NSLS-II Booster

Sergei Gurov for the BINP and NSLS-II team

Budker Institute of Nuclear Physics

Presentation at SFR-2016

Novosibirsk

4 July 2016
Brookhaven National Laboratory

National Synchrotron Light Source

and

National Synchrotron Light Source II

Brookhaven Laboratory located in the center of Long Island, in 100 km from New York. In the first three decades of operation, the NSLS has yielded many discoveries and two Nobel Prizes. The new NSLS-II will produce x-rays more than 10,000 times brighter than the original NSLS.
NSLS-II main parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy</td>
<td>3 GeV</td>
</tr>
<tr>
<td>Ring circumference</td>
<td>792 m</td>
</tr>
<tr>
<td>Horizontal emittance</td>
<td>&lt;1 π nm rad</td>
</tr>
<tr>
<td>Vertical emittance</td>
<td>8 π pm rad</td>
</tr>
<tr>
<td>Beam current</td>
<td>500 mA</td>
</tr>
<tr>
<td>Number of RF buckets</td>
<td>1320</td>
</tr>
<tr>
<td>Number of bunches</td>
<td>1056</td>
</tr>
<tr>
<td>Average bunch charge</td>
<td>1,25 nC</td>
</tr>
<tr>
<td>RF frequency</td>
<td>500 MHz</td>
</tr>
<tr>
<td>RMS energy spread</td>
<td>0,1%</td>
</tr>
</tbody>
</table>
BNL announced a tender on the booster synchrotron which shall be capable of accelerating electron bunches from the minimum linac energy of 170 MeV to a maximum extraction energy of 3.15 GeV for injection into the main storage ring.

The proposal from BINP on the turn-key booster were the most attractive and the contract was signed in May 2010.
BNL and BINP cooperation

BINP produced 21 quadrupole magnets of the 30Q44 and 30Q58 types for the SNS, designed by BNL.

BINP produced 128 quadrupole magnets of 6 types for the NSLS-II Main Ring.

BINP produced three helical undulators for proof-of-principle experiment on coherent electron cooling.
### Table 4.1. General Booster Specifications

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Circumference</td>
<td>158.4 m</td>
</tr>
<tr>
<td>Super-Periodicity</td>
<td>4</td>
</tr>
<tr>
<td>Operating time per year</td>
<td>6000 hr</td>
</tr>
<tr>
<td>Unscheduled Downtime</td>
<td>0.4% (24 hr per year)</td>
</tr>
<tr>
<td>Repetition rate</td>
<td>1 Hz (2 Hz)</td>
</tr>
<tr>
<td>RF frequency</td>
<td>499.68 MHz ± 10kHz</td>
</tr>
<tr>
<td>RF voltage</td>
<td>200V - 1.2 MV</td>
</tr>
<tr>
<td>RF Amplitude and phase jitter at 1.2 MV</td>
<td>±1% and ±1°</td>
</tr>
<tr>
<td>Max RF power</td>
<td>72 kW</td>
</tr>
</tbody>
</table>

### Nominal extraction energy

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal extraction energy</td>
<td>3 GeV</td>
</tr>
<tr>
<td>Horizontal Emittance</td>
<td>&lt;40 nm rad at 3 GeV</td>
</tr>
<tr>
<td>Momentum Spread</td>
<td>&lt;0.1%</td>
</tr>
<tr>
<td>Extracted Beam Angle Jitter</td>
<td>&lt;20% of beam divergence</td>
</tr>
<tr>
<td>Coupling</td>
<td>&lt;10% at 3 GeV</td>
</tr>
<tr>
<td>Charge (Long pulse/ Single pulse mode)</td>
<td>&gt;10 nC/0.5 nC</td>
</tr>
<tr>
<td>Charge transport efficiency between ICTs in LB and BSR TL</td>
<td>&gt;75% (achieved up to 98%)</td>
</tr>
</tbody>
</table>
Scope of work

- Beam dynamics cross checking
- Design and production of booster ring (158 meters)
  Including:
  - Magnets (28+32 dipoles, 24 quadrupoles, 16 sextupoles, and 36 correctors)
  - 160 meters of vacuum channels
  - Injection and extraction (bumps, kickers, pulsed and DC septums)
  - Power supplies
  - Diagnostics
  - Control System and software (together with BNL)
  - Infrastructure (cables, water, and air) (together with BNL)

Excluding: RF system (PETRA 7-cell 500MHz Cu-cavity)

- Installation (together with BNL)
- Testing (together with BNL)
- Commissioning (together with BNL)
- 2 year warranty
During two years, 26 BINP designers participated in the production of all models and detailed production drawings.
Tender
Contract signing
Preliminary Design Review
Final Design Review
Production Readiness Review
Booster Delivery
Assembling
Testing
Extending Integrated Testing
Commissioning

February – March 2010
07.05.2010
October 2010
February 2011
July 2011
December 2011 – June 2012
February – November 2012
May 2012 – January 2013
February – October 2013
09.12.2013 – February 2014
Contract has been signed on 7 May 2010

After 14 months booster was designed and all first article is ready: BD and BF dipoles, quadrupole, sextupole, CX and CY correctors, girder, 6A power supplies.

After 28 months in August 2012 all booster components have been delivered to BNL (New-York)
## Magnets

<table>
<thead>
<tr>
<th>Type</th>
<th>Count</th>
<th>Developers</th>
</tr>
</thead>
<tbody>
<tr>
<td>BF dipoles</td>
<td>28</td>
<td>S. Sinyatkin, A. Sukhanov</td>
</tr>
<tr>
<td>BD dipoles</td>
<td>32</td>
<td></td>
</tr>
<tr>
<td>Quadrupoles</td>
<td>24</td>
<td>A. Philipchenko, V. Kobets</td>
</tr>
<tr>
<td>Sextupoles</td>
<td>16</td>
<td>A. Utkin, N. Nefedov</td>
</tr>
<tr>
<td>CX Correctors</td>
<td>20</td>
<td>V. Petrov, V. Konstantinov</td>
</tr>
<tr>
<td>CY Correctors</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>Girders</td>
<td>44</td>
<td>A. Polyanskiy, L. Shegolev</td>
</tr>
</tbody>
</table>

09.06.11
Magnetic measurements

Nonmagnetic reflectors
Vacuum system

Special transition from an ellipse 43mm x 21mm tube to a round 46 mm tube

Vacuum chamber for bump magnet with 62 mm x 22 mm aperture and stiffening plates
Main technical parameters of the injection magnets

| IS-KIC3  | 20.5 | 38  | 15  | 0.0488 | 1 477 | 20 500 | (0.3) | ± 0.5 |
| IS-KIC4  | 20.5 | 38  | 15  | 0.0488 | 1 477 | 20 500 | (0.3) | ± 0.5 |
| IS-SMP1  | 750  | 30  | 125 | 0.1112 | 2 660 | 195   | 52    | ± 0.1 |

Main technical parameters of the extraction magnets

| XS-BUMPS | 16.9 | 33  | 7.9  | 0.465 | 1 530 | 846   | 728   | ± 0.02 |
| XS-KIS1  | 2*20.5 | 38  | 0.283 | 0.069 | 2 088 | 22 000 | 0.3   | ± 0.2 |
| XS-KIS2  | 2*20.5 | 38  | 0.283 | 0.069 | 2 088 | 22 000 | 0.3   | ± 0.2 |
| XS-SMP1  | 600  | 16  | 48   | 0.8   | 10 200 | 470   | 78    | ± 0.02 |
| XS-SMD1  | 1252 | 20  | 106  | 0.847 | 322   | 10    | ----  | ± 0.02 |
Power supplies of injection and extraction kicker, septum and bump magnets

Extraction Straight

Equipment Protection System
Power supplies for ramped magnets

MPS6 – 8 channel crate for corrector and sextupole magnets

Power supplies for DC septum and quadrupole magnets

Power supplies for dipole magnets from our subcontractor Danfysik
Booster Control System

PSC and PSI
**Diagnostics**
- 36 BPMs
- The tune measurement system
- 6 Fluorescent screens
- 2 SR monitors
- DCCT and FCT
Six fluorescent screens

Video camera with lead shield

ISVF2 – fluorescent screen after injection.
Central bar is 6 mm x 9 mm
36 BPMs

Показания без учета нелинейности и оффсета -6,1 мм
Равновесное положение пучка -10,5 мм

Horizontal ± 1 mm

Vertical ± 0.5 mm
Beam orbit after correction

σX max = 0.573 mm

σY max = 0.412 mm
Ramp manager and degauss of magnets
Ramp Manager
The tune measurement system
The tune measurement system
Two SR monitors

20 + N*40 msec
Emittance Measurement

\[ E = 3 \text{ GeV} : \]

\[ Em_x = 40 \text{ nm*rad} \quad \Rightarrow \text{Later } 35 \text{ nm*rad} \]

\[ Em_y = 3.7 \text{ nm*rad} \]
“The injector complex is very robust. After a break or shutdown, full performance is reestablished after only a few hours. Operation is fairly reliable and re-tuning is required only rarely”, Ferdinand Willeke, IPAC2015, “COMMISSIONING OF NSLS-II”. 

Beam Current 250.1 
Beam Lifetime 8.9 Hrs 
Daily Amp Hours 1479.4 mAh 

Operating Mode: Beamline Operations  Shutters Enabled 

Message From Operations 
Beam is available - TopOff running at 250mA 

http://status.nsls2.bnl.gov 
07/01/2016 06:01:50
The way from control room towards NSLS-II during commissioning

Work under kicker modulators

Thank you!

Extraction Straight