DESIGN OF VISIBLE DIAGNOSTIC BEAMLINE FOR NSLS2 STORAGE RING*

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Abstract

A visible synchrotron light monitor (SLM) beam line has been designed at the NSLS2 storage ring, using the bending magnet radiation. A retractable thin absorber will be placed in front of the first mirror to block the central x-rays. The first mirror will reflect the visible light through a vacuum window. The light is guided by three 6'' diameter mirrors into the experiment hutch. In this paper, we will describe design work on various optical components in the beamline.

INTRODUCTION

The ultra high brightness NSLS-II storage ring is under construction at Brookhaven National Laboratory. It will have 3GeV, 500mA electron beam circulating in the 792m ring, with very low emittance (0.9nm.rad horizontal and 8pm.rad vertical). The ring is composed of 30 DBA cells with 15 fold symmetry. Three damping wigglers will be installed in long straight sections 8, 18 and 28 to lower the emittance [1]. While electrons pass through the bending magnet, synchrotron radiation will be generated covering a wide spectrum. There are other insertion devices in the storage ring which will generate shorter wavelength radiation as well.

Synchrotron radiation has been widely used as diagnostic tool to measure the transverse and longitudinal profile. Three synchrotron light beam lines dedicated for diagnostics are under design and construction for the NSLS-II storage ring: two x-ray beam lines (pinhole and CRL) with the source points from Cell 22 BM_A (first bending in the DBA cell) and Cell22 three-pole wiggler; the third beam line is using visible part of radiation from Cell 30 BM_B (second bending magnet from the cell). Our paper focuses on the design of the visible beam line - SLM.

Table 1: lists major parameters related to the NSLS2 storage ring.

Parameter	Value	Unit	Comment
General machine parameters			
E	3	GeV	Energy
f_{rf}	499.68	MHz	RF freq.
h	1320		har. #
f_{rev}	378.55	kHz	revolution frequency
T_{rev}	2.64	μs	revolution period
C	791.96	m	circumference
I	500	mA	Avg. current
ε_x	0.9	nm.rad	with 3 DW
ε_y	0.008	nm.rad	
σ_E/E	0.09%		with 3 DW
Bending magnet parameters			
ρ	25.02	m	bending radius
B	0.4	Tesla	magnet field
E_c	2.4	keV	critical energy
λ_c	0.52	nm	critical wavelength
Bunch length related			
Vc	3.1	MV	RF voltage
U0	287	keV	bend loss
	674	keV	total loss with 3DW
α	3.63E-4		
fs	3.32	kHz	
σ_t	15.66	ps	RMS bunch length
	30 ~ 45	ps	w/ harmonic cavity
Beam size related			
β_x	2.7763	m	
β_y	19.5252	m	
η_x	0.1370	m	
σ_x	133.05	μm	
σ_y	12.50	μm	

BEAMLINE LAYOUT

NSLS-II ring has 30 DBA cells, each cell has two bending magnets which bend the electron beam 6-deg each. Synchrotron radiation is extracted from the beginning of bending magnets, with horizontal opening angle 0 to 4.25mrad. The nominal source point for user's beam line is 2.125mrad +/- 1.5mrad. To use the same extraction configuration is highly desired for the visible diagnostic beam line. Synchrotron radiation from the dipole has natural open angle depending on the radiation wavelength. With longer wavelength, the synchrotron radiation from dipole will have larger natural open angle. For the 500nm green light, which will be used for most of our measurements, the natural opening angle is ~1.2mrad. To avoid the bending magnet edge radiation, the diagnostic beam line horizontal aperture was selected from 1.25mrad to 4.25mrad. The beamline layout and measurement resolution has been discussed in a previous paper [2]. The visible diagnostic beamline which will guide the radiation from the second dipole after the injection straight (C30) into the experiment room which sits on the experiment floor. The penetration hole of C30-ID will be used since no user's beamline. Crotch absorber and fixed mask will define the SLM aperture to +/-

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1.5mrad horizontally and +/-3.5mrad vertically. Size of the open aperture is determined by the measurement resolution and light intensity. There is more discussion about the system resolution in the SRW tracking section. The beamline was configured to have a thin absorber, called cold finger to block most of the x-rays in the central plane. The first mirror will be about 8-meters away from the source point. Beam height inside the tunnel is 1.2m and 1.4m on the experiment floor. A periscope will bring the light to the proper height over the optical table.

Total power within 3mrad horizontal fan will be ~70W. After the cold finger, the power on to the first mirror is only about 0.5W, since most of the power near the central plane is blocked by cold finger. Vacuum window and mirrors will further filter the UV radiation. Typical power into the SLM lab is around several mW level.

WAVEFRONT TRACKING

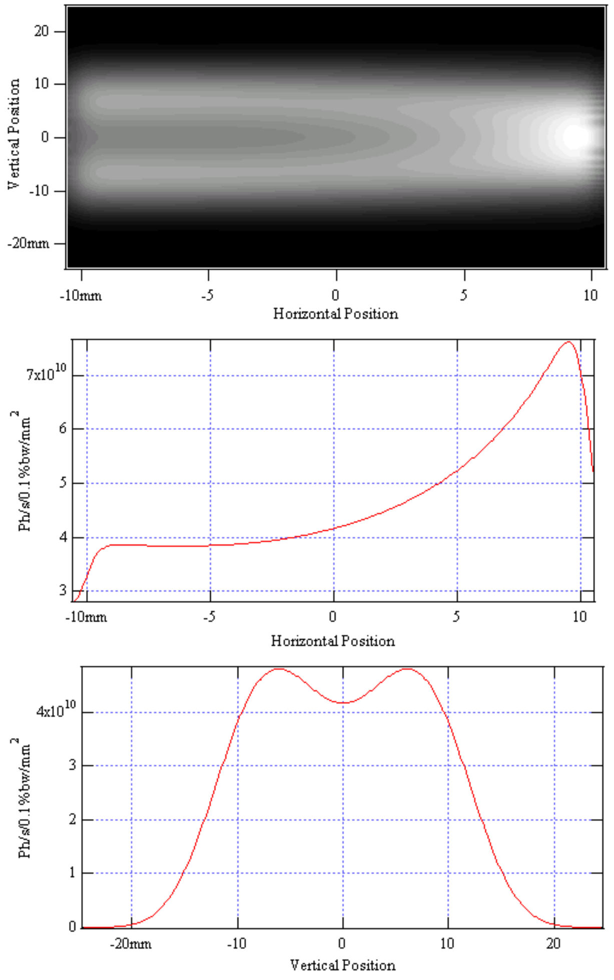

Figure 1: 500nm photon flux at the fixed mask. Upper one shows the Flux(x,y); middle is Flux(x) on the central plane; bottom shows Flux(y) at x=0.

Edge radiation has been investigated using SRW tracking code [3]. Figure 1 shows the wavefront intensity at the fixed mask, which is the first optical component in the diagnostic beamline. One can see the near the edge (+10mm horizontal position in Fig. 1), 500nm photon flux is about 50% more even with the deepest fan we can use. Due to mechanical constraints, the radiation fan cannot be moved deeper into the dipole. Edge radiations could be useful for diagnostics. We keep the option to adjust accepted horizontal fan. Simulated point-spread-function on the image plane agrees well with the theoretical estimation [2].

With cold-finger, there was concern that measurement error might be increased. SRW tracking with and without cold finger were compared, see Fig. 2. On the image plane, some diffraction-like pattern was observed with the cold finger. Vertical electron beam size is about 10 µm, on the image it's dominated by the measurement error, which is about 60 µm at the source plane. The cold finger actually has no influence on the real measurement. The focus lens is located on the optical table, to make an 8:1 image. 1:1 image beamline has been tracked to compare. Looks like both configurations gave the same PSF. Placing lens on optical table is preferred for easy access and adjustment. This will help for double-slit interferometer test. With 1:1 image configuration, the lens needs to be located inside the tunnel.

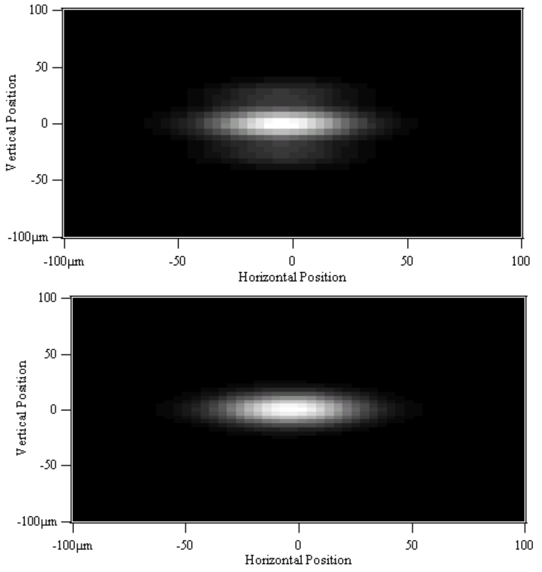

Figure 2: Multi-electron images with (top) and w/o (bottom) cold finger.

MECHANICAL DESIGN

The mechanical design work is moving forward smoothly. Cold finger and first mirror are two critical components in the beamline. The design status is discussed here.

The cold finger is basically a water-cooled thin absorber which blocks the radiation near central plane. Height of cold finger will be 6-mm, it's about +/-0.5mrad. With motion control driven by external motor, the cold finger can be retracted at low-current. This is attractive for some machine studies when more photons are desired. The cold finger could track the electron beam vertical position, in case the beam is steered far off the central plane. This prevents the first mirror from intercepting too much power. The cold finger will have a linear motor of 10 µm/step and a full range more than 32mm. Figure 3 shows the current design of the cold finger, including the motion control part. There is a 6mm thick GlidCop absorber mounted on the frame. The frame can be moved all the way up. Base of the frame has water cooling. An inverse bellow approach was adopted, similar to the scraper design at NSLS2, to have less stress from the pressure difference. Thermal analysis shows the highest temperature on the cold finger is below 150 degC with 500mA of 3GeV electrons stored in the ring.

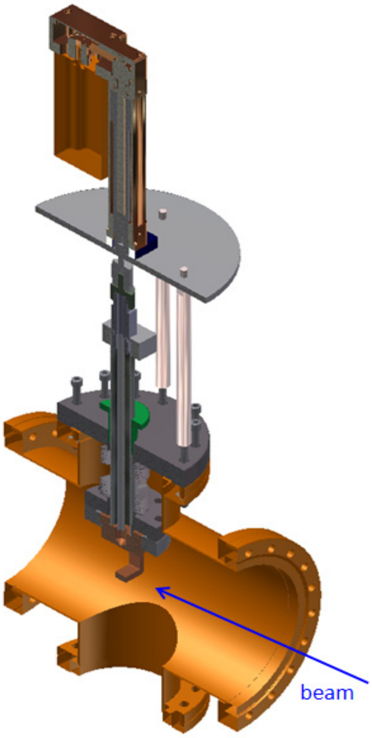

Figure 3: Preliminary thin absorber design with motion control and water cooling channel.

The first mirror body will be made from GlidCop, and the surface of the mirror will have thick layer of Nickel coating and a thin layer of Aluminum coating. The Nickel coating is necessary to make the optical quality surface of the first mirror. The mirror will have a flatness of less than 50nm in the whole working surface, which is about 1/10 of measurement wavelength. The surface slope error should be less than 1 µrad and roughness can be achived less than 1nm. The GlidCop mirror will be brazed onto a stainless steel 304 pipe and will be water cooled. With cold finger in place, the total power deposited on the first mirror is around 0.5W. Cooling water channels are added to prevent accident damage to the mirror. With 70W onto the first mirror, the simulated highest temperature is around 55 degC. This will make sure the mirror will be safe for the worst case scenario. Water flow to the first mirror will cause vibration issues. For those experiments which are sensitive to the vibrations, the water flow rate can be controlled to minimize the effect. The current design of the first mirror body is shown in Figure 4. It will be placed inside a 6'' inner diameter six-way cross. The mirror body will be welded onto the flange. Two temperature sensors will be mounted on the top and bottom edge of the mirror.

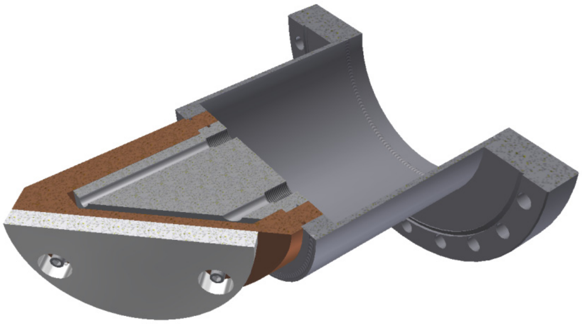

Figure 4: First mirror drawing with water cooling.

The visible light after the first mirror will pass through a 6'' vacuum window and be steered by commercially available mirrors onto the optical table.

Setups and applications have been defined in the experiment room. The whole beamline will be ready for beam commissioning before March 2013.

SUMMARY

Visible diagnostic beam line has been designed at the NSLS-II storage ring. SRW wave front tracking verifies the measurement errors and edge radiation effect. Various measurements will be carried out on the beamline to characterize the 1nm.rad machine. Mechanical design of critical components is maturing. Manufacture of these components will start once the design is finalized. The author wants to thank Dr. Oleg Chubar for his help on SRW tracking.

REFERENCES

[1] NSLS-II preliminary design report, http://www.bnl.gov/nsls2/project/PDR/

[2] W. Cheng, "Synchrotron Light Monitor System for the NSSL2", BIW'10.

[3] Synchrotron Radiation Workshop code: http://www.esrf.eu/Accelerators/Groups/InsertionDevices/Software/SRW