Diagnostics Control Requirements and Applications at NSLS-II

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Abstract. To measure various beam parameters such as beam position, beam size, circulating current, beam emittance, etc., a variety of diagnostic monitors will be deployed at NSLS-II. The Diagnostics Group and the Controls Group are working together on control requirements for the beam monitors. The requirements are originated from and determined by accelerator physics. An attempt of analyzing and translating physics needs into control requirements is made. The basic functionalities and applications of diagnostics controls are also presented.

Introduction

A correct measurement of beam parameters depends on the effective combinations of a variety of beam monitors, control and data acquisitions (DAQ) and high level physics applications. Figure 1 shows the relationship between these systems.

The following beam parameters will be monitored during regular operations:

1) closed orbit (accuracy better than 10% of beam size);
2) working point (tune for both planes with 10-4 resolution);
3) circulating current (0.1% accuracy) and beam lifetime (1% accuracy);
4) injection efficiency;
5) filling pattern (1% of maximal bunch charge);
6) emittance for both planes (10% relative accuracy);
7) energy spread;
8) individual bunch length (2 psec resolution);
9) position of the photon beam for the insertion devices;
10) coherent bunch instabilities;
11) distribution of beam losses around the ring;

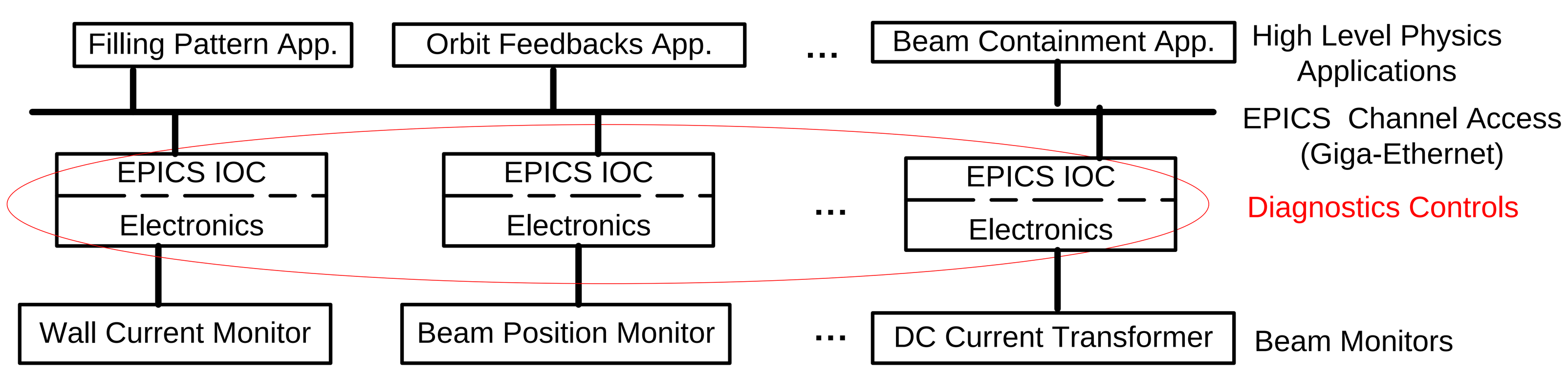

Figure 1: NSLS-II Beam Diagnostics & Control Systems

Table1: Diagnostics Controls Requirements

Accelerator Subsystems	Beam Parameter	Beam Monitor	Controls Requirements
Linac	Fill Pattern	Wall Current Monitor (WCM)	Note 1: For fill pattern measurement: sampling rate: 4GS/s; resolution: 8-bit IOC update rate: 10Hz
	Profile/Position	Fluorescent Screen/CCD (Flag)	Note 2: For all flags: Binary control for pneumatic actuator CCD: 1620*1220@15fps, IOC@10Hz
	Position/Orbit	Beam Position Monitor (BPM)	Single Pass Resolution: 30um rms
LtB (Linac to Booster Transport Line)	Fill Pattern	Fast Current Transformer (FCT)	See Note 1 described in Linac
	Profile/Position	Flag	See Note 2 described in Linac
	Position/Orbit	BPM	Single Pass Resolution: 30um rms
	Bunch Charge	Integrating Current Transformer (ICT) & Beam Charge Monitor (BCM)	Note 3: for all ICTs & BCMs: 20KS/s with 16-bit IOC@10Hz
	Energy Spread	Energy Slit	Note 4: for all slits in transfer lines: stepper motor control with readback;
	Bunch Charge	Faraday Cup	Note 5: for all FCs: Digitizer. 100MHz bw, 1GS/s
Booster	Fill Pattern	FCT	See Note 1 described in Linac
	Profile/Position	Flag	See Note 2 described in Linac
	Position/Orbit	BPM	Resolution: 30um rms
	Circulating Beam Current	DC Current Transformer (DCCT)	20KS/s with 16-bit;1Hz for injection efficiency calculation;
	Bunch Length	Streak Camera	Windows software by vendor
	Tunes	Striplines	Ethernet-based network analyzer
	Emittace	Synchrotron Radiation Monitor	TBD
BtS (Booster to Storage Ring Transport Line)	Fill Pattern	FCT	See Note 1 described in Linac
	Profile/Position	Flag	See Note 2 described in Linac
	Position/Orbit	BPM	Single Pass Resolution: 2um rms@1Hz
	Bunch Charge	ICT & BCM	See Note 3 described in LtB
	Bunch Charge	Faraday Cup	See Note 5
	Energy Spread	Energy Slit	See Note 4 described in LtB
Storage Ring	Fill Pattern	Stripline or synchrotron light with photo-diode (TBD)	See Note 1 described in Linac
	Profile/Position	Flag	See Note 2 described in Linac
	Position/Orbit	BPM	Resolution: 1um rms@10KHz; 0.3um rms@10Hz
	Circulating Beam Current	DCCT	2KS/s with 18-bit@500Hz bw; 1Hz for injection efficiency calculation
	Bunch Length	Streak Camera	Windows software by vendor
	Tunes	Pickup BPM, excitation stripline, Network Analyzer	Ethernet-based instrument control
	Emittance & Energy Spread	Pinhole Camera	Stepper motor control with readback; CCD: 1620*1220@15fps, IOC@1Hz
	Beam Stability	Stripline, Spectrum Analyzer	Ethernet-based instrument control
	Beam Losses	Beam Loss Monitor (BLM), Scraper	TBD

Controls Requirements

To measure various beam parameters, a variety of diagnostic monitors will be deployed in NSLS-II. The Diagnostics Group and the Controls Group are working together on controls requirements for these beam monitors. These Requirements are determined by accelerator physics. According to NSLS-II PDR , the following beam parameters will be monitored during storage ring regular operations. An attempt of analyzing and translating physics needs into controls requirements is made. Table 1 lists the beam monitors associated with beam parameters used in each sub-accelerator and summaries of controls requirement.

Closed Orbit

Requirement: accuracy better than 10% of beam size. The beam position and closed orbit is measured by BPM (Beam Position Monitor). The smallest beam size is expected to be 3.1 um at short ID (Insertion Device) location. So, the BPM pickup buttons and associated electronics should provide position measurement resolution (RMS noise) at 0.3um (10% of beam size) for long-term orbit drift which can be compensated by slow orbit feedback based on 10 Hz Slow Acquisition (SA) BPM data. Additionally, NSLS-II BPM system will provide 10 KHz Fast Acquisition (FA) data for fast orbit feedback (FOFB) as well as turn-by-turn (TBT) data and ADC raw data for physics studies and BPM system debugging. These applications require less position resolution, usually at tens of microns.

Working Points

Requirement: both planes with 10-4 resolution. There're several methods to measure tunes (the fractional par). Most of them need pickup BPM and excitation stripline. One common method is based on network or spectrum analyzer. NSLS-II revolution frequency is 378.7 KHz and the tunes are expected to be 32.35/16.28. 10-4 frequency resolution means ~10Hz (0.28 * 379 KHz ~100 KHz) scanning step for the analyzer. Another is to utilize (FFT) BPM turn-by-turn data to measure tunes. 10-4 resolution means that at least 5120 (1/ (2N) < =10-4, N>=5000, N = 5*1024) TBT samples are needed for FFT.

Circulating Current and Beam Lifetime

Requirement: 0.1% accuracy for circulating current and 1% accuracy for beam lifetime. This is measured by DCCT and associated electronics. Bergoz NPCT with its analog electronics can provide +/-0.1% accuracy. The NPCT has 10 KHz nominal bandwidth. Large bandwidth gives more noise in the measurement so that filtering it to 500 Hz is always a good practice. In this case, one digitizer with 1KS/s sampling rate should be sufficient. The required resolution for digitizer is determined by the requirement on accuracy of beam lifetime measurement: 2% for 20 mA with 60-hour lifetime and 1 minute measurement interval. 18-bit ADC seems adequate for all these applications.

Filling Pattern

Requirement: 20% bunch-to-bunch charge variation. Filling pattern is measured by high-bandwidth (>500MHz) diagnostics monitors such as WCM and FCT. The pulse width of the output signal from Bergoz FCT is about 1 ns. Required 20% means less than 8-bit. So, high-speed digitizer with 2GHz bandwidth, 5GS/s sampling rate and 8-bit resolution should be sufficient for fill pattern monitoring.

Emittance

Requirement: both planes with 10% relative accuracy. emittance is not directly measured by diagnostics. It's calculated from β-function value (assumed to be a constant at the dispersion free location) and beam size (measured by one pinhole CCD camera at one diagnostics beamline). 10% relative accuracy should be achievable by well-designed pinhole optics and high-resolution (1620*1220) digital camera.

Functionalities and Applications

The basic functionalities of diagnostics controls can be summarized as:

1) Measurement of various beam parameters (~10) via a variety of beam monitors (~16).
2) Acquirement and processing of the signals from beam monitors via different electronics and EPICS IOCs.
3) Provision of the processed data as EPICS PVs for high level physics applications.
4) Support of Top-off operation by providing filling pattern measurement to meet the requirements of initial filling storage ring from zero to full charge at 10Hz for Linac injection and at 1(or 2)Hz for Booster injection, as well as 1-minute top-off cycle after filling up.

From the point of view of controls and applications, diagnostics and controls systems can be classified into the following groups, as shown in Figure 2:

1) BPM subsystem for orbit feedbacks, lattice measuring, etc;
2) Filling pattern measurements based on WCM, FCT, stripline/synchrotron light with photo-diode;
3) Loss Control and Monitoring subsystem as well as injection efficiency involving ICT, DCCT, BLM and scraper;
4) Camera-based diagnostics such as screen/flag, pinhole system, streak camera, and synchrotron light monitor (SLM);
5) Network/Spectrum analyzer-based tune measurement and beam stability monitoring;

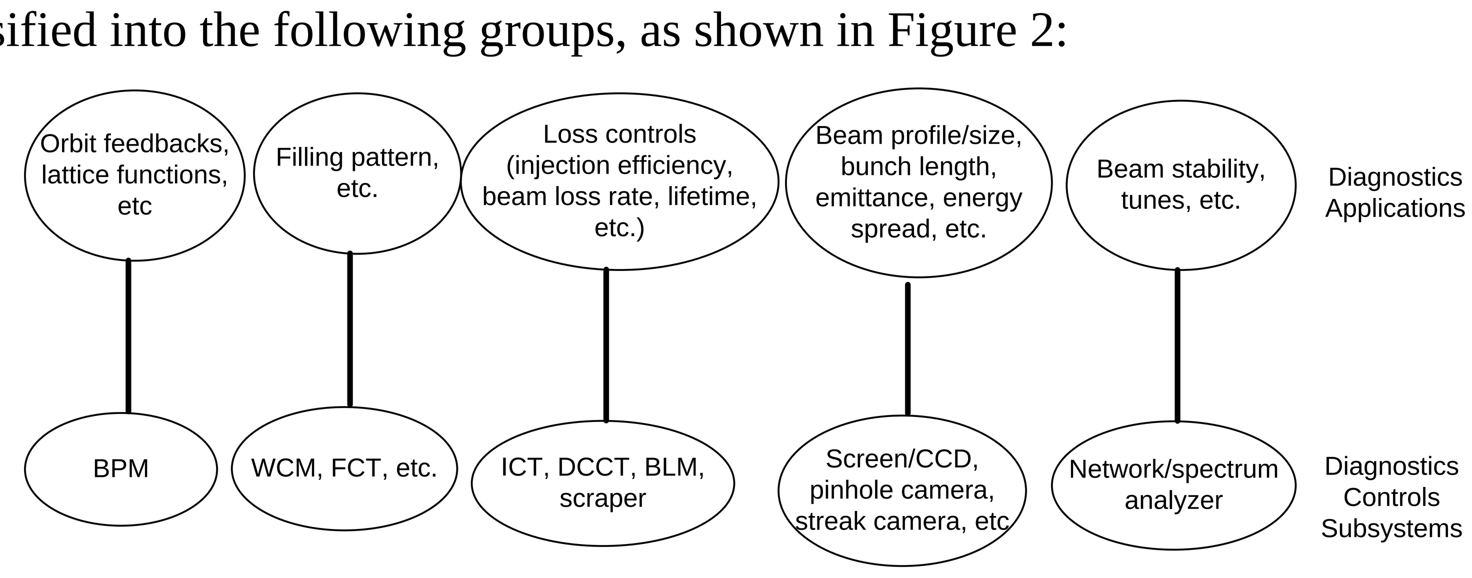

Figure 2: Diagnostics Control Subsystems and Applications