With an accelerator and beamlines par excellence, the TPS will blaze a trail to science frontiers.
The Taiwan Photon Source (TPS) is one of the world’s brightest synchrotron X-ray sources geared toward world-class academic research. This accelerator consists of a low-emittance synchrotron storage ring of 518.4 meters in circumference and a booster ring that are designed in a concentric fashion and housed in a donut-shaped building.

The phase-I beamlines will be available to users in 2016 and will serve scientists worldwide. The TPS is designed to emphasize electron beams of a low emittance and a great brilliance. The TPS storage ring comprises 24 double-bend achromat (DBA) cells, with six straight sections of 12 meters and eighteen straight sections of 7 meters in length. The TPS uses two sets of KEKB type superconducting RF cavities to achieve an electron current of 500 mA in a top-up injection mode and to diminish the high-order-mode instability excited by the electron beam.

### TPS parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy [GeV]</td>
<td>3.0</td>
</tr>
<tr>
<td>Current [mA]</td>
<td>500</td>
</tr>
<tr>
<td>Circumference [m]</td>
<td>518.4</td>
</tr>
<tr>
<td>Natural horizontal emittance [nm • rad]</td>
<td>1.6</td>
</tr>
<tr>
<td>Critical energy of bending magnets [keV]</td>
<td>7.13</td>
</tr>
<tr>
<td>Cell units</td>
<td>24 DBA</td>
</tr>
<tr>
<td>Superperiods</td>
<td>6</td>
</tr>
<tr>
<td>Radiofrequency [MHz]</td>
<td>499.654</td>
</tr>
<tr>
<td>Straight sections</td>
<td>12 m x 6, 7 m x 18</td>
</tr>
</tbody>
</table>
The first synchrotron light from the TPS storage ring at the 3 GeV design energy delivered on December 31, 2014. The TPS created a world record for the fastest commissioning of an advanced accelerator light source. This very fact attests to the high caliber of the design of the accelerator system, and the high standards of the qualities of the subsystems, the alignments of all the components, the integrated diagnostics and control systems, and the various types of magnets.
**THE TPS IS ONE OF THE BRIGHTEST SYNCHROTRON X-RAY SOURCES IN THE WORLD**

Improvements in brilliances of the TPS over those of the TLS are dramatic, to the tune of 3 to 4 orders of magnitude.

- TPS bending BLs @ 10 keV: 10^2 times brighter
- TPS ID BLs @ 1 keV: 10^3 times brighter
- @ 10 keV: 10^4 times brighter

The TPS provides opportunities for scientists in a wide range of researches to reveal structures, electron interactions, functions of matters, and their dynamics, using various spectroscopies, imaging methods, and scattering techniques.
The TPS phase-I beamlines, equipped with advanced X-ray technologies, aim to explore the frontiers of basic and applied sciences.

**PHASE-I BEAMLINE SUMMARY**

<table>
<thead>
<tr>
<th>Insertion devices</th>
<th>Energy range</th>
<th>Experimental techniques</th>
</tr>
</thead>
<tbody>
<tr>
<td>IU22 X 1</td>
<td>5.7–20 keV</td>
<td>Imaging (CDI)</td>
</tr>
<tr>
<td>IU22 X 2</td>
<td>5.6–25 keV</td>
<td>Scattering</td>
</tr>
<tr>
<td>IU22 X 1</td>
<td>7–25 keV</td>
<td>Structural diffraction</td>
</tr>
<tr>
<td>IU22 X 2</td>
<td>4-15 keV</td>
<td>Scattering</td>
</tr>
<tr>
<td>IU22 X 1</td>
<td>5.5–20 keV</td>
<td>XAS</td>
</tr>
<tr>
<td>EPU48 X 2</td>
<td>400–1200 eV</td>
<td>XEOL</td>
</tr>
<tr>
<td>EPU46 X 1</td>
<td>280–1500 eV</td>
<td>RIXS</td>
</tr>
<tr>
<td>EPU46 X 1</td>
<td>280–1500 eV</td>
<td>PES</td>
</tr>
</tbody>
</table>

**CDI**: coherent diffraction imaging  
**XEOL**: X-ray excited optical luminescence  
**RIXS**: resonant inelastic X-ray scattering  
**PES**: photoemission spectroscopy
With a high brilliance of the light source and microfocusing optics, 05A is tailored to protein microcrystallography to reveal 3D molecular structures of complex biological macromolecules previously beyond reach.

**UNIQUE FEATURES**
- Energy range: 5.7 – 20 keV
- Photon flux: > $6 \times 10^{13}$ s$^{-1}$ at 12.4 keV
- Small beam sizes
- Low beam divergences
- Wide and accurate energy tunability
- High position stability
- Beamline automation

**HIGH THROUGHPUT AND REMOTE TECHNIQUES**
- Automated crystal mounting, centering and screening
- Automated energy selection and data collection
- Enable collaborations among worldwide researchers

**PROTEIN MICROCRYSTALLOGRAPHY ENDSTATION**
- Integrated beam shaping 5 to 50 µm beam, user selectable
- Changeable beam divergence 0.1 to 0.5 mrad divergence, user selectable
- On-axis sample video parallax error-free and real time imaging
- High precision PHI axis < 1 µm SOC, suitable for microdiffraction
- Maximum PHI rotation speed up to 130 deg/s suitable for inverse-beam experiments

**SCIENTIFIC OPPORTUNITIES**
- Membrane proteins
- Viruses and large macromolecular assemblies
- Multi-protein and tertiary complexes

**PROTEIN MICROCRYSTALLOGRAPHY ENDSTATION**
- Grid scan to find the best diffracting area
- High-speed and large-size area detector suitable for shutterless and fine-slicing exp.
- Helical data collection to reduce the radiation damage
- Automatic sample changer to enable high throughput crystal screening
- Remote access capability

**3D BIOSTRUCTURES**
Solutions to your problems of Life Sciences
09A Temporally Coherent X-ray Diffraction

09A consists of two experimental endstations: a 9-circle diffractometer equipped with a polarization analyzer and a 2D hybrid array detector for studies of temporal-coherence and subnanosecond-to-submicrosecond dynamics, and a 3-circle high-resolution powder diffractometer to study molecular structures.

**UNIQUE FEATURES**

- **Beam sizes:**
  - $600 \times 700 \ \mu\text{m}^2$
  - $70 \times 3 \ \mu\text{m}^2$ with a compound refractive lens
- **Low beam divergences:**
  - $< 70 (H) \times 20 (V) \ \mu\text{rad}$
- **Photon flux:** $> 10^{13} \ \text{s}^{-1}$ at 14.4 keV
- **Wide and accurate energy tunability:** 3.6 – 25 keV
- **Ultrahigh energy resolution achievable:** $\Delta E / E = 2.8 \times 10^{-8}$ at $E = 14.4 \ \text{keV}$
- **Polarization state of light selectable and analyzable**
- **Time-resolved (TR) experiments**

**EXPERIMENTAL TECHNIQUES**

- **Pump & probe TR-XRD:** timescale from subnanosecond to submicrosecond
- **High resolution XRD:** $\Delta \theta = 0.003^\circ$ with a crystal analyzer
- **High resolution powder XRD:** $\Delta \theta = 0.04 – 0.06^\circ$ with a 1D microstrip detector
- **Ultrahigh angular resolution selectable by swapping to the multianalyzer detector stage**
- **High acquisition speed**
- **Non-ambient environments**
- **Automatic sample changer to enable high throughput data acquisition**
- **Remote access capability**

**TR & GENERAL XRD ENDSTATION**

- **Ultrahigh energy resolution achievable by an asymmetrically cut four-bounce monochromator**
- **Polarization state of light selectable and analyzable**
- **Ultrastable Ti:sapphire laser system with a 35 fs pulse width, can be used to perform laser pump & X-ray probe TR-XRD experiments (timescale from subnanosecond to submicrosecond)**
- **Non-ambient environments (4 K – 300 K)**

**POWDER XRD ENDSTATION**

- **Ultrahigh angular resolution selectable by swapping to the multianalyzer detector stage**
- **High acquisition speed**
- **Non-ambient environments**
- **Automatic sample changer to enable high throughput data acquisition**
- **Remote access capability**

Mapping 4D structures of matter with X-ray scattering

Taiwan Photon Source
National Synchrotron Radiation Research Center
The FORMOSA endstation can resolve minute 3D variations of lattice parameters of crystals with a picometer resolution by a unique white/monochromatic beam algorithm. It is also equipped with many complementary analysis tools for in situ and real-time experiments on diverse systems of interest in nanoscience.

**UNIQUE FEATURES**
- Tapered undulator
- 4-bounce channel-cut monochromator
- White/monochromatic beam
- Energy range: 5 – 30 keV
- Energy resolution: 1 x 10^{-4} at 25 keV
- KB focus at 25 keV: 80 x 80 nm² (lateral)
- Photon flux: 3 x 10^{11} s⁻¹ at 10 keV

**SCIENTIFIC OPPORTUNITIES**
- X-ray Laue nanodiffraction to probe orientations, stresses/strains, phases, dislocations, grain boundaries, and deformations of matters in 3D
- Nanoscience
- Materials science and condensed matters
- Extreme-environment physics

**FORMOSA ENDSTATION (Focus: X-ray for Micro-Structure Analysis)**
- X-ray Laue diffraction by a profiler with a 40 nm depth resolution
- Multifunctional endstation providing nano-Laue XRD, nano-XAS, nano-XRF, nano-XEOL, and nano-PXM simultaneously for diverse research fields
- On-line SEM & chamberscope for real-time imaging to seek out and position the probe to the areas of interest quickly
- Ambient/vacuum (7.6 x 10⁻² – 1 x 10⁻⁷ torr) operation environments
- Quadra-probe with a variable-temperature sample stage (100 – 1,300 K) to provide complementary information (electrical, mechanical, optical and surface)
- A high-speed X-ray detector/scanner, a high-speed computer cluster, and high photon fluxes to facilitate routine 3D structural analyses

**21A X-ray Nanodiffraction**

The FORMOSA endstation can resolve minute 3D variations of lattice parameters of crystals with a picometer resolution by a unique white/monochromatic beam algorithm. It is also equipped with many complementary analysis tools for in situ and real-time experiments on diverse systems of interest in nanoscience.

**3D X-RAY NANODIFFRACTION**

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Taiwan Photon Source

National Synchrotron Radiation Research Center
23A is designed to probe non-destructively and resolve the atomic, chemical, and electronic structures of semiconductor-based devices, with spatial resolutions of tens of nanometers and a few nanometers in the tomographic and coherent modes, respectively.

**UNIQUE FEATURES**
- Nano-X-ray fluorescence
- Nano-X-ray absorption
- Nano-X-ray excited optical luminescence (XEOL)
- Nano-time-resolved XEOL
- Nano-projection X-ray microscopy
- Nano-coherent X-ray diffraction imaging
- Bragg ptychography

**THE EXPERIMENTAL STATION**
- Montel KB optics for nanofocusing (40 nm)
- Fly-scan for XRF and XEOL mappings
- He-cryogenic cooling (10 K – 300 K)
- In-vacuum (~10^{-6} torr)
- Lateral resolution better than 10 nm (using Bragg ptychography)
- SEM integration
- Streak camera for time-resolved XEOL

**SCIENTIFIC OPPORTUNITIES**
- Nanoclusters and nanoparticles
- XEOL and quantum confinement
- Complex oxide heterostructures
- Strains inside nano-devices
- Emergent 2D materials, topological insulators
- In situ failure analysis
- Dynamics of luminescence

**X-RAY BEAM PROPERTIES**
- Energy range: 4 – 15 keV
- Beam size at 10 keV: 40 nm in both H & V directions
- Beam resolution: < 2 \times 10^{-4}
- Photon flux: 5 \times 10^{10} s^{-1} at 10 keV
- High-order harmonic contamination: < 1 \times 10^{-8}

Probing beyond Moore’s and more...
Coherent X-ray Scattering

With intense, coherent X-rays from two collinear in-vacuum undulators, 25A aims to reveal static structures and dynamics of advanced functional materials in life science applications. 25A offers powerful techniques of X-ray photon correlation spectroscopy, ptychography, and small-angle X-ray scattering.

CORE TECHNIQUES
- X-ray photon correlation spectroscopy dynamics of materials, polymers, and systems in life science
- Coherent X-ray diffraction imaging for non-periodic materials
- SAXS/liquid OI-SAXS static structures of materials
- X-ray photon correlation spectroscopy
- Coherent X-ray diffraction imaging

KEY PARAMETERS
- Energy range: 5.56 – 20 keV
- Beam sizes: 1 × 1 or 10 × 10 µm²
- Coherent flux: 4 × 10¹⁰ photons/s at 6 keV
- Q-range: 0.0005 – 3 Å⁻¹
- Time resolution: ~1 ms

SAMPLE ENVIRONMENTS
- Gas membrane cell (~ 50 GPa)
- Temperature-control system (100 K – 550 K)
- Rheometer (torque: 0.5 nN m – 230 mN m)
- Tensile stage (tensile force 0.1 – 200 N)
- LB troughs (compression ratio: 10:1)

X-RAY PHOTON CORRELATION SPECTROSCOPY (XPCS)
- XPCS measures the temporal changes in speckle patterns produced when coherent light is scattered by a disordered system.

COHERENT X-RAY DIFFRACTION IMAGING (CDI)
- CDI is a lensless microscopy. The real-space image of the object can be reconstructed using a phase-retrieval algorithm.
41A
Soft X-ray Scattering

41A consists of two experimental endstations, each specializing in one of the two fields of research below: resonant inelastic X-ray scattering (RIXS) and coherent scattering, the latter including coherent diffraction imaging (CDI) and ptychography.

41A consists of two experimental endstations, each specializing in one of the two fields of research below: resonant inelastic X-ray scattering (RIXS) and coherent scattering, the latter including coherent diffraction imaging (CDI) and ptychography.

X-RAYS OF ENERGIES FROM 400 eV TO 1200 eV

- Photon flux at 1000 eV: 7 \( \times \) 10\(^{15} \) s\(^{-1} \) (0.01\% BW)
- Total resolving power at 900 eV: 60,000 (initial target), 100,000 (final goal)

COHERENT SCATTERING

- Coherent photon flux at 900 eV: \( \sim 1 \times 10^{15} \) s\(^{-1} \) (0.02\% BW)
- Bragg CDI
- Ptychography with a resolution of 10 nm
- Total RIXS resolutions:
  - \( \sim 10 \) meV at O K-edge
  - \( \sim 15 \) meV at Cu L-edge

HIGH-RESOLUTION RIXS

- Through the energy compensation scheme, the RIXS design using active gratings greatly improves efficiency.
- The grating profile is adaptively changed.
- Total RIXS resolutions:
  - \( \sim 10 \) meV at O K-edge
  - \( \sim 15 \) meV at Cu L-edge

SCIENTIFIC OPPORTUNITIES

- Probing the interplays between charge, spin, orbital and lattice degrees of freedom
- Excitations of phonons, magnons, orbitons, electron–hole pairs, band gaps, etc.
- Mapping of electronic states by CDI
- Magnetic ptychography at nanoscales

Unraveling electronic excitations with soft X-rays
Submicron Soft X-ray Spectroscopy

45A consists of two endstations, one from MPI for X-ray angle-/spin-resolved photoemission, X-ray emission, X-ray absorption, and magnetic circular dichroism to study the electronic (occupied and unoccupied) and magnetic structures of the following, among others:
- Topological insulators/metals/superconductors
- Carbon-related systems and nanomaterials
- Photovoltaic materials
- Electron-correlated materials
- Magnetic materials

UNIQUE FEATURES
- Energy range: 280 eV – 1,500 eV
- Small beam size 1.2 (H) × 0.4 (V) µm²
- Energy resolving power at 750 eV: 84,000 (initial target), 140,000 (final goal)
- Photon flux: 1 × 10¹¹ s⁻¹ at 750 eV

TKU ENDSTATION
- Varied line-spacing X-ray emission spectrometer
- X-ray excited optical luminoescence system
- In situ liquid/gas cell sample system
- Magnetic circular dichroism chamber with a 2 tesla magnetic flux density
- High precision 5-axis (x, y, z, azimuth, and polar) sample manipulator with an LHe cryostat

MPI ENDSTATION
- SPCE PHOIBOS 225 hemispherical electron energy analyzer
- Four-channel micro-Mott detector
- A molecular-beam-epitaxy (MBE) thin-film growth system with a sample transfer mechanism
- LEED, an ion sputtering gun, and e-beam heaters for sample preparations and surface characterizations
The National Synchrotron Radiation Research Center (NSRRC) is a non-profit and research institute, funded by the Ministry of Science and Technology (MOST) in Taiwan, to provide two synchrotron light sources (1st: 1.5 GeV-Taiwan Light Source (TLS) and 2nd: 3 GeV-Taiwan Photon Source (TPS)) for researchers in Taiwan and overseas to conduct frontier scientific experiments. The TLS consists of 25 beamlines and over 50 experimental stations. The TPS will accommodate ~40 beamlines (partly available for sponsor, co-sponsor, or customization per request). Currently, the NSRRC has over 2,000 users annually, the largest number of users among all large scaled scientific research facilities administrated under the MOST in Taiwan.

Apply for beam time at http://portal.nsrrc.org.tw