MAGNETIC MEASUREMENT OF THE NSLS-II BOOSTER DIPOLE WITH COMBINE FUNCTIONS*

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Abstract

The magnetic system of NSLS II Booster is designed, manufactured and tested in BINP, Russia. The booster dipole incorporates quadrupole and sextupole components and has rather tight requirement for the field quality $\pm 2\cdot 10^{-4}$ in the good field region ±2 cm. The magnets provide the booster operation in the energy range from 170 MeV to 3.15 GeV with 2 Hz repetition frequency. This report contains description of the magnetic measurement bench and the results achieved for the DC case; AC magnet test including vacuum chamber influence is described in [1].

INTRODUCTION

The NSLS II is a third generation light source under construction at Brookhaven National Laboratory [2]. The project includes a highly optimized 3 GeV electron storage ring, linac pre-injector and full-energy booster-synchrotron. Budker Institute of Nuclear Physics (BINP) builds booster for NSLS-II. The booster should accelerate the electron beam continuously and reliably from minimum injection energy of 170 MeV to maximum extraction energy of 3.15 GeV with average beam current of 20 mA. The booster shall be capable of multi-bunch and single bunch operation.

The booster BF (BD) dipoles contains focusing (defocusing) quadrupole and sextupole components but should provide rather high field quality $\pm 2\cdot 10^{-4}$ in the good field region ±2 cm in the whole energy range Dipole parameters are listed in Table 1.

Table 1: NSLS II Booster Dipole Specification

Dipole parameters	BF	BD
Number	28	32
Effective magnetic length	1.24 m	1.30 m
Bending angle	3.2673°	8.3911°
Curvature radius	21.7 m	8.8 m
Vertical pole gap	±14 mm	±13 mm
Field at injection	0.03068 T	0.07516 T
Field at extraction	0.46021 T	1.12734 T
Quadrupole K_1 at extraction	0.82 m^{-2}	-0.55m^{-2}
Sextupole K_2 at extraction	3.6 m^{-3}	-4.3 m^{-3}
Good field region (v × h)	±12 × ±20 mm	

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MEASUREMENT BENCH

A required accuracy of the magnetic measurement for different field components at the extraction energy is listed in Table 2.

Table 2: Measurement Accuracy Requirements

Field component	Accuracy
ΔB/B=(ΔL/L)	$\pm 2\cdot 10^{-4}$
ΔG/G	$\pm 4\cdot 10^{-4}$
ΔS/S	$\pm 7\cdot 10^{-4}$

The field map measurement is provided by the Hall sensor array fixed transversely inside the pole gap and moved along the magnet in a special rail. Detailed study allows converting specified field measurement accuracy into the mechanical facility tolerances, shown in Table 3.

Table 3: Tolerance for the Bench Design

Parameter	Accuracy
Rel.positioning of the Hall probes (x, y, z)	±20 µm
Transv.positioning of the probes carriage in the rail for BD (BF)	±50 (100) µm
Long.positioning of the probes carriage	±0.5 mm
Hall sensor tilt	±20 mrad
Carriage tilt rel.to median plane for BD(BF)	±0.5 (1.0) mrad
Sensor calibration	±0.5 Gs
Zero field calibration	±0.5 Gs

Hall sensors, twenty (Fig.1) for the BD magnet and 17 for the BF one are fixed at the copper plate which is equipped with the heating element and the platinum temperature sensor for temperature stabilization [3, 4]. The carriage with probes (Fig.3) is mounted at the mandrel which is allows to adjust Hall sensors in vertical and horizontal plane. The mandrel has seats for angular reflectors (Fig.1) for precise coordinate definition by the laser tracker during the field mapping. The guiding rail base surfaces non-flatness is inside 40 µm at 2 m length.

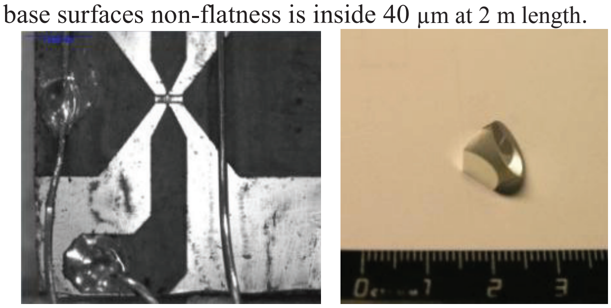

Figure 1: A single Hall sensor (left) and angular reflector.

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Figure 2: Hall probe array.

TESTS AND CALIBRATIONS

Characteristics of the Hall sensors are shown in Table 4. The center of the sensors is linked to the carriage base with the help of the optical microscope (accuracy ~±1 µm). Then the carriage with the angular reflectors is installed in the guide so that the sensor array is positioned in the magnet median plane.

To fix the coordinates of the Hall sensors relatively to the angular reflectors, the flowing procedure is performed: (1) the carriage with the reflectors, laser tracker and 7-8 "parking lots" for the standard 1.5 inch spherical reflector are mounted on the granite slab of a coordinate measuring machine (CMM), (2) the laser tracker is linked to the coordinate system of the CMM by spherical reflectors with RMS accuracy of 7-15 µm, coordinates of the angular reflectors installed at the mandrel are measured by the tracker while the coordinates of the Hall sensors are measured simultaneously by the CMM.

Fig.4 shows the Hall probe coordinates during the magnetic field measurement.

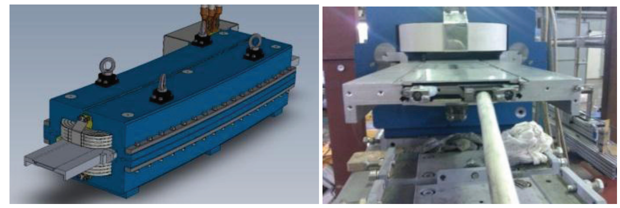

Figure 3: The magnet with the guide (left), the magnet at the measurement facility.

After this procedure, sensors are calibrated in a uniform magnetic field using the NMR probe. The whole procedure takes around 5 hours (around third of this period is for the thermal stabilization).

Table 4: Hall Probes Parameters

Parameter	Value
Sensitive area (mm^2)	0.1 × 0.05
Magnetic susceptibility at 0.1 T, (mV/mT)	105 – 115
Nonlinearity for 2T (%)	±0.8
Divergence coefficient at 0.1 T (%)	~0.08

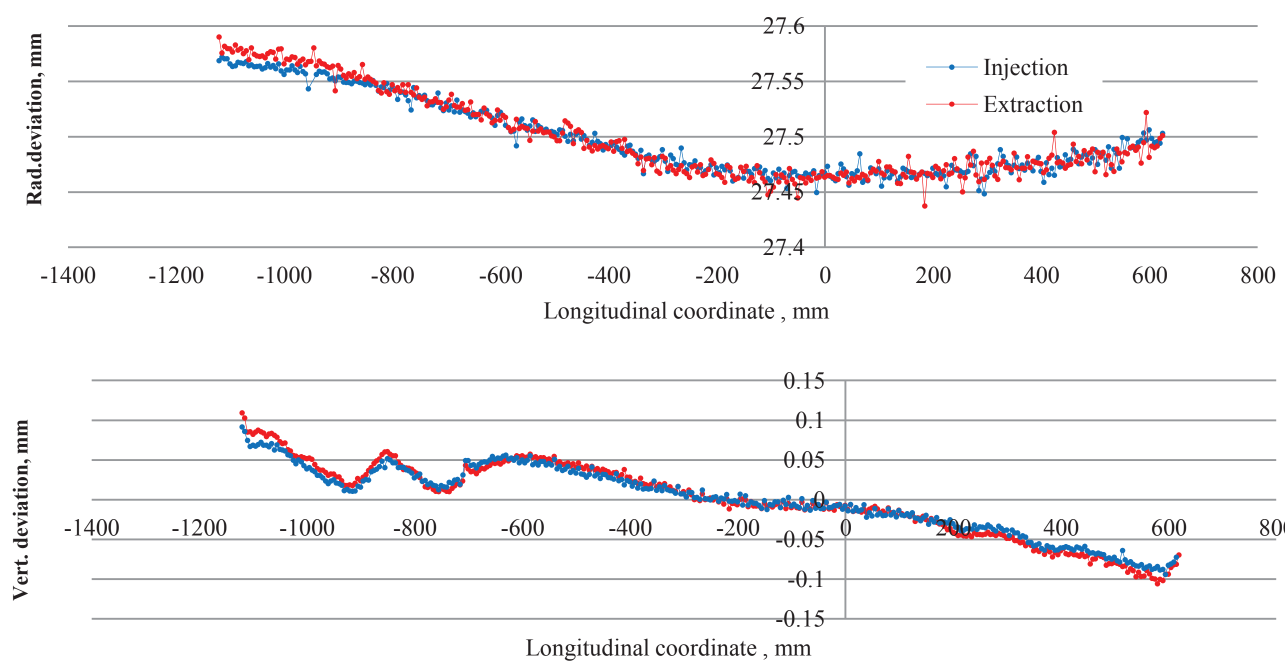

Figure 4: Vertical and radial deviation of the carriage with Hall probes.

MEASUREMENT RESULTS

Magnetic measurements were carried out for 11 values of excitation current for prototypes and for 6 currents for the serial samples. The measurements were performed using the code WinHall developed at BINP. Example of the BF magnet is illustrated in Fig 5.

After the measurement the values of the magnetic field and Hall sensors coordinates were processed together to define the magnetic central line of the field relatively to the alignment marks, to calculate the field integrals, quadrupole and sextupole components as a function of the transverse coordinates and the field-energy dependence. More detailed magnetic measurement results are presented in [2].

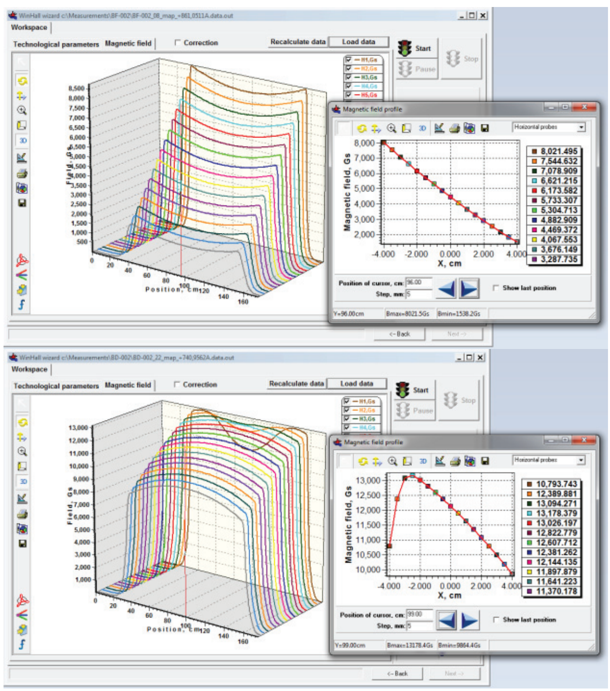

Figure 5: Example of magnetic measurements BF and BD magnets.

ACKNOWLEDGMENT

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