OPTICS FOR THE ALBA LATTICE

M. Muñoz, D. Einfeld, CELLS, P.O. Box 68, 08193, Bellaterra, SPAIN

Abstract

ALBA is a third generation light source being built in Spain. Since 2003 a redesign of the accelerator complex is under way and a thorough investigation of the optimization of the lattice has been done [1], [2]. ALBA will be a medium energy machine (3 GeV), providing a small emittance (4.3 nm-rad) and beam sizes, with a large number of straight sections for insertion devices, in a small circumference (268 m). The responsibility for the construction (and future operation) of the ALBA facility belongs to the Consortium for the Construction, Equipping and Exploitation of the Synchrotron Light source (CELLS). CELLS is funded on the basis of an equal share between the MEC (Ministerio de Educacin y Ciencia) of the Spanish Government and the DURSI (Departament dUniversitats, Recerca i Societat de la informaci) of the Generalitat de Catalunya.

LINEAR OPTICS

The scientific case for ALBA requires a high flux density with a relatively beam size in both planes (under 150μm in the horizontal and 8 μm in the vertical) at the insertion devices, and a natural emittance under 5 nm-rad.

The first approach for the design of the lattice was presented in [1] and [2]. Since then, the design has been optimized, reducing the maximum values of the optical functions, increasing the dynamic aperture and increasing the available number of straight section for insertion devices.

Key components of the design, dictatded by the budget, are:

- Most of the vertical focusing in the bending magnets, due to the inclusion of a large gradient (6 T/m).
- As many cells as possible (16).
- Distribute dispersion to reduce the emittance.
- Short straight sections for IDs or instrumentation.
- Long straight section for injection.
- Mini beta sections in the straight sections used for insertion devices.

The resulting design consists in a expanded DBA structure lattice with fourfold symmetric , where each quarter is composed of four basic cells (two so called matching cells and two regular cells,) with a long (8 m) straight section and three medium one (4.2 meters). There are also 8 short straight sections 2.2 meters long that will be used for diagnostic devices and for the RF system. The optical functions for one quarter of the machine are show in figure 1. The main parameters of the machine are shown in table 1.

Table 1: Parameters of the storage ring

Name	Value
Circumference (C)	268.8 m
Energy (E)	3 GeV
Horizontal Emittance (ϵ_x)	4.3 nm-rad
Horizontal Tune (Q_x)	18.178
Vertical Tune (Q_y)	8.37
Horizontal Chromaticity (ξ_x)	-39
Vertical Chromaticity (ξ_y)	-27
Momentum Compaction Factor (α_p)	8.8×10^{-4}
Second Order α_p (α_{p_2})	2.1×10^{-3}
Energy Spread ($\Delta E/E$)	1.05×10^{-3}
Revolution Frequency (f_0)	1.115 MHz
Horizontal Damping Time (τ_x)	4.1 ms
Vertical Damping Time (τ_y)	5.3 ms
Longitudinal Damping Time (τ_ϵ)	3.1 ms
Horizontal (J_x)	1.3
Vertical Partition Number (J_y)	1
Longitudinal Partition Number (J_ϵ)	1.7
Energy Loss per turn (U_0)	1.01 MeV
Harmonic Number (h)	448

The design presented in this paper is a the final one, having gone through several iterations with the different groups inside the project (magnets, vacuum, RF, etc) in order to check the feasibility of the lattice, is the final one. For more details in the components and in the project see reference [3]. The strength of the magnets still allows some flexibility and the possibility to move the working point $\pm$0.5 units, and to compensate the detuning and the beta beat introduced by imperfections and insertion devices.

Table 2 shows the beam size and divergence in the different possible source points. These values fulfil the requirements of the scientific case. Optics modes with zero dispersion in the straight sections and with smaller beam cross section in the medium straight sections are under investigation.

Closed orbit system

The correction system for ALBA will consists primarily of 120 BPMs distributed along the machine, and up to 120 vertical and horizontal correctors, integrated in the sextupoles magnet. To minimize the effect of the alignment errors, the magnets will be placed and pre-aligned in girders. The current configuration of the girder consist in

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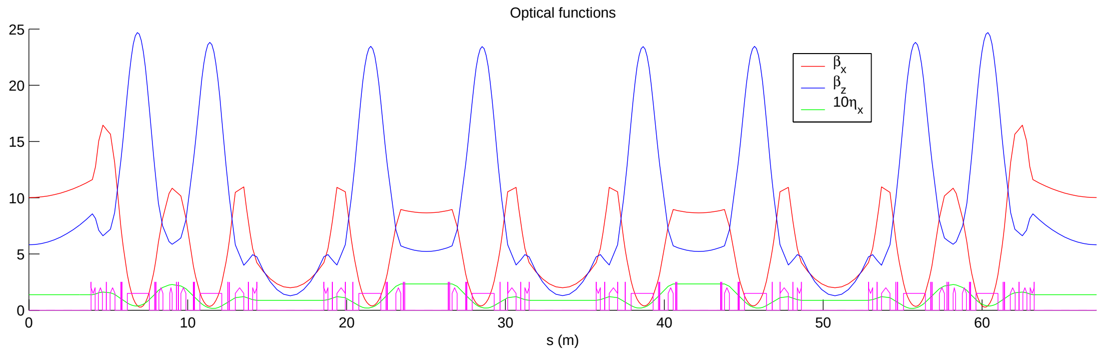

Figure 1: Optical functions for a quarter of the machine. All the units are in meters.

mounting in a girder the bending magnet and the surrounding quadrupoles and sextupoles, separating the girders with the straight sections. This configuration can compensate errors up to 300 μm in the position of the girders and up to 60 μm in the position of the elements with respect to the girders, with a maximum strength of the correctors of 500 μrad. Figure 2 shows the statistics for a realistic case (100 μm in the girder position, 60 μm and 100 μrad in the elements). The same corrector coils will be used for the fast orbit feedback system, using a solution similar to the one adopted at the Swiss Light Source [4].

NON LINEAR DYNAMICS

The lattice used for ALBA presents a relatively small natural chromaticity when compared with the other modern synchrotron light sources (SLS, Diamond, SOLEIL). This makes it possible to correct the chromaticity and compensate for non-linearities preserving a large enough dynamic operation, even not having an optimal phase advance between the sextupoles. The dynamic aperture for the on-energy particles and for off-momentum particles with a $\pm$3% energy deviation is shown in figure 3. Figure 4 shows the tune shift with amplitude and energy. The physical aperture is defined by the vacuum chamber in the vertical (a projected vertical gap of $\pm$7 mm in the middle of the long straight section) and by the vacuum chamber and the injection system in the horizontal (a projecter horizontal aperture of $\pm$18 mm). Estimations based in the injection process and in the Touschek process shows that the minimum required aperture is of 15 mm in the middle of the straight sections and of 10 mm in the bending magnets.

The energy acceptace of the lattice, even when including misalignment errors, correction system and the physical limitations due to the vacuum chamber and septum sheet is larger than the one provided by the RF system. The lattice provides enough dynamic aperture even for values larger than the RF acceptance (3.5%).

Figure 5 shows the frequency map for the lattice, including the vertical physical aperture due to the vacuum chamber ($\pm$ 4 mm for the small gap insertion devices), and the error and correction system.

Table 2: Beam size and divergence at the source points, assuming 1% coupling, for the long, medium and short straight sections, and for the center of one of the bending magnets.

Name	σ_x	σ'_x	σ_y	σ'_y
	$[\mu$m]	$[\mu$rad]	$[\mu$m]	$[\mu$rad]
Long ID	266	20	15.6	3.2
Medium ID	132	47	7.4	6.2
Short ID	308	22	15.4	3.2
Bending SP	49	109	32	2.2

LIFETIME

The three main contributions to the lifetime of a modern synchrotron light source are the elastic scattering, the Bremsstrahlung and the Touschek lifetime. The contribu-

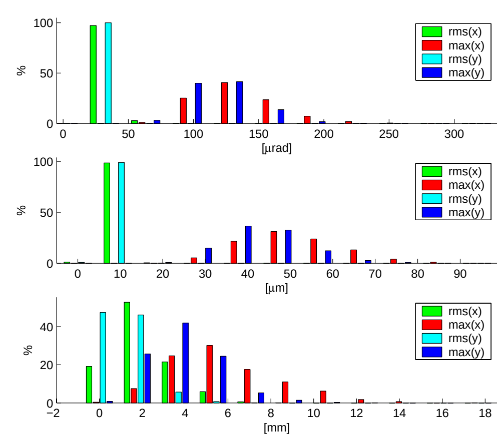

Figure 2: Statistics for 1000 sample machines, applying errors of 100 μm in the girder position and of 60 μm in the element respect the girder position. Bottom graph shows the statistics of uncorrected orbit, middle graph the ones of the corrected orbits, and top graph the ones of the correctors. The correction has been performed using SVD with 90 eigenvalues out of 120.

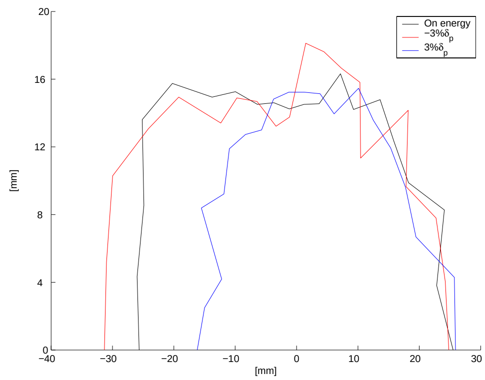

Figure 3: Dynamic Aperture at the center of the long straight section for injection ($\beta_x = 10.8\,\mathrm{m},\ \beta_y = 5.7\,\mathrm{m}$), for the on-momentum particle and for particles with $\pm 3\%$ energy deviation for the ideal machine. The particles are tracked for 400 turns. The effect of the chromatic closed orbit is included.

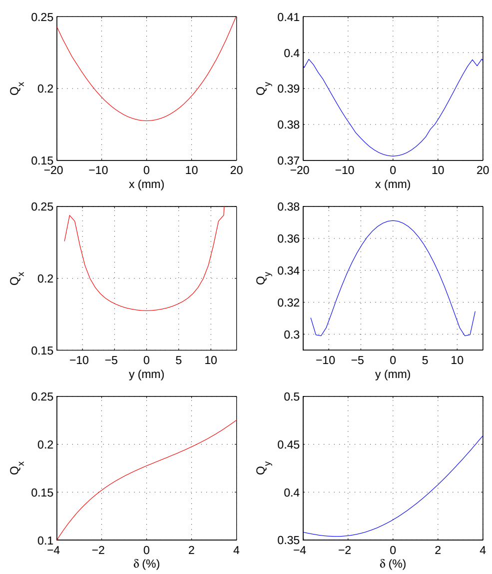

Figure 4: Tune shift versus horizontal amplitude (top), vertical amplitude (middel) and energy (bottom). The chromaticity is corrected to (1,1)

tion of each one has been calculated, assuming 400 mA of current, with 400 bunches, 1 nTorr of residual N_2 pressure, and for the Touschek case, the errors, correction system, and RF limitations, and vacuum chamber aperture limitations. The value of each contribution and the total lifetime are:

- Elastic scattering: 78 h
- Bremsstrahlung: 60 h
- Touschek: 28 h
- TOTAL LIFETIME 15 h

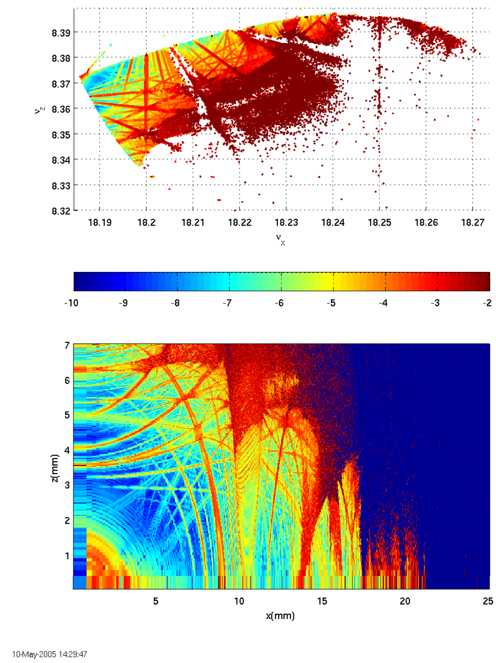

Figure 5: Frequency map for a sample machine, including closed orbit errors and correction.

The lifetime of 15 hours is enough for top-up operation, and can be increased by the used of a harmonic RF cavity.

CONCLUSION

The current design of the ALBA machine is a mature design, that has gone through several iterations, in order to ensure the mechanical feasibility of the lattice. It fufils all the requirements of the scientific case for ALBA, and offers similar performance to modern projects like SOLEIL or Diamond, with a much smaller circumference.

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