OPTICS FOR SOLEIL AT 2.5 GEV[1]

P. Nghiem°, P. Brunelle*, J.-L. Laclare°, M.-P. Level°, A. Nadji°, J. Payet°°, M. Sommer*, A. Tkatchenko°°

° Projet SOLEIL, DRIF CNRS, Av. de La Terrasse, Bât. 5, 91198 Gif sur Yvette, France
* LURE, Centre Universitaire Paris-Sud, Bât. 209 A, 91405 Orsay Cedex, France
°° CEA Saclay, LNS, Groupe Théorie, 91191 Gif sur Yvette

Abstract

We analyse here the different steps of the optimization procedure and present the new lattices obtained at 2.5 GeV. In order to assure easy commissioning and comfortable operation, special attention has been paid to minimize error sensitivity and maximize dynamic aperture and energy acceptance for all proposed operating points.

1. INTRODUCTION

Following the decision to increase the energy of the SOLEIL ring from 2.15 GeV to 2.5 GeV [1], new optics have to be optimized. While keeping the basic structure described in Table 1 and especially the same ring circumference, one aims to obtain at least the excellent performances achieved at the previous energy, in terms of emittance, brilliance, error sensitivity, dynamic aperture, energy acceptance, etc. [2].

Table 1. SOLEIL basic structure.

Circumference	336.55 m
Type	DB (A)
Number of superperiods	4
Number of cells/period	4
Long straights	4 x ~14 m
Medium straights	8 x ~ 7 m
Dipoles	32 in 1 family
Quadrupoles (2 types)	160 in 8 families
Sextupoles	112 in 8 families

2. OPTIMIZATION PROCEDURE

High brilliance criteria combined with low structure periodicity often induce large sextupole strengths and small dynamic aperture. To overcome these difficulties, we have adopted the following optimization procedure in five steps :

• *1st step*, Tune and Emittance. Select the regions in the tune diagram where not only low emittance can be obtained, but also where there is a minimum of systematic destructive resonances together with a minimum sensitivity to dipolar and quadrupolar errors. Optionally, one can also try to have tunes near to a coupling resonance in order to better control horizontal/vertical coupling, and also vertical tune below half integer in order to avoid or reduce resistive wall instabilities. In the study at the previous energy, we already found out three 'good' regions [2]. One region is free of resonances but the emittance is not so small, an other one allows to achieve the smallest emittance but with a rather small dynamic aperture, and a third region which is a good compromise between the two previous ones. This last region is selected to start with the present studies : $\nu_x \sim 18.3$, $\nu_z \sim 8.3$.

• *2nd step*, Beta Functions. They should be chosen by taking into account the criteria of low emittance which defines β_x inside dipoles, high brilliance from insertions which constrains mainly β_z, minimum beam stay clear for injection which asks for a reasonable ratio of β_{max}/β_{inj}, low error sensitivity and low chromaticity which impose low β_{max}. Globally, we search also for a maximum of symmetry and regularity of β functions along the lattice which are useful for the sextupole compensation associated with the regular induced phase advance, so as for the machine operation where it is convenient to have same β's in equivalent sections.

• *3rd step*, Sextupole position. It seems fundamental that the lower sextupole strengths are, the better will be dynamic aperture and energy acceptance. For this reason, sextupoles should be located where β_x and β_z are well decoupled and this should happen in at least 2 such positions where the dispersion η_x is large.

• *4th step*, Chromaticity Correction and Dynamic Aperture Optimization. These two purposes are achieved by separate sextupoles in Chasman Green-like lattices and by the same ones in dispersion distributed lattices. We optimize the dynamic aperture only at nominal energy (dp/p=0), on the basis of analytical formulae where only first order quantities are involved [3], [4]. One can first minimize some specific low order resonance strengths but this is in general not necessary, especially when the first step is fairly done. The strategy consists mainly in minimizing the first order amplitude distorsions of sextupolar resonances and adjusting the linear terms of tune shifts with betatron excursion $(d\nu/dy)_o$ to avoid the crossing of destructive resonances.

• *5th step*, Momentum Acceptance. When the previous steps are well achieved, we have in general a very good momentum acceptance and no extra optimization is necessary. When the momentum acceptance is nevertheless small, we set one sextupole after an other at fixed strengths and go back to the 4th step with the

[1] Work supported by CNRS, CEA, MENESR.

remaining sextupoles in order to flatten as far as possible the dependence in dp/p of tunes or β's.

3. RESULTS

It is important to apply scrupulously these five steps, to not hesitate to go back to the first step if necessary and to discard solutions which lead to bad compromises. The 3rd step for example is very important, its achievement often implies a re-arrangement of magnetic elements and sometimes a change of the circumference. In the study at the previous energy where the dipole field was 1.56 T, the circumference of 336 m has been imposed by the sextupole location optimization.

Now, designing the machine for a higher energy, we have also searched to decrease the dipole field to 1.4 T. But it induced a too important lengthening of dipoles, leading to a larger vertical chromaticity and bad locations of sextupoles. By balancing in an other way the straight lengths, the dynamic aperture becomes acceptable but remains less comfortable than previously. As each performance comes back to its previous level only when the circumference is lengthened by 10 m, this solution was abandoned.

In opposition, with the same dipole field as previously and simply by an increase of the dipole length while consequently shortening the medium straight, performances are not noticeably deteriorated and this solution was adopted. Table 2 summarizes the main features of the low emittance and Chasman Green-like lattices. All calculations have been performed with the BETA code [6].

Table 2. Lattice main features.

Lattice type	Low emittance	Chasman Green-like
Emittance	3.1 nm.rad	9.6 nm.rad
Tunes ν_x / ν_z	18.28 / 8.38	18.30 / 8.32
β_x / β_z max	28.6 m / 18.5 m	28.9 m / 19.4 m
β_x / β_z in long straights	10.0 m / 8.0 m	10.1 m / 8.0 m
β_x / β_z in medium straights	4.2 m / 1.3 m	4.5 m/ 1.3 m
Norm. nat. chromaticity H / V	-3.03 / -2.66	-3.34 / -2.74
Relative energy spread	$9.24\ 10^{-4}$	$9.24\ 10^{-4}$
Dispersion max / long straights / medium straights	0.28 m / 0.18 m / 0.12 m	0.5 m / 0.0 m / 0.0 m
Momentum compaction factor	$4.76\ 10^{-4}$	$6.42\ 10^{-4}$

The emittance is lowered by a factor of 3 from the Chasman Green-like lattice when the dispersion is distributed, although the two lattice types have about the same tunes and beta functions. For the sake of simplicity, in the following we will only discuss the low emittance lattice case which can be considered as the standard lattice, knowing that the results for the Chasman Green-like case are at least as good.

The beta functions displayed in Fig. 1 satisfy well the criteria of the above 2nd step and allow to reach the targeted brilliance with appropriate undulators [1].

With reasonable sextupole strengths and while cancelling the natural chromaticities, the dynamic aperture at nominal momentum presented at Fig.2a is at least comparable to the vacuum chamber. The tune variation with betatron excursion in Fig. 2b illustrates the method of acting on $(d\nu/dy)_0$ to avoid the crossing of destructive resonances. In the horizontal phase space (z = 0) of Fig. 2.c, the relative regularity of motion attests the limited effects of resonances in the stable zone. A detailed exploration of the space phase by 2nd order tracking shows the presence of islands when the tune verifies $m\nu_x = n$, with m, n integers and n not always a multiple of the lattice period. Provided that random magnetic errors are kept small, one can consider that the dynamic aperture is not reduced since these islands are surrounded by stable regions. We suppose that the closed orbit is almost perfectly corrected, that quadrupolar default resonances are compensated with independent quadrupole power supplies, and finally that higher multipolar errors are below tolerances. Anyway, an other sextupole tuning avoiding to have $m\nu_x = n$ is available with slightly smaller dynamic apertures.

The energy acceptance is very large. Fig. 3 shows that dynamic apertures for momentum deviations up to ± 6% are still not negligible. Indeed, as can be seen in Fig. 4, the tune dependence in momentum deviation is still flat within this range and integer tunes are reached for dp/p larger than ± 10 %. These results are necessary to obtain a comfortable Touschek lifetime which is larger than 10 h in all operating modes [5]. It has to be noticed that synchrotron motion is not yet taken into account in dynamic aperture calculation but one can expect that it will induce only a marginal change.

The sensitivity to magnetic errors is relatively low. With standard dipolar errors defined as

- quadrupole misalignment : $\sigma_{x,z} = 1\ 10^{-4}$ m
- dipole field error : σ_B /B= $1\ 10^{-3}$
- dipole misalignment : $\sigma_{s,z} = 5\ 10^{-4}$ m,
  $\sigma_{\theta s} = 2\ 10^{-4}$ rad

a set of 100 samples following a gaussian distribution truncated at 3 rms deviations indicates that there are up to 96 % of stable cases. For 10 samples of these errors divided by a factor of 2 (after first turn steering or by use of girders), the dynamic aperture as displayed in Fig. 5, is still large.

4. CONCLUSION

The above decomposition of lattice optimization into five steps could appear to be trivial, nevertheless a scrupulous application of these steps seems to be necessary. The strategy is in fact simple : to keep in mind at each step the final objectives in terms of brilliance, acceptance, error sensitivity... As failing in any of these steps could compromise the final result, one has very often to go back to the first step. So this procedure is very time consuming but it seems that it is the price to pay for this kind of 3rd generation machine where one has to conciliate very high brilliance and comfortable operation.

Results so obtained are fully satisfying, but further studies remain to be done concerning effect of synchrotron motion, of insertion devices, etc.

5. REFERENCES

[1] J.-L. Laclare et al., "Status of the SOLEIL project", This conference.

[2] P. Brunelle et al., "SOLEIL : optics and performances of the source", report APD SOLEIL/A/95-03.

[3] P. Audy, Thesis, Université Paris-Sud, Orsay, France, 1989.

[4] P. Audy et al., report LNS 89-14, 1989.

[5] A. Nadji et al., "Energy acceptance and Touschek lifetime calculation for the SOLEIL project", This conference.

[6] J. Payet et al., BETA code, LNS version.

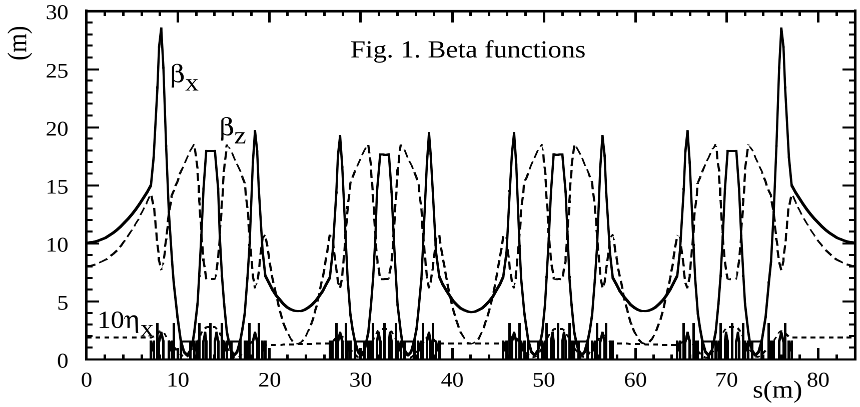

Fig. 1. Beta functions

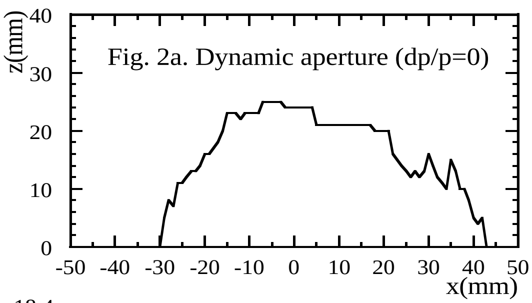

Fig. 2a. Dynamic aperture (dp/p=0)

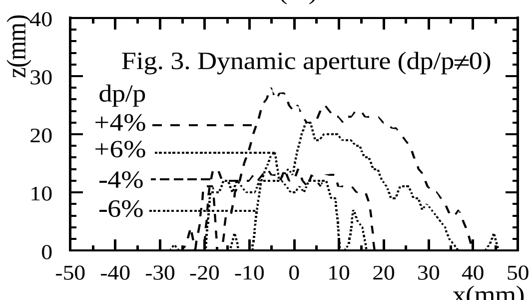

Fig. 3. Dynamic aperture (dp/p≠0)

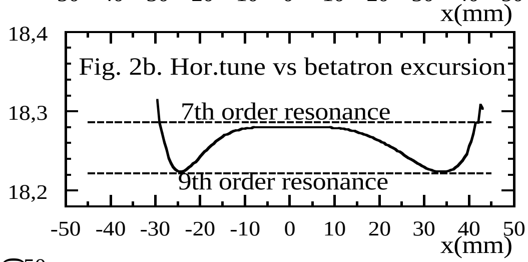

Fig. 2b. Hor.tune vs betatron excursion

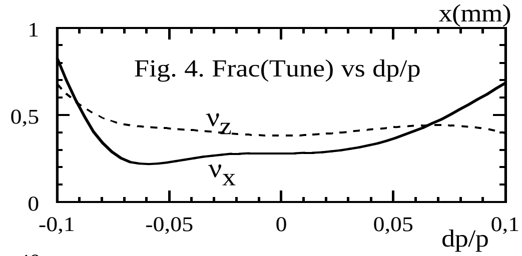

Fig. 4. Frac(Tune) vs dp/p

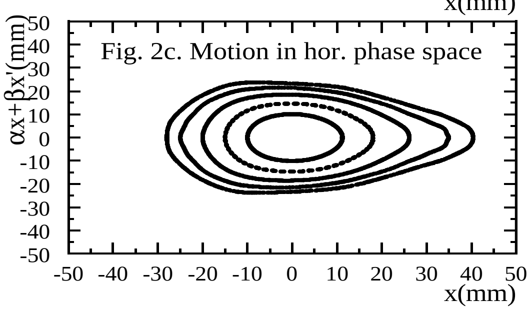

Fig. 2c. Motion in hor. phase space

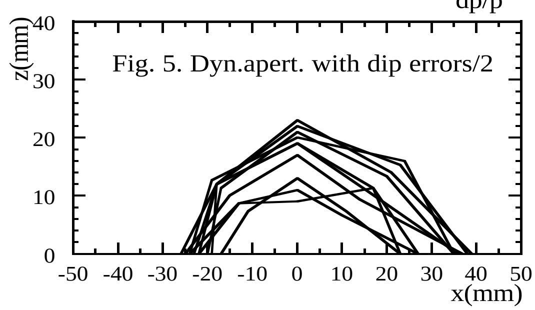

Fig. 5. Dyn.apert. with dip errors/2