PROGRESS REPORT ON THE CONSTRUCTION OF SOLEIL

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Abstract

The construction phase of SOLEIL, the French third generation Synchrotron radiation Source has begun in January 2002 with the aim of starting Users operation in spring 2006. The machine now consists in a 354 m circumference ring, with 16 DB cells and 24 straight sections. The optics, with distributed dispersion, features a low 3.7 nmrad emittance at the 2.75 GeV operating energy, so as to provide high brilliance, from the VUV up to the hard X ray domain. In order to provide a long lifetime (18 hours), and beam position stabilities in the micron range, significant attention was paid at each design stage (optics, magnets, beam position monitors, vacuum and RF systems,..), including on the design of the building, the construction of which will start in summer 2003. All the magnets have been designed and are in the last stage to be ordered. The qualification of the 352 MHz super-conducting RF cavity prototype has been done on the ESRF ring. Insertion devices are being designed with the goal of serving a very large scientific community with high performances in an energy range as large as 5 eV to 18 keV with undulators. The contract was placed for the 100 MeV Linac for a delivery summer 2004.

1 INTRODUCTION

Since the beginning of 2001, a new SOLEIL team has being constituted and the detailed design has been finalised. The construction period (phase 1), has started in 2002 with the goal of completing the commissioning of the machine and of the 10 first beamlines beginning of 2006 followed by a gradual installation of 14 other beamlines in parallel to operation up to 2009 (phase 2). Due to the new scientific context as well as new developments and studies, improvements have been brought to several parts of the SOLEIL equipment.

2 LATTICE

The lattice consists of 16 DB cells and 4 super periods in which the 2 central cells are modified to create 2 additional straight sections (3.6m) by drifting apart the two quadrupole doublets located in-between the two bending magnets of the cell [1]. The machine provides now 24 straight sections (4x12m, 12x7m, 8x3.6m) among which 20 are dedicated to install insertion devices (one long straight is necessary to locate the injection equipments, two medium straights will be occupied by the super-conducting RF cavities and a short straight is reserved for diagnostics and feedbacks). Figure 1 shows the optical functions of one of the four super periods and the table 1 gives the main parameters.

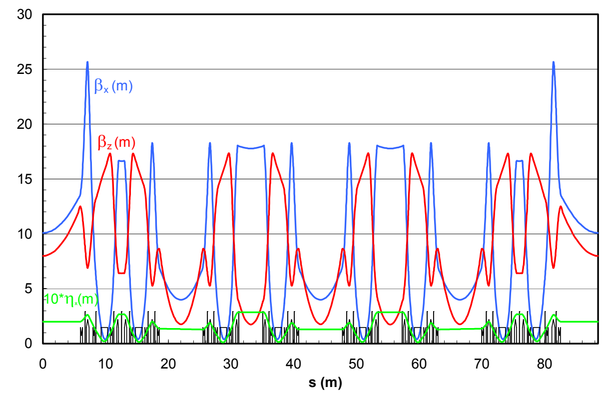


Fig. 1 Lattice and optical functions for one super period of the storage ring

Table 1 Main parameters of the storage ring

Energy	2.75 GeV
Circumference	354.097 m
Horizontal emittance (rms)	3.73 nmrad
N. of cells / N. of super periods	16 / 4
Straight sections	12 m x 4 ; 7 m x 12 ; 3.6 m x 8
Betatron tunes, ν_x / ν_z	18.2 / 10.3
Chromaticities ξ_x / ξ_z	- 2.84/- 2.23
Momentum compaction	4.38×10^{-4}
Energy dispersion	$1.016\ 10^{-3}$
Radio Frequency	352.202 MHz
Peak RF Voltage	4.8 MV
Max energy loss per turn (IDs)	1 300 keV
Design current (416 bunches)	500 mA

A good dynamic acceptance is achieved even for large energy deviation (up to 6%) thanks, among others, to a small variation of the tune with energy.

Beam dynamics was computed, using a full 6D tracking code (extension of TRACY II) which allows to take into account non linear betatron and synchrotron motions, synchrotron radiation and coupling from horizontal to vertical plane [2]. As predicted, due to the low value of the first order and the relatively high value of the second order of the momentum compaction the dynamics is dominated by the non linear synchrotron motion. Moreover it has been shown that the 1% coupling induces vertical betatron amplitudes from Touschek scattering which lead to losses in small vertical gaps undulators. In order to avoid this effect a new working point, a little more far away from the coupling resonance, has been chosen.

For 500 mA distributed in 416 bunches, the Touschek lifetime calculated with natural bunch length, 1%

coupling and 5mm aperture in short straight section (undulator of 1.8 meter long) is $\tau_{T1/2}$ = 36 h. Combined with a vacuum lifetime of 27 h for a pressure of 10^{-9} mbar, this gives a total beam lifetime of approximately 18 h.

3 MAGNETS

All the magnets have been designed with 3D model on TOSCA code. For dipoles (1m magnetic length and 5.36m bending radius) the H structure has been preferred in order to reduce the effect of saturation due to the high 1.71T field value. The main parameters of the quadrupoles and sextupoles are:

	Quadrupoles	Sextupoles
Number	132 / 28	88* / 32**
Length (mm)	320 / 460	160 mm
Bore (mm)	66 mm	73 mm
Force	19 T/m / 23 T/m	320 T/m²
Useful Zone	35 mm	35 mm

For the quadrupoles (figure of 8 structure), the profile have been very well optimised leading to very small multipolar components: respectively 9 10^{-6} and –5 10^{-5} for the 12 poles and the 20 poles expressed in $\Delta B/B$ at 30 mm. The sextupoles include horizontal and vertical dipoles correctors (respectively 7 mTxm and 4.4 mTxm) as well as skew quadrupoles (51.2 mT). They are compacts (*) or with ears (**) following their position in the cell in order to allow Xray extraction lines.

Contracts have been placed for dipoles, quadrupoles and sextupoles.

4 ULTRA VACUUM SYSTEM

In the dipole vacuum chamber, the 12 kW power and the power density (~ 200 W/mm^2 at normal incidence) to be dissipated are relatively high due to the short bending radius. It requires a combination of two absorbers, a crotch absorber in the antechamber part followed by a longitudinal absorber. Based on the ANKA design, the cooling system of the crotch has been improved by spreading the power on 3 rows of teeth cooled by six water channels for each jaw.

Material will be stainless steel 316LN for dipole vessels, BPMs and bellows and aluminium 6061 for all straight part of the machine (quadrupoles, sextupoles and insertions). All Aluminium vacuum chambers will be coated with NEG (Ti, Zr, V). The main advantage is a very low photon stimulated desorption rate after activation of the NEG which leads to an estimated conditioning time of 23Ah to reach a 10^{-9} mbar average pressure instead of 730 Ah for uncoated stainless steel. The effect on the machine impedance has been evaluated. The resistive wall instability threshold (multibunch mode) would not be modified but the transverse mode coupling one (single bunch mode) might be lower specially for narrow gap insertions. Further investigation will be done.

5 RF SYSTEM

The superconducting HOM free RF prototype was tested in 2002 on the ESRF storage ring. It generated in stable and reliable conditions, a peak RF voltage of more than 3 MV, with a power of about 200 kW through each main coupler [3]. This level of performance corresponds to the SOLEIL requirements for the first year of operation starting in 2005, therefore, it was decided that this prototype will be the first RF cavity. It will be installed after some modifications to reduce some over heating of the dipole type HOM couplers and undue high static cryogenic losses. In parallel, the design of a second cryomodule integrating all the prototype experience has been launched.

For the 352 MHz power source, after an extensive study of the different technological options, solid state amplifier based on the technology developed at LURE and already chosen for the booster, have been adopted. Each cavity will be powered by a 200 kW (4x 50 kW) amplifier which is constituted by about 750 modules. Many advantages as reliability, easy maintenance, simple start-up procedures (no high voltage) etc. are expected. The booster transmitter is already under construction and the manufacture of the storage ring modules will be launched very soon.

6 INSERTION DEVICES

Among the proposed ID beamlines, six IDs of four different kinds have been identified to begin operating for the commissioning of SOLEIL (phase 1). Table 2 presents their principal characteristics and Figure 2 shows the expected brilliance performances.

Table 2: Principal characteristics of the IDs

	HU640	**HU256**	**HU80**	**U20**
Numb.	1	1	1	3
Energy	5 – 40 eV	10 – 1000* eV	80 –1500* eV	3 – 18 keV
Type	Electro.	Electro.	Apple II	Hybrid in vacuum
Polar.	Circ./Lin. variable	Circ./Lin.	Circ./Lin.	Linear
Min. gap	19 mm	15 mm	15 mm	5.5 mm
Period	640 mm	256 mm	80 mm	20 mm
N. per.	14	14	21	90
B_{xmax} B_{zmax}	0.09 T 0.11 T	0.275 T 0.400 T	0.76 T 0.85 T	- 1.03 T
S. Sect.	Long	Medium	Medium	Short

For these two beamlines, the large energy range to be covered requires one additional undulator (respectively HU60 and HU40) which will be built later.

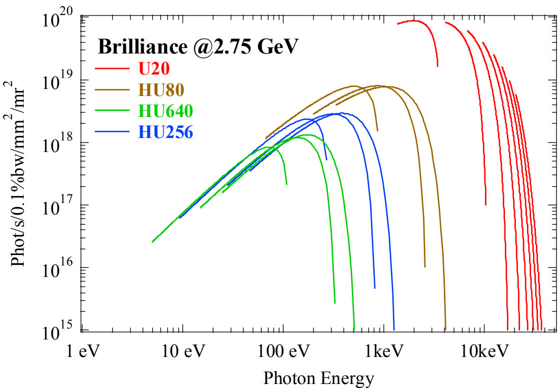
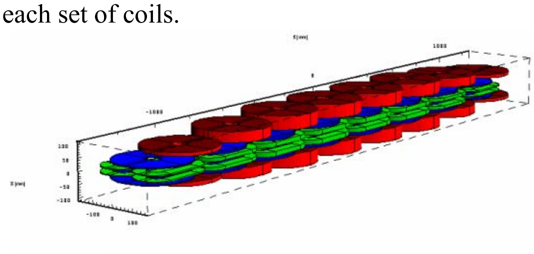


Fig 2: Brilliance phase 1.

The elliptical undulator HU640

HU640 is designed to produce any kind of polarization from linear to circular by tuning the values of the vertical and horizontal components of the field (resp. Bz and Bx) and by varying the phasing between both components. The magnetic structure is composed of three sets of coils (red, blue and green in the figure 1). Green coils produce the horizontal components Bx. Blue and red coils which are shifted each other by a quarter of period, produce Bz. HU640 can be switched rapidly (rising time of 0.2 s from -Bxmax to +Bxmax) at a repetition rate of 1 Hz

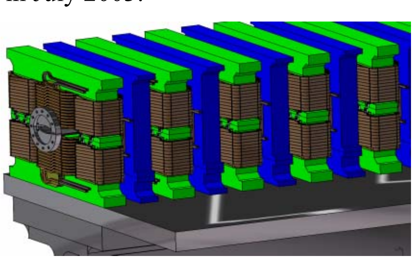
Both Bz and Bx are produced by air-coils in order to avoid cross talk between components. The operation of the ID is then completely linear with the currents injected in each set of coils.



The elliptical undulator HU256

As the horizontal field required for vertical polarization is relatively high (0.275T), no existing model are available, so an original design has been proposed, taking into account that the design of the vacuum chamber (made in aluminium with NEG coating) does not need any opening in the medium plan. The magnet assembly is constituted by an alternated succession of 28 vertical dipoles and 28 horizontal dipoles, magnetically independent.

The call for tender for these 2 undulators will be launched in July 2003.



7 BEAM POSITION STABILITY

In order to avoid differential settlement between the experimental hall and the ring tunnel) the chosen solution consists in an unique slab (0.80 m thick) for storage ring and experimental hall, built on simple piles (548) anchored down to the sand layer at - 15 m. The stability specifications are satisfied: For example, when a new beamline is installed, the total static deformation of the neighbouring beamline and of the nearest point of the ring will be less than 40 µm.

The girders have been carefully designed both for static specifications and dynamic specifications (3 jacks with locking system) with its first resonance mode higher than 40 Hz in order to avoid any amplification of technical or cultural noise.

For both slow and fast orbit feedbacks we select a new type of BPMs (electronics DSP based) developed by I-Tech company. This system combines the advantages of 4 channels system (first turns and turn by turn measurements) and those of electrode multiplexing system (good intrinsic stability and low sensitivity to beam current and bunch pattern) thanks to a new automatic calibration scheme proposed by SOLEIL.

8 TOP UP INJECTION

The injector system, composed of a 100 MeV electron LINAC followed by a full energy (2.75 GeV) booster synchrotron has being designed in view of top-up injection:

- The LINAC specifications have been defined in order to be able to compensate a lifetime as bad as 4 hours by injecting one pulse every 2 min. The contract has been placed in October 2002, first tests are expected in December for a commissioning in summer 2004.
- The booster design (22 FODO cells with 36 dipoles) provides a 150 nmrad emittance . The power supplies (switching type with digital regulation loop following the SLS concept) work at 3 Hz frequency and can be operated on a single pulse basis.

The dipoles are under construction and the calls for tenders for multipoles have been launched beginning April. All injection/extraction elements designs are finalised.

9 REFERENCES

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[3] J. Jacob et al., “Successful beam test of the SOLEIL SC HOM free cavity prototype at the ESRF ring,” this conference.