COMMISSIONING OF THE FIRST INSERTION DEVICES AT SOLEIL

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Abstract

The 2.75 GeV storage ring of the SOLEIL third generation light source in France consists of 16 cells and 24 straight sections (4x12m, 12x7m, 8x3.6m) for a total circumference of 354 m [1]. 24 insertion devices (ID) are planned for providing high brilliance radiation from UV to hard X ray. They consist of adjustable polarisation sources in the UV-soft X ray (electromagnetic devices of periods 640 mm and 256 mm, APPLE-II type undulators of periods ranging between 80 and 34 mm) and planar devices for the production of hard X ray (in vacuum undulators of period 20 or 24 mm and one 50 mm period in vacuum wiggler). During the commissioning of the presently installed ten ID's (HU640, 3xHU256, 3xHU80, 3xU20), the effects on the beam have been studied in terms of closed orbit distortions (COD), tune shifts, additional coupling and compared with the expectations from magnetic measurements in laboratory. The COD was compensated using a Feed ForWard (FFW) with local correctors. The radiation observed at the beam lines is also analysed.

INTRODUCTION

The main characteristics of the undulators installed in the storage ring which are in the final commissioning phase are given in table 1. Ten ID's are presently installed in the storage ring, 3x U20, 3xHU80, 3xHU256 and one HU640.

Table 1: Parameters of the ID's under commissioning. Energy E, period λ, useful length L, gap g, polarisation Pol, horizontal and vertical peak fields B_x and B_z.

	U20	HU80	HU256	HU640
Type	Hybrid In-vaccum	PPM APPLE II	EM	EM
E[keV]	4-30	0.045-1,5	0.01-1	0.005-0.04
λ[mm]	20	80	256	640
L[m]	1.96	1.6	3.1	9
g[mm]	5.5-30	15.5-260	16/50	20
Pol	Lin.	Lin./Cir.	Lin./Cir.	Lin./Cir.
Bx[T]	-	0.67	0.33	0.09
Bz[T]	0.96	0.95	0.44	0.11

PERMANENT MAGNET UNDULATORS

U20

The in-vacuum undulators of SOLEIL are planar and hybrid. The magnetic design was performed by SOLEIL using RADIA code [2]. The first one PROXIMA1 was manufactured by Danfysik as a turn key product based on SOLEIL magnetic design and ESRF mechanical design. The 2nd, SWING and the 3rd, CRISTAL were built in house in a dedicated clean room, using ID Builder a dedicated software developed at SOLEIL for the magnetic assembly, shimming and magic fingers.

The first step of the commissioning with beam is the determination of the vertical magnetic axis of the undulator relative to the beam axis (see Table 2).

Table 2: Vertical Position of the magnetic axis

Undulator	Magnetic axis position
PROXIMA1	-180 µm
SWING	100 µm
CRISTAL	0

Then the field integrals measured in the magnetic measurement Lab and the ones deduced from the beam characteristics are compared. There is rather good agreement of the behaviour of the field integral curves, except for an offset of around 50 G.cm which could be due to the dismounting of the magnetic system after the magnetic measurement in order to install it in the vacuum chamber.

Finally, the Close Orbit Distortions (COD) are measured and the FFW corrections are set-up and applied.

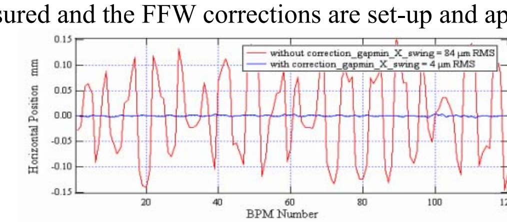

Figure 1: Horizontal FFW correction of SWING

Each undulator has two electromagnet correctors, located at the entrance and the exit, producing both vertical and horizontal fields. After correctors' calibration and measurement of the COD at different gap, a correction table is established. We reduced the COD from 84µm RMS without correction down to 4µm RMS with correction (see figure 1).

The injection efficiency is reduced when each of the 3 undulators is closed to the 5.5 mm minimum gap due to the effect of the roll off of the peak field (see table 3), and is recovered from 10 mm gap onwards,. For the 3 U20, a significant additional horizontal focusing was measured (plus some horizontal chromaticity variation for one undulator) due to field integral transverse variation.

Table 3: Injection efficiency at minimum gap 5.5 mm

Undulator	Injection efficiency
PROXIMA1	75%
SWING	85%
CRISTAL	88%
3 U20 closed together	50%

The commissioning of the 3 beamlines is under progress. The measured spectrum is very close to the calculated one. We can see in Figure 2 the high harmonics recorded on CRISTAL.

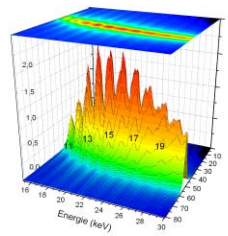

Figure 2: High harmonics spectrum of U20 CRISTAL.

HU80

Three 80 mm period quasi-periodic Apple-II type [3] undulators HU80 where constructed in the scope of the SOLEIL-ELETTRA collaboration [4], [5]. The magnetic design of these undulators was optimised using the RADIA code. Two of the three HU80 were assembled magnetically and shimmed by ELETTRA. SOLEIL has performed magnetic assembly and shimming of the third HU80, plus some extra shimming and magic finger re-adjustment of one of the two HU80 supplied by ELETTRA (in order to further improve flatness of field integrals and reduce phase-dependent normal and skew quadrupole variation). Besides this, a whole set of magnetic measurements (field and field integrals) at different gaps and phases of all three HU80 were performed in the SOLEIL lab before their installation on the storage ring.

All three HU80 were successfully commissioned with beam during machine-dedicated shifts. A complete characterization of the COD versus undulator gap and phase in parallel and anti-parallel displacement modes was performed (see figure 3), and 2D FFW correction tables for the on-board correction coils were calculated and stored in the high-level control system. In the vertical plane, the maximal COD (~60 µm peak to peak) was observed in helical mode at minimal gap, because of the relatively large residual horizontal 2nd field integral (~1.5 G.m^2) produced by these undulators in such mode.

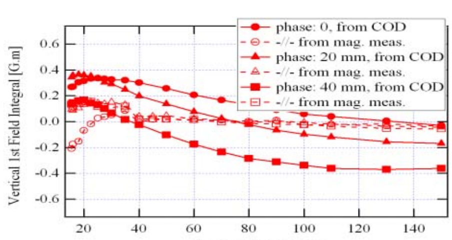

Figure 3: Vertical field integrals of one HU80 vs gap. The discrepancy between the COD and measurement data is explained by the proximity of the iron extremity of an HU256 undulator installed close to the HU80.

This peculiarity is explained by additional magnetic interaction, which is introduced by the quasi-periodic modification of the main magnetic field, and which is not compensated by the magnetic design of the undulator extremities (since the extremities were optimised for the HU80 without the quasi-periodic option). The use of the 2D FFW correction tables allows the maximal COD from ~+/- 40 µm to be reduced down to +/- 5 µm for any value of undulator gap and phase.

The measured tune shift variation due to change of undulator gap and phase agrees well with the intrinsic 2nd order effect, calculated with the BETA code using RADIA kick maps.

To facilitate the alignment of the beamline optical elements with respect to the undulator emission axis, a special diagnostics setup, dedicated for measuring the intensity distributions of monochromatic undulator radiation in projection geometry - “DiagOn” - has been developed in the SOLEIL Experiments Division [9]. In its soft X-ray version, this setup consists of a multilayer mirror, a fluorescent screen, an optical lens and a CCD camera. The measured image at 180 eV and the simulated one are shown in figure 4.

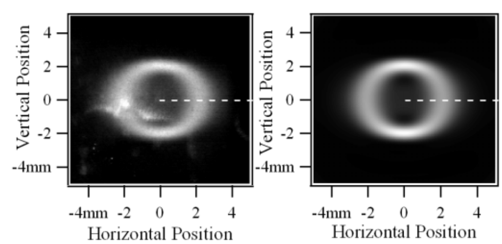

Figure 4: Ring image registered by “DiagOn” (left) at 20 m from the HU80 TEMPO in linear vertical polarisation at 180 eV photon energy and SRW [8] simulation (right),

ELECTROMAGNETIC UNDULATORS

HU256

The electromagnetic undulators HU256 were designed by SOLEIL and three were manufactured by Budker Institute of Nuclear Physics [6]. They are dedicated to CASSIOPEE, PLEIADES and ANTARES beamlines. They are made by independent H shape yoke dipoles powered in 2 families, and provide helical magnetic field.

The COD has been corrected along the hysteresis cycles, for both horizontal and vertical linear polarisation modes, with and without quasi-periodic field for the 3 HU256.

Whereas the field integrals generated by the three HU256 are quite different, with up to 100 G.cm for ANTARES and up to 600 G.cm for PLEIADES, the COD was finally contained within +/- 2 µm RMS for both undulators. The FFW correction for the linear polarisations takes about three minutes to achieve a complete cycle, which is very long for users, and will be improved in a second step.

The task becomes harder with the helical polarisation, which consists in driving two main power supplies to finally reach a couple of current values, taking into

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account the hysterisis effect. It results in driving one power supply while the other stays at its value, leading to two dimensions correction tables. Tests are on the way to check the practicality of this process.

Very small values of the Tune shift versus current were measured on the beam, with both horizontal and vertical polarisations, as expected from peak field magnetic measurements: about 8.10^{-4} at maximum vertical field (figure 5), and 5.10^{-4} at maximum horizontal field. No additional effect has been observed for this type of undulators.

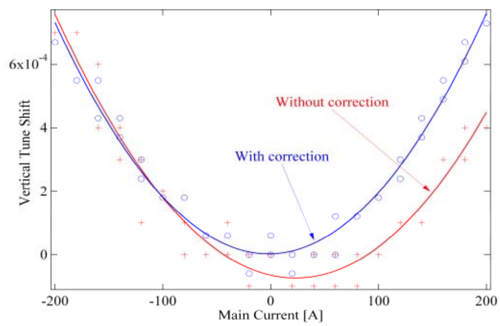

Figure 5: Vertical Tune shift versus current for an HU256, in linear horizontal polarisation mode.

HU640

The electromagnetic undulator HU640 [7] was designed by SOLEIL using RADIA and built by Danfysik. It is dedicated to the VUV beamline DESIRS. With its three sets of coils supplied by three power supplies (PS1 for the B_x field, PS2 for the B_z field and PS3 for the B_z field shifted by 90°) it produces from planar to circular polarisations.

The magnetic measurement of the peak field performed at SOLEIL Lab showed a good agreement with the calculation.

In a first stage, the COD was corrected by moving the passive correction coils in the vertical and horizontal planes. It enabled a drastic reduction of the main COD and of the orbit transfer from plane to plane. In a second stage, active correction coils located at the extremities have been calibrated on the beam and have been used to correct the COD for the 3 different excitations with PS1, PS2 and PS3. The corrections shrink the COD by a factor of up to 50 as presented on figure 6 for PS1.

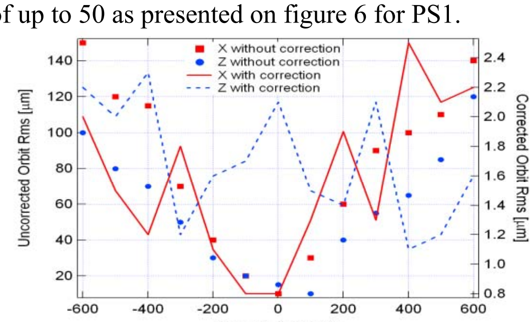

Figure 6: Rms orbit before (left scale) and after(right scale) active correction.

The tune shifts induced by the HU640 were measured with the PS's operating independently (one is on, the 2 others off). The parabolic behaviour follows the predicted values within 10% when varying PS2 and PS3. Unexpectedly, when operating PS1 the tune shifts vary linearly with the current. This effect seems to result from the uncorrected normal and skew quadrupole fields generated by the coils (figure 7).

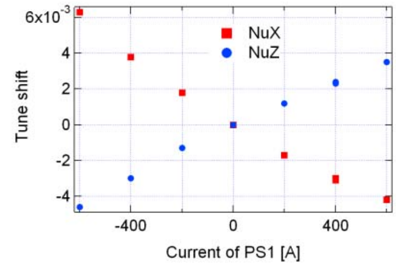

Figure 7: Tune shift induced by PS1

Due to this skew quadrupole, the SOLEIL low natural beam coupling is increased when PS1 varies or when PS1 and PS2 are operating simultaneously (see table 4).

Table 4: Coupling versus the current of PS1 and PS2. The nominal beam coupling of the storage ring in bold

		Current of PS1 (A)				
		-600	-300	0	300	600
Current of PS2 (A)	-440	0.79%	-	0.63%	-	0.63%
	0	0.92%	0.7%	**0.62%**	0.63%	0.76%
	440	1.7%	0.86%	0.59%	0.69%	1.02%

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