STATUS OF THE SOLEIL PROJECT*

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Abstract

Following the decision in September 2000 to build "SOLEIL", the project studies developed in the APD report (foundation phase report June 1999) were resumed with the objective of launching the construction phase beginning of year 2002. In order to face the increasing demand of the users for high brilliance in the hard X ray domain in particular for bio-cristallography, the nominal operation energy has been pushed from 2.5 GeV to 2.75 GeV. For the same reason, a new optics have been chosen which will enable to install up to 21 insertion device beam lines instead of 14 previously, keeping also the possibility of 22 bending magnet beam lines. 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 (50 keV with wiggler). Detailed studies on beam position stability have progressed with the identification of the environmental sources of vibrations and with the choice of a different type of foundations for the building. The R&D program on the superconducting RF cavity prototype is being pursued. The specifications of the LINAC and Booster have been revised in view of top-up injection.

1 INTRODUCTION

Since the beginning of 2001, a new SOLEIL team is being constituted with the goal of finalising the project detailed design [1] in order to start the construction in 2002 with a commissioning of the source and of 10 beam lines expected end of 2005 (phase 1), and a gradual installation of 14 other beam lines 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 NOMINAL ENERGY

In order to satisfy the demand of high brilliance for high energy photons (3-18 keV) the nominal energy has been pushed from 2.5 GeV to 2.75 GeV. As a consequence, the photon flux from undulators is increased by a factor 5 at energies above 10 keV while it is reduced by less than 30% around 5-10 eV.

The machine equipment has been revised to guaranty a reliable operation at 2.75 GeV with an beam current of up to 500 mA. This concerns more specially the dipole photons absorbers for which a new solution based on the SLS and ANKA modified design was developed, the RF system which was doubled and the dipole itself for which the H shape has been preferred to the previous C shape to prevent saturation problem.

3 NEW LATTICE

Taking into account the need of more and more insertion devices, the SOLEIL team looked for the possibility of increasing the number of straight sections without increasing the number of cells which would be prohibitive for the budget. The idea was to create a new straight section (3.6m) by drifting apart the two quadrupole doublets located in-between the two bending magnets of the DB cell. In order not to increase too much the total circumference of the machine, only two cells over the four cells of a super period were modified (the modified cells are the central ones). With the same motivation, the four long straight sections have been shortened from 14 m to 12 m.

The circumference of the storage ring increased from 337 m to 354 m with a lengthening of 17 m i.e. 5%. With this minor modification the machine provides now 24 straight sections (4x12m, 12x7m, 8x3.6m) among which 21 are dedicated to install insertion devices (one long straight is necessary to locate the injection equipments and two medium straights will be occupied by the super-conducting RF cavities). The total effective length free for insertion devices is of 104 m which represents a record value of 29 % of the machine circumference.

Figure 1 shows the optical functions of one of the four super periods of the new lattice integrating 8 bending magnets, 6 straight sections (1x12 m, 3x7 m, 2x3.6 m), 40 quadrupoles (8 triplets on each side of the large and medium sections, 8 doublets) and 30 sextupoles.

Linear and non linear optics were optimised and very good results have been obtained leading to the same performances than those of the previous lattice [2]:

With tunes Qx = 18.28 and Qz = 10.26, we have the following results:

- Horizontal emittance εx = 3.7 nmrad @ 2.75 GeV
- Beta functions in the small straight section matched for "high energy " undulators : βz = 2 m to permits small gap and βx = 17 m which gives a low horizontal divergence more favourable to operation on high harmonics.
- Good dynamic acceptance even for large energy deviation (up to 6%) thanks, among others, to a small variation of the tune with energy.

A peak RF voltage of 4.8 MV was determined to insure also longitudinal energy acceptance of ± 6%.

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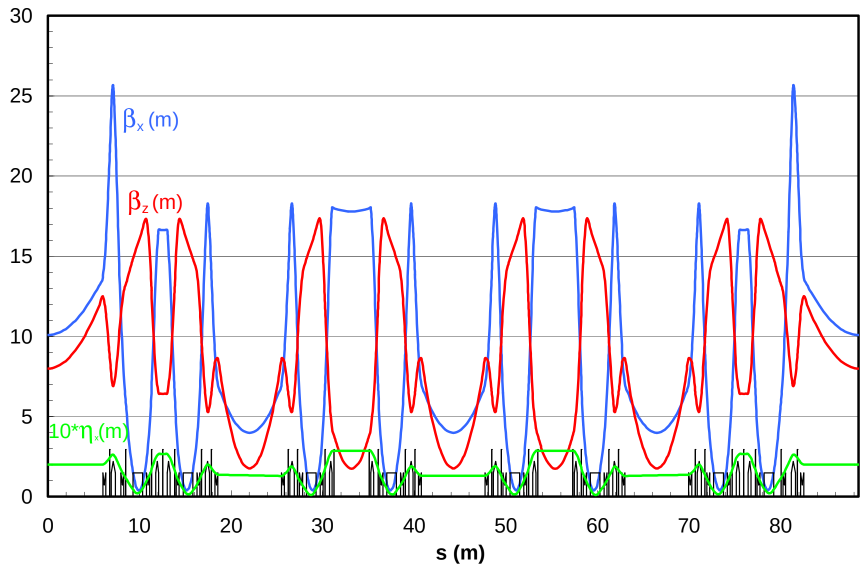

Fig. 1 Lattice and optical functions for one super period of the storage ring

Nevertheless, this value was computed using the first order momentum compaction α_1. If α_1 is small, α_2 must be considered, the synchrotron motion becomes non linear and the RF bucket centered around $\delta = 0$ is asymmetric in energy leading to a decrease in Touschek beam lifetime. For SOLEIL, $\alpha_1 = 4.38\ 10^{-4}$ and $\alpha_2 = 4.454\ 10^{-3}$. The RF bucket is then asymmetric with an upper limit at + 5% ($|\alpha_1/2\alpha_2|$) and a lower limit at – 10% ($-|\alpha_1/\alpha_2|$). A particle with a positive energy deviation of + 5% for example can be lost because its separatrix can bring it to a negative energy deviation as high as – 10%. Due to this effect, the Touschek lifetime calculated with linear motion is reduced by a factor 1.5 [3].

4 MAIN PARAMETERS

Main parameters are given in the following table :

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
N. of dipoles / Nominal field	32 / 1.71 T
N. of quad. / Max. gradient	160 / 23 T/m
N. of sextu. / Max. strength	120 / 320 T/m^2
Betatron tunes, Q_x / Q_y	18.28 / 10.26
Chromaticities ξ_x / ξ_y	- 2.84/- 2.23
Momentum compaction	4.38×10^{-4}
Energy dispersion	$1.16\ 10^{-3}$
Radio Frequency	352.202 MHz
Peak RF Voltage	4.8 MV
Energy Loss per Turn (IDs)	1 300 keV

The expected performances in the 2 main operation modes will be :

Operation	Multibunch	Temporal structure
Beam current	500 mA	8 x 10 mA
Beam lifetime	20 h	18 h
Coupling factor	K^2 =1%	K^2 =10%

Note: Beam gas and Touschek lifetimes are calculated with the following hypothesis:

- The pressure is 10^{-9} torr for 500 mA.
- The vertical aperture is 13 mm (respectively 8 mm) for an undulator of 6 meter long (respectively 3.6 m).
- Touschek lifetime is calculated for natural bunch length ($\sigma_s = 14$ ps).

5 INSERTION DEVICES

SOLEIL was optimized for soft X-ray, for which the brilliance reaches a value larger than 10^{20} ph/s/0.1%bw/mm²/mr², but the challenge is to serve a very large scientific community with high performances in an energy range as large as 5 eV to 30 keV [4].

For low energy photon production, long period insertions are needed so they will be installed in the large straight sections. Vertical polarized beams are requested by nearly all low and medium energy beam lines. The limitation will come from the maximum power density acceptable by the beam line optics but also from the heating of the slot in the dipole vacuum chamber. For example to reach 5 eV we chose an electromagnetic 500 mm period length with 20 periods. At 2.75 GeV, with 100% vertical polarization rate the power deposited in the vacuum chamber is 378 W with a power density of 920 W/mrad^2. The vacuum chamber has been redesigned with a water cooled copper slot in order to avoid too much heating.

For high energy photon production, short periods are needed and the undulators will have to be operated on high harmonics. To reach 18 keV, we propose 1.8 m long in vacuum undulators of 20 mm period, which could be installed in the short straights of the new lattice. With a 5 mm gap bringing a 15% lifetime reduction, the brilliance would then be about 10^{19}. For the 30 – 50 keV domain, a wiggler hybrid type, 100 mm period, 2.2 T, 1.8 m long, is proposed. It gives a 7.10^{16} brilliance at 30 keV. However, due to the non zero dispersion, such a wiggler increases the emittance by 7% which is still considered acceptable. The 2nd order effect of all the insertion devices on the dynamic aperture is being investigated.

6 BEAM STABILITY

6.1 Beam position stability

During the APD phase, we tried to develop solutions to minimize the effect of mechanical vibrations as well as closed orbit drifts in the long or medium term [1]. Moreover we made several vibration measurement campaigns on the site. It appeared that the noise has a quasi-sinusoidal variation between night and day with a maximum excursion for the day of 0.35 µm peak to peak, on which some events going up to 0.7µm are superimposed. The analysis showed that almost all these events are at a frequency of 2.5 Hz and then can be simulated as a planar wave. The specifications on the acceptable emittance variation ($\delta\sigma/\sigma < 10\%$, $\delta\sigma'/\sigma' < 10\%$) are well met for a standard coupling of 1% but are not completely satisfied if the coupling factor is decreased to 0.1% . After new investigations it was found that the source of large events are generated by some particular trucks traveling on the 2 adjacent roads, in correlation with some kind of irregularities of the roads. The repair of theses roads and the maintenance of the quality of their surface in the time will get us rid of these vibrations which should guarantee a very good beam position stability.

Furthermore, the foundations of the synchrotron building were reviewed and it was shown that the initial solution cannot respect the stability criteria for the experimental hall slab (differential settlement in comparison with the ring tunnel). The new solution consisting in an unique slab (0.80 m thick) for storage ring and experimental hall, built on simple piles anchored down to the sand layer at - 15 m satisfies the stability specifications. Furthermore, when a new beamline is installed, the total static deformation of the nearest point of the ring will be less than 40 µm.

6.2 Longitudinal stability

A superconducting HOM free RF system was developed for SOLEIL in collaboration with CERN and CEA/DAPNIA. The first power tests of the cavity prototype were made with success in December 1999. An accelerating field of above 7 MV/m was obtained in the 2 cells of the superconducting cavity exceeding widely the specifications (5 MV/m). Some anomalies were observed on the liquid helium distribution, on the mechanical tuning system and on the tuning of the HOM's couplers. After some minor modifications this cryomodule was mounted in January 2002 on the ESRF storage ring in order to be tested with beam in mid 2002 [5]. In parallel, the re-design of a second cryomodule integrating all the prototype experience has just been launched.

7 INJECTOR

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

- The LINAC specifications have been upgraded in order to be able to compensate a lifetime as bad as 4 hours by injecting one pulse every 2 min.
- The new booster design [6] has the same basic structure but 22 FODO cells with only 2 straight sections and 36 dipoles. It provides a 130 nmrad emittance . The power supplies work at 3 Hz frequency and can be operated on a single pulse basis.

8 MISCELLANEOUS

Among the different improvements in study for the SOLEIL equipment, we can point out the choice of aluminium vessels with NEG coating for all straight parts of the machine (quadrupoles, sextupoles and insertions), new type of BPMs (DSP based electronics) better adapted for fast feedback and turn by turn measurements and switching type power supplies with digital regulation loop.

9 CONCLUSIONS

The 1999 SOLEIL design has been modified in order to better answer to the new user requests and to integrate new developments. The total cost was reevaluated leading to an investment cost of 207 M€ of which 59 M€ for the accelerators and sources.

The call for tender for the LINAC has already been launched, the ones for the booster and storage ring magnets will follow in the next months and the groundbreaking is planned for the end of the year.

10 REFERENCES

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