SIAM PHOTON SOURCE: PRESENT MACHINE STATUS AND FUTURE UPGRADES

P. Klysubun*, S. Boonsuya, N. Juntong, K. Kittimanapun, S. Kongtawong, S. Krainara,
A. Kwankasem, T. Pulampong, P. Sudmuang, N. Suradet,
SLRI, Nakhon Ratchasima, Thailand

Abstract

Siam Photon Source, the Thailand synchrotron light source, has received several upgrades in recent years. Most important of which are the improvement of the positional stability of the stored electron beam, and the installation of 2 IDs, i.e. a 2.2 T hybrid multipole wiggler and a 6.5 T superconducting wavelength shifter, to extend the available SR spectrum into hard x-ray region. The beam stability improvement was achieved through several activities, including improving the BPM system, upgrading the existing corrector power supplies, and implementing global orbit feedback. The two new IDs provide higher-intensity and higher-energy (up to 25 keV) synchrotron light, which will be utilized for MX, high-energy SAXS, WAXS, XAS, and microtomography. Ongoing machine upgrades include increasing the energy of the booster and transport line to 1.2 GeV for full-energy injection and eventual top-up operation. Utilization of the electron beam is also being explored. A beam test facility, which extracts electron beam in the booster for characterizing high-energy particle sensors, as well as calibrating other beam diagnostic instruments, has been constructed and is now in operation.

INTRODUCTION

Siam Photon Source (SPS) has been in operation for synchrotron radiation users for 11 years. During these time the accelerator facilities have been continually improved. [1] In recent years, substantial improvements have been made, i.e. available photon energy has been extended into hard x-ray region. Positional stability of the photon beam, as well as machine reliability, have been markedly improved. Besides generating synchrotron radiation, electron beam itself is now utilized for characterization of high-energy particle detectors.

MACHINE OPERATION

In fiscal year 2016, which started from October 1, 2015 and ended on September 30, 2016, we had operated the 1.2 GeV storage ring in user mode of operation. The monthly operation had been such that the first 5 days of each month were reserved for maintenance, installation, repair, and machine study. The rest of the month were user beamtime. During these user beam periods the photon beam were provided to users 24/7. The electron beam was injected twice a day from 8:30 AM to 9:00 AM and from 8:30 PM to 9:00 PM. The maximum beam current was 150 mA. The number of user beamtime per day was 23 hours. A typical daily operation of the SPS is shown in Fig. 1.

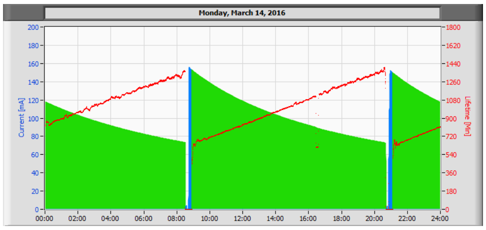

Figure 1: Example of daily SPS operation.

The total number of user beamtime that was scheduled was 4,475 hours. We were able to deliver 4,343 hours, corresponding to Machine Availability of 97.1%. (Fig. 2) Mean Time Between Failures (MTBF) and Mean Time To Recover (MTTR) of FY 2016 are shown in Fig. 3.

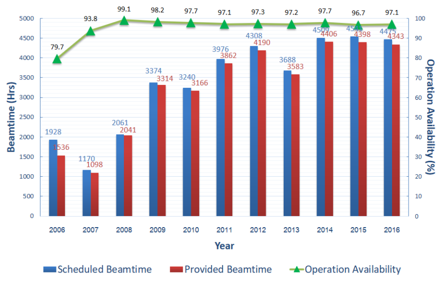

Figure 2: Operation statistics from FY 2006 to FY 2016.

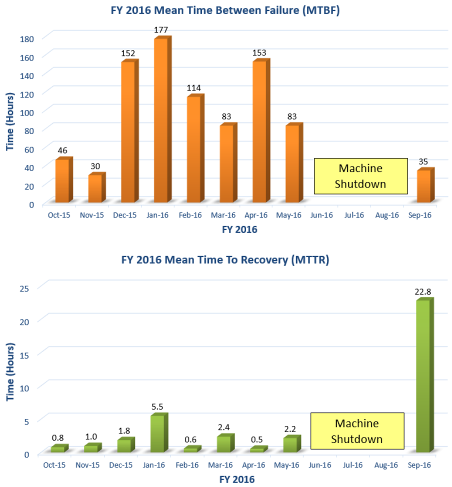

Figure 3: FY 2016 monthly MTBF and MTTR.

In Fig. 3, the MTTR of September 2016 is significantly higher than that of the other months. The reason is that the failure was the vacuum leakage at the front-end of BL1

---

* pklysubun@slri.or.th

ISBN 978-3-95450-182-3

beamline, which took considerable amount of time to recover.

In FY 2016 there were 60 instances of beam trip (Fig. 4). The most frequent cause came from magnet power supplies (14 times), followed by electrical system (8 times). The RF system, which caused considerable downtime in the previous year, contributed only 12% this year (7 times). This is a good indication that the problems associated with the solid-state power amplifier had finally been resolved.

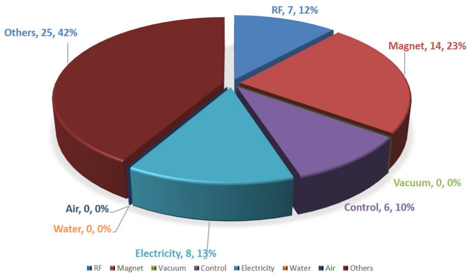

Figure 4: Causes of machine trip in FY 2016.

MACHINE IMPROVEMENTS

2nd Storage Ring RF System

A new RF system was successfully installed in the storage ring during 2016 Machine Shutdown. [2] The new cavity (Fig. 5) has maximum cavity voltage of 300 kV. (The old one has 125 kV.) The new amplifier (Fig. 6) has maximum power of 80 kW. (The old one has 30 kW.) The new system will allow SLRI to operate the superconducting wavelength shifter (SWLS) at its maximum magnetic field of 6.5 Tesla, which will in turn increase both the flux and the photon energy delivered to BL7 beamline.

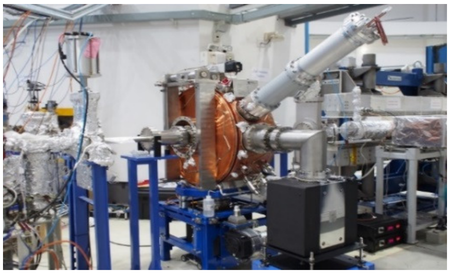

Figure 5: The new 300 kV RF cavity.

Table 1: Main Parameters of the 300 kV Cavity

Parameters	Values
Resonant frequency	118 MHz
Maximum cavity power	30 kW
Maximum coupler power	120 kW
Shunt impedance	1.56 MΩ
Quality factor Q_0	19000
Operation Temperature	42 °C
Cooling Water Flow	241 l/min

However, increasing the SWLS magnetic field is currently pending in order to give the Safety Group the time to properly conduct the investigation of radiation level in the Experimental Hall. In the future, the stored beam current will be increased as well.

Figure 6: The new 80 kW solid-state RF amplifier.

Improvement of Injection Efficiency

We were able to improve the injection efficiency significantly by employing an optimization algorithm called Robust Conjugate Direction Search (RCDS), [3] which was developed at SLAC. The algorithm successfully optimized the magnet currents of both Low-energy Beam Transport (LBT) and High-energy Beam Transport (HBT). (Fig. 7) After optimizing the LBT, the beam current in the booster synchrotron increased to more than 30 mA, and the injection rate to the storage ring increased from 40 mA/min to the record value of more than 100 mA/min. This enables us to reduce the injection time by half, from previously 1 hour to 30 minutes.

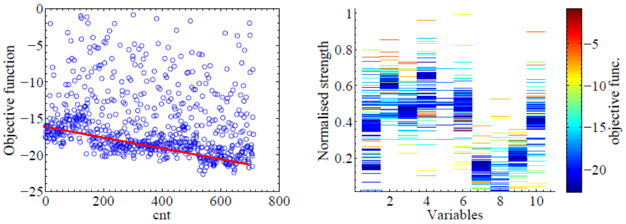

Figure 7: Injection optimization with RCDS.

In addition, we had developed a system for monitoring the efficiency of the beam transfer between each step of the injection process, from the electron gun to the storage ring (Fig. 8). This system proved to be extremely useful in assuring efficient injection and investigating the causes of low injection rate.

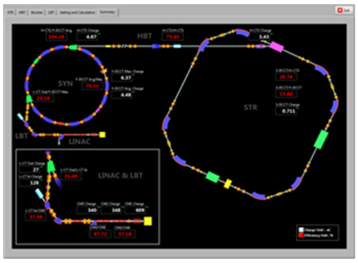

Figure 8: Injection monitoring system.

Reduction of Perturbations from IDs

Two high-field insertion devices, a 2.2 T multipole wiggler (MPW) and a 6.5 T superconducting wavelength shifter (SWLS) were installed in the SPS storage ring back in 2013. Installing such high-field magnets in a low-energy ring introduce considerable perturbation to the electron optics. Matching of optical functions as well as corrections of linear effects and closed orbit distortion were performed. [4,5] However, nonlinear effects had not been thoroughly studied and corrected due to time constraint.

Consequences from the nonlinear effects include reduction of beam lifetime and enlargement of electron beam size. After investigation, the main cause was found to be from the MPW. Its good field region spans only ±5 mm. The most severe consequence is the reduction of dynamic aperture (DA), as shown in Fig. 9. The DA decreases by approximately 75% by the MPW. In the case of SWLS, the DA is reduced by only about 25%. This is the reason the beam cannot be injected to the storage ring when the MPW gap is fully closed.

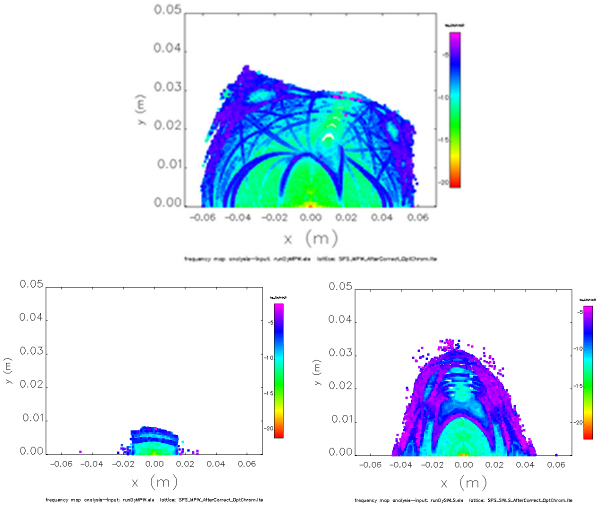

Figure 9: Dynamic apertures: (top) bare ring, (bottom left) with MPW, (bottom right) with SWLS.

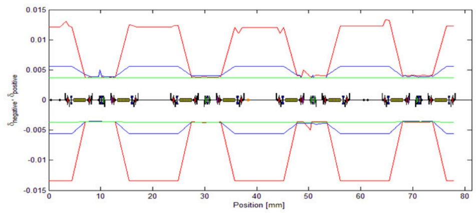

Figure 10: Momentum acceptance of the SPS storage ring with MPW when RF cavity voltage was 115 kV (green), 125 kV (blue), and 300 kV (red).

Another factor affected by the nonlinear effect from the MPW is the momentum acceptance (MA), which in turn affects the beam lifetime. MA is typically linearly proportional to the RF acceptance, which is determined by the RF voltage. However, it can be limited by the nonlinear effects, as shown in Fig. 10.

SLRI Beam Test Facility

Prior to last year, electron beam at SPS was used solely for synchrotron radiation generation. Now, a beam test facility (BTF) has been constructed and utilized for characterization of high energy particle detectors. [6] The new facility welcomes both domestic and international users.

FUTURE PLANS

Last year the energy upgrade of the booster synchrotron from 1.0 to 1.2 GeV was successfully completed. Work on injection to the storage ring at full energy is currently ongoing. While the SPS will be utilized and continually improved in the future, design work on a new 3 GeV machine, the SPS-II, is already underway. [7] Construction of the new high energy machine will provide users with higher-energy and more brilliant synchrotron light, making new experimental techniques available that are not achievable with the low energy SPS.

ACKNOWLEDGEMENT

The authors would like to express their sincerest gratitude to all members of Accelerator Division and all the supporting SLRI staffs.

REFERENCES

[1] P. Klysubun *et al.*, “Present status of the Siam Photon Source”, in *Proc. EPAC ’08*, Genoa, Italy, June 2008, paper WEPC034, pp. 2061-2063.

[2] N. Juntong *et al.*, “Commissioning of the SLRI storage ring second RF system”, presented at IPAC’17, Copenhagen, Denmark, May 2017, paper THPIK102, this conference.

[3] T. Pulampong, P. Klysubun, S. Kongtawong, S. Krainara, and P. Sudmuang, “Online optimisation applications at SPS”, presented at IPAC’17, Copenhagen, Denmark, May 2017, paper THPAB151, this conference.

[4] P. Sudmuang *et al.*, “Commissioning of the 2.4 T Multipole Wiggler and 6.5 T Superconducting Wavelength Shifter at Siam Photon Source”, in *Proc. IPAC ’14*, Dresden, Germany, June 2014, paper TUPRO068, pp. 1192-1194.

[5] P. Sunwong, P. Sudmuang, T. Pulampong, S. Krainara, S. Kongtawong, and P. Klysubun, “Minimization of nonlinear effects of insertion devices at SPS storage ring”, in *Proc. IPAC ’16*, Busan, South Korea, May 2016, paper THPMR049, pp. 3515-3517.

[6] K. Kittimanapun, N. Chanlek, P. Klysubun, S. Krainara, and S. Supajeerapan, “Improvement of electron intensity reduction system at SLRI beam test facility”, presented at IPAC’17, Copenhagen, Denmark, May 2017, paper MOPIK015, this conference.

[7] P. Klysubun, T. Pulampong, and P. Sudmuang, “Design and optimisation of SPS-II storage ring”, presented at IPAC’17, Copenhagen, Denmark, May 2017, paper MOPIK015, this conference.