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# Coupling Impedance Studies of the Current Transformers at ALBA

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Abstract

ALBA is equipped with two different current transformers (FCT and DCCT), and a third one (ICT) is now in design stage to be installed in 2019. A comparative study of the different currents transformers was carried out in order to characterize their contribution to longitudinal and transverse impedance. The gap in the vacuum chamber of the current transformers was varied in order to study its effect on the heat deposited by the beam in the corresponding device and on the resonance in the longitudinal impedance spectrum. The simulation results are compared to the experience with the existing current transformers in operation.

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# FIRST STUDY FOR AN UPGRADE OF THE ALBA LATTICE

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*Abstract*

ALBA has started a study that will produce the design of a new lattice for a diffraction limited photon source. The baseline lattice should preserve the present circumference and energy, and keep the insertion device beamline source points as much as possible unchanged. The first solution is a 16-fold periodic ring based on a 7BA cell with dispersion bump, paired sextupoles and anti-bends. An emittance of 155 pm·rad would be reached without longitudinal gradient in the dipole magnets.

## INTRODUCTION

The community of third generation light sources is presently designing and building new lattices with emittance below 200 pm·rad for the upgrade of the present storage rings. ALBA is the Spanish synchrotron light source operated for users since 2012 with an electron beam of 4.50 nm·rad emittance [1]. After seven years of successful operation and continouos improvements, a first feasibility study is started for a possible upgrade with lower emittance. The first approach is to take advantage of the most advanced studies carried out in similar light sources to have a starting lattice as reference for the new achievable parameters.

Studies carried out at SOLEIL [2] showed that with the available technology the use of 7BA and 6BA cells combined with longitudinal gradient dipoles can reduce the emittance by about a factor 20 (for ALBA 250-300 pm·rad) and keep both the geometric constraints, such as the circumference of the ring and the available straight sections to not impact the existing insertion device beamlines, and the optics conditions such as high beta functions at the injection point. The limitation of such lattices comes from the non-linear optics affected by the strong quadrupoles and the subsequent high chromaticities.

In order to further decrease the emittance with acceptable non-linear optics, more sophisticated lattices must be developed and the geometric constraints relaxed. As in SOLEIL [3], for ALBA a totally symmetric ring with many identical hybrid 7BA cells, that combine the sextupole pairing scheme and dispersion bump as in ESRF-EBS [4] with anti-bends as in SLS-2 [5], can be a feasible solution with a natural emittance of 155 pm·rad provided that the injection scheme is changed by adopting either new pulsed multipole kicker or on-axis solutions, which are presently under development in many other synchrotrons.

## UPGRADE LATTICE

The present ALBA synchrotron storage ring is a four-fold symmetry lattice composed of 16 double-bend cells

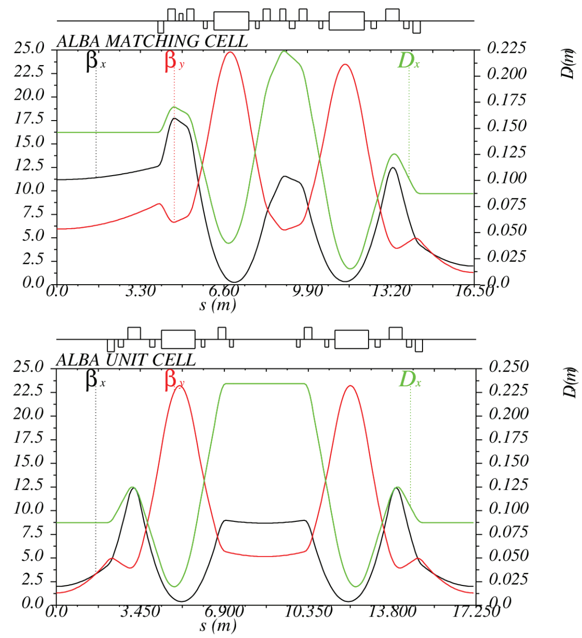


Figure 1: Optics of the two types of double bend cell in the present ALBA lattice.

of two types (Fig. 1). It provides 4 long straight sections of 7.8 m with high beta functions, one of which houses the injection kickers, and 12 medium straight section of 4 m with low beta functions.

The upgrade lattice under study has been designed with 16 identical hybrid 7BA cells that provide 4.3 m long straight sections (Fig. 2). It has two dispersion bumps where paired chromatic sextupoles are located with $3\pi$ and $\pi$ horizontal and vertical phase advance to get a $-I$ transformation between them and compensate most of their non-linear kicks (Fig. 3). In addition there are two anti-bend magnets with 0.3 T field and 32 T/m focusing gradient, placed at the dispersion peaks in order to control the dispersion and push the emittance down.

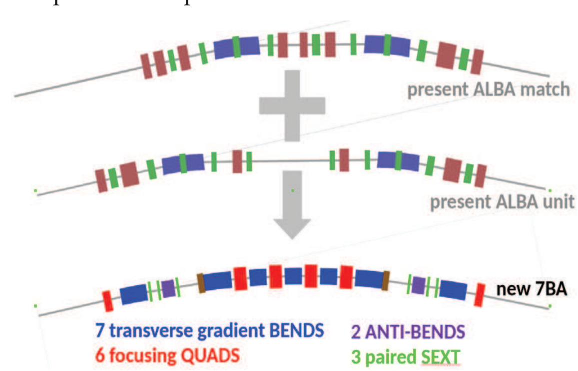


Figure 2: In the upgrade lattice, the two types of double-bend cell (8 matching cells plus 8 unit cells) of the present lattice are replaced by 16 identical hybrid 7-bend achromatic cells.

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The bending magnets field is 0.8 T, much lower than the present 1.4 T, combined with a maximum defocusing gradient of 45 T/m. No longitudinal gradient is employed, although its effects are discussed later. The maximum gradient of the quadrupoles is 80 T/m and the sextupoles are limited to 2000 $T/m^2$ over a 100 mm long yoke.

Due to the change of the ring symmetry, not all the present centres of the straight sections can be preserved. Over the 12 current medium straight sections, 8 of them keep their positions and 4 would be shifted by 68 mm in the radial direction, which still allows alignment with the existing front wall holes of the tunnel. Moreover the current 4 long straight sections would be shifted by 240 mm towards ouside, that instead is not compatible with the existing front wall holes. It must be said that only one of the long straight sections is presently used for the injection and the other ones are still clear.

Table 1: Main ALBA Storage Ring Parameters

| | Present | Upgrade |
|---|---|---|
| Emittance | 4.5 nm·rad | 155 pm·rad |
| Energy | 3 GeV | 3 GeV |
| Circumference | 268.8 m | 269.0 m |
| Number of cells | 8+8 | 16 |
| Number of straights | 4 / 12 / 8 | 16 |
| Straight lengths | 7.8 / 4 / 2.3 m | 4.30 m |
| Straight ratio | 36% | 25% |
| Working point | 18.15, 8.36 | 43.26, 13.26 |
| Chromaticity | -39, -29 | -94, -92 |
| Mom. Comp. factor | $8.9\cdot10^{-4}$ | $1.8\cdot10^{-4}$ |
| Energy spread | $1.0\cdot10^{-3}$ | $1.2\cdot10^{-3}$ |
| Energy loss per turn | 1023 keV | 630 keV |
| Damping times | 4 / 5 / 3 ms | 4 / 8 / 12 ms |

## LINEAR OPTICS

The beta functions at the straight section centres have been fixed at 1.5 m in both planes (Fig. 3), twice the beta of the matched electron to diffraction limited photon emittance ($L_{und}/\pi$) over the present 2 m long undulators. Solutions with betas closer to the matched values give higher emittance, but further investigations have to be performed with an extensive use of genetic algorithms.

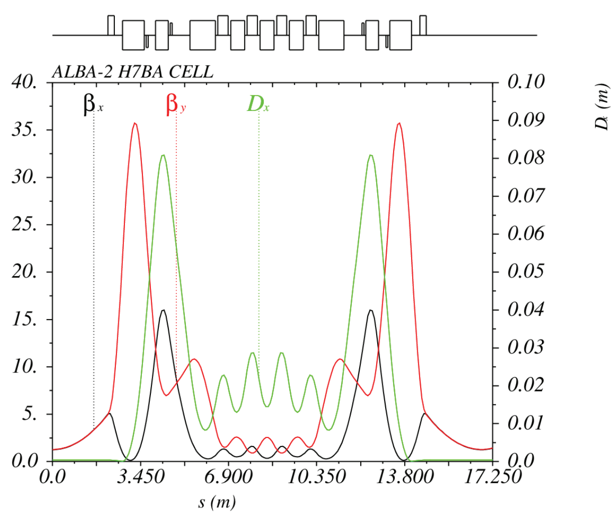

Figure 3: Optics of the upgrade ALBA cell.

The option of introducing longitudinal gradient in the two couples of dipoles that produce the dispersion bump has been tested as well and the emittance could be reduced to 140 pm·rad. This solution can be further studied especially if the dipole based beamlines are interested in this type of light source.

## NON-LINEAR OPTICS

Non-linear simulations have been performed with the AT 2.0 tracking code [6] and a first dynamic aperture optimisation has been run using the NSGA-II genetic algorithm library [7]. The dynamic aperture reaches 1.5-2 mm in both planes according to 4-D simulations with RF on (Figs. 4-6). The Touschek lifetime estimate with 0.5 mA per bunch (250 mA with uniform filling pattern) and 2 MV RF voltage is about 5.7 hours with 50% coupling (Fig. 7). The effect of intra-beam scattering has not been taken into account, but it is expected that under these conditions it produces emittance and energy spread growths that must be assessed.

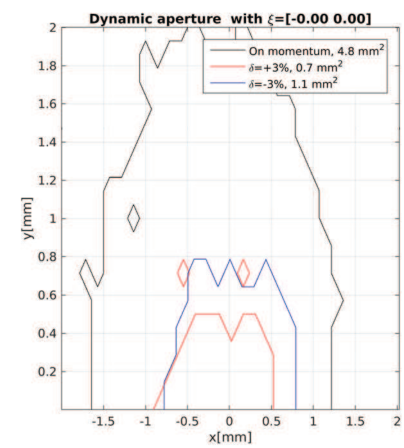

Figure 4: Dynamic aaperture at the straight section centre with $\beta_{x,y}$ = 1.5 mm.

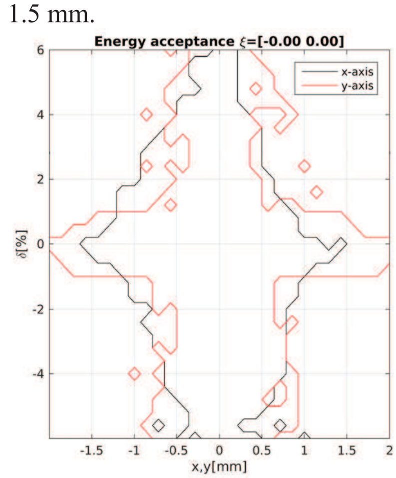

Figure 5: Relative momentum apertures at the straight section centre with $\beta_{x,y}$ = 1.5 mm.

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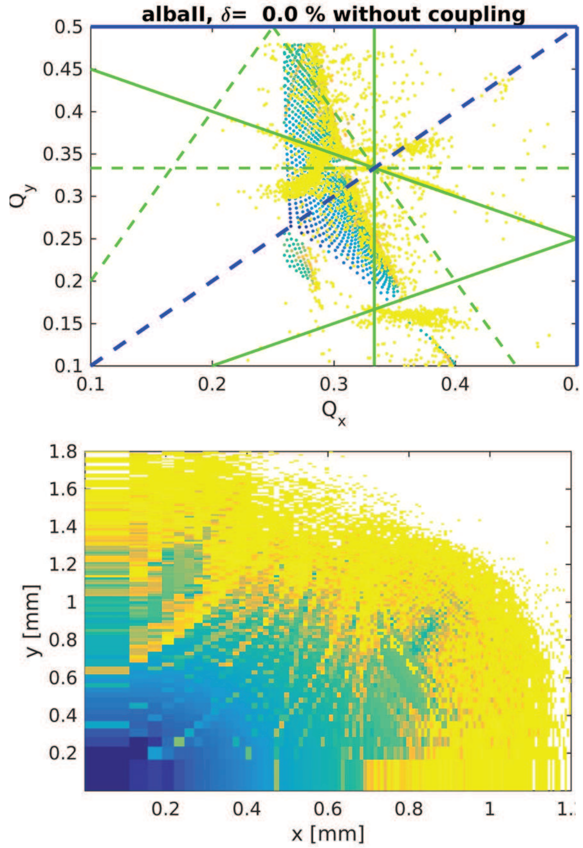


Figure 6: Frequency map analysis.

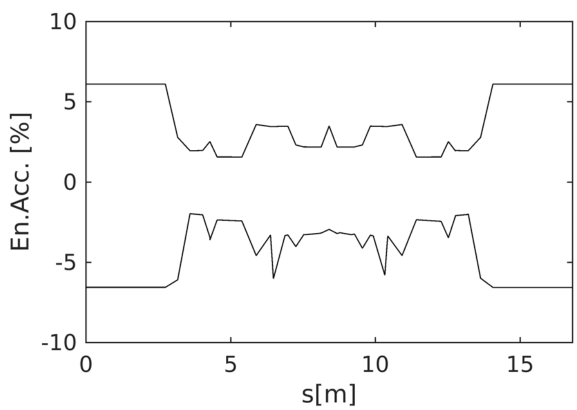


Figure 7: Local Touschek momentum acceptance along a single cell.

## CONCLUSION AND PERSPECTIVES

The solution to approach a diffraction limited lattice for ALBA makes mandatory leaving the present periodicity of the ring and adopting a fully symmetric lattice. As a consequence not all the straight section centres can be preserved and small shifts of some insertion device beamline must be taken into account. Last but not least, a solution for the beamlines based on dipoles must be studied testing whatever method to have dipole fields of 1.4 T as in the present bending magnets.

Concerning the injection, the present ALBA booster has an emittance as small as 10 nm·rad which makes it already suitable for an upgraded lattice with small dynamic aperture. The upgrade hence will affect only the injection scheme that can not be the present off-axis four kicker scheme anymore. In fact studies to test a pulsed multipole kicker at ALBA are in progress [8] and their developments can be applied to the upgraded lattice. Other off-momentum or on-axis injection schemes have to be considered and studied as well in order to define the most appropriate.

Finally, not only optimisations with an extensive use of tools based on genetic algorithms are foreseen to further adjust all the linear and non-linear parameters of the 7BA cell, but also increasing the number of bends to a 9BA is an option to be investigated to push the emittance below 100 pm·rad.

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