STATUS OF THE SOLEIL INSERTION DEVICES

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Abstract

SOLEIL is the French 2.75 GeV synchrotron radiation light source of low emittance under construction near Paris. It will provide high intensity photons covering a wide spectral range from the IR to the hard x-rays. The storage ring commissioning started in late May 2006, and the first photons on the first beam line are expected during summer 2006. The first set of Insertion Devices (ID), installed before the commissioning or within the first year of operation of the machine, consists of one 640 mm period and three 256 mm period electromagnetic helical undulators, three 80 mm period APPLE-II type undulators, and three 20 mm period in-vacuum undulators. All these IDs make use of a wide panoply of technical solutions for generating various types of magnetic fields. Magnetic and conceptual designs were performed by SOLEIL, and the technical realisation was carried out together with different manufacturers. The design specificities of the different types of IDs and the magnetic field characterisation and optimisation is reported.

INTRODUCTION

The commissioning of SOLEIL's storage ring has begun in May 2006, with four Insertion Devices (ID) of Phase 1 already installed in the machine (see table 1) [1], [2], and another two under preparation. Then the phase 2 will shortly arrive with two electromagnetic and two APPLE-II type IDs now under final measurement. The production will be continued up to 2008 to reach a total of twenty four ID segments. The next devices mainly consist in eight APPLE-II type undulators with smaller periods and four in-vacuum undulators with similar periods. Two further exotic IDs are planned: a super-conducting wiggler with a 42-44 mm period and an EMPHU with a 65 mm period based on ESRF design.

Table 1: Characteristics of Phase 1 Insertion Devices: useful length L, energy E, period λ, gap g, polarization Pol and horizontal and vertical peak fields B_x and B_z.

	HU640	HU256	HU80	U20 (x3)
Type	EM	EM	PPM (APPLE-II)	Hybrid (in-vacuum)
E [keV]	0,005-0,04	0,01-1	0,045-1,5	4-30
λ [mm]	640	256	80	20
L [m]	9	3.1	1.6	1.96
g [mm]	20	16/50	15.5-260	5.5-30
Pol	Lin./Cir.	Lin./Cir.	Lin./Cir.	Lin.
B_x [T]	0.09	0.33	0.67	-
B_z [T]	0.11	0.44	0.95	0.96

ELECTROMAGNETIC UNDULATORS

HU640

HU640 [3] is a 10m long electromagnetic helical undulator without iron built by DANFYSIK and dedicated to the VUV beamline DESIRS. The amplitude of the transverse magnetic components B_x and B_z as well as the phase between them is tuned by means of three independent power supplies.

The magnetic measurements were performed with a specific bench designed and built by SOLEIL. It uses alternatively a Hall probe or an impregnated coils carriage, pulled by a belt going through the undulator. The precise position of the carriage along the ID was given by a laser interferometer. The peak field measurements showed a good correlation with the magnetic calculation, achieved with the RADIA code [4]. Hall probe and coils measurements confirmed the linear response of the field and residual field integrals versus current and a good peak-to-peak homogeneity (about 1.10^{-4} T of standard deviation). Table 2 summarizes the measured performances with respect to tolerances given by the beam dynamics and the users' requirements. These results are horizontal and vertical first field integrals (resp. I_x and I_z) and second field integrals (resp. $I2_x$ and $I2_z$). Fig. 1 illustrates the magnetic field measured along the axis with Hall probes for different currents in the power supplies.

Table 2: Integrals obtained on HU640

	Required	Measured
I_x [G.cm]	+/- 20	+/- 40
I_z [G.cm]	+/- 20	+/- 40
$I2_x$ [G.cm²]	+/- 27510	+/- 45850
$I2_z$ [G.cm²]	+/- 27510	+/- 45850
Phase error [°]	σ_ϕ<4	1<σ_ϕ<2,7

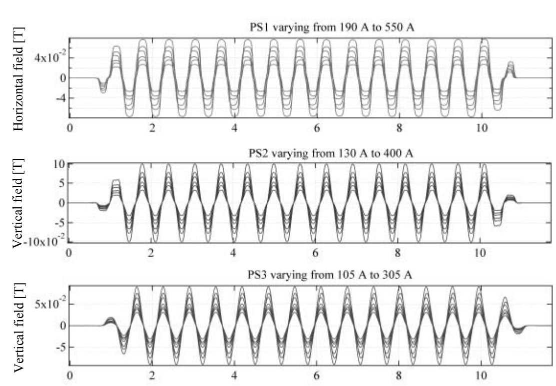

Fig. 1: On-axis field shape of HU640

HU256

HU256 [5] is an electromagnetic undulator based on independent H yokes dipoles, providing helical field with a 256 mm period. Three HU256 built by Budker Institute of Nuclear Physics are dedicated to CASSIOPEE, PLEIADES and ANTARES beamlines. They can provide both planar quasiperiodic and helical polarization modes.

The measurements were carried out by a Hall probes bench [6] provided by BINP to characterize field shape and peaks and a stretched wire bench designed by SOLEIL to correct field integrals. The field measurements allowed us to validate a cycling method to obtain a good reproducibility of the field despite the iron induced hysteresis, and to characterize the peak field versus main current for each component. With the stretched wire software, the correction currents minimizing the integral variations are automatically generated while covering the cycle of currents. Several iterations are necessary yet, because changing a correction current somewhere in the cycle can modify the integrals among the other points of the cycle. Fig. 2 shows the first integral of vertical field measured before and after correction for Linear Horizontal mode. Table 3 summaries the correction results obtained on the two first undulators.

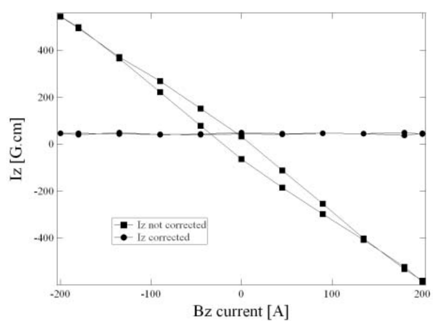

Figure 2: Iz Correction of HU256 ANTARES

Table 3: Results on correction with HU256 (1st integrals in G.cm and 2nd integrals in G.m²) for linear horizontal (LH), linear vertical (LV), quasiperiodic or not (Q), and circular (Cir) polarization modes.

	CASSIOPEE		PLEIADES				
	LH	LV	LH	LV	LHQ	LVQ	Cir
I_x	-	0/19	-3/6	-9/0	-9/4	-2/7	-55/-2
$I2_x$	-	-	-0.07/0.13	-0.36/0	-0.33/0.02	0/0.26	-3.87/5.79
I_z	-10/52	-	-1/8	0/28	-5/2	-2/9	-184/4
$I2_z$	-1.40/3.07	-	-0.16/0.22	0/0.42	-0.18/0.25	-0.26/0.09	-5.81/0

PERMANENT MAGNET UNDULATORS

HU80

SOLEIL has to build 12 undulators for adjustable polarization in the soft-X ray range. HU80 is an 80 mm period APPLE-II type undulator providing quasi-periodic field with taper option. For the first 3 HU80, dedicated to TEMPO, µFOC and PLEIADES beamlines, collaboration has been established with ELETTRA [7]. Two undulators were assembled magnetically and shimmed by ELETTRA and one by SOLEIL. Undulator carriages were constructed by RMP.

Magnetic measurements of all three devices were carried out at SOLEIL using ESRF-type 3.5 m long bench gathering Hall probes and a body-less coil. The measurements consisted in checking the on-axis magnetic field vs longitudinal position and field integrals vs horizontal position in the mid-planes of the undulators, for different gap and phase values.

The first HU80 was installed on the ring in March 2006. For the second HU80, extra "virtual" shimming and re-adjustment of the magic fingers was performed at SOLEIL. During the extra shimming, phase-dependent magnetic interaction effects were taking into account, which allowed reducing the phase-dependent variation of the on-axis normal quadrupole from 370 G to 90 G, and the skew quadrupole from 150 G to 100 G. The H and V field integrals measured before and after these operations are shown in Fig. 3; the field integral results on the first two HU80 are summarized in table 4. A new Genetic Algorithm based computer code [8] was used for the extra shimming of the 2nd HU80, as well as for the magnet sorting, swapping and shimming of the 3rd HU80 (at the time of this writing, final adjustment of the magic fingers of this undulator is carried out).

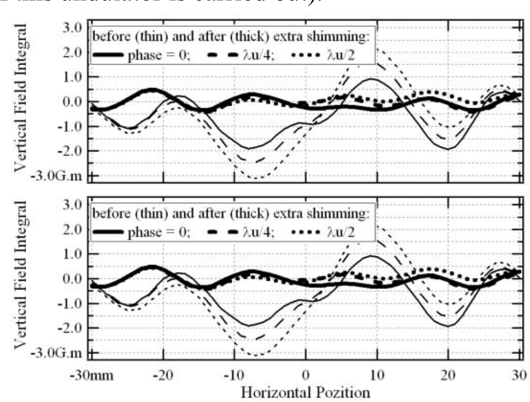

Figure 3: I_z and I_x at gap 15.5 mm for HU80 µFOC

Table 4: Field integrals of HU80#1 and #2 at 15.5/30 mm gap and 0 phase (without active correction).

	Tolerance	TEMPO	µFOC
I_x [G.m]	+/- 0.2	-0.2/0	-0.1/0.1
I_z [G.m]	+/- 0.2	0/0.4	-0.2/0
$I2_x$ [G.m²]	+/- 1	0.02/0.01	-0.4/-0.1
$I2_z$ [G.m²]	+/- 1	0.6/0.5	-0.3/-0.4

Further developments of APPLE-II type undulators go along with a reduction of the period length down to 34 mm. The new improved design of magnet holders will allow both stronger tightening with smaller screws, and easier shimming and swapping procedures. Fig. 4 shows a prototype made by SOLEIL to this end.

Figure 4: Five magnets module prototype for the further 52 mm period APPLE-II type undulator.

U20

In-vacuum undulators are planned on SOLEIL for providing high energy photons. The first series of U20 [9] are planar hybrid in-vacuum undulators with a 20 mm period. The magnets are Sm_2CO_{17} ones and the poles made of vanadium Permendur. The first one for PROXIMA1 was delivered by Danfysik (turn-key) based on the magnetic design of SOLEIL and the mechanical design of ESRF. SOLEIL has the full responsibility for the construction of the second and the third IDs using the drawings of the constructor. The second one dedicated to SWING was recently assembled, swapped and shimmed by using a dedicated method and software and final correction with magic fingers is under way.

The assembling of the magnets is made inside a clean room to allow the measurements and the vacuum chamber installation in the same place, without moving the undulator. The magnetic measurements are performed using a 5.5m long ESRF type bench. A special tool is used for the installation of the vacuum chamber, which requires to dismantle the inside girders from the carriage. Table 5 shows the achieved field integrals and figure 5 the 11th harmonic during the shimming procedure.

Table 5: Field integrals with U20 at gap=5.5 mm | gap=10 mm : I_x, I_z, $I2_x$, $I2_z$ and phase error φ (average Av. or at minimum gap Min.)

	Required	PROXIMA1	SWING
I_x [G.cm]	50	-20/+20	-70/-20	-
I_z [G.cm]	50	-50/0	-10/40	-
$I2_x$ [G.cm²]	4000	3000/-1000	-2600/-1200	-
$I2_z$ [G.cm²]	4000	-2600/-1200 (vs gap)	-
φ [°]	2.5	2.8 (Av.) / 2.3 (Min)	2.6

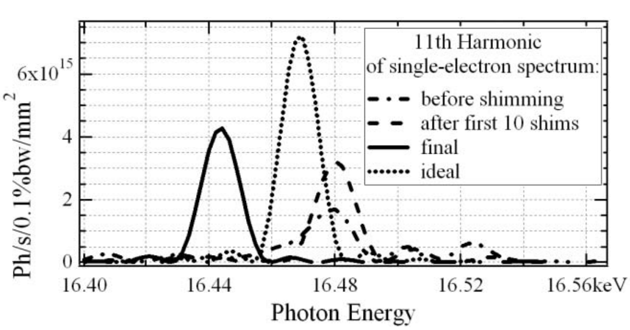

Figure 5: 11th harmonic during shimming

Motorisation

To drive the mechanical carriages, SOLEIL developed its own motorisation system based on Berger Lahr stepper motors VRDM3913 in association with PLC controller (TLCC) and power units (TLC6). They provide both electric and mechanical brakes and can give to the girders the needed 10 kN. The gap and phase positions are given by very high precision (0.1µm) absolute linear optical encoders TR-Electronic LT140-S fixed on the girders, with multiple advantages:

- Measurement directly related to the movement of the girder (taking into account the mechanical clearances)
- No need of "homing"
- Safeguarded positions in case of power supply shutdown.

These improvements allow reproducibility better than 3µm. The IDs' securities are gathered in one electronic box developed by SOLEIL and the controller is connected through an Ethernet link to the machine network. The software for developing PLC is "CODESYS Norm IEC 61131-3".

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