ISBN: 978-3-95450-231-8 ISSN: 2673-5490 doi: 10.18429/JACoW-IPAC2023-WEOGA1

ALBA II ACCELERATOR UPGRADE PROJECT STATUS*

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Abstract

ALBA is working on the upgrade project that shall transform the actual storage ring, in operation since 2012, into a 4th generation light source, in which the soft X-rays part of the spectrum shall be diffraction limited. The project was launched in 2021 with an R&D budget to build prototypes of the more critical components. The storage ring upgrade is based on a 6BA lattice which has to comply with several constraints imposed by the decision of maintaining the same circumference (269 m), the same number of cells (16), the same beam energy (3 GeV), and as many of the source points as possible unperturbed. At present, the lattice optimization, iterating with the technical constrains of space and performance, is ongoing. This paper presents the status of the project, with the present proposed lattice, first magnet's designs, the vacuum chamber and the girder design concept, the proposed RF system with fundamental and harmonics cavities, and the general context of the upgrade.

INTRODUCTION

The main goal of the accelerator upgrade for ALBA II is the transformation of ALBA into a diffraction limited storage ring, which implies the reduction of the emittance by at least a factor of twenty.

The upgrade has been conceived as a cost and time effective process, to be realized by the end of the decade and profiting at maximum from the existing infrastructures, in particular the building which is now hosting the facility. It has been decided that the storage ring (SR) upgrade will be done without any major modification of the shielding tunnel. Furthermore, the requirement of maintaining the Insertion Devices (IDs) as close as possible to their present position will preserve them operative for ALBA II and will imply minor modifications to the beamlines.

Another important decision has been the determination of the beam energy of ALBA II, which will be maintained at 3 GeV, after having considered several factors, between them, that increasing the energy of the SR would require replacing the whole booster, which increases the cost of the project and lengthens its realization. Also, the circumference of the SR is constrained to be about 270 m in order to reuse the tunnel; and since we want to preserve also the IDs position, a sixteen-cell geometry is imposed, which implies that a very compact cell is required.

* Work supported by the Spanish and Catalan Governments, and co-funded by the European Union – NextGenerationEU project 28.50.460D.74903 from the Recovery and Resilience Mechanism.
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LATTICE

Since the last lattice proposal was presented in 2021 [1] several iterations have been performed in order to deal with the dynamic aperture requirement for injection, lifetime, space between magnets, aperture for the vacuum chamber and synchrotron light extraction for the beamlines.

One of the main changes with respect to the previous design is the positioning of the horizontal sextupole at the centre between the dipole magnets instead of the quadrupole (Fig. 1). It has a detrimental effect on the ultimate emittance, but it significantly reduces the sextupole strength for the chromaticity correction, which leaves room for further dynamic aperture optimization.

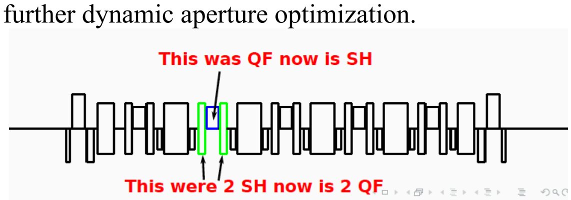

Figure 1: Change on the sextupole/quadrupole position.

Another change, which is quite a challenge, is the suppression of the 1st sextupole of the cell, which implies an asymmetric configuration of sextupoles along the cell (Fig. 2). This has been done to ensure sufficient aperture in the vertical plane in order to properly extract the synchrotron light out of polarising soft x-ray undulators.

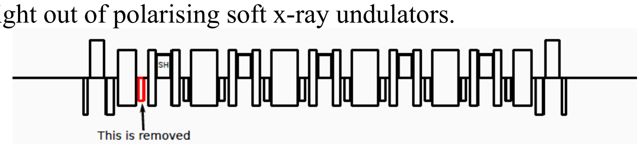

Figure 2: Suppression of the 1st sextupole of the cell.

The current optical functions (Fig. 3) are quite similar to the previous design, but the emittance has increased from 140 up to 185 pmrad.

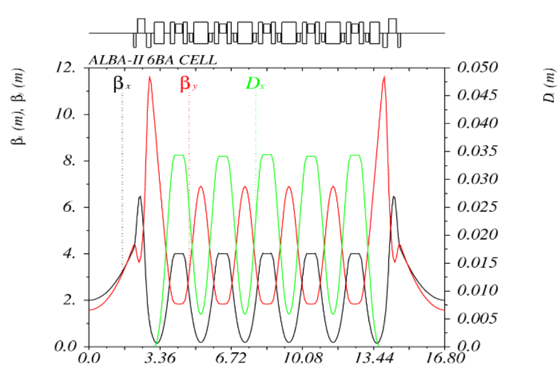

Figure 3: Optical functions.

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The details of current lattice design are presented in [2] and its performance for correction in [3].

MAGNETS

Ten different types of magnets are needed to fulfil the requirements imposed by the 6BA lattice. In total, ALBA II will be equipped with 632 individual magnets, including combined Dipole-Quadrupoles (QD/QDS), Reverse Bends (QF), Quadrupoles (Q1, Q2, Q3), Sextupoles (SH/SV), and Correctors (CORR). So far, no Octupoles are considered for ALBA II.

The 3D design and optimization of all the magnets is underway. Some representative magnets parameters are shown in Table 1.

Table 1: Parameters of the Main Magnets Types

Magnet	Bore diameter [mm]	Iron length [mm]	Field [T ; T/m; T/m²]	Efficiency [%]
Q3	20	190.6	108 T/m	90
QF	27.8	282.5	-0.4 T 70 T/m	91
QD	20	833.4	1 T -15 T/m	99
QDS	20	602.6	0.82 T 2 T/m	>99
SH	24	96.2	5000 T/m²	95
SV	26	174.0	-4000 T/m²	98
COR	36	20	0.06 T	>99

One of the main issues we are facing, due to the compactness of the lattice is the cross-talk between the magnets, in particular the corrector and quadrupole located at the straight section (Fig. 4 left). In the Fig. 4 right it can be seen how the leak field of the corrector enters inside the yoke of the quadrupole and introduces unwanted multipoles. At the moment we are investigating the best way to compensate this effect, since there is no space to separate the magnets.

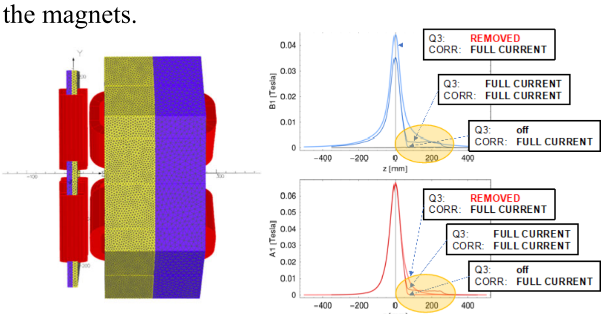

Figure 4: Corrector and Q3 separated by 55 mm yoke to yoke; and magnetic cross-talk.

Prototypes of all the different type of magnets, listed in Table 1 will be fabricated, allowing the assessment of the performance and of any cross-talk effects before the series production.

VACUUM

Aiming to get the best vacuum performance, the lowest impedance effects, while keeping the overall project risk and maintainability under control, the solution for the vacuum system will rely on a hybrid configuration, combining NEG-coated copper round chambers with conventional copper chambers with antechambers for localized pumping, and stainless-steel chambers at the position of the correctors.

Due to the compactness of the lattice, we are exploring the use of Matsumoto-Ohtsuka (MO)-type flanges. [4].

After a careful and detailed analysis of the vacuum chamber configuration, we have determined that four different types of chambers will be needed.

- Dipole copper vacuum chambers, with antechambers for direct pumping;
- Quadrupole-Reverse Bend copper vacuum chambers featuring distributed absorbers;
- Straight stainless-steel chambers with integrated BPM and below.
- Straight sections copper chambers, with and without pumping ports.

Figure 5 shows three types of chambers connected together with MO flanges. Such a prototype will be constructed in order to assess the production techniques.

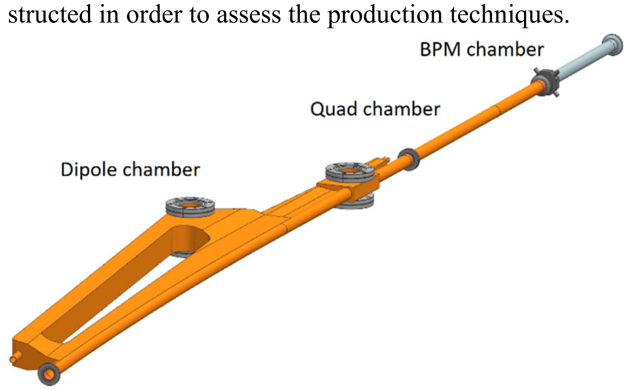

Figure 5: Vacuum chamber design.

GIRDER

The girder design has been started in parallel to the magnets and vacuum design in order to be able to detect as soon as possible all the possible interferences.

Since it is required for the installation to be as short as possible, in order to minimise the dark period for the users, the concept is that the whole girder with magnets and vacuum chamber, with cooling and electrical connections, will be assembled and tested in an assembly area, and the whole structure shall then be moved into the tunnel.

Figure 6 shows the present design of the girders for a complete cell, with three different girder lengths, 2.0, 2.6 and 3.6 meters.

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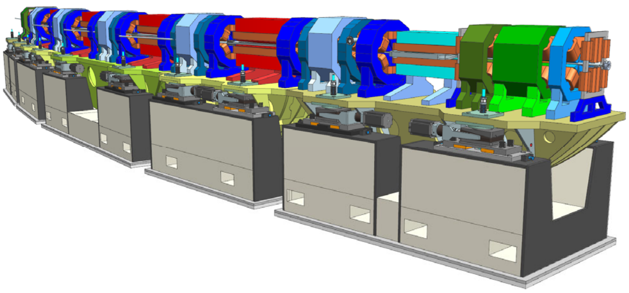

Figure 6: Girder, magnets and vacuum assembly of a cell.

A thorough investigation has been performed in order to determine the most stable girder design, in terms of highest vibration mode frequencies and smallest deformation. Fig. 7 shows the current design with the 1st eigenmode at 124 Hz and a maximum deformation of 3 µm.

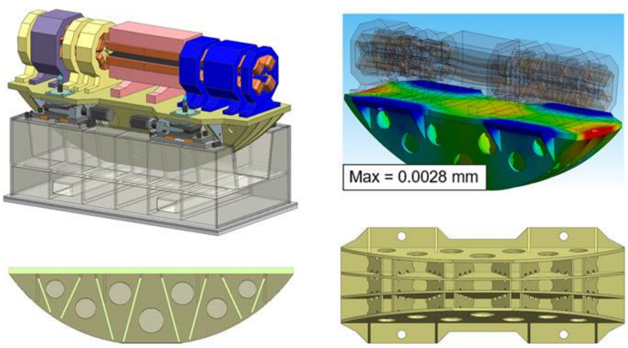

Figure 7: Girder design and FEA analysis.

RF

The main RF system of ALBA will be reused for ALBA II, since its operation parameters will be very similar and the nominal frequency will be kept at 500 MHz.

But for ALBA II the use of a 3rd harmonic system (3HC) is mandatory for increasing the bunch length, and so, the lifetime. For this purpose, a complementary RF system operating at 1.5 GHz shall be foreseen.

In summary, ALBA II will have six cavities working at the fundamental frequency of 500 MHz, and four 3rd harmonic cavities at 1.5 GHz. Both will be active normal conducting HOM damped cavities. Table 2 shows the main parameters of both systems.

Table 2: Main RF Parameters for ALBA II Storage Ring

Parameter	Fundamental RF system	3rd Harmonic RF system	Unit
Frequency	500	1,500	MHz
Cavity Voltage	400	165	kV
Number of cavities	6	4	-
Coupling factor	3,7	0,7	-
Shunt Impedance	3.3	1.1	MOhm
Quality factor	29500	13000	-
Synchronous phase	147.2	-12.2	degrees
Bunch lengthening factor	-	3.9	-
Transmitter power	92	3.2	kW
Power to beam	65	-10.5	kW

The bunch lengthening expected with this double RF system is estimated to be 3.9, with a Touschek lifetime above 20 hours for a 300 mA beam current in uniform multi-bunch mode and full coupling [5].

The uniform filling pattern is the optimum to avoid beam loading transient effects, which would deteriorate the bunch lengthening. In case that the vacuum provided by the hybrid vacuum system, with NEG and localized pumping, it is not enough to avoid ion trapping effects, then, gaps in the train will be needed. In this case, we have simulated that with a gap of up to 4% the Touschek lifetime will be still over 10 hours.

A prototype of the 3rd harmonic active cavity has been tested successfully in collaboration with DESY and HZB, both in single and multi-bunch mode, which has demonstrated the feasibility of such a system for ALBA II. Figure 8 shows the bunch lengthening tests done at BESSY II [6].

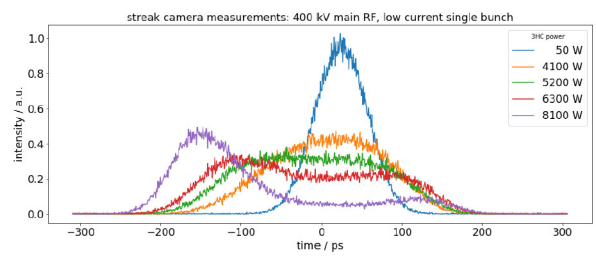

Figure 8: Bunch lengthening beam tests at BESSY II with the 3rd Harmonic EU Active Cavity Prototype.

UPGRADE PROJECT

The upgrade ALBA II is a larger project than only the accelerator replacement. It includes also the renovation of the existing beamlines, and the expansion of the infrastructure towards an adjacent land to allow for the construction of up to three new long beamlines. It will also serve as a synergy centre to create a scientific and technological pole in the area. Figure 9 shows an artistic view of the future ALBA II infrastructure.

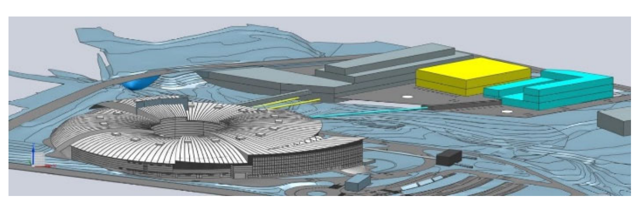

Figure 9: Artistic view of future ALBA II infrastructure.

The project is not yet fully approved, but we are already operating with a budget for prototype construction, and the close-by land for the expansion has already been secured. for ALBA II.

CONCLUSION

The project for upgrading ALBA to an ultra-low emittance, 4th generation, light source ALBA II is underway. Still under design, a series of prototypes for magnets, vacuum chambers, girders, pulsed elements and a superconductor undulator are foreseen [7].

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