Design Status of the Diagnostic System for the TPS

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Abstract

Taiwan Photon Source (TPS) is a 3 GeV synchrotron light source which is being in construction at NSRRC. Designs of various diagnostics are undergoing and will deploy in the future to satisfy stringent requirements of TPS for commissioning, top-up injection, and operation. These designs which include beam intensity observation, trajectory and beam positions measurement, destructive profile measurement, synchrotron radiation monitors, beam loss monitors, orbit and bunch-by-bunch feedbacks, filling pattern and etc. are in final design phase. Details of current status and implementation of the planned beam instrumentation system for the TPS will be summarized in this report.

Introduction

- Civil construction was started from February 2010.
- The building will be finished in 2012.
- *Scheduled commissioning start in late 2013.*

Major parameters of the TPS booster synchrotron and the storage ring

	Booster Synchrotron	Storage Ring
Circumference (m)	496.8	518.4
Energy (GeV)	150 MeV – 3 GeV	3.0
Natural emittance (nm-rad)	10.32 @ 3 GeV	1.6
Revolution period (ns)	1656	1729.2
Revolution frequency (kHz)	603.865	578.30
Radiofrequency (MHz)	499.654	499.654
Harmonic number	828	864
SR loss/turn, dipole (MeV)	0.586 @ 3 GeV	0.85269
Betatron tune ν_x/ν_y	14.369/9.405	26.18 /13.28
Synchrotron tune ns	-	0.00611
Momentum compaction (α_1, α_2)	-	2.4×10^{-4}, 2.1×10^{-3}
Natural energy spread	9.553×10^{-4}	8.86×10^{-4}
Damping partition $J_x/J_y/J_s$	1.82/1.00/1.18	0.9977/1.0/ 2.0023
Damping time $\tau_x/\tau_y/\tau_s$ (ms)	9.34/ 16.96 / 14.32	12.20/ 12.17 / 6.08
Natural chromaticity ξ_x/ξ_y	-16.86/-13.29	-75 / -26
Dipole bending radius ρ (m)	17.1887	8.40338
Repetition rate (Hz)	3	-

The electron beam sizes and divergence

Source point	σ_x (μm)	$\sigma_{x'}$ (μrad)	σ_y (μm)	$\sigma_{y'}$ (μrad)
12 m straight center	165.10	12.49	9.85	1.63
7 m straight center	120.81	17.26	5.11	3.14
Dipole (1° source point)	39.73	76.11	15.81	1.11

Linac and Transport Line Diagnostics

Linac diagnostics

Monitor	Quantity	Beam parameters
YAG:Ce screen	5	Position & Profile
WCM	1	Intensity distribution
FCT	2	Intensity distribution
ICT	1	Charge at exit of the linac

- TPS 150 MeV linac has been contract to RI Research Instruments GmbH.
- The schedule for delivery and commissioning is in early 2011 at test site.
- The linac will move to the TPS building in late 2012 after TPS building available.
- All diagnostics of the linac system is provided by the vendor.
- YAG:Ce screen monitors for beam position and profile observation.
- The fast current transformers (FCT) for monitor the distribution of charge.
- The integrating current transformer (ICT) for monitoring total bunch train charge.

LTB diagnostics instruments

Monitor	Quantity	Beam parameters
YAG:Ce/OTR screen	6	Position, profile(1 at diagnostic branch). OTR screen will be adopted for the site of high precision profile measurement to avoid saturation of YAG:Ce screen.
FCT	2	Beam intensity
ICT	1	Beam charge
BPM and single pass electronics	7	Beam position
Energy define slit	1	1 pair of horizontal jar

BTS diagnostics instruments

Monitor	Quantity	Beam parameters
YAG:Ce/OTR screen	3	Position, profile, booster extraction beam emittance
FCT	1	Beam intensity
ICT	2	Beam charge, installed at upstream and downstream of the BTS
BPM and single pass electronics	6	Beam position, relative intensity

- The YAG:Ce fluorescence screens will provide information of beam position and profile.
- The OTR screens are also considered to be used for high precision of beam emittance and energy spread measurement
- The ICT will provide information of beam charge pass LTB and BTS and hence the beam losses during the injection cycle.
- The beam trajectory will be monitored with BPM equipped with Libera Brilliance Single-Pass, its functionality for single pass measurement.

Booster Ring Diagnostics

Booster synchrotron diagnostics instruments

Monitor	Quantity	Beam parameters
NPCT	1	Averaged beam current
FCT	1	Fill pattern
BPM (4 button pick-ups)	60	Beam position
Set of striplines and amplifiers	2	Betatron tune, bunch cleaning system
YAG:Ce screen (fluorescent screen)	6	Beam profile and position at injection, extraction, and at every lattice cells
Synchrotron light monitor, profile and streak camera (visible light)	2	Beam size (emittance), bunch length
Bunch cleaning system	1	-

- Fluorescent screens will be installed at injection and extraction section and at the other lattice cells to facilitate booster commissioning, troubleshooting and psychology needing.
- Booster orbit will be monitored with 60 BPMs with turn-by-turn capability.
- The sum signal from the receivers can be used to monitor fast history of the beam current.
- Circulating current will be measured with NPCT, while bunch pattern will be monitored with FCT.
- For tune measurement, the electron beam will be excited with white noise using striplines. The beam response will be observed with a real-time spectrum analyzer connected to the dedicated BPM buttons with the front end.
- There will be an extra set of striplines for a bunch cleaning system and for users who need a specific filling pattern in the storage ring.
- Synchrotron radiation from a dipole will be used to observe the beam profile during energy ramping and emittance measurements.
- The capability to monitor bunch length with a streak-camera will be also provided.

Storage Ring Diagnostics

Storage ring diagnostics instruments

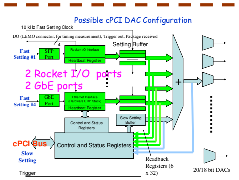
Monitor	Quantity	Beam parameters
NPCT	1	Averaged beam current, beam lifetime
Sum signal of BPM buttons	1	Fill pattern, bunch current
BPM (4 button pick-ups)	168	7 BPM/cell
BPM (4 button pick-ups)	1	For bunch-by-bunch feedback pickups
Striplines	1	Betatron tune measurement
Transverse kickers and amplifiers	2	Horizontal and vertical kicker for transverse feedback and bunch cleaning usage.
YAG:Ce screen (Fluorescent screen)	1	Beam profile and position just after injection septum
PIN diode type beam loss monitors	4~6 per cell	Beam loss pattern
Scintillation loss monitor	24	High counting rate type beam loss monitor
Scrapers	2 sets per plane	1 set = 2 blades

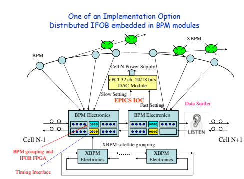
- The storage ring diagnostics including averaged beam current, fill pattern, beam lifetime, closed orbit, working tunes, chromaticity, beam size, beam loss pattern, beam density distribution, emittance, bunch length, and etc.
- The NPCT provides a resolution of better than 1 μA/Hz[1/2] and has large dynamic range and bandwidth to make itself a versatile device for measuring lifetime and injection efficiency.
- The storage ring filling pattern observed from the sum signal of BPM buttons by wide bandwidth fast digitizer sampling at RF or a multiple of RF frequency will enable measurement of the bunch current to better than 0.5% accuracy.
- Libera Brilliance BPM was chosen as baseline design at the conceptual design phase.
- Updated BPM electronics platform equip with more advanced parts and enhanced functionality are in serious consideration and discussed with the possible vendor. The TPS will most likely adopt the new BPM platform.

Synchrotron radiation diagnostics instruments

Monitor	Quantity	Beam parameters
X-ray pinhole camera	2	Emittance vertical and horizontal planes. Averaged profile, single turn profile, profile of the selected bunch.
Streak camera	1	Bunch length.
Time correlated single photon counting system (Visible light or X-ray)	1	Filling pattern. Isolated bunch purity.
XBPM	1 or 2 per beamline	Position and angle of ID radiations.
Visible light synchrotron light diagnostic station, Imaging and streak camera	1	Alternative beam size measurement (emittance), either imaging the vertical polarized synchrotron light or interferometer, bunch length.

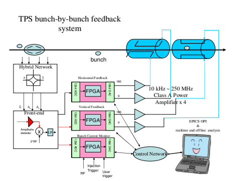
- The photon diagnostics for the TPS storage ring will utilize visible and X-ray synchrotron radiation generated in a bending magnet.
- Visible light beamline will be built to measure various beam parameters by streak camera, CCD camera and interferometer.
- Synchroscan mode operate for the streak camera at 250 MHz is preferred. Integrating the streak camera system with EPICS is preferred.
- Two X-ray pinhole cameras imaging the electron beam from bending magnets is the baseline design for the emittance measurement and measure the electron beam size at all currents from < 1 mA to 400 mA.
- The X-ray photon BPMs (XBPM) will be installed at each beamline. The slow data for control system access and the fast data for feedback purpose.
- Prototype of Libera Photon has been testing intensively at the 1.5 GeV TLS.
- Measuring the filling pattern by using time correlated single photon counting (TCSPC) is also considered. And APD detector to detect scattered X-ray photon will provide signal input for the TCSPC system. More than six order of dynamic range are expected.





Infrastructure for orbit measurement, control and feedback

- Slow orbit acquisition will perform by channel access to the BPM platform embedded EPICS IOC up to 10Hz rate.
- Fast orbit beam position will circulate around all BPM platform at 10 kHz rate by using FPGA grouping scheme (e.g. Diamond Communication Controller or Gigabit Ethernet Grouping) or a new design.
- The TPS will adopt special design high performance corrector power supply. The power supply will use analog regulator, adopt bias analogue PWM scheme to improve zero current crossover problem.
- Improves integrated noise level form DC to 1 kHz down to a few part per million of the output full scale corresponding to nano-radian level kick for slow corrector with maximum ±600 μrad kick.
- Control of each cell's corrector will be through a special design 20 bits (or 18 bits) DAC module. This module will provide EPICS CA interface via cPCI backplane for configuration, and setting and status monitoring.
- The 10 KHz rate data stream fast setting ports might configure as Rocket I/O for orbit feedback application and Gigabit Ethernet for global feed-forward applications.
- Functionalities of this FPGA module will perform: one for BPM data grouping and the other for feedback engine. BPM data grouping provides a way to distribute all BPM and XBPM data around the TPS storage ring at all BPM platforms in 10 kHz rate.
- Orbit feedback computation will distribute to the FPGA modules installed at the BPM platform in each cell.
- Sniffer nodes will be setup to capture orbit information in 10 kHz rate for more than 10 sec and decimated data at lower rate for much longer record time for various applications and analysis.



Bunch-by-bunch feedbacks and diagnostics

- Transverse coupled-bunch instability mainly caused by the resistive wall impedance and other sources will deteriorate beam quality. Two plane Bunch-by-bunch feedback system is planned to suppressed instabilities.
- Transverse feedback kickers are planned to adopt the SLS/ELETRA design and compatible with TPS vacuum vessel. Transverse signals pick-up will be used as an extra BPM and installed at location of high beta function.
- Beside feedback functionality, the feedback electronics and software also support bunch oscillation data capture for analysis to deduce rich beam information, tune measurement, bunch clearing, and beam excitation and etc.
- Features of the planned system include the latest high dynamic range ADC/DAC (12/16 bits), high performance FPGA, flexible signal processing chains, flexible filter design, bunch feedback, tune measurement, bunch cleaning, various beam excitation scheme, flexible connectivity, and seamless integrated with the control system.
- On-line control interface to operate feedback system and off-line analysis tools should be included.
- Testing of the Libera Bunch-by-Bunch and the iGp are on going at the 1.5 GeV Taiwan Light Source.

Summary

Beam diagnostics designs and implementation for the TPS are in proceed. Status is summarized in this report. The critical diagnostic systems, addressing beam stability and low emittance monitoring, are being investigated in the design phase. Major procurement are scheduled in 2011~2012. Optimizing the design, prototyping and working out on specifications are current efforts. System integration is planned in 2013. Delivering a best diagnostics system to satisfy stringent requirements of TPS is the goals.

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