BNL-81646-2008-CP

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Presented at the 11th European Particle Accelerator Conference (EPAC '08)
Genoa, Italy
June 23-27, 2008

July 2008

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DISCLAIMER

STATUS OF THE NSLS-II INJECTION SYSTEM DESIGN*

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Abstract

The NSLS-II is a new ultra-bright 3rd generation 3 GeV light source that will be built at Brookhaven National Laboratory. Its design is well under way [1]. The requirements for the compact injector complex, which will continuously provide 3 GeV electrons for top-off injection into the storage ring, are demanding: high reliability, relatively high charge and low losses. The injector consists of a linear accelerator, a full-energy booster, as well as transport lines, and an injection straight section. In this paper we give an overview of the NSLS-II injector, discuss its status, specifications, and the design challenges.

OVERVIEW

The NSLS-II injector will be able to fill the storage ring from 0 to 500 mA in reasonable time and support the top-off mode of injection, for which the NSLS-II users have established the following requirements (Table 1).

Table 1 User Requirements.

Stability of average current	<1%
Time between injections	>1 min
Bunch-to-bunch variation of current	<20%

To meet these requirements, NSLS-II will utilize a full-energy injection system operating in top-off mode with minimal disturbance to the circulating beam.

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

The main subsystems of the NSLS-II injector, the linac and booster, are foreseen as semi-turnkey procurements.

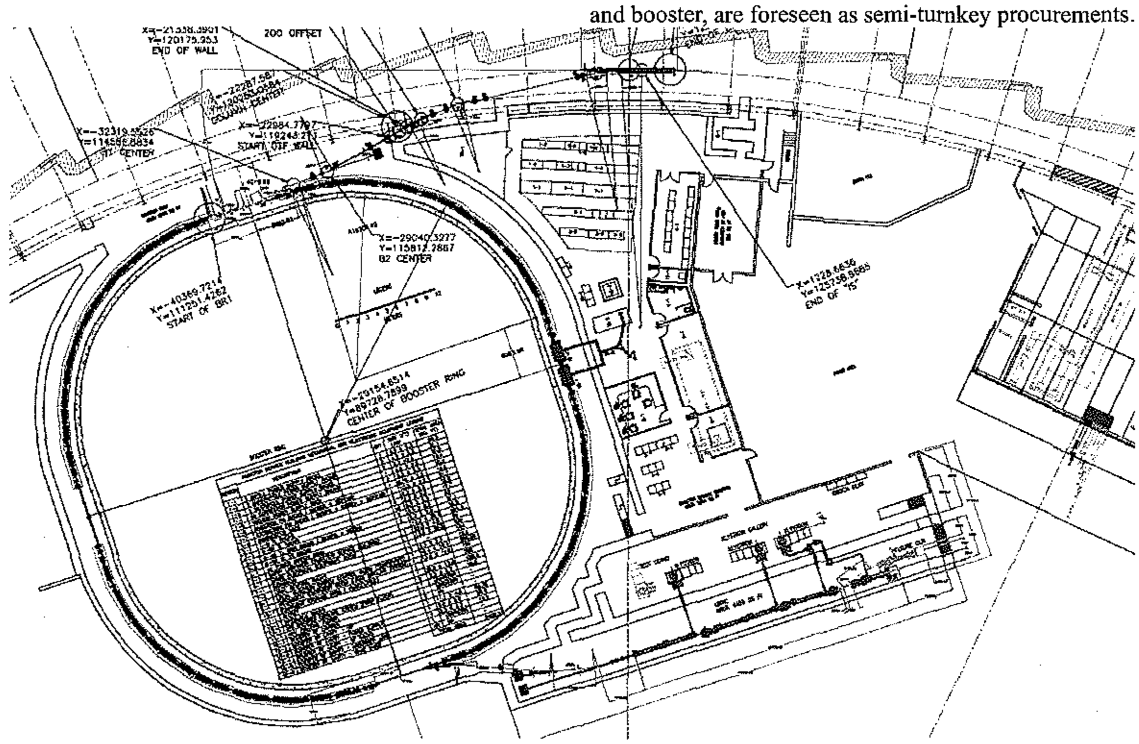

Figure 1: NSLS-II injector layout

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

The current stage of the NSLS-II injector design is described in details in NSLS-II Preliminary Design Report [2].

*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.

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STUDIES OF INJECTION PROCESS

During initial stage of the injector design we carried out a set of simulations of injection into the NSLS-II storage ring [3]. The model of the storage ring included the following: the RF cavity, the effects of radiation damping and quantum fluctuations, field errors, misalignments and their correction, coupling correction, insertion devices and compensation of their impact on the linear optics. The injected beam was simulated in the presence of misalignment, mismatch and errors.

From these studies, we established the requirements and tolerances for the parameters of the injected beam. These requirements were then translated into specifications for the injector subsystems.

LINAC

Requirements on the NSLS-II linac are summarized in table 2.

Table 2 Linac requirements

Energy	200 MeV
RF frequency	3 GHz
Bunches per train	80..150
Total charge in bunch train	<15 nC

Due to large (1320) number of RF buckets in the storage ring, the multi-bunch mode of injection will be used, so that the linac will produce and accelerate trains of bunches with a high total charge for subsequent injection into the booster. The latter requirement on charge is motivated by the basic top-off format, wherein a total charge increment is implemented by adding a single bunch train only once per minute. The appropriate contingency is applied on the value of the total charge to account for limited efficiency of the beam transport throughout the injector.

High linac energy eases the compensation of the energy slew along the bunch train induced by the beam loading; it also relaxes requirements on the injection process into the booster. It ensures necessary redundancy so that, the linac will be able to deliver the beam even should a single klystron fail.

As a way of maintaining the uniformity of the storage ring bunch pattern we are studying the possibility of generating flexible bunch trains in the injector by manipulating the gun's grid voltage. Top-off with flexible bunch trains will assure the high uniformity of the charge distribution in the storage ring's buckets.

BOOSTER

The booster will accelerate electrons from 200 MeV to the nominal energy of 3 GeV. Since we will use the multi-bunch injection, a 1 Hz repetition rate is sufficient for the booster power supplies. Our detailed simulation of the injected beam's dynamics in the realistic NSLS-II storage ring lattice established the requirement for a low equilibrium emittance. The booster circumference is exactly 1/5 of that of the storage ring, so affording enough room for the low-emittance lattice design.

The NSLS-II booster requirements are summarized in table 3.

Table 3 Booster requirements

Energy ramp	0.2 → 3 GeV
Repetition rate	1 Hz
Circumference	158.4 m
RF frequency	500 MHz
Horizontal emittance at 3 GeV	30 nm
Current	20 mA

The booster lattice is based on the low-emittance FODO solution similar to the ASP booster [4]. The four-fold symmetric magnetic structure consists of 60 combined-function magnets. The booster RF system contains two PETRA-type 500 MHz RF cavities.

Optimization of the booster lattice is ongoing. We are focusing on reaching a large on- and off-energy dynamic aperture and large energy acceptance. The lattice is optimized with the help of tune scans, i.e. wherein we compute the emittance and dynamic aperture (DA) are computed as functions of tunes. We also calculate energy acceptance at low energy and are planning to perform careful modelling of the injection process.

Particular attention is paid to maximizing the straight section length. A long injection straight section will enable beam stacking at low energy, which will reduce the amount of charge required from the linac.

The design of the injection and extraction systems focuses on reaching maximum stability of in- and out-coming beams and avoiding beam losses.

The NSLS-II booster will operate with relatively high circulating current. We are carrying out collective effects analysis calculating thresholds for head-tail and multi-bunch instabilities.

TRANSPORT LINES

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

Currently, the optics of the transport line are designed, together with the completion of studies of tolerance and flexibility, analysis of trajectory and focusing correction, and design of the magnet, power supply, vacuum, diagnostics and safety systems.

INJECTION STRAIGHT SECTION

The Injection ring straight section (Fig. 2) consists of a DC pre-septum, a pulsed septum and four kickers located in the 9.3 meters straight section of the storage ring.

Figure 2: NSLS-II injection straight section layout

The design of the straight section is in progress; currently the layout of the injection bump and the parameters of the pulsed magnet are being optimized (Table 4). We foresee including weak and short kicker magnets for accurate cancellation of the injection bump's residuals and as feedback for compensation of the injection's transients.

Table 4 Requirements of the storage ring injection system

Kicker pulse width	5.2 μs
Kicker angle	8.25 mrad
DC/Pulsed septa angles	150/80 mrad
Nominal orbit bump	15 mm
DA at injection point	>11 mm

A Pulsed Magnet Laboratory will be established at the NSLS-II for prototyping the magnets and power supplies, minimizing jitter and noise in the magnet current and field pulses and for measurement and acceptance testing of pulsed magnets received from vendors before installing them in accelerators.

SUMMARY

The design of the NSLS-II injector is established and the requirements of the main subsystems are finalized. Specifications on utilities and interfaces with conventional constructions were worked out during last year. The detailed design of the NSLS-II injector subsystems is under way, with their completion aimed for the commissioning of the injector in 2013.

REFERENCES

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