RESEARCH ARTICLE | JULY 27 2016

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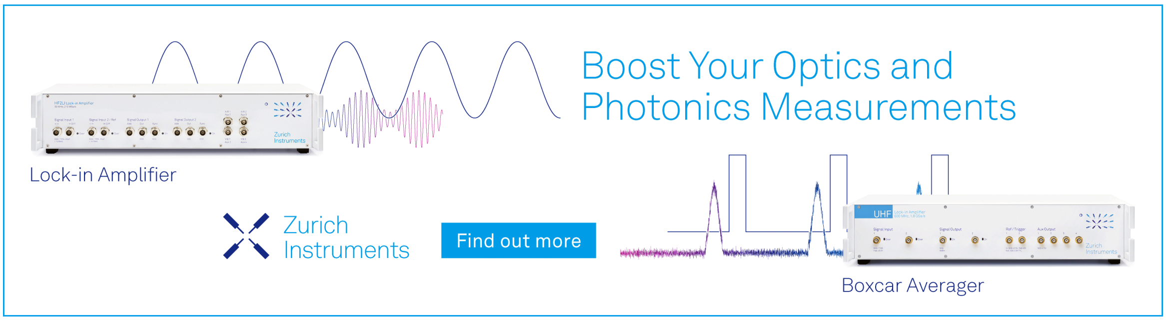
AIP Conf. Proc. 1741, 020012 (2016)
https://doi.org/10.1063/1.4952791



EPU Correction Scheme Study at the CLS

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Abstract. The Canadian Light Source (CLS) Quantum Materials Spectroscopy Center (QMSC) beamline will employ a novel double period (55 mm, 180 mm) elliptically polarizing undulator (EPU) to produce photons of arbitrary polarization in the soft X-ray regime. The long period and high field of the 180 mm period EPU will have a strong dynamic focusing effect on the storage ring electron beam. We have considered two partial correction schemes, a 4 m long planar array of BESSY-II style current strips, and soft iron L-shims. In this paper we briefly consider the implementation of these correction schemes.

INTRODUCTION

The CLS is a 2.9 GeV synchrotron with nine 5.5 meter straight sections available for insertion devices. Several of the straight sections are chicaned to allow for two IDs in one straight. The QMSC straight will use a double ID whereby independent EPUs, side-by-side, can be translated into place. This setup allows a single ID to cover two energy regimes and maximize flux by taking advantage of the full length of the straight. The parameters of the low energy (high energy) device are an energy range of 15 eV to 200 eV (200 eV to 1.2 keV), period of 180 mm (55 mm), 41 full size poles (141), and a gap range of 12.5 mm to 270 mm (12.5 mm to 220 mm). Moreover, the device is designed to be quasi-periodic to reduce higher order contamination. The polarization state of low energy photons (< 100 eV) from the undulator will be influenced by the Fresnel coefficients of reflection of the beamline optics. This contribution affects the eccentricity and inclination of the photon polarization state. Thus low energy circularly polarized photons at the source may not be circularly polarized when they are received at the end station. Therefore, the undulator will operate in universal mode to compensate for the changes in eccentricity and inclination (1,2,3). Different operational modes can have a different dynamic focusing effect on the CLS injected and stored electron beam. We consider two types of correction, current strips (active), and L-shims (passive).

KICKMAP STUDIES

The ID potential and associated kicks were calculated from the ID 3D magnetic field using RADIA (4,5). The kickmap accounts for the transverse motion an electron through a longitudinal field and can account for a field that varies transversely. The dynamic focusing goes with the period squared and inversely proportional to the electron beam energy (6). The roll-off effect is significant in EPUs operated in vertical polarization mode. As this EPU will operate in universal mode a large number of device configurations must be examined. Our approach will be to numerically calculate the 3D magnetic fields for a single sub-girder, including permeability, and apply superposition to account for the three other sub-girders. The derived model does not include phase dependent magnetic interaction. The total magnetic field is then used to calculate the kickmap. The magnetic signature from a set of shims, active or otherwise, may be added to the ID magnetic field act to null the kickmap in the magnetic midplane of the device. In the case of active correction singular value decomposition (SVD) can be used to calculate the currents required to null the kickmap.

Proceedings of the 12th International Conference on Synchrotron Radiation Instrumentation – SRI2015
AIP Conf. Proc. 1741, 020012-1–020012-4; doi: 10.1063/1.4952791
Published by AIP Publishing. 978-0-7354-1398-6/$30.00

L-SHIMS

We evaluated soft-iron shims for the 55 mm EPU. The thin L-shaped pieces of steel have been described elsewhere (7). An example of such a shim is shown in Fig. 1. The shims manipulate the magnetic field of the ID in the horizontal and vertical planes. Fig. 1 also shows the differential magnetic field between a configuration with no L-shim and one with an L-shim. For a single operational mode (or polarization state) a L-shim can correct well. When operational modes change the L-shims can negatively affect the kickmap. Figure (2) shows an example of a 1-D kick map of the undulator and a L-shim designed for vertical polarization (blue). The effect of the same shim in planar mode (black) is shown as well. The shim does not compensate well in the planar mode. The L-shims are suitable for a limited number of EPU configurations and we require a more robust solution.

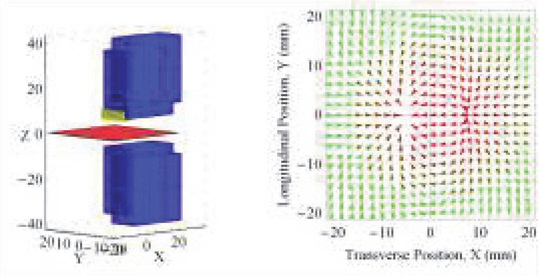

FIGURE 1. A qualitative example of the differential magnetic field (right) in the magnetic midplane due to a vertical L-shim (left, gold) on an EPU55 magnet block (left, blue)

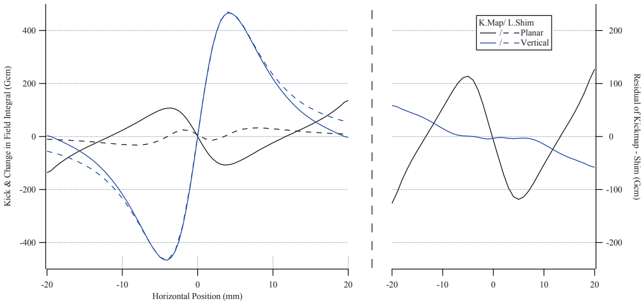

FIGURE 2. The left graph shows the 1D kickmap. Solid lines show the ID (vertical polarization mode) kickmap (blue) and the dashed lines shows the kickmap L-shim signature. A change in polarization mode from vertical to horizontal planar (black) shows a reduced shim signature.

Current Strips

The CLS current strip array will adopt the approach of BESSY (8,9) which uses two regular arrays of conductors mounted flush with the EPU vacuum chamber, as shown in Fig. 3. The layout uses 24 equidistant conductors with a nominal rectangular cross-section of 3 mm x 0.3 mm and a center-to-center distance of 4 mm. The design will be implemented as a flexible printed circuit board with a polyimide substrate (10). The peak current required of any individual conductor is 14 A. A substantial operational difference, compared to existing current strips at other facilities, is each conductor will be powered by an independent power supply. The field integral signature for an individual conductor is calculated analytically from a current carrying filament of finite length. The field from a conductor of rectangular cross-section is calculated from the integral sum of filaments.

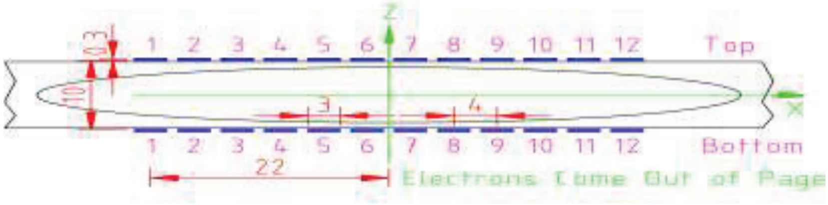

FIGURE 3. Schematic of the QMSC current strip layout.

The current strip conductors were modeled in ELEGANT (11, 12) to study the tolerances in layout and operation of the wires. Position tolerances were developed by adding a small random displacement to the nominal transverse position of the conductors. The perturbations were derived from a random Gaussian distribution with zero mean and a standard deviation of sigma. For each type of displacement a total of 201 ELEGANT simulations were done. The effect of the perturbations on dynamic aperture and tunes were evaluated. It was found that the uncertainty in the horizontal tune becomes large when sigma exceeds 100 µm. The dynamic aperture was relatively insensitive to the random misalignments. Systematic misalignments were studied by increasing the transverse positions of the set of wires. It was found that the tunes and dynamic aperture were again less sensitive to this type of error. A similar approach was used to evaluate the tolerance for noise in power supply current and an upper limit of 200 mA was determined. The results are summarized in Table 1.

Table 1. Summary of current strip position and operational tolerances.

Type of Mechanical Layout Error	**Tolerance**
Δ horz.-relative	100 µm
Δ vert.-relative	100 µm
Δ horz.-absolute	400 µm
Δ vert.-absolute	500 µm
Absolute current error	200 mA

An example of the current strip correction capacity is calculated in 2D and shown in Fig. (4). The EPU180 2D kickmap horizontal and vertical kicks in the x-z plane are calculated for linear quarter phase. The conductor correction current values were calculated and applied to the map. It is clear that the conductors compensate well in the magnetic midplane but cannot completely compensate off plane.

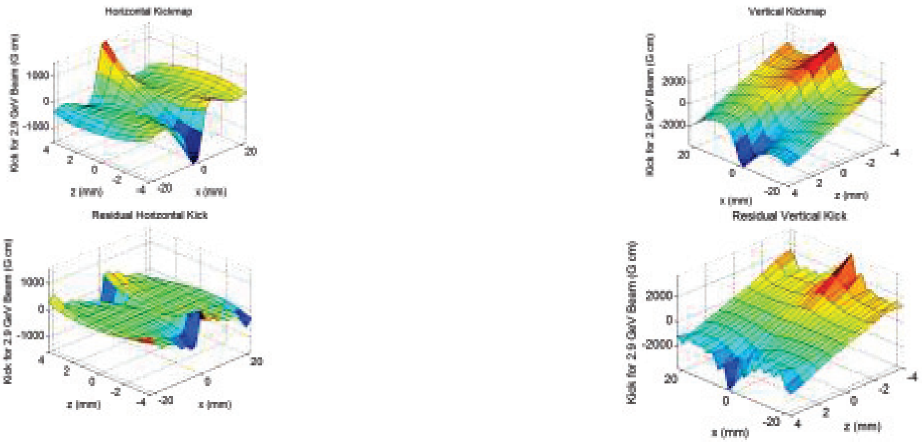

FIGURE 4. 2D kickmaps calculated in the x-z plane at 2.9 GeV. The 2D horizontal kickmap and vertical kickmap are shown in the top left and top right, respectively. The residual kickmaps, post current strip compensation, for the horizontal and vertical planes are shown in the bottom left and bottom right. Clearly, the current strips compensate well in the magnetic midplane but cannot complete compensate out of plane.

To understand the effect on dynamic aperture we performed tracking simulations for different operational modes. We continue with our example of linear quarter phase and present survival plots with active current strip compensation with respect to the bare lattice. Fig. (5) clearly shows that the currents strips restore the dynamic aperture in linear quarter phase at 15 mm gap. This active compensation works well in other ID operational modes as well. The restored dynamic aperture implies injection into the storage ring will be unhindered by the EPU180.

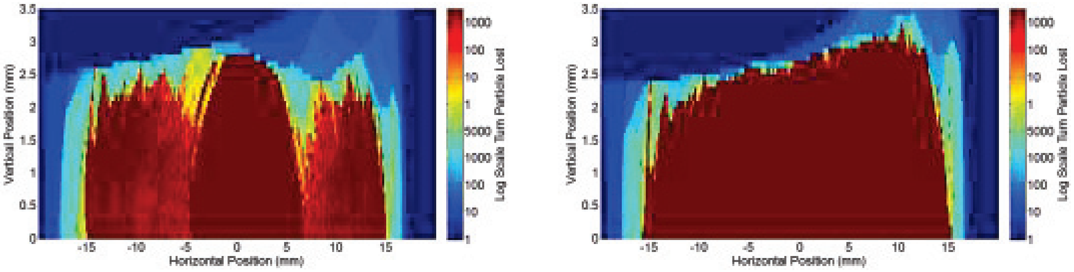

FIGURE 5.Off momentum at 2.9 GeV (δ=0.01) survival plot for linear quarter phase without compensation (left) and with compensation (right). The dynamic aperture is nearly restored by the current strip compensation.

SUMMARY

The CLS double EPU180/55 will operate in universal mode and requires a compensation scheme for the dynamic focusing effects. We have briefly evaluated passive and active correction schemes for the QMSC low/high energy EPU. It was found the L-shim scheme is effective in particular modes but overall does not work well when changing modes. The active correction scheme appears to be the most robust option for CLS. We have developed a mechanical layout and an associated set of tolerances to insure that a model can be constructed that can accurately match the measured effect of the current strips on the CLS beam dynamics.

ACKNOWLEDGMENTS

The CLS is supported by CFI, NSERC, NRC, CIHR, the Province of Saskatchewan, WD, and the University of Saskatchewan. This research was enabled by the use of computing resources provided by WestGrid and Compute/Calcul Canada.

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