15th International Particle Accelerator Conference,Nashville, TN JACoW Publishing
ISBN: 978-3-95450-247-9 ISSN: 2673-5490 doi: 10.18429/JACoW-IPAC2024-THPC01

STATUS OF THE ALBA-II LATTICE STUDIES

M. Carlà, G. Benedetti, O.R. Blanco García, Z. Martí, F. Pérez
ALBA-CELLS Synchrotron, Carrer de la LLum, Cerdanyola del Vallès, Barcelona, Spain

Abstract

Due to the constrains imposed by the tight geometry of the ALBA storage ring, the initial 6BA lattice envisioned for the ALBA-II upgrade was reconsidered in favor of a more relaxed 5BA configuration. The first engineering studies of magnets and vacuum chambers made evident many short comings of the 6BA optics. The here proposed 5BA optics allows for an easier integration at cost of a small increase of the natural emittance. The employed linear and non-linear optics optimization process is here described along with the first studies about dynamic aperture and lifetime.

INTRODUCTION

During the last year of lattice design work for the ALBA-II upgrade new constraints emerged. Namely it was required to keep below ~1 cm the transverse displacement of any insertion device with respect to its nominal position in order to avoid any major realignment of the beamlines. In addition, it was required to maintain the overall length of the ring in order to avoid changes of the main RF system frequency in the storage and booster rings. This new requirements along with the already limited flexibility of the 6BA lattice [1] under investigation, made it necessary a substantial rework of the optics.

The proposed lattice is now based on 16 5BA cells where, in order to match the 4-fold symmetry of the current ring and avoid any displacement of the insertion device beamlines, the length of the straight sections has been set accordingly, resulting in three different lengths. Figure 1 shows the optics functions along half of a quarter ring with half a long (L), a short (S) and half a medium (M) straight section. The four long sections in the ring have an identical high horizontal beta, one of which will be used for injection, other two will host the RF system and the last one will be devoted to an insertion device. This new optics performs better in terms of dynamic aperture (DA) and lifetime (lt.) at cost of an increase of the horizontal equilibrium emittance.

The main parameters of the new 5BA lattice are listed in Table 1. The number of magnet families increased to adjust the variation in length of the straight sections, see Table 2. Table 3 shows the maximum field and gradients used on the design.

Table 1: 5BA lattice main parameters. H.C. refers to harmonic cavity working on the 3^{rd} harmonic of the main RF frequency.

Energy	3	GeV
Circumference	268.8	m
Natural emittance	244	pm·rad
Symmetry	4	
Number of arc cells	16	
Type of arc cell	5BA	
Number of straight sections	16	
H.,V. tune	35.41, 12.24	
Synchrotron tune w/o H.C.	0.00266	
Natural chromaticity	-76, -35	
Momentum compact. factor	$1.3\cdot10^{-4}$	
Energy spread	$1.2\cdot10^{-3}$	
Energy loss per turn	911	keV
H.,V.,L. damping time	2.7, 5.9, 7.0	ms
Main RF voltage	2.4	MV
Harmonic Number	448	
Bunch length w/o H.C.	9.0	ps
Total beam current	300	mA
Touschek lt.		
1% coupling	1.0	h
100% coupling	5.9	h
100% coup. & H.C.	>20.0	h
Types of straights	L/M/S	
Straight length	4.7/4.4/3.5	m
β_x at straight center	13.8/2.7/4.9	m
β_y at straight center	3.8/2.3/2.0	m
Straight sequence in 1/4 ring	L-S-M-S	

Table 2: Magnet Families and Number

Type	**No.Fam.**	**Family Name**	**No.**
Bending	2	QD, QDS	48,32
Rev. Bend	2	QF, QFS	64,64
Quadrupole	3	LQ1,LQ2,LQ3	8,8,8
Quadrupole	3	MQ1,MQ2,MQ3	8,8,8
Quadrupole	3	SQ1,SQ2,SQ3	16,16,16
Sextupole	4	SH1 to SH4	64
Sextupole	7	SV1 to SV7	112
Total	24		480

BEAM DYNAMICS OPTIMIZATION

The optimization process is divided into several steps. Each step targets a different aspect, such as linear optics of the unit cell, injection cell and so on. However, each step is carried out in a similar fashion. The fitness of a candidate solution is evaluated through a scalar cost function which adds up with proper weights the contribution of the different metrics that need to be optimized at that particular step (e.g. emittance, DA...). The optimization is obtained by minimizing such a cost function.

The evaluation of the lattice parameters during the lattice optimization relies exclusively on the UFO code [2, 3], a

ISBN: 978-3-95450-247-9 ISSN: 2673-5490 doi: 10.18429/JACoW-IPAC2024-THPC01

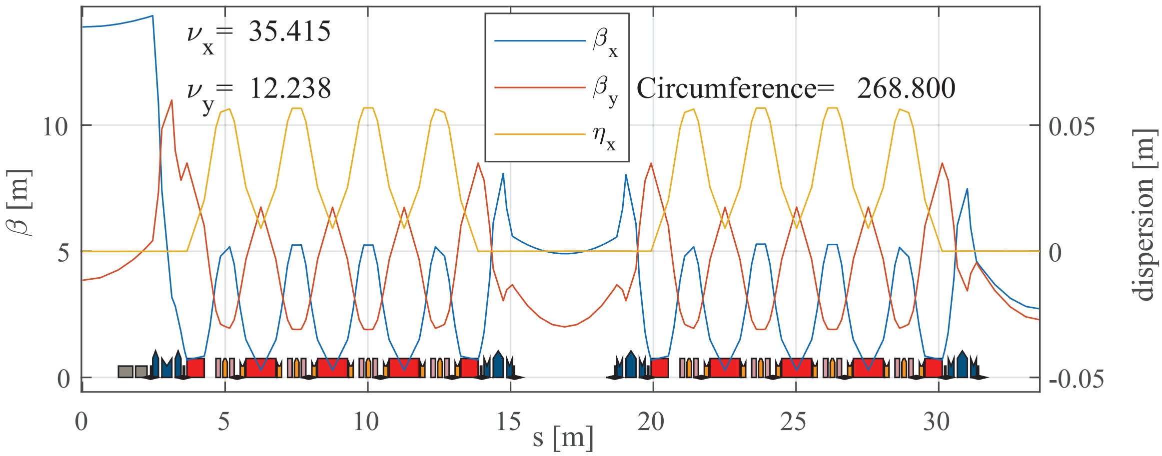

Figure 1: Optical functions for half a quadrant of the storage ring. Bending magnets in bright red, reverse bends in pink, quadrupoles in blue and sextupoles in yellow. The full quadrant is obtained by adding another half quadrant with mirror symmetry w.r.t. the one shown above. Four quadrants compose the entire ring. The injection point is at $s = 0$ m.

Table 3: Maximum magnetic field and gradients. $B\rho = 10.0069$ Tm, θ is the bending angle, L is the magnet length, and k_q, k_s are the quadrupole and sextupole gradients.

Type		**Units**	**Value**
Dipole	$B\rho\ \theta/L$	T	1.06
Reverse Bend	$B\rho\ \theta/L$	T	-0.54
Quadrupole	$B\rho\ k_q$	T/m	70.4
Sextupole	$\frac{1}{2}B\rho\ k_s$	T/m^2	3370

fast GPU tracking code developed in-house specifically to support the optics design process of ALBA-II.

Some rework of the non-linear optics optimization routine was required. In fact, during the simulation of off-axis injection we observed that sometimes particles inside the dynamic aperture got trapped in some skew sextupolar resonance and, instead of damping correctly towards the reference orbit, they remained in a high amplitude island. While it is likely that those trajectories would eventually damp to the reference orbit due to machine imperfections, it is very difficult to predict accurately their evolution. Therefore it was decided to penalize in the optimization process optics exhibiting this behaviour, aiming to find a well behaved solution.

In order to estimate if a particle got stuck into a stable resonance the dynamic aperture computation routine was updated to include a fixed transverse damping and a check on the rms orbit computed over the last 100 turns, after tracking for 10^4 turns equivalent to approximately 3 damping times. Figure 2 shows a comparison of the DA obtained using the old algorithm, which looks only at the stability and the modified algorithm which takes into account the final orbit. Apart from this change the optimization follows the procedure previously used in [1].

The non-linear optics optimization still relies on grouping sextupoles in 11 families (4 horizontal + 7 vertical, see Table 2) following a 16-fold symmetry despite the reduction of the linear optics to 4-fold symmetry. A larger number of sextupoles families could be attempted but the required computation time for the optimization would be much longer.

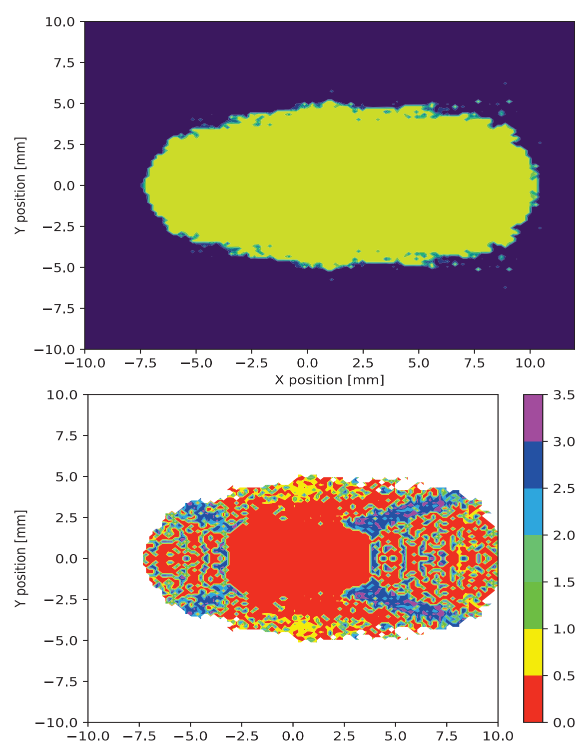

Figure 2: Comparison of the dynamic aperture obtained by checking only for particles stability (TOP) and a color coded map (BOTTOM), in millimeters, of the final rms orbit computed after 3 damping times for the very same optics. Only the particles in the red area damp correctly towards the reference orbit while the other ones remain with large oscillation.

ISBN: 978-3-95450-247-9 ISSN: 2673-5490 doi: 10.18429/JACoW-IPAC2024-THPC01

NON-LINEAR OPTICS PERFORMANCES

Figure 3 shows the dynamic aperture for the new 5BA optics. The island trapping is limited only to very high amplitudes, and from the simulation appears that injection up to 6 mm should be possible. Additionally, Fig. 4 shows the frequency map overlaid on the resonance diagram in 4-fold symmetry. For this symmetry there are no resonances crossing the tune footprint up to the third order.

The off-energy behaviour is summarized in Figs. 5 and 6. Simulations of the Touschek beam lifetime carried out with the code Accelerator Toolbox for Python [4,5] show 1.0 hour at 1% coupling which increases to 5.9 hours at 100% coupling [6,7] and to 23.0 hours when the bunch lengthening produced by the third harmonic RF system is also considered [8].

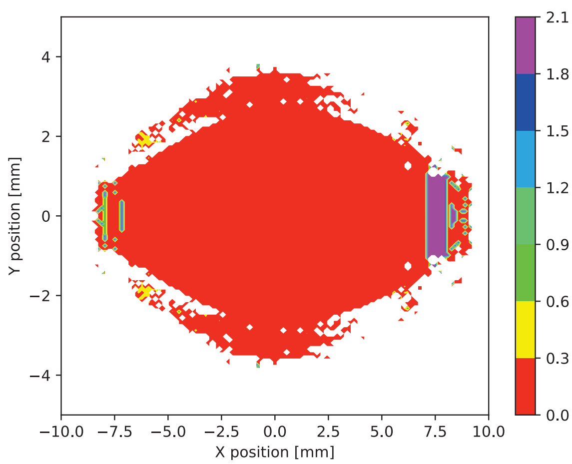

Figure 3: Color coded map (in millimiters) of the final rms orbit computed after 3 damping times. Almost all of the stable particles damp on to the reference orbit.

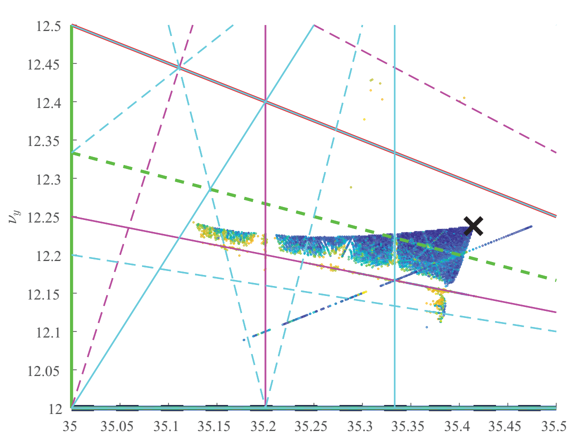

Figure 4: Frequency map of the 5BA ring. The tune working point is marked with a cross. Normal (bold) and skew (dashed) resonances of 4^{th} (green), 5^{th} (magenta), and 6^{th} (light-blue) order in 4-fold symmetry superimposed.

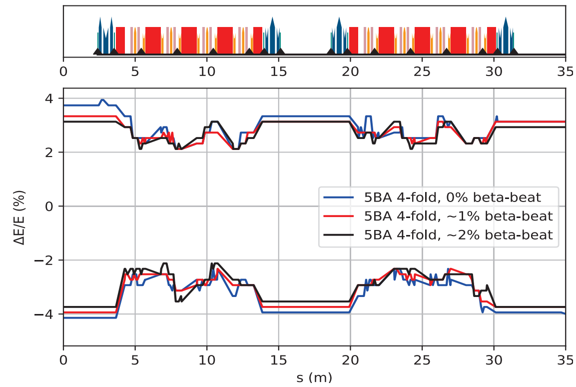

Figure 5: Momentum aperture along half quadrant computed without errors and with up to 2% rms beta-beating.

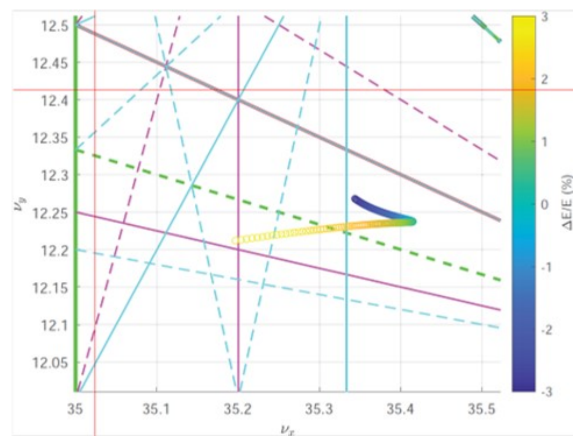

Figure 6: Tune shift with energy. Normal (bold) and skew (dashed) resonances of 4^{th} (green), 5^{th} (magenta), and 6^{th} (light-blue) order in 4-fold symmetry superimposed.

CONCLUSION

After a first development phase targeting a high performance 6BA lattice for the ALBA-II upgrade, it was decided to simplify the design switching to a 5BA configuration. The new optics provides more flexibility allowing to fulfill the requirement to preserve the beamlines position with an acceptable growth of the horizontal equilibrium emittance.

Work to achieve a better control of the beta functions at the insertion devices is ongoing. Also a new design of the injection cell, using a quadrupole doublet instead of a triplet is under investigation.

REFERENCES

[1] G. Benedetti, M. Carlà, U. Iriso, Z. Martí, and F. Perez, "Progress on the 6BA lattice for ALBA-II", in *Proc. IPAC'23*, Venice, Italy, May 2023, pp. 3098–3100. doi:10.18429/JACoW-IPAC2023-WEPL001

[2] https://github.com/mcarla/ufo

[3] M. Carlà and M. Canals, "UFO, a GPU code tailored toward MBA lattice optimization", in *Proc. IPAC'22*, Bangkok, Thailand, Jun. 2022, pp. 2346–2349. doi:10.18429/JACoW-IPAC2022-WEPOMS043

ISBN: 978-3-95450-247-9 ISSN: 2673-5490 doi: 10.18429/JACoW-IPAC2024-THPC01

[4] Accelerator Toolbox (AT), `https://atcollab.github.io/at`

[5] Python, `https://www.python.org/`

[6] Z. Martí, G. Benedetti, M. Carlà, U. Iriso, and L. Torino, "Full coupling studies at ALBA", in *Proc. IPAC'22*, Bangkok, Thailand, Jun. 2022, pp. 1667–1670. `doi:10.18429/JACoW-IPAC2022-WEOZSP4`

[7] M. Carlà, G. Benedetti, L. Torino, U. Iriso, and Z. Martí, "AC excitation studies for full coupling operation", in *Proc. IPAC'23*, Venice, Italy, May 2023, pp. 508–511. `doi:10.18429/JACoW-IPAC2023-MOPL002`

[8] I. Bellafont, F. Perez, and P. Solans, "Longitudinal beam dynamics studies with a third harmonic RF system for ALBA-II", in *Proc. IPAC'23*, Venice, Italy, May 2023, pp. 3534–3537. `doi:10.18429/JACoW-IPAC2023-WEPL179`

[9] G. Benedetti, M. Carlà, U. Iriso, Z. Martí, and F. Pérez, "A distributed sextupoles lattice for the ALBA low emittance upgrade", in *Proc. IPAC'21*, Campinas, Brazil, May 2021, pp. 2762–2765. `doi:10.18429/JACoW-IPAC2021-WEPAB074`

[10] Z. Martí, G. Benedetti, M. Carlà, U. Iriso, "Performances of the ALBA-II lattice with alignment and magnetic errors", in *Proc. IPAC'23*, Venice, Italy.

[11] F. Pérez *et al.*, "ALBA II acelerator upgrade project", in *Proc. IPAC'22*, Bangkok, Thailand, Jun. 2022, pp. 1467–1470. `doi:10.18429/JACoW-IPAC2022-TUPOMS027`

[12] F. Pérez *et al.*, "ALBA II accelerator upgrade project status", in *Proc. IPAC'23*, Venice, Italy, May 2023, pp. 2582–2585. `doi:10.18429/JACoW-IPAC2023-WEOGA1`

[13] G. Benedetti, M. Carlà, and M. Pont, "A double dipole kicker for off and on-axis injection for ALBA-II", in *Proc. IPAC'22*, Bangkok, Thailand, Jun. 2022, pp. 2701–2704. `doi:10.18429/JACoW-IPAC2022-THPOPT047`