

STATUS OF THE SOLEIL PROJECT¹

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Abstract

With the goal to be prepared for a start of construction in January 99, the SOLEIL project was recently reviewed. The main characteristics have been confirmed while some options have been revised. The preinjector is now a 100 MeV electron linac installed together with the Booster inside the storage ring. The storage ring energy is increased to 2.5 GeV in order to meet the new user's requirements on the brilliance ($B > 10^{18}$) around 10 keV. Optics were reoptimised with an emphasis on the energy acceptance so as to obtain large Touschek lifetime. New designs of vacuum chamber and magnetic elements are in progress and a new type of superconducting cavity with heavily damped HOM's at 353 MHz is being prototyped.

1. INTRODUCTION

From many discussions with potential users on the performances of SOLEIL [1] in all its specific energy photon domain (5 eV-100 KeV) as well as in the different operating modes (multi-bunch mode for high brilliance, few-bunch mode for temporal structure and FEL) it has been decided to increase the energy of the Source from 2.15 to 2.5 GeV.

All the accelerators (Linac, Booster, Storage Ring) have been reoptimised and detailed designs of the major components are underway.

2. STORAGE RING

2.1. Main characteristics and Performances

In order to achieve a better complementarity with the ESRF and in particular to satisfy the demand of high brilliance around 10 keV ($B > 10^{18}$) two solutions were considered :

- Short period minigap undulators.
- Increase of the energy of the electron beam.

The first proposition implies an undulator of 1.6 cm period with a 4 mm gap which leads to a poor beam gas lifetime penalizing all the beamlines. Top off injection is then compulsory to restore the beam and ensure satisfying operation.

The alternative is less risky, since the performance specifications are obtained (see below) with a 3.4 cm period undulator with a 15 mm gap (instead of 20 mm for

the standard undulator at 2.15 GeV). As a result, the beam gas lifetime (behaving like $\gamma^2 g^2$) is preserved and the Touschek lifetime is increased ($\gamma^{5/2}$).

New lattices were optimised, keeping the same ring circumference [2]. Comfortable dynamic apertures even at large energy deviation (up to 6 %) are obtained for all proposed operating points. Table 1 gives the main characteristics of the storage ring and the new typical operating point.

Table 1.a. Main characteristics of the ring.

Energy (GeV)	1.5/2.5
Circumference (m)	336
Lattice cell type	DB
Nb of cells ; nb of superperiods	16 ; 4
Straight section length	14mx4+7mx12
Dipole : nb, field (T) (2.5 GeV)	32 ; 1.56
Quad.: nb, max grad. (T/m), [nb fam.]	160; 21; [8]
Sext. : nb, max str. (T/m ²), [nb fam.]	112; 320; [8]
Rad. loss/turn (keV) (2.5 GeV)	645+155[ID]
RF freq. (MHz); Max peak volt. (MV)	353 ; 4
Harmonic nb	396

Table 1.b. Typical operation point.

Emittance (nm.rad) ϵ_x	3.1
Energy (GeV)	2.5
Betatron tunes ν_x, ν_z	18.28, 8.38
Synchrotron tune ν_s	$5.1 \cdot 10^{-3}$
Momentum compaction α	$4.76 \cdot 10^{-4}$
Energy spread σ_E	$9.24 \cdot 10^{-4}$
Damping times (ms) τ_s, τ_x, τ_z	4.33, 8.66, 8.66
Natural bunch length (mm), σ_L	4.1
V_{RF} (MV) for $\epsilon_{RF} = 6 \%$	3.8
Natural chromaticities (ξ_x, ξ_z)	- 3.03, - 2.68

When Touschek collisions with large energy deviation occur in dispersive sections they induce large betatron oscillations. The study was made taking into account the non linear chromatic orbit as well as energy variation of the optical functions [3]. The results show that, for SOLEIL, Touschek lifetime is still limited by physical aperture and RF acceptance. A vacuum chamber

¹ Work supported by CNRS, CEA, MENESR.

horizontal dimension of 70 mm is chosen as a compromise between improved lifetime and reasonable RF and magnetic system design. In the vertical plane, the dimension of 25 mm retained for the arcs and triplets has been determined by beam gas scattering in the insertion devices (the 15 mm minimum gap implies a 13 mm vacuum chamber height which corresponds to 25 mm in the dipole). The Touschek effect should also be considered in this plane when transverse coupling is not negligible. The lifetime increases roughly linearly with the coupling up to around 10 %, then saturates and decreases beyond 80 %. The total lifetime for the 2 main expected modes of operation (2.5 GeV, $\epsilon_x = 3.1$ nm.rad) are :

- 1) High brilliance with 500 mA ($\kappa^2 = 0.01$), $\tau = 17$ h.
- 2) Temporal structure with 9×10 mA ($\kappa^2 = 0.1$), $\tau = 18$ h.

Remarks :

- Beam gas scattering is calculated for 10^{-9} Torr dynamic pressure at 500 mA.
- Touschek lifetime is calculated for the natural bunch length ($s_1 = 13$ ps). If bunch lengthening occurs as we expect (s_1 (10 mA) = 24 ps), lifetime becomes 25 h.

Fig. 1 shows the brilliance calculated in the first operating mode from the bending magnets and several types of insertion devices, covering the full energy range from 5 eV to 100 keV. Notice that brilliance is around 10^{19} à 10 keV (meanwhile, we have to correct this value by taking into account the energy spread of the beam which reduces the brilliance by a factor 3.6 for the 13th harmonic). For the lowest energy (5 eV), one can get the same brilliance as at 2.15 GeV, but at the price of a factor 2 increase in dissipated power, which nonetheless remains reasonable (140 W and 200 W respectively for U70 and U50).

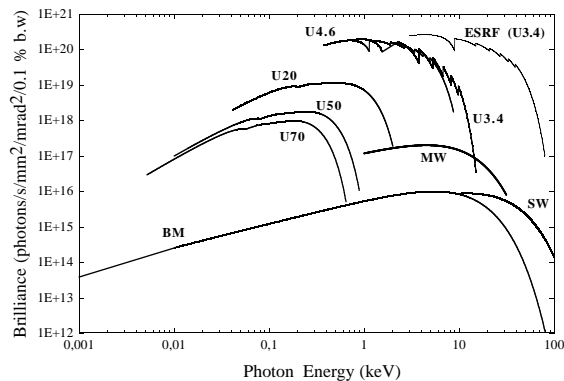


Fig. 1. Typical brilliances for SOLEIL. Comparison with some ESRF sources.

2.2. Technical studies

Magnetic and vacuum systems were reviewed as a whole taking into account the presence of vacuum pumps in the quadrupoles and a minimum clearance between

vacuum chamber and the poles allowing micro transverse displacement of the vessel necessary for BPM mechanical stability. Fig. 2 shows the quadrupole and vacuum chamber cross section and Table 2 gives dipole and quadrupole main characteristics. Although the standard optics need only 8 families, the 160 quadrupoles will be powered by individual power supplies. The question of whether in situ bake-out should be incorporated in the design is still under discussion and test are in progress on a beam line of DCI dedicated to PSD measurements at LURE [4]. Nevertheless, a very thin bake-out system (printed circuit, glass fiber or air and aluminium foil) less than 2 mm thick is being studied in order to allow a 170° bake-out.

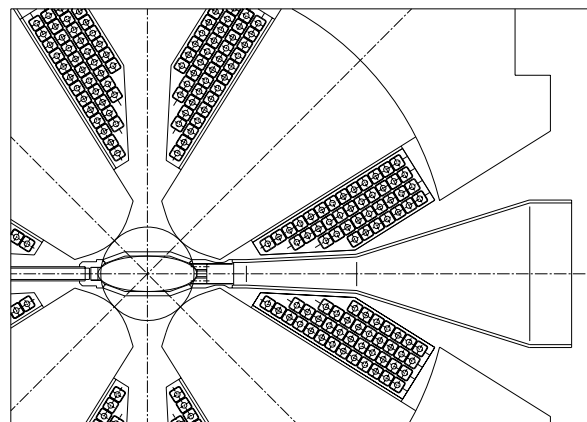


Fig. 2. Quadrupole and vacuum chamber cross section.

Table 2. Main dipole and quadrupole characteristics.

	Dip.	Quad.
Gap or bore Ø (mm)	37	66
Strength max	1.7 T	21 T/m
Nb of families	1	8
Nb of power supplies	1	160
Total power (kW)	245	720
U (V), I (A)	490/500	18/250
Good field region (mm)	± 20	± 30
Homogeneity :	required	3 10 ⁻³
	computed	1.5 10 ⁻³
Reproducibility	1 10 ⁻³	10 ⁻³

From the beginning of the SOLEIL project, a superconducting cavity based on the general principles of the Cornell monomode cavity (large beam-tubes, ferrite dampers) has been considered. R&D program which involves collaboration with other European laboratories, in particular CERN and ESRF is now set up and a new design at 353 MHz is being investigated [5]. It consists of a pair of single-cell cavities linked by a large beam pipe, such that the coupling is very weak for the fundamental mode, but very strong for the HOMs. After the optimization of the cavity shape, beam pipe opening and length, the simulations show that harmful HOMs can be sufficiently damped to ensure absolute beam stability for SOLEIL by classical dampers without ferrite in the vacuum chamber. The construction of a prototype is underway.

3. INJECTOR

3.1. Linac ELIOS

A new 100 MeV electron Linac was studied. The main parameters are shown below :

S band Linac, $f = 2\,998.55$ MHz
 Energy : $100\text{ MeV} \pm 5\text{ MeV}$, $\Delta E/E < \pm 1.5\%$
 Repetition rate : $F_r = 10$ Hz (see below)
 Beam power : ≈ 2 watts
 Emittance : 10^{-6} m.rad at 100 MeV

Two operating modes are foreseen :

- Few pulses (1 to 3) of 2 ns durations separated by 125 ns for temporal structure modes.
- A 300 ns macropulse duration modulated at 353 MHz for multibunch operation.

The total accelerated charges are respectively of 1 nC (1 W) and 3 nC (2 W) while the gun intensity peak varies from 180 mA to 30 mA. In both modes the storage ring filling time is ≤ 1 min. The linac is composed of the following elements : triode gun (90 kV, 250 mA), prebuncher (10 kV, 200 W), buncher (SW, 15 MeV, 5 MW) focalised by a solenoid, 2 accelerating sections (TW, $2\pi/3$) 3 m long of 45 MeV each. The sections are powered by two klystrons (35 MW operating at 24 and 18 MW) and two modulators (80 MW, 25 MW HF). This choice ensures an excellent reliability since it will be possible to still deliver beam in case of a major component failure.

3.2. Booster

The booster accelerates the 100 MeV electron beam to full energy of 2.5 GeV. The optics chosen is a FODO structure, with fourfold symmetry and missing magnets in order to have zero dispersion in the straights. The main characteristics are given in Table 3.

Table 3. Booster main characteristics.

Energy (GeV), injection/ejection	0.1/2.5
Emittance (injected, ejected)	$10^{-6}/2.5\ 10^{-7}$
Orbit length (m)	142.78
Dipoles : nb ; l (m) ; gap (m)	24 ; 2.17 ; 0.032
Field (T) : min, max	0.04 ; 1
Quad. : nb ; l (m) ; bore radius (m)	40 ; 0.4 ; 0.030
Maximum gradient (Tm^{-1})	11
Betatron tunes	6.30 ; 5.30
Max optical functions $\beta_x = \beta_z$ (m)	13.2
Natural chromaticities $\xi_x = \xi_z$	-1.4
Momentum compaction α	$3.32\ 10^{-2}$
RF : frequency (MHz), V_{max} (MV)	352.75 ; 1.1

The injection repetition rate has been reviewed and the advantages and drawbacks of 1 Hz and 10 Hz cycle were compared. It turns out that beam dynamics is much easier at 10 Hz : no energy spread problem in the linac, no high peak current in the linac and the booster, easier crossing of the resonances during the faster energy ramping in the booster, safety margin for a fast injection in the two operating modes. The investment cost is higher (resonant H.V. power supplies in addition to DC instead of ramped power supplies) but will be compensated by lower operation cost (only circuit losses have to be delivered by the mains). The 10 Hz repetition rate was then adopted.

The transfer beamlines as well as the injection/ejection have also been studied. Fig. 3 shows the general layout of the accelerators and the experimental hall.

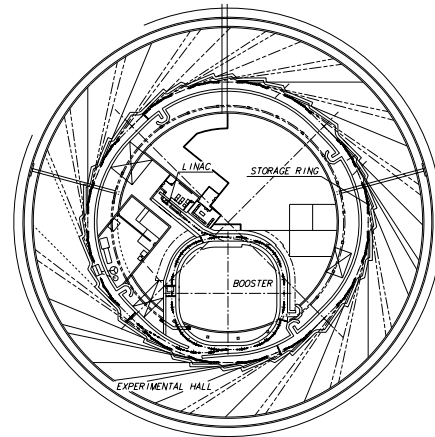


Fig. 3. General layout of SOLEIL.

4. CONCLUSION

The new nominal energy 2.5 GeV offers better performances at high photon beam energy and better electron beam dynamic behaviour with acceptable consequences in the low energy domain.

New improvements have been obtained in optics and Touschek lifetime as well in the design of HOM suppressors in superconducting cavities. In all technical designs special attention is paid to reliability and low operation cost.

5. REFERENCES

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