

## STATUS OF THE NSLS-II INJECTION SYSTEM DEVELOPMENT\*

T. Shaftan<sup>#</sup>, J. Rose, R. Filler, G. Wang, R. Heese, G. Ganetis, A. Blednykh, W. Casey, L. Dalesio, F. Willeke, S. Ozaki, M. Ferreira, P.K. Job, Y. Kawashima, B. Kosciuk, S. Kowalski, E.D. Johnson, H. Ma, D. Padrao, B. Parker, C. Spataro, P. Singh, G. Fries, D. Hseuh, O. Singh, Y. Li, W. Guo, L.H. Yu, R. Meier, R. Faussete, M. Rehak, I. Pinayev, S. Krinsky, J. Skaritka, S. Sharma, Y. Hu (BNL, Upton, Long Island, New York, U.S.A.)

### Abstract

We discuss the status of, and our plans for developing the NSLS-II injector. The injector consists of a 200 MeV linac, a 3-GeV booster, transport lines and an injection straight section. The system design now is almost complete, and the development of the injector in the procurement phase. We plan to commission the injector in 2012-2013.

### OVERVIEW

NSLS-II is a new third-generation storage-ring light source that is under construction at Brookhaven National Laboratory [1]. The NSLS-II injector [2] will be able to fill the storage ring from 0 to 500 mA in few minutes and support the top-off mode of injection. Sustaining an average storage-ring current at the level of 0.5% in the

top-off mode requires delivering 7.5 nC of charge once per minute. This amount of charge is distributed over 80 to 150 bunches in flexible bunch trains. The shortest bunch train (160 ns) is limited by the beam's loading in the linac, while the booster's revolution period (528 ns) limits the longest train.

The NSLS-II injector will support two basic formats of bunch pattern in the storage ring: Uniform fill with an ion-clearing gap; and, a few groups of bunch trains separated by short gaps. We also are considering implementing complex patterns in future such as 100% uniform fill, and camshaft bunches.

We foresee the main subsystems of the NSLS-II injector, the linac, and booster as semi-turnkey procurements.

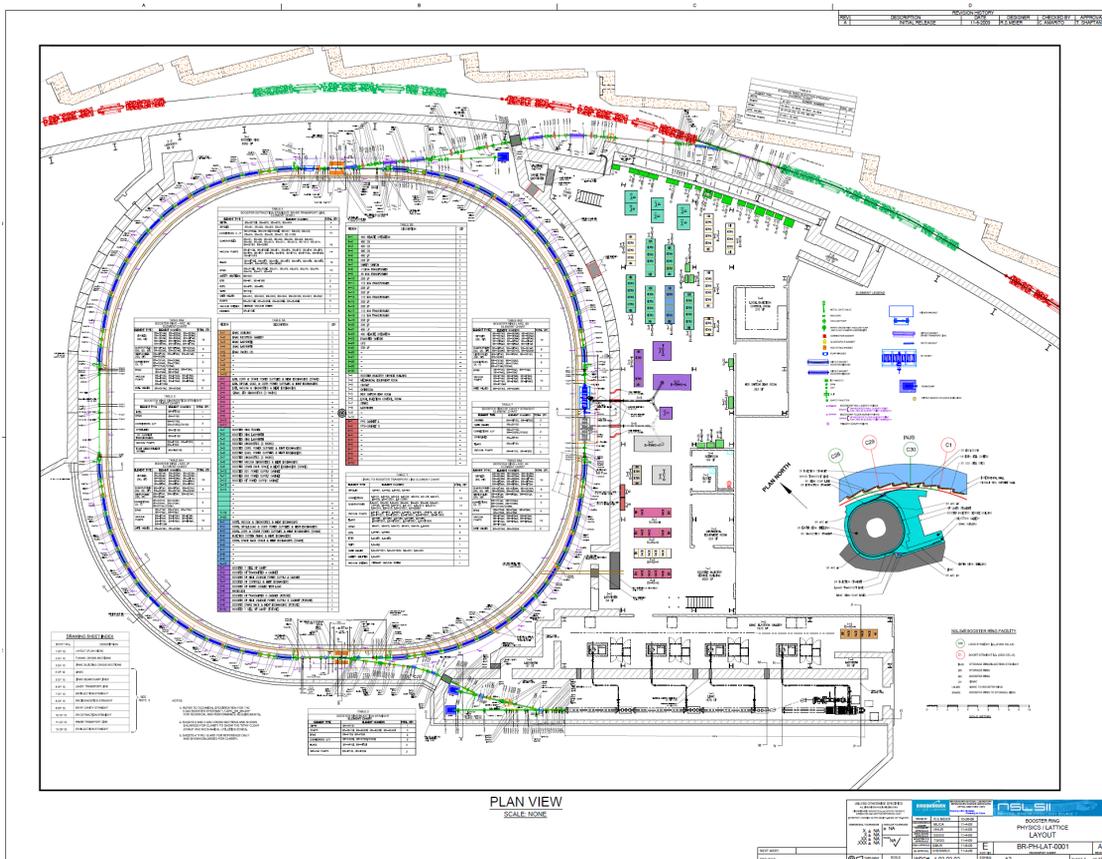


Figure 1: Layout of the NSLS-II injector.

\*This manuscript has been co-authored by employees of Brookhaven Science Associates, LLC, under Contract No. DE-AC02-98CH10886 with the U.S. Department of Energy.  
<sup>#</sup>shaftan@bnl.gov

Figure 1 depicts the injector's layout, wherein the linac and booster are housed in separate tunnels, and the injector's service area is adjacent to these accelerators and

the ring injection's straight section. The layout shows a possible set-up of the linac, together with a future upgrade that adds a second gun supplying exclusively single bunches for fast switching between the injection modes.

### LINAC

The linac will contain a 100-keV thermionic gun, a 500 MHz/ 3 GHz bunching system, along with accelerating structures powered by 3 GHz klystrons.

To support the top-off requirements, we considered a realistic loss budget of 50%. Thus, the linac is specified to produce 15 nC in the bunch trains, or 0.5 nC in a single bunch.

At this amount of charge, the beam loading is significant and loading compensation is essential to meet the specifications of the booster's energy acceptance. Also, tight requirements are imposed on the bunch train's uniformity, the train edge's quality, and amount of parasitic charge in the "empty" RF buckets.

The contract for the NSLS-II linac was awarded to Research Instruments GmbH in April, 2010. The Front-End of the linac, the 100-keV part containing the gun and a low-energy buncher, will be delivered to BNL in advance so we can test the model of beam dynamics, and carry out experiments in generating flexible bunch patterns.

### BOOSTER

The booster will accelerate electrons from 200 MeV to the nominal energy of 3 GeV. Since we will use multi-bunch injection, we specified a 1 Hz repetition rate, and did not preclude an upgrade to 2 Hz. The booster circumference is exactly 1/5 of that of the storage ring, which is long enough to allow a low-emittance lattice design can be installed.

Fig.2 shows one quarter of the NSLS-II booster lattice,  $\beta$ -functions and dispersion, and Table 1 summarizes the lattice parameters.

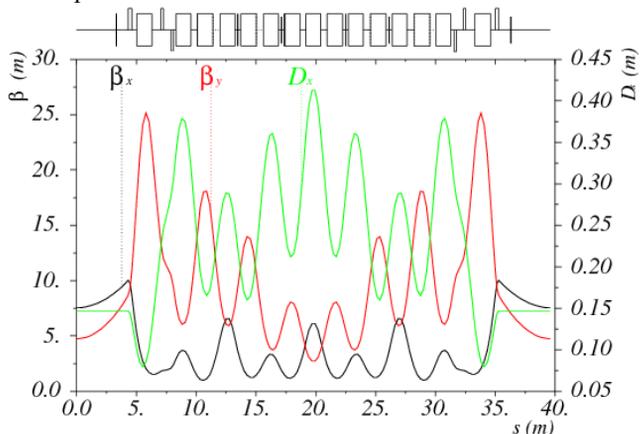


Figure 2: The NSLS-II booster lattice.

Table 1: Booster ring's parameters

Parameter	Value
Emittance, nm	39
Circumference, m	158.4
Booster current, mA	20
RF frequency, MHz	499.68
RF voltage, MV	1.2
Harmonic number	264
X/Y tune	9.64/3.41
X/Y chromaticity	-9.9/-12.9
Momentum Compaction	0.0084
Energy loss per turn, keV	686
X/Y/E damping time, ms	4.8/4.7/2.3
Damped energy spread, %	0.82
Damped bunch length, mm	16.2

The booster lattice is based on the low-emittance FODO solution similar to that of the ASP booster [3]. The four-fold symmetric magnet lattice consists of 60 combined-function magnets. The booster RF system contains a seven cell PETRA-type 500 MHz RF cavity.

In order to reduce the demand on the linac's beam charge, the booster injection was designed so that we could accomplish beam stacking (Fig. 3) [4]. Two trains of bunches are injected sequentially into the booster. The second bunch train of 7.5 nC is added 100 ms later (limited by the 10-Hz linac repetition rate) to the first train circulating in the machine at the injection energy; then, the total charge of 15 nC is accelerated to 3 GeV.

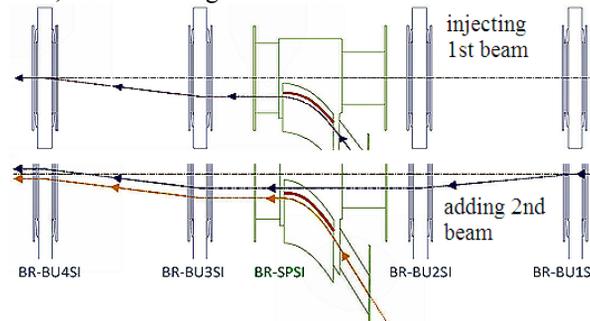


Figure 3: Beam-stacking schematics.

We paid particular attention to preserving the quality of the extracted beam at the level provided by the low-emittance booster lattice. This translates into the tight tolerances of the booster's extraction system. One of the most challenging devices is the extraction kicker, whose short pulse waveform must exhibit minimal ripple and jitter.

The NSLS-II booster will operate with relatively high circulating current of 20 mA (28 mA max). The collective effects were assessed [5] and the transverse instability of coupled bunches is considered as a potential concern at intermediate energy along the ramp.

The contract for the NSLS-II booster was awarded to Budker Institute of Nuclear Physics in May, 2010. The scope of procurement excludes the RF system and some of the accelerator components that will be supplied by BNL.

## TRANSPORT LINES

The transport lines will connect the linac, booster, and storage ring. Three short diagnostics beamlines ending in the beam dumps (Fig. 1) affords us a complete set of instrumentation for machine commissioning [6].

Design of the diagnostics lines is completed, and we have developed methods of measuring energy, energy spread, emittance, dispersion, and Twiss functions at the exits of the linac and booster [7]. The following figure illustrates measurement of the Twiss functions in the booster-to-storage ring diagnostics line (BSR TL).

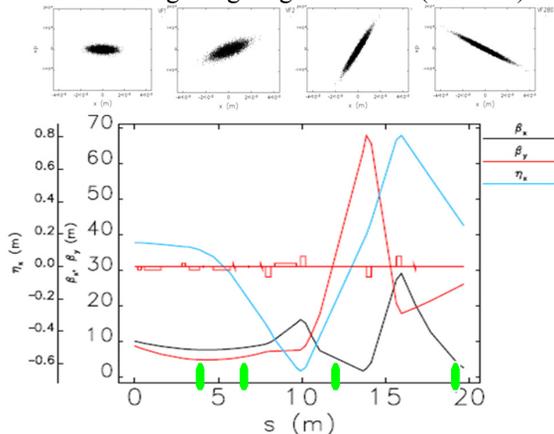


Figure 4: Twiss functions and dispersion along the BSR TL during measurements (ELEGANT [8] has been used in the simulations). Green markers show the beam monitor's locations.

Transport line magnets, supports, vacuum and diagnostics equipment are being specified and will be procured in 2010-2011.

## INJECTION STRAIGHT SECTION

The storage ring's injection straight section consists of a DC pre-septum, a pulsed septum, and four kickers located in the 9.3 meter long straight section of the storage ring.

To closely match the kicker's waveforms, we are considering employing a single 4 kV, 18 kA, half-sine 5.2  $\mu$ s power supply to power all four magnets in parallel.

The design of the straight section is nearing completion.

A Pulsed Magnet Laboratory (PML) was established at the NSLS-II for prototyping the magnets and power supplies, minimizing jitter and noise in the magnet's current and field pulses, and for measuring and acceptance testing of the pulsed magnets received from vendors before installing them in accelerators. Over the past few months, PML developed a prototype of the booster's extraction kicker and succeeded in achieving

highly reproducible waveforms with the ripples on a 0.7% level (Fig. 5).

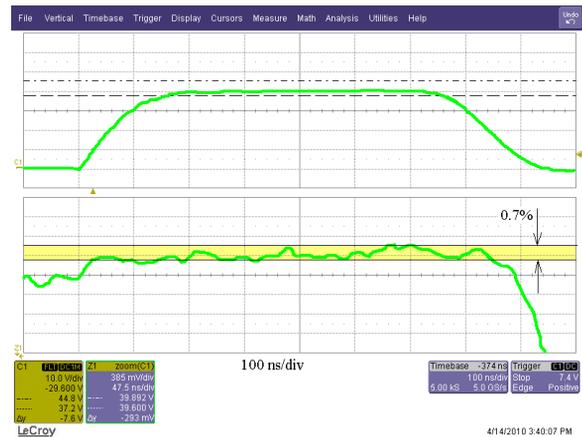


Figure 5: Waveform generated by the prototype of the booster's extraction kicker developed in BNL's pulsed magnet laboratory.

In 2009, we hosted a Pulsed Magnet Design and Measurement workshop that discussed critical issues in developing of state-of-the-art pulsed-power systems for accelerators [9].

## SUMMARY

The NSLS-II injector has entered its procurement stage. The injector building will be available for installing the accelerator components in May 2011. This installation will begin with the booster RF system, proceed with the establishment of the linac and booster, and conclude with our installing the injection straight section in the storage ring.

At the end of the commissioning, the injector will perform at a level suitable of supporting the initial set of the NSLS-II's storage-ring specifications: 25 mA at 3 GeV without entering the top-off mode.

The injector will reach its design performance after the commissioning of the storage ring; we anticipate improving its' capabilities via detailed tuning and a number of upgrades.

## REFERENCES

- [1]<http://accelconf.web.cern.ch/AccelConf/p07/PAPERS/MOOAAB01.PDF>
- [2]<http://accelconf.web.cern.ch/accelconf/e08/papers/wepc089.pdf>
- [3]<http://epaper.kek.jp/p05/PAPERS/RPAE084.PDF>
- [4] R.P. Fliller III et al., These Proceedings, TUPEC041
- [5] A. Blednykh et al., These Proceedings, TUPD084
- [6] R.P. Fliller III et al., These Proceedings, TUPEC042
- [7] G. Wang et al., These Proceedings, WEPEA084
- [8]<http://www.aps.anl.gov/Science/Publications/lnotes/lis287.pdf>
- [9][http://groups.nsls2.bnl.gov/publications/Staff%20Publications/90966\\_Proceedings%20Pulsed%20Magnet%20Design\\_Measurment%20Workshop.pdf](http://groups.nsls2.bnl.gov/publications/Staff%20Publications/90966_Proceedings%20Pulsed%20Magnet%20Design_Measurment%20Workshop.pdf)