STATUS OF LATTICE STUDIES FOR ALBA-II

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Abstract

A 5BA lattice with an emittance of 206 pm·rad at 3 GeV and a circumference of 268.8 m is under design for ALBA-II. The injection is performed off-axis in a straight section only 4.7 m long with a single non-linear kicker needing a horizontal dynamic aperture larger than 6 mm. An optics of the injection section with asymmetric waists of the beta functions, low horizontal beta at the septum location and high beta at the kicker, has proved to perform better than a high beta section. This arrangement in the injection sections allows tuning equal phase advances and chromatic functions in all the cells and recover a pseudo 16-fold symmetric ring both on- and off-energy. The robustness of this solution in presence of errors has improved the injection efficiency with errors from 90% to 100%, keeping the dynamic aperture larger than 7 mm and the same Touschek lifetime longer than 6 hours. The magnetic design along with the performances of the lattice with errors and the injection process are presented in this paper.

INTRODUCTION

The ALBA-II storage ring consists of 16 cells that have the same arc but three different straight section lengths matched by quadrupole triplets. The main aspects of the cell architecture were already presented in [1]. In the last version of the lattice [2], high beta functions were employed in the injection straight section, to achieve the necessary horizontal dynamic aperture (DA) larger than -5 mm, and in three more symmetric straight sections. The best performances of that 4-fold lattice, evaluated with all the effects of errors and corrections, achieved an injection efficiency of 93% on average (more than 50% of the error seeds). Besides this, we realized that due to the large tune shift with energy, Touschek particles within the energy acceptance were crossing the resonance $Q_x = 0.5$ making necessary some evaluations in order to guarantee a reliable estimate of the lifetime. The work of the last year has been dedicated from one side to improve the lattice performances by refining the model and the optimization technique, and on the other side to develop a new optics of the injection section with asymmetric waists that allowed to recover a pseudo 16-fold symmetry with matched phase advances and chromatic amplitude function W_x in all the straight sections. The main benefit of this change in the lattice is its robustness to errors rendering 100% of injection efficiency for more than 90% of the simulated error seeds.

NEW INJECTION SECTION

A new optics for the injection section with low β_x at the septum and high β_x at the double-dipole kicker (DDK, [3, 4]) was implemented adding a quadrupole in the middle of the straight section (Fig. 1). This optics of the injection section allows using the matching quadrupole triplets to make the phase advance of all the straight sections equal, hence recovering a 16-fold symmetry on-energy, while off-energy periodicity 16 is obtained by matching the horizontal chromatic amplitude function W_x at the end of each arc. This configuration renders both large horizontal dynamic aperture at the DDK and good momentum aperture for Touschek lifetime. As additional benefit, the low β_x at the injection point allows the thin-septum blade being positioned closer to the stored beam. Consequently the thin-septum magnet can be shifted towards the DDK leaving more room for the thick-

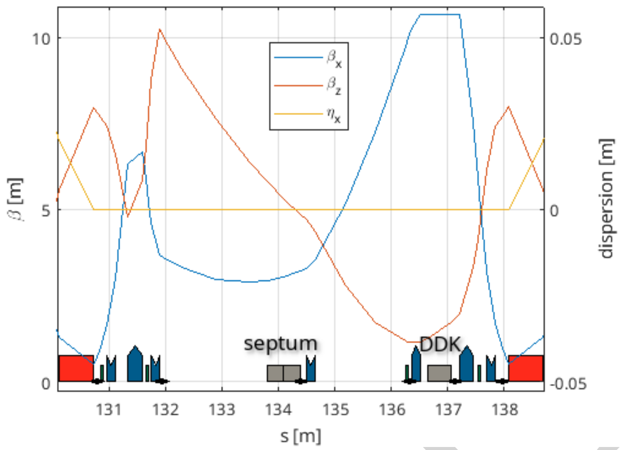

Figure 1: The new optics of the injection section with asymmetric waists to produce low β_x at the thin-septum position and high β_x at the kicker (DDK).

Table 1: Main Parameters of the 5BA Baseline Lattice

Energy	3	GeV
Circumference	268.8	m
Natural emittance	206	pm·rad
Emit. 50% coupling & IDs	158, 79	pm·rad
Betatron tunes	38.17, 13.28	
Natural chromaticity	-95, -34	
Momentum compact. factor	$1.1{\cdot}10^{-4}$	
Energy spread	$1.2{\cdot}10^{-3}$	
Energy loss per turn	910	keV
Damping times	2.7, 5.8, 6.9	ms
Main RF voltage	2.4	MV
Harmonic Number	448	
Bunch length w/o HC	9.0	ps
Total beam current	300	mA
Lifetime 50% coupling & HC	6	h
Straight lengths	4.7, 3.5, 4.4	m
β_x at straight centers	3.4, 2.5, 3.1	m
β_y at straight centers	1.9, 1.7, 1.9	m

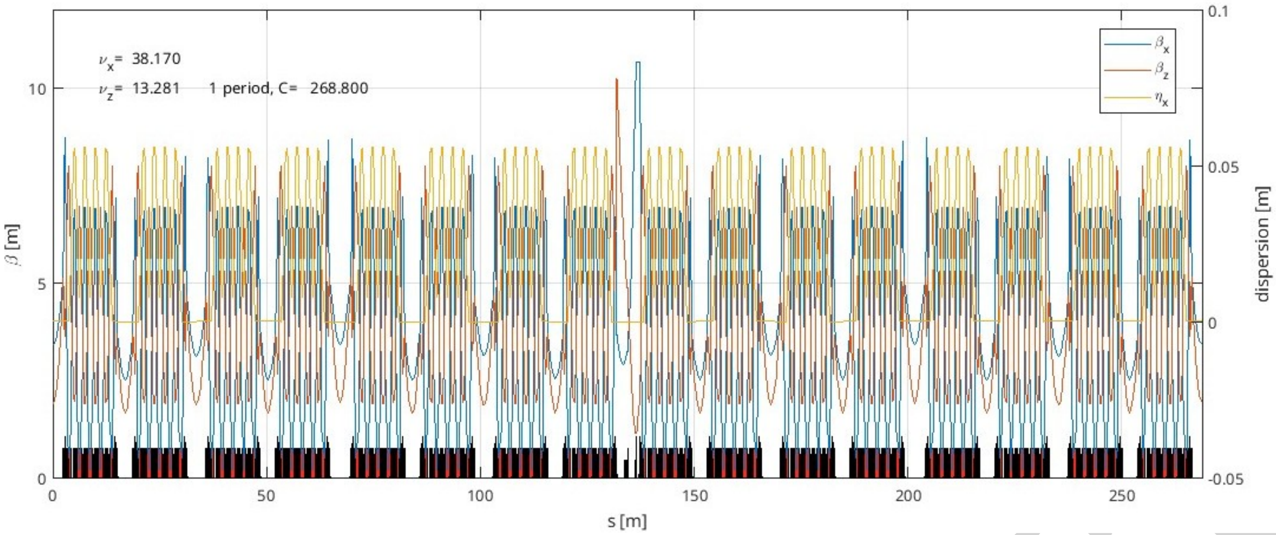

Figure 2: Beta and dispersion functions in the ring. The injection is performed in the long straight section at the center.

septum and avoiding mechanical interferences between the transfer line and the storage ring. The pseudo 16-fold optics of the ring is shown in Fig. 2 while the main parameters of ALBA-II are listed in Table 1.

16-FOLD LATTICE OPTIMIZATION

Several upgrades were implemented in the modeling and in the optimization process aimed at reducing the effect of errors, improving the correction, finding optics solutions with better performances.

To reduce the sensitivity to errors the pairs of the reverse-bends QF and QFS were installed in the same girder. These are also the magnets with higher systematic multipole errors, consequently their magnetic design was further optimized in order to reduce the lower order multipoles [5].

The settings of 11 families of sextupoles and octupoles are initialized with an SVD correction of the 1^{st} order resonance driving terms (RDT). In addition the individual sextupoles located in the arc upstream and downstream of the injection are added as free parameters. The optimization is performed with the tracking code UFO [6, 7], that was upgraded by introducing the physical aperture of the vacuum chamber and implementing the Piwinsky formula for Touschek lifetime calculation. Genetic algorithms are used targeting two objectives: DA and lifetime.

Scans of tunes and chromaticities were studied to find the best working point. $Q_x = 38$ was confirmed to be a good value since it guarantees an emittance around 200 pm·rad, cancellation of horizontal 1^{st} order RDTs every 5 cells, quadrupole gradients below 100 T/m. Q_y instead was moved from 12 to 13 to get lower vertical betas in the straight sections, while 14 performed better for the crossed RDTs cancellation but it was discarded to avoid a 4^{th} order resonance.

DYNAMIC AND PHYSICAL APERTURE

The horizontal DA achieves -8 mm without errors (Fig. 3). The vacuum chamber section was changed from round ∅ =16 mm to rhombic 20 mm wide [8] in order the horizontal DA not to be limited by the physical aperture.

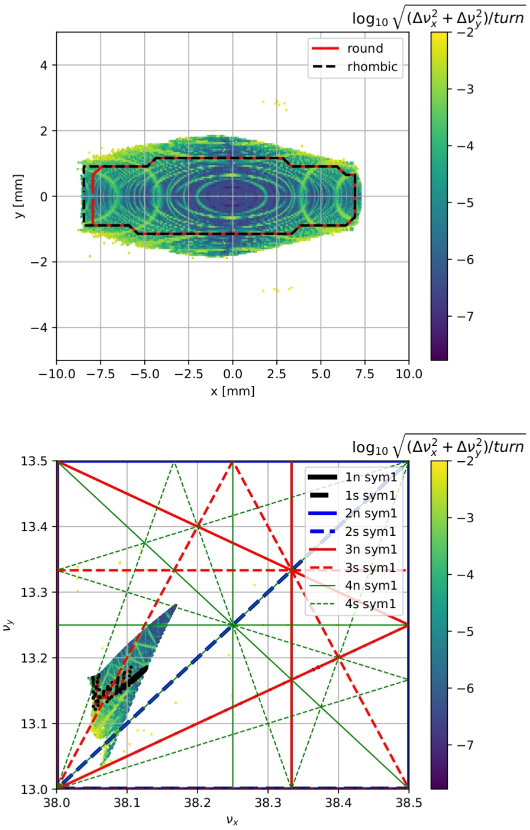

Figure 3: DA on-energy (top) and its tune footprint (bottom). The boundaries when the physical aperture of the vacuum chamber is taken into account are also depicted.

LIFETIME CROSSING HALF-INTEGER RESONANCE STOPBAND

Octupole magnets were installed only next to the sextupoles in the arcs in order to correct the tune shift with amplitude and assure large DA. No octupole was introduced so far in the straight sections due to the very tight arrangement of them. The drawback is an increase of the tune shift with energy which in the end is the main cause limiting the lifetime. According to our model, the energy acceptance of 3.5% would render a Touschek lifetime of 11 hours with harmonic cavity (HC [9]) and without errors. However, as shown in Fig. 4, Touschek particles at energy deviation of 2.5% are crossing the half-integer resonance $Q_x = 0.5$. In general, particles can cross a resonance without being lost only if the passage is fast and the resonance stopband is sufficiently narrow, that means that only if we trust that our error model is very complete, particles crossing a resonance can be taken into account for lifetime. So far, we prefer taking as educated guess the lifetime estimation cutting the energy acceptance at 2.5% when $Q_x = 0.5$, that gives 7 hours (6 hours on average with errors, Fig. 5-right).

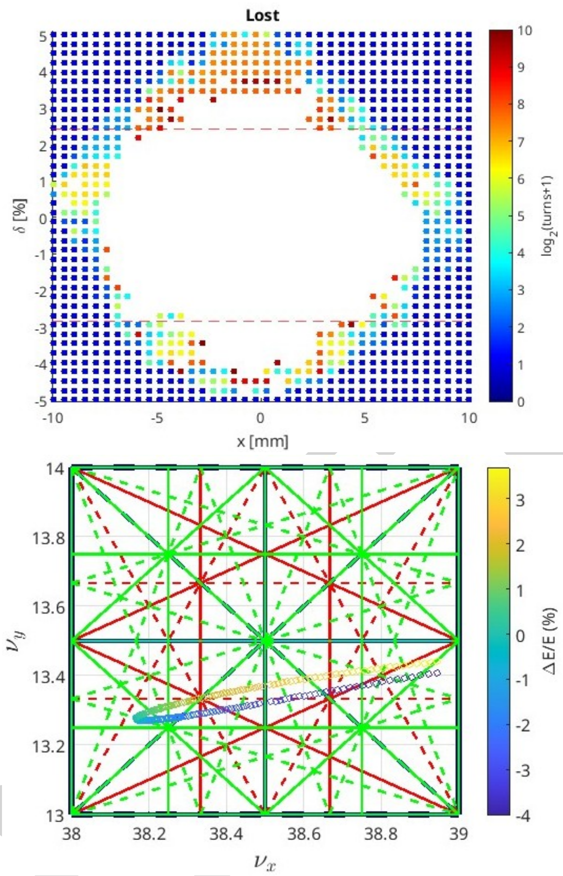

Figure 4: Energy acceptance reaching 3.5% (top). The large tune shift with energy make particles cross the half-integer resonance (bottom).

PERFORMANCES WITH ERRORS

The performances of the lattice with realistic errors in the magnetic fields, the alignment, the noise of beam position monitors and in the RF settings, are evaluated with the Simulated Commissioning (SC) toolkit for Matlab [10, 11]. The injection efficiency was evaluated including in the AT2 model the AC skew quadrupole excitation that produces the emittance coupling of 50% [12] and the time dependent non-linear field of the injection DDK.

The new pseudo 16-fold lattice has larger DA and, what is more important, it performs much better in terms of sensitivity to errors. The injection efficiency for more than 90% of the error seeds achieves 100%, while in the previous 4-fold solution the 50% of the seeds was below 93% of injection efficiency (Fig. 5-left).

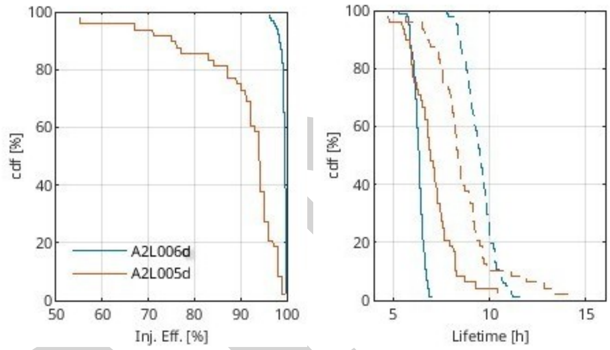

Figure 5: Cumulative distribution function of injection efficiency (left) and Touschek lifetime with HC (right) cutting at the half-integer resonance (solid lines) and crossing the resonance (dotted lines), for 100 error seeds. The new 16-fold lattice A2L006d (blue lines) is compared to the previous 4-fold solution A2L005d (red lines).

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CONCLUSION AND OUTLOOK

A new optics of the injection straight section with asymmetric waists allowed recovering a 16-fold symmetric lattice, both on- and off-energy, that performs better in terms of sensitivity to errors and achieves 100% of injection efficiency. The most important issue not fully optimized yet is the lifetime of 6 hours limited by the large tune shift with energy. However a study to include octupole magnets in the non-dispersive region of the straight sections is now in progress aimed at correcting the horizontal tune shift with amplitude by keeping a small tune shift with energy.

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