SSRF BEAM INSTRUMENTATIONS SYSTEM*

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Abstract

We present an overview of the beam instrumentation system that will be implemented at the Shanghai Synchrotron Radiation Facility (SSRF). The system specification, sensors layout and data acquisition system architecture are introduced. Several key technologies such as Storage Ring BPM pickup, digital BPM processor and soft IOC are detailed.

OVERVIEW

SSRF is a third generation light source, consisting of a 150MeV linear accelerator (LINAC), a LINAC to booster transfer line (LTB), a full energy booster (BS), a booster to storage ring transfer line (BTS), and a 3.5GeV storage ring (SR) [1].

SSRF construction officially began at 25th of December 2004. In this summer the LINAC was commissioned and archived the design goal. The booster commissioning started at the Sep.30 on schedule, and the first stored beam was archived in the next day. The most of beam instrumentation components work well and give the strong support for rapid commissioning. The storage ring commissioning will begin at the end of this year.

Table 1 shows the specification of the various diagnostics systems.

Table 1: SSRF Beam Instrumentation Specifications.

	Measurement	Specification
LINAC LTB BTS	Beam position	Resolution 100 μ m@2Hz
	Beam profile	Resolution 200 μ m@2Hz
	Bunch charge	Relative accuracy 2%
	Energy	Relative accuracy 0.1%
	Emmitance	Relative accuracy 10%
BS	Beam position	Resolution 100 μ m@1.67MHz
	Beam profile	Resolution 200 μ m@2Hz
	DC current	Resolution 50 μ A@10kHz
	Tune	Resolution 0.001
SR	Beam position	Resolution 10 μ m@694kHz Resolution 1 μ m@10kHz
	Beam profile	Resolution 10 μ m
	Beam length	Resolution 2ps
	DC current	Resolution 10 μ A@1Hz
	Tune	Resolution 0.0001

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SYSTEM ARCHITECTURE

Diagnostics Sensor Layout

Based on the above requirements, a broad range of beam instrumentation systems, consisting of 257 sensors and 1 dedicated diagnostics beam line, has been included in the design of all parts.

The key diagnostics subsystem is the beam position monitor (BPM) based on stripline pickups and button pickups. The BPM electrode assemblies for the LINAC, LTB, BS and BTS share a common mechanical design. They contain 15 cm long (for LINAC) or 10 cm long (for other parts), shorted striplines with 50-ohm impedance. The four button pickup assembly is employed in the ring due to small size and low coupling impedance.

PCT manufactured by Bergoz Electronics is used for measuring the average beam current, the beam life time and the injection efficiency into the booster and storage ring.

Wall current monitor (WCM) manufactured by TOYAMA is chosen to present the longitudinal distribution of the beam in the LINAC, LTB, BS and BTS.

The beam profile monitor (PM) is based on an $A1_2O_3$ (Cr) screen material and a standard charge-coupled device (CCD) video camera. They are placed over the whole machine to trace the beam at the beginning stage.

Monitoring of the charge in the LINAC and BTS is based on the use of integration current transformers (ICT) manufactured by Bergoz. A faraday cup is employed as a reference at the end of LINAC.

The stripline kicker assembly with two electrodes is used to excite beam motion for tune measurement in the both booster and storage ring. The tune value will be derived from the turn by turn data of anyone of Libera units in the booster or ring.

The dedicated diagnostics beam line is located at the end of the 2^{nd} bending magnet of the first cell in the ring. It contains a stream camera, a fast gated camera, two space interferometers (horizontal and vertical) and a standard CCD.

A multi bunch transverse feedback system (MBTF, bandwidth 250MHz), consists of a button BPM assembly, a Spring-8 digital signal processing module and 2 stripline kickers, will be implemented in the storage ring to minimize bunch by bunch instability.

The slow orbit feedback system (bandwidth < 0.1Hz) based on Libera 10Hz data, EPICS CA protocol and MatLAB application will be implemented for the storage ring in the first stage. In the second stage the fast orbit feedback system (bandwidth 100Hz) based on Libera 10kHz data, private optical network and VME feedback controller will be added. Then both of them work together to stable the beam orbit on micron level.

Table 2 gives a summary of the various systems in all locations.

Table 2: SSRF Beam Instrumentation sensors distribution.

	LINAC	LTB	BS	BTS	SR
Stripline BPM	3	3	50	5	
Button BPM					152
PCT			1		2
WCM	5	2	1	3	
PM	5	3	4	4	2
ICT	1			1	
Faraday cup	1				
Tune monitor			1		1
Slit		2		1	
Scraper					2
Diag beamline					1
MBTF					1
Orbit feedback					1

Data Acquisition System

The beam instrumentation data acquisition system is designed on EPICS platform, which follows "standard model" architecture[2], shown in Fig 1.

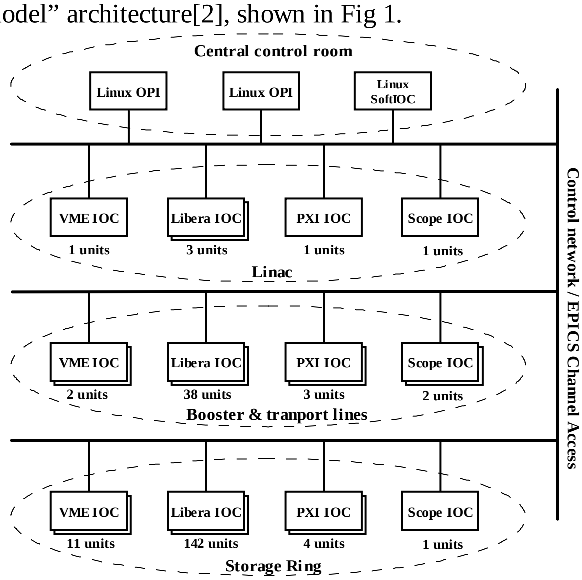

Figure 1: SSRF BI data acquisition system architecture.

There are five kinds of IOCs involved into the beam instrumentation:

- VME bus IOCs (11 in the ring, 2 in the booster, 1 in the LINAC), running VxWorks real time operation system and EPICS core, are equiped with timing module to deliver trigger signals for each diagnostics station..
- Libera[3] embedded IOCs (142 in the ring, 30 in the booster, 3 in the LTB, 5 in the BTS, 3 in the LINAC), running Linux EPICS kernel, are dedicated devices for BPM signal processing and orbit feedback system. Two extra Libera IOCs will be used for booster and storage ring tune measurement.
- PXI bus IOCs (4 in the ring, 3 in the booster, 1 in the Linac), running Windows operating system and Shared Memory IOC EPICS interface, are used for profile monitor, slit, scraper, PCT data acquisition and beam feedback system control.
- Scope embedded IOCs (1 in the ring, 2 in the booster, 1 in the LINAC), running Windows EPICS kernel, are used for wall current monitor, ICT and faraday cup data sampling.
- Soft IOCs (1 in the ring, 1 in the booster), running Linux EPICS kernel, collecting turn by turn beam position data from Libera IOCs, provide online beam spectrum and tune monitor service.

Fig. 2 presents the diagram of the associated software.

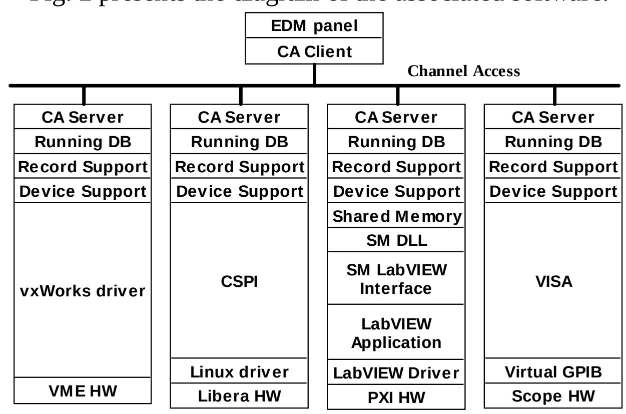

Figure 2: Diagram of SSRF BI software system.

The timing card (Event receiver) is a standard VME bus module used by Swiss Light Source and Diamond Light Source, which driver package is supported by EPICS community.

The libera EPICS support package is adopted from Diamond Light Source, which talks to hardware through Control System Programming Interface (CSPI) layer and linux device drivers. All data path including ADC raw data, turn by turn, first turn and slow acquisition can be access via EPICS CA.

PXI IOC software can be separated into two parts. The first part is LabVIEW low level application, which is developed in house, to complete raw data acquisition and signal processing. The second part is the Shared Memory IOCcore and SM LabVIEW library, which is developed and maintained by SNS/ORNL[4], to implement the interface between low level LabVIEW application and EPICS CA server.

Scope IOC software is developed by SSRF BI group following the Windows EPICS application rule. The device driver module talks to hardware via VISA and virtual GPIB layer.

On the operator side almost the all panels are made on EDM platform except the LINAC emmitance monitor, which is a MatLAB application connected to EPICS via MCA.

KEY DEVICES

Button Pickup Assembly

The button pickup assembly is the most critical component in the ring BPM and orbit feedback system. To give better installation accuracy and lower magnetic permeability, the pickup assembly is designed in a pair buttons structure with two Titanium button-type electrodes, two 50 Ω SMA feedthroughs and a 316L SST housing flange. Small button size (10mm diameter) and small gap (0.3mm) between button and housing is chosen to minimize coupling impedance. Total of 400 pieces of pickup assemblies has been fabricated by Kyocera and delivered to SSRF site. Mechanical inspection, vacuum inspection, LCR meter inspection and TDR scope check have been applied to all units. The result shows that all units meet the specification.

Digital BPM Processor

All BPM signal processing and data acquisition will be uniformed into one kind of electronics: Libera digital EBPM processor, which is produced by Instrumentation Technologies. Since Libera samples RF signal directly and produces beam position data using DDC and digital filtering technologies, it has capability to deliver turn-by-turn data, fast orbit data and slow orbit data at the same time [5].

Total 200 units have been fabricated and delivered to the site at the end of July 2007. A dedicated EPICS and LabVIEW based evaluation platform has been built to do final acceptance test. Evaluation result proves this device fully satisfied the requirement of LINAC, booster and ring. The preliminary operation during the LINAC commissioning shows that RMS noise is lower than 33 microns for 1nC single-pass beam.

Soft IOC

Two HP workstations, running as soft IOCs, have been added into the booster and storage ring respectively. This soft IOC will collect turn-by-turn beam position data from all Libera IOCs and calculate beam spectrum, tune, RMS noise, and histogram online. The raw data and derived results will be represented in different forms such as XY plot, histogram plot and water-fall plot.

PROGRESS

The LINAC BI system installation has been completed at the end of March 2007. The half an years operation proves itself a precise meter and diagnostics toolkits for operator.

The booster commissioning started at the 30th Sep. The first beam went to the end of LTB within 2 hours and accumulated in the booster within 24 hours. The fully functional BI system plays a key component during this rapid commissioning. Fig. 3-5 shows the details of the beam.

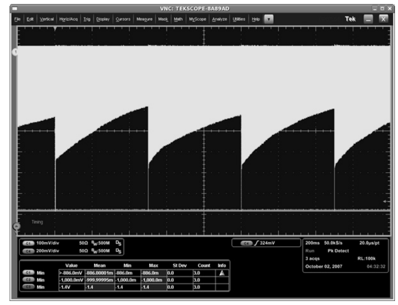

Figure 3: Stored beam signal from WCM.

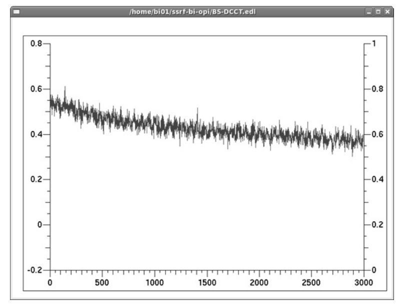

Figure 4: Average beam current from PCT.

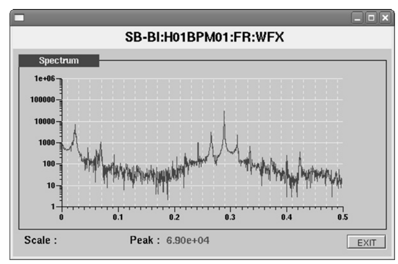

Figure 5: X plane tune calculated from Libera TBT data.

The ring BPM pickups and electronics have been delivered to SSRF site. Other components in the ring are still in fabrication stage. The pre-commissioning date of the ring BI system is scheduled to Dec 2007.

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