BEAM DIAGNOSTIC INSTRUMENTATION FOR THE NSLS-II BOOSTER *

O.I. Meshkov, BINP, Novosibirsk, Russia; NSU, Novosibirsk, Russia
V.V. Smaluk, BINP, Novosibirsk, Russia

Abstract

For a successful commissioning and for effective operation of the NSLS-II Booster a number of beam parameters should be measured in real-time mode. The main parameters and features of the diagnostics of the NSLS-II booster are briefly described. The diagnostics will be applied as well as during booster commissioning as well as during routine operations.

List of diagnostics

Six fluorescent screens (beam flags) are used for Booster commissioning and troubleshooting. The beam closed orbit is measured using electrostatic BPMs with turn-by-turn capability. The circulating current and beam lifetime are measured with DCCT. The fill pattern is monitored with FCT. The betatron tunes are measured with a set of two pairs of striplines, the first pair is for excitation and the second one – for beam response measurement. Visible synchrotron radiation is used for observation of the beam image during ramp and for emittance measurement. (Fig.1)

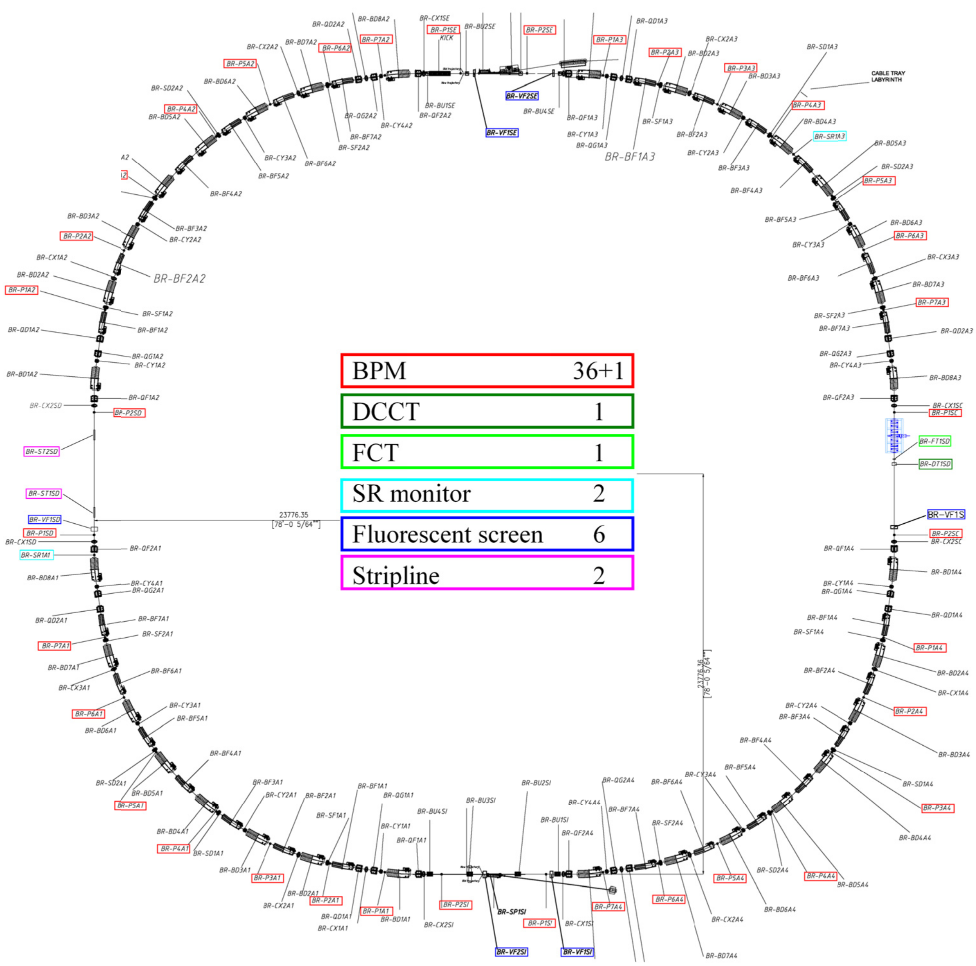

Figure 1. Layout of Booster beam diagnostic

The supplied equipment and subsystem components are durable and capable of operating in the accelerator environment (with the presence of EMI, radiation, vibration, etc.). The schematic layout of the Booster is shown in Fig. 1, the beam diagnostic instruments are marked. The beam diagnostic instruments are listed in

ISBN 978-3-95450-125-0

Table 1: Booster beam diagnostic instruments.

Diagnostic device	**Number**
BPM	37
DCCT	1
FCT	1
SR monitor	2
Fluorescent screens (Beam flags)	6
Stripline	2
Tune measurement system	1

Beam Position Monitors

To provide the accuracy of orbit measurement, which is sufficient for good orbit correction, it is recommended to use at least 4 BPMs per one period of betatron oscillation. One more BPM will be installed between the extraction septum magnets. Therefore, total number of BPMs is 37. Each BPM consists of four RF pickup electrodes connected to vacuum-tight feedthroughs with a characteristic impedance of 50 Ω.

Two types of BPM have been designed. The 1st-type BPM has an elliptical cross-section 41×24 mm, the button electrodes are placed at an angle of 45 degrees relative to the horizontal axis, total number is 28. The 2nd-type BPM has an elliptical cross-section 60×21 mm, the button electrodes are placed at an angle of 30 degrees relative to the horizontal axis, total number is 9.The BPM electronics should provide turn-by-turn beam position measurements and the beam orbit measurement. The vacuum-tight feedthrough with mounted button electrode and SMA plug is produced by MPF Products [1]. This part of BPM is exactly the same as for NSLS-II beam transport lines.

DC Current Transformer

A DC Current Transformer is used to measure the beam current, lifetime and injection efficiency. A Bergoz New Parametric Current Transformer (NPCT) [2] has been chosen. The device should provide the following specifications:

Beam current range	0-50 mA
Resolution	<5 μA/Hz$^{1/2}$
Bandwidth	DC to 10 kHz
Output voltage range from	−10 V to 10 V

The In-Flange NPCT-CF4.5"-60.4-120-UHV-C30-H with radiation-tolerant sensor will be installed at the Booster. The In-Flange version of the transformer is mounted in the vacuum chamber between two flanges, has short axial length, includes a ceramic gap vacuum-brazed on kovar.

Fast Current Transformer

A fast current transformer is used to measure individual bunch charges (intensity) and filling pattern. To fulfill the Specifications, the wideband current transformer Bergoz FCT-WB-CF6"-60.4-40-20:1-UHV-H [3] has been chosen

Bergoz In-flange.FCT is a wideband current transformer designed to be bolted in place as part of the accelerator vacuum chamber. Its purpose is to observe the beam longitudinal profile or waveform up to the highest possible frequency allowed by the current transformer bandwidth.

Table 2: Specifications of Bergoz FCT

Turns ratio	20:1
Sensitivity (nominal)	1.25 V/A
Rise time (typ.)	200 ps
Droop	<6 %/μs
Upper cutoff frequency -3 dB (typ.)	1750 MHz
Lower cutoff frequency -3 dB	<9.5 kHz
Position sensitivity (on axis)	0.2 %/mm
L/R time constant (min.)	17 μs
Max. charge/pulse (pulses <1 ns)	0.4 μC
Max. peak current (pulses >1 ns)	400 A
Max. r.m.s. current (f > 10 kHz)	1.4 A

Fluorescent Screens

The beam flag consists of an integrated system of components that can be reconfigured and interchanged, whereby Cerium-doped Yttrium Aluminum Garnet (YAG:Ce) screen can be easily taken out of a UHV-compatible body. Typical resolution of the fluorescent screen is about 50 μm. The YAG plates are produced by Crytur Company [4] (Czech Republic).

The screen is placed inside a cylindrical volume and move inside and outside of the vacuum chamber. The CCD-camera is placed outside the median plane of the accelerator and is radiation-protected with the lead shield. The screen can move between two fixed positions, inside and outside of the vacuum chamber.

The CCD camera GC1290 [5] (Allied Vision Technology, USA) will be used for the beam image registration. To move the beam flag, the pneumatic drive DSNU-25-80-PPS-A [6] (FESTO Company, Holland) is used.

Synchrotron Radiation Monitor

The synchrotron radiation (SR) monitor provides routine measurements of transverse beam profiles and

ISBN 978-3-95450-125-0

beam sizes with spatial resolution better than 50 μm in each plane. The synchrotron radiation monitor consists of a metallic mirror placed inside the vacuum chamber, light output window, image formatting optics and a CCD camera. Two ports of SR output are proposed; the first one is located in the 3rd arc, the second one is close to the diagnostic straight section.

Tune Measurement System

The tune measurement system should provide measurement of the betatron tunes in the range of ±0.5 (in units of the revolution frequency) around the design working point. The measurements have to be performed for a single bunch charge of 100 pC and for a train of 150 bunches with 10 pC/bunch for each injector cycle without any data drop. The tunes should be available to the injector control system during whole energy ramp duration T_R between the beam injection and extraction with at least 20 time steps. The system should have an ability of magnifying the tune range of interest and providing sampling of every booster ramp (Tab. 3).

Table 3: Parameters of the tune measurement system

Tune measurement error	less than 0.0005
Time of a single measurement (ν_x and ν_y) (measurement mode)	~4 ms
Time of one scanning in full frequency range (search mode)	500 ms

Budker Institute has a large experience in development and usage of tune measurement systems. A tune measurement system, similar to the described below, has been implemented for the Siberia-2 storage ring at Kurchatov Institute (Moscow, Russia).

The system is able to perform tune measurements using two methods.

The kicking method is the main one. The beam is excited by radio frequency (RF) pulses with the frequency close to $f_B = (1 + \nu_{x,y})f_0$, where f_0 is the revolution frequency, $\nu_{x,y}$ – is the fractional part of the horizontal (vertical) tune. Duration of the RF pulse is 100-500 μs.

The second method of tune measurement is based on white noise beam excitation. To excite the betatron oscillations, white-noise signal is used instead of RF pulses. Total number of measurements during the Booster energy ramp is 128 (64). The measurements of horizontal and vertical tunes are performed simultaneously.

Striplines

Two identical sets of four 50-Ohm striplines are used. One set is a kicker for beam excitation; another one is a pickup for measurement of a beam response signal..

The stripline electrodes used for kick are mounted at the angle of 45° relative to the horizontal plane using a BINP-made 50 Ω/450°C vacuum-tight feedthrough for SMA plug with bearing capacity Characteristic impedance of the stripline is close to 50 Ω. The length of stripline is 450 mm, which is about 3λ/4 (λ is the wavelength) at RF frequency of 499.68 MHz.

Design of Interface Between Booster Diagnostics System and Booster Control System

Booster Diagnostics control subsystem will conform to NSLS-II control system standards. It will be EPICS-based and the preferable operating systems for IOCs are RTEMS (Real-Time Executive for Multiprocessor Systems) and Linux. The diagnostics controls pursue the utilization of commercial off-the-shelf hardware to reduce cost as well to achieve better reliability.

Conclusion

A list of typical problems of the accelerator physics related to the measurements of beam parameters can be conventionally divided into three stages.

1. Commissioning: passing of the beam in transport lines; measuring of the beam emittance and matching it with the accelerator acceptance; observation and correction of the beam trajectory at the first turn closing; beam monitoring during adjustment of injection and capture by the accelerating RF-field.
2. Operative control for a regular work. At this stage routine measurement and correction of the following beam parameters are necessary: circulating current and lifetime; filling pattern; closed orbit; betatron and synchrotron frequencies; chromaticity; longitudinal and transverse beam sizes.
3. Accelerator physics tasks necessary for the optimization of the machine operation: measurement and correction of magnet lattice functions; study of nonlinear beam dynamics; research of collective effects and suppression of instabilities; analysis of external beam-perturbing factors.

We believe that the diagnostics described above are adequate for solving of all these problems.

REFERENCES

[1] http://www.mpfpi.com/2010catalog_coaxial-5.5.pdf
[2] http://www.bergoz.com/index.php?option=com_content&view=article&id=35&Itemid=48
[3] http://www.bergoz.com/index.php?option=com_content&view=article&id=23&Itemid=28
[4]http://www.crytur.cz
[5] http://www.alliedvisiontec.com/emea/products/cameras/gigabit-ethernet/prosilica-gc/gc1290.html
[6] http://www.festo.com/cat/en-us_us/data/doc_enus/PDF/US/DSNU-ISO_ENUS.PDF

ISBN 978-3-95450-125-0