PRELIMINARY DESIGN OF SOLEIL INSERTION DEVICES

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Abstract

SOLEIL is a third generation storage ring (nominal energy of 2.75 GeV) conceived to provide high photon flux and brilliance in the 5 eV – 50 keV domain. The trade off between the energy range, the high power and variable polarization requirements led us to adopt different six types of insertion devices.

This paper will present in details the preliminary magnetic designs of the first three insertion devices as well as their optical performances.

1 INTRODUCTION

The SOLEIL source covers the energy range 5 eV to 50 keV. The domain extending from 5 eV to 18 keV is covered by undulators and for higher energies hybrid wigglers are used. To fulfil the requirements of the users (spectral range, brilliance and flux, polarisation …) different types of insertion device have been proposed:

- One electromagnetic undulator (HU500) composed of very large periods (500 mm) covering the VUV domain (5 eV - 40 eV) with all kinds of polarization (linear/circular/helicoïdal).
- Electromagnetic or PPM undulators (HU200 and HU300) composed of shorter periods (200 mm and 300 mm) covering the soft X-rays from 10 eV to 200 eV. Linear/circular variable polarization will be provided. These undulators will be coupled with Apple II-type [1] undulators (HU50 and HU80) in order to extend the capabilities in the medium range of the domain (up to 1.5 keV).
- In-vacuum undulators U20 of 20 mm-periods. These undulators will provide high brilliance up to 18 keV. For higher energy, the trade off between high flux and effects on the beam dynamics leds us to propose a hybrid wiggler. W100 is composed of 18 periods of 100 mm with a maximum magnetic field of 2.2 T (minimum magnetic gap: 10 mm).

Fig. 1. shows the proposed IDs selected to fit with the users proposals.

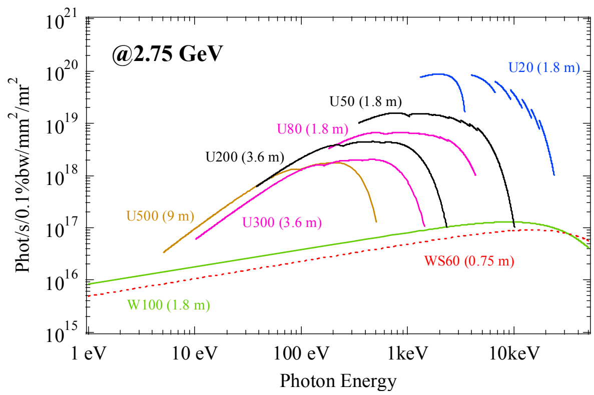

Figure 1: Brilliance of SOLEIL. Identical colours indicates which IDs are installed on the same straight section. The length of IDs is mentioned in parenthesis.

2 ID TO BE BUILT FOR THE COMMISIONNING

Among the proposed ID beam lines, six have been selected to begin operating for the commissioning (HU500, HU200, HU80 and 3 U20). At the moment, designs of HU500, HU80 and U20 are under study. Table 1 presents the magnetic characteristics of the selected IDs.

Table1: Characteristics of the selected IDs

	HU500	HU80	U20
Type	Electro.	Apple II	Hybrid in vacuum
Polar.	Circ./Lin.	Circ./Lin.	Linear
Mag. gap	20 mm	15 mm – 300 mm	5.5 mm – 70 mm
Period	500 mm	80 mm	20 mm
N. per.	18	21	89
B_{xmax} B_{zmax}	0.13 T 0.16 T	0.6 T 0.67 T	- 0.97 T
Section	Long	Medium	Short

2.1 The elliptical undulator HU500

HU500 is a 9 meter electromagnetic undulator composed of 18 periods of 500 mm. It allows to produce any kind of polarization from linear to circular by tuning the values of the vertical and horizontal components of the field (resp. B_z and B_x) and by varying the phasing between both components. HU500 can be switched rapidely (rising time of 0.2 s from $-B_{xmax}$ to $+B_{xmax}$) at a frequency of 1 Hz. HU500 will be installed on a long straight section.

An original design is under feasibility study at the moment and will be evaluated in the next three months. The magnetic structure is composed of three sets of coils (A,B and C in the figure 2). Coils C produce the horizontal components B_x. Coils A and B which are shifted each other by a quarter of period produce B_z. The mixing of both vertical contributions results in a phase shift as follow:

$$B_z(s)=B_0\cos[k_0s+\phi]=B_A\cos[k_0s]+B_B\sin[k_0s]=B_A(s)+B_B(s)$$

where B_A and B_B are the maximum fields produced respectively by the coils A and B, $k_0=2\pi/\lambda_0$ (λ_0 is the period). The phase shift ϕ is given by:

$$\mathrm{Tan}[\phi]=-B_B/B_A=-K_BI_B/K_AI_A \qquad (1)$$

The maximum values B_A and B_B are linearly adjusted by variation of the currents I_A and I_B.

Both B_z and B_x are produced by air-coils (mounted on non magnetic poles) in order to avoid cross talk between components. The operation of the ID is then completely linear with the currents injected in each set of coils.

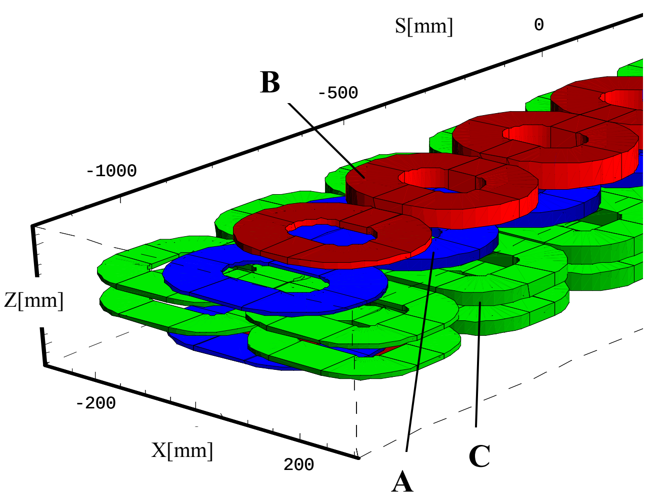

Fig. 2: Layout of one extremity of the ID.

However, residual Fourier components of $B_A(s)$ and $B_B(s)$ can affect the phase shift operation. In particular, for a phase ϕ and currents I_A and I_B verifying (1), the maximum of $B_z(s)$ does not remains constant if the geometry is not adequate (low level of harmonics 3 and 5). The geometry of coils A and B has been optimised (reduction of the components 3 and 5) by evaluating the contribution of each single turn on the components 1, 3 and 5. The level of harmonics 3 and 5 has been reduced to less than 0.2 % of the main harmonic for the coils B (1% for the coils A). From the adopted geometry, the magnetic fields $B_A(s)$ and $B_B(s)$ have been computed with the code RADIA [2] with B_x=0 for different values of I_A and I_B verifying the following condition:

$$I_A=\cos[\phi].I_{AMAX} \text{ and } I_B=\sin[\phi].I_{BMAX} \qquad (2)$$

For different values of ϕ extending from 0 to $\pi/2$, the maximum of the resulting field $B_z(s)$ remains constant within 1 % . The spectrum computed with SRW [3] is not significantly affected as shown on Fig. 3. Similarly, complementary computations have been achieved for circular polarization (B_x=0.15 T, B_z=0.15 T and $\Phi=\pi/2$). Calculations with SRW have shown as predicted only one harmonic peaked at 2.9 eV.

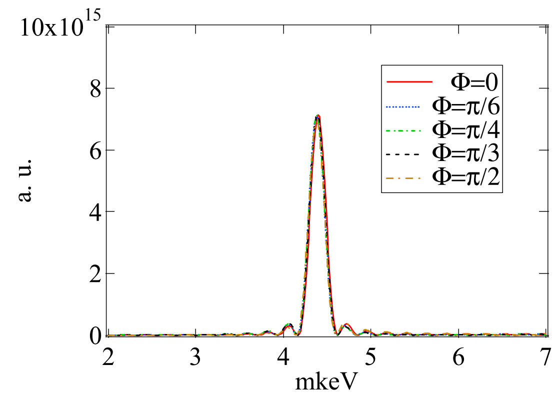

Fig.3: Spectrum for different dephasing Φ.

A set of correctors, driven by the same current as the main coils, has been added at each extremities in order to center the electron path inside the undulator and to cancel first and second field integral. These correctors are mounted on non-magnetic poles and can be vertically adjusted. The typical height of the end correctors is ¼ and ¾ of the height of main coils. Table 2 summarized the charateristics of the coils.

Table 2: Characteristics of the coils.

	Coil A	Coil B	Coil C
Main coil	. 70 turns . 5 layers of 14 turns . I=307 A . U=12 V . R=40 mΩ . 6 x 6 water hole diam.=4	. 117 turns . 9 layers of 13 turns . I=348 A . U=21.5 V . R=60 mΩ . 6 x 6 water hole diam.=4	. 54 turns . 6 layers of 9 turns . I=188 A . U=4 V . R=22 mΩ . 6 x 6 water hole diam.=4
Ga[between upper/lower coils	95 mm	160 mm	20 mm
Corrector ¼	Idem except 14 turns	Idem except 13 turns	Idem except 9 turns
Corrector ¾	Idem except 42 turns	Idem except 52 turns	Idem except 18 turns

Complementary studies of feasibility are under progress. In particular, various coil positioning and other geometries are tested in order to reduce the power consumption.

2.2 The elliptical undulator HU80

HU80 is a Apple II [1] type undulator. It is composed of 21 periods (80 mm length) of pure permanent magnets of NdFeB (B_r=1.15 T). Table 3 presents the characteristics of HU80 magnets.

Table 3: Characteristics of HU80 magnets.

Grade	NdFeB (1.15 T)
Main magnet blocks	45 mm (X axis) 20 mm (Z axis) 20 mm (S axis)
Chamfers	5 mm x 5 mm

The magnet assembly is split into four magnet arrays. Two are installed on a lower jaw, two on the upper jaw. Arrays can move longitudinally resulting in a change of the phase between horizontal and vertical components B_x and B_z. The excursion of the motion is +/- 40 mm and the minimum gap is 15 mm. The maximum horizontal and vertical fields are respectively 0.85 T and 0.76 T (pure vertical and horizontal polarizations). Figure 4 presents the B_x and B_z components versus phase shift for the minimum gap.

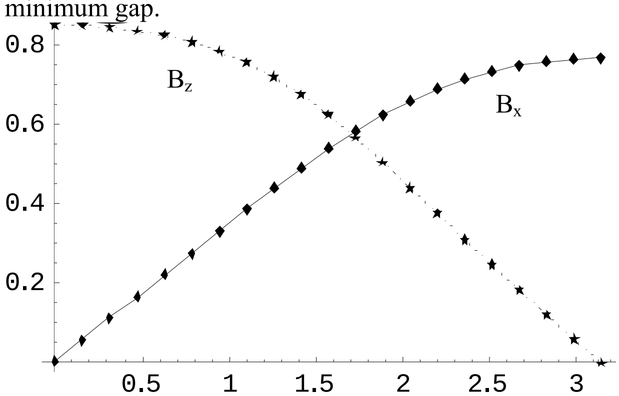

Fig. 4: Transverse components [T] versus phase shift [rad] for the gap 15 mm.

Due to the dissymetry of both curves, pure circular polarization can not be obtained with $B_x = B_z$ and $\Phi=\pi/2$. The maximum polarization rate is mentioned for different photon energies in Table 3 (operation on harmonic 1).

Table 3: Polarization rate for various photon energies.

Photon energy	Gap [mm]	B_x [T]	B_z [T]	Φ [rad]	Polar. rate
44 eV	15	0.544	0.631	1.57	99 %
87 eV	25	0.299	0.418	1.73	97 %
224 eV	35	0.173	0.279	1.88	94 %
397 eV	45	0.103	0.186	1.88	92 %

Additional studies have been achieved on the non-unit μ effect of magnets. Due to the non-linearity of NdFeB, the first field integral is not completely cancelled at all gaps and the phase shifts. A solution has been proposed at the ESRF [4]. The terminations of the traditionnal Halbach structure [5] have been replaced by a set of three magnets whose dimensions optimisations allow to reduce the first field integral for any phase and gap (+/- 100 μT. m down to +/- 12 μT. m). It results in a reduction of the closed orbit, which is compatible with the position stability beam requirements.

2.3 The in-vacuum undulator U20

U20 is a hybrid structure composed of 89 periods of 20 mm. To minimize the risk of demagnetisation from the exposure to the electron beam and baking a grade of Sm_2Co_{17} have beam chosen instead of NdFeB. This results however in a roughly 10 % reduction of the magnetization. Magnetic poles are composed of Vanadium Permendur which has a high saturation magnetization (2.34 T). The achieved vertical field is 1.03 T (0.97 T on the main Fourier component) at the minimum gap of 5.5 mm (beam aperture: 5mm) . The maximum power emitted by U20 is 3900 W but a cooled diaphragm (2 mm x 1 mm instealled at 15 m from the center of the ID) will be installed in front of the first optics. The power deposited on the mirrors is expected to be reduced by a factor of 10 (280 W) with a low useful flux reduction (20 %). Table 4 summarize the magnetic characteristics of U20.

Table 4: Magnetic characteristics U20

Magnet block Dimensions	Sm_2Co_{17} (1.05 T) 70 mm (x-axis) 7 mm (s-axis) 40 mm (z-axis)
Poles Dimensions	Vanadium Permendur 50 mm (x-axis) 3 mm (s-axis) 25 mm (z-axis)
Magnetic field for a gap of 5.5 mm	1.03 T (0.97 T on the main Fourier component)
Flux through the diaphragm	5 keV: 2.10^{15} Ph/s/0.1% BW 10 keV: 4.5 10^{14} Ph/s/0.1% BW 15 keV: 1.3 10^{14} Ph/s/0.1% BW

3 REFERENCES

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