SIMULATION AND CORRECTION OF THE CLOSED ORBIT DISTORTION FOR THE NEW LATTICE OF SOLEIL*

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Abstract

The SOLEIL lattice has been modified in order to satisfy the growing interest in the use of undulators as the privileged photon sources. The sensitivity of the new optics to dipolar errors has been studied. The expected values of horizontal and vertical orbit distortions are calculated analytically using statistical formulae and computed with the BETA tracking program in order to take into account the effects of the sextupoles. The number and the location of beam position monitors and correctors have been revised. We report here the closed orbit distortion and its correction, using SVD method for the minimum necessary configuration of correctors and Beam Position Monitors system.

1 INTRODUCTION

The new lattice of SOLEIL [1] is still composed of 4 super-periods (each one consisting of 4 cells), but henceforward it provides 24 straight sections instead of 16 previously. Two new straight sections have been created in each super-period by drifting apart the two quadrupole doublets located between the two Bending Magnets (BM) of the DB cell. Figure1 shows the betatron functions in half a super-period. One can see the two different types of cells.

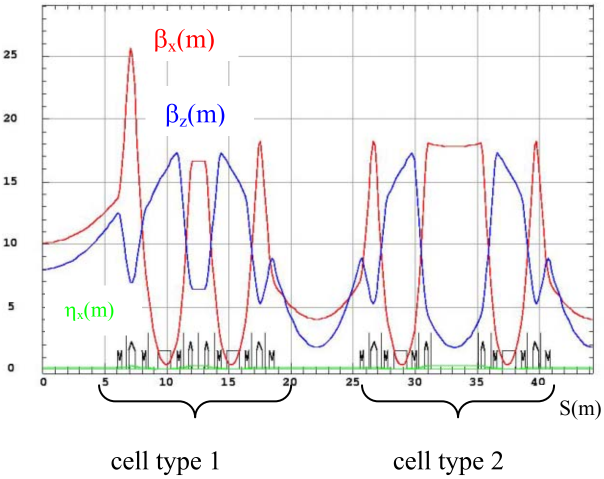

Figure 1: Optical functions for half a super-period.

The new optics tunes are around 18.29 and 10.26 respectively in the horizontal and vertical plane. This optics change necessitates a re-optimisation of the closed orbit correction scheme in order to keep the optimum SOLEIL performances. As in the previous lattice, groups of focusing and defocusing quadrupoles are rigidly mounted on girders, introducing a correlation which has to be taken into account in the simulation. There are 14 girders per super-period and they are of three types: the one for the quadrupole triplets, the one for the doublet (new straight section) and the one for the four quadrupoles in the "achromats". As in the SLS machine, the BM will be sitting on the extremities of two adjacent girders[2]. Starting from realistic displacement error settings, we estimate the Closed Orbit Distortion (C.O.D.), then we propose the new Beam Position Monitor (BPM) and corrector layout. Finally we show the results of the orbit correction and corollary different important parameters such as the number, the strength and the resolution of the correctors.

2 CLOSED ORBIT DISTORTION

Following experience at other facilities, and with present surveying/mechanical technologies, the tolerances which are thought likely to occur are shown in Table 1. The effects of these alignment errors on the closed orbit have been calculated both analytically, using statistical formulae which don't take into account sextupoles effect and numerically, using the BETA code [3] tracking program in order to take into account the latter effect.

To get a proper statistics, 200 different errors seeds have been chosen in the simulation. It should be noted that all assigned errors are gaussian distributed with a cut at $\pm 3\sigma$.

Table 1: Alignment Tolerances.

Error type	r.m.s magnitude
Quad. transverse displacement x,z	0.03mm
Girder transverse displacement x,z	0.1mm
Girder roll error	0.1mrad
BM transverse displacement x,z	0.5mm
BM longitudinal displacement s	0.5mm
BM relative field error	0.001
BM roll error	0.1mrad

Figure 2 displays the r.m.s C.O.D. calculated analytically along a super-period. Maximum r.m.s values of 4.8mm and 2.4mm are observed respectively in the horizontal and vertical plane. Using numerical calculation, the maximum values of the C.O.D. (15mm and 7mm respectively in horizontal and vertical plane) are very close to 3 standard deviation of the C.O.D. determined by the analytical approach. This indicates that the sextupole influence is statistically negligible.

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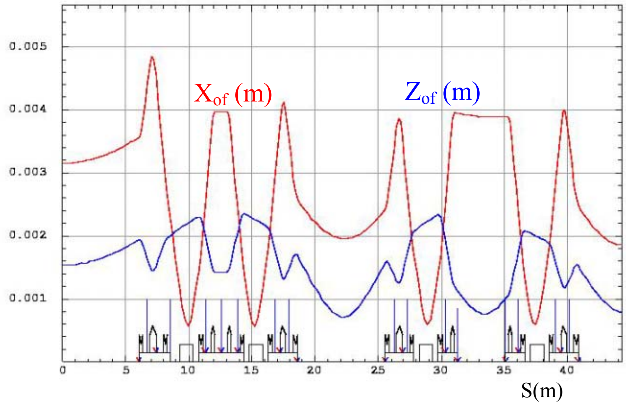

Figure 2: r.m.s C.O.D. in half a super-period.

One can note that even if the dynamic aperture is severely reduced, no case over the 200 random machines is linearly unstable.

3 BPMS AND CORRECTORS LAYOUT

The BPMs must be placed at crucial points. They are located close to the quadrupoles (*the most important source of C.O.D)* or close to the sextupoles *(C.O.D in the sextupole creates a tune shift which can deteriorate the nominal dynamic aperture)* and at both ends of each straight section (Insertion Devices *location where the correction is the most important*). Each of the four super-periods will contain 30 BPMs (7 in cell type1 and 8 in cell type2), corresponding to a total of 120 for the machine. Their positions are indicated in figure 3. Even if the phase advance does not vary too much in the "achromat", we preferred to keep the central BPM because it is located at a privileged position where the dispersion function has its maximum value [1]. This information is very important to calibrate the linear optics model and for the Beam Based Alignment.

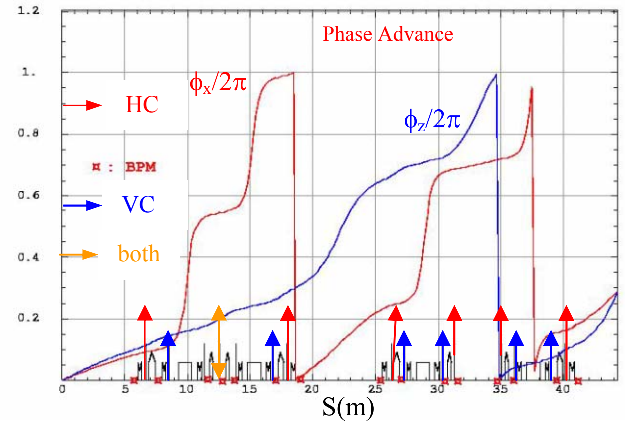

Figure 3: BPMs locations in half a super-period.

Taking into account the compactness of the lattice and discarding the possibility of incorporating the correctors inside the quadrupoles for several reasons, the correctors are most efficiently located within the sextupoles as additional coils. There are thus 7 possible correctors in cell type 1 and 8 in cell type 2, corresponding to 30 possible correctors per super-period, i.e. 120 possible correctors for all the machine. Figures 4 and 5 show the eigenvalues (respectively in horizontal and vertical plane) of the corrector to BPM response matrix in descending order when all BPMs and correctors are used. The machine periodicity is exhibited in the discontinuous changes of the eigenvalues. In the horizontal plane, the large decrease at n=56, indicates that 64 of the correctors are redundant and therefore do not contribute much to orbit correction. The same remark is made for the vertical plane, where the first large decrease is at n=32, followed by n=56 and n=64. In order to reinforce this result, we look to figure3 and see that the phase advance presents roughly 3 parts of nearly constant phase, indicating that not all the correctors are truly independent. The minimum configuration of correctors is then composed of 56 horizontal and 32 vertical correctors. Combining the information from the phase advance and the values of β_x and β_z functions, their choice becomes obvious. Starting from this minimum configuration, any addition of other (independent) correctors will be helpful if the right number of eigenvalues is used. After a systematic study, where the number of correctors was varied from 56 to 120 in the horizontal plane and from 32 to120 in the vertical plane, we choose 56 correctors in each plane. This is based on the best compromise between the number of correctors, residual closed orbit, machine performance after correction in terms of linear and non-linear optics and corrector strength (see Fig. 3). The results of the correction are then given with this configuration.

4 CLOSED ORBIT CORRECTION

The orbit correction scheme is based on the Singular Value Decomposition (SVD) algorithm. It has the advantage of being able to handle an unequal number of BPMs and correctors and to minimize the strengths of the correctors. The results of the correction of 200 random error sets are given in the following figures 6 and 7.

In the horizontal plane, the maximum residual closed orbit is close to 500µm and always located in the BMs. This value will be improved by a proper distribution of the BMs around the ring according to their magnetic length, after magnetic measurements. In the straight sections, the r.m.s residual value is around 25µm and the maximum value is less than 100 µm. In the vertical plane, the residual closed orbit is lower. Its maximum is about 150µm in the BMs. In the straight sections, the r.m.s residual closed orbit is less than 15µm and the maximum is around 50µm. With no errors on the BPMs, the maximum r.m.s values and the maximum values of the correctors to correct the above C.O.D. are listed in the Table 2.

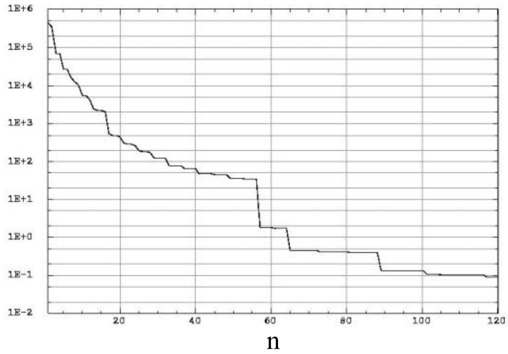

Figure 4: Eigenvalues in the horizontal plane.

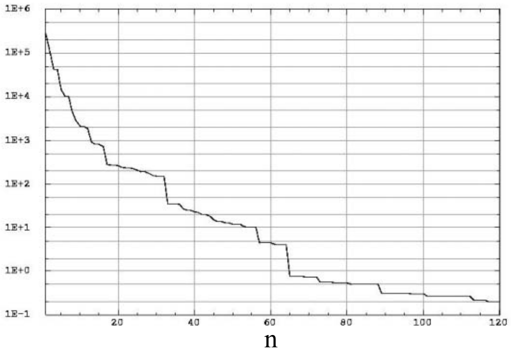

Figure 5: Eigenvalues in the vertical plane.

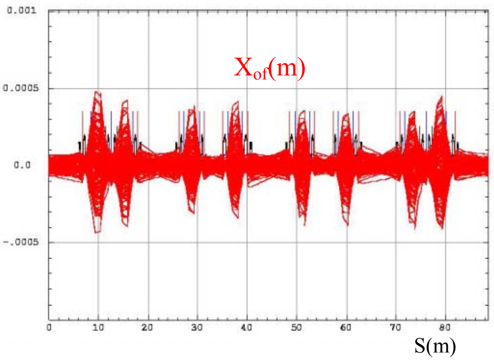

Figure 6: Residual horizontal closed orbit after correction for 1/4th of the lattice.

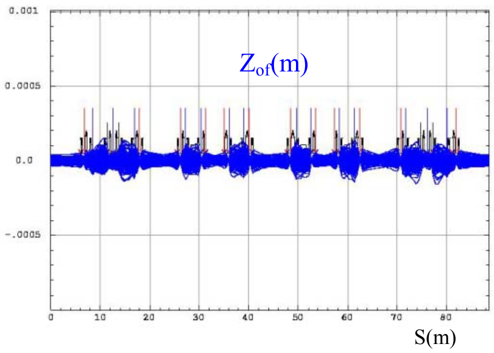

Figure 7: Residual vertical closed orbit after correction for 1/4th of the lattice.

Table 2: Deflexion Angles of the Correctors after Performing the Orbit Correction

	Horizontal plane	Vertical plane
Max r.m.s value	0.126mrad	0.0638mrad
Maximum value	0.372mrad	0.188mrad

Compared to the values obtained in the case of independent elements, these values are lower by 1.25 and 2.2 in horizontal and vertical plane respectively.

When taking into account BPM displacement errors of 100µm-r.m.s (in each plane) and output accuracy of 0.2µm-r.m.s, the maximum values for the correctors become 0.401mrad and 0.238mrad respectively in the horizontal and vertical plane. Taking into account the probable difficulty of the first turn steering, the ground settlement effect (the machine will be re-aligned only twice a year), exotic optics (such as low α, lower emittance …) which can be more sensitive, position and angular closed orbit bumps in different locations of the machine, we propose to design the maximum corrector kick at 0.8mrad which is a factor of two larger than the maximum value obtained above. In addition, each corrector must be capable of steering the beam by an amount that is small compared with the beam stability tolerance. Taking into account an expected tolerance on the BPMs resolution of 0.2µm-r.m.s, we deduce statistically that 0.02µrad is the minimum r.m.s value for the correctors variation. The two extreme values (0.8mrad and 0.02µrad) conduct to a resolution of 2.5 10^{-5} and a 16 bits power supply for the correctors.

5 CONCLUSION

Even if all the sextupoles will be equipped with coils for dipolar correction, we showed here that a minimum configuration making use of 56 correctors in each plane and 120 BPMs allows to obtain satisfactory results. With this correction system, the maximum corrector strength required to correct the errors of Table 1 and BPM displacement errors is of 0.4mrad. However, it was decided to take a factor 2 margin and to design the maximum corrector deflexion at 0.8mrad.

6 REFERENCES

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[3] J. Payet, BETA version LNS, LNS/GT/93-06.