SYNCHROTRON RADIATION DIAGNOSTICS FOR THE NSLS BOOSTER*

T. Shaftan[#] and I. Pinayev,
BNL-NSLS, Upton, NY 11973, U.S.A.

Abstract

We developed an optical diagnostics system for the NSLS booster-synchrotron utilizing synchrotron radiation from the dipole magnet. MATLAB based software allows to study the electron beam properties along the energy ramp. Trajectory, beam sizes and coupling at the different instants of time are retrieved from the analysis of the electron beam image. In the paper we present some studies results and upgrade plans.

INTRODUCTION

The NSLS injection system consists of a thermionic gun followed by a 120 MeV linac and ramping (120-740 MeV) booster synchrotron [1]. Over past year we were developing diagnostics to enable beam studies for characterization, improvement and troubleshooting of the NSLS injection system. As a part of this effort we developed Synchrotron Radiation Monitor (SRM) for the booster. Complete description of the SRM can be found in [2]. SRM represents a simple set-up with an imaging system and a CCD camera observing synchrotron radiation from one of the booster bends.

Performing beam studies we observed synchrotron radiation profiles recorded during booster ramp, followed by their analysis to retrieve electron beam parameters from the data. In this paper we present results of some beam studies using SRM. In conclusion we discuss upgrade plans which will expand capabilities of this diagnostics.

BEAM DURING ENERGY RAMP

Measuring booster beam properties during the energy ramp we triggered frame-grabber by a "system start" signal and recorded consecutive frames (Fig. 1)
Energy ramp in the NSLS booster takes 320 ms. Due to camera running in 30 Hz mode we observe 10-11 frames during the ramp. Therefore each frame represents the data accumulated during 33 ms. In figure 1 we observe damping of the injected beam during acceleration. Another observation is in quite significant X-Y coupling present in the circulated beam.

The booster extraction system consists of a pulsed kicker (PK), two septa and two pulsed Back-Leg Winding coils (BLW). The BLW coils are wrapped around the main dipole yoke and driven by a half-sine pulse with a width of 1 ms. They assist the kicker bump by bringing the orbit closer to the extraction septa just prior to pulsing the PK. The last frame corresponds to BLW pulse "slowly" moving beam towards the septum channel.

Appropriate image processing software, together with the frame-grabbing program was implemented in Matlab using Data Acquisition and Image Processing Toolboxes [4]. In Figure (2) we show the image processing of the images obtained during one booster ramp cycle. The 2_D data is fitted with an assumed Gaussian intensity distribution with arbitrary tilt angle.
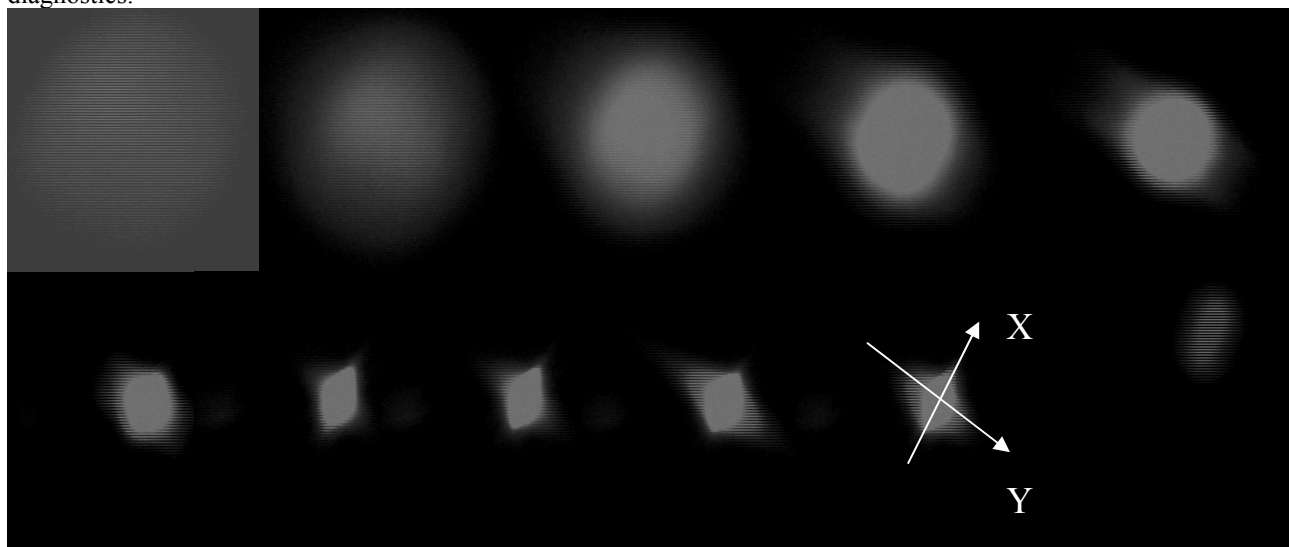

Fig. 1: Consecutive frames measured during energy ramp. Each frame represents data accumulated during 33 milliseconds.

The computed data are beam centroid (X,Y), widths (σ_x, σ_y) and orientation tilt angle. Figure (3) shows these parameters obtained from the data of Figure (2), plotted versus time during the booster ramp cycle.
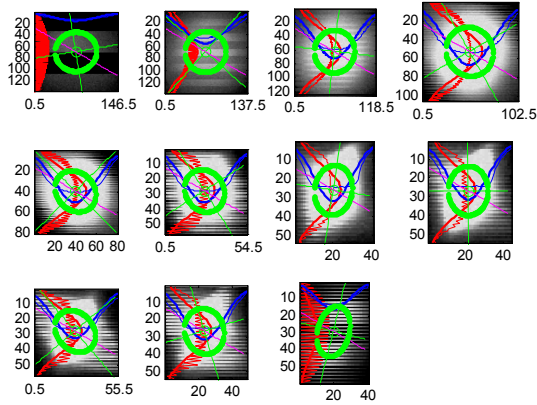

Fig 2: Image data and data processing to obtain horizontal and vertical position and size of the beam. Horizontal(blue) and vertical(red) beam profiles are shown together with the centroid position and beam axis orientation angles shown in green.
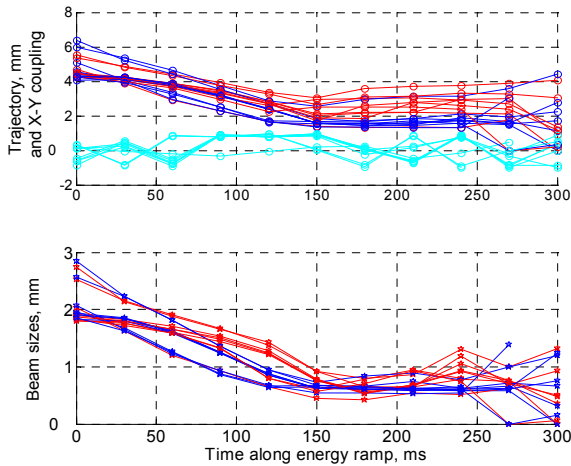

Fig. 3: Upper plot shows several beam trajectories in units of mm during energy ramp. Dimensionless X-Y coupling is shown in cyan color. RMS beam sizes in mm are presented on lower plot. Red and blue traces correspond to the horizontal and vertical directions correspondingly.

CONTROL AND DIAGNOSTICS OF VERTICAL ORBIT DURING BOOSTER RAMP

Original NSLS booster design did not provide with freedom in controlling beam orbit during the energy ramp. Booster trim magnets were driven by DC power supplies with static values that were optimized for injection efficiency. Software was developed by S. Ramamourthy and P. Pearson to enable control of these trim values and therefore the booster orbit along the ramp. During commissioning and calibration of the ramping trims system we used the SRM.

Setting various combinations of the trim strengths we were observing motion of the booster orbit during the ramp (Fig. 4).
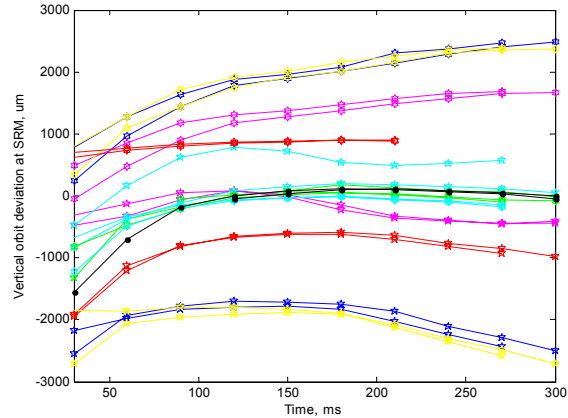

Fig. 4: Vertical booster orbits during energy ramp for different trim settings.

Changing ramp tables for the booster trims and analyzing Fig. 4 and similar measurements we were able to characterize booster orbit (both coordinate and angle) at extraction.

CALIBRATION OF BACK-LEG WINDINGS

We used the SRM in calibration of the BLWs analyzing images similar to the last frame in Fig. 1.
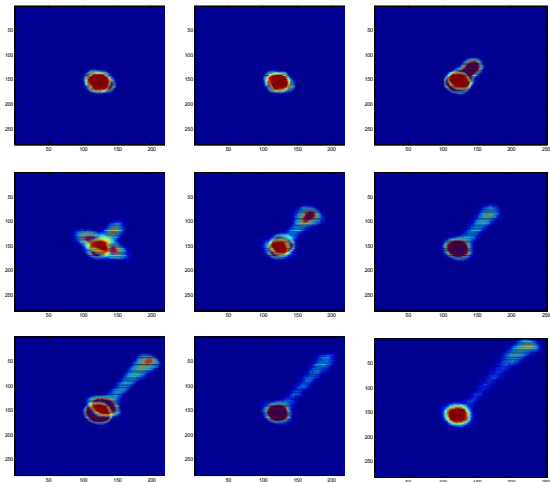

Fig. 5: Images recorded for different BLW amplitudes

Increasing the BLW amplitudes we were able to measure corresponding deviations of orbit at the SRM location. Using the booster lattice data together with the measured deviations we determine calibrations for BLW.

UPGRADE PLANS

Current design of the booster SRM allows measuring of all required parameters with the resolution sufficient for current beam studies. This diagnostics is quite effective during hardware start-up and commissioning, since CCD sensitivity is far more superior to any other booster diagnostics (pick-up electrodes or DC current transformer).

We plan to increase time resolution of the system by adding a fast CCD camera with the exposition time down to 10 microseconds. This will provide with rather short integration time (100 booster revolutions) at extraction, where synchrotron radiation intensity is sufficiently high.

We consider another upgrade by installing Position Sensitive Detector for online measurements of the booster orbit. Simple set-up will enable measuring booster orbit with about 10 micron resolution and in frequency range of several kilohertz.

Another upgrade is planned to install a fast photodiode for measurements of the booster current through energy ramp.

ACKNOWLEDGEMENTS

REFERENCES

[1] R. Heese "The NSLS booster synchrotron", http://epaper.kek.jp/p79/PDF/PAC1979_3839.PDF

[2] I. Pinayev and T. Shaftan, in Proceedings of BIW-2006

[3] www.mathworks.com