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CLS ID-10 chicane configuration: From "Simple Sharing" to extended performance with high-speed polarization switching

K.V. Kaznacheyev[a,*], Ch. Karunakaran[a], F. He[a], M. Sigrist[a], T. Summers[a], M. Obst[a,b], A.P. Hitchcock[b]

[a]*Canadian Light Source Inc., University of Saskatchewan, Saskatoon, SK, Canada S7N 0X4*
[b]*BIMR, Department of Chemistry, McMaster University, Hamilton, ON, Canada L8S 4M1*

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Abstract

The chicane scheme adopted for the elliptically polarized undulators (EPU) in the ID10 section at the Canadian Light Source (CLS) not only permits independent operation of two beamlines, but also allows to redirect beams from two EPUs into a single beamline with a performance similar to a "dedicated" configuration. Fast switching at kHz rates will be achieved by piezo shutters located after exit slits which will block the light of alternate polarization.

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1. Motivation

At the Canadian Light Source (CLS) it is a policy to share each straight between two beamlines, where possible, trying to match research projects of different experimental teams. The ID10 section is shared between the soft X-ray SpectroMicroscopy (SM) and the Resonance Elastic and Inelastic (soft) X-ray Scattering (REIXS) groups. Both beamlines cover an energy range of 100–2000 eV and are designed to perform advanced polarization measurements. Both beamlines use Apple II-type elliptically polarized undulators (EPU) and can extend their capability by redirecting the light from the two EPUs into a single-beam line. To ensure stable operation, only schemes with fixed electron beam path and polarization switching done by mechanical choppers in the beamline were considered. The Swiss Light Source, on their SIM and SIS beamlines, uses a space-shared mode, where two sources (electron bunches in upstream/downstream undulators) are shifted laterally but the light propagates though the optical system along the same path [1]. The two beams are separated close to the exit slit where a mechanical chopper is used to switch between alternate polarization at kHz frequencies. The Bessy II UE56 tandem uses a chicane scheme with angular separation [2]. Two light beams with alternative polarizations propagate through the system along different paths but focused back at the exit slit. In the following, these two chicane schemes are analyzed in the context of implementation of rapid polarization switching for the SM/ REIXS CLS beamlines.

2. Performance

The SM beamline, which uses the upstream EPU and inboard allocation, has been commissioned and is open to general users [3]. It hosts two experiments. A long arm branch (microscopy) is designed to match single-diffraction mode of STXM operation. The short arm branch (spectroscopy) is designed to accept the full EPU cone and uses additional focusing to match the light spot to the field of view of a photoemission electron microscope (PEEM) (Fig. 1a). The REIXS beamline is in procurement stage. Both beamlines use the electron beam as the effective

*Corresponding author.
E-mail address: kkaznatcheev@lightsource.ca (K.V. Kaznacheyev).

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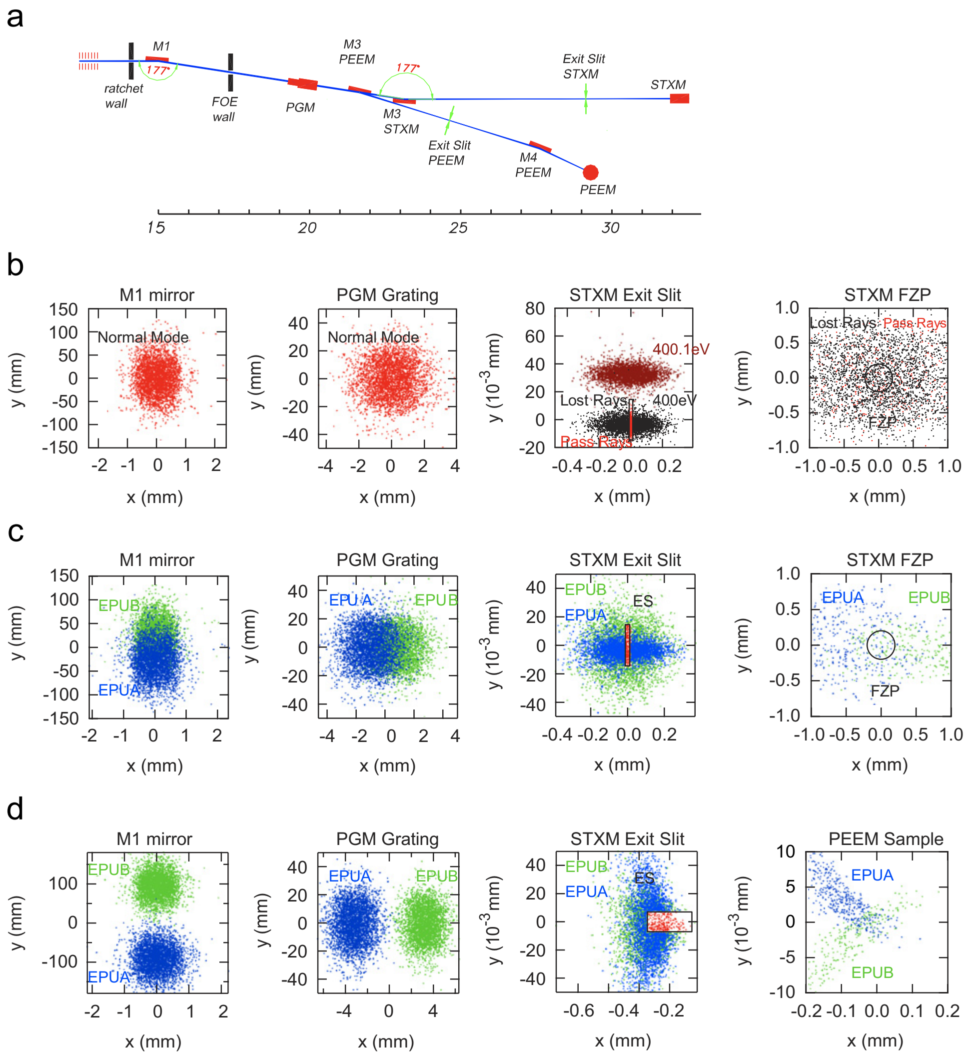
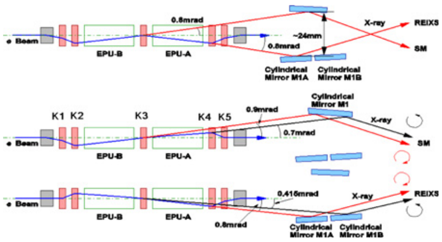
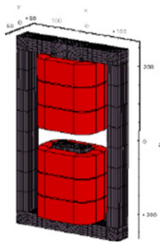
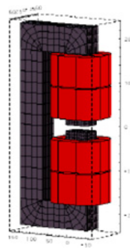
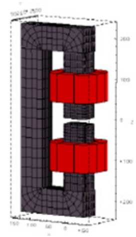


Fig. 1. (a) CLS–SM optical layout and ray tracing (400 eV, 500 l/mm, Cff 2.0), (b) STXM in normal operation mode, (c) STXM in 2−>1 mode (blue trace from upstream EPU, green from downstream) with 65 μrad canting, (d) PEEM in 2→1 250 μrad mode. Exit slit (shown as rectangular) corresponds to 4500 resolving power, and single-diffraction mode acceptance for STXM.

entrance slit. Since the phase acceptance differs in the two branches, the SM line uses a plane grating monochromator (PGM) in collimated light and two separate toroidal focusing mirrors, whereas REIXS uses a variable line spacing PGM, and experiment-specific phase matching is done after the exit slit. The 5 m long ID10 straight section can be shared by two 1.7 m long EPUs separated by ~2.0 m. For normal operation upstream EPU feeds the SM beamline, downstream undulator is reserved for REIXS as shown in Table 1 (inset). To extend beamline operation to 2 keV, the grazing angle on a mirror is kept at 1.5°. Twenty-four millimeters mirror-to-mirror pole separation is required to avoid space conflict (where light reflected by the SM M1 strikes the REIXS M1 mirror or vice versa). Although thus appears to be a tight fit, the face-to-face configuration actually minimizes spatial constraints, allowing installation even three internally water-cooled mirrors, each mounted on 3-axis manipulators, into a single 0.5 m long vessel. A symmetrical e- beam path (along the meridional plane) is chosen, and this determines the chicane angles. For normal operation, the SM canted angle is set to 0.75 mrad and the REIXS canted angle is 0.90 mrad. For two EPU in one beamline mode, only one beamline is active and one can envision 2→1 operation where the canted angle is reduced and the first mirror of the active beam line is moved to the central position to intercept (and redirect) both beams. For the cylindrical M1 mirrors used in the SM and REIXS this approach would drastically change light focusing conditions since the incident angle changes and result in an unacceptable reduction of beamline resolving power. This problem can be overcome at the expense of a more complex chicane arrangement in both angular and space share 2→1 schemes.

If the M1 mirror vessel is fixed, six chicane magnets are needed for the space sharing mode and five for the angular sharing mode. To keep good modulation between alternative polarization, the separation of the two light beams

Table 1
Technical parameters of ID10 chicane magnets; inset—e-beam trajectory and chicane operation mode

	K1, K5	K2, K4	K3
			
Maximum angle of bend (mrad)	3.0	4.4	2.2
Air gap (mm)	40	15	15
Peak flux density at $x = 0$ (T)	0.272	0.599	0.291
Max integrated flux density (T m)	0.0288	0.0420	0.0208
Integrated quadrupole (T)/sextupole (T/m)	/−0.269	−0.0035/−0.577	0.0002/−0.29
Ampere-turns coil/current density (A/mm^2)	6 × 1836/0.9	4 × 2100/1.0	2 × 1806/0.86
Height × width × length (mm^3)	510 × 320 × 128	460 × 213 × 111	460 × 213 × 111

should be ~2σ (angular or spatial). The β functions for the CLS straight ($\beta_x = 9.75$ m, $\beta_y = 3.2$ m) are such that the e-beam is extremely extended along the x direction, and thus both higher magnet strength and longer space are needed to build adequate separation for space share mode. The ID-10 engineering layout also favors magnet locations at the ends rather than in the middle of the straight. Because of this, the magnet layout for angular sharing scheme is more compact and can be designed with moderate strength electromagnets (Table 1).

The space-shared mode also poses a difficulty for STXM operation. The STXM exit slit width required for single-diffraction mode operation is much smaller that the size of the projected e-beam (Fig. 1b). The exit slit position cannot coincide with the location of horizontal foci, as only one beam will go through and so they should be placed further upstream. This results in an intensity penalty for normal operation.

Tracing analysis of STXM in 2→1 angular share mode is shown in Fig. 1c. Good spectroscopic performance (even with a single-M1 mirror), but only moderate polarization modulation is achieved. Tracing analysis for the PEEM (spectroscopic) branch is shown in Fig. 1d. With its large acceptance, the angular separation can be increased to 250 μrad (~2x fwhm) which results in almost 100% polarization modulation. The effect of an out-of-focus condition for the downstream EPU is masked by a strong astigmatic coma of the M3PEEM mirror, which limits the overall resolving power to ~2500. This problem is overcome in the VLS PGM design used in the REIXS beamline. As the REIXS group has a stringent energy resolution requirement in 2→1 mode, they have opted for two separate M1 mirrors, one with a focus at the upstream EPU and the other with a focus at the downstream EPU. A resolving power >7000 is predicted from ray tracing for both 1→1 and 2→1 operation of the REIXS line.

From the above analysis we conclude, that angular share mode has distinct advantages for SM/REIXS operation. The beam paths for 2→1 operation modes are shown in Table 1. The upstream EPU e-beam trajectory is almost identical to 1→1 mode. An initial deflection of the e-beam by storage ring steering magnets are used to reduce the deflection required by the outermost chicane to 2.7 mrad and by the innermost chicane magnet to 3.8 mrad. The middle magnet, which is set to deflect beam by 1.7 mrad in normal operation, controls the beam in 2→1 mode. Small ~0.05 mrad deflection is needed for STXM but can be enhanced to 0.25 mrad for PEEM. A mirror-like image chicane scheme (by changing chicane magnet polarity) will be used by REIXS in 2→1 operation.

Although 2→1 operation is still a distant future, some tests are done to warrant it visibility. To minimize radiation exposure of the sample during measurements to only the active acquisition time both STXM and PEEM branches already have piezo shutters installed after their exit slits. A 45 mm long cantilevered plate makes a ~400 μm tip deflection which is sufficient to completely block the SR beam. Two such piezo shutters will permit fast polarization switching at 1 kHz. Beamline diagnostic elements, such as a 4-jaw scanning aperture combined with a downstream photodiode, ensure precise positioning of the shutter relative to the beam.

The SM-EPU is a four independent quadrant Apple II-type 75 mm period undulator [4]. It was assembled and shimmed by the CLS. First integrals were suppressed below 0.5 Gm, the second integrals did not exceed 1.5 Gm^2 and the phase errors are kept within 7°. Studies of the impact of SM EPU gap and phase changes on the storage ring during commissioning showed that beam movement and tune shifts are small and easily compensated by the correction coils using a feed forward algorithm. However, the large skew quadrupole component caused significant changes in the transverse coupling. Currently it is corrected by a small air coil mounted downstream of the SM–EPU. Stationary correction coils attached to the EPU structures will be used in the long term. No drastic off-axis effects were recorded and the electron beam trajectory is stable and well contained within the ID10 straight, even at extreme canted angles (up to 1 mrad) and lateral offsets (up to 270 μm). Fine tuning of the EPU cone is done by adjusting beam position monitor offsets in the closed orbit correction system rather than adjusting the chicane magnet currents. A 30 μrad EPU adjustment accuracy is required for uniform ZP illumination in the STXM. This is readily achieved and has proved to be stable over long periods (>1 month).

In conclusion, the CLS ID10 five magnet chicane configuration permits independent operation of SM/REIXS beamlines as well as $2\rightarrow1$ mode, where two EPUs (tuned to complimentary polarizations) are redirected into either beamline. The optical performance, power load issues, engineering and magnet layout of ID10 straight strongly favors the angular-shared mode with adjustable angular separation. Near dedicated performance is expected with two separate M1 mirrors (REIXS), whereas the single-fixed mirror in the SM line will limit energy resolving power in $2\rightarrow1$ operation to ~2500. A cantilevered piezo chopper has been designed to switch alternative polarization at kHz switching frequency. The SM EPU is commissioned and shows good spectroscopic performance, little e- beam disturbance and is consistent with $2\rightarrow1$ mode. The REIXS EPU will be installed in 2008.

Acknowledgments

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