PROJECT CHARTER

SIAM PHOTON SOURCE II (SPS-II)

SYNCHROTRON LIGHT RESEARCH INSTITUTE

Revision Date: August 24, 2022

PROJECT NAME

SIAM PHOTON SOURCE II (SPS-II)

EXECUTING ORGANIZATION

Synchrotron Light Research Institute (SLRI)
Ministry of Higher Education, Science, Research, and Innovation

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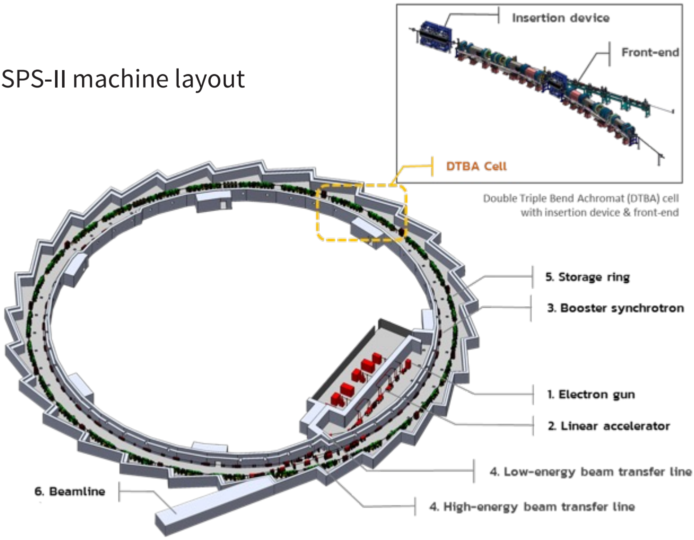
SCOPE

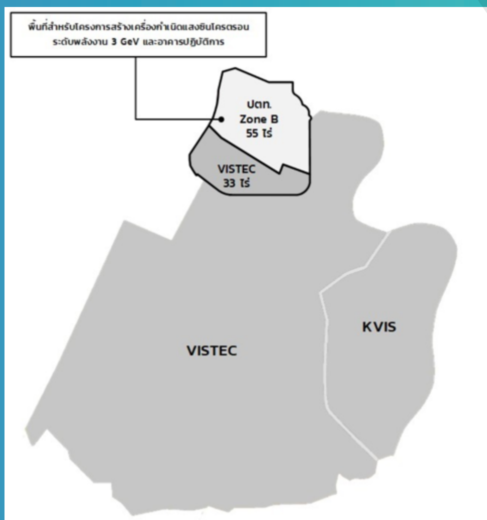
Siam Photon Source II (SPS-II) is aimed to be one of the most important scientific research infrastructures in Southeast Asia. It will play a significant role in supporting Thailand, as well as other ASEAN countries, in the transition to research and innovation-driven economy. The facility will be available to synchrotron radiation users from within Thailand, from all the ASEAN countries, and from around the world. This new light source will strengthen scientific community in the region by providing high-energy and high-intensity synchrotron light for both academic and industrial research. The facility will be constructed at the Eastern Economic Corridor (EEC) area in the EECi (EEC of innovation) district in order to provide support to the high-tech industry in the area.

The SPS-II project in the first phase encompasses a synchrotron radiation research facility with a 3 GeV storage ring-based synchrotron light source. Injector system is a linear accelerator-booster synchrotron combination. There are seven insertion device (ID) photon beamlines in the 1st phase. The facility campus has a total of five buildings.

SPS-II facility layout

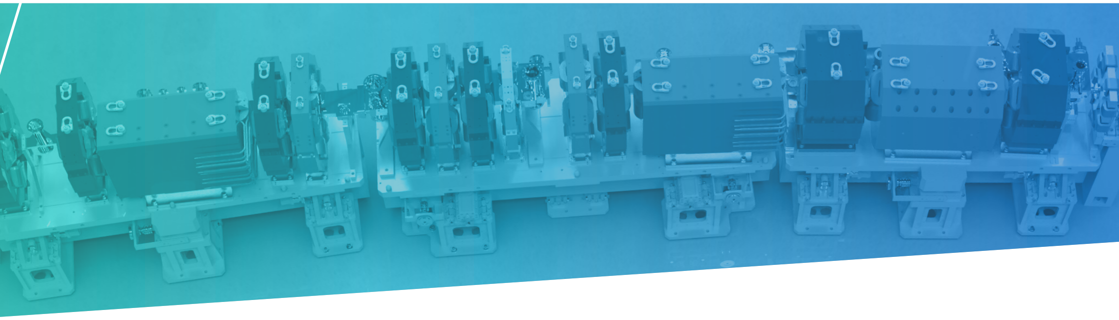
SPS-II machine layout





LOCATION/AREA

Eastern Economic Corridor of Innovation (EECi),
Wangchan Valley, Rayong
88 rai (34.8 acres)



DESCRIPTION OF KEY COMPONENTS

SPS-II accelerator complex consists of 3 main components: a 150 MeV injector linac, a 3 GeV synchrotron booster, and a 3 GeV electron storage ring. Initially, a full energy injector was chosen over a synchrotron booster because it can be utilized as the source for a Soft X-ray Free Electron Laser (SX-FEL) in the future. However, after economic considerations, the injector system was changed to a linac/booster combination. Electrons are supplied to the linac by a thermionic pulsed DC gun. The 3 GeV storage ring has a circumference of 327.5 m and the electron beam emittance of 0.97 nm-rad. The lattice is a Double Triple Bend Achromat (DTBA) lattice first proposed for the upgrade of Diamond Light Source. The ring consists of 14 DTBA cells, resulting in 14 long and 14 short straights. Maximum stored beam current will be 300 mA.

Beam injection from the linac to the storage ring is executed with a Pulsed Multipole (PM) magnet. The PM magnet design chosen is a Non-Linear Kicker (NLK) magnet design developed for BESSY-II in Germany.

Storage ring RF system of SPS-II has a frequency of 119 MHz, while the RF accelerating voltage is 1.5 MV at the beginning, and can be increased up to 1.8 MV when the storage ring straights are fully occupied by Insertion Devices (IDs). All the RF cavities are normal conducting, and the RF power is supplied by solid-state RF amplifiers together with Digital Low-Level RF (DLLRF) controllers. Third harmonic cavities (Landau cavities) will be installed to suppress beam instabilities.

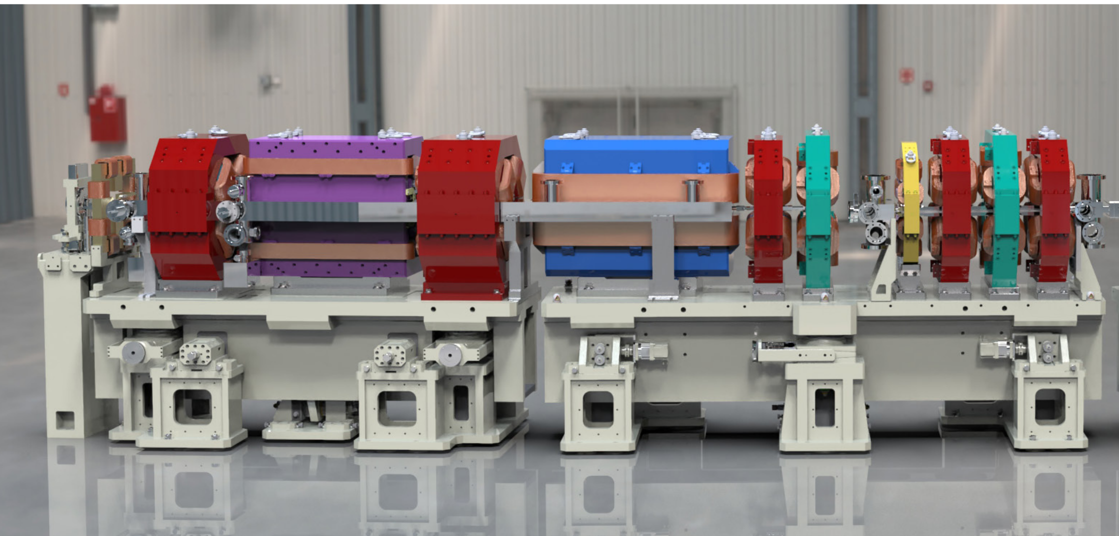
Like most recent synchrotron light sources, the main radiation sources will be IDs, however, infrared radiation can also be extracted from SPS-II bending magnets. SPS-II will be operated mainly in top-up mode.

1. ACCELERATOR COMPLEX

1. 150 MeV linear accelerator
2. 3 GeV booster synchrotron
3. 3 GeV electron storage ring

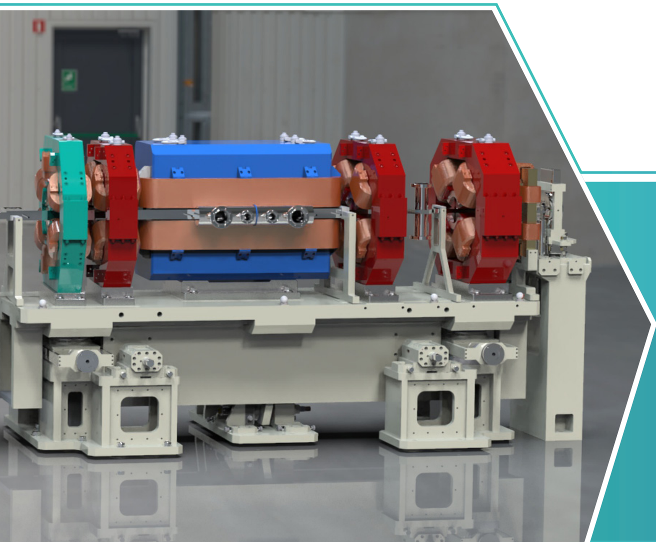
Parameter	Value
Beam energy	150 MeV
Normalized emittance	≤ 50 mm·mrad
RMS energy spread	≤ 0.5 %
Bunch train charge (MBM)	> 6 nC
Bunch charge (SBM)	≥ 1.5 nC
Bunch train duration (MBM)	150-600 ns
Bunch duration (SBM)	< 1 ns
Repetition rate range	1-5 Hz
Nominal repetition rate	2 Hz

SPS-II linac main parameters



Parameters	SPS	SPS-II
Circumference (m)	81.3	327.5
Energy (GeV)	1.2	3.0
Relativistic factor γ	2348.34	5870.85
Emittance ε_{x0} (mm·mrad)	41.0	0.96
Beam current (mA)	150	300
Nat. energy spread σ_E (%)	0.066	0.077
Nat. chromaticity ξ_x/ξ_y	-8.7/-6.4	-65.6/-76.7
Tune Q_x/Q_y	4.75/2.82	34.24/12.31
Momentum compaction α_c	1.70e-2	3.33e-4
Damping times hor./ver./long.(ms)	10.7/9.8/4.7	9.7/11.3/6.2
Straight/circumference	0.33	0.35
Energy loss per turn U_0(MeV)	0.066	0.577
RF frequency (MHz)	118.00	119.00
RF voltage (MV)	0.3	1.5
Harmonic number	32	130
Overvoltage V/U_0	4.5	2.6
Synchronous phase (degree)	167.29	157.34
Synchrotron tune	0.00460	0.00178
Nat. bunch length (mm)	29.03	7.48
Nat. bunch duration (ps)	96.8	24.9

SPS-II storage ring main parameters

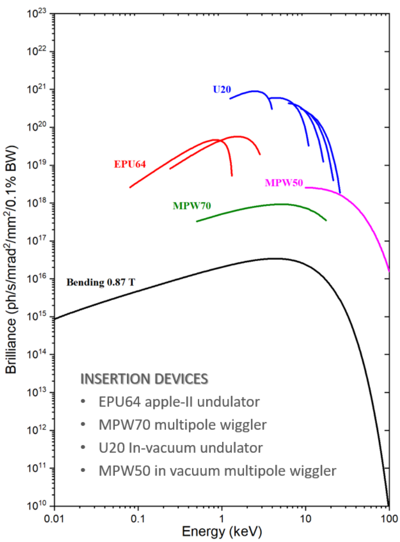


SPS-II storage ring half-cell

2. PHOTON BEAMLINES

The SPS-II storage ring can accommodate 21 insertion device (ID) beamlines and up to 14 bending magnet (BM) beamlines. In the first phase of operation, 7 beamlines will be constructed, which include 6 ID beamlines and 1 BM beamline as followed.

1. **High Resolution Soft X-ray Spectroscopy (HRSXS) Beamline**
   Photon energy range: 0.08 – 2.5 keV
2. **Tender X-ray Absorption Spectroscopy (TXAS) Beamline**
   Photon energy range: 1.0 – 1.3 keV
3. **Hard X-ray Absorption Spectroscopy (HXAS) Beamline**
   Photon energy range: 2.4 – 40 keV
4. **X-ray Microtomography (XMCT) Beamline**
   Photon energy range: 5.0 – 60 keV
5. **Small and Wide Angle X-ray Scattering (SWAXS) Beamline**
   Photon energy range: 8.0 – 20 keV
6. **High Resolution X-ray Diffraction (HRXRD) Beamline and Macromolecular Crystallography (MX) Beamline**
   Photon energy range: 5.0 – 25 keV
7. **Infrared (IR) beamline**
   Photon energy range: 0.012 - 2.5 eV



SPS-II spectral brilliance

Photon beamlines, sources, energy ranges and applicable research fields

	Photon Beamlines	Source	Energy Range	Application Research Field
1	HRSXS	EPU64	0.08 – 2.5 keV	Material, Energy, Device, Environment
2	TXAS	MPW70	1.0 – 1.3 keV	Agriculture, Archaeology, Cultural heritage, Environment, Material, Energy
3	HXAS	MPW50	2.4 – 40 keV	Agriculture, Archaeology, Cultural heritage, Environment, Material, Energy
4	XMCT	MPW50	5.0 – 60 keV	Medicine, Biology, Forensic, Environmental, Archaeology, Paleontology
5	SWAXS	U20	8.0 – 20 keV	Polymer, Medical, Material, Environment
6	HRXRD + MX	U20	5.0 – 25 keV	Material, Energy, Environment. Medical, Biology
7	IR	Bending Magnet	0.012 - 2.5 eV (0.5-100 μm)	Food, Agriculture, Medical, Biology, Forensic

3. BUILDINGS AND UTILITIES

SPS-II campus

2020 (2563)	2021 (2564)	2022 (2565)	2023 (2566)	2024 (2567)	20 (25

BUILDING CONSTRUCTION PLAN

Prepared the conceptual design of the building

Prepare detail design of:
- Synchrotron building
- Utilities building
- Guesthouse
- RF vacuum magnet lab.
- Administration & user support building
- Power substation

Preparatory survey of the project by Japan International Cooperation Agency (JICA)

SEP 2022 - MAY 2023

✱ Submit the budget proposal to Budget Bureau

✱ Pledge by GOJ and signing loan agreement

Synchrotron building

Guesthouse

RF, vac magnet lab

MACHINE CONSTRUCTION PLAN

Prepare design drawings & specifications for the machine component and its related utilities

Local manufacturing plan

Fabricate and assembly the prototype of machine components and measurement/calibration system that will be used as a developing guidelines to the local manufacturer.

Prepare Term Of Reference (TOR), standard-design drawings and specification for oversea procurement

International procurement of 150 MeV L

International procurement of:
- Smachine alignment instrumentati
- high performance power supply
- RF Cavities and RF amplifier
- Instrumentation for beam diagnost
- vacuum components.

BEAMLINE CONSTRUCTION PLAN

Prepare detail design & specifications for the beamlines system and experimental station

Local manufacturing plans and develop the prototype of beamline components
- Technical design drawing of beamline components such as double crystal monochromator (DCM), mirror systems and insertion devices etc.
- Fabricate and assembly the prototype of beamline component

Local fab
- Bea
- Fixe
- Vac
- Bea
- Etc.

International procuren
- Beamline mirror sy
- Monochromator
- Measurement equi
- insertion devices
- Mirrors

PROJECT START DATE:
1 October 2020

TARGET END DATE:
30 September 2030

BUDGETS / SOURCES:

9,352.8935 MB	JICA ODA loan
1,445.0230 MB	Budget Bureau

25 (68)	2026 (2569)	2027 (2570)	2028 (2571)	2029 (2572)	2030 (2573)

CONSTRUCTION

Utilities building

and machine utilities

Power substation

uum & boratories.

Administration & user support building

Assembly and quality testing of the machine components

Installation of machine and control instrumentation

Installation & commissioning of Linac

Linacprocurement

on

tic and control system

Installation
- LTB
- Booster
- BTS
- Storage ring (STR)

Commissioning of:
- LTB
- Booster
- BTS
- STR

Commissioning of the machine with IDs

Final machine commission

Installation of
- IDs
- Front-end

Construction of hutches and utilities

rication and manufacturing implementation
m diagnostics
ed mask, photon absorber, beam stopper, beam aperture
uum chambers and tubes
mline mirror system

Assembly and quality testing of the beamline components

Beamline commissioning

Beamlines and End stations installation

nent (direct and via local distributor) of
stem
oment's & Detector for end stations

- Power supplies and amplifiers
- Vacuum fittings, pumps and measurement systems
- Etc.

SCIENTIFIC OPPORTUNITIES:

Lower electron beam emittance, higher beam current, together with the use of in-vacuum undulators in SPS-II, will provide researchers with x-rays with more than 1 million times more intense than currently achievable with SPS. Higher energy and higher intensity photons provided by SPS-II will enable several new scientific opportunities to researchers, which are not at present attainable with SPS or anywhere else in Southeast Asia.

Higher energy photons will result in increased penetration depth and the ability to excite core electrons of heavy elements. Microtomographic imaging of dense objects can also be carried out, allowing researchers to study dense materials such as alloy composites, fossilized dinosaur skeletons and bones, and others. Excitation of K-shell electrons of heavy elements, rather than L-shell ones as in the case of SPS, will improve immensely the spectral quality of the measurement. Higher intensity photons will enable researchers to study even lower concentration of trace elements, while also shorten the measurement time. In-situ studies can be performed at better temporal resolution. Furthermore, photon beam can be focused to micro- and nanometer size due to low the very low emittance of the electron beam, improving spatial resolution of all imaging techniques. As the electron beam emittance approaches diffraction limit, degrees of spatial and temporal coherence of the generated x-rays increase considerably. This will enable researchers to perform new experimental techniques that require coherent radiation such as coherent scattering, coherent diffraction imaging, and phase contrast imaging/tomography.

The experimental techniques chosen above were based on past utilization of SPS, which reflects the present needs of Thai and ASEAN synchrotron light users, as well as on future trends of scientific development. Below are some of the scientific cases that will be enabled by the SPS-II.

BIOMEDICAL RESEARCH

Advanced biomedical research requires the ability to image organs and tissues at high spatial resolution. XMCT technique enables medical doctors to obtain both 2- and 3-dimensional images of organs, tissues, and bones of interest, which help them to better understand the effects of diseases and ailments, the mechanism of infection, as well as to investigate the effectiveness of countermeasures from promising new drugs and other remedies. Particularly poor contrast tissues such as heart, lung, brain, and breast can be imaged with better contrast ratio with phase-contrast imaging.

Furthermore, Macromolecular crystallography reveals molecular structure of proteins, enzymes, and viruses, which in turn gives scientists the understanding of the mechanism of infection, leading to the development of new medicines. Synchrotron radiation beam with higher photon fluxes focused down to micrometer size will allow scientists to obtained diffraction pattern even from very small protein crystals, while the data collection time is reduced.

FOOD AND AGRICULTURE

The ability to measure quantitatively the amount of nutrients such as proteins and minerals is indispensable in the development of functional food, which increases its popularity rapidly in the food industrial sector in recent years. Improvement of agricultural engineering and food processing will be accelerated with precise measurement of remaining nutrients after each particular process. Quality and safety of packaged food will also be improved by the ability to accurately measure trace amount of contamination.

INDUSTRIAL CATALYST

Catalyst plays an utmost important role in chemical reaction utilized by chemical and petrochemical industries. Effective use of catalyst reduces the production cost immensely by both reducing the chemical reaction time and increasing the efficiency of the reaction process. In order to improve the effectiveness of existing catalysts or invent novel catalysts, chemical and structural transformations of the chemicals involved in the process, as well as those of the catalyst itself, have to be well understood. Several techniques including XAS and HRSXS can be performed in-situ to study the performance of catalysts.

ADVANCED MATERIALS

Advanced materials such as novel ceramics synthesized from inorganic oxides and piezoelectric materials are becoming more popular due to their wide range of applications. Since their special properties are closely related to the chemical states of the constituent atoms and local atomic structure. XAS, HRXRD, and XANES techniques are highly applicable for the study of these materials. In-situ study can be performed to investigate the changes these materials undergo when subjected to different conditions. Development of other novel materials including construction materials, polymers, metallic alloys, and plastics, will be aided by SR experimental techniques. Investigation of microcracks in construction materials can be be investigated with high resolution XMCT.

ENVIRONMENT

With higher brilliance synchrotron light, we can detect even lower concentration of contamination in water, soil, and plants. Being able to precisely identify the chemical states of the elements in the pollutants helps us to be able to identify more accurately the source of the pollution, determine the level of toxicity, and even understand the mechanism of propagation of the pollutants in the environment. Moreover, the effectiveness of particular remediation can be investigated in order to find the best or most suitable solution. Early detection and remediation of pollution in agricultural/farming area can prevent or reduce the subsequent economic loss.

MICROELECTRONICS AND SPINTRONICS

Probing magnetic properties, as well as electronic structure, of magnetic thin films and multilayers, both of which are promising candidates as future microelectronic and spintronic devices, can be performed with HRSXS technique. The technique is also useful for research on two-dimensional materials and graphene-based devices.

ARCHAEOLOGY AND PALEONTOLOGY

Archaeological and paleontological samples are precious and invaluable. Scientific investigation with non-destructive methods such as XAS, XRF, and XRD with synchrotron radiation are ideally suited for studying of such samples. Characterization of elemental constituents of archaeological samples or cultural heritage objects gives an insight into how they were made in the past, where the constituting ingredients were from, and even whether there was any connection between different geographical locations in the past. The obtained information can be used to replicate accurately the materials to be used for restoration, as well as to determine the optimal conditions for preservation. Internal structure of these samples can also be meticulously studied with high resolution XMCT.

MAJOR MILESTONES

Sep 2022	MOU signing between PTT, VISTEC and SLRI
	JICA's preparatory survey starts
	Submit revised project proposal to National Economics and Social Development Council
Apr 2022	JICA's final survey report completed
Aug 2023	Sign loan agreement with JICA
Oct 2023	Budget released by JICA and Budget Bureau
Jan 2024	Building and utilities construction started
Mar 2027	Synchrotron building construction finished
April 2027	Machine installation started
Aug 2028	All buildings completed
Oct 2028	Linac commissioning completed
Apr 2029	Synchrotron booster ring commissioning completed
Jul 2029	Storage ring commissioning completed
Aug 2029	Beamlines installation started
Apr 2030	Beamlines commission completed
June 2030	Final machine commission completed
July 2030	SPS-II facilities ready for service

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