STATUS OF NSLS-II INJECTOR*

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Abstract

We discuss the current status and plans for developing the NSLS-II injector. The latter consists of a 200 MeV linac, a 3-GeV booster synchrotron, transport lines and the storage ring injection straight section. The system design and installation are complete. Last year we concluded 200-MeV linac commissioning and are planning to commission the 3 GeV booster during the fall of 2013.

INTRODUCTION

The NSLS-II [1] is a state-of-the-art 3 GeV synchrotron light source under construction at Brookhaven National Laboratory. It will provide ultra-bright synchrotron radiation of 10^{21}·photons·s^{-1}·mm^{2}mrad^2·0.1%BW^{-1} at 2 keV and high photon flux of 10^{15}·photons·s^{-1}·0.1%BW^{-1}. The facility will support a minimum of 60 beamlines. Construction started in 2009 and commissioning is expected to be completed in 2014.

The NSLS-II injector, specified in [2], is developed in a staged approach. The 200-MeV linac is a turn-key system procured from Research Instruments GmbH (RI) [3]. The linear accelerator was installed and commissioned in the spring of 2012. The set of beam parameters required for the next stage of injector development is established.

The NSLS-II booster-synchrotron is a joint venture with Budker Institute of nuclear physics (BINP) [4]. The BINP team has delivered the detailed design based on our specification [5] and manufactured the booster ring including injection and extraction system, beam diagnostics, power supplies except for the RF system that was developed in-house [6]. Three large dipole power supplies were subcontracted from Danfysik [7]. Booster controls and the diagnostics system capitalized on power supply interfaces and controls [8, 9] and the BPM electronics [10] developed in-house for the NSLS-II storage ring. Installation of the booster system is now complete and the injector integrated testing is nearing completion [11].

We built Linac-to-Booster (LtB) and Booster-to-Storage Ring (BST) transport lines procuring beam line components from several manufacturers and designing and building vacuum chambers and support stands at BNL and in the local shops.

Storage ring injection straight section consists of four kickers, DC preseptum and pulsed septum together with transition chambers populated with the beam diagnostics.

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We are developing the kickers at NSLS-II, while procuring DC and the pulsed septa from BINP and Danfysik correspondingly. The injection straight components are currently under assembly and testing.

LINAC COMMISSIONING

The 200-MeV 3-GHz linear accelerator (Figure 1) consists of a 100 keV thermionic gun, bunching system, four accelerating cavities and focusing optics. The RF pulses are provided by three 42 MW RF klystrons (one serves as a hot spare) from Thales powered by Solid State modulators from Scandinova.

Figure 1: 200-MeV linac in the NSLS-II tunnel.

In March-April of 2012 we, together with the RI team, commissioned [12] the linac achieving performance specifications suitable for injection into the booster. During the commissioning we tested the system performance in single- (SBM) and multi-bunch (MBM) modes of operation. Comparison between the measured beam parameters versus our specifications is summarized below.

Table 1: Linac Beam Parameters: Measurements versus Specifications

Parameter	Spec		SBM	MBM
Energy, MeV	200		201	210
Charge, nC	>0.5 SBM	>15 MBM	0.5	11
Bunch train Length, ns	160 – 300		N/A	160-300
Bunch train Uniformity	<10%		N/A	25%

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Parameter	Spec	SBM	MBM
Energy Spread	<0.5% RMS	0.14% FWHM	0.41% FWHM
Emittance, nm rad	X/Y<38	X: 58, Y: 63	X: 56, Y: 47

In Figure 2 we show one of the results from the linac commissioning – the bunch energy spectrum measured in the LtB spectrometer at 200 MeV. Beam loading [13] is compensated by adding a short ramp in the RF power waveform.

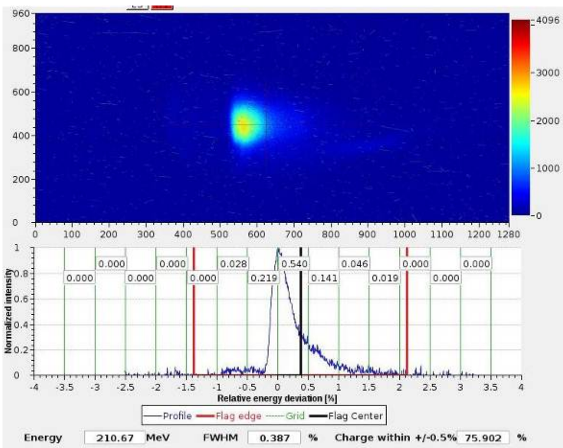

Figure 2: Energy spectrum of 210 MeV 11 nC beam in the MBM mode.

The “boxed” numbers in Figure 2 report percentages of the bunch charge per 0.5% bins of the energy distribution. One can see that about 76% of the distribution fits within 1% of the energy spread window, which satisfies requirements for the booster commissioning

3-GEV BOOSTER

The NSLS-II booster will accelerate beam up to the nominal energy of 3 GeV. The 158.4 m long ring is comprised of four arcs with the FODO-like combined function magnet structure and matching quadrupole triplets. The main booster parameters are listed in Table 2. The booster lattice contains 32 defocusing dipoles powered by two 750A/±700V BD power supplies and 28 focusing dipoles powered by a single 900A/±220V BF power supply.

The booster dipoles are of the combined-function type with quadrupole and sextupole components of their field defined by the pole shape. A novel field mapping technique based on a combination of a Hall probe array and a laser-tracker allowed to measure and fiducialize the design orbit position in the magnets with a precision of better than 100 microns. [14].

The Booster injection system is designed to operate in either single cycle injection or the beam stacking mode. Injection and extraction kicker pulsers are the PFN-type with thyrotron switches. With the goal of preserving the output beam emittance, the field waveform in the extraction kickers is optimized so the pulse flatness of less than 0.2% is achieved.

Table 2: The Main Parameters of the Booster Beam

Energy	200 MeV	3 GeV
Repetition rate, Hz	up to 2 Hz	
RF frequency, MHz	499.68	
RF harmonic number	264	
RF voltage, MeV	0.2	1.2
RF acceptance, %	1.65	0.54
Betatron tunes	9.646 X / 3.411 Y	
Natural chromaticity	–9.5 X /–13.5 Y	
Momentum compaction	0.00882	
X emittance, nm rad		37.4
Energy spread		8.31·10-4
Energy loss/turn, keV	0.0135	685.8

A part of the booster arc and the extraction straight are shown in the photograph below (Figure 3).

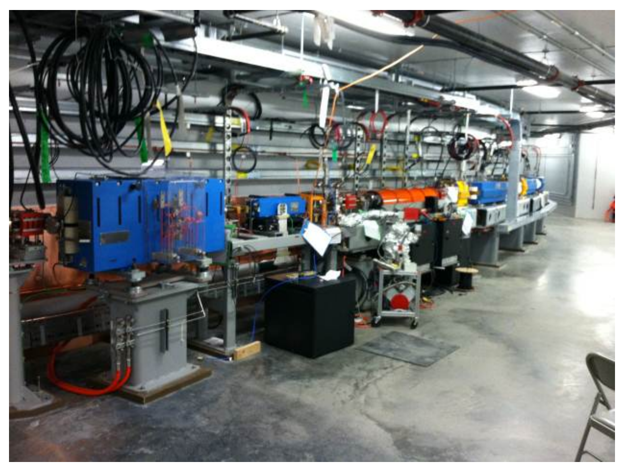

Figure 3: Exit of Arc 4 and the extraction system of the booster-synchrotron.

The Booster commissioning will begin in the fall of 2013 with the goal of achieving the beam parameters needed for injecting into the storage ring for early operation of the NSLS-II accelerator complex. Upgrade to extended capabilities, such as 2 Hz or the beam stacking modes is possible to enhance the injector performance.

TRANSPORT LINES

Our transport line optics design includes a spectrometer for the energy measurements and a dispersion-free region for tuning Twiss parameters of the beam coming to the booster and to the storage ring. Prior to the injection straight sections in both rings we set-up small segments equipped with two correctors and two BPMs for launching the beam through the injection septa.

The transport lines are equipped with full set of diagnostics for measurement of the 200 MeV and 3 GeV beams after the linac and the booster. We invested into non-invasive beam diagnostics (BPMs, ICTs, FCTs) so that the beam optimization can be largely done without disturbing injector operations.

Installation of the transport line elements required for the injector commissioning is complete (Figure 4).

Figure 4: Booster-to-Storage Ring transport line in the booster tunnel.

Following experience from the linac commissioning substantial scope of the supplemental shielding is being added to the transport channels. Analysis, design and installation of the shields are under way [15].

In April we began Integrated Testing of the transport line and booster software panels and High-Level Applications [11]. During these tests we separately commission injection, first-turn, acceleration, extraction and transport software tools without the actual beam but using beamline models for simulation of the beam diagnostics signals in EPICS process variables.

STORAGE RING INJECTION STRAIGHT SECTION

Similarly to other modern light sources we use 1-turn injection enabled by 5.2 µs (2 SR turns) half-sine, 8.5 mrad kicker pulses. Ferrite kicker magnets are driven by 10 kV pulsers with IGBT-switches in-series. Excellent pulse-to-pulse peak kicker field stability of <0.01% has been measured on the prototype system.

An out-of-vacuum 150 µs full-sine, 100 mrad septum system from Danfysik was successfully tested at the factory and delivered to BNL. Low leakage field in the storage ring chamber and high stability of the septum waveform (amplitude stability of 0.1%, time jitter below 10 ns) were demonstrated.

NSLS-II Pulsed Magnet laboratory is equipped for production and testing of the storage ring kickers and pre-installation tests of the pulsed septum.

Both kicker and septum systems will be integrated with the NSLS-II type of controls and installed into the storage ring tunnel during summer months of 2013.

SUMMARY

Installation and testing of the NSLS-II injector is coming to completion. The 200-MeV linac was commissioned in 2012 and we are looking forward to the booster commissioning later this year.

The injector development is a joint effort of the NSLS-II team together with our colleagues at Research Instrument GmbH, Budker Institute of nuclear physics and Danfysik.

The present injector system has a significant upgrade potential. The performance of the NSLS-II injector can be upgraded to higher charge rate, higher beam quality, more flexible bunch trains and higher reliability.

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