CONTROLS AND DATA ACQUISITION FOR NSLS-II LOSS CONTROL AND MONITORING *

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Abstract

The NSLS-II Loss Control and Monitoring (LCM) system is safety-related, but not safety-credited. This definition and requirement makes implementation requirements of controls and data acquisition (DAQ) for the LCM less stringent. However, the LCM is one of the most complicated diagnostics subsystems since it involves so many components including beam intensity monitors, scrapers, and different types of beam loss monitors, and the component interacts with each other. The control & DAQ system design and prototype test results are presented.

INTRODUCTION

The shielding for the NSLS-II storage ring (SR) will provide adequate protection for the full injected beam losses in two cells of the ring around the injection point, but the remainder of the ring is shielded for lower losses of <10% top-off injection beam current. This will require a system to insure that beam losses do not exceed levels for a period of time that could cause excessive radiation exposure outside the shield walls. NSLS-II Loss Control and Monitoring (LCM) [1] system is designed to control the beam losses to the more heavily shielded injection region while monitoring the losses outside this region. To achieve this goal, scrapers are installed in the injection region to intercept beam particles that might be lost outside this region. The scrapers will be thin (< 1Xrad) that will allow low energy electrons to penetrate and the subsequent dipole will separate them from the stored beam. The dipole will provide significant local shielding for particles that hit inside the gap and a source for the loss monitor system that will measure the amount of beam lost in the injection region. To measure the charge loss quantitatively, we will measure the electron component of the shower as beam electrons hit the vacuum chamber (VC) wall [2]. This will be done using the Cerenkov light as electrons transit ultra-pure fused silica rods placed close to the inner edge of the VC. The entire length of the rod will collect light from the electrons of the spread out shower resulting from the small glancing angle of the lost beam particles to the VC wall.

Overall, NSLS-II LCM system is designed to prevent excessive radiation levels in occupied areas by limiting beam power loses using engineered devices, interfaces or alarms to operator. However, LCM system is safety "related", but not "credited" like PPS (Personnel Protection System) and EPS (Equipment Protection System), Area radiation monitors are part of the PPS and will provide the final protection in a safety credited system.

COMPONENTS AND FUNCTIONALITIES

The LCM will consist of three types of components: beam intensity monitors [3], scrapers and beam loss monitors. These subsystems will:

1. monitor and limit the beam power losses from the accelerators and transport lines;
2. control the major beam losses in the SR to the heavily shielded Injection Region (INR);
3. monitor the SR beam losses in the INR and account for losses in the remainder of the SR.

The LCM system will monitor the beam current losses, which is difference between two consecutive current monitors. Figure 1 shows the injection efficiency around the whole machine measured by Bergoz ICT [4] and Bergoz DCCT. The beam loss times the energy of the system transporting that beam (i.e booster dipole or transport dipole field or linac RF gradient) to determine the beam power lost. If the lost beam power exceeds the shielding design level at that location, then alarms will be issued to operators and the accelerator control systems that action is required to lower level in order to continue injection. If corrective action isn't taken within a specified time period, that insures potential radiation exposures don't exceed administrative levels, then the LCM could prevent continuing injection. The decisions made by the LCM are not as critical, as the credited PPS and therefore will be made in a non-safety rated control computer that will stop.

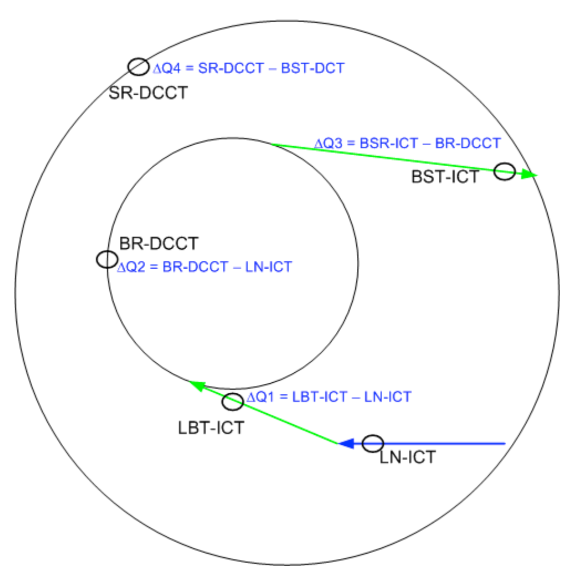

Figure 1: NSLS-II injection efficiency measurements.

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In order to control the SR beam losses to the more heavily shielded INR, a set of five scrapers are planned in this region. There will be 3 horizontal scrapers (Hscraper1 & 2, HscraperX) and 2 vertical scrapers (Vscraper1 & 2) in the Injection Region.

If the amount of charge loss that hits the scrapers in the INR can be measured, then an estimate of the beam charge loss outside the INR is the remaining unaccounted charge loss. The Cerenkov Beam Loss Monitor (CBLM) is designed to measure the beam charge that hit the scraper and deflected by the subsequent dipoles into the CBLMs. There will be five CBLMs in the INR with three in dipole magnets and two in quadrupole magnets.

The locations of the scrapers and CBLMs together with their Twiss parameters for the NSLS-II SR are shown in Figure 2.

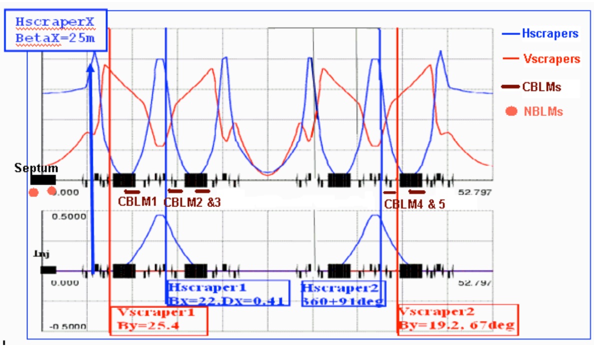

Figure 2: Scrapers and CBLMs locations together with Twiss functions in the injection region.

CONTROLS & DATA ACQUISITION

LCM is one of the most complicated diagnostics subsystems. It involves so many components including beam intensity monitors, scrapers, and Cerenkov beam loss monitors, and the component interacts with each other.

Beam Intensity Monitors

There are two types of beam intensity monitors: Bergoz ICT and Bergoz NPCT. They are used to measure the beam charge or beam current around the whole machine and then calculate the beam losses. GE ICS-710-A high-resolution compactPCI digitizer (24-bit, up to ~215KS/s, 8-channel, 4M Bytes memory, up to -10V~10V input range) is selected as standard for all slow-speed while high accuracy applications including beam intensity measurements. Additional to the cPCI digitizer, Allen-Bradley PLC digital I/O modules (with Ethernet communication module) will be used to setup DCCT's and BCM's range, bipolarity, etc.

Scrapers

Scrapers are used to limit a majority of the beam losses to the Injection Region. From controls point of view, scrapers are just two blades driven by motors together with limit switches, position readback, temperature monitoring, etc. For scraper motor control, we will use the motion controller/driver Delta Tau GeoBrick LV PC [5] which is the standard for all motion control applications at NSLS-II. Considering potential radiation damage, we are evaluating LVDT-based position sensors for the scraper position measurements.

Cerenkov Beam Loss Monitors

In electron rings one difficulty in measuring local charge loss using scintillators or ionization chambers is the gamma ray signal from distant beam loss locations. The use of Cerenkov light from high energy electrons passing through a glass rod will eliminate this sensitivity, as well as that from low energy electrons whose direction is greatly affected by the magnetic fields of the accelerator lattice. From controls point of view, the CBLM signal output is from Hamamatsu photodiode module [6]. This signal will be digitized by GE ICS-710-A digitizer which is also used for beam intensity monitors.

PROTOTYPE TESTS

We have completed prototype tests on beam intensity monitors including Bergoz ICT and Bergoz NPCT. And we also have evaluated the performance of ICS-710-A digitizer. See Ref. [3] for more details.

Soft Interlock

As the definition of NSLS-II LCM system, LCM is safety related, but not credited like PPS and EPS. However, the first ICT at the end of Linac (see Figure 1) is still 'interlocked' to the e-Gun: the Gun will be inhibited (no beam injected) by disabling its timing trigger if the total charge in one second (charge rate Q_{rate}) measured by the ICT exceeds threshold (for now, it's 25nC/s). That's to say, Q_{rate} <= 25 nC/s for safety reason. We call this kind of interlock as 'soft interlock'. Figure 3 shows the architecture of the whole system. The main concern about this soft interlock is that the communication between different systems (basically the timing IOC and the ICT/digitizer IOC) is over Ethernet.

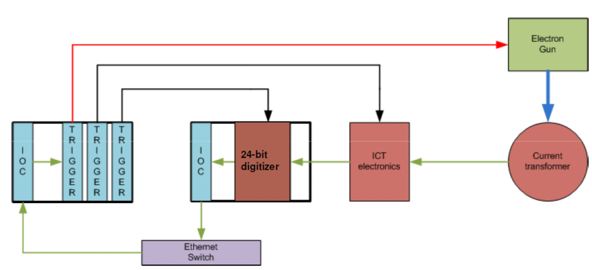

Figure 3: ICT soft interlock.

However, tests have been performed to determine the latency in the system. The worst case has been found to be 18 ms (see Figure 4). Since the repetition time of the LINAC is 100ms or more, this soft interlock system can detect a fault and prevent the next LINAC pulse from occurring.

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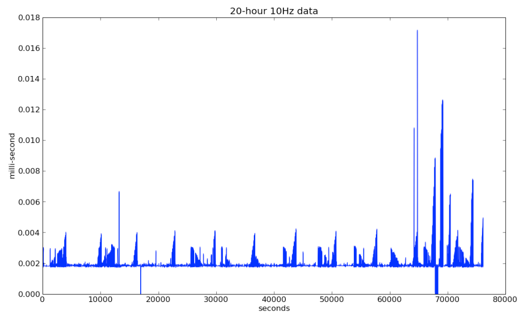

Figure 4: Network (EPICS channel access) latency tests.

CBLM Tests at NSLS

For LCM controls and DAQ, the most challenging part is the beam loss measurement: how to calibrate the CBLM signals to absolute charge loss/sec? We installed the prototype CBLMs in one dipole end at NSLS and got some preliminary results.

The prototype CBLM consisted of a 10mm OD rod, 1m long of Suprasil 2B [7] mounted in an Aluminium tube and coupled through air to a Hamamatsu PD module [6] in an Al and Pb box for shielding, as shown in Figure 5.

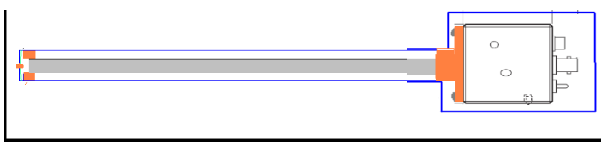

Figure 5: Prototype CBLM.

Calibration of the CBLM signals to absolute charge loss/sec is done using the scraper dominated reduced lifetime to measure local beam loss rate that will hit the CBLM in the dipole downstream of the scraper. The CBLM signal will then scale with the local loss rate as seen in Figure 6. The result shown in Figure 6 is very encouraging. It shows CBLM output signal scales linearly with local loss rate Io/τ over a 40 dB dynamic range.

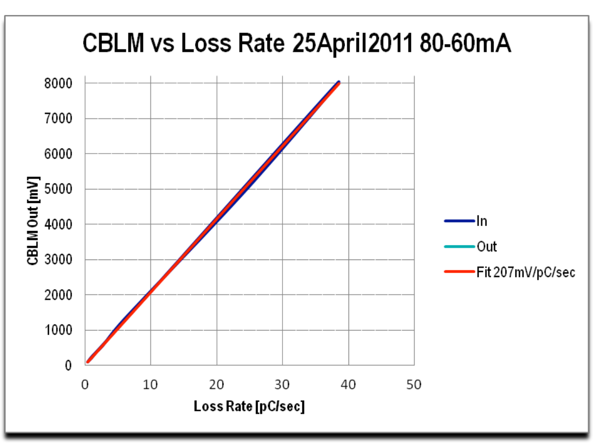

Figure 6: CBLM calibration.

Figure 7 shows beam loss detected by CBLM vs. the stored beam decay at NSLS. Again, the system works linearly.

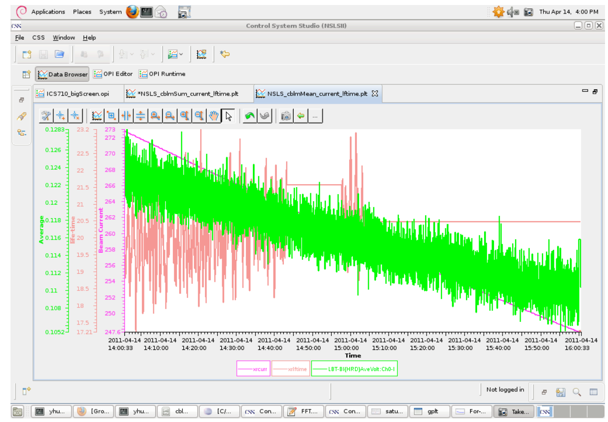

Figure 7: Beam loss vs. stored beam at NSLS.

CONCLUSIONS

From a controls point of view, LCM is one of the most complicated diagnostics subsystems. This system is safety related, but not credited so that we innovatively adopt the concept of "soft interlock." The most challenging part of LCM is the calibration of the Cerenkov beam loss monitor signal and the prototype tests of CBLM at NSLS seem encouraging. Future work will show the impact of using the vertical scrapers and the fraction of Touschek losses that will be controlled by the horizontal scrapers.

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[4] http://www.bergoz.com/.

[5] http://www.deltatau.co.uk/.

[6] C10439-9440(x), Hamamatsu PD module.

[7] Suprasil 2B, a product of Heraeus Quartz Glass, http://www.optics.heraeus-quarzglas.com/.

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