NSLS-II INJECTOR SYSTEM DIAGNOSTICS UPDATE FOR LINAC COMMISSIONING

D. Padrazo, O. Singh, I. Pinayev, S. Seletskiy, R. Fliller, T. Shaftan, B. Kosciuk, Y. Hu
Brookhaven National Laboratory, Upton, NY 11973, USA

Abstract

The NSLS-II Injector System Diagnostics provides instrumentation in the LINAC, Transfer Line (LBT) and Beam Dumps for measuring key beam parameters. These instruments will be adequate in providing staged commissioning of NSLS-II LINAC. This instrumentation will provide sufficient diagnostics to determine bunch charge, length, transverse size, position, and beam losses. The LBT will include key instruments to be used for beam commissioning and tune-up, particularly, BPM, Beam Dumps/Faraday Cup, ICT, FCT, Flags, and Energy Slit. Measurements of beam charge, bunch train, bunch charge, energy jitter, emittance, and energy spread, as well as measurements for beam current, bunch train pattern, tune and chromaticity can be achieved. This paper will detail implementation and status of the NSLS-II Injector System Diagnostics required for LINAC Commissioning.

INTRODUCTION

The NSLS-II is a state of the art 3GeV synchrotron light source being developed at Brookhaven National Laboratory. The injection system consists of a 200 MeV LINAC, a 3 GeV booster synchrotron, and associated transfer lines. The instrumentation in the LINAC provides sufficient beam diagnostics to determine bunch charge, length, transverse size, position, and beam losses. The LTB and BST includes key instruments to be used for beam commissioning and tune-up, particularly the beam dumps and those diagnostics elements within the booster vault. Measurements of beam charge, bunch train, bunch charge, energy jitter, emittance, and energy spread, can be achieved. Booster diagnostic provides measurements for orbit correction, injection matching and transverse profile. In addition, elements are provided to measure beam current, bunch train pattern, tune and chromaticity measurements. This paper will detail the implementation of these diagnostics components required for the NSLS-II Injector System commissioning.

LINAC DIAGNOSTICS

A turn-key procurement (Research Instruments), the NSLS-II LINAC is specified to have an output energy of 200MeV, energy spread of 0.5%, bunch length of 20ps, and normalized emmittance of 55 mm-mmrad. The LINAC will be capable of operating in single bunch mode with a charge of up to 0.5nC, or in multibunch mode with a bunch train of 80 to 150 bunches, separated by 2ns with a charge per train of 15nC. The LINAC will have a 100kV electron gun with thermionic cathode, sub-harmonic pre-buncher, 3 GHz pre-buncher, 3GHz buncher, and a 3 GHz acceleration section. LINAC diagnostics consist of a Wall Current Monitor (WCM) after the gun, and another after the buncher. There is a WCM, FLAG, and Beam Position Monitor (BPM) before each LINAC tank. This will provide sufficient diagnostics to determine bunch charge, length, transverse size, and position. The WCMs also provide a measure of the beam losses in the LINAC. Refer to the Diagnostics Table of Elements and the Plan View of Injector as shown in Table 1 and Fig. 1 respectively.

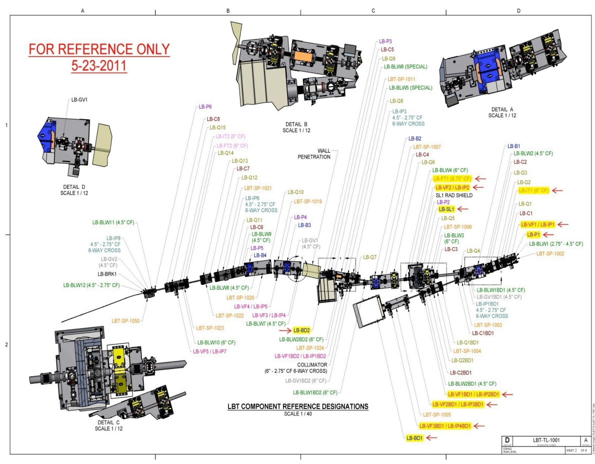

Figure 1: (LBT) LINAC To Booster Transport.

Table 1: Diagnostics – LINAC / GUN

System	Qty	Type	Abbrv.	Parameter Measured
Electron Source (Gun)	2	Wall Current Monitor	WCM	Intensity; longitudinal beam characteristics
Linac	3	Fluorescent Screens	FLAGS	Position; transverse profile
Linac	3	Wall Current Monitor	WCM	Bunch charge; intensity; beam loss
Linac	5	Beam position monitor	BPM	Beam position

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LINAC TO BOOSTER (LTB) TRANSPORT LINE DIAGNOSTICS

The layout of the LTB transport line is shown in Fig. 1. It consists of 3 sections, a LINAC to achromatic section, an achromatic, and a matching section into the booster. In addition, there are two beam *dumps* located in the LINAC vault that are used for commissioning, tune-up and diagnostics. Table 2 shows the available diagnostics in the LTB. There are *Flags* at the start of the LTB, after the *Energy Slit*, and prior to booster injection that are used for commissioning to obtain beam transverse position and profiles. There are two Screens integrated within a custom vacuum assembly, one used for Low Beam Charge (Cerium activated Yttrium Aluminum Garnet -YAG), and one for High Beam Charge (Optical Transition Radiation - OTR). After collision with electron beam, both screens emit light. YAG emits light by scintillation, OTR screen emits light by Transition Radiation. Custom optics transports screen images to a CCD camera where the image is collected and Transmitted to IOC.

There is an *Integrating Current Transformer* (ICT) and a *Fast Current Transformer* (FCT) to measure the beam charge and bunch train at each end of LTB.

An *Energy Slit* is placed at the maximum dispersion location in the achromat, to remove any low energy particles.

Six *BPMs* are placed through the LTB. The first is located at the end of the LINAC. One exists after the *Energy Slit* for online energy jitter measurement. These two *BPMs* will be implemented for LINAC commissioning. Four *BPMs* are in the matching section for matching into the booster, and will be implemented for Booster commissioning. There is also a Safety Shutter placed before the exit of the LINAC vault that will allow safe operation of the LINAC independent of the status of the booster.

The *beam dump lines* are equipped with *Flags*, including three *Flags* in the "straight ahead" beam dump line for emittance measurement. The second *beam dump line* will have sufficient dispersion to perform an energy spread and energy jitter measurement. Incorporated into each beam dump will be the design of a *Faraday Cup* which will also act as a beam stop and will measure gross charge per train, capturing the entire charge of the electron beam and its shower for all dumps.

Bergoz Fast Current Transformers (FCT) is used for fill pattern monitoring. The Bergoz FCT is directly mounted on the beam chamber with a ceramic break and RF shielding, and will provide electrical signal proportional to the charge of individual bunches. It has 1.75 GHz bandwidth with a 200 psec rise time. Fast ADC sampling (>1GS/s) of the FCT output voltage will make charge distribution available to the control system. The information obtained will be used in the top-off algorithm.

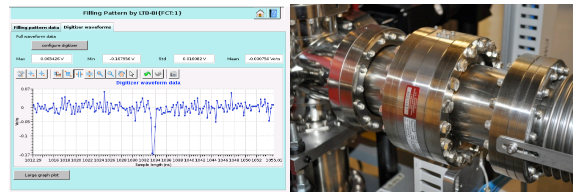

Figure 2: Fast Current Transformer (FCT)

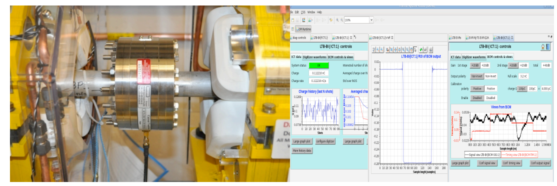

Figure 3: Integrating Current Transformer (ICT)

Table 2: Diagnostics—Transport Lines

Type	Qty (LTB)	Qty (BSR)	Resolution	Beam Parameter Measured
Screens (OTR + YAG)	9	10	10/30 µm	Energy spread; electron beam size, position
Fast current xfmr	2	2	~0.6 pC per bunch	Fill pattern; bunch charge
Energy slit	1	1	n/a	Beam energy spread
Integrating current xfmr	2	2	~4 pC	Injected bunch charge; injection efficiency
BPM (40× 90 mm elliptical)	1		30 µm .5nC	Beam position Total Charge (Single Bunch)
BPM (40 mm round)	5	8	30 µm .5nC	Beam position Total Charge (Single Bunch)
Faraday cup	2	1		Bunch charge

The ICT/BCM will provide a multiply time integral output, and is proportional to the beam pulse charge irrespective of the bunch width or bunch frequency spectrum. For NSLS-II Linac injection, with the maximum 150 bunches (500MHz RF), the bunch train to be integrated and measured is 298ns long. It will pass through the ICT and the ICT output will be a

368ns long signal with rise-time of about 20ns, fall-time of about 30ns and a flat top (if the 150 bunches are evenly charged). Bergoz BCM is comprised of a chassis and module. It has a bipolar voltage output that is directly proportional to the total beam charge. BCM electronics are made in various versions. The BCM-IHR-E (Integrate-Hold-Reset) module has been selected to measure single pulse or bunch trains up to 5us long.

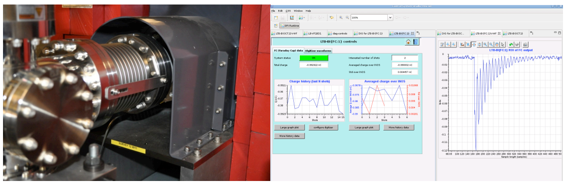

Figure 4: Faraday Cup (FC)

The *Faraday cup* is incorporated into each *Beam Dump* in LBT. The beam dump is comprised of six steel plates assembled such that the first plate incorporates a knife edge to interface with the beam pipe. The assembly is mounted on a G-10 base plate for isolation. It will measure the gross charge per train. As such, the maximum beam energy encountered in LBT is 230MeV, with a charge delivered by LINAC between .05 – 22nC in trains of 1-150 bunches.

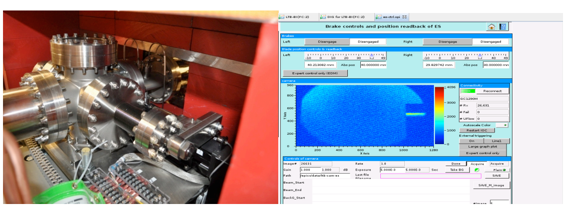

Figure 5: Energy Slit (ES)

The *Energy Slit* is designed to remove electrons outside of the specified energy range and is located in LBT region with peak dispersion (~ 1.1m). Nominal β-functions – Horizontal 6m and Vertical .1m. Emittances are 55 mm-mrad for both planes. Position of each blade is individually adjusted in 60mm range, with a step increment not exceeding 250μ, and a travel time across the range ≤ 1min. The tungsten blades are 70mm x 40mm x 20mm in cross section. It has the capability to intercept 100% of the beam. A CCD camera via optical transport is provided to observe operation and image on two phosphor coated tungsten blades. Two 100mm linear stages are driven by stepper motors with mechanism preventing motion when de-energized via two limit switches and home switches for each stage. There are linear potentiometers provided as encoders for position read back via PLC interface.

There are two Flag chamber design configurations for LBT (Radia Beam Technologies). A large aperture vacuum assembly to be employed in high dispersion region, including the 2nd beam dump of transport line, as well as a small aperture vacuum assembly to accommodate the remainder of the LBT. The Prosilica GC1290 Camera with manual focusing is used to capture beam image. The optical transport overall length is less than 1 meter. An illuminated virtual target is provided for calibration and alignment, and a Field of View is large enough to image the entire target.

Figure 6: Flags

Table 3: Small Aperture Specifications

Resolution (σ_{sys})	≤ 4.9 lp/mm (G2E1)
Modulation	≥ 58 % Contrast
Field of View	≥ 25 mm (Diameter)

Table 4: Large Aperture Specifications

Resolution (σ_{sys})	≤ 2.83 lp/mm (G2E1)
Modulation	≥ 52 % Contrast
Field of View	≥ 35mm (Diameter)

Table 5: Camera Specifications

Pixel Count	1280 x 960
Sensor Type	CCD Progressive
Sensor Size	1/3”
Pixel Size	3.75μm
Transfer Type	GigE

CONTROLS INTERFACE FOR DIAGNOSTICS

Diagnostics controls can also be considered as data acquisition (DAQ) rather than device control. Diagnostics control subsystem conform to NSLS-II control system standards. It is EPICS-based and the preferred operating systems for IOCs are RTEMS (Real-Time Executive for Multiprocessor Systems) and Linux. For VME-based controls, the CPU board is standardized as Motorola MVME3100. Whenever possible, diagnostics controls utilizes commercial off-the-shelf hardware to reduce cost as well to achieve better reliability. Although NSLS-II Linac and Booster are turn-key solutions provided by vendors, the intention is to standardize the diagnostics controls for the whole machine. Each type of beam monitor requires electronics (device controller) to process its output signal. The proposed electronics for the above groups and associated EPICS IOC platform are listed in Table 6.

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Table 6: Controls Electronics and IOC Platform

Type	Controls Electronics	EPICS IOC Platform
WCM/FCT/FC	Acquiris Digitizer DC252 (2GHz bw,10 bit, 4-8 GB/sec)	CompactPCI/Linux
DCCT and ICT	• GE cPCI Digitizer ICS-710-A(24-bit, 200KS/s, 8-Chan • Allen-Bradley PLC (DAC, Digital I/O)	CompactPCI/Linux
BPM	• In-House development custom electronics	VME/RTEMS/PC/Linux
Gigabit Ethernet cameras	Prosilica	PC/Linux
Stepper motor based	• Delta Tau GeoBrick LV PC • HYTEC MDS-8	PC/Linux
Instrument controls	Windows-based network/spectrum analyzer	PC/Linux
Digital I/O and DAC	• Allen-Bradley PLC	PC/Linux

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