THE SIAM PHOTON PROJECT

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Abstract

The Siam Photon Project promoted by the National Synchrotron Research Center of Thailand is described. In this project, a 1.0 GeV storage ring with four long straight sections for insertion devices will be built. The major facilities are transferred from the shut down SORTEC Laboratory in Tsukuba, Japan. The storage ring, the Siam Photon Source, is modified so that the beam emittance is reduced and the insertion devices can be installed. The machine design and some the beam line concepts are described.

1 INTRODUCTION

The Siam Photon Project is promoted by the Ministry of Science, Technology and Environment of Thailand. For implementing the project, the National Synchrotron Research Center (NSRC), which is in the campus of the Suranaree University of Technology located in Nakhon Ratchasima, about 250 km to the northeast of Bangkok, has been established.

The Siam Photon Project aims at promoting the scientific researches based on spectroscopic methods in the vacuum ultraviolet and soft x-ray regions [1, 2] in the first stage, and later, the applications of x-rays from a superconducting wiggler will be considered. Applications of synchrotron radiation to the development of new technology will also be considered.

The Siam Photon Project is also promoted as a part of the human resources development plan. Through this project, young scientists and engineers will be trained in the various fields of accelerator physics and technology, beam line optics and measurement technology and practical application technology. Training in basic and applied science is naturally realized.

The Siam Photon Project is summarized as follows:

(1) A 1.0 GeV electron storage ring referred to as the *Siam Photon Source* will be constructed. Future grade up of the electron energy to 1.2 GeV is considered. The storage ring will be equipped with four long straight sections for insertion devices.

(2) Beam lines and experimental stations to be built are for advanced spectroscopic studies on gaseous atoms and molecules, those adsorbed on solid surfaces, solid materials and surfaces and interfaces. Experiments planned include:

  a. Spin- and angle-resolved photoemission
  b. Soft x-ray fluorescence
  c. Magnetic circular dichroism
  d. Photoelectron-photoion coincidence measurements
  e. Two-color experiments by simultaneous irradiation with laser and synchrotron light
  f. High resolution spectroscopy of gaseous atoms and molecules

(3) Conventional beam lines for routine photoabsorption experiments and radiation biology will be built.

(4) Beam lines for basic researches on metrology using synchrotron radiation as an intensity standard of light and on microlithography and micromachining will be built.

(5) The installation of superconducting wiggler magnets is considered. Beam lines will be built for x-ray experiments associated with

  a. Protein crystallography
  b. X-ray microscopy
  c. Applications to metallurgy and mineralogy
  d. X-ray microanalysis

The synchrotron radiation source built in the Siam Photon Project is the modified SORTEC ring[3, 4] that was owned by the SORTEC Corporation in Tsukuba, Japan, and transferred to NSRC along with the injector linac and the booster synchrotron.

2 INJECTOR AND BOOSTER

The injector linac and the booster synchrotron used in the Siam Photon Source system are those of the SORTEC facility.They are used without modification. The low energy beam transport line between the injector and the booster is also from the SORTEC system used without modification. The simple distinctive features of the linac and the synchrotron are summarized as follows:

2. 1 Injector Linac

(a) Electrons are accelerated up to 40 MeV with two acceleration tubes.
(b) The length of an acceleration tube is 2.3 m.
(c) The RF power supplied by a klystron (PV-3035) is 35 MW.
(d) The electron beam current is 60-80 mA.

2. 2 Booster Synchrotron

(a) The booster synchrotron accelerates electons from 40 MeV to 1.0 GeV.
(b) An inflector magnet and four bump magnets are used for beam injection.
(c) The yorks of the bending and quadrupole magnets are made of laminated silicon steel plates of 0.5 mm thickness.
(d) The RF acceleration cavity is of the reentrant type and made of copper.
(e) Major parameters characterizing the booster synchrotron are summarized as

Circumference:	43.19 m
Bending radius:	3.03 m
Lattice structure:	FODO
Beam current:	30 mA
Repetition rate:	1.25 Hz
Betatron tune (ν_x / ν_y):	2.25/1.25
Maximum dipole field:	1.1 T
Maximum gradient of quadrupole field:	4.8 T/m
RF frequency:	118 MHz
Maximum RF voltage:	60 kV
Chamber pressure (with beam):	$< 1 \times 10^{-6}$ Torr

3 STORAGE RING

The layout of the Siam Photon Source with its injector linac and booster synchrotron is shown in Fig. 1.

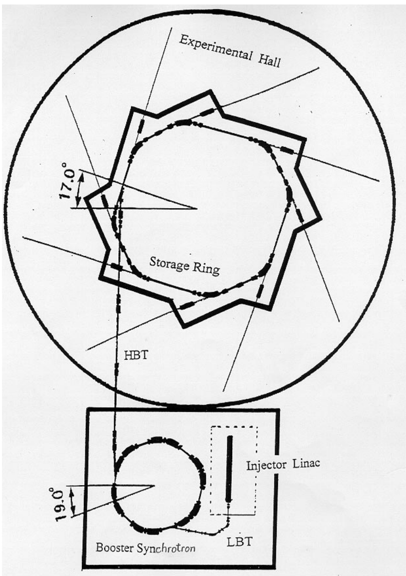

Fig.1. The layout of component accelerators of the Siam Photon Source.

The magnet lattice structure and other components of the storage ring are shown in Fig.2.

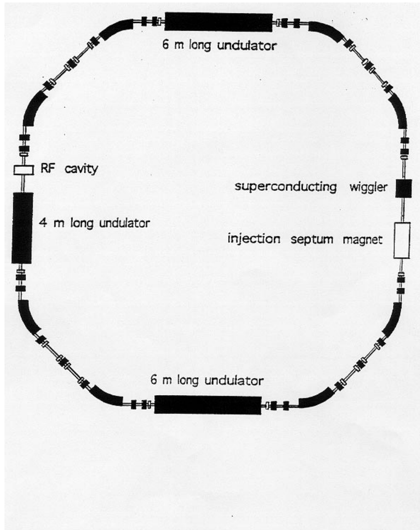

Fig.2. Schematic illustration of magnets, the RF cavity and insertion devices in the Siam Photon ring

The reformation of the SORTEC ring is made as follows:

(1) The lattice structure is changed from the quadrupole doublet lattice to the double bend achromat (DBA) lattice so that the natural emittance of the lattice is reduced. To fulfill this modification, the numbers of quadrupole magnets and sextupole magnets are increased.
(2) Four long straight sections are built so that insertion devices may be installed.
(3) To materialize the items (1) and (2), the vacuum chambers are newly built.
(4) The whole control system is newly built.
(5) Three undulators and a superconducting magnet wiggler will be installed. Out of these four insertion devices, at least, a Halbach type undulator is constructed in the first 5 year term plan. The installation of a superconducting magnet wiggler will be considered when the commissioning of the storage ring is completed.
(6) The high energy beam transport line, that makes the new configuration of the storage ring and the booster synchrotron possible, is newly built.
(7) Two beam lines are installed subsequently to the completion of the storage ring construction. Two beam lines and four experimental stations will be added in the following second stage program. The installation of x-ray beam lines associated with the superconducting wiggler will be considered in this period.
(8) The injector linac and the booster synchrotron are installed underground. The accelerated electrons are transported to the storage ring

through a tunnel and injected into the ring from the inside of the ring. This makes it possible to use the whole area around the storage ring. The installation of the injector and booster systems underground also makes the radiation shielding quite simple.

4 PRESENT STATUS

The basic beam dynamics calculation on the proposed magnet lattice structure has been completed. The detailed results are reported elsewhere[5-7)]. The unit cell of the DBA structure used in this calculation is shown in Fig. 3.

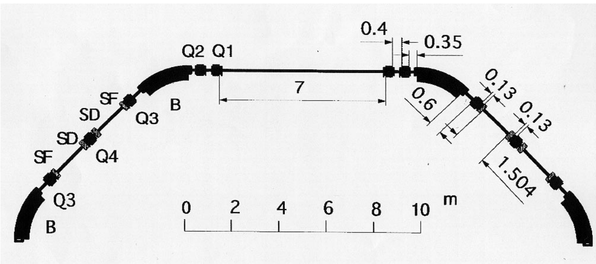

Fig.3 The unit cell of the DBA structure adopted in the Siam Photon Source.

The machine parameters of the Siam Photon Ring are summerized in Table I. Twenty eight quadrupole and 16 sextupole magnets are included in the whole ring. By the alteration described here, the natural emittance is reduced from 500 π.nm.rad to 72 π.nm.rad. The corresponding beam sizes are reduced from (x = 2.0 mm, y = 0.7 mm) to (z = 0.15 mm).

The bending magnet is of the ordinary sector type with a bending angle of 45 degree. The radius of curvature of the orbit in the bending part is 2.780 m. The circumference is 81.3 m, which is about 1.8 times as large as that of the original SORTEC ring.

TABLE I ***Parameters of the Siam Photon Ring***

electron energy	1.0 GeV
circumference	81.3 m
magnet lattice	double bend achromat
superperiodicity	4
long straight sections	7 m x 4
betatron wave number ν_x / ν_Z	4.71 / 2.78
momentum compaction	0.0214
natural emittance	72 π.nm. rad
natural chromaticity ξ_x / ξ_y	-7.96 / -6.45
RF voltage	120 kV
RF frequency	118 MHz
harmonic number	32
energy spread	5.02×10^{-4}
energy loss per turn	31.8 keV/ turn
synchrotron oscillation frequency	13.5 kHz
critical energy of SR	958 eV
bunch length	135 ps
beam sizes σ_x /σ_z	0.94/ 0.15 mm
damping times τ_x/ τ_Z/ τ_E	18.9/ 17.0/ 8.1 ms

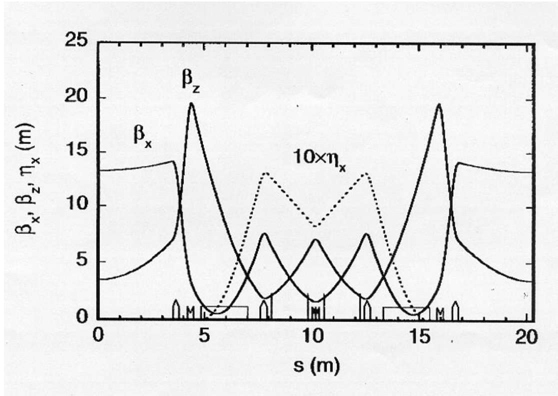

Fig.4. Spatial variations of Twiss parameters and dispersion. The full line represents the data β_x, and the dotted line η_x.

The engineering design work of the magnets to be built newly has been finished. Their basic features are not different from those of the SORTEC ring. The calculated example of the spatial variation of the Twiss parameters and the dispersion is shown in Fig. 4.

The data have not been finalized yet and the calculation is still underway [7)]. The dispersion is zero in the straight sections where the insertion devices are installed. This is the condition compelled by the requirement of the beam stability. The spatial variation of the β functions appears to be reasonable. As is shown in Table I, the beam emittance is not small enough to make the beam size very small. However, a lot of interesting work can be carried out with a light beam supplied by the electron beam of the present quality. The effect of the strong magnetic field of the superconducting magnet is not yet calculated.

Three bump magnets are used for the injection of the beam. The finalized locations of these magnets are not shown in Figs. 1 through 3. The calculated example of the dynamic aperture of the beam is shown in Fig. 5. It is wide enough for the beam to be stored easily.

The total power dissipation due to radiation loss is 13.2 KW. If all of this power is consumed in the bending magnet parts of the orbit and synchrotron radiation emitted in a horizontal aperture of 1 milliradian is 2.1 W. From the simple consideration, it is concluded that the first mirror shall be cooled forcibly as in the case of the undulator beam lines.

The RF cavity has also proved to work very well. The Q value of the cavity is 20,100 and the shunt impedance is 1.35 MW. The power supply can afford to send 14KW, which is compared with the expected radiation loss of 13.2 KW.

All the vacuum chambers will be renewed. This is caused by the change in the magnetic lattice structure of the storage ring as well as in the circumference of the

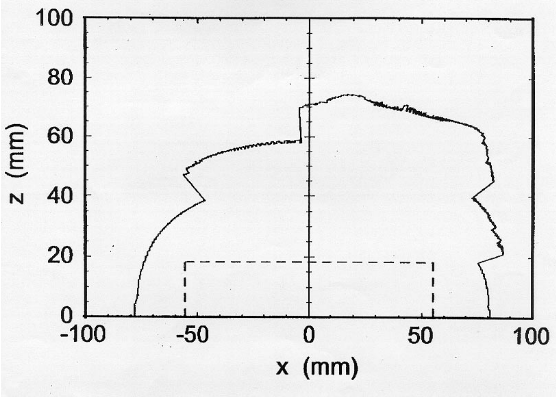

Fig.5. Calculated example of the dynamic aperture. Dotted curve : Scanning along x and z directions in the cartesian coordinate. Full curve : Scanning along r and θ directions in the two dimentional polar coordinate.

storage ring. The total pumping speed is 27,600 l/s. The expected ultimate pressure in the chambers are made of aluminum. The engineering design work has been completed. The construction will start soon in Yokohama.

Various types of beam monitors will be installed. They are fluorescent plate monitors, beam position monitors of the electrostatic induction type, current monitors, and the port of observing synchrotron radiation. Many of them are mounted in the vacuum chambers.

The fluorescent plate monitor will be used only in the initial stage of commissioning. Four of them are installed in the four straight sections. The plates are made of 99.5% pure Al_2O_3. The beam position monitor of the electrostatic induction type consists of four metal plates of the button type. The current monitor is a sort of transformer which detects the induced magnetic field. The current sensitivity is 10 μA.

Observing synchrotron radiation for monitoring the electron beam is made to find the profile of the beam cross section. The emitted light is observed with a TV camera and the intensity versus the position in the beam cross section is analyzed. This system is also used for measuring the light intensity and record it with a streak camera.

The control system is also renewed completely. The conceptual design has been established and the system is now open to bidding. The constructor will be decided in a few month.

In the first phase of construction in the Siam Photon Project, one planar undulator is planned to be built. The practical design work has not yet started. It will be made along with the beam line design work. Since the electron energy of the storage ring is low, the photon energy range covered by the first harmonic lines is lower than about 200 eV. Thus, the third and fifth harmonics are also used for experiments. Then, using an undulator with a magnet period of 5 cm, the spectral range up to 1 keV is covered and brilliant light is obtained in the energy region for quite interesting innershell excitations. The spectra of the undulator light are shown in Fig. 6. The spectrum of light emitted from an ordinary bending magnet part is shown for comparison.

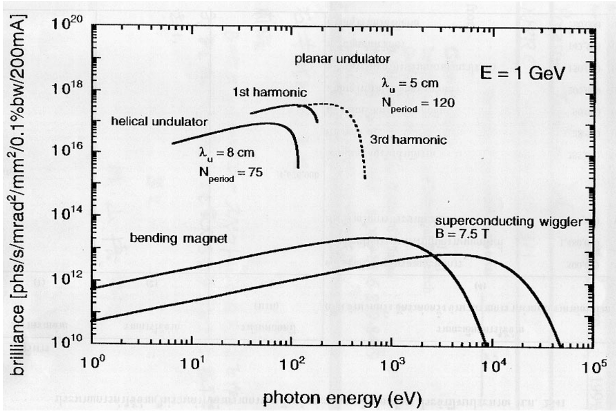

Fig.6. The spectra of light emitted from the undulators Planned in the Siam Photon Project

The distinctive aspect of the high energy beam transport line of Siam Photon Source is that the electron beam is deflected by only a small angle in the horizontal directions and runs horizontally almost straight as shown in Fig. 1. This minimize the beam divergence in the horizontal direction in the beam transport line. The conceptual design work has been finished and the engineering work is underway.

5 BEAM LINES

The Siam Photon Source will be equipped with 8 beam lines and 15 experimental stations. In the first period of the Siam Photon Project, 3 experimental stations will be built. The practical design work for the beam line has not started yet. We are now discussing the types of the possible standard beam line. The design work will start in a few months. The brief summary of the discussion having been made in described in what follows.

The front end is located inside the radiation shield wall and consists of a few shutters and values. A front focusing system is the mirror system upstream of the entrance slit of the monochromator. It includes a defining beam aperture, a deflection mirror and two focusing mirrors. The light beam from the storage ring is focused through the front focusing system on the entrance split.

In the Siam Photon Project the adopted monochromators are of the constant deviation angle type (CDM), in which the incident and exit slits and the grating are mounted on fixed locations in the grazing incidence configuration. The plane grating has groove spacings not constant but varying nonlinearly. The monochromator equipped with this type of grating is referred to as the Harada-Koike monochromator that will be adopted in the beam line built here.

TABLE II ***Experimental Stations***

Station	Monochromator	Spectral Range	Equipment	Source
1. Photemission -Surfaces and interfaces	Harada-Koike	10eV - 1KeV	PESp	Revolver undulator
2. Soft X-ray fluorescence	Harada-Koike	10eV - 1KeV	SXESp, Mon-II	Rovolver undulator
3. VUV absorption -reflection (Radiation effects)	Seya-Namioka	5-30eV	Sample chamber,	Bending section SXASp
4. Photoemission -Magnetic circular dichroism-	CDM	30eV-1KeV	SXASp, PYSp	Helical undulator
5. XANES	CDM	30eV-1KeV	SXASp, PYSp	Bending section

CDM: Constant deflection angle monochromator
Mon-II : Second monochromator
PESp : Photoelectron spectrometer
SXESp : SoftX-ray fluorescence spectrometer
SXASp : Photoabsorption spectrometer
PYSp : Photoyield spectrometer

Two mirrors are used in the rear focusing system, one for horizontal focusing and the other for vertical focusing. The rear focusing system focuses monochromatized light on the surface of a sample into a small spot shape. Materials of the mirrors and the gratings used here are either quartz or SiC. Water cooled holders should be prepared for some of the mirrors.

Photoemission and fluorescence measurements will be made in the major experimental stations built first. In a photoemission instrument, an electron energy analyzer is the central measurement unit. In a fluorescence instrument, a second monochromator characterizes the system. In the vacuum chamber for an absorption-reflection measurement system, only a sample holder and a few accessories are placed along with a cryostat. In addition to the main instrument, some subsidiary instruments for characterizing sample surfaces such as an Auger electron analyzer and a LEED analysis system are provided in the photoemission equipment.

The experimental arrangements under consideration tentatively are summarized in Table II

6 BUILDING

The building of the Siam Photon Laboratory in which all the synchrotron radiation facilities are contained in now under construction. The construction is expected to be completed in May, 1999. The ground breaking ceremony was held on February 28, 1998.

7 ACKNOWLEDGEMENT

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