STATUS OF THE SOLEIL PROJECT*

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Abstract

The detailed study of SOLEIL is going on, with the objective to start construction in January 99. The building preliminary design is completed and the detailed design, on the reference site, will be finished in July 98. By that time, the specifications of all major components on the critical path will be ready to launch call for tenders.

Taking into account the very high targeted brilliance of the radiation source, beam stability becomes the major concern. A large effort was put into fighting multibunch and single bunch instabilities as well as ensuring a very good beam position stability.

Simulations and measurements on a copper prototype of the RF two-cavity superconducting system have proved that the selected design is able to provide longitudinal stability for a beam of more than 500 mA. Magnetic and vacuum systems, girders and buildings are designed with the goal of minimizing beam vibrations and closed orbit drifts.

The optimized energy acceptance is larger than ± 6 % leading to a long Touschek beam lifetime of about 40 hours at 500 mA. Topping up injection is also considered.

Finally, theoretical developments were made, as for example, the detailed study of the vertical dispersion and betatron coupling.

1. INTRODUCTION

Last major change which corresponds to an increase of the storage ring energy from 2.15 to 2.5 GeV was made one year ago [1]. Since then, theoretical and technical studies have been carried out with the objective of reaching the very highest performances in terms of brilliance, stability in position and energy, lifetime.

2. STORAGE RING

2.1. Parameters and performances

Let us recall the main parameters of the ring and the operating points :

Table 1.a. Main Parameters of the ring.

Nominal energy (GeV)	2.5
Circumference (m)	337.073
Structure	Double Bend
Nb of cells	16
Superperiods	4
Straight section length	4 × 14.1 m ; 12 × 7 m
Rad. loss per turn (keV)	645 + 155 (ID)
Power (kW)	400
RF Freq. (MHz)	352.202
Max. voltage (MV)	4
Harmonic	396

Table 1.b. Nominal and FEL operating points.

Energy (GeV)	2.5	1.5*
Emittance (nmrad)	3.0	4.6**
Betatron tune	18.28 ; 8.38	19.7 ; 7.6*
Energy spread	$9.24\ 10^{-4}$	$8\ 10^{-4}$**
Bunch length (ps)	12	14

*FEL operation ** Taking into account IBS effect

Performances for the main modes of operation :

- High brilliance (E = 2.5 GeV) :
ε_x = 3 nmrad ; ε_z = 0.03 nmrad ; K^2 = 0.01
I = 500 mA ; τ = 20 h ; Brilliance from ID around 1 keV : B = 2 10^{20} ph/s/mm^2/mrad^2/0.1% bw
- Temporal structure (E = 2.5 GeV) :
ε_x = 3 nmrad ; ε_z = 0.3 nmrad ; K^2 = 0.1
I = 9 × 10 mA ; τ = 18 h ; 9 bunches (σ < 30 ps) spaced by 120 ns.

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• FEL (E = 1.5 GeV) :
ε_x = 4.5 nmrad ; ε_z = 0.9 nmrad ; K^2 = 0.2
I = 4 × 20 mA ; τ = 5 h
100 nm< λ < 350 nm FEL radiation.

Estimation of coupling (betatron coupling and vertical dispersion) was performed with standard errors. Skew quadrupole correctors allowing to adjust coupling between 1 % and 20 % (depending on operating modes) are being determined [2].

2.2. Beam position Stability [3]

The stability of beam position, from DC to 100 Hz, is of course very important. Therefore we tried to develop solutions to minimize the effect of mechanical vibrations as well as closed orbit drifts in the long or medium term.

- For the vibrations, we consider the standard but severe tolerance i.e. a closed orbit displacement less than one tenth of the size and the divergence of the beam. This criterion is valid when the data acquisition time is very short (<< 1s), in most of the cases, these values could be relaxed. For the computation, one assumes numerous uncorrelated in situ vibration sources. The use of girders to support the triplets and quadruplets of quadrupoles minimizes the closed orbit response thanks to a partial compensation of the effect of F and D quadrupoles. This leads to tolerances on magnet vibrations of 1.3 µm peak to peak vertically and 2.8 µm horizontally. Due to the design of the magnets (see below) we can fixe them rigidly on the girders without any intermediate adjusting elements, sources of mechanical vibration amplification. The study of the girder are underway with the aim of avoiding mechanical resonance up to 50 Hz. A prototype of a simplified girder, with its jacks and a load simulating magnetic elements will be tested in December. Meanwile, taken into account the uncertainties of the overall problem, we chose to tolerance the slab at 1µm in both planes.
- Against the drifts, several precautions were already adopted as for example a minimum clearance of 2 mm between vacuum chambers and magnet poles and the same temperature (23°) for the experimental hall, the inside of the tunnel (± 0.1°) and the magnet water cooling (± 0.1°). In order to rely on our BPM's positionning, we decided to stabilize their temperature at 23° ± 0.1 avoiding thermal constraints. They are rigidly fixed on the girder and systematically next to a bellow. The required sensitivity of the BPM is 0.2 µm DC in the cells and 0.2 µm up to 100 Hz for the BPM located at both ends of ID straight sections. We consider a global slow feedback based on cell BPM's and if necessary a global dynamic feedback with insertion BPM's.

The study of the chambers of the arcs is completed. Differents prototypes will be fabricated before the end of 1998 : Quadrupole chamber, dipole chamber and crotch, BPM with RF shielded bellow modules.

2.3. Longitudinal beam stability

The coupled bunch instabilities driven by the higher order modes (HOM) of cavities degrade the brilliance via two mechanisms : the energy oscillation induces enlarged source size in a non zero dispersion section, and in addition, leads to an increase in effective energy spread. For SOLEIL, a superconducting HOM free RF system, capable of providing the necessary beam power and RF voltage was developed. It consists in a pair of single-cell cavities linked by a large pipe such that the coupling is very weak for the fundamental mode, but very strong for the HOM's which can be extracted by two pairs (longitudinal and transverse) of couplers. The cavity system and coupler arrangement were designed by simulation codes and a copper prototype allowed to validate the chosen option and to achieve the final optimization of the couplers [4].

The construction of the Nb/Cu cavities is underway at CERN, they will be ready for measurements next month.

2.4. Beam lifetime

The performances are given for 10^{-9} Torr dynamic pressure at 500 mA. Meanwhile we optimize the pumping system (effective pumping of 96 $\ell.s^{-1}$ per vacuum chamber meter) in order to reach 5 10^{-10} Torr after a beam conditionning of 460 A.h. We expect to obtain this result after about one year of operation.

Optics was optimized to obtain comfortable dynamic apertures even up to 6 % in energy deviation and ensure a good lifetime (Touschek as well as beam gas lifetime). In order to preserve it, a high quality of the magnetic field is required which leads to tolerances on the quadrupole pole profile of ± 0.02 mm. This precision is reached by a machining of the poles which in addition to the gain over the purity of the field allows to suppress adjusting elements between magnets and girders. 3D calculations are underway to design the end chamfer. A quadrupole prototype is under construction to obtain the magnetic length equal to the mechanical one. Each quadrupole will be individually powered. This allows to precisely adjust the β functions and offers the possibility to match different beam size in the straight sections according to the experiments. For the dipoles, machining of the pole at ± 0.02 mm has also been adopted. The gap (37 mm) is relatively small and we need both a very good closed orbit and a low and stable coupling to provide very high brilliance. 3D computation allowed to obtain equal mechanical and magnetic lengths. The specifications of dipoles and quadrupoles are completed and ready for tendering. The sextupole provides sextupolar field but on top horizontal and vertical dipolar fields and skew quadrupolar fields. The design (pole profile, current excitation of the auxiliary coils) was optimized to minimize the unwanted multipolar components [5]. 3D calculations are in progress but due to the small length of the magnet, a prototype will be necessary. The Table 3 presents the main characteristics of the magnetic elements.

Table 3. Main storage ring magnet characteristics.

	Dip.	QF/QD	Sext
Number	32	160	112
Gap or bore ϕ (mm)	37	66	78
Strength_{nom}	1.56 T	21 T/m 18 T/m	320 T/m^2
Length (m)	1.052	0.46 0.32	0.16
Good field re. (mm)	± 20	± 30	± 30
I_{max} (A)	552	250	475
U (V)	512	19 12	84 ; 168 ; 336
Homogeneity :			
- required	10^{-3}	$3\ 10^{-3}$	10^{-2}
- computed (3D)	$5\ 10^{-4}$	$3\ 10^{-3}$	
Reproducibility	10^{-3}	10^{-3}	10^{-2}

2.5. Topping up injection

In order to reach higher integrated brilliance, but also to keep constant thermal load on the vacuum chamber and the beamline optics, it could be interesting to adopt topping up injection. Beyond the difficulties linked with the injector reliability and the operating cost, we have to solve, at the early stage of the project, the problem of experimental background which could be created by particle losses upstream the photon beamlines. In the transfer line, in order to stop the particles which will not be accepted by the storage ring aperture, we will install two collimators in the vertical plane and three one in horizontal plane. For each collimator a second one is necessary at the end of the straight section to stop the created shower. Lead collars are associated with each collimator and neutron shielding is also forseen. In the storage ring, we consider the possibility to install 16 collimators (one per achromat) to stop particle lost after Touschek collisions and eventual RF trip. Furtermore, the topping up injection option is already included in the safety system.

2.6. Insertions

From the answers to the call for scientific projects, it comes out a large demand for circularly polarized radiation in all the energy range : 5 eV to a few keV. The study of various insertion devices shows that we can cover the domain of excellence of SOLEIL with only two undulators :

- 50 eV to 500 eV : an electromagnetic undulator of 25 cm period length, which delivers 10^{14} to 10^{15} ph/s with nearly 100 % polarization (for a 1.5 m long undulator and through a 0.3×0.3 mrad^2 pine hole).

- 500 eV to 2 keV : a permanent magnet undulator, ESRF HELIOS type, of 5.2 cm period length with the same flux and polarization performances as the previous one. This undulator allows also to reach 3 keV but with a reduction of a factor 10 in flux.

For the range 8 eV to 50 eV, one can consider an electromagnetic undulator of 50 cm period length which gives a flux of 10^{14} ph/s with 90 % polarization in a cone of 0.7×0.7 mrad^2.

3. INJECTOR

The injector is composed of a 100 MeV electron Linac [6] followed by a fast cycling booster which accelerates the beam to full energy of 2.5 GeV [7]. Both of them have been studied in details, as well as the transfer lines and the injection/ejection.

4. CONCLUSION

All theoretical studies and technical developments have progressed with the goal of ensuring the beam performance targets. The detailed studies of the major components are already completed, they could be ordered at the begining of 99 if the decision is made in the next few months.

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