The Status of Siam the Siam Photon Laboratory

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Introductory Remark
The Siam Photon Project started in March 1996. It is as follows:
(1) A synchrotron radiation source with a 1 GeV storage ring is built along with beam lines for
spectroscopic research.
(2) Using the synchrotron radiation source, advanced scientific research is promoted.
(3) Human resources development in science and technology is promoted by performing the project.
Since the project started from scratch, we did not have any persons who had experience in
synchrotron radiation science and technology. The education of basic science such as physics,
chemistry and mathematics at universities in Thailand, particularly in the graduate school level, was
weak. We expected the implementation of a big scale project in advanced science would make a
breakthrough in such a situation.
In addition to these, another important purpose of the project existed. It is expected ripple effects.
The project was expected to open new opportunities in basic science fields encouraging physicists
and chemists to participate in the fulfillment of the project. This could stimulate the research
activities in the fundamental sciences of the country. The implementation of the project includes
plenty of construction work not only in the civil engineering but the electronics and the precision
mechanical engineering. Impact to the semiconductor engineering was also emphasized.
The accelerator complex consists of three component accelerators: A 40 MeV injector linac, a 1
GeV booster synchrotron and a 1 GeV light source storage ring. The structure of the light source
has been reported in many places¹,². The accelerator complex has a distinctive aspect: It consists of
second-hand machines with the reformed storage ring. The original accelerator complex was owned
by the SORTEC Laboratory in Tsukuba, Japan. The SORTEC accelerator system was donated to
the National Synchrotron Research Center (NSRC) that owns the Siam Photon Laboratory. The
components of the dismantled machines were transported to NSRC eight years ago.
Among the component accelerators, the injector linac and the booster synchrotron were not
reformed and used in the Siam Photon Source in their original structures. Also the low energy beam
transport (LBT) line between the linac and the synchrotron was not reformed. The original
SORTEC storage ring has the design optimized for the microlithography research and not quite
suitable for various scientific researches. Thus, the storage ring structure was modified so that the
light source is suitable for the scientific use¹-³. The new storage ring has four long straight sections
and the natural emittance of the beam is one seventh as small as that of the original SORTEC
storage ring. In other words, it has the four-fold symmetry and provides us with more brilliant light.
Reformed portions are as follows:
(1) The magnet lattice was changed from the quadrupole doublet lattice similar to the FODO lattice
to the double bend achromat (DBA) lattice. We obtain synchrotron radiation with higher brilliance by doing this.
(2) More quadrupole magnets, sextupole magnets and steering magnets were added to complete the
DBA lattice. The beam adjustment can be performed in an easier way.
(3) Four long straight sections for insertion devices were inserted. The necessity for this is obvious.
The reformed storage ring has a circumference of 81.3 m, which is almost double as large as
(4) The machine control system was renewed. The control system of the SORTEC machine was old and many parts were degraded. The system design was not updated. This is the reason for the renewal. The machine control system is composed of personal computers (PC’s) and programmable device controllers (PLC’s). In the machine control room, three PC’s, one for the control server (CNT-SRC) and other for the data acquisition server (ACQ-SRV), are installed along with four PC’s used as the operational terminal equipment. Two of the additional computers are used to control the admittance to the controlled access areas and to record the personal histories of stay in the controlled access areas. We installed the device control stations (DCS’s) in the various rooms where many power supplies and controllers are placed. The ordinary Ethernet is used for LAN connecting the computers and DCS’s. PLC’s are used for the connection purpose. A hub is located in the control room. DCS’s and PLC’s are connected to the hub with optical fibers with 100 Base T cable. More details are presented elsewhere.

(5) The vacuum chambers were renewed. Because the magnet lattice structure was changed, the vacuum chambers must be changed. New vacuum chambers are made of aluminum. The background pressure is as low as \(10^{-11}\) Torr. Beam position monitors of the button type were installed in the chambers. We replaced the old ones used in the SORTEC ring with them. In addition to these, the structure of the high-energy beam transport (HBT) line connecting the synchrotron with the storage ring was reformed. In this part, the electron beam is deflected twice in the horizontal direction by quite small angles. Thus, not only bending magnets were replaced but a few focusing magnets and a few steering magnets were added.

The electron beam is bent twice horizontally in the low energy beam transport (LBT) line. The LBT line has the magnet lattice structure of DBA. At the center between the two bending magnets, a slit is inserted and it defines the energy of the electron beam coming out of the LBT line. The line is equipped with a Faraday cup for the measurements of the beam intensity and the spectrum of the electron beam energy.

Among the component accelerators, the linac and the synchrotron had been installed underground. This facilitates the radiation shielding and the beam injection from the inside of the storage ring. By this, all the space around the storage ring can be used for optical experiments.

A planar undulator of the Hallback type will be installed in the storage ring. It has only one pair of magnet array. Generated light covers the spectral range from 20 eV to 600 eV using the 1st and 3rd harmonics bands. If we use the 5th harmonics band, we can expand the available spectral range up to 800 eV. The period length is 64 mm and total length is 2.5 m. A C-shaped frame for magnet support is employed. The inspection of the performance to clear the specifications has shown that the undulator is built very well. No mechanical deformation was found when the magnet gap was changed continuously. The magnet gap can be changed by computer control. The software prepared by NSRC works well to change the magnet gap smoothly.

The vacuum chamber in the undulator part of the storage ring was specially designed to increase the conductance. The minimum magnet gap is 26 mm. The gap inside the vacuum chamber at the part where the electron beam exists is very narrow. Therefore, the conductance for existing gases along the beam direction is low. On the other hand, the metal surface area where outgasing occurs is large. Thus, the pressure in the chamber may be high. In order to avoid this situation, we designed the vacuum chamber consisting of a tube with a large diameter with the narrow gap portion to attach it. There is a wide aperture at the border between the two parts of the chamber. The vacuum chamber in the undulator part is made of stainless steel. The construction of the undulator and the vacuum chamber has been completed. It will soon be installed into the storage ring.

Only two optical beam lines have been installed in the light source system. One of the beam lines is for the electron beam monitoring with visible synchrotron light. Synchrotron light is guided to an optical system with a telescope and a TV camera where the image of the light source is finely obtained. We assume that the image represents the cross sectional view of the electron beam. The changes of the shape and location of the image are taken to be those of the electron beam. This
observation is conveniently used for the beam diagnosis.

Another beam line is for photoemission experiments. The monochromator used is of the constant deflection angle type with the non-linearly varied line spacing plane grating. An average resolving power of 5,000 is attained. Monochromatized light is focused on a sample as a small spot. No optical element is installed in the area inside the radiation shield wall in the building. The energy calibration of the monochromator was carried out by measuring the locations of the Fermi edge of an Au film at various photon energies. The corresponding readouts of the rotary encoder attached to the grating system were compared with the kinetic energy values at the Fermi edge.

The photoemission measurement system consists of a UPS angle-resolved photoemission energy analyzer, an Anger electron energy analyzer (CLAM), a helium discharge tube and a head-on type x-ray tube. The system is also equipped with a sample holder and manipulator and a separate sample preparation chamber. The x-ray tube is for XPS measurements. Ultraviolet light from a helium discharge tube is used for the calibration of the energy analyzer system.

Present Status

In the past two years, work for improving the machine performance has been carried out. The beam line and the attached experimental station were adjusted during this period. By the end of January 2004, the maximum stored current reached 216 mA. The beam lifetime at a stored current of 100 mA is about 7 hrs. This value is that of the design goal.

As the first experiment using the beam line, the 3p-3d resonant photoemission was observed on clean Ni(111). The results will be submitted for publication soon. In this study, we focused our attention on the change of the intermediate states as the excitation energy is varied. The change in the intermediate states shows up as the change of the spectral band shape. If the excitation energy is high enough, the spectral band shape does not depend on the excitation energy and resulting spectra have the shape of the Anger electron spectrum. If the excitation energy falls into the region where the complete 3p-3d resonance occurs, resulting spectra have the shape of that of two hole bound state spectrum. In the intermediate energy region, spectral band shape varies continuously depending on the excitation energy. We attribute this to the change of the intermediate states.

Trouble Shooting

We have spent two years for the commissioning and improving the machine performance. Some of problems were reported already. Among the problems we had to overcome, three issues are worth mentioning. All others are caused by various pieces of degradation of the components or accidents.

One of the three issues is the non-uniform floor settlement. This occurred both in the linac-synchrotron room and in the storage ring room. We repeated machine alignment as the measures. The irregular floor subsidence stopped in two years after the completion of the building construction. We consider that this irregular subsidence of the floor is caused by the use of bad quality piles to support the floor and the defects in the design of the fundation.

The second serious problem was the breakdown of the synchronous pulse generator in the machine control system. This part existed in the system for controlling the timing of beam injection. An installed battery had died; the memories in a board had disappeared; a built-in computer had been broken. Thus, the SORTEC timer system was abandoned and a new timer system has been built. We used the design developed by KEK and SPring8.

The third one is the beam instability and most serious. It occurred in the linac and the storage ring. The linac beam instability was caused by occasional fluctuations of the electron beam energy. They are converted to the fluctuations of the beam intensity. This was partly caused by the accumulation of various pieces of the degradation of the components in the microwave electrical circuit. Some of the problems were attributable to the inappropriate circuit design and the use of improper circuit components. The adjustment of the control circuit was imperfect. Large noise arising from the breakdown discharge in the high voltage circuit prevented the proper operation of various monitors and the fine tuning of the controls and power supplies circuit could not be carried out.
As cures, most of the defects have been removed; the fine tuning of the controls and the power supplied was carried out; a voltage amplifier had been installed at each beam current monitor; the emission current from the electron gun has been increased. These enhanced the injection efficiency. Now, the fluctuations of the beam energy have been fixed within the level that does not affect the injection efficiency. At present, noise cannot be removed completely, although it does not make crucial influence on the machine performance.

The beam instability in the storage ring was such that the location of the electron beam in the storage ring moved quite frequently and the beam was lost suddenly. This caused large COD that could not be corrected. The beam lifetime was short. The quite abnormal distribution of the betatron functions was found with the very large magnitudes of the betatron functions at a few points along the electron orbit. This explained the observed anomalous features of the stored beam. The beam scraping may have occurred.

We inspected the characteristics of the quadrupole magnets and found that the short-circuit occurred between coil-layers of many quadrupole magnets. The defects of the quadrupole magnets explained the observed fact that the electron beam could not pass through the centers of quadrupole magnets. We have replaced the worst four coils with new ones. This drastically improved the machine performance. The construction of 64 coils to replace old coils is almost in its final stage.

**Future Plan**

Since the light source part has started working well, we will move our primary effort to the construction of new beam lines and experimental stations. We wish to fill the experimental hall with beam lines and experimental stations as planned. The urgent task is to build the undulator beam line. We are now carrying out the design work for this. On the other hand, existing beam line will be used for the research of surface electronic structures of transition metals, such as Ni(111), Cr(100), Cr(110) and Cu(100) and Cu(110). Studies of deeper core level excitations will also be made. Outside users are coming to use the experimental stations. A few groups trying to use the facility appear to be interested in transition metals, semiconductors and polymers. We have almost finished the design study of the x-ray beam line for superconducting magnet wiggler. For x-ray generation, we are still carrying out the feasibility studies. For the machine performance improvement such as computer controlled operating point adjustment, increase in the beam injection efficiency and automatic COD correction, continuous efforts will be carried out.

**REFERENCE**

3. W. Pairsuwan, G. Isoyama, and T. Ishii, Proceedings of the 8th International Conference on Synchrotron Radiation Instrumentation, held at San Francisco in August, 2003( to be published by American Institute of Physics)