INSERTION DEVICE DEVELOPMENT AT THE CANADIAN LIGHT SOURCE

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Abstract

The Canadian Light Source (CLS) is a 2.9 GeV 3rd generation light source in Saskatoon, Canada. The latest expansion of operations includes adding 4 insertion devices (IDs) in 2 straight sections. These devices will include a hybrid permanent magnet wiggler, an in-vacuum undulator (IVU) and 2 APPLE-II type undulators. Longer term developments include the replacement of two planar undulators with APPLE-II devices and the addition of a superconducting wiggler and another IVU in a common straight section serving multiple beamlines. Completion of all of these devices will bring the total number of IDs at the CLS to 13, installed in 8 straight sections, and serving 14 beam lines.

NEW INSERTION DEVICES

Currently the CLS has 4 empty straight sections available for future beamline development. Sections 7 and 9 will be the first to be developed for the BioXAS and Quantum Materials Spectroscopy Center (QMSC) beamlines. BioXAS will be for the use of x-ray spectroscopy and imaging in the field of Life Sciences and QMSC for ARPES and spin resolved photoemission.

IVU & Wiggler

The next expansion will be in section #7 and include a hybrid wiggler and an IVU installed in the same section and separated by a three magnet chicane with an 8 mrad separation angle. The downstream wiggler will be a hybrid permanent magnet device assembled from NdFeB magnet blocks and cobalt steel poles, with a peak field of >2.1 T and a total length of 1.64 m. The device is designed with a 'flat top' field which will create a wide radiation fan that will be used as a source for two separate beamlines. The central beam line will have an on axis critical energy of 11.8 keV and the acceptance of the side beamline will be 5 mrad off the central axis and have a critical energy of >90% of the central beamline.

The upstream IVU will have a period of 19.1 mm, total length of 1.59 m, and consist of a hybrid magnetic structure with NdFeB magnetic blocks and high flux cobalt steel poles. The ID will cover the energy range of 5 to 21 keV using up to the 11th harmonic.

APPLE-IIs

Section #9 will contain a Double Elliptically Polarizing Undulator (D-EPU) consisting of two APPLE-II type magnetic arrays mounted on a common support structure. Each array will cover a separate but overlapping energy range from 15-200 eV and 200-1000 eV with both circular and variable linear polarizations. The arrays will both be the full length of the straight section (~3.9 m) and mounted side by side on separate girders using a common c-frame with independent gap and phase control. The entire structure will be translated horizontally to allow the users to remotely select either array as the source for a single common beamline. Together these devices will provide the QMSC beamline with a wider energy range and higher flux than is available at any other single end station at the CLS (Fig. 1). A modification of the structure to make both of the EPUs quasi-periodic is being investigated for possible implementation.

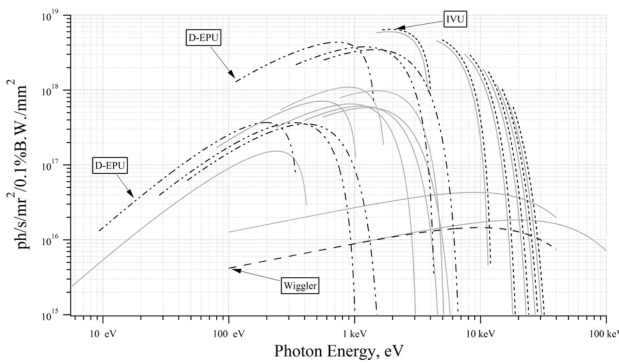


Figure 1: Brilliance of IDs, new devices in black dashes, existing devices solid grey.

IMPACT OF INSERTION DEVICES

The effects of these devices on the beam dynamics has been done using kickmaps[1] calculated in Radia[2] and imported into the optics code elegant[3] for tracking. Simulations have been performed to measure the effects on the dynamic aperture and tune shifts (see Table 1) of the stored beam.

Table 1: Tune Shifts

Polarisation		Wiggler	D-EPU	
			$\lambda = 180$	$\lambda = 54$
Horizontal	$\Delta\nu_x$	~0	0.0047	0.0006
	$\Delta\nu_y$	0.0150	0.0005	0.0044
Circular	$\Delta\nu_x$	-	-0.0084	-0.0093
	$\Delta\nu_y$	-	0.0040	0.0060
Linear 45°	$\Delta\nu_x$	-	0.0017	-0.0002
	$\Delta\nu_y$	-	0.0048	0.0055
Vertical	$\Delta\nu_x$	-	-0.0199	-0.0150
	$\Delta\nu_y$	-	0.0070	0.0071

Correction Schemes

Different correction schemes will be used to minimize the interaction these devices have on the stability of the stored beam and the effect on the beam dynamics. These include 'magic finger' trim magnets for integrated multipoles and horizontal and vertical steering coils at the entrance and exit of the device for corrections of the e-beam trajectory using feed-forward tables.

The APPLE-II devices will also have L-shaped iron shims placed on magnets to correct dynamic focusing for certain modes, and a system of longitudinal current strips placed on the vacuum chamber to generate multipole fields to correct the dynamic focusing of the devices. A proposed geometry for the current strips needed for the low energy EPU requires six parallel strips with a cross-section of 3x 0.3 mm^2 placed on the top and bottom of the vacuum chamber and split into two families for correction of normal and skew multipoles. The first order field integrals (see Fig. 2) generated by these families are used to correct for the second order dynamic effects of the design.

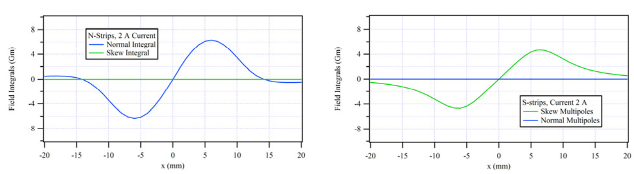
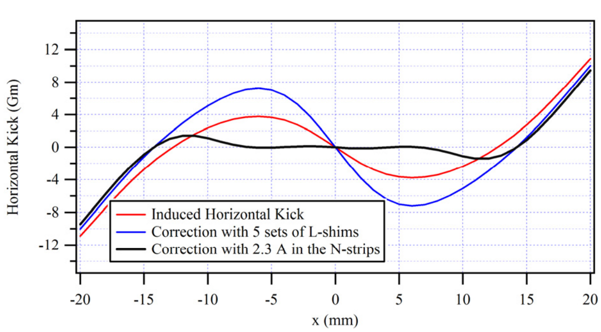


Figure 2: Normal (blue) and Skew (green) multipoles of the N-Family (left) and S-Family (right) current strips with 2 amps current.

The combined effect of the dynamic field integrals, L-shims, and current strips are shown (see Fig. 3) for select polarisations at gaps corresponding to a photon energy of 15 eV. These corrections work well for the horizontal kicks on the x-axis but typically increase the kicks in the opposite plane along the y-axis (not shown). Similar results can be found for the inclined linear polarisation modes for the vertical kicks corrected with the S-Family strips.



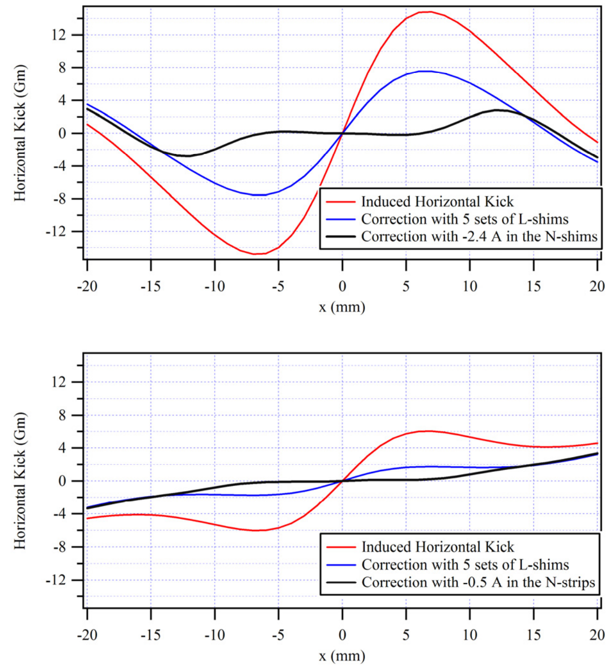


Figure 3: Correction of the horizontal kick along the x-axis(y=0) using L-shims and N-Family current strips for the Horizontal, Circular, and Vertical polarisation modes (top to bottom).

The wiggler may also require using adjacent quadrupoles to compensate for tune shifts and to restore the dynamic aperture of the lattice. The effects of tune correction on the dynamic aperture using three upstream and three downstream quadrupoles calculated using kickmaps is shown in Fig. 4.

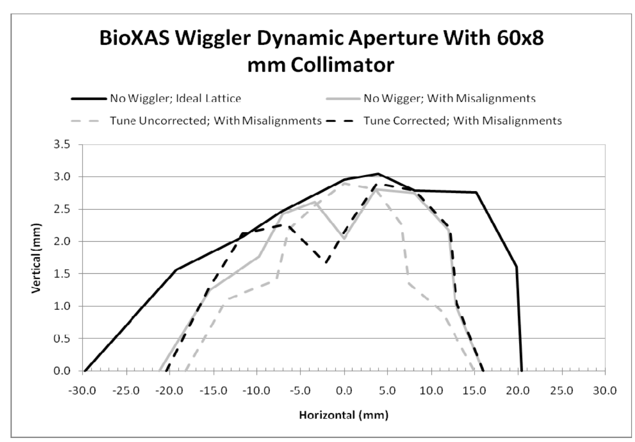


Figure 4: Dynamic Aperture of misaligned CLS lattice without wiggler (solid grey), with wiggler before tune correction (grey dashed) and with wiggler after tune correction (black dashed).

Additional Challenges

The complexity of the support structure for the D-EPU is increased by several additional factors. Spatial constraints are imposed by the front-end of an upstream bending magnet beamline, and the space available in the storage ring tunnel. The large forces require a large stiff frame to limit deflections of the girders, minimise field errors, and allow for accurate and repeatable transverse positioning needed for switching between the low and high energy magnetic arrays. The size of the assembled device presents several complications and limitations that must be considered during assembly, magnetic field measurement, and installation.

SUMMARY

These additional (see summary in Table 2) IDs present unique and challenging developments for the CLS. The IVU and wiggler are planned to be the first permanent magnet IDs procured as turnkey devices from industry and the D-EPU will be the largest and most complex device built in-house at the CLS.

Table 2: Summary of IDs

Parameter	**IVU**	**Wiggler**	**D-EPU**	
Location	7.1	7.2	9	
Period, λ	19.1mm	150mm	54mm	180mm
Total Length	1586mm	1639mm	3905mm	3834mm
# poles	166	22	145	43
k-value	1.77	29.4	4.9	7.6
Energy Range	5-21keV	-	0.2-1keV	15-200eV
Critical Energy	-	11.8keV	-	-
Peak Field	0.99T	2.1T	0.97T	0.45T
Min. Gap	5.2mm	11mm	12mm	19mm
Material	Hybrid NdFeB	Hybrid NdFeB	NdFeB	NdFeB

ACKNOWLEDGEMENTS

The Canadian Light Source would like to acknowledge the contributions of our retired colleague and current collaborator Ingvar Blomqvist for his continued work and assistance with the magnetic designs of all of the IDs detailed in this paper.

REFERENCES

[1] P. Elleaume, "A New Approach to the Electron Beam Dynamics in Undulators and Wigglers" EPAC'92, Berlin, March 1992, p.661 (1992); http://www.JACoW.org.

[2] P. Elleaume, O. Chubar, J. Chavanne, "Computing 3D Magnetic Fields from Insertion Devices" PAC'97, Vancouver, May 1997, p.3509 (1997); http://www.JACoW.org.

[3] M. Borland, "elegant: A Flexible SDDS-Compliant Code for Accelerator Simulation," Advanced Photon Source LS-287, September 2000.