PROPOSED DIAGNOSTICS FOR THE NSLS-II

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Abstract

The National Synchrotron Light Source is performing R&D of a new 3 GeV electron storage ring to be used for the facility upgrade [1]. To satisfy the demands for the brightness and stability of the future light source a state-of-the-art diagnostics system is a necessity. We present our preliminary design with focus on the requirements for instrumentation and technical solutions to achieve them.

INTRODUCTION

NSLS-II light source will be characterized by extremely small emittances of less than 1.5 nm [2]. Most beamlines will utilize synchrotron radiation (SR) from insertion devices installed in the straight sections. The electron beam size in the straights is expected to be σ_x=90 μ in horizontal plane and σ_y=5 μm in vertical plane. In this paper we consider that required stability of the electron beam should be better then 10% of the beam size. Such demand translates into the limit on beam motion to <10 μm in horizontal plane and to submicron level in the vertical plane.

Table 1: Parameters of NSLS-II Storage Ring

Lattice	24 cell, TBA
Energy	3 GeV
Accelerating Frequency	500 MHz
Circumference	630
Injection Energy	3 GeV
Beam Current	500 mA
Natural Emittance (H)	<1.5 nm
Betatron Coupling	0.5%
Straight Section β-functions (H & V)	4.9, 3.5 m
Stability Required (H & V)	10% of beam size

Top-off mode [3, 4] of operation will provide constant thermal load on the user optics thus improving stability of the X-ray beams. Another advantage of top-off operation is that orbit beam diagnostic system is not influenced by the electron beam current dependent effects. The top-off mode is realized by continuous injection with opened users' shutters. Therefore, for the purpose of radiation safety it requires constant monitoring of the storage ring status and injection efficiency.

High quality diagnostic system will facilitate fast commissioning of the storage ring and reaching operational parameters.

CURRENT MONITORS

The nominal electron beam current circulating in the NSLS-II storage ring is 500 mA. In order to provide constant heat load on the optics of the users' beamlines the stored current will be controlled to 1%. Available commercial parametric current transformer (PCT) provides 10 μA resolution should be adequate for the task. The model PCT-H-116-1000mA manufactured by Bergoz is a good candidate for such purpose [5]. The electron beam lifetime without harmonic stretching is expected to be about 3 hours, which will result in high radiation environment. Consequently, the rad-hard sensor head is chosen for better stability. Two such PCTs will be used for redundancy needed for radiation safety during top-off operation.

We also want to monitor an amount of the charge coming from the injection system into the storage ring. Beam charge monitor (BCM) installed before the septum will provide needed information. The Bergoz model BCM-IHR (Integrate-Hold-Reset) will provide required sensitivity and accuracy. Comparison of the increase of circulating beam and injected charge can be used for the real-time diagnose of problems with injection.

ORBIT MONITORING

Orbit of the electron beam will be monitored using RF beam position monitors (BPM). It is expected that total of 192 pick-up electrodes (8 per super-period) will be placed around the ring. We plan to use the modified ESRF button design, which is also used at SLS, and will be used at DIAMOND and Soleil [6]. The BPM signal will be processed at RF frequency of f_0=500 MHz. The signal level may be estimated from the formula below [7]:

$$V = \frac{2\pi r^2 Z}{Dc} f_0 I_{avg} \quad (1)$$

where r=7.5 mm is button radius, D=30 mm is vacuum chamber radius, c=3×10^8 is speed of light, I_{avg}=500 mA is average current, Z=50 Ω is cable impedance. After substituting the values into the formula, one easily obtains the amplitude of 0.83 V. Such signal should provide sufficient signal-to-noise ratio. The cut-off frequency of the low-pass filter formed by a button capacitance of 4 pF in parallel with cable impedance is about 800 MHz. Therefore, no reduction of signal level is expected.. To avoid overloading of the front-end electronics with the higher frequency components filtering maybe needed.

The voltage induced in the pick-up electrodes will be analyzed by the Instrumentation Technologies units, utilizing digital signal processing [8]. These units demonstrated the required submicron resolution, high accuracy, and stability [9]. They also allow to perform turn-by-turn measurements. Such functionality will eliminate the need of using screens in the storage ring for injection diagnostics.

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DIAGNOSTIC WITH SYNCHROTRON RADIATION

The synchrotron radiation provides non-destructive tools for measuring parameters of the electron beam. Visible light from the bending magnet can be used for direct observation of the electron beam. Part of the light coupled into the dual-sweep streak-camera will be used for bunch length measurement and study of beam instabilities.

Some users require not only stable average current but also uniform fill of the electron bunch train. Significant bunch-to-bunch variations of the electron beam current can also adversely affect the accuracy of orbit monitoring system. Consequently, we will take care of uniformity of the filling pattern. The charge of the individual bunches will be observed using fast photodiode illuminated by the synchrotron radiation, this signal will be measured by fast digital oscilloscope and will be analyzed by computer for the determination of the parameters of next injection.

Pinhole camera can be used for emittance measurements. Having two pinhole cameras installed in the regions with zero and non-zero dispersion will allow to measure energy spread of the electron beam.

The pinhole camera resolution is defined by two major factors: geometrical resolution $\sigma_{pinhole}$ and diffraction $\sigma_{diffraction}$. The estimation formulas for each factor can be found elsewhere [10]. For the system with magnification factor of unity they can be found as follows:

$$\sigma_{pinhole} = w/3^{1/2} \qquad (2)$$

$$\sigma_{diffraction} = 3^{1/2}/2\pi \frac{\lambda L}{w} \qquad (3)$$

where w is pinhole size, L is distance from pinhole to screen, λ is observation wavelength. The optimal pinhole size will correspond to the equal value of factor:

$$w_{opt} = \sqrt{\frac{3\lambda L}{2\pi}} \qquad (4)$$

We can estimate the resolution using the following parameters: L=5 m, $\lambda=\lambda c=0.18$ nm. The ultimate resolution of the pinhole camera will be $\sigma = \sqrt{\lambda L/\pi} = 17\ \mu$. This resolution is barely adequate for horizontal beam size measurement but is larger than the vertical beam size. We will continue to explore the alternative methods, such as laser wire [11].

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This manuscript has been authored by Brookhaven Science Associates, LLC under Contract No. DE-AC02-98CH1-886 with the U.S. Department of Energy. The United States Government retains, and the publisher, by accepting the article for publication, acknowledges, a world-wide license to publish or reproduce the published form of this manuscript, or allow others to do so, for the United States Government purposes.

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