BEAM DIAGNOSTICS AT SIAM PHOTON SOURCE

P. Klysubun†, S. Klinkhieo, S. Kongtawong, S. Krainara, T. Pulampong, P. Sudmuang, N. Suradet,
SLRI, Nakhon Ratchasima, Thailand

Abstract

In recent years the beam diagnostics and instrumentation of Siam Photon Source (SPS), Thailand synchrotron radiation facility, have been significantly improved for both the booster synchrotron and the 1.2 GeV storage ring. Additional diagnostics have been designed, fabricated, and installed, and the existing systems have been upgraded. This paper describes the current status of the beam diagnostics at SPS, as well as their respective performances. These systems include beam position monitors (BPMs), a diagnostics beamline, beam loss monitors (BLMs), real-time tune measurement setups, and others. Apart from the instrument hardware, the acquisition electronics along with the processing software have been improved as well. The details of these upgrades are reported herewith.

INTRODUCTION AND OVERVIEW

Siam Photon Source [1,2] is the Thailand 1.2 GeV synchrotron light source operated by Synchrotron Light Research Institute (SLRI). The facility is located in the province of Nakhon Ratchasima, approximately 250 km northeast of Bangkok. The accelerator complex comprises of a thermionic electron gun, a 40 MeV linac (LINAC), a low energy beam transport line (LBT) transferring 40 MeV electrons to a 1.2 GeV booster synchrotron (SYN), followed by a high energy beam transport line (HBT) transporting the electron beam to a 1.2 GeV storage ring (STR). The maximum stored beam current has been 150 mA, but soon will be increased after the installation of a new 300 kV RF cavity and a 80 kW solid-state RF amplifier, replacing the old 120 kV cavity and 30 kW amplifier, just completed in August this year. Delivered user beamtime ranges from 4,000 – 4,500 hours per year. Currently there are 10 photon beamlines utilizing the generated synchrotron radiation from infrared to x-ray spectral regions. To ensure stable and reliable operation, as well as to aid machine physicists in maximizing the machine performances, several types of beam diagnostics are placed along the electron beam paths to measure and monitor the characteristics of the electron beam.

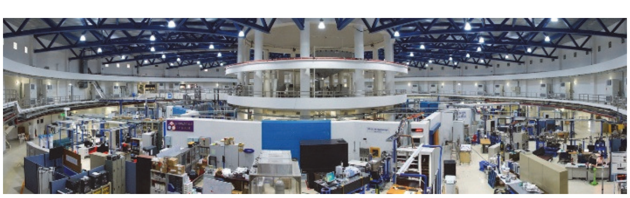

Figure 1: SPS experimental hall.

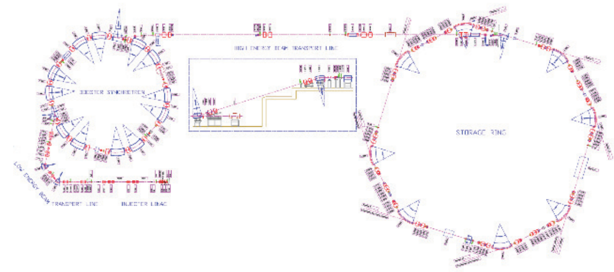

Figure 2: SPS machine layout.

LINAC AND LBT DIAGNOSTICS

Current Monitors (CMs)

Three wall current monitors (WCMs) placed along the beam path are used to measure the beam current in the linac section. The first CM (CM1) is located between the first and the second pre-bunchers (PB1 and PB2). The second and third CMs (CM2, CM3) are located at the entrance and the exit of the linac, respectively. A Pearson Electronics Model 3100 pulse current transformer (LCT) is located at the end of the LBT just before the beam entering the injection septum.

Screen Monitors (SMs)

The LBT is equipped with 3 SMs to monitor the transverse beam profile as well as the beam position. CCD cameras capture the beam images and send them to the control room. A unified control system controls the screens, the CCD cameras, as well as the lighting.

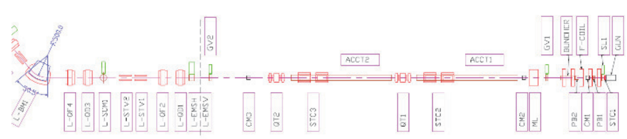

Figure 3: Linac and part of the LBT.

BOOSTER SYNCHROTRON AND HBT DIAGNOSTICS

Direct Current Current Transformer (DCCT)

The booster synchrotron is equipped with a DCCT capable of measuring 0 – 100 mA (± 0.2 mA) beam current. The output voltage is displayed directly on an oscilloscope in the control room.

† pklysubun@slri.or.th

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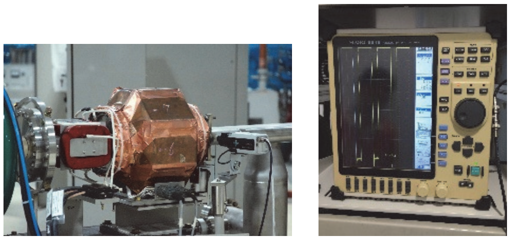

Figure 4: Booster DCCT (left) and oscilloscope displaying beam current in the control room (right).

Stripline Kicker

The stripline kicker is used to excite the beam for betatron tune measurement. [3] White noise generated with a function generator is sent to the stripline kicker. The resulting turn-by-turn signal is picked up by a button-type BPM connected to a Libera SPARK module. The collected signal is then analyzed with a MatLAB computer code. At first when we did not possess a necessary equipment for amplifying the white noise signal synchronously with the increasing beam energy, tune measurement at higher beam energy was found to be rather difficult. In 2016 we replaced the old Agilent 33250A function generator with a new Keysight 33500B 2-channel function generator. The white noise signal from one channel is combined with the ramping pattern from the other and sent to the stripline kicker. The whole measurement during energy ramping has to be performed piecewise (in 9.4 msec duration) with the help of a delay unit due to the limit of the Libera SPARK buffer size. The obtained set of data can be easily stitched together in software.

Fast kicker can also be used in place of the stripline kicker. This tune measurement setup has proved to be extremely useful for controlling machine parameters to maintain constant tunes during energy ramping and optimization of the operating point.

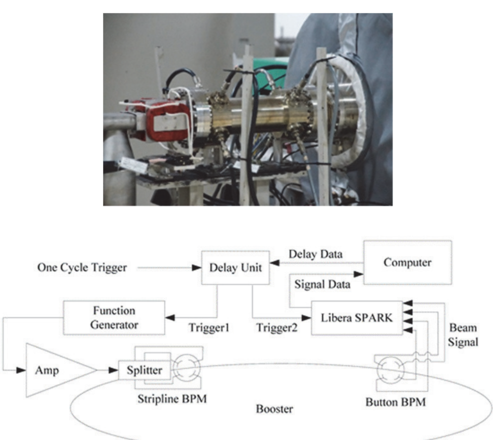

Figure 5: (Top) Stripline kicker. (Bottom) Schematic of the tune measurement setup. [3]

Screen Monitors (SMs)

The booster synchrotron and the HBT are equipped with 4 and 5 SMs, respectively. The control system is the same one described in the previous section.

Current Monitors (CMs)

Two WCMs are positioned in the HBT to monitor the beam current delivered to the storage ring. One integrated current transformer (ICT) from Bergoz Instrumentation (Bergoz Turbo-ICT FEFA) was recently added at the beginning of the HBT.

STORAGE RING DIAGNOSTICS

Beam Position Monitors (BPMs)

Originally there were 5 button-type BPMs in each of the 4 superperiods of the storage ring. Four additional BPMs were later added upstream and downstream of the 2.2 T Multipole Wiggler (MPW) and the 6.5 T Superconducting Wavelength Shifter (SWLS), resulting in the total of 24 BPMs overall. The button pick-up has N-type connector, and the button signals are collected and processed by Bergoz MX-BPM-118.00MHz electronic modules. Due to noisy signals all the BPM cables were replaced in 2011 with higher quality cables with better EM shielding and lower loss rate (HUBER&SHUNER SUCOFEED cables). [4] Instead of using the beam position data from the Bergoz electronics, we opt to calculate the transverse beam position from the electrode signals with 16-bit Allen-Bradley Programmable Logic Controllers (PLCs). The beam position from the PLCs are then moving averaged with a LabVIEW code. The sampling interval is 100 msec. [4] The averaged transverse position data can be accessed by MatLAB via Open Process Control (OPC) Toolbox.

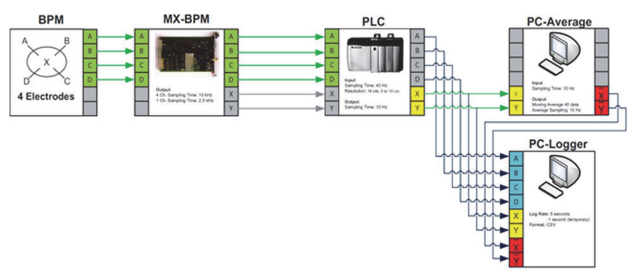

Figure 6: SPS storage ring BPM system. [5]

Diagnostics Beamline

The SPS diagnostics beamline [6] measures the transverse beam profile as well as monitors positional stability of the beam by utilizing optical synchrotron radiation (SR) from a bending magnet. The setup comprises of direct optical imaging and SR interferometer. The first beam splitter splits half of the light to the direct imaging system, which has an apochromatic lens focusing the beam to a CCD camera. The distance from the source point to the lens is 8.5 m. The rest of the beam is transmitted to the horizontal and vertical interferometers to measure the transverse beam profile in each plane. Both the beam image and the interference patterns are fitted using LabVIEW programming codes to determine the transverse beam profile. The schematic of the setup is shown in Fig. 7.

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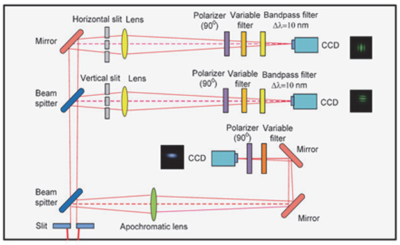

Figure 7: Schematic layout of the transverse beam profile monitor. [6]

Beam Loss Monitors (BLMs)

The SPS storage ring BLM system has received a major overhaul in 2014 in order to enhance its performance. [7] The system consists of 50 Bergoz PIN-diode type BLMs spread around the ring. Each of the BLM unit contains 2 PIN diodes operating in coincidence mode, and is powered by a regulated low noise power supply. Placement of these BLMs is not fixed since they were designed to be easily movable to accommodate investigation of beam loss. Mostly they are placed in the areas with large betatron and dispersion functions. RF shielded cables (HUBER&SHUNER RG-223/U) carry the beam loss signal to a National Instruments PXIe-6612 counter modules based on PXI Express platform. There are a total of 8 counter modules which are installed in an NI PXIe-1078 PXI Express chassis with a NI PXIe-8820 2.2 GHz Celeron dual-core controller processor and 2 GB, 1333 MHz memory. The PXI platform was chosen because of its performance, ruggedness, cost effectiveness, and expandability. The loss rate is calculated and displayed with the use of a LabVIEW code.

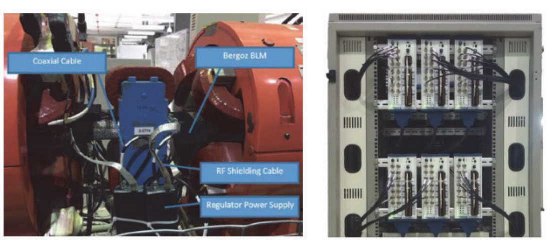

Figure 8: BLM unit (left) and PXIe counter modules (right). [7]

Direct Current Current Transformer (DCCT)

The storage ring is equipped with a DCCT capable of measuring 0 – 600 mA (± 0.1 mA) stored beam current. The output voltage is read by an Agilent 34401A digital multimeter (DMM). The integration time of the DMM is set to 10 NPLCs (Number of Power Line Cycles), which corresponds to 0.2 s. The readout is then sent to the PLC.

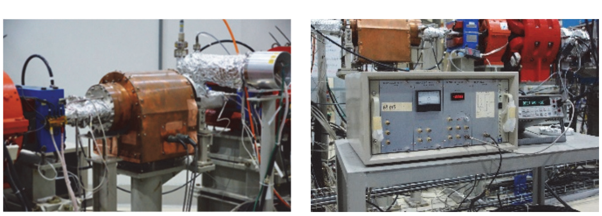

Figure 9: Storage ring DCCT.

Stripline Kicker

The stripline kicker is used for real-time tune measurement. The schematic of the setup is depicted in Figure 10. FM signal is generated by a Rohde & Schwarz SMC100A signal generator and sent to one of the striplines to excite the beam. The beam response is pick-up by two other striplines in diagonal position. The two signals are then combined with 180° phase difference. The sum signal is then sent to a Tektronix RSA5103A real-time spectrum analyzer.

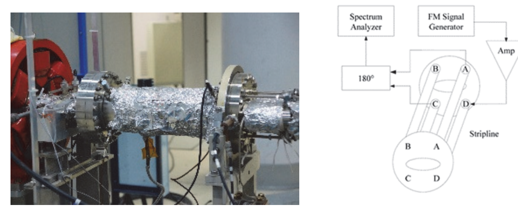

Figure 10: Stripline kicker (right) and real-time tune measurement setup (left) for the SPS storage ring. [3]

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