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Diagnosing NSLS-II: A New Advanced Synchrotron Light Source

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Abstract. NSLS-II, the successor to NSLS (National Synchrotron Light Source) at Brookhaven National Lab is scheduled to be open to users worldwide by 2015 as a world-class advanced synchrotron light source because of its unique features: its half-mile-circumference (792 m) Storage Ring provides the highest beam intensity (500 mA) at medium-energy (3 GeV) with sub-nm-rad horizontal emittance (down to 0.5 nm-rad) and diffraction-limited vertical emittance at a wavelength of 1 Å (<8 pm-rad). As the eyes of NSLS-II accelerators to observe fascinating particle beams, beam diagnostics and controls systems are designed to monitor and diagnose the electron beam quality so that NSLS-II could be tuned up to reach its highest performance. The design and implementation of NSLS-II diagnostics and controls are described. Preliminary commissioning results of NSLS-II accelerators, including Linac, Booster, and and Storage Ring, are presented.

Introduction

The NSLS-II beam diagnostics and controls systems are designed to monitor the electron beam of NSLS-II accelerator complex. The beam quality is measured by a variety of parameters such as bunch charge, bunch structure (filling pattern), beam position/orbit, beam size/profile, energy & energy spread, circulating beam current, tunes, beam emittance, bunch length and beam losses. Figure 1 briefly shows the beam parameters measured from Linac to Storage Ring.

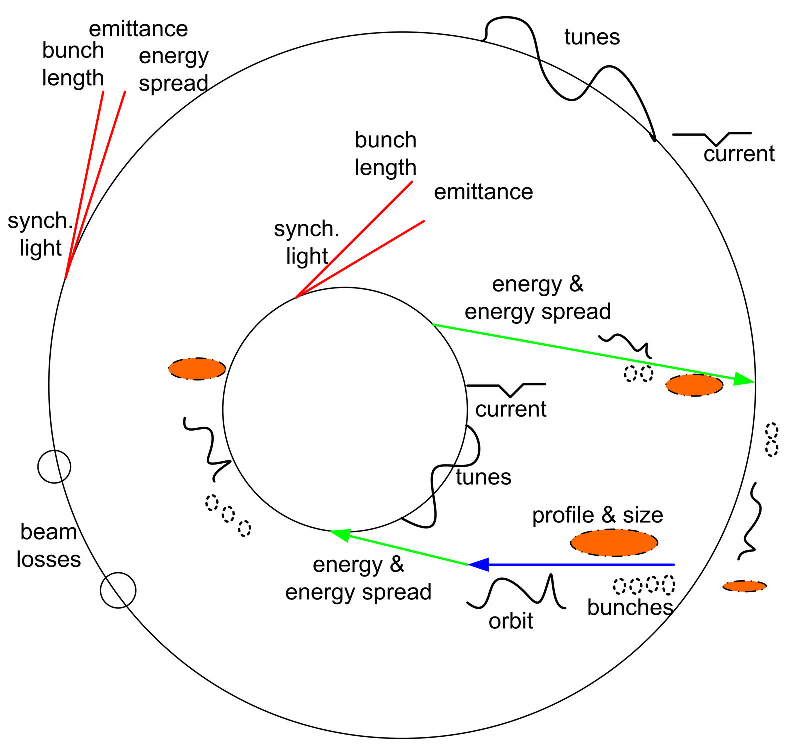

Figure 1: Beam Parameters Measured at NSLS-II

Beam Monitors and Subsystems

The NSLS-II accelerators consist of one Injector and one storage ring (SR). According to the functionality as well as geographical distribution, the Injector is divided into 4 sub-accelerators: Linac, Linac to Booster (LtB) transfer line (including 2 beam dumps), Booster, Booster to Storage ring (BtS) transfer line (including 1 beam dump). Table 1 gives a summary of the diagnostic monitors distributed over the whole machine. From system functionality and application point of view, the variety of beam monitors as shown in Table 1 could be classified into a few subsystems such as BPM, filling pattern, beam intensity, loss control and monitoring, beam profile, tunes, etc., as shown in Fig. 2

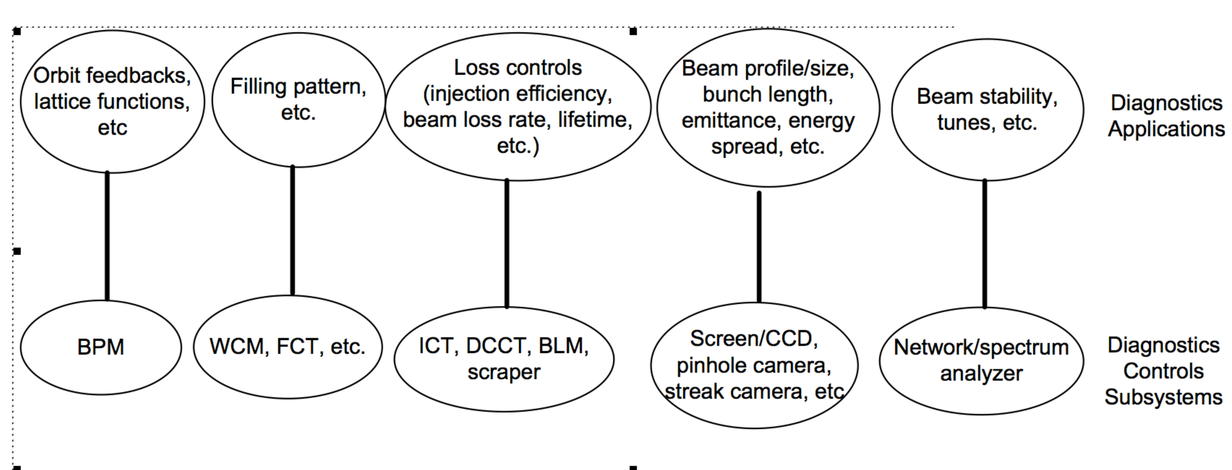

Figure 2: Diagnostics Subsystems and Applications

Table 1: Beam Monitors at NSLS-II

	Linac	Ltb	Booster	BtS	SR
WCM	5				
Screen/Flag	6	9	6	8	1
BPM	5	6	37	8	180
FCT / FPM		2	1	2	1
Bergoz ICT		2		2	
Energy Slit		1		1	
Faraday Cup	1	2		1	
Bergoz DCCT			1		1
Streak Camera					1
Visible Light Monitor			1		1
X-ray diag. beam-line					1
Tune Monitor			1		1
Transverse Feedback					1
Beam Loss Monitor					5
Beam Scrapers					5
Photon/x-ray BPM					1 or 2 per BL

Controls Interfaces for Diagnostics

Diagnostics controls are actually more about data acquisition (DAQ) than device control. Diagnostics control subsystem will conform to NSLS-II control system standards. It will be EPICS-based and the preferable operating systems for IOCs are RTEMS (Real-Time Executive for Multiprocessor Systems) and Linux/Debian.

Classifications of Control Interfaces

From point view of controls, the beam monitors output signals/interfaces can be classified into the following several groups.

1) Analog output with high-bandwidth (>500MHz): WCM, FCT, etc. ;

2) Analog output with low-bandwidth (<10KHz): DCCT, ICT&BCM;

3) Simultaneous 4-channle RF signals: BPM;

4) Gigabit-Ethernet camera interface: CCD camera, streak camera etc.

5) Stepper motor driven: linear stage in diagnostics beam-lines, energy slit, beam scraper, etc.

6) Ethernet-based instrument: Windows XP-based network/spectrum analyzer for tune monitor and beam stability monitor;

There are other miscellaneous I/Os for diagnostics: binary input/output including TTL I/O for DCCT range settings, pneumatic actuator with limit switch in flag, limit switch in stepper-based stage, temperature sensors for diagnostics beamline mirror, etc.

Controls and Data Acquisitions for Diagnostics

Each type of beam monitor requires electronics (device controller) to process its output signal. The electronics for the above groups and associated EPICS IOC platform are listed in Table 2. Figure 3 shows the controls interfaces for these various beam monitors.

Table 2: Diagnostics Electronics and IOC Platform

Beam Monitor	Diagnostics Electronics	IOC platform
WCM & FCT	Acqiris DC252 (2GHz bw, 10-bit, 4~8GS/s)	cPCI/Linux
DCCT & ICT	1)GE ICS-710-A (24-bit, 200KS/s, 8-ch) 2)Allen-Bradley PLC (DAC, Digital I/O)	cPCI/Linux
BPM	In-house BPM receiver [3]	PC/Linux
Profile / camera	PC/Linux	PC/Linux
Slit & scraper	Delta Tau GeoBrick LV	PC/Linux
Tune	Network analyzer	PC/Linux

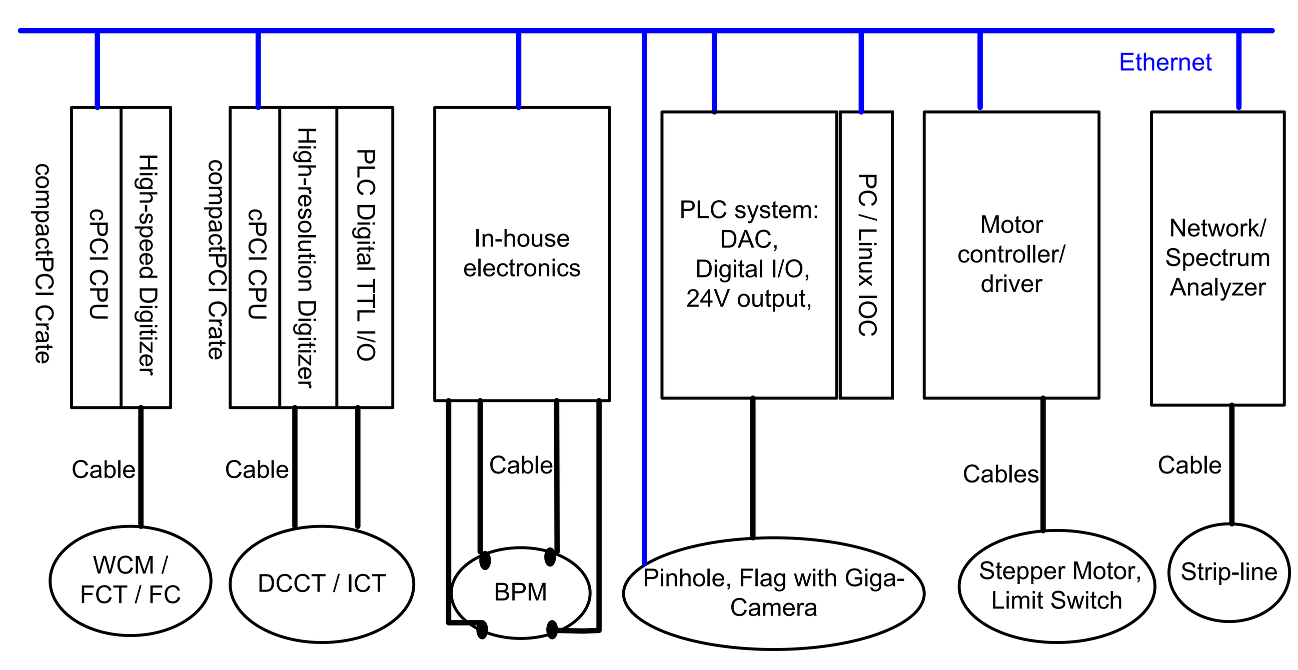

Figure 3: Diagnostics Controls Interfaces

NSLS-II Machine Commissioing

NSLS-II Storage Ring commissioning started in March 2014. A total of 50-mA stored beam in the Storage Ring was achieved with super-conducting RF recently (see Fig. 4). Although this is still far away from the designed value at 500 mA, it is a major milestone for the NSLS-II Project because the accelerators, including Linac, Booster, and Storage Ring, have been proven working in principle.

During NSLS-II Storage Ring commissioning, we successfully filled any RF bucket using different patterns as shown in Figure 5 . The slow orbit feedback was tested and proved to be working as shown in Fig 6. Figure 7 shows the first beam observed by the first Flag at NSLS-II Linac.

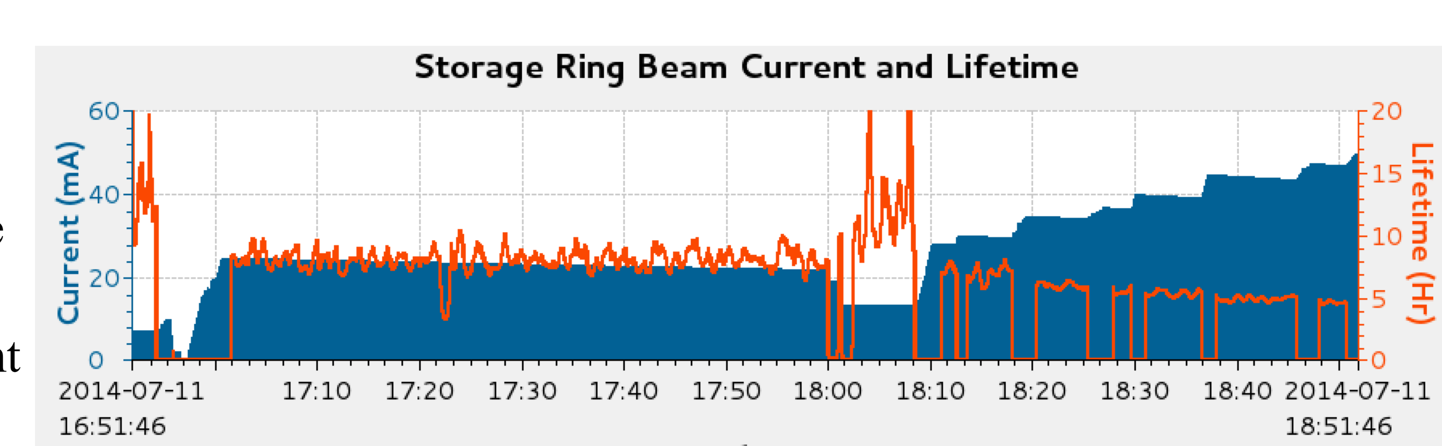

Figure 4: NSLS-II Milestone -- 50-mA Stored Beam

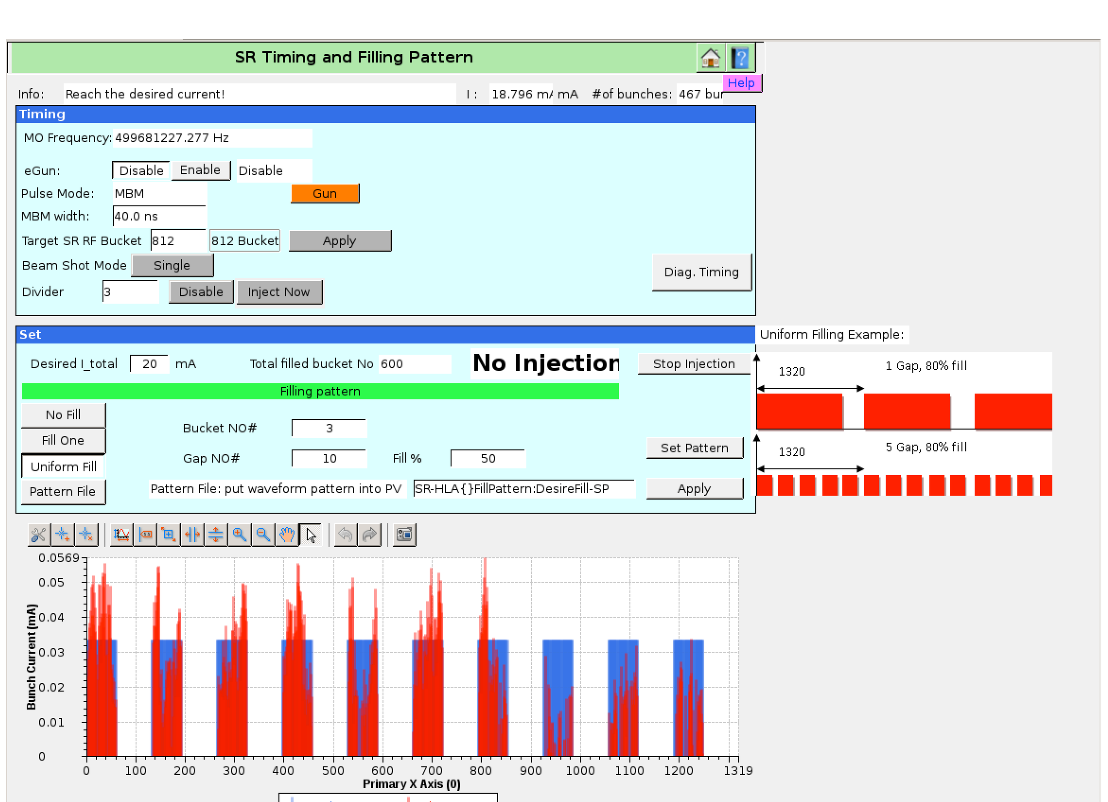

Figure 5: Storage Ring Filing Pattern

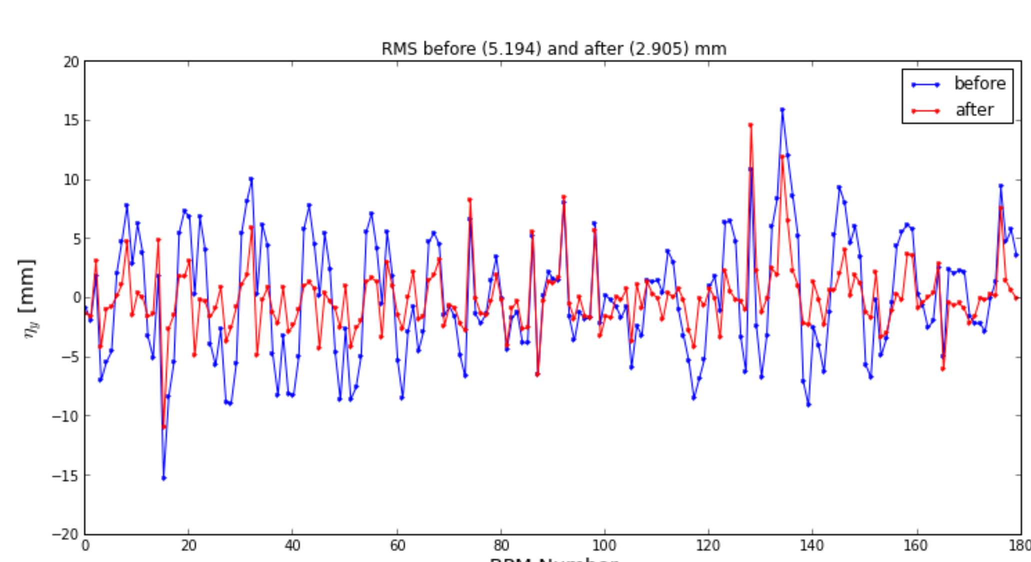

Figure 6: Preliminary Test of Slow Orbit Feedback

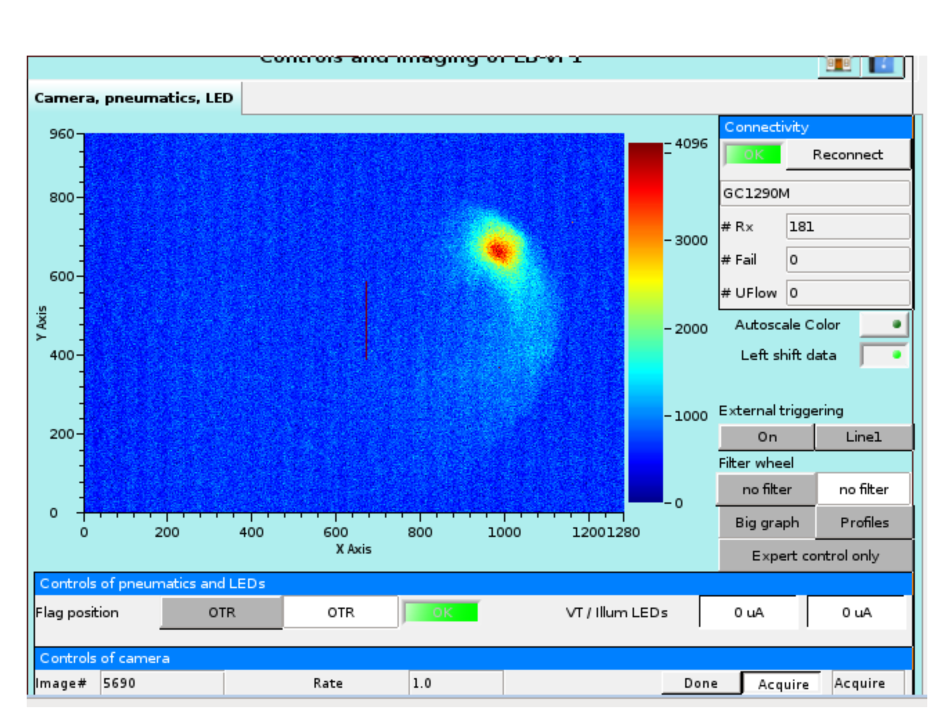

Figure 7: First Beam Observed by one Linac Flag