THE SOLEIL II INSERTION DEVICES

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Abstract

The SOLEIL II Insertion Devices (ID) range from long period Adjustable Phase Undulator, APPLE X, Dual undulators for the intermediate energy spectral range, and in vacuum undulators, cryogenic permanent magnet undulators and wigglers for hard X-rays.

INTRODUCTION

The synchrotron facility SOLEIL (electron beam of 2.75 GeV energy, 500 mA current, 3.9 nm.rad emittance) has been operating since 2006, with a variety of insertion devices enabling to cover five decades in photon energy. On SOLEIL II [1-4], due to the higher number of magnetic elements required to reduce the emittance down to 85 pm.rad, the available length devoted to insertion devices is reduced by 30 %. Choices and technical developments are here reported. SOLEIL II is planned in two stages: construction in stage 1 and towards full performance in stage 2. The evolution of the SOLEIL ID panoply is listed in Table 1.

SOLEIL PRESENT ID PANOPLY

SOLEIL accommodates 12 medium, 8 short and 4 long straight sections with 20 beamlines on insertion devices. In short straight sections are mainly installed planar In Vacuum Undulators (IVU) of period 20 and 24 mm, an In Vacuum Wiggler IVW50 [5] of period 50 mm and three Cryogenic Permanent Magnet Undulator (CPMU) of period 18 mm. The minimum gap of the IVU and CPMU is 5.5 mm gap except 8 mm for IVU24 and 4.5 mm for the IVW50. In the long straight sections, the installed IDs are the two canted CPMU18 [6, 7] and the 10 m long electromagnetic undulator of 640 mm period, HU640. HU640 does not fit in SOLEIL II. In the medium straight sections are installed up to two Elliptically Polarised Undulators (EPU) called generically HU (Helical Undulator) of APPLE II type with a minimum gap of 15.5 mm (except HU36 down to 11.5 mm), or electromagnetic ones HU256, or an out of vacuum wiggler W164, and an Electromagnetic/Permanent Magnet Helical Undulator (EMPHU) of 65 mm period enables fast polarization switching [8].

Table 1: SOLEIL and SOLEIL II (SII) panoply of insertion devices (in italic, to be built). SS for Straight Section. DUAL N for 2 m long DUAL system with new undulator, while DUAL is reusing existing IDs.

Beamline	Present SS	Present ID	SII SS	SII P1	SII P2
LUCIA	SDM16	HU52	SD03C	IVU24	IVU24
PSICHE	SDC03	IVW50	SD04C	IVW50	*CPMW35*
PLEIADES	SDM04	HU80-HU256	SD05MC	HU60	*AX63*
DEIMOS	SDM07	HU52-EMPHU65	SD06L	DUAL HU52-EMPHU65	*Dual HU52-EMPHU65*
PUMA	SDM06	W164	SD07MC		*CPMU16*
CRISTAL	SDC06	CPMU18	SD08C	IVU20	*CPMU15*
GALAXIES	SDC07	IVU20	SD09C	CPMU18	*CPMU16*
TEMPO	SDM08	HU80-HU44	SD10ML	IVU20	*DUALNHU40-HU70*
DESIRS	SDL05	HU640	SD11L	DUAL HU44-HU80	*APU250*
HERMES	SDM10	HU64-HU42	SD12ML	*APU250*	*DUAL HU64-HU42*
PX-ID	SDC10	IVU20-IVU24	SD13C	DUAL HU42-HU64	*CPMU16*
SWING	SDC11	IVU20	SD14C	IVU20	*CPMU15*
ANTARES	SDM12	HU60-HU256	SD15MC	IVU20	*DUALN HU60-HU90*
ANATOMIX	SDL13	CPMU18	SD16L	HU80	CPMU18
NANOSCOPIUM	SDL13	CPMU18	SD16L	CPMU18	CPMU18
SEXTANTS	SDM14	HU80-HU44	SD17MC	CPMU18	*CPMUE38*
SIXS	SDC14	IVU20	SD18C	*AX42*	*CPMU16*
SIRIUS	SDC15	HU36	SD19C	IVU20	*AX38 or CPMU*
CASSIOPEE	SDM15	HU60-HU256	SD20ML	HU36	*DUALN HU44-HU130*
				DUALN HU44-HU130	

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INSERTION DEVICES FOR SOLEIL II STAGE 1

For SOLEIL II, the number of beamlines on insertion devices is reduced to 19, PROXIMA-1 moving to a bending magnet source. Some ID-based beamlines (DESIRS, CASSIOPEE, LUCIA, PX_ID) should move and their new insertion devices will be built in priority besides the one of PX_ID. In stage 1, the majority of the existing insertion devices will be re-employed (see Table 1). Some IDs will move from one beamline to another: IVU24 from PX-ID to LUCIA which does not need the variable polarization anymore, the former IVU20 from CRISTAL before the installation of its new CPMU18 to the PUMA beamline where the new required spectral range has been restricted, and HU80 from SEXTANTS to ANTARES for widening the spectral range with one single ID instead of two. All 4 electromagnetic undulators (HU640 and HU256) do not fit in the new straight sections. Two EPUs cannot be put one after the other anymore.

Re-employed Insertion Devices

Concerning the high photon energy beamlines, they will mostly keep their present IDs with a possibility to reduce the gap from 5.5 mm to 4.5 mm except for the canted sections (ANATOMIX and NANOSCOPIUM) for which the 5.5 mm gap of the CPMUs will be kept. The RF transitions, photon absorbers, and extremity flanges of the IVUs and CPMUs will be modified. A recent test in SOLEIL with the CRISTAL CPMU18 closed at 4.5 mm demonstrated a flux increase by 30 % measured on the beamline.

Concerning the VUV soft X-ray beamlines with variable polarization, PLEIADES and ANTARES will have one EPU instead of two presently, while DEIMOS, TEMPO and HERMES will have a DUAL solution with their two existing IDs of 1.6 m long each that will be mounted on a plate enabling to have one or the other aligned on the beam with an horizontal translation. This scheme has been successfully prototyped. Each APPLEII remained within 10 µm after 200 cycles of back-and-forth motion occurred during six months (see Fig. 1) [9].

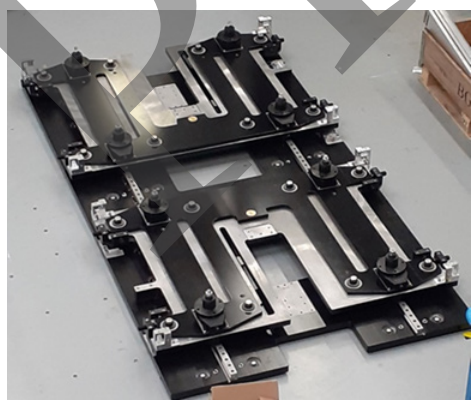

Figure 1: DUAL motorized platform supporting recycled undulator carriages.

New Insertion Devices

The first ID to be built for SOLEIL II restart is the 5 m long Adjustable Phase Undulator (APU) of 20 periods of 250 mm with 4 mobile jaws, for replacing the 10 m long HU640 to cover the 5-40 eV required spectral energy range [6]. The power limitation on the vacuum chamber (with added specific absorbers) and first mirror (500 W) lead to a moderate magnetic field of 0.46 T. Main NdFeB magnet blocks (of remanent field Br = 1.37 T), installed on individual holders equipped with flexors, can be adjusted in position within ± 0.5 mm via a wedge spacer. Compensation magnet blocks reduce by typically eight times the magnetic forces acting between jaws in all directions. The gap can be varied between 25 mm and 240 mm (for parking position) and the jaw dephasing can be tuned within ±125 mm, enabling the photon energy and polarization change with the undulator operated at minimum gap. The mechanical design is shown in Fig. 2. A 3-period prototype is under construction, with magnets from either recycled or raw material to check the field profile and magnetic deformation under load.

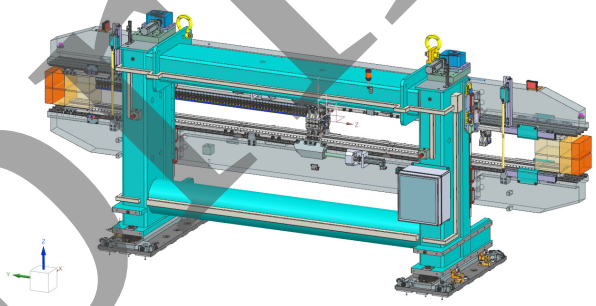

Figure 2: Mechanical design of APU250 undulator.

The second ID to be built for SOLEIL II restart is the 2 m long DUAL undulator for CASSIOPEE, aiming at reaching the 10-1500 eV spectral range. A 2 m long DUAL with two APPLE II HU110 and HU40 of 12.5 mm gap was initially planned, considering a preliminary study of the photon absorbers. The detailed thermo-mechanical study with the proper vacuum chamber drawings concluded that the power deposition was too high for the HU110 enabling it to reach 10 eV. It was required to get closer to the total deposited power and angular aperture of those of the HU80 undulator closed at 12.5 mm, the minimum gap authorized on SOLEIL II for APPLE IIs, which has been thermally accepted. An APPLE I undulator of period 130 mm and minimum gap of 14 mm is then designed (see Fig. 3), reaching 0.873 T effective field in vertical and horizontal plane (with NdFeB magnets of 1.32 T remanent field). The emitted power has been divided by 2. The period of the corresponding high energy ID is raised from 40 to 44 mm to account for a better overlap for intermediate energy photons with this new choice.

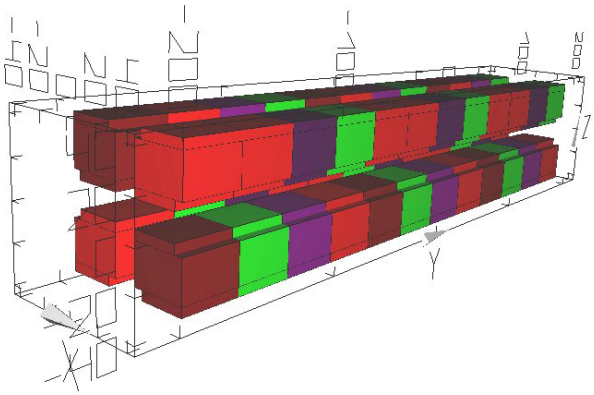

Figure 3: RADIA [10] model of the APPLE 1 HU130.

The third ID to be built is for the SEXTANTS beamline, to be available for one year after the restart of SOLEIL II. To cover the 0.15-1 keV spectral range, an APPLE X [11] of 42 mm is chosen. Using NdFeB of 1.39 T remanent field, the vertical and horizontal fields reach 1.156 T at minimum round gap of 11.5 mm, enabling to reach the 150 eV minimum photon energy. The longitudinal magnetization is fixed to 45° enabling the reduction of the forces between two adjacent magnets [12]. Compensation magnets enable to significantly reduce the magnetic force (see Fig. 4).

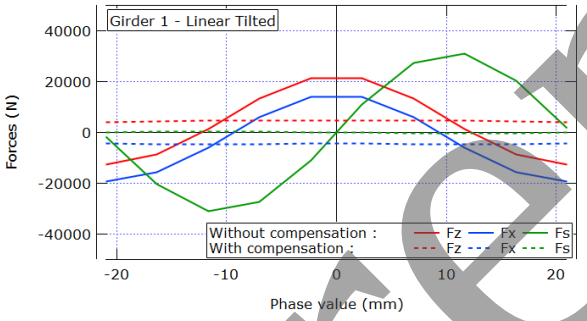

Figure 4: APPLE X 42 force compensation.

INSERTION DEVICES FOR SOLEIL II STAGE 2

During SOLEIL II stage 2 aiming at reaching the full performance, the majority of the IVUs will be replaced with CPMUs. For PSICHE beamline, the IVW will be replaced by a shorter Cryogenic Permanent Magnet Wiggler (CPMW) of typically 1 m long, closed at 3.5 mm minimum gap. More automated process for the construction of the CPMU has been developed with the LEAPS-INNOV CPMU12 prototype of 1 m long. Supermodules of ten periods can be mechanically and magnetically measured with a robot, and the height of the poles corrected (see Fig. 5) to a few micron precision.

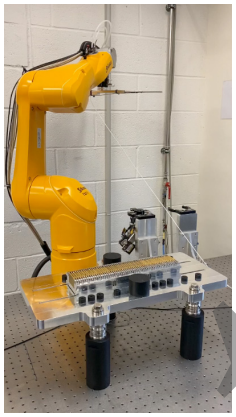

Figure 5: Robot for the supermodule measurement and adjustment.

A new embbeded Hall probe bench for CPMU has been developed with a vacuum compatible linear motor (3 m long) and Optical feedback of the Hall probe using piezzo motors (SAFALI based feedback correction [13]). It is shown in Fig. 6, with the Position Sensitive Detectors (PSD) to correct for the Hall probe position, and the Hall probe carriage moving inside the vaccum chamber.

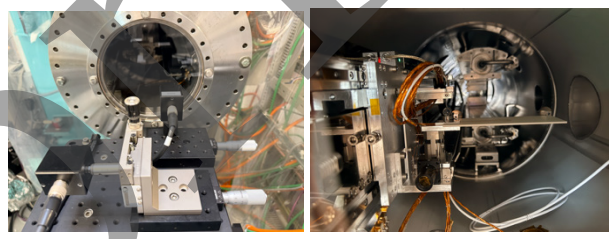

Figure 6: New CPMU bench (PSD tables and Hall probe carriage).

Besides, additional 2 m long DUAL undulators will be built for ANTARES and TEMPO beamlines. New out of vacuum APPLE X will also be constructed for PLEIADES, and possibly for SIRIUS, depending on the final choices of the beamline branches. For SEXTANTS beamline, it is also planned to move to a Cryogenic Elliptically Polarised called CPMUE of period 38 mm, with a 10.9 mm magnetic gap and a cooled vacuum chamber.

CONCLUSION

SOLEIL II has an ambitious program of renewing the insertion devices, enabling the enhancement of the flux in addition to the brilliance and coherent flux increase resulting from the emittance reduction.

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