New Optics for SOLEIL[1]

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Abstract

More flexible optics with 12 and 16 periods have been studied in order to reach an emittance value in the range of 4 nm.rad at 2.15 GeV. A two superperiod machine (2 long straight sections) is being optimized to keep low emittance and good dynamic aperture. Two solutions are tested to match the optical functions, one being a 6 quadrupole system producing a unit transfer matrix.

1. INTRODUCTION

A 8 fold symmetry structure, based on a modified DBA lattice, has already been optimized and studied in details [1].

Recently, there was a further request for more flexibility in order to provide two more modes of operation : high brilliance and Free Electron Laser (FEL). So a new storage ring configuration, with a total length about 320 m, is currently being studied with the same basic structure (12 or 16 periods) providing emittances of 4 nm.rad and 2 nm.rad respectively and tunable up to 30 nm.rad for FEL operation [2]. The first results on the optimization of a 2 superperiod machine in terms of optical function matching and dynamic aperture are presented here.

2. LINEAR LATTICE CHARACTERISTICS

2.1. Basic Regular Structure

The optical functions have been optimized to reach small emittances and to provide low vertical beta-function (βz) in straight sections for insertion device, the smaller emittances being obtained with non zero dispersion everywhere in the lattice. Table 1 shows the reached emittances compared to the theoretical minimum values of a Chasman-Green structure.

Table 1.

	With achromat		Without achromat	
Emittance (nm.rad)	Theoretical minimum	Reached value	Theoretical minimum	Reached value
12 periods	7.9	11	2.6	3.9
16 periods	3.3	4.8	1.1	1.7

The optical functions over one period are shown in figure 1 and figure 2 for structures with 12 (4 nm.rad) and 16 (1.7 nm.rad) periods respectively. The horizontal beta-function (βx) is smoother in the 16 period configuration.

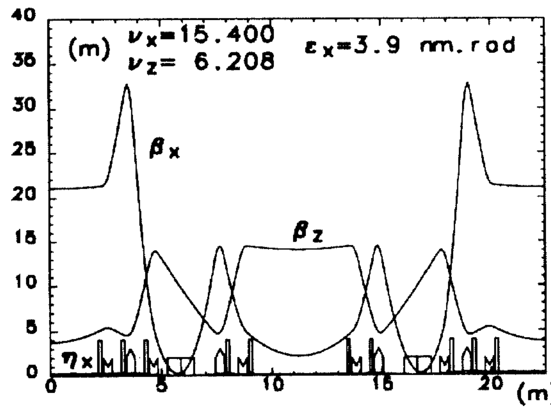

Figure 1.

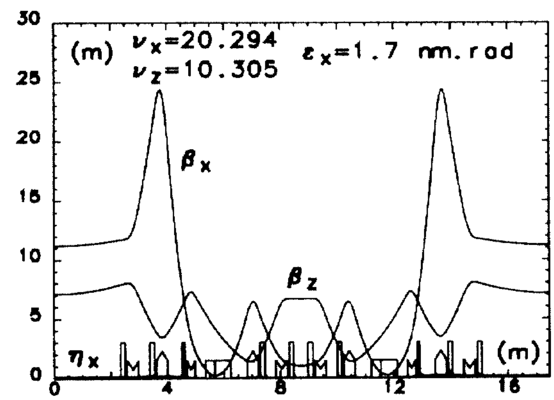

Figure 2.

The working point of these machines must be chosen, taking into account the phase advance in the long straight section between the arcs, such to avoid the proximity of low order nonlinear resonances and to minimize the closed orbit error sensitivity.

2.2. Racetrack Configuration

The 2 superperiod machine consists in the 12 or 16 periods described previously and two long straight sections with 10.3 m free space for FEL operation.

To keep the emittance, the optical functions in the arcs must remain unchanged. The values of βx and βz required for the FEL operation are about 6 m but with a higher emittance (30 nm.rad) and lower energy (1.5 GeV). In order to satisfy these constraints, six independent quadrupole families are needed.

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Therefore two solutions can be contemplated :

1) The last three quadrupoles of the arc are disconnected from their families and an additional triplet is inserted at each extremity of the long straight sections (figure 3).

2) The regular structure of the arcs remains unchanged and six independent quadrupoles are used to match the beam parameters and to provide a phase advance of 2π between the arcs (figure 4).

The first solution has been tested for the 16 period arcs (11 and 2 nm.rad) and the second with the 12 period arcs (4 nm.rad). The optic is less flexible with solution 1 than with solution 2. With solution 1, the high value of βx in the long straight sections, necessary to maintain the 2 nm.rad emittance, is unfavorable for an insertion device.

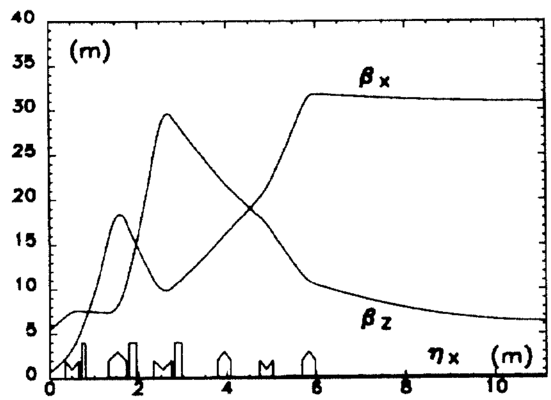

Figure 3.

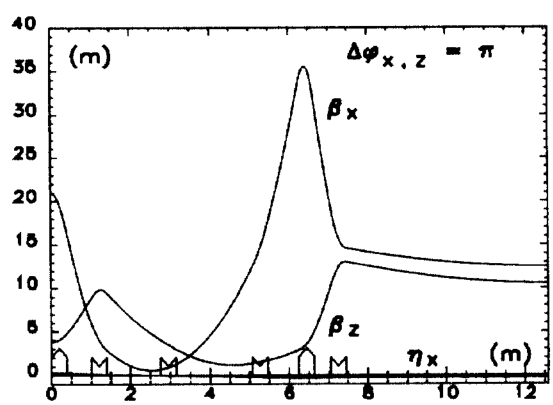

Figure 4.

3. DYNAMIC APERTURE OPTIMIZATION

3.1. Procedure

In the low emittance lattice where there are no dispersion free straight section it is not possible to separate chromaticity correction from dynamic aperture optimization. Therefore the optimization procedure has to satisfy simultaneously the following constraints :

- compensation of the natural chromaticities,
- minimization of third order stop bands,
- adjustment of tune shifts with amplitude to avoid the crossing of low order resonances.

Figure 5 shows the variations of the fractional part of $v_x = f\ (x,\ z = 0)$ and $v_z = g\ (z,\ x = 0)$ in the case of the 2 superperiod lattice (solution 2) for 2 different sextupolar correction tunings.

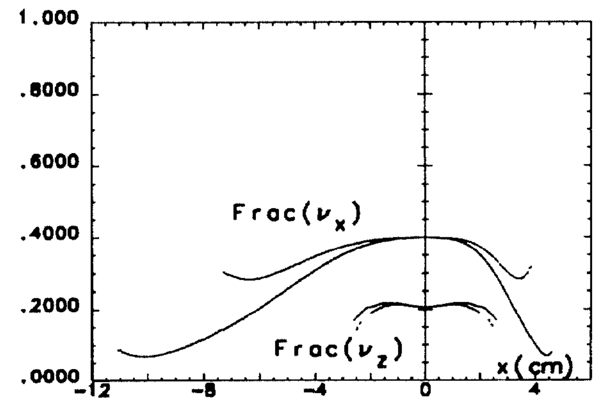

Figure 5.

3.2. Basic Regular Structure

Five sextupole families are necessary for chromaticity compensation and tune shifts with amplitude adjustment. Because of the strong focusing, the required sextupolar fields are very strong and cannot be created in quadrupoles as foreseen in the previous design [1].

The optimized dynamic aperture for the 12 period machine is greather than the physical aperture needed for both a good injection rate and a good gas lifetime. For the 2 nm.rad lattice, it is only close to the physical aperture and requires further optimization. These results are used as starting points for the 2 superperiod lattice optimization.

3.3. Racetrack Configuration

With 2 superperiods the number of systematic resonances is increased when compared to the 12 or 16 period machine. A reduction of the dynamic aperture is thus expected.

For solution 1, 8 sextupole families are used (5 in the arcs and 3 in the modified triplet of the arcs). Figure 6 shows the optimized dynamic aperture compared with the 16 period regular machine. The expected reduction appears clearly. The dynamic aperture becomes close to the physical aperture. No working point can be far enough to avoid the very strong effect of the resonances.

For solution 2, only 5 families in the arcs are used. The compensation of the nonlinear effects obtained in the regular basic structure remains approximatively valid for the

Racetrack Configuration because of the unit transfer matrix between the arcs. So the dynamic aperture is only slightly modified compared to the 12 period machine as shown in figure 7.

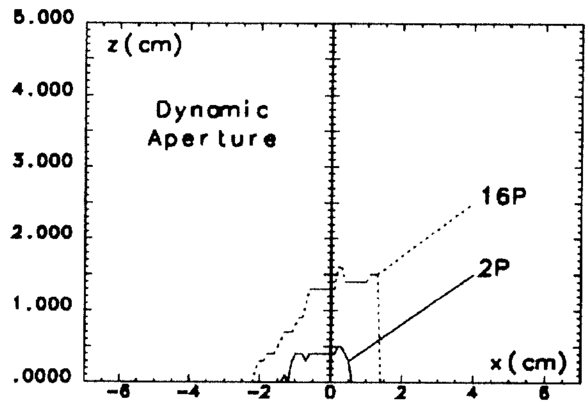

Figure 6.

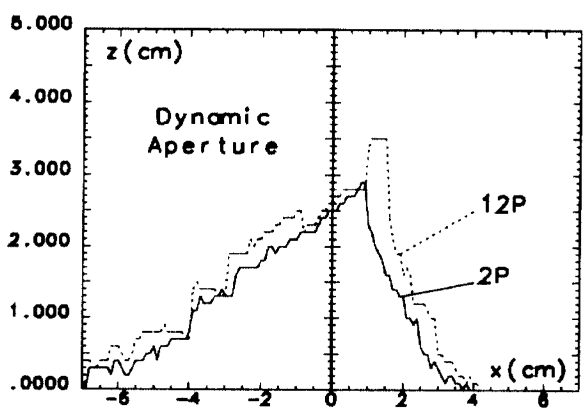

Figure 7.

4. CLOSED ORBIT ERROR SENSITIVITY

The stability of the Racetrack Configuration against closed orbit errors has been tested in the case of solution 2. Following standard deviations of magnetic elements errors have been considered :

• quadrupole transverse displacements	$1\ 10^{-4}$ m
• dipole longitudinal displacement	$2\ 10^{-4}$ m
• dipole rotation about longitudinal axis	$5\ 10^{-4}$ rad
• dipole relative magnetic field error	$5\ 10^{-4}$

Over 100 sets of random errors within 3 standard deviations, the machine remains stable and the maximum orbit excursion is about 25 mm in both horizontal and vertical planes.

5. CONCLUSION

Low emittances (≤ 4 nm.rad) are reached in a two superperiod ring at 2.15 GeV. The matching of optical functions requires 6 additional quadrupole families. The unit matrix scheme is a solution to obtain a flexible optic and a very good dynamic aperture in the case of the 12 period arcs.

Studies are still going on and this solution will be applied now to the 16 period machine to reach smaller emittances while keeping a maximum length about 320 m.

Other studies are in progress aiming to :

• reduce the β-maxima by reversing quadrupole triplet polarities (figure 8),

• ease the matching of β-function in the straight sections in order to optimize the photon emission profile from insertion devices,

• give more flexibility to the optics in the long straight sections for the 30 nm. rad FEL operation.

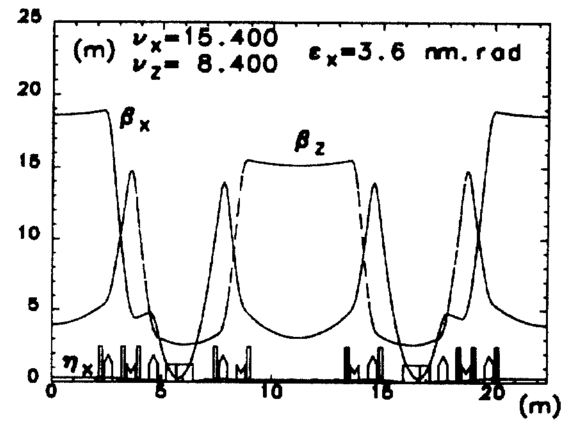

Figure 8.

The main criteria to choose the design configuration and the emittance of SOLEIL will be a both flexible optics and good dynamic aperture (taking into account the effect of undulators and wigglers).

6. REFERENCES

[1] M.-P. Level et al., "SOLEIL a New Synchrotron Radiation Source for LURE", in the Proceedings of Particle Acceleretator Conference, Washington, USA, May 1993, Vol. 2, pp. 1465-67.

[2] G. Flynn, C. Herbeaux, M.-P. Level, A. Nadji, H. Zyngier, "New Developments on SOLEIL, the LURE Project", this conference.