INSERTION DEVICES COMMISSIONING AT THE CLS

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INTRODUCTION

The Canadian Light Source (CLS) storage ring was commissioned in early 2004[1] and has been supplying light to a growing number of beamlines over the last two years[2]. Insertion devices (IDs) for the beamlines include three planar undulators, an elliptically polarizing undulator (EPU) and a superconducting (SC) wiggler. The properties of the IDs are shown in Table 1 and Fig. 1.

Table 1: CLS Insertion Devices

ID	Gap (min.)	Period	Poles	Photon energies
	mm	mm		eV
Undulators				
EPU	15	75	43	100 – 1000 (Circular) 100 – 3000 (Linear)
SGM	25	185	19	5.5 - 250
PGM	12.5	45	53	250 -1900
Hybrid	5.5	20	145	6k –18k
Wiggler				Critical energy
SC	15	35	60	10k

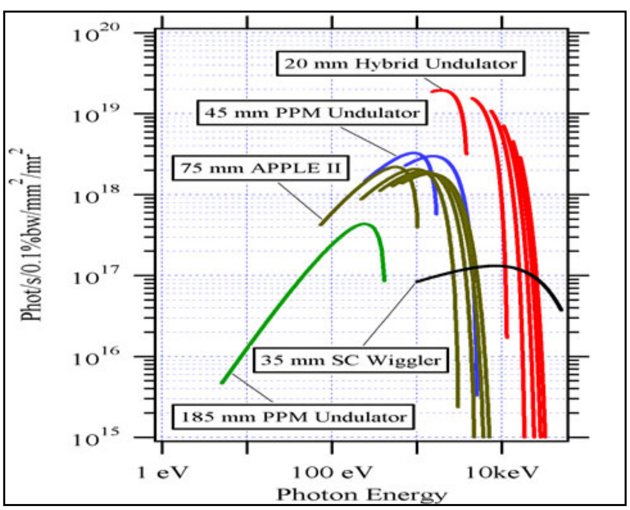

Figure 1. Brilliance: Tuning Curves for CLS Undulators and Photon Curve for the SC Wiggler.

Two of the planar undulators (PGM and SGM) occupy the same straight in the CLS lattice where a small magnet “chicane” is used to separate the two beams by an angle of 1.6 mrad. Such a small chicane allows both beams to pass through the same beamline front end after which there is adequate separation to direct the beams to respective beamlines. The third planar undulator (Hybrid) is an in-vacuum device that can operate at a gap as low as 5.5 mm. This device is also in a chicaned straight where there is room to install another device in the future.

The EPU has a chicaning arrangement that allows several options for delivering the beam. In the near future a second EPU will be placed in the same straight. A system of five chicane magnets will allow the two EPU beams to be delivered with the options shown in Fig. 2.

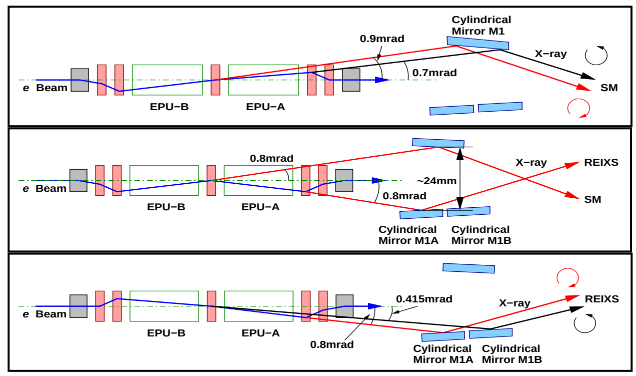

Figure 2. Chicane Modes for SM EPU (installed) and REIXS EPU (future) beamlines. Chicaning allows for light from both IDs to be independently directed towards either or both beamline (enabling rapid polarization switching).

The SC wiggler occupies a single straight where there is no chicane. The location of the various IDs and beamlines is shown in Fig. 3.

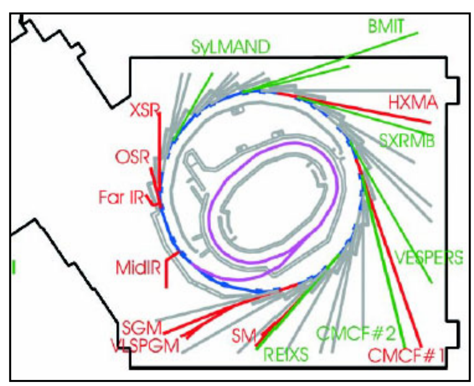

Figure 3. Red: Present CLS beamlines and IDs: HXMA (Hard Xray MicroAnalysis) using SC wiggler; CMCF (Canadian Macromolecular Crystallography Facility) and Hybrid; SM (Soft Xray Spectromicroscopy) and EPU; VLSPGM (Variable Line Spacing Plane Grating Monochrometer); and SGM (High Resolution Spherical Grating Monochrometer). Also shown are two Infrared (IR) beamlines, and the Xray and the Optical Synchrotron Radiation (XSR and OSR) diagnostic beamlines. Green: Future Beamlines.

COMMISSIONING

Planar Undulators

The optimum length for IDs in the CLS lattice is about 1.7 m. The 5.2 m straights provide ample room for installing two undulators. Chicane magnets are used to send the electron beam through the two IDs at slightly different angles. Typically the “kicks” from the magnets are +0.8 mrad, −1.6 mrad and +0.8 mrad. Consequently the photon beams are have an angular divergence of 1.6 mrad. (In some straights the signs of the kicks may be reversed.)

The SGM and PGM planar undulators, installed in the same straight, have little or no effect on the storage ring performance. Photons produced by these IDs pass easily through the shared front end. The two photon beams are routinely delivered to the two respective beam lines.

The small gap (12.5 mm) for the PGM undulator requires a small vacuum chamber. An ALS type vacuum chamber is used with an inside gap of 7.5 mm. This represents the minimum vertical aperture in CLS lattice. This small aperture “scrapes” the beam producing the high levels of radiation while the beam is injected or stored. Local shielding is in place downstream from this chamber to block the radiation from reaching the experimental floor.

Hybrid (In-vacuum) Undulator

Like the other planar IDs the in-vacuum undulator has little or no impact on the electron beam optics. This ID is placed in the upstream end of the straight with room remaining for a second ID. Chicane magnets are also used in this straight. The geometry of the present and future beamlines requires that the chicane angles are −,+,−.

The small gap (5.5 mm) represents the minimum vertical aperture while beam is stored. To date, at apertures below 10 mm the ID gap is reducing the beam lifetime. It is not totally understood why the lifetime is reduced at such a large gap as this is not the minimum aperture. The problem is probably excessive out-gassing as the photon flux is increased. Indeed the lifetime has slowly improved as the vacuum conditioning proceeds. Steering of the electron beam has demonstrated that the decreased lifetime is not due to ID misalignment.

Elliptically Polarizing Undulator (EPU)

The EPU was expected to have a significant impact on the storage ring optics. For this reason detailed measurements of the EPU magnetic fields were made and the potential impact studied with the optics code DIMAD.

The magnetic field integrals for the EPU at minimum gap are shown in Fig. 4. The field integrals varied very little as a function of the phase (polarization) of the EPU. The field plots show a strong skew quadrupole component. Simulations showed that this would result in transverse coupling of about 0.3%. In the DIMAD analysis the higher order multipoles reduced the dynamic aperture of the storage ring by a factor of two in both planes.

The EPU was installed with a compensating skew quadrupole in the same straight. Commissioning results confirmed the DIMAD results. At minimum gap and a variety of polarizations a coupling change of 0.3% was observed. By good luck, with the EPU at minimum gap, the coupling of the storage ring is reduced! The coupling at all gaps is shown in Fig. 5.

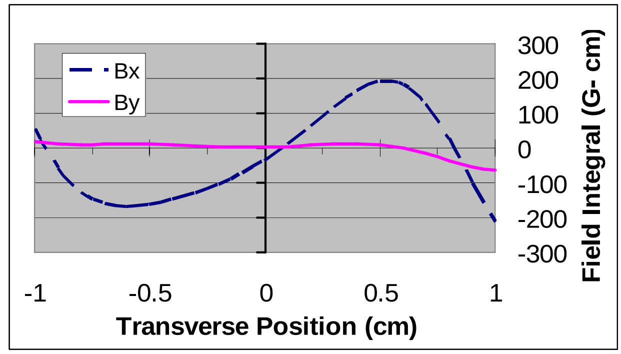

Figure 4: Measured EPU field integrals at minimum gap.

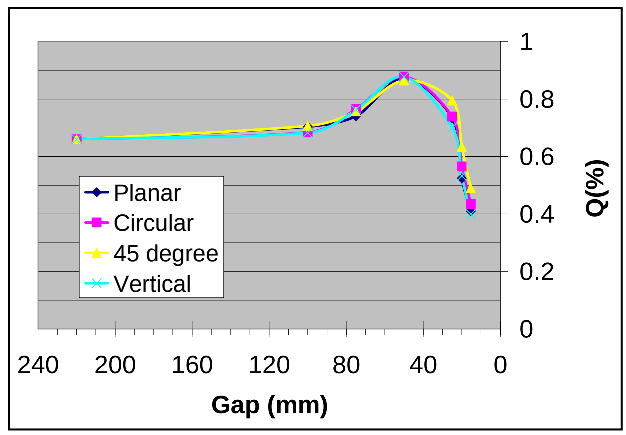

Figure 5 : Transverse Coupling, Q, vs EPU gap. At minimum gap the storage ring coupling is reduced.

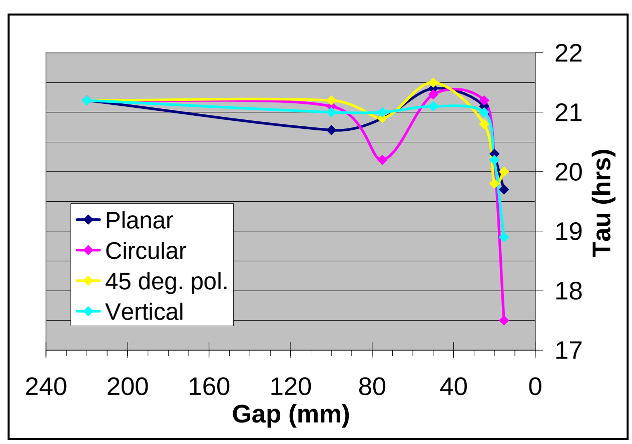

Figure 6: Beam Lifetime vs. EPU gap measured at 150 mA. The lifetime follows the trend of the coupling shown in Fig. 5. For the circular mode the decrease in lifetime is ~17%.

At minimum gap a horizontal tune shift of +.001 was observed for planar polarization and −0.002 for the circular mode. The maximum vertical tune shift for any polarization was +0.002

The beam lifetime increased at small gaps as shown in Fig. 6. This was expected from the dynamic aperture studies but could also be a result of the smaller transverse coupling. (A small increase in lifetime is seen where the coupling is maximum.) The smallest lifetime, a decrease of 16%, is observed in the circular mode.

Superconducting Wiggler

The 2 Tesla, 64 pole superconducting wiggler has the greatest impact on the CLS lattice. Before installation the SC wiggler was modelled using the beam optics code DIMAD. For this purpose every pole was modelled and each pole was considered to be a constant field (hard edge) dipole. To accurately simulate both the 1st field integral and the constant field, B, is given by $B=\pi/4\ B_{max}$ where B_{max} is the maximum field the usual sinusoidal representation. The pole width, W, is given by $W=4\lambda_w/\pi^2$ where λ_w is the wiggler wavelength. Pole face rotations of half the bend angle were applied at the entrance and exit of each pole (with the appropriate half poles and the beginning and end of the device.)

The optics model predicted a vertical tune shift from 4.2800 to 4.2851 in the CLS lattice with negligible tune shift in the horizontal plane. As well the wiggler introduced betatron beating as shown in Fig.7.

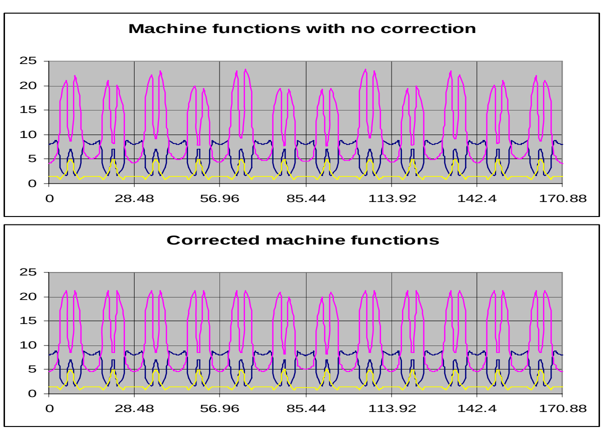

Figure 7: Effect of the SC wiggler on CLS machine functions before and after correction. Wiggler is at the centre of the plot. β_y is most effected.

The CLS lattice[3] has three families of quadrupoles. The effect of the wiggler[4] can be corrected by decoupling the quadrupole configuration as follows:

Q1Q2Q3Q3Q2Q1 (SCW) Q1Q2Q3Q3Q2Q1

→ Q9Q8Q7Q6Q5Q4 (SCW) Q4Q5Q6Q7Q8Q9

The six “new” quadrupole families were used to match β_x, β_y, and η_x (Fig. 7) to the rest of the lattice and adjust the horizontal and vertical tunes. As well the dispersion at the location of the wiggler could be freely adjusted.

Commissioning of the SC wiggler proceeded with little difficulty. The two power supplies activating alternating poles were adjusted so that the ID produced no net kick over a wide range of operating fields. Consequently the wiggler field can be ramped up without perturbing the electron orbit. At full field the horizontal and vertical tune shifts are ~0 and 0.0048, more or less in agreement with the DIMAD model.

Adjustment of the quadrupoles was applied as described above. In practice, however, it appears that such an adjustment is not required with beam quality and beam lifetime virtually unaffected if the tune is simply adjusted globally.

A collimator upstream of the SC wiggler is the minimum horizontal aperture in the storage ring. The wide injected beam (ε_x = 550 nm-rad) and betatron oscillations cause some beam loss and high levels of radiation at the wiggler. Local shielding is used here as well.

OTHER ACTIVITY

Orbit Control and ID Lookup Tables

Orbit stability requires beam oscillations no larger than 10% of the damped electron beam size. In the horizontal plane where the beam size approaches 1 mm this requirement is no problem. In the vertical plane the beam size can be a small as 10 microns in the IDs. Correction coils are built into all the IDs to compensate for small kicks and beam shifts in both planes produced when the gap sizes are changed. As well, there is a lookup table regulating the skew quadrupole installed to compensate for changes in coupling from different EPU gaps.

Coupling Correction

An array of 36 skew quadrupoles are used to control the transverse coupling in the storage ring [5]. Vertical coupling less than 0.1% has been achieved. Attempts have been made to reduce the coupling locally where required while keeping the coupling larger elsewhere. Some success has been achieved [2]. This technique should be useful for reducing the beam size in the in-vacuum undulator and the EPU.

REFERENCES

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[3] L. Dallin, “CLS Main Ring Lattice”, CLS Report 5.2.69.2 Rev 3, January 13, 2004.

[4] L. Dallin, “Effect of SC Wigglers on the Storage Ring”, CLS Report 5.2.69.6 Rev 0, December 13, 2004. (internal document)

[5] L. Dallin, “Local Transverse Coupling Control”, PAC2001, p. 2677.

CLS documents at: http://www.lightsource.ca