PROGRESS OF THE COHERENT SOFT XRAY STRAIGHT SECTION LAYOUT AT NSLS-II

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Abstract

The National Synchrotron Light Source II (NSLS-II) is the new light source under construction at Brookhaven National Laboratory (BNL). The Coherent Soft X rays beam line (CSX) is one of the six beamlines included in the baseline project. Following the request of CSX scientists for a source providing adjustable polarized radiation from 160 eV to 1.7 keV, two Advanced Planar Polarized Light Emitter II (APPLE-II)-type undulators will be installed in a 6.6 m long straight section. Each device is 2 m long, the period is 49.2 mm and the minimum gap is 11.5 mm. The different operation modes of the beamline and the layout of the straight section are reviewed here.

CSX LAYOUT

The CSX beamline has a coherent branch and a polarization branch. Two identical APPLE-II-type undulators (2 m long, 49.2 mm period, and a 11.5 mm minimum gap) will be used to deliver polarized photon beams from 160 eV up to 1700 eV [1].

Coherent Branch

The two APPLE-II-type undulators will be used in line to deliver the maximum flux to the coherent branch. D. Shapiro et al demonstrated that the use of a phaser between the two undulators would increase the flux by a factor of three [2]. They also demonstrated that the flux might be maximal as the phasing parameter φ is not equal to 2 π but at a value smaller than 15 rad. The phasing parameter φ is defined as:

$$\varphi = \frac{\pi}{\lambda}\int_{-\infty}^{+\infty} x_e^{\prime 2}(s)ds \qquad (1)$$

where λ is the wavelength of the radiation and

$$x_e'(s) = \frac{e}{\gamma mc}\int_{-\infty}^{s} B_y(\tilde{s})d\tilde{s} \qquad (2)$$

is the electron trajectory angle, e and m_e are the charge and the mass of electron, c id the speed of light, γ is the electron energy E normalized to the electron mass. At NSLS-II, E=3 GeV, γ~5871. The magnet must provide phasing at any wavelength between λ_{min} and λ_{max} where λ_{min} (resp. λ_{max}) is the wavelength that corresponds to a radiation with an energy of 1700 eV (resp. 160 eV). The phasing parameter φ required for each wavelength will be determined from simulations and magnetic measurements, and special "operation tables" will be stored in the control system and used at the CSX beamline during operations.

Canted Mode

The polarization branch requires full control of the beam polarization, including the capability to switch between opposite polarization states at rates from 10 Hz to 1 kHz. Such high frequencies cannot be achieved by a mechanical displacement of the girders of the APPLE-II-type undulator. Instead, one cants the electron beam with angle θ between the devices in order to separate the two photon beams emitted in each device; the photon beam with the requested polarization is then focused to the sample. Among the different methods successfully developed [3], [4], [5], CSX will use the static approach already used at BESSY-II. It consists of a set of three chicanes, one located upstream, one in the middle, and one downstream of the straight section. The chicanes located at each end kicks with angle -θ/2. A mechanical chopper located in the beamline selects the photon beam at a rate as high as 1.0 kHz. This setup with 3 chicanes also allows the operation of each branch in parallel, each insertion device being dedicated to one branch.

A small canting angle as low as 0.16 mrad between the two APPLE-II undulators is enough to split the photon beams into two distinct spots. The 0.08 mrad angle required at each end of the straight section is actually a small fraction, about 10%, of the maximum steering angle of the slow corrector [6] disposed all along the storage ring to correct the closed orbit. Therefore it is possible to use the existing slow correctors located at each side of the straight section as shown in Fig. 1 without any impact on their efficiency. However using these slow correctors will cause the electron beam to travel slightly off-axis of a pair of quadrupoles and a pair of sextupoles. Since there is only one pair of quadrupoles within the bump that can be used to rematch optics, the β-distortion cannot be completely restricted inside the bump. Beam dynamics simulations have been carried out with the programs ELEGANT [7] and MAD [8] to rematch the optics and calculate the Dynamic Aperture (DA). The global optics distortion is smaller than 0.02%, and is negligible. The variation of global tunes, chromaticities and emittance also are negligible as shown in Table 1. After tracking on-momentum DA, no reduction was found. So far, the tracking does not include any energy offsets; however no effect on the DAs of lattices with or without this bump is expected.

In addition due to this small canting angle, the two devices can be kept aligned as the photon beam is delivered to the polarization branch; a negligible flux reduction is expected on harmonics.

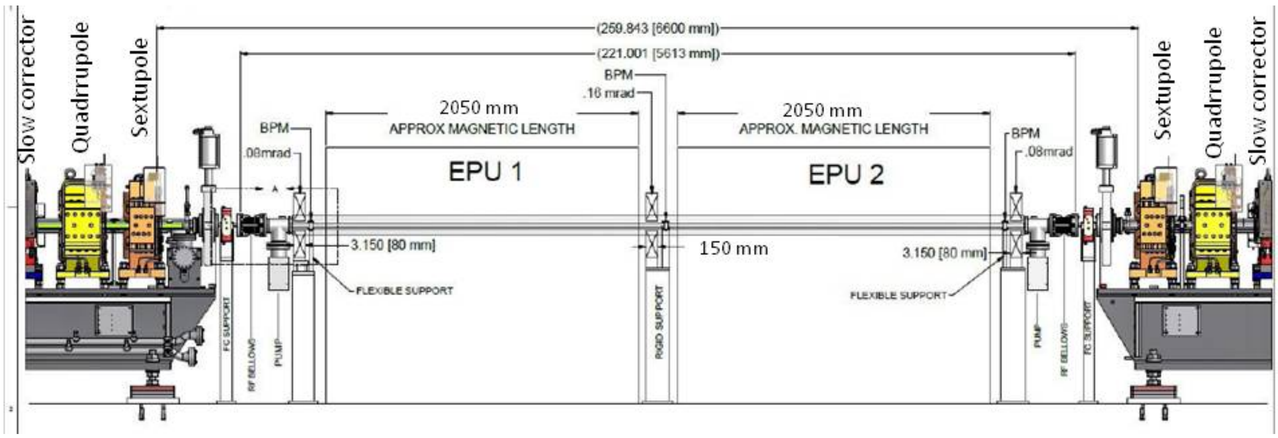

Figure 1: Layout of the CSX straight section.

Table 1: Global parameters comparison

Parameters	**With kick**	**Without kick**
ν_x	33.14757	33.14757
ν_y	16.27001	16.26999
Chromaticity x	0.09694837	0.09696375
Chromaticity y	0.257674	0.258315
Horizontal emittance [nm]	0.9298842	0.9298432

PHASER MAGNET

Permanent magnet technology offers numerous advantages compared to electromagnet technology: a compact design, no unpredictable hysteresis and a negligible interaction, at the expense of more complex mechanical design [5]. The 3D magnetostatic software RADIA [9] was used to calculate the magnetic field of the phaser.

Geometry

The geometry is displayed in Fig 2. The characteristics of the magnet blocks and rods made of Samarium Cobalt (Sm_2Co_{17}) are listed in Table 2. The arrangement of the magnets in the main body of the phaser follows the Halbach structure. Four rotatable rods are located at the end of the phaser. The length of the phaser is less than 110 mm.

Table 2: Parameters of the Magnet Blocks and Rods

Parameters	**Width [mm]**	**Thickness [mm]**	**Heigth [mm]**
Block	60	18	36
Rod	65	7.1	7.1

In the phasing mode the magnetization of the four magnet rods is longitudinal as pictured in Fig. 2. The gap is adjusted to set the phasing parameter.

In the canted mode the rods are rotated with a $\pi/2$ angle so that their magnetization points toward the vertical axis. The gap is closed at 13.6 mm to set the field integral at 1.6 Tmm. The trajectory of a 3 GeV electron is shown in Fig. 3 for the two different modes. In the canted mode, the use of the slow corrector 4.163 m ahead the centre causes a horizontal offset of about 0.12 mm at the entrance of the straight section.

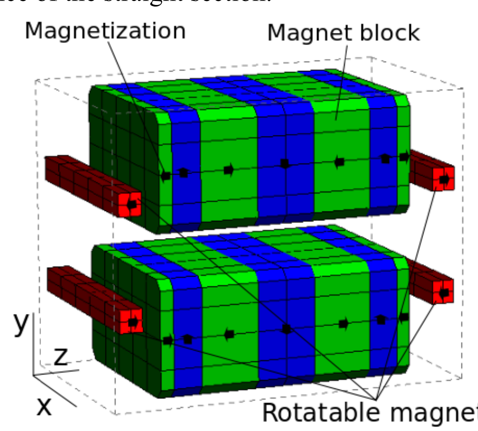

Figure 2: Geometry of the phaser.

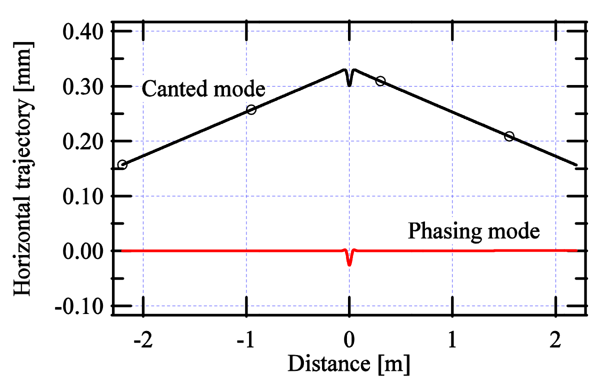

Figure 3: Electron trajectory in the straight section for the canted (line with makers) and phasing mode (line).

The variation of the phasing parameter with respect to the gap is displayed in Fig. 4 for two different photon energies, 160 eV and 1700 eV. The upper limit of the phasing at 160 eV drives the minimum value of the gap. The lower limit of the phasing parameter at 1700 eV determines the maximum gap value. Opening the gap at a value as high as 100 mm is required to ensure proper phasing.

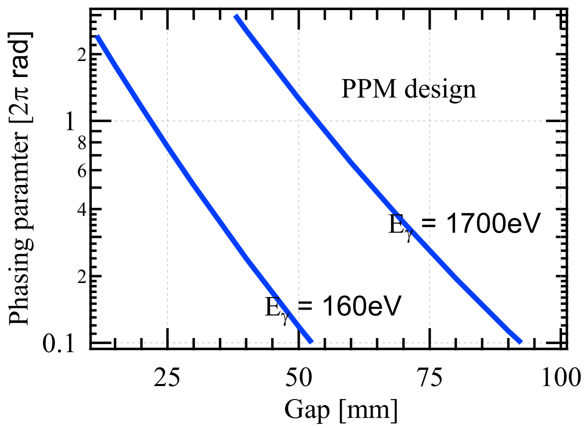

Figure 4: Variation of the phasing parameter.

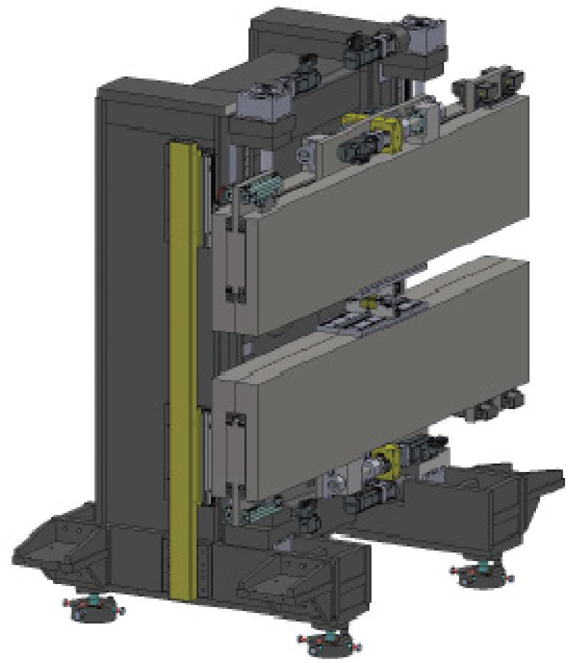

Figure 5: 3D-CAD rendering of an APPLE-II-type undulator with four moveable arrays

APPLE-II STATUS

A contract with a vendor was issued in mid April 2011 for the procurement of the two APPLE-II. The delivery at BNL of the two devices is planned for mid February 2013. A conceptual design review has been conducted to finalize the magnetic design and overview a preliminary mechanical design. The proposed support structure is a C-frame; the gap drive system is connected to two central girders. The phase drive system mounted on each central girder allows the longitudinal displacement of the four sub girders with the magnet arrays. Strong emphasis will be made at the preliminary and final design reviews on the mechanical deformation with various gap / phase combinations to prevent uncontrollable field quality variations. Both reviews will take place before the end of this year. Figure 1 shows the vendor's 3D-CAD rendering of an APPLE-II.

CONCLUSION

The present status of the CSX straight section has been presented. A magnetic design for the phaser is proposed and a vendor for the procurement of the two insertion devices was selected. The straight section layout is not finalized; the design efforts are now focused on the vacuum chamber and the integration along the vacuum chamber of flat wires. The flat wires will provide an active shimming of the dynamic multipoles generated by the APPLE-II-type undulators, à la BESSY [10].

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