

THE 65 mm PERIOD ELECTROMAGNETIC/PERMANENT MAGNETS HELICAL UNDULATOR AT SOLEIL

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Abstract

SOLEIL prepares a new 65 mm period Electromagnetic/Permanent Magnets Helical Undulator (EMPHU), with a rapid switching at 5 Hz of the polarization required for dichroism experiments. The vertical field B_z is produced by coils fed by a fast switching power supply (designed and built in house [1]), with a maximum current of 350 A and a polarity switching time shorter than 100 ms. The coils consist of 25 stacked copper layers shaped by water jet cutting. The current flows in 16 layers and nine of them are cooled with thermal drain to a water piping. Four additional power supplies feed two types of correction coils for the dynamic compensation of the field integrals, besides the ones for the termination. 1.28 T remanence NdFeB permanent magnets generate the horizontal field B_x . First harmonic of B_z and B_x in the helical configuration reach 0.24 T at 14.7 mm minimum gap. The static magnetic configuration was optimised and the trajectory was checked for insuring a good reproducibility of the photon beam pointing when sweeping from one helicity to the other.

INTRODUCTION

The EMPHU consists of 26 periods of 65 mm length. The overall length is 1750 mm. The EMPHU is made of coils, steel poles and permanent magnets fixed on two girders (upper and lower ones). The two girders are attached to a motorized carriage which can move the girders vertically with a gap varying between 14.7 mm and 250 mm. The vertical movement is needed to change the peak field values. The EMPHU uses permanent magnets for the horizontal field and coils around poles for the vertical one. This configuration offers the flexibility to provide a pure helical field or a linear horizontal field when the power supply is switched off.

EMPHU DESCRIPTION

Magnetic Design

The EMPHU design [2] comports poles surrounded by serpentine coil [3] fabricated with copper sheet [4] because the period is too small for hollow conductor. The space ratio between poles and coils is efficiently optimized to produce the vertical field; the space between the poles is efficiently filled by an array of permanent magnets to produce the horizontal field (see Figure 1). Table 1 shows the main characteristics of the EMPHU.

At the entrance and at the exit, the design integrates two different poles with a limited number of turns in order to compensate the first and second field integrals.

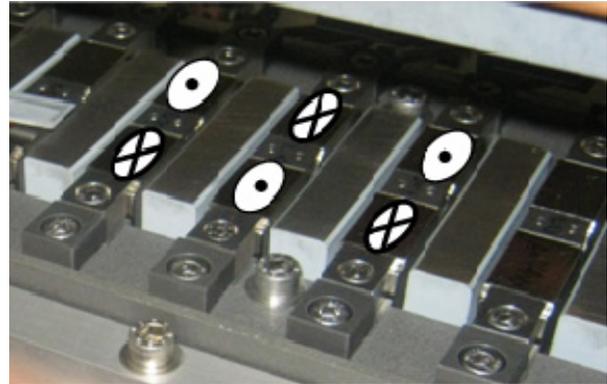


Figure 1: EMPHU detail with permanent magnets and poles.

Table 1: Peak (peak) and First Harmonic Components (H1) of Horizontal (B_x) and Vertical Magnetic Field (B_z)

Parameter	Unit	Value
B_z (Peak)	T	0.2414
B_x (Peak)	T	0.2731
B_z (H1)	T	0.2387
B_x (H1)	T	0.2435
Period length	m	0.065
Maximum current	A	350
Minimum Gap	m	0.0147

Vertical Field

Standard silicon-steel (Powercore M270) was selected because of AC application. The magnetic properties of some samples of the steel supply has been measured and used in the 3D model. The coil is fed by a 350 A current which polarity can be switched in less than 100 ms. In order to centre the wiggling of the electron beam on the axis, the structure starting from a 25%, 75%, 100% repartition is adjusted so that a trade-off between number of turns around the poles and longitudinal length of those poles is found. The laminations are stacked and glued before machining. The pole is wire cut in order to achieve very tight tolerances on the shape ($\pm 20 \mu\text{m}$). The elementary serpentine coil is made of two Current Carrier Sheets (CCS) and a Thermal Drain Sheet (TDS) which are water cut. After machining, the serpentine coil is stacked around the pole as shown in Figure 2 with thin layers of Kapton for insulation.

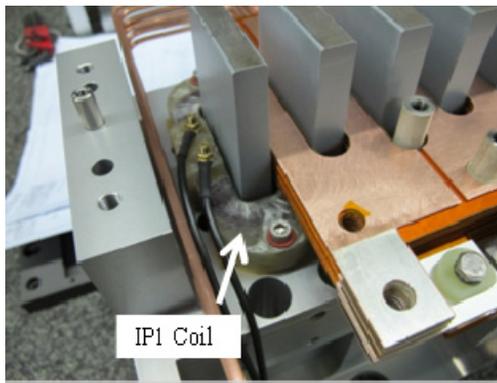


Figure 2: Assembling of the serpentine coil and IP1 correction coil on the EMPHU

Horizontal Field

The horizontal field is generated by an array of NdFeB permanent magnets with a remanent magnetic field of 1.28 T. The direction of magnetisation is vertical. Two permanent magnets are installed between two poles. The magnetic field configuration is designed for the vertical trajectory of the electron beam to wiggle around the axis. As for the vertical field, the usual 25%, 75% and 100 % field structure is slightly adapted by adjusting the longitudinal length of the permanent magnets

Correction Coils

The EMPHU is equipped of four embedded correctors which produce vertical field and also two external correctors able to produce both vertical and horizontal field. Figure 3 shows the external corrector and one embedded corrector (HUE) localized on the sides of the undulator. The second one (IP1) is localized around the first pole of the undulator. The functions of the correctors are:

- For IP1, CVE and CHE to keep the beam on-axis
- For HUE to keep the emission direction on-axis.

Around the first and last poles, corrector coils are installed in order to finely tune the vertical magnetic field integral during switching transition. Extra horizontal and vertical steerers are added on both sides of the undulator.

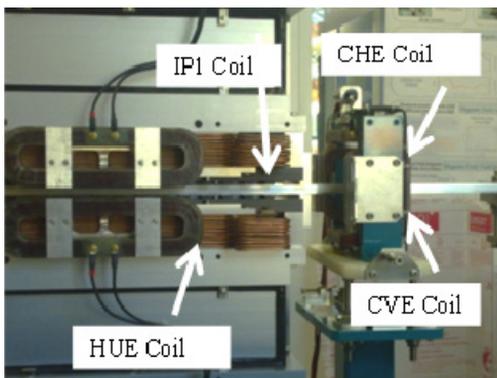


Figure 3: Layout of the entrance correctors.

STATIC MEASUREMENTS

Static measurements are performed with the standard SOLEIL bench equipped with a bodiless coil controlled by two XY tables and two rotation stages and with a set of three Hall probes controlled by a three axis system.

Results

Figure 4 shows that the horizontal trajectory for the best corrector setup (for IP1, HU and CVE), the electron beam can be kept on-axis for both current polarities. Figure 5 shows that the direction of emission is also on axis for both current polarities. All radiations are computed using B2E [5].

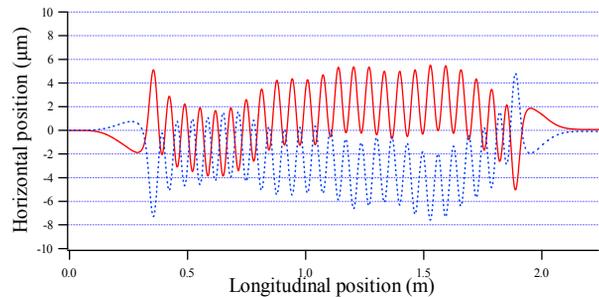


Figure 4: Horizontal trajectory with the best correction setup for +350A (plain red) and -350 A (dashed blue).

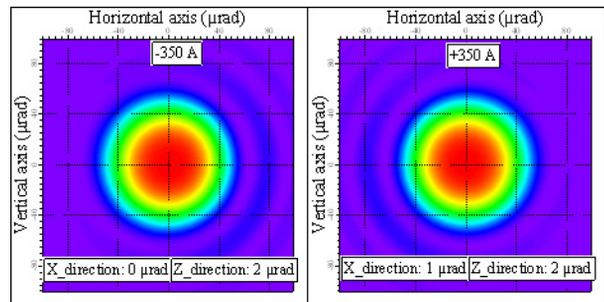


Figure 5: Computed radiation at 350 eV corresponding to Figure 3 data.

Temperature measurements show that some heat from the TDS is going to the permanent magnets and induces a drift of the wavelength radiated by the EMPHU. This heat transfer will be minimized by an air cooling system.

DYNAMIC MEASUREMENTS

The EMPHU is able to switch the polarization of the photon quickly enough. Dynamical measurement of the magnetic field is crucial to check the robustness of the EMPHU device during the transition time in order to keep the electron beam on axis without any kick angle. Thus, first and second integrals have to be null even during transition. In this section, the methods to characterise the undulator are described here below.

First Integral Measurement

The field integral during the switching of the power supply is measured with a fluxmeter (Metrolab PDI

5025), the flux variation being induced by the field flipping rather than the measurement coil rotation.

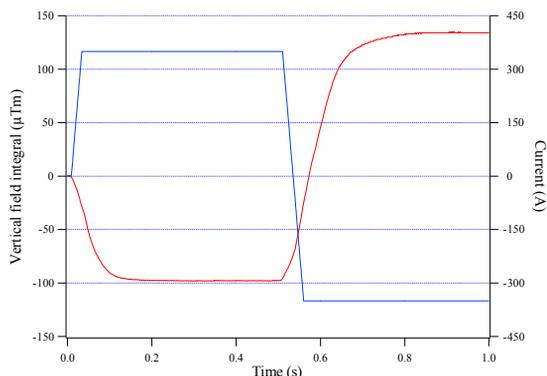


Figure 6: First integral (red) during switching time without any correction. Excitation current (blue). Data points acquired every millisecond.

Figure 6 shows first integral modification during the fast switching without any correction. The residual first integral is small. The field setting time is about 300 ms when the current setting time lasts 50 ms. from +350 A to -350 A because of Eddy current in the TDS. The EMPHU is in process of modification in order to reduce it. Computation with 3D Elektra code [6] shows that the proposed solution will give a 70 ms response time shown in Figure 7.

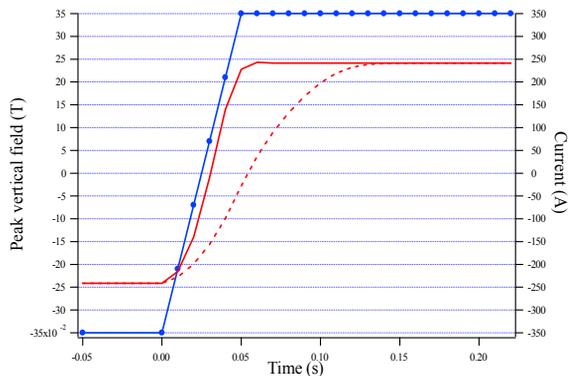


Figure 7: 3D Elektra computation: Peak vertical field current situation (dashed red) and proposed solution (plain red). Excitation current in blue.

Second Field Integral Measurement

The second field integral is measured with a bodiless coil twisted in its middle [7]. Figure 8 shows preliminary results where, as there is no correction, the electron beam exits from the EMPHU with a large misalignment.

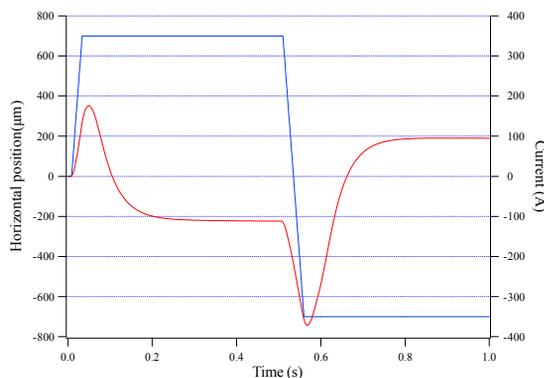


Figure 8: Horizontal position at exit (red) during switching time without any correction. Excitation current (blue). Data points acquired every millisecond.

CONCLUSIONS

The undulator is still in the process of measurements. Few changes will be done in order to minimize the heat transfer between the TDS and the permanent magnet and also to reduce the setting time of the magnet field.

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