SSRF BEAM DIAGNOSTICS SYSTEM COMMISSIONING*

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Abstract

SSRF is a 432 m-circumference synchrotron light source with a 150MeV linac, a 3.5GeV full energy booster, and a 3.5GeV storage ring. Principal diagnostics systems have been installed and nearly all have been commissioned during past two years. Data have been obtained on beam position, beam profile, current, and synchrotron radiation diagnostics beamline on the storage ring. Multi bunch transverse feedback system has been applied on the ring. Results for the 150MeV electron beams in the linac, up to 3.5GeV in the booster, and 3.5GeV in the ring will be presented.

INTRODUCTION

SSRF is a 3.5 GeV energy dedicated electron synchrotron radiation source. Recently the commissioning performance goals of the whole facility were met. Multi-bunch beam intensity of the ring has reached 200mA. At 200 mA, the lifetime is larger than 10 hour with all ID gaps closed. The commissioning process went very rapidly. Instrumentation played a critical role [1].

Table 1 shows the primary specification of the various diagnostics systems.

Table 1: SSRF Beam Instrumentation Specifications

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

To meet above requirements a beam instrumentation system, consisting of 61 stripline BPMs, 152 button BPMs, 2 DCCTs, 11 Wall Current Monitors (WCM), 3 ICTs, 1 faraday cup, 18 screen monitors, 2 tune monitors, 3 transport line slits, 2 ring scrapers, 1 multi bunch feedback system and 1 dedicated diagnostics beam line, has been developed, implemented and commissioned during past 4 years.

The data acquisition system for beam instrumentation is designed on EPICS platform, which follows “standard model” 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 [2].

BEAM POSITION MONITORS

Position Measurement

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.

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.

For the Ring 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 3 um position resolution provides a powerful platform for accelerator physicists and operators to perform Response matrix measurement, Optics optimization, global and local phase advance measurement and phase space measurement.

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Figure 1 shows position resolution test result for COD measurement of the Ring.

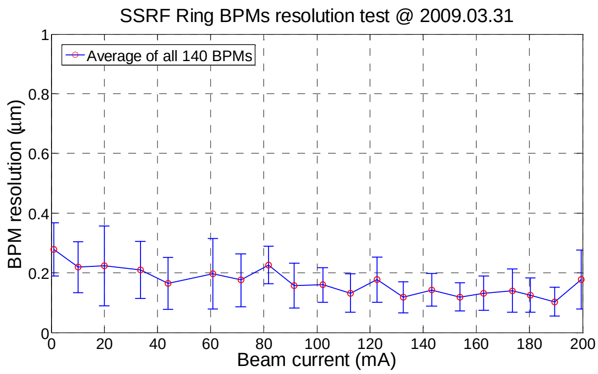

Figure 1: Ring BPM COD resolution test.

Tune Measurement

The Ring and Booster share the same tune monitor design, which is based on continuous harmonic excitation method. The measurement system employs a LAN based function generator, which output, after splitting and amplification, is fed to a strip line kicker. A dedicated BPM pickup equipped with Libera processor is used to observe the beam spectrum and betatron peaks. The betatron tunes and beam sizes have been measured under various configurations of function generator to figure out the best setup. The resolution of tune measurement is better than 0.001. Fig. 2 shows the Booster tune drift during ramping.

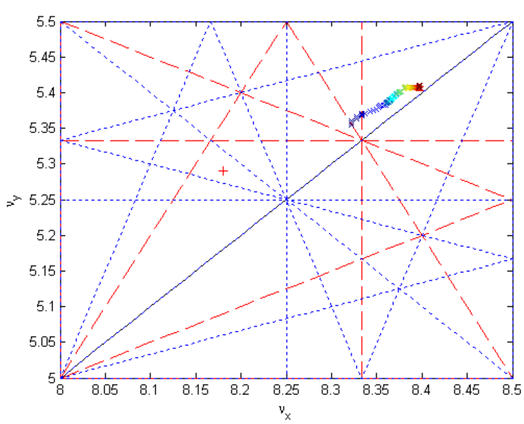

Figure 2: Booster tune drift during ramping.

Filling Pattern Monitor

A filling pattern monitor, which consists of a dedicated BPM pickup, a PXI based IOC and waveform recorder module (Acquiris DC252, BW 2GHz, sampling rate 8GHz), has been developed to perform bunch charge measurement and filling pattern observation in the Ring. By summing the BPM pickup voltage signals of four buttons in RF combiners, the position sensitivity is considerably reduced. Calibrated by DCCT readings the filling pattern monitor reaches 1pC resolution at 1nC range for bunch charge measurement.

DIAGNOSTICS BEAM LINE

The ring synchrotron radiation diagnostics beam line works with visible light, which consists of five branches for different measurements: an imaging system focused on source point to monitor electron beam profile; two SR interferometers (horizontal and vertical) to perform the precise beam size measurement; a 2D streak camera (HAMAMAZU C5680) for bunch length measurement and multi bunch instability study; a fast gated camera (gate width 3ns) for injection optimization [3].

The imaging system was ready on day one and the first stored beam was confirmed with this device. The interferometers have been online since June 2008. Experiments with high current beam (larger than 30mA) shows the beam size measurements deviation is about 1μm. The beam sizes have been measured with this device under various beam current conditions, which is shown in Fig. 3.

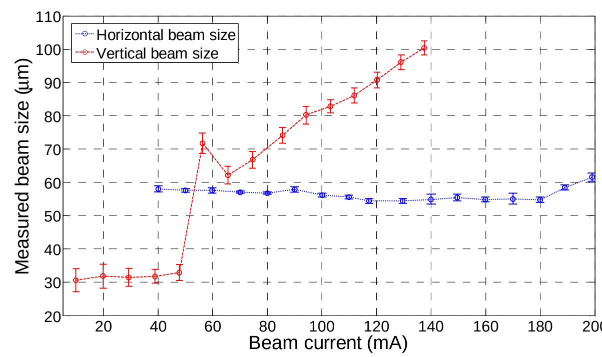

Figure 3: Beam size measured by interferometer.

The primary tests of streak camera and fast gated camera showed the performance of them agreed with the FAT report from producers. Both of them will be put online soon. Another Xray pinhole camera is in manufacture stage and will be installed in the same location to measure beam profile and position for cross checking.

TRANSVERSE FEEDBACK

The SSRF ring transverse feedback is a digital system based on Spring8 board. Two dedicated ID BPMs located in the second straight section are used to detect transverse movement. Separate horizontal and vertical stripline kickers, located in injection straight, are used to apply base band correction kick to the beam. The kicker electrodes are individually driven with opposite polarities by 100 kHz - 250 MHz, solid-state, commercial BONN amplifiers.

Beam size blow-up introduced by multi bunch instability is observed with interferometer in both vertical and horizontal plane. The current thresholds of instability are around 45mA and 190mA respectively (Fig. 3). After applying transverse feedback, the beam size is minimized down to normal level. The attenuation for betatron oscillation is larger than 40dB, which is proved by beam spectrum calculated from Libera turn-by-turn data. Fig. 4 shows measured beam sizes with feedback on & off.

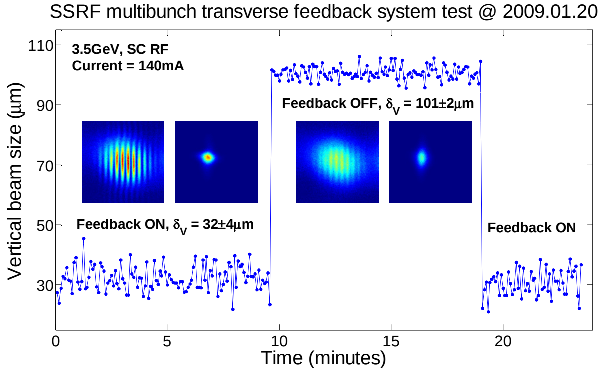

Figure 4: Measured beam size @ feedback on & off.

BEAM INTENSITY MONITORS

3 integration current transformers (ICT) manufactured by Bergoz are placed at the end of Linac, low energy transport line and high energy transport line respectively. Outputs of ICTs are fed to a scope embedded IOC (TEK DPO7054). Bunch charge information is derived from sampled ICT waveform. With this configuration Linac bunch charge and Booster transfer efficiency have been measured. A faraday cup is employed as a reference at the end of LINAC.

11 Wall current monitor (WCM) manufactured by TOYAMA is chosen to present the longitudinal distribution of the beam in the Linac (2), low energy transport line (2), Booster (1) and high energy transport line (3).

Stored beam current in the Ring and Booster is measured using parametric current transformer (DCCT) manufactured by Bergoz. A mounting, cooling and shielding system has been fabricated based on SPEAR3 design for installation of NPCT toroid. Both offline test and online test indicate that the resolution of DCCT system is better than 2μA @ 1Hz for the Ring and 30uA @ 10 kHz for the Booster. Fig. 5 shows resolution evaluation result of the Ring DCCT.

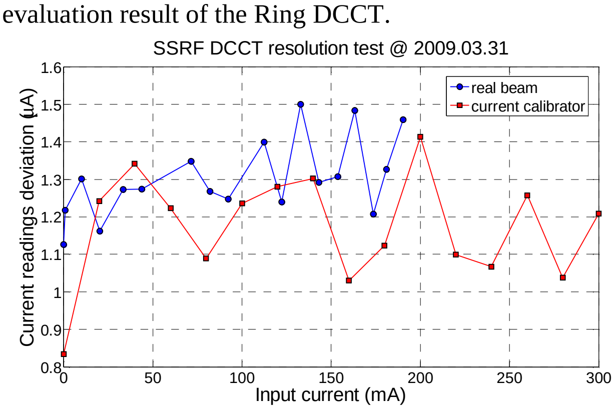

Figure 5: Ring DCCT resolution evaluation result.

PROFILE MONITOR

Fluorescent screen / OTR beam profile monitors are installed in the Linac (5), low energy transport lines (3), Booster (4), high energy transport line (3), and Ring (2) for visual observation of beam profile and position. The luminescent screen is instrumented with a gated CCD camera, which is synchronized with "Gun fire" events via main timing system. Video signals will run through video cables and video multiplexer into PXI IOC.

SCRAPER & SLIT

A horizontal and vertical combined scraper is installed in the injection section to get information about the transverse beam distribution, to eliminate possible beam halos and to establish an alternative method for measuring beam life time in the storage ring. Scraper motion control is implemented in a dedicated PXI-based diagnostics IOC. Ten microns repeatability of blade motion is achieved. The same design was used for transport line slits.

SUMMARY

The diagnostics system has passed commissioning stage and been online for regular operation. Sub-micron level position resolution and turn by turn measurement capability make BPM system the most important toolkits in commissioning and daily operation. All other beam instruments such as DCCT, tune monitor, multi bunch transverse feedback and so on work well and have demonstrated the required performance. Fast orbit feedback system and Xray pinhole camera will be commissioned in the soon future.

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