STATUS OF NSLS-II BOOSTER

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Abstract

The National Synchrotron Light Source II is a third generation light source under construction at Brookhaven National Laboratory. The project includes a highly optimized 3 GeV electron storage ring, linac pre-injector and full-energy booster-synchrotron. Budker Institute of Nuclear Physics builds booster for NSLS-II. The booster should accelerate the electron beam continuously and reliably from minimal 170 MeV injection energy to maximal energy of 3.15 GeV and average beam current of 20 mA. The booster shall be capable of multi-bunch and single bunch operation. This paper summarizes the status of NSLS-II booster and the main designed parameters.

INTRODUCTION

The injector system includes 200MeV linac and booster with energy up to 3GeV. The conceptual design has been done by BNL [1]. The tender on the design, production and commissioning of NSLS-II booster was started in January 2010. Budker Institute of Nuclear Physics has won this tender in May 2010. The preliminary design review was approved at BNL in October 2010 and the Final Design Review was approved in February 2011. The current status of the booster project and the main designed booster parameters are discussed in this paper.

BOOSTER LATTICE AND DESIGN

The main parameters of the designed booster are summarized in Table 1. The lattice provides rather low horizontal emittance of 37.4 nm·rad at the energy of extraction.

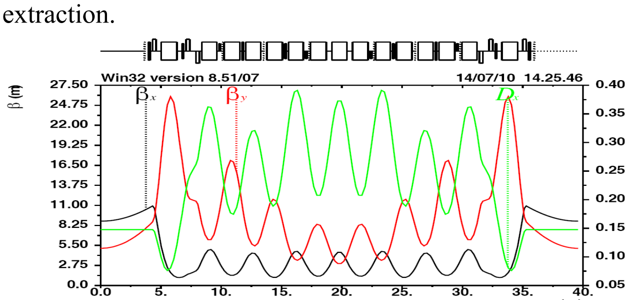

Figure 1: The betatron and dispersion functions for the lattice quadrant.

Table 1: NSLS-II Booster Main Parameters

Energy, MeV	200	3000
Circumference, m	158.4	
Number of periods	4	
Repetition rate, Hz	1 / 2	
Bunch number	1; 80-150	
Total current, mA	up to 28	
RF frequency, MHz	499.68	
Betatron tunes: ν_x/ν_y	9.646 / 3.411	
Natural chromaticity: ξ_x/ξ_y	–9.5/–13.5	
Corrected chromaticity: ξ_x/ξ_y	1.25 / 2.05	
Momentum comp. factor, α	0.00882	
Hor. Emittance: ε_x, nm rad	0.17	37.4
Energy spread, σ_E/E	$0.55\cdot10^{-4}$	$8.31\cdot10^{-4}$
Energy loss per turn, U_0, keV	0.0135	685.8
Damping times: (τ_x, τ_s), s	15.6; 7.8	0.0046; 0.0023

The Booster magnetic lattice includes four quadrants. Every quadrant contains five regular cells with two modified cells at the ends of the quadrant for dispersion suppression. Each quadrant contains the following magnetic elements:

- 8 combined function defocusing dipole magnets (BD) with 8.39° bending angle,
- 7 combined function focusing dipole magnets (BF) with 3.27° bending angle. Both dipoles are H-shape curved magnets with parallel ends. To compensate major part of chromaticity a sextupole component is incorporated in both dipole magnets,
- 6 quadrupole magnets to adjust the tune point,
- 4 sextupole magnets arranged in two families to increase flexibility for the chromaticity compensation.

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Two long opposite straight sections of the ring are reserved for beam injection and extraction devices, another straight section is reserved for RF cavities, and the remaining one is intended for the beam diagnostics equipment.

MAGNETIC SYSTEM

Designed parameters of ramped magnets are summarized in Table 2. The dies for all magnets have been produced. Tooling for yoke stacking, coil winding and coil impregnation are in progress.

Table 2: Designed Parameters of Ramped Magnets

Magnets	Total Number	Magnetic length, m	Magnetic force for 3 GeV		
			T	T/m	T/m^2
BF Dipoles	28	1.24	0.46	8.2	36
BD Dipoles	32	1.30	1.13	-5.6	-43
Quadrupoles	8+8+8	0.30		20.4	
Sextupoles	1x16	0.12			±400
Correctors	12+8+16	0.13	0.08 0.13		

POWER SUPPLIES

The Booster magnetic system requires 59 Power Supplies (MPS) with a total peak power of about 1.3MVA. The Main parameters of the booster magnets power supplies are presented in Table 3.

All the PSs are current sources with a current feedback loop for stabilization. The power supplies are synchronized with time interval corresponding to the rate of up to 2Hz. Fig. 2 shows a scenario consisting of two halves of cosine with small plateaus for injections and extractions (any acceleration shape is possible, here only the '1-cosine' shape is shown). The required current accuracy is 10^{-4} for the plateaus and 10^{-3} for the ramp up (calculated accuracy is related to current level and not to the maximum MPS output level).

Table 3: Main parameters of Power Supplies

PSs for	Number of PSs	Current (max), A	Peak Voltage, V	Peak output Power, (Total), kVA
Dipoles BF	1	900	220	180
Dipoles BD	2	750	700	1050
Quads	3	167	160	72
Sextupoles	16	6	60	6
Correctors	36	6	60	13
DC Septum	1	500	12	6

Due to the big difference between the required output peak power and the average power consumption, the power supplies are designed with recuperation into capacitor banks of the reactive energy stored in the magnets. The recuperation system will minimize the peak power being transferred from the AC mains.

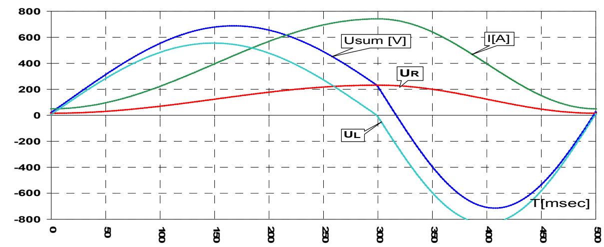

Figure 2: Current and voltage plots for 2Hz cycles for '1-cosine' shape of current ramps.

The power supplies for BF and BD dipoles will be developed and supplied by Danfysik A/S as a subcontractor of BINP.

INJECTION AND EXTRACTION SYSTEM

Injection into the booster is performed with 200 MeV linear accelerator. There may be two types of injection into the booster:

- Single-turn injection of a single 0.5 nC bunch or a pulse train of 80 to 150 bunches separated by 2 nsec with a total charge of 15 nC.
- Accumulation mode. In this case, a new portion, which doubles the charge in each bunch, is added after 100 msec.

For realization of the single-turn injection and accumulation, four fast ferrite kickers and a pulse eddy-current type septum magnet are installed in the long straight section. The kicker and septum magnets are made out of vacuum. The vacuum chamber of the kicker is made of aluminum oxide ceramic. There is a titanium (TiN) coating of 5 μm thickness on the inner surface of the chamber. The coating is made as strips of 3.4 mm width with 3.4 mm spacing.

Table 4: Main Designed Parameters of IES Magnets

Magnets	Q-ty	Magnetic length, m	Field T	Angle mrad	Pulse μs
Injection System for 200 MeV					
Kicker	4	0.207	0.055	15	0.3
Septum AC)	1	0.75	0.11	125	100
Extraction System for 3 GeV					
Bump	4	0.17	0.46	7.8	1500
Kicker	1	0.83	0.073	5.8	0.3
Septum(AC)	1	0.6	0.8	48	100
Septum(DC)	1	1.2	0.89	106	-

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The booster extraction system consists of four slow orbit bumpers, AC septum, DC septum and a kicker. Injection and extraction AC septums and kickers are similar in design.

According to the technical specification: the total beam angular deviation dX' caused by instability of the systems involved in beam extraction from the booster should not exceed 20% of angular beam spread. It means that stability of the field septum magnets shall be better than 0.02%. The ripple and droop over the entire kicker flat-top of 300 nsec waveform shall be less than 0.2 %.

By the present moment the magnets are under manufacturing.

VACUUM SYSTEM

An average pressure is below 10^{-7} Torr by integral of current of 1 Ampere-hour (an average flux of photons is 10^{19} ph/sec). The obtaining of this pressure is carried out by Gamma Vacuum ion pumps. The total quantity of ion pumps with pumping speed of 45 l/s (Nitrogen) is 71 pieces located with the distance of 2.5 meters. The calculations showed that the total photon-desorbed gas load is much higher than the thermal desorption gas load in spite of impact behavior of the booster. All vacuum chambers are to be made of stainless steel 316L.

Each arc vacuum section will have a convection-enhanced "Pirani" gauge, two inverted-magnetron cold cathode gauges as the primary gauges, and sixteen 45 l/s ion pumps. One set of vacuum gauges and two ion pumps (for Diagnostics and Injection straights) and three ion pumps (for Extraction straight) will be installed in the straight sections to handle the extra outgassing from RF cavities, kickers, septums and diagnostics. The residual gas analyzer heads will also be installed in the straight sections for diagnostics during operation and maintenance periods.

At present time the press-molds for dipole vacuum chambers are produced and the prototype of arc vacuum chamber is in production.

DIAGNOSTICS

For successful commissioning and effective operation of the projected NSLS-II Booster, a set of beam diagnostic instruments has been designed [2]. Fluorescent screens are used for the Booster commissioning and troubleshooting. The closed orbit is measured using electrostatic BPMs with turn-by-turn capability. 36 BPMs are installed in the Booster, one more BPM is installed between the extraction septum magnets. The circulating current and beam lifetime are measured using a DC current transformer. The fill pattern is monitored by fast current transformer. Visible synchrotron radiation is registered for observation of the beam image, transverse profiles of the beam are measured. Betatron tunes are measured using two pairs of striplines, the first pair is for beam excitation and the second one - for beam response measurement. The beam diagnostic systems provide measurement and correction of the beam closed orbit, betatron tunes, beta functions and dispersion during the ramp.

CONTROL AND TIMING SYSTEM

The booster control system will be designed and developed using EPICS to be easily integrated into the BNL control system. It will be built using all NSLS-II standards: use of EPICS for middle level control, front-end controllers will run Linux or RTEMS, and with the use of VME, cPCI cards and PLCs for I/O. The PLC controllers will be Allen-Bradley devices connected to EPICS IOCs via Ethernet. The control network will have managed switch, to which all the control system controllers are connected. The instrumentation network will be isolated over separate ports and has its own switches. The operator interface will be PCs running Linux.

The Booster Timing System (BTS) provides the control of the beam injection from linac and beam extraction from booster to the storage ring by triggering the injection and extraction pulse magnets at the correct time. Also, BTS provides measurement systems with the signals synchronized with the passage of the beam, with injection and extraction processes. BTS is based on the equipment produced by Mirco Research Finland Oy: VME Event Receivers with RF output (VME-EVR-230RF), PMC Event Receivers (PMC-EVR-230), and Fan-Out Modules (VME and cPCI FOUT-12).

SURVEY AND ALIGNMENT

Booster secondary control network includes 108 monuments located in the whole space of the booster tunnel. The relative position of the secondary alignment network marks should be defined with not less than ±0.025 mm accuracy.

Table 5: Alignment Tolerances for Booster Elements

Source of error	Tolerance
Dipole; Quadrupole; Sextupole; BPM misalignment	0.15 mm
Dipole; Quadrupole; Sextupole; BPM roll	0.2 mrad

CONCLUSIONS

NSLS-II booster project has gone through Final Design Review milestone. The first pre-serial (magnets of each type, power supplies for sextupoles and correctors, one girder assembled with magnets, vacuum chamber and BPM) are in progress.

REFERENCES

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