NEW SPECIFICATIONS FOR THE SOLEIL PROJECT[1]

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Continuous interaction with potential users has led to an evolution of the source requirements : maximum brilliance greater than 10^{20} ph/s/mm^2/mrad^2/0.1 % $\Delta\lambda/\lambda$ from undulators in the keV energy range, while keeping the LURE specificities such as temporal structure and FEL operation. To meet these goals an optics tunable from 2 to 30 nm.rad has been optimized. Two kinds of straight sections (14 m and 7 m long) with high and low β functions are available for long undulators or special devices producing various polarizations and different wavelengths.

I. INTRODUCTION

From the beginning of the SOLEIL project studies, the specifications have changed continuously [1, 2]. The basic characteristics remain the same, namely a polyvalent synchrotron radiation source in the 10 eV-20 keV energy range with a large number of undulators, a few special 10-20 keV sources and up to 40 beamlines to satisfy the VUV and soft X-rays communities. However, the performances required are now more ambitious such as extremely high brilliance and possible FEL operation. This paper discusses the choice of the configuration, gives higlights on the optics and presents beam lifetime for different tunings and brilliance calculations for various insertion devices. Detailed studies can be found in a general paper [3].

II. CHOICE OF THE CONFIGURATION

The choice concerns the cell lattice as well as the length and number of long straight sections. Furthermore, as only few 10-20 keV sources are required, short wigglers are preferred rather than superconducting bending magnets, the choice of the configuration takes this into account.

A. Basic cell lattice

Extensive studies have been undertaken in order to choose the best lattice providing the very low emittance ($\approx$ 2 nm.rad) needed to reach the required high brilliance of 10^{20} ph/s/mm^2/mrad^2/0.1 % $\Delta\lambda/\lambda$ from undulators.

In order to allow for a large number of undulators, multiple bend structures were not considered while DB and TB structures were compared as well as bending magnet field index efficiency and various arrangements of multiplets. It turns out that for the same number of periods, TBA and DBA have more or less the same practical minimum emittance, the ratio to the theoretical minimum emittance being larger for the TBA. When the dispersion is distributed, the results are similar. A field index has only a small effect (10 to 20 %) on the value of the final emittance. Both structures require 16 cells in order to reach an emittance around 2 nm.rad. As there is no superconducting bending magnet planned, the simplest DB structure (n = 0) is chosen.

B. FEL dedicated straight section

The aim of the FEL is to provide a powerful tunable (350-100 nm) picosecond source with a practical lifetime (> 10 h) and a reasonable gain (50 %) in order to perform user experiments [4].

The optimized energy of 1.5 GeV results from a compromise between mirror degradation and gain on the one hand and laser power and beam lifetime on the other.

Similarly the length of the straight section was determined as a compromise between the maximum length of the insertion device which defines the gain and the stability of the optical cavity. As the FEL is designed for experimental use, the optical cavity mechanics must be outside the shielding for providing various FEL parameters according to the users requirements. Taking into account the deformation due to local heating, the mirror curvature radius cannot be too large ($\approx$ 30 m) in order to keep the cavity stable. This point leads to an optical cavity length of around 40 m and an optimum length for the straight section of 14 m.

C. Number of long straight sections

Different configurations have been studied with 8, 4 and 2 superperiods. As the symmetry order is decreased the optimization of the optics in terms of optical function matching and dynamic aperture becomes more difficult. For 2 superperiods a unit matrix scheme with 6 additional quadrupole families is needed, which increases dramatically the length of the optical cavity, while for 8 superperiods good results are obtained without additional quadrupoles. After a longer optimization a good solution with 4 superperiods was found and retained for SOLEIL. It offers a better solution for the FEL operation (no additional quadrupole) and two long additional straight sections open for future experiments.

III. OPTICS RESULTS

The energy range for machine operation is 1.5 GeV (FEL and temporal structure operation) to 2.15 GeV (high brilliance operation). Table 1 shows the main machine parameters given at 2.15 GeV.

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Table 1 : Machine parameters.

Energy (GeV)	2.15
Circumference (m)	336
Lattice cell type	DB + 4 long straights
Number of cells, number of superperiods	16, 4
Straight length	14.1 m x 4 + 7.4 m x 12
Dipole : field (T), nb	1.56, 32
Quad. : max gradient (T/m), nb, [nb of families]	18, 160, [8]
Sext. : max strength (T/m^2), nb, [nb of families]	250, 112, [8]
Radiation loss per turn (keV)	410 + 90 [insertion devices]
RF frequency (MHz), max peak voltage (MV)	500, 3

A large number of operating points have been studied in order to obtain low emittance and to provide low vertical beta-functions in straight sections for insertion devices. The horizontal emittance is about 7 nm.rad in the Chasman-Green structure and reaches 2.4 nm.rad with distributed dispersion.

In every case a comfortable dynamic aperture is available even with energy deviation up to ± 4 % for chromaticity $\xi_{x,z} = 0$ and up to ± 3 % for $\xi_z = +1$ (high positive chromaticity is expected to increase the single bunch current threshold).

The characteristics for one of the nominal operating points are listed in Table 2. Fig. 1 and Fig. 2 show the corresponding optical functions and dynamic aperture.

Table 2 : Typical operating point characteristics.

Emittance (nm.rad)	2.7
Betatron tunes ν_x, ν_z	18.30, 8.38
Synchrotron tune ν_s	5.3 10^{-3}
Momentum compaction α	3.8 10^{-4}
Energy spread σ_ε	8.6 10^{-4}
Damping times (ms) τ_s, τ_x, τ_z	5.85, 11.7, 11.7
Natural bunch length* (mm), σ_ℓ	3.3
Natural chromaticities (ξ_x, ξ_z)	- 2.98, - 2.90

* *(V_{RF} = 1.9 MV for ε_{RF} = 4 %)*

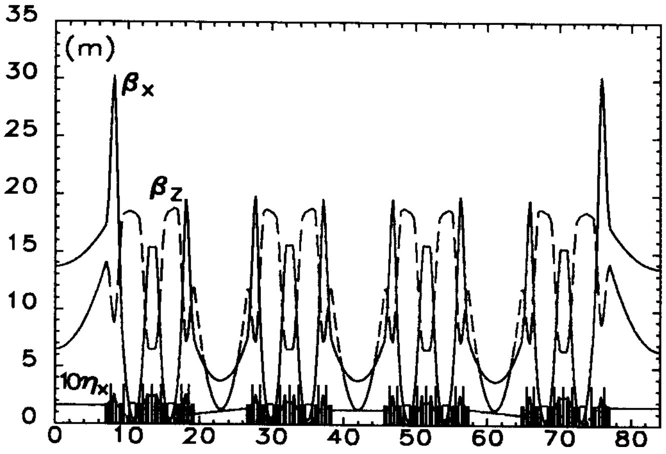


Fig. 1. Optical functions for the typical operating point.

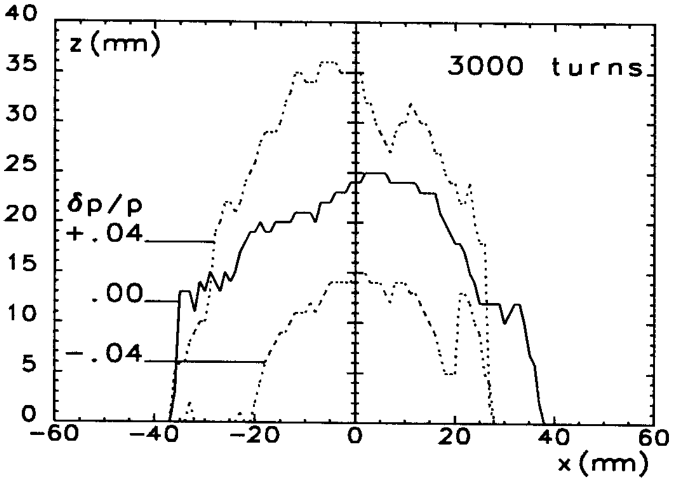


Fig. 2. Dynamic aperture for the typical operating point.

A special operating point has been optimized for FEL operation and temporal structure with an emittance of 30 nm.rad at 2.15 GeV, i.e. 15 nm.rad at 1.5 GeV and zero dispersion in the long straight sections. Its characteristics are given in Table 3 at 1.5 GeV.

Table 3 : FEL operating point characteristics.

Emittance (nm.rad)	15
Betatron tunes ν_x, ν_z	19.40, 6.38
Synchrotron tune ν_s	15.2 10^{-3}
Momentum compaction α	1.3 10^{-3}
Energy spread σ_ε	6.0 10^{-4}
Damping times (ms) τ_s, τ_x, τ_z	17, 34, 34
Natural bunch length* (mm), σ_ℓ	2.8
Natural chromamicitie (ξ_x, ξ_z)	- 2.87, - 3.41

* *(V_{RF} = 3 MV for ε_{RF} = 4 %).*

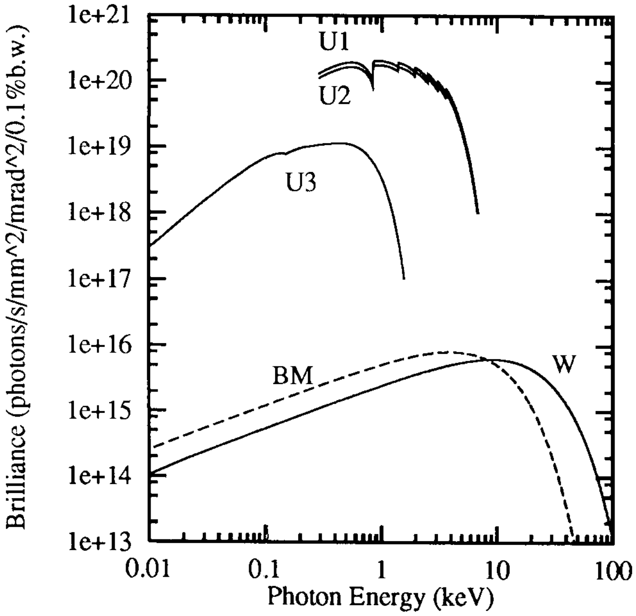
The sensitivity of all the optics has been tested versus standard alignment errors, the machine remains stable over 100 sets of random errors (3 σ). The injection study taking into account those closed orbit distortions led to a beam stay clear of $\Delta x = \pm 40$ mm ; $\Delta z = \pm 17$ mm. The individual effect of each multipolar field component was computed, the maximum values retained as tolerances were the ones which kept the dynamic aperture almost unchanged. The reduction due to the global effect of all systematic and random multipolar field tolerances is about 10 %.

IV. BRILLIANCE AND BEAM LIFETIME

A. Brilliance

Fig. 3 shows the brilliance calculated at the typical operating point with a beam current of 500 mA, and a coupling factor of 1 %, from the bending magnet and several types of insertion devices.

It is worthwhile to remark that the maximum brilliance at about 2 10^{20} ph/s/mm^2/mrad^2/0.1 % $\Delta\lambda/\lambda$, is obtained in both kinds of straight sections (with respectively an undulator length of 10 m and 7 m) due to the fact that β_z can be lower in the shorter straight sections. The longer ones could be dedicated to future developments.



U1 : λ = 4.6 cm N = 220 K_{max} = 2.2
U2 : λ = 4.6 cm N = 150 K_{max} = 2.2
U3 : λ = 20 cm N = 50 K_{max} = 6.7
W : 1 pole superconducting wiggler, B_{max} = 3.5 T

Fig. 3. Typical brilliance for SOLEIL.

B. Beam lifetime

Three modes of operation are expected :

1) High brilliance at 2.15 GeV with 500 mA.

2) Temporal structure at 2.15 GeV with 8 x 10 mA.

3) FEL compatible with temporal structure at 1.5 GeV with 8 x 10 mA.

Beam gas (τ_v) and Touschek lifetimes have been computed for different emittance, coupling and energy values. The pressure taken for the calculation is 10^9 Torr for 500 mA and 2 10^{-10} for 80 mA while the maximum RF voltage is assumed to be 3 MV providing an energy acceptance of 4 %.

Table 4 shows the results for the three modes of operation, the values in bold type correspond to beam lifetime larger than 10 h and maximum factor of merit (brilliance x beam lifetime).

Table 4 : Beam lifetime for three modes of operation.

E (GeV)	2.15		1.5
ε_x (nm.rad)	2.7		15
I (mA)	500	8 x 10	8 x 10
τ_v(h)	33	164	115
τ_{tot} (h), κ^2			
0.01	**12.5**	2	3
0.10	22	6	8
1	27	**11**	**14**

V. CONCLUSION

The SOLEIL parameters optimized in order to reach the targets, are presently completely defined and the ultra vacuum and magnetic element systems detailed studies are now in progress.

The machine offers very high performance at 2.15 GeV with extremely high brilliance from undulators as well as at 1.5 GeV with the FEL providing the possibility of two color experiments as already shown on Super-ACO [5].

SOLEIL associated with the ETOILES project [6], which would cover the whole infrared domain with synchronized FEL, will be a unique multipurpose high performance tool.

VI. ACKNOWLEDGMENT

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VII. REFERENCES

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