Diagnostics Development in SRRC

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Abstract. There are several new developments in diagnostics at the SRRC. These new developments include an orbit feedback system, tune monitor, filling pattern monitor, time-domain coupled-bunch oscillation monitor, and an improved synchrotron radiation monitor. A global orbit feedback system as well as a local orbit feedback system have been developed to eliminate excursions from the reference orbit that are caused by various perturbations. A digital receiver-based tune monitor provides a fast tune reading as a complementary tool to the commercial spectrum analyzer. Transient digitizers are used to acquire real-time filling patterns. Turn-by-turn and bunch-by-bunch beam signals acquired by the transient digitizer can extract information from coupled-bunch oscillations. Updated synchrotron radiation monitors provide a more convenient user interface.

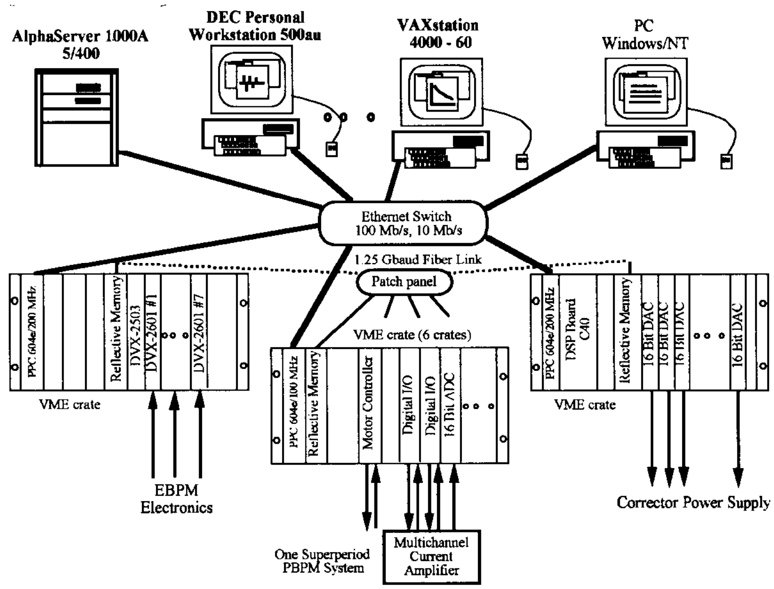
INTRODUCTION

The accelerator complex of the SRRC is composed of a 50 MeV linac, a 1.3 GeV booster synchrotron, and a 1.3–1.5 GeV storage ring (Taiwan Light Source, TLS). The machine was dedicated in October, 1994. To meet stringent requirements, beam instrumentation system development is a continuous effort. The system includes all standard diagnostic devices that are used in modern synchrotron light sources. To accommodate the increased demands of machine operation and accelerator physics, various diagnostics and associated electronics are used to improve machine performance continually. Some of these new developments are highlighted in the following paragraphs.

ORBIT MEASUREMENT AND ORBIT FEEDBACK

The orbit is acquired by 52 sets of button-type beam position monitors (eBPMs). About 40 eBPMs are equipped with switched-electrode electronics developed in-house.

Bergoz's BPM electronics are used for the other eBPMs. The orbit is acquired at a 1 kHz rate using high-performance data acquisition modules (Analogic DVX 2503) located in an VME crate. The CPU module in the VME crate is a PowerPC-based system running LynxOS 2.4. The acquired orbit is processed further and updated in the control database 10 times per second. The fast orbit information is sent to a corrector control crate through a 1.2 GB/s reflective memory network. Photon BPM (pBPM) information is also acquired by another VME crate and stored in the reflective memory. Global as well as local orbit feedback control algorithms execute in DSP modules in the corrector control VME crate. Figure 1 shows the configuration of the orbit acquisition and orbit control system.

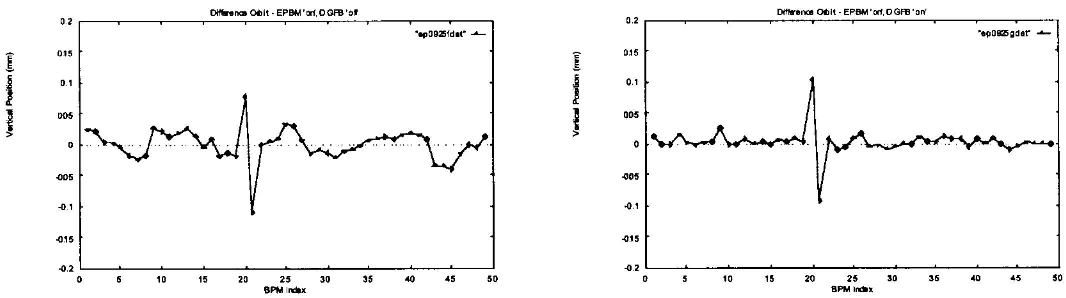


Orbit Feedback System - Hardware Configuration

FIGURE 1. Functional block diagram of the beam position acquisition system and corrector control system.

The orbit feedback system has been tested to suppress various perturbations. Global orbit feedback maintains a reference orbit. Local feedback is used to keep beamline source point position and angle constant within stringent requirements. Feed-forward orbit control is widely used to reduce orbit excursion during the operation of the undulators. However, it has been shown that global orbit feedback is also effective in eliminating orbit excursion caused by the undulators' operation (1). For example, in the operation of exotic undulators, it is possible to change the phase and gap during the experiment scenario in an elliptical polarization undulator with the phase varying mechanically. It is not simple to do this two-dimensional feed-forward orbit control.

Figure 2 shows the global orbit feedback loop used to eliminate the orbit leakage of a dynamic local bump (2). This dynamic bump will be used to enhance the production of polarized light from the bending magnet (EPBM). A flip rate from 1 Hz to 10 Hz is tested. Trapezoid or sinusoid waveforms are available. The source of the bump leakage comes from a non-ideal local bump and small discrepancies in the characteristics of power supplies, correctors, and vacuum chambers at the corrector sites.



(a) Snapshot of the orbit with global feedback off, showing a small orbit leakage.

(b) Snapshot of the orbit with global feedback on. No orbit leakage is seen.

FIGURE 2. Difference orbit for EPBM operation with feedback off (a) and on (b).

The effectiveness of the orbit feedback system is dependent on the performance of the eBPMs/pBPMs, correctors, and control algorithms. Continuous upgrading of these crucial items, combined with third-harmonic cavity and coupled-bunch feedback projects will enable TLS to achieve high beam stability in the coming year.

DIGITAL RECEIVER-BASED TUNE MONITOR

A digital receiver-based tune monitor has been implemented as a dedicated system. The system includes rf front-end electronics and a digital-to-analog converter, multi-channel digital receivers, and a digital signal processor as shown in the upper part of Figure 3. A portion of the beam spectrum is processed by the rf front-end electronics

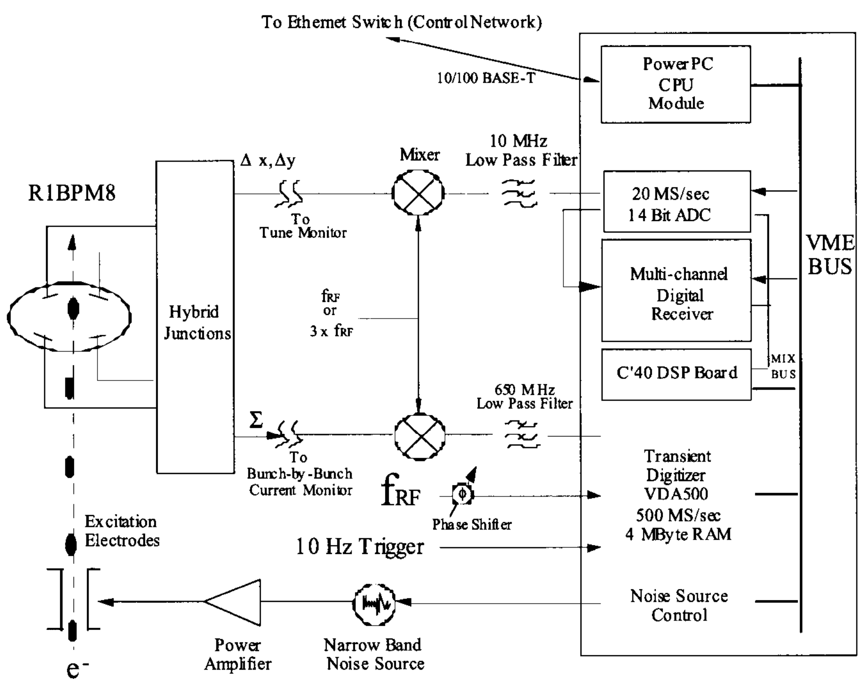


FIGURE 3. Functional block diagram of the digital receiver tune monitor and bunch-by-bunch current monitor.

and down-converted to a baseband signal. The ADC converts the baseband signal to digital data streams and sends them to the digital receiver. A digital tuner performs digital mixing, low-pass filtering, and data formatting. The output I/Q data stream is processed by the DSP to get the spectrum and perform peak identification. The ADC module, digital receiver module, and DSP module are contained in a VME crate. The 14 bits, 20 MS/sec ADC provides a more than 70 dB dynamic range and 8 MHz real-time bandwidth. Narrow bandwidth white-noise excitation is available if the stored beam is quiet.

The frequency and decimation factor of the low-pass filter are software programmable. The tune update rate is limited by the computation power of the DSP chips. Three channels of digital receiver are implemented on a single C40 DSP via a Fourier transform. The spectrum update time is less than 10 msec. To increase the speed, we will need to upgrade to multiple DSPs or a new generation DSP (eg., 320C6x). Processing gain for 1024 points FFT is about 30 dB for an input signal with 0 dB SNR. Appropriate data averaging algorithms are used for data smoothing. The measured tune is updated in the machine database every 100 msec (the data update rate of the control system). About ten spectra per second are displayed on the console computer. The user interface is based on the PV-WAVE package. Histogram and spectrogram displays are available to satisfy various needs. A fast tune update signal, with msec time resolution, is available at the local VME crate for accelerator physics studies or monitoring the power supply ripple. The booster will install a dedicated tune monitor to aid in tuning lattice parameters in the near future.

To examine the performance of the tune monitor, a sinusoidal current with 0.2 Amp peak-to-peak is applied to a quadrupole trim as shown in Figure 4(a). The tune variation due to this excitation is about 0.0009. It is estimated that the resolution of the tune monitor is about 0.0002. Results are consistent with the parameters of the tune monitor. These parameters include sampling rate, decimation factor, and data length.

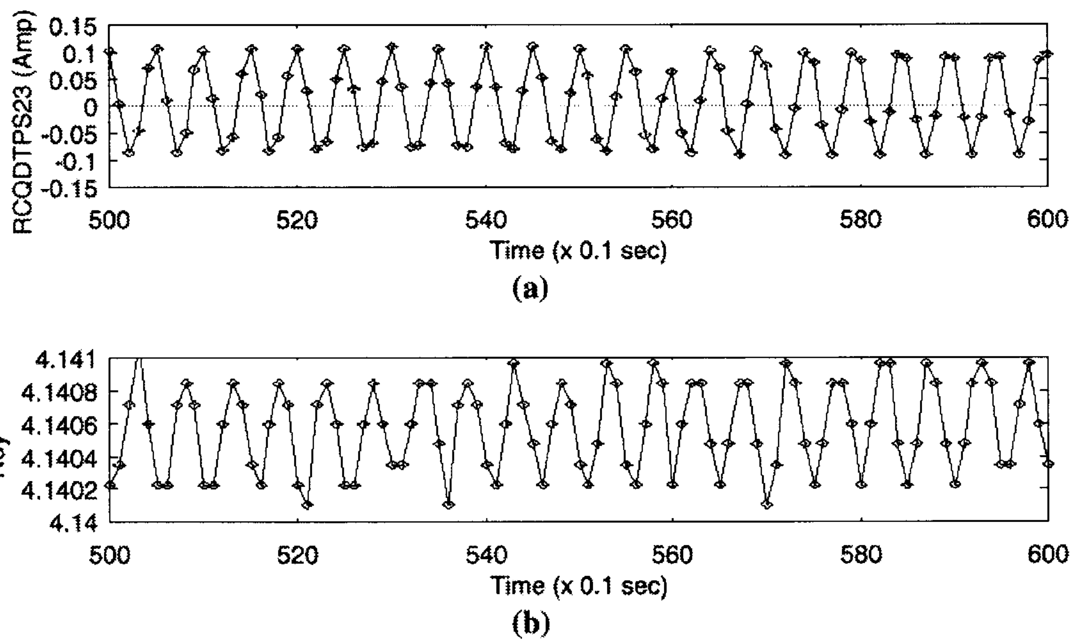


FIGURE 4. Tune variation due to a 200 mA peak-to-peak sinusoidal wave applied to the quadrupole trim (RCR1QDPS16).

The tune change due to the focusing error of the undulator U5 is shown in Figure 5. This operation first closed the gap to 18.5 mm, then opened the gap to 220 mm. The hysteresis loop near the minimum gap is due to an intentional 1 second delay in the tune value update. The gap opening was changed at 1 mm/sec for this test run.

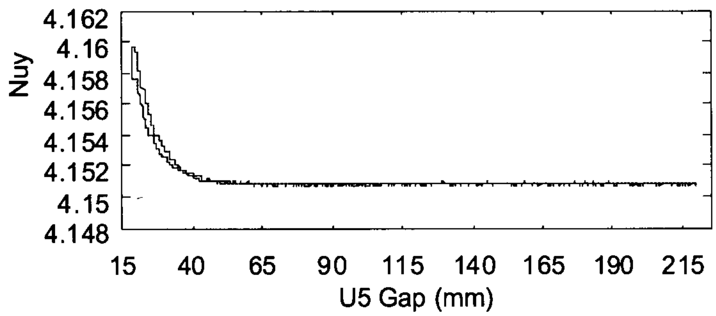


FIGURE 5. Vertical tune shift versus U5 gap.

Figure 6 shows the working point evolution on the tune diagram during energy ramping from 1.3 GeV to 1.5 GeV. In this test, power supply currents were increased linearly. Tune is spread over in a small region during this ramping test. The ramping route is not optimized for this test run.

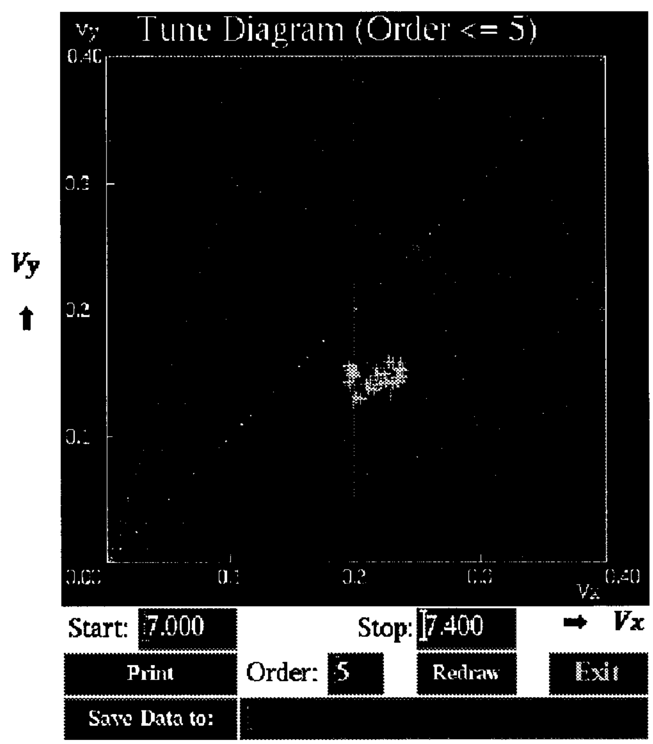


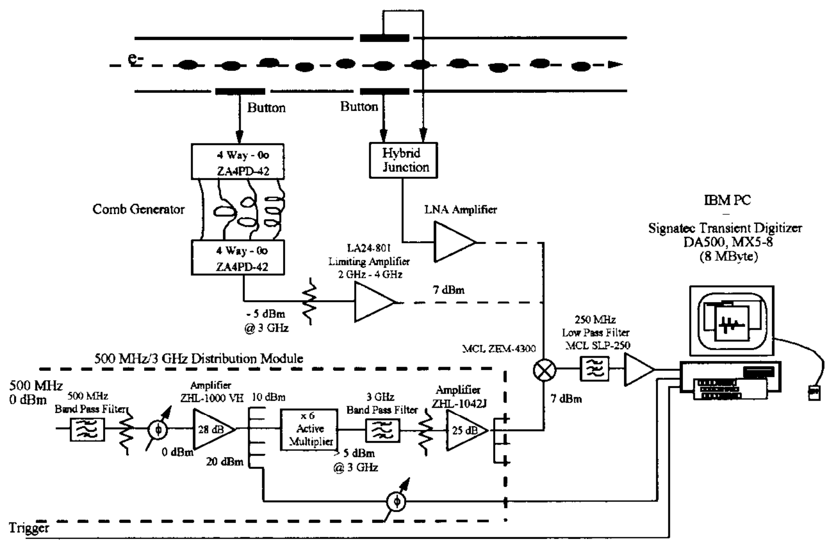
FIGURE 6. Tune evolution on tune diagram during energy ramping test run.

FILLING PATTERN MONITOR

The coupled-bunch oscillation is strongly dependent on the filling pattern of a stored beam. The population distribution in the stored beam can be easily observed by a wide bandwidth oscilloscope. However, a dedicated filling pattern measurement (3) is useful from an injection control, instabilities-study point of view. Controlling the filling pattern is possible if real-time filling pattern information is available. The injection parameters can be adjusted dynamically to achieve the desired filling pattern. The filling pattern acquisition system is shown in lower part of Figure 3. The digitizer uses 500 MHz rf as an external clock to synchronize with the bunch signal. One data point is acquired for each bunch. The next consecutive 200 data points represent the filling pattern. Post-processing the data of consecutive turns can be used to improve amplitude resolution.

COUPLED-BUNCH OSCILLATION OBSERVATION SYSTEM

Coupled-bunched oscillations in longitudinal as well as transverse directions are detected by a bunch-by-bunch, turn-by-turn phase and transverse oscillation detector. Data is digitized by a 500 MS/sec ADC and stored in 8 MB of onboard memory. The 8 MB memory is capable of storing signals for every bucket of TLS for up to 40,000 turns. The schematic diagram is shown in Figure 7. The control console accesses bunch oscillation data (stored on a local disk) via the NFS file system. Time-domain coupled-bunch oscillation data are an elegant tool for diagnostics (4). Such a system also plays an important role in the fast beam-ion instability (FBII) experiments in many facilities (5). This system will help the FBII study at TLS soon.



Transverse/Longitudinal Coupled-Bunch Oscillation Observer
(Turn-by-Turn, Bunch-by-Bunch)

FIGURE 7. Functional block diagram of the 500 MS/sec digitizer system.

To test the performance of this coupled-bunch oscillation observation system, the stable stored beam has been intentionally excited by a 50-cycle burst at the synchrotron oscillation frequency. Figure 8 shows the synchrotron oscillation of three consecutive bunches on 15,000 turns. Strong damping was observed for the test lattice.

The tune shift along the bunch train is also interesting in a study of multibunch instabilities. The tune of an individual bunch can be obtained by performing an FFT of acquired data. Since the frequency precision of the FFT is limited by the sampling rate, however, the theoretical resolution of a 32 K point FFT is about 0.00005 in tune.

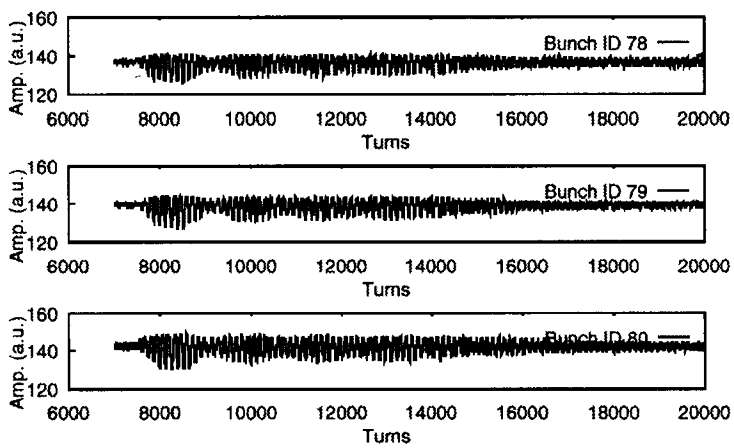


FIGURE 8. Observed synchrotron oscillation of three consecutive bunches. The beam is excited by a 50-cycle burst at the synchrotron oscillation frequency.

SYNCHROTRON RADIATION MONITOR SYSTEM

The synchrotron radiation monitor currently operates with visible light. The diagnostic station is equipped with a CCD camera imaging system. The working wavelength is 500 nm with a 10 nm passband. One-to-one conjugation ratio optics are used. The horizontal acceptance angle is 8 mrad, to minimize the depth of the field and diffraction effects. The beam profile is acquired by a PCI bus-based frame grabber. The captured real-time image (30 frames per second) is displayed on a local SVGA monitor. The image is sent to the console via the control network at about 10 frames per second. On the control console, a PV-WAVE package aided fast prototyping of the user interface. Time structure is observed by a streak camera with a low-jitter clock source.

The present diagnostic station shares the front-end with a VUV beamline. It is inconvenient for the operation of a shutter and valve during injection. To relieve this inconvenience, to eliminate heat load problems at the first mirror, and to improve the performance of the optical system, a dedicated diagnostics beamline is being planned. The new diagnostics station will be equipped with standard profile monitoring and time-structure measurement facilities. The thermal and optics designs will be improved.

SUMMARY

Diagnostics play a crucial role in pushing to ultimate machine performance and in doing advanced machine physics. To accommodate high orbit stability, the orbit acquisition and orbit feedback system will continue to improve its reliability and its performance. Orbit feedback has been tested in TLS and is expected to be useful in increasing orbit stability. A prototype digital receiver-based tune monitor provides a fast tune reading as a complementary tool to a commercial spectrum analyzer. Test results show that a rapidly measured tune is possible with high reliability. Transient digitizers are used to acquire a real-time filling pattern. Turn-by-turn and bunch-by-bunch beam signals acquired by the transient digitizer can be extracted from coupled-bunch oscillations. Time domain analysis will help provide diagnostics for the longitudinal and transverse feedback systems. Updated synchrotron radiation monitors provide a more convenient user interface. Planning of a dedicated diagnostics beamline is under way.

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