ALBA DYNAMIC APERTURE OPTIMIZATION

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Abstract

The lattice of ALBA, the 3 GeV synchrotron light source in Spain, provides extremely low emittance of the beam. It is known that such lattices require strong sextupole magnets to compensate natural chromaticities. The paper describes strategy and results of the ALBA dynamic aperture optimization including both tune point selecting and sextupoles arrangement to increase the DA size.

INTRODUCTION

ALBA will be a 3rd generation light source to be built in Cerdanyola near Barcelona (Spain). The storage ring working at 3 GeV with circumference of 268.8 m, has been designed for a maximum current of 400 mA. The lattice is based on an extended DBA structure and has four fold symmetry of nominal emittance of 4 nm [1]. Fig.1 shows the optical function for the nominal lattice ALBA-25.

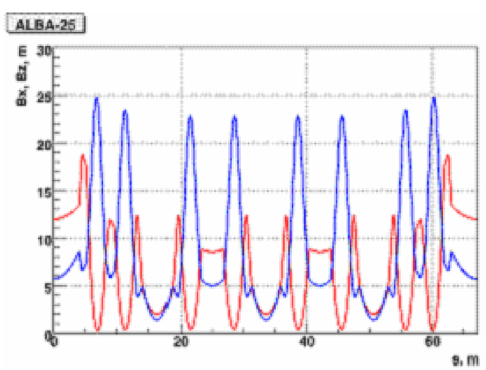


Figure 1: Machine functions along the ALBA-25 ring.

Table 1 lists main parameters of the storage ring.

Table 1: Main parameters of ALBA-25

Energy	3 GeV
Circumference	268.8 m
Current	400 mA
Tunes	18.25/8.37
Chromaticity	-39/-27
Emittance	4.4 nm-rad

To study an ability and potential performance of the ALBA light source lattice with low emittance and large dynamic aperture, we have considered several alternative tune points in the rather large tune area. Results of the study are given in this paper.

SEVEN ALBA TUNE POINTS

Seven alternative tune points for the ALBA lattice are listed in Table 2.

Table 2: ALBA light source alternative tune points

Points	Qx	Qz	Cx	Cz
ALBA-25	18.25	8.37	-39.6	-26.9
1	18.25	8.75	-42.2	-25.7
2	18.25	9.25	-45.6	-25.7
3	18.75	8.25	-44.3	-28.5
4	18.75	8.75	-46.7	-27.2
5	18.75	9.25	-49.6	-26.3
6	19.25	8.25	-50.1	-30.2
7	19.25	8.75	-53.2	-27.5

For each point the following procedure is applied:

- The lattice functions are matched carefully as close as possible to the reference ones of ALBA-25
- On- and off-energy (for ±3% momentum deviation) dynamic aperture is optimized by the method described briefly in the next section
- Dynamic aperture tune scan is performed to define the maximum aperture in the vicinity of the particular point
- All particular tune scans is combined in a single plot to obtain the general view on the ALBA dynamic aperture in the large tune area

Results of the procedure described are discussed below.

DYNAMIC APERTURE OPTIMIZATION

We propose to correct the chromaticity by N small steps along the vector $\vec{\xi} = (\xi_{x0}, \xi_{y0})$ as it is shown in Fig.2. At each step 1/N-th fraction of the horizontal and vertical chromaticity is compensated by a single (in some sense the best for this particular step) pair of focusing and defocusing sextupoles (SF_i, SD_j).

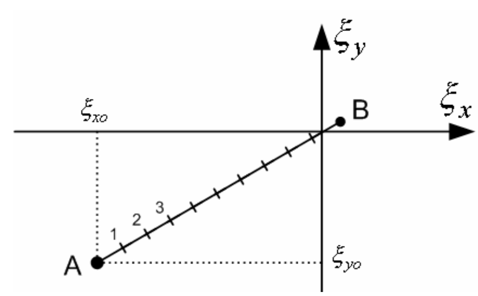


Figure 2: Step-by-step chromaticity compensation. A and B indicate initial and final points respectively.

To find the best pair of sextupoles, we try all possible (SF, SD) - combinations and the pair demonstrating the largest dynamic aperture are fixed at this step. At the next steps the procedure is repeated until the chromaticity will reach the desired value.

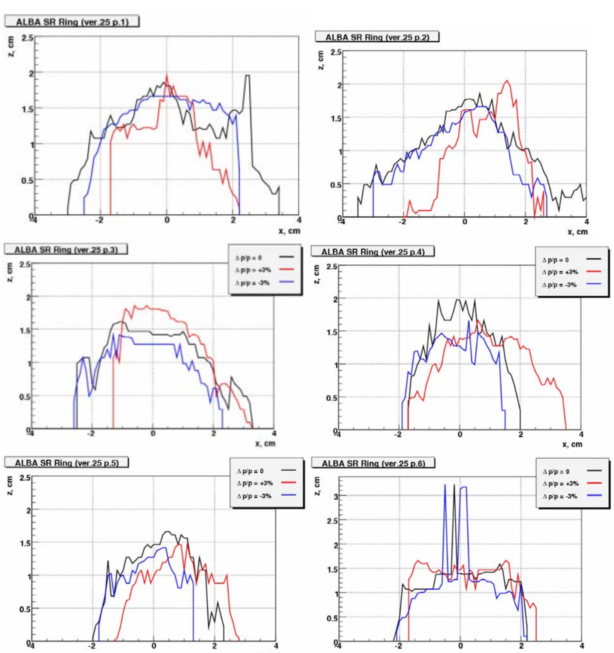
As the DA boundary has rather complicated shape, an important problem is fast and reliable comparison of different apertures, provided by sextupole pairs tested at the particular step. Several functional criteria have been studied: the DA area, the area of ellipse inscribed into the DA boundary, the DA area normalized by the length of the boundary curve, etc. Weight factors can be introduced if there are some particular goals: for instance, increasing of the horizontal aperture while keeping the vertical aperture equal to the mechanical one (say, limited by small-gap undulator). Actually, it is difficult to indicate the only criterion because its effectiveness is usually defined by a specific task.

Once the chromaticity is corrected we optimize DA further exploiting sextupoles placed in the dispersion-free sections. A gradient search algorithm is used for this purpose.

The algorithm may be naturally extended for increasing the off-momentum aperture: instead of a single DA with $\Delta p / p = 0$ several DAs with specified $(\Delta p / p)_i$ are optimized and no modifications are required.

RESULTS

The dynamic aperture for all the tune points under consideration is shown in Fig.3. As the betatron functions at the output azimuth are about the same for all the structures, the DA size can be compared directly.



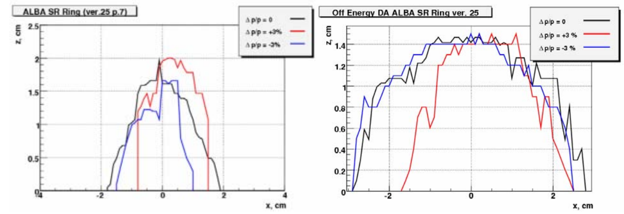


Figure 3: On- and off-energy DA for the seven alternative tune points of the ALBA lattice. The last plot is an original ALBA-25 DA for reference.

As dimensions of the dynamic aperture depend on the strength and location of betatron resonances around the particular tune point, it is interesting to study these resonances by plotting the maximum DA size as a function of the betatron frequencies. Several such plots are given below with short analysis as examples.

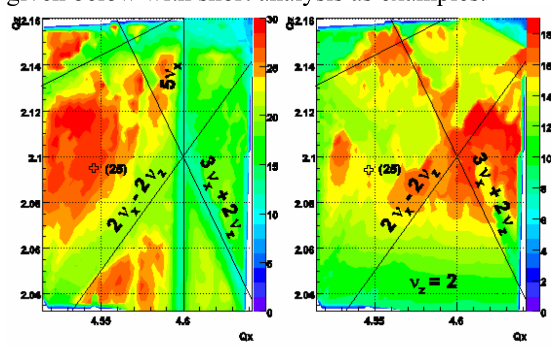


Figure 4: DA vs. betatron tunes for ALBA-25. Here and below the left plot corresponds to the horizontal DA while the right one to the vertical DA. Color indicate maximum (red) and minimum (blue) DA. Units for the color scale are in cm.

For ALBA-25 (Fig.4) the horizontal dynamic aperture is defined mainly by the nod of three high-order sextupole resonances $5\nu_x = 92$, $2\nu_x - 2\nu_z = 20$ and $3\nu_x + 2\nu_z = 71$. For the vertical DA the most dangerous resonance is an integer resonance $\nu_z = 8$ providing the optical instability of the vertical motion.

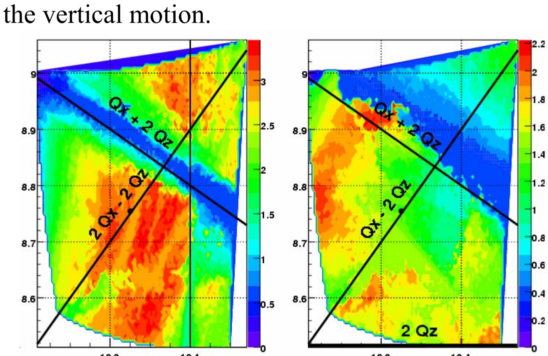


Figure 5: DA vs. betatron tunes for the Point 1.

For the point 1 a strong sextupole coupling resonance $\nu_x + 2\nu_z = 36$ play important role in the forming of the DA hills and valleys

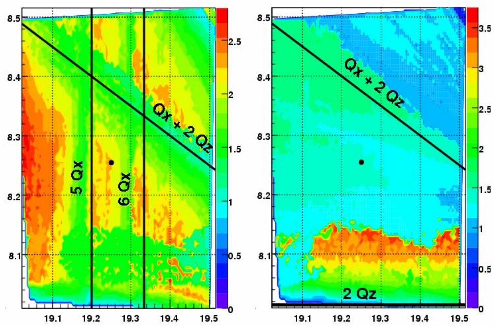


Figure 6: The resonance pattern around Point 6.

In the third example, the tune scan for the point No.6 clearly demonstrates influence of the high order sextupole resonances. The resonances $5\nu_x = 96$ and $6\nu_x = 116$ reduce the horizontal DA significantly.

A complete picture of the resonance pattern in the tune region $\nu_x = 18 \div 19.5$ and $\nu_z = 8 \div 9.5$ is given in Fig.7.

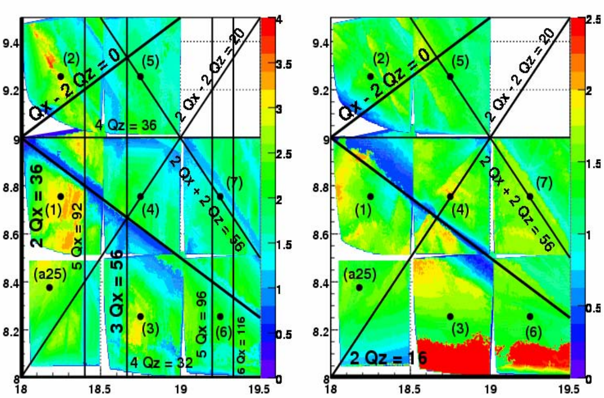


Figure 7: DA tune scans for all 7 tune points. Apparent increase of the vertical dynamic aperture down to the points 3 and 6 (red color area) is a non-realistic and explained by the betatron function growing close to the strong and unstable integer resonance $\nu_z = 8$.

Histograms in Fig.8 compare the dynamic aperture for different points.

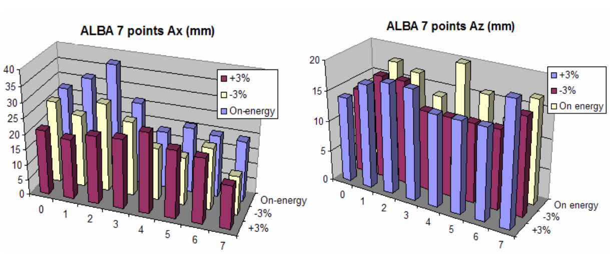


Figure 8: Comparison of the maximum horizontal (left) and vertical (right) apertures for the tested tune points.

CONCLUSIONS

The following conclusions can be made from the above study:

- After the optimization of the dynamic aperture all seven points seem suitable for reliable operation. The points 1, 2 and 3 look not worse (and even better) than the original ALBA-25
- From our experience. small tune shift (~±0.1) according to the DA scans results and re-optimization can open the dynamic aperture by 10-20% more
- All seven points are obtained from the ALBA-25 lattice by increasing either horizontal or vertical betatron frequencies (i.e., by stronger focusing of the original structure). This fact inevitable results in growing of the corresponding chromaticity (as it is seen from Table 1) and also in increasing of the sextupoles strength.

REFERENCES

[1] M.Muñoz, D.Einfeld. Optics for the ALBA light source. Proc. PAC 2005, Knoxville, Tennessee, pp. 3777-3779