BEAM INSTRUMENTATION SYSTEM DEVELOPMENT AND COMMISSIONING IN SSRF

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Abstract

In recent months the first beams have been stored in the Storage Ring of the Shanghai Synchrotron Radiation Facility (SSRF). The brief introduction will be given of the beam diagnostics system development. The initial commissioning results including beam profile monitors, beam position monitors (BPMs), DC current monitors (DCCT), and synchrotron radiation monitor (SRM) will be reported in this paper.

SYSTEM 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].

Table 1 shows the specification of the various diagnostics systems.

Table 1: SSRF Beam Instrumentation Specifications

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

To meet this specification a beam instrumentation system, consisting of 257 sensors and 1 dedicated diagnostics beam line, has been developed and implemented. Table 2 gives a summary of the various subsystems in all locations.

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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

The key components are beam position monitors (BPM) based on stripline pickups for the LINAC, LTB, Booster and BTS, and button pickups for the Ring. PCT manufactured by Bergoz Electronics is used to measure 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. Beam profile monitor (PM) is based on an $A1_2O_3$ (Cr), YAG and OTR screen material and a standard charge-coupled device (CCD) video camera. Integration current transformers (ICT) manufactured by Bergoz and faraday cup is employed to measure bunch charge. Stripline kicker assembly with two electrodes is used to excite beam motion for tune measurement in the both booster and storage ring. 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, has been 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 has been test in the storage ring at the first stage. At the second stage the fast orbit feedback system (bandwidth 100Hz) based on Libera 10 kHz 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. The dedicated diagnostics beam line is located at the end of the 2nd 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.

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

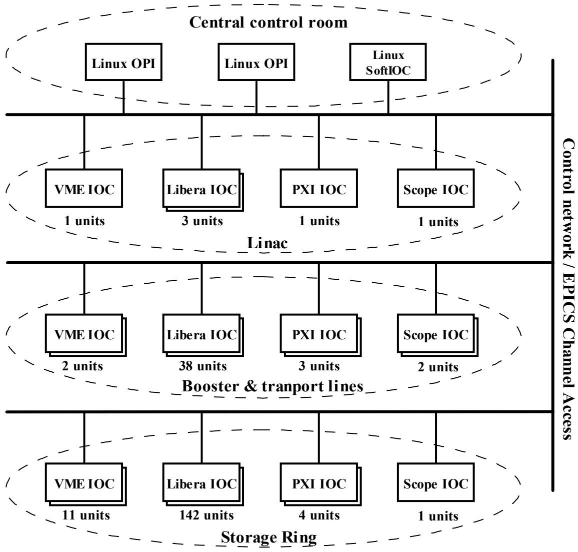

Figure 1: SSRF BI data acquisition system architecture

Five kinds of IOCs were used in this system: VME bus IOC, Libera embedded IOC, PXI bus IOC, scope embedded IOCs, and soft IOC.

Fig. 2 presents the diagram of the associated software. The timing card (Event receiver) is a standard VME bus module 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. PXI IOC software can be separated into two parts: LabVIEW low level application to complete raw data acquisition and signal processing, and the Shared Memory IOCcore to implement the interface between low level LabVIEW application and EPICS CA server. Scope IOC software is developed by SSRF BI group. The device driver module talks to hardware via VISA and virtual GPIB layer.

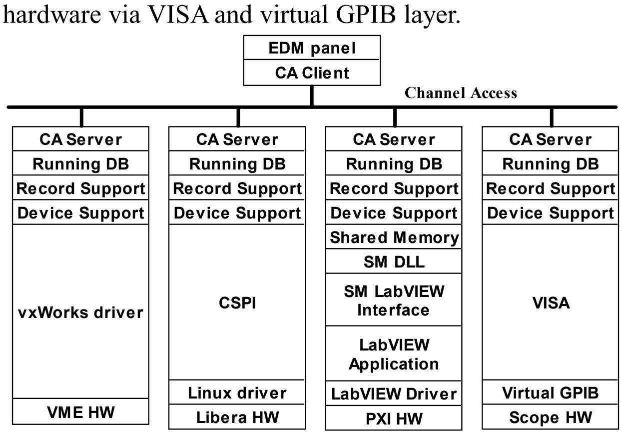

Figure 2: Diagram of SSRF BI software system

COMMISSIONING

Beam position monitor

Beam position monitor system fully equipped with Libera EBPM processors, which provides raw ADC data, turn by turn (694kHz @ ring, 1.67MHz @ booster) data, fast application (10kHz) data and close orbit (10Hz) data at the same time, is the most powerful tools during the commissioning and machine study of SSRF [3].

Beam position in the LINAC is calculated from raw ADC data of Libera. 40um position resolution and 3pC bunch charge sensitivity have been reached during commissioning. Calibrated by ICT, the sum signal of BPM has been use to give a fast estimation of bunch charge and transport efficiency of LINAC during daily operation.

For the booster raw ADC data and turn by turn (1.67MHz) data are much useful than others. Synchronized by gun-shot trigger the raw ADC data could deliver first turn information. In this way 30 BPMs around the booster ring acted as beam arriving monitor to help operator tuning the machine to store injected beam during the day one commissioning. Decimated turn by turn data from all BPMs is used to present dynamic beam orbit during energy ramping. The beam spectrum, calculated from 400k samples of turn by turn data acquired with the tune exciting kickers on, is used to determine the tune drift during energy ramping. Turn by turn position resolution is better than 50um with 1mA beam current. The resolution of tune measurement is better than 0.001. Fig. 3 showed a typical ramping tune measurement.

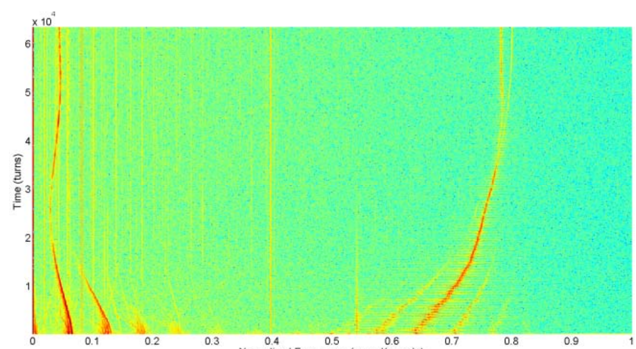

Figure 3: Ramping tune measurement in the booster

As same as booster commissioning the first turn information derived from raw ADC data help operator to determine beam loss location and tuning machine to store the first beam very quickly (few hours). SA data (10Hz), which position resolution reaches hundred nm level, resents precise closed orbit of the ring. Calibrated by DCCT the sum signal of SA data also could be used to present beam current and calculate beam lifetime. The beam spectrum (FFT of fast application data) is ideal tools to identify orbit noise source. With one million samples the frequency range of beam spectrum could cover from .1 Hz to 5 kHz. Current dependent instability has been observed with this tool. Global turn by turn capability and 5 um position resolution provides a powerful platform to accelerator physicists and operators. Response matrix measurement, Optics optimization, global and local phase advance measurement, phase space measurement, daily operation tune monitor (resolution E-4) and precise tune measurement (better than E-5) have been performed based on turn by turn data. Fig. 4 showed a typical COD measurement in the ring.

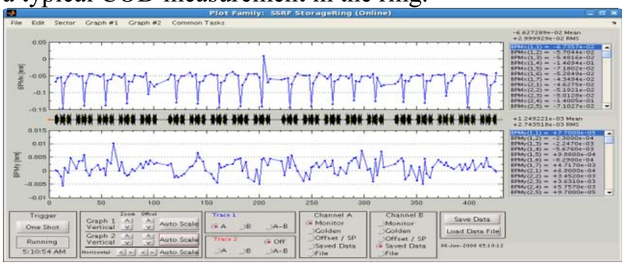

Figure 4: Measured COD in the ring

DCCT

The same design and hardware configuration has been used for the booster and ring DCCT system. A PXI based 6.5 digits digital multi meter module is adopted to digitize PCT output voltage signal at 10k Hz sampling rate.

10 kHz raw data is used to present beam current during energy ramping for the booster. This measurement suffered for huge baseline drift (10 times large than signal) due to magnet power supplies ramping at the beginning stage. After the evaluation of noise signal repeatability the baseline adjustment has been performed to remove this drift. The results showed that the beam current waveform could be perfect restored with baseline adjustment. Current resolution is better than 0.03mA @ 10 kHz with this processing.

In the ring 10 kHz raw data is averaged to 2 Hz to remove high frequency noise. Data acquisition trigger is a little bit behind injection trigger (10 ms) to avoid spike noise signal from injection power supplies. Current resolution is better than 1.6 uA @ 2 Hz. Beam lifetime is calculated in DCCT IOC with exponential decay curve fitting. The measurement uncertainty of beam lifetime is about 1%. Fig. 5 showed a typical measurement of beam current and beam lifetime.

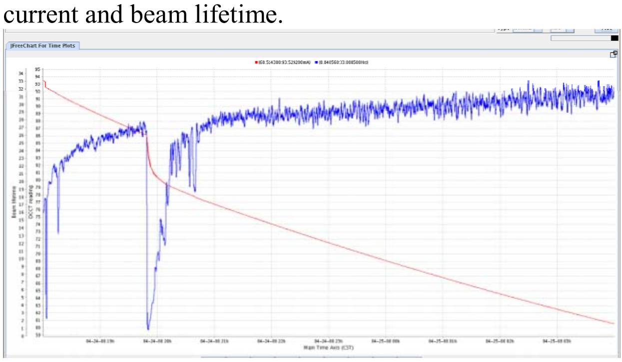

Figure 5: Beam current and lifetime measurement

Synchrotron radiation monitor

The ring synchrotron radiation diagnostics beam line consists of five branches for different measurements: a normal imaging system to measure electron beam profile; two SR interferometers (horizontal and vertical) to do the precise beam size measurement; a 2D streak camera for bunch length measurement and multi bunch instability study; a fast gated camera (gate width 3ns) for injection optimization.

In the first stage imaging system and interferometers have been implemented. The image system captured the first light at the day one. The preliminary experiments of interferometers showed the vertical beam size is about 60 to 100 micron. Fig. 6 showed a typical interfere pattern during beam size measurement.

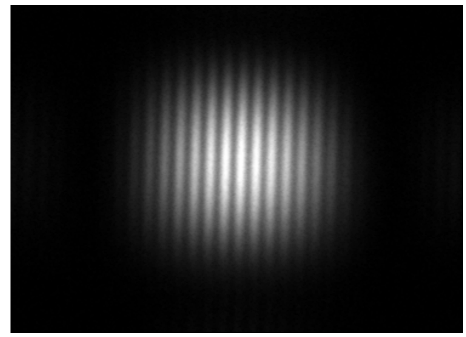

Figure 6: Interfere pattern during beam size measurement

Other components

Phosphor screen beam profile monitors became the favourite instruments during LINAC, transport line, and booster commissioning. For injection commissioning operators like to use oscilloscope with wall current monitors.

CONCLUSION

Both the machine and the diagnostics systems have now been commissioned for 100 mA runs. Sub-micron level position resolution and turn by turn measurement capability make BPM system the most important toolkits in operation. All other beam instruments such as DCCT, SRM and so on work well and have demonstrated the required performance. Streak camera and transverse feedback system will be commissioned in the soon future to join the next run.

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