STUDY OF THE NON-LINEAR BEHAVIOUR OF PARTICLES AND THE EFFECT OF ID IN THE LSB STORAGE RING

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Abstract

The LSB will be a 3rd generation light source operating in the energy range 2.5-3 GeV and at low emittance (ca. 10 nm·rad). Effects due to non-linear terms are very critical in this kind of accelerator. In this paper, we present a study of the effect on the dynamic aperture and on the tune shift. The linear and non-linear effects due to the insertion devices in the LSB storage ring have also been evaluated using the RACETRACK code. The calculations have been carried out for both on-energy particles and for a momentum deviation up to ±3%.

1 INTRODUCTION

The LSB [1] will be a third generation light source working at an energy of 2.5 GeV. The lattice is a TBA formed by 12 cells with gradient in the bending magnets. Table 1 shows the main parameters of the machine. A more detailed description of the lattice is given in these proceedings [2].

Table 1: Machine Parameters

Energy	2.5	GeV
Number of Cells	12	
Cell Length	20.987	m
Circumference	251.844	m
Q_x	14.20	
Q_v	8.30	
Equilibrium Emittance	8.35	nm·rad
Coupling	5%	
Horizontal Emittance	7.85	nm·rad
Vertical Emittance	0.5	nm·rad
Relative Energy Spread	$8.61\cdot10^{-4}$	
J_x	1.50	
J_v	1.00	
J_e	1.50	
α_n	$1.9\cdot10^{-3}$	
Critical Photon Energy	4.2	keV
Harmonic number	420	
RF Frequency	500	MHz

2 CHROMATICITY CORRECTION

The chromaticity correction is done with two sextupole families placed inside the achromat. The sextupole strengths are selected to provide a low positive chromaticity. The values of the sextupole strengths are:

$$S_2\cdot L1 = 15.582\ m^{-1}$$
$$S_2\cdot L2 = -10.1\ m^{-1}$$

where L1 and L2 are the length of each sextupole. A third sextupole family is located in the straight sections to achieve extra flexibility and to compensate possible non-linear effects. At the present moment, the strength of this family is set to zero.

3 DYNAMIC APERTURE

The sextupolar field will reduce the maximum possible (stable) oscillation amplitude of the particles. This area is called the dynamic aperture (DA). In order to have a reliable machine, DA should be similar to the physical aperture, and about 50 times the electron beam size for each plane ($DA\approx50\sigma_{H,V}$).

The dynamic aperture is computed by tracking a single particle for 1000 turns. We have used a different number of lattice codes (MAD, BETA, OPTICK and RACETRACK) to evaluate it. Figure 1 shows the dynamic aperture for the ideal lattice (no errors in the magnets), for an on-energy particle and for particles with energy deviation of ±3%, calculated by MAD [3]. The dynamic aperture for a machine with dipolar (displacement of magnets and errors in the dipolar field of the bending magnets) errors and corrector system is presented in Figure 2. The values (rms) of the errors applied to the lattice are:

- Transverse misalignment of magnets: $\Delta x,y = 0.1$ mm
- Roll angle misalignment of quads: $\Delta\theta=5\times10^{-4}$ rad
- Field imperfections in the dipoles: $\Delta B/B_0 = 5\times10^{-4}$

In all the cases that have been studied, the dynamic aperture is larger than 50σ in both directions (more than 80 times in the horizontal and 400 in the vertical) for on-energy particles, and the different codes agree with these results.

4 TUNE SHIFT

The presence of the sextupoles in the machine will affect the tune shift with the amplitude and the energy dispersion. The working point and the tune shift with the energy deviation (up to ±3%) are shown in Figure 3.

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This figure also shows the resonances up to 4th order, including the non-superperiodic resonances.

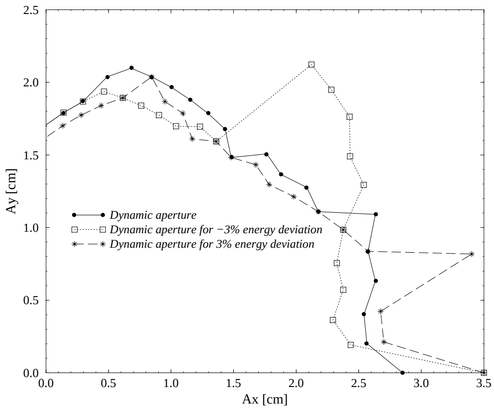

Figure: 1 Dynamic aperture for the ideal machine.

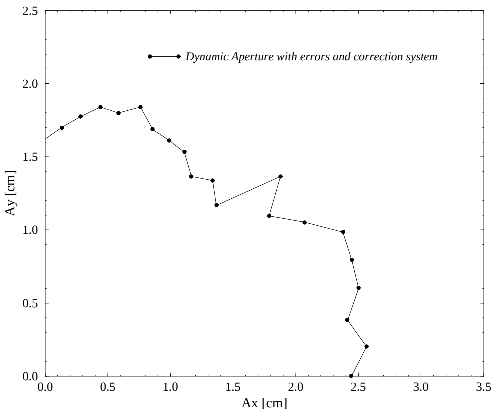

Figure: 2 Dynamic aperture with orbit errors and correction system.

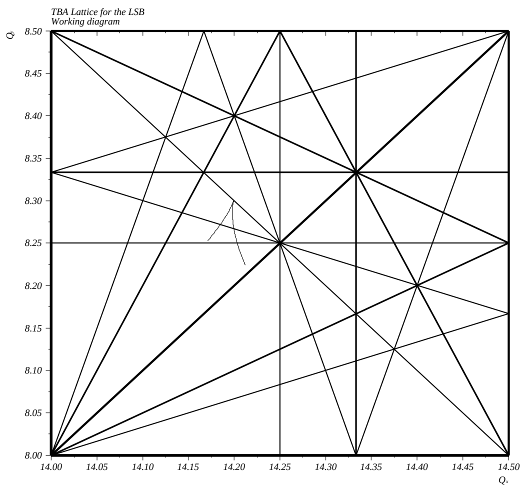

Figure 3: Working point and tune shift with the energy deviation.

The tune shift with the amplitude in both directions (horizontal and vertical) is shown in Figures 4 and 5.

5 EFFECT OF INSERTION DEVICES

In a modern synchrotron light source, the dynamic of the electrons also depends on the characteristics of the insertion devices (IDs). The presence of IDs with high K value can reduce the dynamic aperture up to a working point where a safe operation of the machine is not possible. The insertion devices considered in this paper are described in more detail in [4]. All of them are 6 meters long.

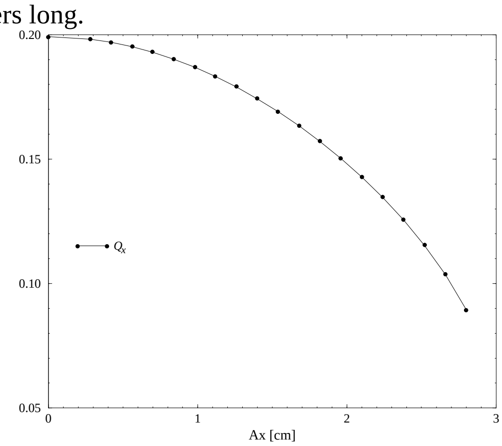

Figure: 4 Tune versus amplitude in the horizontal plane.

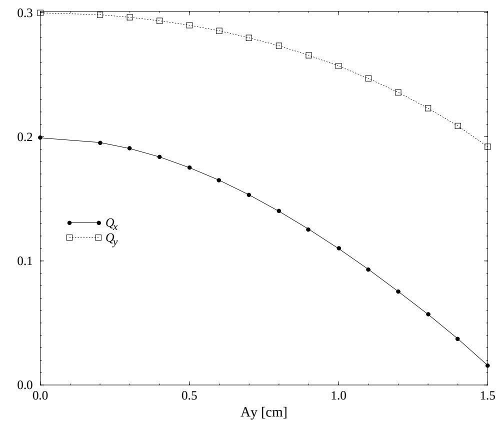

Figure: 5 Horizontal and vertical tune versus vertical amplitude.

5.1 Linear effects in the lattice due to the IDs

The RACETRACK code [5] has been used to compute the effect of the IDs in the machine. Each ID has been considered independently, ie only one ID has been put in the lattice at a time, and always has been at the same position for each ID. In all the cases (also for dynamic aperture calculations), the ID has been considered as a linear element (like a quadrupole in the middle of the straight). The strength of this quadrupole is given by the ID constant (K) and by its length.

The first approach to see how big are the effects of the ID in the machine is to compute the changes in the vertical tune (tune shift) and in the vertical beta function variation (the beta shift), in our case, where the DA is computed. Table 2 shows the characteristics of the IDs and the tune, betatron and chromaticity shifts corresponding to the vertical plane. As expected, these values are proportional with the K values.

Table:2 List of the linear ID effect in the machine.

ID	**λ [cm]**	**K []**	**ΔQ_v []**	**$\Delta\beta_{DA}$ [m]**	**$\Delta\xi_v$ []**
U46	4.6	2.1	-0.004	0.09	0.03
U60	6.0	3.7	-0.008	0.16	0.05
W95	9.5	10.7	-0.03	0.5	0.2
W180	18.0	31.9	-0.06	1.13	0.5

5.2 Dynamic Aperture Changes due to the IDs

In the case of the undulator U46 the DA changes are very small, similar to the bare machine. For U60 the changes on the dynamic aperture are larger than the previous case, but they are still small. For all IDs the tune has been adjusted with the quadrupoles located in the straight sections. Also the chromaticity has been compensated using the sextupoles located in the achromat region (see Figure 6).

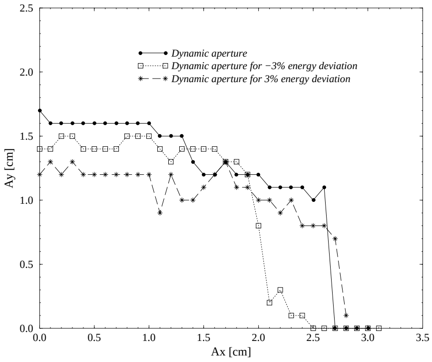

Figure: 6 Machine dynamic aperture with U60 in.

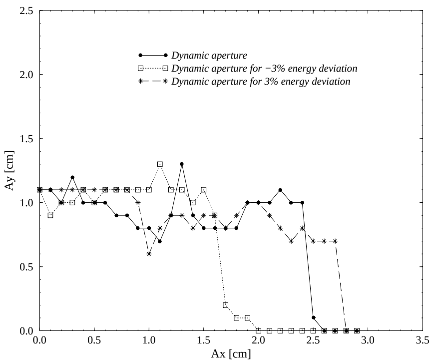

Figure: 7 Machine dynamic aperture with W95 in.

In the case of the multipole wigglers the situation is not as good as in the undulator case. The intense magnetic field produces a larger impact on the beam dynamics and the dynamic aperture reduction is quite dramatic. For instance, in W95 (Figure 7) the vertical dynamic aperture has been reduced to the half the value for all $\Delta p/p$ values. Particularly for $\Delta p/p$=-3% this reduction is in both planes. The same behaviour is observed for W180 (Figure 8), and in this case the reduction is slightly bigger.

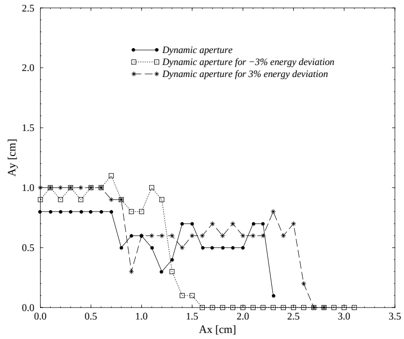

Figure: 8 Machine dynamic aperture with W180 in.

However, when we compensate the tune shift and the chromaticity, as sow in the previous figures, we recover partially the horizontal dynamic aperture in all the cases. The vertical aperture is still reduced by a factor of 2, but in this plane the beam is much smaller and the dynamic aperture is still similar to the physical one [6]. In the worst case, the dynamic aperture is still 200 times the vertical beam size and 70 in times the horizontal for on-energy particles.

6 CONCLUSIONS

The non-linear effects due to the presence of the sextupoles in the linear lattice are shown to be small enough, providing a large dynamic aperture and small tune shift. The effect of the insertion devices has been studied and the reduction of the dynamic aperture has been observed, further studies will be done to increase the dynamic aperture with the insertion devices included, playing with the harmonic sextupoles in the straight sections and matching the alpha values in the middle of the insertion devices.

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