ALTERNATIVE LATTICE SETTINGS FOR ALBA STORAGE RING

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Abstract

ALBA is a new synchrotron light source under construction near Barcelona, Spain. The lattice for ALBA [1, 2] is based in an expanded DBA optics, with finite dispersion in the straight sections. In order to simplify commissioning and minimize the possible impact of high field wigglers, to achromatic optics are reviewed, including the non linear optimization.

INTRODUCTION

The present lattice for ALBA has been selected in order to provide minimum betas at the medium and long straight sections, and minimum effective emittance, in order to provide a small beam cross section in the straight sections for insertion devices, by allowing some residual dispersion in the straights [1, 2]. The working point has been selected to provide good energy acceptance and dynamic aperture (DA) at the nominal chromaticity of (+1,+1)

To minimize the impact of superconducting wigglers placed in a non-zero dispersion straight in the DA, and the convenience of having a pure achromat lattice for commissioning, two different achromat lattices has been developed. The first one has zero dispersion in both medium and long straight, and the second one only in the long straight. Both lattice have the same working point as the original, and the sextupoles settings have been matched to provide a maximum energy acceptance and DA.

LINEAR LATTICE MATCHING

MADX [3] has been used to find the quadrupole settings in each case. This software is well known as an optimal tool for such studies, in particular the MATCHING command, which will be intensively used in this section. In each case, we start from the ALBA-25 (the nominal optics[2]) quadrupole settings .

Zero Dispersion in the LMSS and LSS

In this case, the lattice has been matched to provide zero dispersion in the middle and long straight, zero alpha for both planes in the middle (to keep the symmetry of the lattice), and small values of the beta functions in the middle and long straight. Figure 1 shows the best solution found, know as A25-LMSS. Table 1 shows the main parameters.

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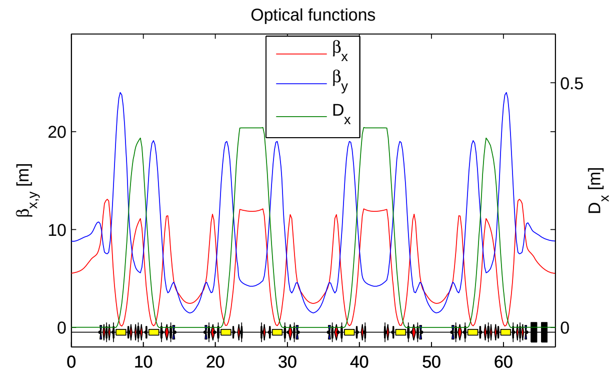

Figure 1: Half quadrant optics of ALBA-25 with zero dispersion in the MLSS and LSS.

Zero Dispersion only in the LSS

In this, case (A25-LSS) a small amount of finite dispersion is allowed in the middle straight sections, with values similar to the original lattice. Figure 2. shows the optical functions.

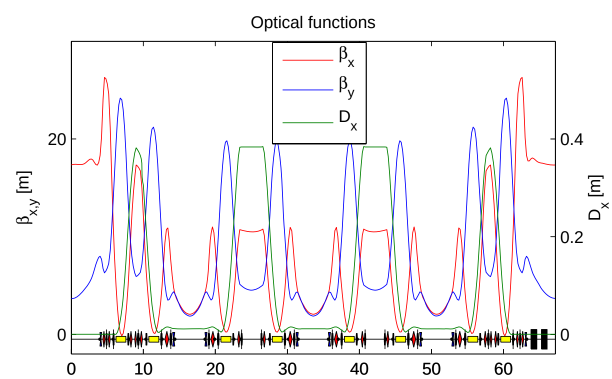

Figure 2: Half quadrant optics of ALBA-25 with zero dispersion only in the LSS.

Table 1 shows the most relevant parameters for the reference optics and the two new lattices. The new required strengths of the quadrupoles are well within the margin of the magnets of ALBA, currently in production and evaluation, with some safety margin.

SEXTUPOLE SETTINGS

A new procedure has been developed using the AcceleratorToolbox to evaluate the settings of the sextupoles for (+1,+1) chromaticity, while optimizing the DA.

Table 1: Parameters of the three lattices. The vertical beam size is calculated for the nominal case of 1% coupling

	ALBA-25	MLSS	LSS
Tunes:			
Q_x	18.18	18.18	18.18
Q_y	8.37	8.37	8.37
Emittance [nm]	4.5	10	10
Chromaticities:			
C_x	-39	-39	-46
C_y	-27	24	-25
Beam size at IDs:			
σ_x [μm]	135	157	145
σ_y [μm]	7	12	14

In the A25-LSS and A25-LMSS lattices some sextupoles are placed in zero dispersion regions. Those sextupoles, the ones placed on the zero dispersion straight, do not contribute to the chromaticity and can be used to optimize the dynamic aperture. The typical approach consists in separating the sextupole families in those two groups. However, setting the chromaticity (2 constrains) do not fix all the sextupole values in the non zero dispersion regions (5 values). Within this 3 (5-2) remaining degrees of freedom, the DA can have large changes, specially the off momentum DA. For this reason is better to in account this 3 degrees of freedom as well as the sextupoles in the zero dispersion zones (4 values).

The starting point to optimize the DA is the one with the the sextupoles at zero (natural chromaticity). At this setting, the tune for off momentum particles is to far away from the nominal one, and the resonances in between will prevent the optimization path towards the target chromaticity (+1,+1). Hence the method employ, performs an optimization at constant chromaticity with 7 $(3 + 4)$ free parameters in the optimization.

Optimize at Constant Chromaticity

A setting of the sextupoles can be understood as a vector with nine components, each one being the integrated sextupole strength for each family.

$$m = (md_1, md_2, md_3, md_4, md_5, mf_1, mf_2, mf_3, mf_4) \tag{1}$$

Where md_i are the sextupole strengths of the i-th defocusing family, while mf_i are the sextupole strengths of the i-th focusing family. Constant chromaticity implies two linear constrains , one for each plane, and we can define the constrains with a 2×9 matrix:

$$\begin{aligned} \xi_x &= \sum_{i=1:9} a_{x,i}\, m_i + \xi_{x,0} \qquad & A_\xi &= a_x \times a_y \\ \xi_y &= \sum_{i=1:9} a_{y,i}\, m_i + \xi_{y,0} \qquad & A_\xi m + \xi_0 &= \xi \end{aligned} \tag{2}$$

where $a_{x,i}$ and $a_{y,i}$ are the sensitivity coefficients of the i-th sextupole family for the x and y planes respectively and A_ξ is the above mentioned 2×9 matrix. Linear algebra tells that the settings accomplishing this restriction can be written using the null space matrix of the that previous matrix:

$$m_\xi = N_\xi r + m_0 \quad N_\xi \quad = null(A_\xi) \tag{3}$$

where m_ξ is an arbitrary sextupole setting accomplishing the chromatic condition, r is an arbitrary $7D$ vector, m_0 is a the sextupole setting accomplishing the chromatic condition with the minimum modulus and N_ξ is the null space matrix of A_ξ.

Before the DA: The Tune Shifts

However, even if optimization is at constant chromaticity, the non linear terms in the tune with momentum deviation behavior may bring the tune at high energy deviations ($\pm 3\%$) beyond important resonances, leadin to holes in the DA, which are not seen in the DA area calculation. For this reasons, before optimizing the DA area, the tune shifts are minimized. The optimization is based on a SIMPLEX [4] routine. Some extra features have been added, as resizing after a convergence (it converges only after two consecutive convergences at the same point). The cost function contains the first and second derivatives with the amplitude, and the second and third derivatives with the energy (the first one is the chromaticity and is fixed).

Optimizing the DA

After the optimization of the tune shift, the behavior at small amplitudes is quite good, but still the DA area can be around few tens of the mechanical aperture area. To completely optimize the DA, it will be used as cost function. The first try was to define the cost function as the DA area at -3% momentum deviation, which is, according to experience with the nominal lattice the worse case. However, several different cost functions where also tested, for example the average of the DA at two energies: -3% and 3%. Of course in this case, the optimization is more robust, in the sense that it will probably lead to a better solution, but the optimization is slower, and less solutions are obtained. To speed up the optimization, only 7 points of the DA border are calculated, and the criterion for the stability is surviving to 256 turns, using a SIMPLEX routine with the above mentioned modifications.

Results

The performances of the lattices A25-LMSS and A25-LSS with their optimized sextupoles are presented in this section. For each optimization, and for each lattice, up to 10 different solutions have been compared (starting in a different point in the solutions space). The solution kept in each case is the one that minimizes the required sextupole strength. The final values of the sextupolar strength are well within the margin of the sextupoles and power supplies of the ALBA machine.

Figures 5 and 3 show the DA on and off energy (up to $\pm 3\%$) for the two lattices. In all cases the DA is larger than the physical limit (the septum is locate at 18 mm in the horizontal plane and the vertical aperture is close to 6 mm).

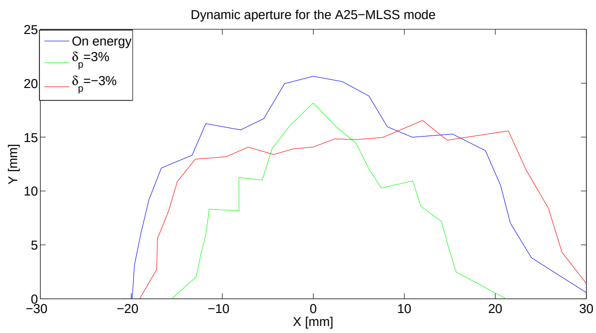

Figure 3: Dynamic aperture for the A25-LMSS

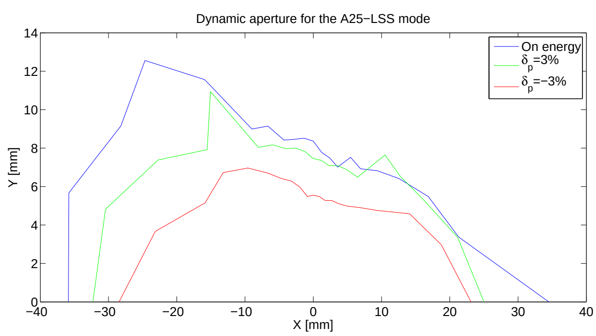

Figure 4: Dynamic aperture for the A25-MSS

The FMA for the A25-LMSS for the on energy particles is plotted in Figure. 4, as indicated, the two main resonances that could limit the stability are $2\nu_x - \nu_y = 28$ and $\nu_x + 2\nu_y = 35$. Possibly, a better pattern could be obtained shifting the working point to the lest of the diagram in order to stay further from those resonances.

The FMA for the A25-LSS is plotted in Figure. 6, the main resonances appearing in the aperture are of higher order than the lines shown (7th or 8th order possibly)

The energy acceptance, relevant for the Touschek lifetime, was also evaluated in the two case, with values above 2.5 % in the two cases.

CONCLUSIONS

The values for the emittance and the beam sizes still provide a quality beam if the use of this lattice for user operation is required. The method developed to calculate the settings of the sextupoles produces good values of the DA and energy acceptance and can be employ to optimize the nominal lattice in presence of insertion devices.

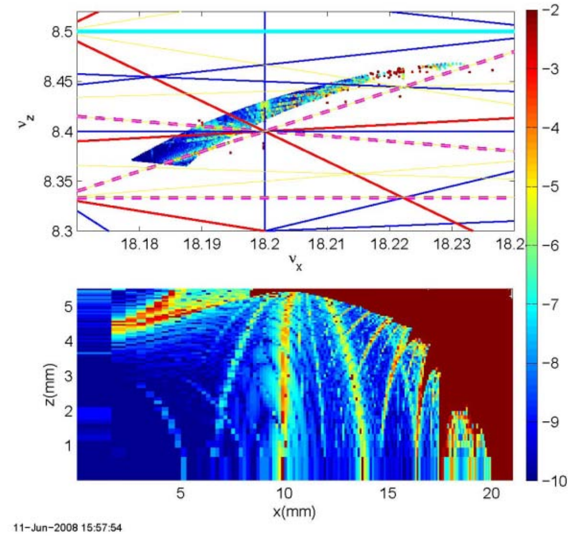

Figure 5: FMA in the $x - y$ plane for the best sextupoles setting found for A25-MLSS

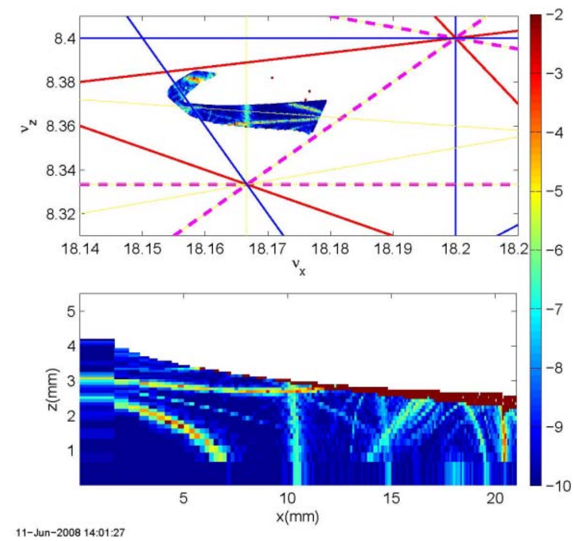

Figure 6: FMA in the $x - y$ plane for the best sextupoles setting found for A25-LSS

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