Available online at www.sciencedirect.com
ScienceDirect
Nuclear Instruments and Methods in Physics Research A 575 (2007) 33–37
NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A
www.elsevier.com/locate/nima

First SOLEIL insertion devices are ready to produce photons for users

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Available online 12 January 2007

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 beamline were observed in September 2006. The first set of Insertion Devices (ID), either already installed before the ring commissioning or to be installed within the first year of operation of the machine, consists of one 640 mm period and three 256 mm period electromagnetic elliptical 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 realization was carried out together with different manufacturers. The design specificities of the different types of IDs, as well as the results of the shimming and magnetic measurements performed at SOLEIL are reported.

PACS: 29.20.Dh; 07.85.Qe; 41.60.−m; 41.60.Cr

Keywords: Insertion devices; Undulators; Synchrotron radiation sources

1. Introduction

The commissioning of the SOLEIL storage ring has begun in May 2006, with four insertion devices of the phase 1 (electromagnetic undulators HU640 and HU256, APPLE-II undulator HU80 and in-vacuum undulator U20, see Table 1) already installed in the storage ring [1–4]. Shortly after this, the adjustments and magnetic measurements of five more Insertion Devices (IDs) (two HU256, two HU80 and one U20) have been finished. The magnetic assembly of the third in-vacuum undulator U20 (the last in-vacuum undulator dedicated for the phase 1) is in progress at the time of this writing.

The production of insertion devices will be continued up to 2009 to reach a total of 25 ID segments. The phase 2 insertion devices will include eight more APPLE-II type undulators with smaller periods (down to 34 mm) and five in-vacuum undulators with the periods of 20–26 mm. Two "exotic" IDs are planned: an in-vacuum multi-pole hybrid wiggler with a 42–44 mm period and a fast-switching electromagnet/permanent magnet helical undulator (EMPHU) inspired from the ESRF design [5]. The initial design and optimization of all SOLEIL insertion devices were done using the RADIA computer code [6]. The finite-element computer code MERMAID was used for the final optimizations of the electromagnetic undulator HU256 [7,8].

2. Electromagnetic undulators

2.1. Elliptical undulator HU640

HU640 [9] is a 640 mm period 10 m long electromagnetic elliptical undulator consisting of three sets of pure coils (without iron yokes). The amplitudes of the transverse

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doi:10.1016/j.nima.2007.01.018

Table 1
Characteristics of the SOLEIL phase 1 insertion devices

	HU640	HU256	HU80	U20
Type	EM	EM	PPM (APPLE-II)	Hybrid (in-vacuum)
Number of segments (phase I)	1	3	3	3
Photon energy range (eV)	5–40	10–100	40–1500	4000–30000
Radiation polarization	Linear/elliptical	Linear/elliptical	Linear/elliptical	Linear
Period (mm)	640	256	80	20
Effective length (m)	9	3.1	1.6	1.96
Magnetic gap (mm)	20	16 (vert.)/50 (hor.)	15.5–260	5.5–30
Horizontal peak field (T)	0.09	0.33	0.65	—
Vertical peak field (T)	0.11	0.4	0.95	0.96

magnetic field components B_x and B_z as well as the phase shift between them are tuned by means of three independent power supplies. This undulator was build by DANFYSIK and it is dedicated for the SOLEIL VUV beamline DESIRS.

Magnetic measurements of the HU640 were performed on a special bench designed and constructed at SOLEIL. The bench uses alternatively a Hall probe or an impregnated coils carriage, pulled by a belt passing through the undulator. The precise position of the carriage along the ID was given by a laser interferometer. Hall probe and coil measurements confirmed the linear response of the field and the residual field integrals versus current and a good peak-to-peak homogeneity ($\sim 1 \times 10^{-4}$ T RMS). Table 2 summarizes the measured field characteristics and compares them with the corresponding specifications. In this table, the horizontal and vertical peak fields at maximal currents (resp. $B_{x\max}$ and $B_{z\max}$), first field integrals (resp. I_x and I_z), second field integrals (resp. $I2_x$ and $I2_z$), and the estimated RMS radiation phase error (σ_ϕ) are given.

Fig. 1 illustrates the magnetic field measured along the undulator axis with Hall probes for different currents in power supplies.

2.2. Elliptical undulators HU256

HU256 is an electromagnetic undulator based on independent horizontal and vertical H-type dipoles, providing elliptical field with a period of 256 mm [3,7]. Three undulators HU256 were built by Budker Institute of Nuclear Physics (BINP) and are dedicated for CASSIOPEE, PLEIADES and ANTARES beamlines. The undulators can operate in linear and elliptical polarization modes, with an optional quasi-periodic modulation both for the horizontal and vertical magnetic field components.

The measurements of the transverse magnetic field components versus longitudinal position were carried out by a Hall probe bench provided by BINP [8]; the first and second field integrals were measured using a stretched wire bench constructed by SOLEIL. The field measurements allowed to validate a cycling method for obtaining a good reproducibility of the field despite the iron-induced hysteresis, and to characterize the peak field versus main current for each component. Based on the measured field integral data, preliminary values of necessary correcting currents for the steering coils, located on the yokes at the extremities of the undulator, were found for the main modes of operation. Fig. 2 shows the first vertical field integral measured before and after applying the calculated correction for the Linear Horizontal polarization mode. Table 3 summaries the results of the field integral measurements obtained for the three undulators HU256 after applying the calculated correcting currents.

Table 2
Peak magnetic fields, field integrals and phase error of HU640

	Specifications	Measured
$B_{x\max}/B_{z\max}$ (T)	0.092/0.11	0.095/0.147
I_x (G m)	± 0.2	± 0.4
I_z (G m)	± 0.2	± 0.4
$I2_x$ (G m^2)	± 2.75	± 4.6
$I2_z$ (G m^2)	± 2.75	± 4.6
σ_ϕ (degree)	$\sigma_\phi < 4$	$1 < \sigma_\phi < 2.7$

3. Permanent magnet undulators

3.1. Apple-II undulators HU80

SOLEIL has to build 12 variable polarization permanent magnet (APPLE-II or compartible) undulators for the soft X-ray range. The first three APPLE-II undulators have period 80 mm. They provide quasi-periodic magnetic field with taper option. For the construction of the three HU80 undulators, dedicated for TEMPO, μFOC and PLEIADES beamlines, collaboration between SOLEIL and ELETTRA has been established [10]. In the scope of this collaboration, two undulators were assembled magnetically and shimmed by ELETTRA and one by SOLEIL. The NdFeB magnet blocks for the first two undulators were supplied by NEOMAX (Japan), and for the third one by NEOREM (Finland). Undulator carriages were constructed by RMP (Italy).

Magnetic measurements of all three devices were carried out at SOLEIL using ESRF-type 3.5 m long bench