STATUS OF THE SOLEIL PROJECT[1]

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Abstract :

During this year, the configuration of the ring has been defined (cell structure, periodicity, superperiodicity, length of the straight sections). A large number of operating points have been studied to reach, with a fair safety margin, the project's required performances. Special attention was paid to optimizing energy acceptance up to ± 4 %, leading to a maximized beam lifetime even at very high brilliance. Optics with negative momentum compaction factor are also under consideration.

This paper presents all these results and deals with the magnet design, RF and vacuum chamber R&D.

1. INTRODUCTION

In May 1996, the 2 French research institutions, CNRS and CEA, decided to formally structure the progress toward the construction of SOLEIL as a joint venture, with the creation of a project team, supervised by a council, itself adviced by a scientific committee.

The SOLEIL project is a multipurpose synchrotron radiation source which will provide radiation from the far infrared to the X-ray range (about 20 keV) with a large number of undulators optimized in the VUV and soft X-ray range and a few specific wigglers in the 10 to 20 keV domain. The undulator brilliance is required to reach a value of 10^{20} ph/s/mrad^2/mm^2/0.1 % $\Delta\lambda/\lambda$. in the keV range. The machine is expected to be operated also in a few-bunch mode for time resolved experiments and one straight section will be dedicated to a Free Electron Laser (FEL).

2. MAIN CHARACTERISTICS

The present machine design meets these requirements with a 2.15 GeV, 336 m circumference storage ring made of 16 cells and 4 superperiods. The injector is composed of an electron linac of 100 MeV followed by a full energy booster. The linac has been specialy designed to be compatible with a positron linac option (if necessary) [1]. The source provides a very high flexibility of the optics : variable emittance between 2 and 30 nm.rad [2] as well as positive and negative momentum compaction optics.

In every case, a comfortable dynamic aperture is available even with an energy deviation up to ± 4 %, in order to provide good Touschek lifetime $\tau \geq 12$ h for the maximum brilliance (see below).

The closed orbit correction was studied from a statistical point of view by two different methods [3].

Table 1. 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 %)

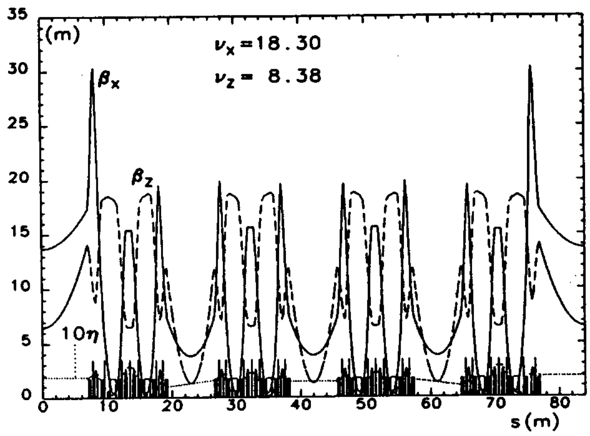

Fig. 1. Optical functions for the typical operating point.

3. PERFORMANCES

Fig. 2 shows the brilliance calculated at the typical operating point (ε_x = 2.7 nm.rad) with a beam current of 500 mA, and a coupling factor of 1 %, from the bending magnet and several types of insertion devices, covering the full energy range from 10 eV to 100 keV.

The maximum brilliance of about 2.10^{20} ph/s/mrad^2/mm^2/0.1 % $\Delta\lambda/\lambda$, is obtained around 1 keV with a 7 m long straight section.

One of the four 14 m long straight sections is dedicated to the FEL designed for experimental use and especially for pump-probe experiments, another is used for injection and the other two free long straight sections are open for future developments : at the moment, very long undulators and also several undulators with different magnetic axis (magnetic chicane) are considered.

In the high energy range, wavelength shifters (single period superconducting wigglers) are foreseen and short minigap undulators (U1.6) are under study.

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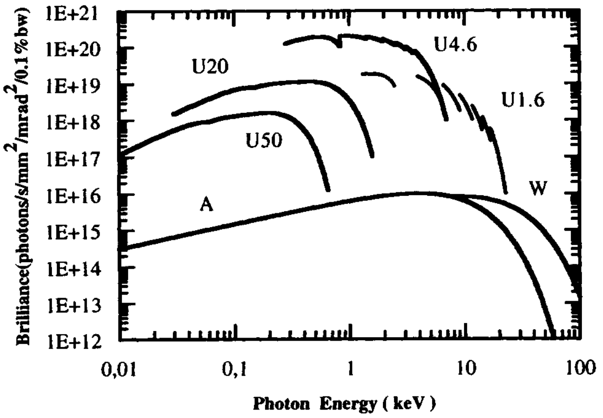

U4.6 :	λ = 4.6 cm	N = 150	K_{max} = 2.2
U20 :	λ = 20 cm	N = 50	K_{max} = 3.5
U50 :	λ = 50 cm	N = 20	K_{max} = 3.9
U1.6	λ = 1.6 cm	N = 30	K_{max} = 1.5

W : 1 pole superconducting wiggler, B_{max} = 3.5 T

Fig. 2. Typical brilliance for SOLEIL.

The FEL will be operated at 1.5 GeV with an optical cavity (like the FEL on Super-ACO at LURE). The FEL with a gain of about 50 % will be tunable in the 350-100 nm range with $\Delta\lambda/\lambda = 10^{-4}$ and deliver micropulses of a few picoseconds separated by 270 ns. The ultimate brilliance will reach some 10^{26} ph/s/mrad²/mm²/0.1 % $\Delta\lambda/\lambda$ and extension of the wavelength to the far UV through harmonic generation is envisaged [4].

Another FEL built on a linear accelerator derived from the CLIO-FEL at LURE will provide mid and far infrared laser light. Its synchronization with the SOLEIL machine will offer an extremely large variety of technicolor experiments for users [5].

4. RF SYSTEM

Coupled bunch instabilities driven by the higher order modes (HOM) of the cavities are one of the performance limitations of storage ring synchrotron radiation sources.

A quantitative estimation of the effect of longitudinal phase-energy oscillations produced by longitudinal coupled bunch instabilities on undulator brilliance has been carried out. Such oscillations affect undulator performance via two mechanisms. First, if, as in the case of SOLEIL, a non-zero dispersion function exists in all undulator, the presence of energy oscillations of relative amplitude ε will result in source point center of mass oscillations of amplitude $\eta_x\varepsilon$. Because user experiments average over times very long compared to the frequency of these oscillations, the result from the user point of view will be an enlarged source size and thus a reduced brilliance. The second mechanism is due to the fact that energy oscillations are equivalent to an increase in effective beam energy spread.

Numerical calculations, taking into account the non-gaussian form of effective source dimension and energy spread were performed to estimate the importance of these two effects. The results (fig. 3) show that the strongest effect comes from source size (distributed dispersion). An energy oscillation amplitude of 10^{-3}, corresponding to a phase amplitude of 11 ps, would result in a brilliance reduction of about 35 %. In fact, experience on other machines shows that phase-energy oscillation amplitudes when instabilities are excited are often not constant in time but oscillate at low frequency. Thus, such oscillations would probably not introduce a constant brilliance reduction but rather a variable one which would contribute to instrumental noise for many types of synchrotron radiation experiments. It seems reasonable to impose the same tolerance on transverse source point oscillations as for closed orbit oscillations : $\sigma_x/10$ over a single user run (where σ_x is the horizontal dimension). This would correspond to an energy oscillation amplitude of only 1 10^{-4} or 1 ps in phase which is close to the limit of what one could hope to measure. The final criterion which should thus be adopted is a total absence of measurable phase-energy oscillations.

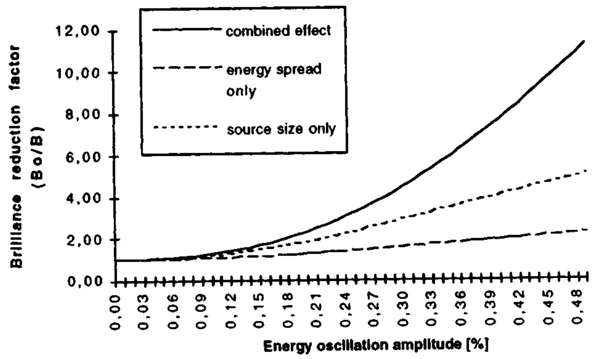

Fig. 3 . Brilliance reduction due to bunch energy oscillations.

Several possible solutions for the RF system have been considered in light of this objective. Of all of these possibilities the superconducting monomode cavity option appears to us to be the most promising because it would assure complete longitudinal beam stability at the current planned for SOLEIL [6]. For this reason, it has been decided to begin an intensive R&D program aimed the development of a superconducting monomode cavity for SOLEIL, based on the general principles of the Cornell monomode cavity (large beam-tubes, ferrite dampers). The goal of this program, which will involve collaboration with other European laboratories, will be to develop a standardized superconducting RF system compatible with the major European synchrotron light source projects and sufficiently simple to be installed in laboratories unspecialized in superconducting RF technology and to operate reliably over the entire lifetime of such a machine. This will require work mainly on the main RF power coupler, the mechanical design of the cryostat, mounting conditions and the ferrite loads.

5. THE VACUUM SYSTEM

The technical choices of raw material and vacuum chamber geometry, were confirmed after the workshop on vacuum system for future SR sources recently held at Orsay [7]. There was an agreement on the fact that Al and SS/Cu absorber vessels can provide the same ultimate beam gas lifetime while the photon stimulated desorption (PSD) which dominates the dynamic pressure in the storage ring is similar for large integrated photon dose. Otherwise, the advantages (good thermal conductivity...) are balanced by the drawbacks (problem related to the connection with standard elements...) and therefore other considerations dominate, such as laboratory experience. Consequently SS has been chosen for the vacuum vessels of SOLEIL except for ID chambers which will be aluminum or copper plated for beam stability reasons (resistive wall instability).

In the dipole sections, the radiated power is absorbed on a crotch located downstream in an ante-chamber (fan shape). The maximum power density applied is about 150 W/mm^2. In the quadrupole and sextupole sections, the vacuum vessel consists of a single chamber with copper longitudinal absorbers. Cooling tubes on the opposite side are added in order to reduce the temperature gradient due to the secondary photon power load which is a nuisance for the thermal and the mechanical stability of the vessels and particularly for the stability of the BPM's.

The question of whether in situ bake out should be incorporated in the design was widely discussed and in order to decide on this issue, tests will be performed on a beamline of DCI dedicated to PSD measurements at LURE. A possible consequence of the results of these tests could be a re-design of the bake out system and perhaps the suppression of in situ bake out. This could allow a reduction in dipole gaps and quadrupole and sextupole bore radii. A minimum clearance of 1 mm would be kept between vacuum chamber and the poles to allow small transverse displacements of the vessels without touching the magnet poles, necessary for beam stability.

A shielded bellow module prototype has been designed on the basis of the one proposed at SLAC for the B factory [8]. The RF fingers sliding between spring fingers and a sleeve have been replaced by wide flex bands (one per side of the chamber section) in order to improve contact for large transverse displacements.

6. MAGNETIC SYSTEM

The magnetic system includes 32 dipoles, 160 quadrupoles and 112 sextupoles.

All magnets are laminated and the current design takes into account room (± 4 mm) for baking in situ.

The quadrupole presents a symmetrical aperture in the mid plane which allows beamlines to run through and vacuum pumps to be laterally linked to the vacuum chamber. The yokes of the sextupoles are closed with a notch for beamline crossing.

Table 2. Main characteristics.

	Dipole	Quad.	Sext.
Gap or bore Ø (mm)	52	76	85
Strength max	1.7 T	20 T/m	250 T/m^2
Nb per family	32	8-24-32	8-16-32
Nb of families	1	3-3-2	4-3-1
Nb of power sup.	1	3-9-8	4-6-4
Tot. power (kW)	600	700	340
U (V)	500	70	60
I (A)	1 200	500	400

7. CONCLUSION

The main SOLEIL specifications are confirmed and technical studies are in progress.

If the decision for funding the machine and the choice of site is made before Spring 1997, the construction could start in 1999 and last for 8 years in two phases. The first phase of four years will include the construction of the machine and 6 fully equipped new beamlines. The construction of the other beamlines (20 funded in the project) are planned in the second phase.

8. ACKNOWLEDGEMENTS

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9. REFERENCES

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