered
beam time

Beamline Commissioning & Pilot Experiments

User Service

2017: Scheduled user shift ~ 4,111 hrs (33 weeks); Delivered user time 4,046 hrs (Jan. ~ Dec.)
2018: Scheduled user time ~ 4,488 hrs; Delivered user time 1772 hrs (Jan. ~ May)

2016
2017
2018

1,615 hrs
1,595 hrs
4,046 hrs
1,772 hrs

Availability (%)

Month

Year

Scheduled user time (hour)
Delivered user time (hour)
Availability (%)
Reliability and Stability

- More than 98.5% availability were achieved.

- Short-term stability satisfy requirements of most of users. Continuous effects are on-going.

- Long-term drift can be controlled within acceptable range without unintentional beam trip happened.

- Orbit reproducibility of each refill less than 5 μm/μrad at ID center.
  * Further investigation/improvement is required.
  => Operation procedures and/or hardware improvement.
  * Improve machine reliability are highly helpful to minimize the impact.

- Injection transient cannot be accepted by strict beamline requirements. Real-time gating in data acquisition during injection or post processing to remove deteriorate data is the current reality.
An Example: 60 Hz Orbit Motion Study

Feedforward and feedback to correct 60 Hz beam motion (Vertical)

An Example: Source locating for 60 Hz beam motion

SRF2 Transmitter On, SRF3 On

Compound effects of fans to cool bellows & BPMs at up/down-stream of ID straight and two RF transmitters
Long-term Stability of Position and Angle at ID Center

41A EPU48 center y
41A EPU48 center y’
41A EPU48 center x
41A EPU48 center x’

1 μm
1 μrad

~ 6 Days

21A IUT22 center x
21A IUT22 center x’
21A IUT22 center y
21A IUT22 center y’

1 μm
1 μrad

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Short-term Stability of Position and Angle at ID Center

41A EPU48 center y
41A EPU48 center y’
41A EPU48 center x
41A EPU48 center x’

Reproducibility of Position and Angle at ID Center in each Refill

21A IUT22 center x
21A IUT22 center x’
21A IUT22 center y
21A IUT22 center y’

Reproducibility < 5 μm < 5 μrad

~ 2 Hours

~ 1 Hour to reach thermal equilibrium
Mitigate Effects of the Injection Transient

- Improve kickers matching.
- Improve magnetic shielding.
- Grounding and isolation.

Centroid motion of the electron bunches observed by beam position monitor

Photon flux observation by QBPM #2 (after DCM) of TPS 05A

Photon flux reduced

Integrated photon flux reduction improve about 25 times

850 μsec

2016/03/22

2016/03/22

Integrated photon flux reduction improve about 25 times
TPS Development in Progress
Goals:

- Deliver sufficient power for Phase-III beamlines running at 500 mA.
- Provide option to reduce power level of each RF station to increase reliability.
- Provide sufficient beam current (~ 300 mA) when one system in trouble.

Features:

- Same KEKB type SRF cavity as previous two SRF stations.
  - System integration at NSSRC labs.
  - Good training chance to enhance maintenance capability.
- DLLRF to enhance performance and functionality.
  - Loop optimization is simple.
  - Rich diagnostics functionality.
  - Lower noise.
- In-house manufactured supporting system as much as possible (include DLLRF) to enhance capability and to avoid obsolesce of components.
  - Up-to-date design.
  - Spare units.

Friday Talks:
(08:30 ~ 10:00) Chaoen Wang
(09:30 ~ 10:00) Zong-Kai Liu
Digital Low Level RF (DLLRF) and Solid-State Amplifier (SSA) Development

DLLRF Test at TPS Booster Synchrotron

20 kW SSA prototype

- 80 kW prototype will be available in early of 2019.
- 300 kW SSA in evaluation.

80 kW prototype will be available in early of 2019.
300 kW SSA in evaluation.
07A IU22: Installation is in progress (June 2018).

13A IU24: Due to ball screws and linear guides are in short supply, delivery will be postponed for 3 months (Due 2019/3/25). Installation will be scheduled during 2019～2020.


19A CU15: In final integration and measurement phase at NSRRC lab.
- 77K Cryo-cooler vibration reduction.
- Field measurement at operation temperature.
- Installation will be scheduled in 2019.

27A EPU66: Magnetic block and mechanical frame in procurement process.

31A MPW-W100: Magnetic and mechanical design in progress.

39A EPU168: Mechanical design in progress.
CU/CUT in Vacuum and in-situ fielding mapping Setup

Features

- In-situ field mapping.
- Support small gap (3 mm) measurement.
- Dynamic monitor and correction for position of the Hall probe.
- Support on-the-fly measurement.

Reproducibility of the measurement system

<table>
<thead>
<tr>
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<th>Phase error (degree)</th>
<th>Half integral deviation (%)</th>
<th>Peak field deviation(%)</th>
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<tbody>
<tr>
<td>STD</td>
<td>&lt;0.2</td>
<td>&lt;0.1</td>
<td>&lt;0.02</td>
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</table>

Laser System

Multi-axes Rotating Stage

Position Sensitive Detector

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CU15 (19A)
In final integration phase

W100 (31A)
Magnetic and mechanical design in progress

**W100 parameters**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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<td>Peak field strength</td>
<td>1.81T</td>
</tr>
<tr>
<td>Period length</td>
<td>100 mm</td>
</tr>
<tr>
<td>Number of periods (main pole)</td>
<td>4</td>
</tr>
<tr>
<td>Magnet length array length</td>
<td>&lt; 600 mm</td>
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<tr>
<td>Pole gap</td>
<td>14 mm</td>
</tr>
<tr>
<td>Deflection parameter, k</td>
<td>16.91</td>
</tr>
<tr>
<td>Critical Energy</td>
<td>10.8 keV</td>
</tr>
<tr>
<td>Photon energy</td>
<td>5-50 keV</td>
</tr>
<tr>
<td>Total radiation power</td>
<td>3.7 kW</td>
</tr>
<tr>
<td>Power density</td>
<td>3.11 kW/mrad²</td>
</tr>
</tbody>
</table>

**Brilliance [Ph/s/mm²/mrad² in 0.1% b.w.]**

- TPS IU22-3m-Gap 7mm
- TPS CU15-2m-Gap 5.0mm
- MAX IV IU17.6-2m-Gap 4.0mm
- NSLS II IU22-3m-Gap 6.8mm

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### Taper Undulator CUT15 (15A)

<table>
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<th>Schedule</th>
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<tbody>
<tr>
<td>Design</td>
<td>3 months</td>
</tr>
<tr>
<td>Mechanical frame + magnet manufacturing</td>
<td>12 months</td>
</tr>
<tr>
<td>Manufacturing of the cryogenic system, vacuum system and temperature control system</td>
<td>-- (include. Above)</td>
</tr>
<tr>
<td>Acceptance Test (include field measurement)</td>
<td>3 months</td>
</tr>
<tr>
<td>Assembly work</td>
<td>3 months</td>
</tr>
<tr>
<td>Cooling test and vacuum test</td>
<td>1 month</td>
</tr>
<tr>
<td>Field measurement and final tuning</td>
<td>2 months</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>~ 24 months</td>
</tr>
</tbody>
</table>

### EPU66 (27A)

**Parts procurement in progress**

<table>
<thead>
<tr>
<th>EPU66 parameters</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Type</td>
<td>APPLE-II</td>
</tr>
<tr>
<td>Period length</td>
<td>66 mm</td>
</tr>
<tr>
<td>Number of period</td>
<td>62</td>
</tr>
<tr>
<td>Minimum gap</td>
<td>16.8 mm</td>
</tr>
<tr>
<td>Max $K_y$, Min E1 at H.L.</td>
<td>5.3, 84 eV</td>
</tr>
<tr>
<td>Max $K_y = K_x$, Min E1 at C.P.</td>
<td>3.2, 117 eV</td>
</tr>
<tr>
<td>Max $K_y$, Min E1 at V.L.</td>
<td>3.9, 149 eV</td>
</tr>
</tbody>
</table>

### EPU168 (39A)

**Magnetic and mechanical design in progress**

<table>
<thead>
<tr>
<th>EPU168 parameters</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Type</td>
<td>APPLE-II</td>
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<tr>
<td>Period length</td>
<td>168 mm</td>
</tr>
<tr>
<td>Number of period</td>
<td>23</td>
</tr>
<tr>
<td>Minimum gap</td>
<td>28 mm</td>
</tr>
<tr>
<td>Max $K_y$, Min E1 at H.L.</td>
<td>8.1, 15 eV</td>
</tr>
<tr>
<td>Max $K_y = K_x$, Min E1 at C.P.</td>
<td>3.5, 39 eV</td>
</tr>
<tr>
<td>Max $K_y$, Min E1 at V.L.</td>
<td>3.5, 72 eV</td>
</tr>
</tbody>
</table>

### Finalized specifications

- **CUT15 with taper 0.7mm g6.0mm g4.5mm**
- **IUT22 with taper 2mm g5.5mm**

![Graph showing Flux Density vs. Photon Energy for CUT15 and IUT22](image)

CWRF 2018, June 25 - 29, 2018  Hsinchu, Taiwan
Update of the vacuum chamber:

- Storage ring SR14 and SR20 vacuum chamber modification to support (EPU66, EPU168).

- TPS-EPU66/EPU168 vacuum chamber design and construction.

Front-end construction:

- 19A (CU15) high-resolution powder X-ray diffraction.

- 31A (W100) projection X-ray microscopy.

- 07A (IU22) micro-focus protein crystallography.

- 27A (EPU66) soft X-ray nanoscopy.
Multi-shot of longitudinal beam motion. The synchrotron oscillation due to the energy variation was observed.

The accumulated longitudinal beam profile and Gaussian fit of the center bunch during ramping.

Measured and model fitted bunch profiles at varied bunch current below the threshold of microwave instability for the case with RF voltage 2.8 MV and IU gaps open.

Measured and model fitted bunch length as a function of bunch current at the TPS storage ring below the threshold of microwave instability.
Accelerator Related R&D - Cont.

Low-alpha mode R&D

- Short X-ray pulse (a few picosecond)
- Coherent THz/IR radiation

Bunch length measurements in high emittance, low alpha lattices, where the linear momentum compaction factor is $\alpha_1 = -6.16 \times 10^{-6}$ (red and green) and $-6 \times 10^{-7}$ (blue).

Other efforts

- Lattice optimization
- IDs alignment
- ID commissioning and optimization
- Compatibility between accelerator and beamlines
- Beam-based modeling
- Operation automation
- Fault diagnostics
- Beam lifetime/losses study
- Feasibility study to increase FOFB bandwidth
- Thermal effect study
- Tidal effect study
- MBA lattice study
- …
- … etc.
Efforts for TPS

Continuous Efforts:

- Improve machine reliability.
- Improve stability.
  - Beam noise suppression.
  - Reduce orbit drift.
  - Improve orbit reproducibility of each-refill.
  - Increase FOFB bandwidth to ~1000 Hz range (now is 300 Hz).
- Continuous ID commissioning and lattice optimization.
- Advanced beam physics study
- Develop various beam-based optimization algorithm
- Develop tool to assist machine operation and problem diagnostic by latest technologies.
Key Missions in Progress

- Development of the 3\textsuperscript{rd} SRF system.
  - Third SRF module
  - Solid-state high power RF transmitter.
  - Digital Low Level RF (DLLRF) control system
- Phase-II IDs: IU22 (07A), IU24 (13A), EPU168 (39A), EPU66 (27A), CU (19A), CUT (15A), W100 (31A).
- Phase III insertion devices: Fast Polarizing Switching EPU (35A), U175 (37A), …etc.

Machine Development and Feasibility Study

- Minimized injection transient study.
- Novel insertion devices development.
- Low $\alpha$ mode in storage ring.
- Study feasibility to adopt Robinson wigglers to reduce beam emittance.
- Use harmonic cavity to increase bunch length and lifetime.
- Investigate possibility to upgrade TPS to delivery diffraction limited hard X-ray with new lattice in 2030s.
Summary

Taiwan Light Source

➢ Smooth operation for user service.

➢ Upgrade subsystems which are difficult to maintain or least reliable gradually.

Taiwan Photon Source

➢ Smooth operation of TPS for last two years.

➢ Reliability and stability improved significantly since its start operation. Both are the common goals to improve for short- and long-term efforts.

➢ 300 mA top-up operation since late May, 2016. 400 mA stored beam operation since November 2017.

➢ Improve compatibility of the storage ring and beamlines are current focus.

➢ The 3rd SRF system project and Phase-II and III beamlines are the highest priority short-term goals.

➢ Various machine development plans are in progress.
Thank you for your attention!