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TOWARDS A LOW ALPHA LATTICE FOR THE ALBA STORAGE RING

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A proposal of a low alpha lattice for the ALBA third generation light source is presented. Opposed to most of other machines, belonging to the same category, ALBA employs an optimized lattice making use of combined function dipoles. This has permitted a very compact design stripped out of all not strictly necessary quadrupoles resulting in a lack of flexibility. For such a reason the common approaches used in many other synchrotrons cannot be directly applied to ALBA and a different strategy has to be worked out

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A proposal of a low alpha lattice for the ALBA third generation light source is presented. Opposed to most of other machines, belonging to the same category, ALBA employs an optimized lattice making use of combined function dipoles. This has permitted a very compact design stripped out of all not strictly necessary quadrupoles resulting in a lack of flexibility. For such a reason the common approaches used in many other synchrotrons can not be directly applied to ALBA and a different strategy has to be worked out.

INTRODUCTION

A new low momentum compaction factor lattice (low α) has been investigated for the ALBA light source [1] in order to provide users with pulses of x-ray shorter than one ps and coherent THz radiation. Such operation mode can be obtained by carefully tuning the lattice function in order to produce an almost isochronous ring. Because of the little flexibility imposed by the design of the ALBA storage ring different lattices and solutions have been investigated.

The first order contribution to the momentum compaction factor is given by the integral of the linear dispersion in the bend parts of the trajectory, for instance in the bending magnets. An explicit expression of the first order momentum compaction factor is given by:

$$\alpha_0 = \frac{1}{L}\int \frac{\eta_1(s)}{\rho(s)} ds$$

Where η_1 is the linear dispersion, ρ is the radius of curvature and L the length of the ring. It is clear that to achieve the low momentum compaction factor a negative dispersion has to be generated inside the bending magnets such that the negative and positive contributions cancel out each other. Different schemes to achieve such condition have been already proposed and successfully employed in other machines [2] [3].

However trying to apply such schemes on ALBA results in a very difficult task. The ALBA storage ring is composed by four identical arcs, each arc by two double bend achromat cells enclosed by other two modified double bend achromat cells, known as the matching cell in order to provide long straight sections where the injection is performed. Because the injection is of the off-axis kind, the matching cells have been designed to produce a higher value of the horizontal beta in the long straight sections. One of the driving requirements behind the ALBA design was cost and performance optimization, the result is a very compact and elegant design stripped out of all non strictly necessary quadrupoles, where all the magnets are designed to provide almost exactly the required field.

DBA Cell

The DBA cell in the nominal lattice has mirror symmetry, but in the actual machine each quadrupole is feed by an individual power supply. In a first attempt such a symmetry has been maintained.

To *push down* the dispersion function up to negative values in the middle of the bending magnets, the chromatic quadrupole, between the dipoles, has to be made stronger. Several matching attempts have been done using MAD-X [5] and Elegant [4] software, but no solution has been found without exceeding the maximum attainable field of the chromatic quadrupoles, that already in the nominal lattice are close to saturation. The most promising solutions are reported in Fig. 1 .

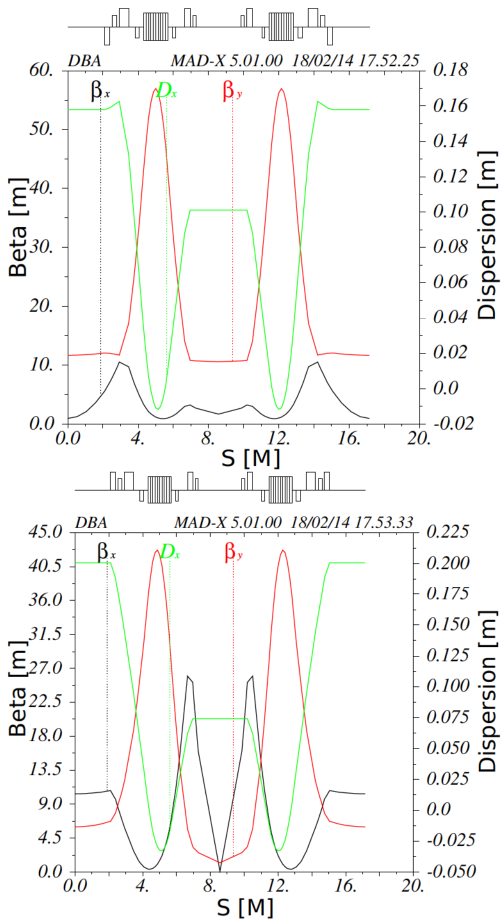

Figure 1: Two different solutions for the DBA cell. The one on the top is workable up to 2.4 GeV, the one on the bottom up to 2.0 GeV

In order to apply such solution to the machine without modifying the existing hardware a new working energy at 2.4 GeV and 2.0 GeV has been fixed to reduce the beam rigidity and make all the quadrupoles more effective.

Matching Cell

Once selected a suitable design for the DBA cell, the matching cell has been tuned with the same procedure as the DBA cell, to provide small momentum compaction factor and at the same time to keep good lattice parameters for the injection. Special care has been made to maintain the horizontal beta function in the long straight section at a high value to permit the injection. In the 2.4 GeV case the

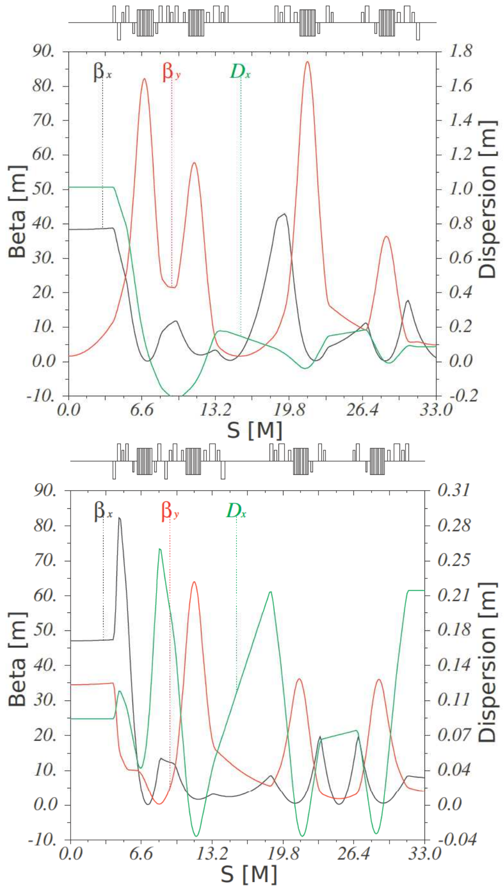

Figure 2: Two different solutions for the full arc. The one on the top is workable up to 2.4 GeV, the one on the botto up to 2.0 GeV

DBA lattice functions resulted too far from the nominal case and, because of the limited number of available quadrupoles, it was impossible to satisfy all the conditions at the same time. For this reason during this last matching procedure the condition on the DBA cells symmetry has been released giving rise to a complete breaking in the symmetry of the DBA cells, but still keeping the 4 fold symmetry of the ring. The obtained solutions are depicted in Fig. 2 and the main parameters are reported in Table 1.

Because the matching process is mainly driven by the constraints imposed by the low alpha condition and by the periodicity of the ring, given the limited degrees of freedom of the lattice, any solution results in higher emittance. This results in a degradation in performance for the x-ray production, since the emittance of such a photon beam is mainly determined by the electron beam emittance. On the contrary for the THz radiation this do not represent a real issue, since in this case the photon beam would be anyway diffraction limited.

Table 1: Low Alpha and Nominal Lattice Parameters Comparison

	Nominal	**2.4 GeV**	**2.0 GeV**
Q_x	18.155	18.106	18.360
Q_y	8.363	6.092	8.192
α_1	8.8×10^{-4}	$< 10^{-6}$	$< 10^{-6}$
Q'_x	-40.0	-50.0	-69.4
Q'_y	-27.7	-71.2	-54.1
ϵ	4.3 nm	19.2 nm	13.8 nm
ϵ at 3 GeV	4.3 nm	30 nm	31 nm

Non Linear Lattice

A first attempt to find a suitable sextupoles configuration has been carried out for the 2.4 GeV lattice. ALBA employs 9 families of sextupoles, where 4 of them consists of several sextupoles dislocated at different positions of each arc where the beta and dispersion functions assume the same values, exploiting the internal symmetry of the double bend achromat cells. This way the chromaticity correction is obtained by parting the needed strength over multiple sextupole. Unluckily the low momentum compaction factor lattice break such symmetry necessitating a new arrangement of the sextupoles. The initial nine families of sextupoles have been rearranged in 15 independent families. Nonetheless, because each sex-

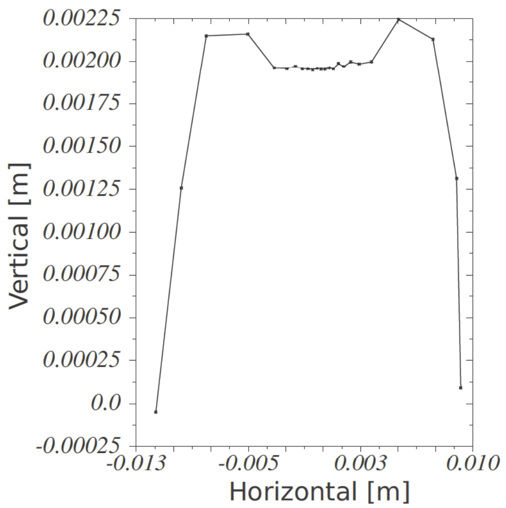

Figure 3: Dynamic aperture, calculated at the injection, obtained after splitting the sextupoles into 15 independent families

tupole family is powered in series by one power supply, some effort has been spent looking for a suitable configuration employing only 9 families even with some minor rearrangement of cabling, in order to be able to test the linear lattice on the machine without the need of new hardware.

The software Elegant and OPA have been used to optimize the non linear behavior of the lattice, in particular a target function composed by a linear combination of sextupolar driving term, chromaticities and second order momentum compaction factor, has been used as target function for a random-walk optimization algorithm.

The resulting dynamic aperture is reported in figure 3. Even if the dynamic aperture would be enough to inject and store a beam it is far from being satisfactory for normal operation.

ALTERNATIVE APPROACH

Because of the difficulties due to the large change in optical function, a different approach to reach low alpha operation in a storage ring has been investigated. A magnetic chicane placed in one long straight section can be used to zero and finely tune the momentum compaction factor of the whole ring, while being transparent from the point of view of the lattice functions in the rest of the ring. Such solution is not to be considered competitive in other machines where the lattice is flexible enough to ensure low alpha operation while keeping the emittance at low value. While in the case of ALBA the increase of emittance (27 nm at 3 GeV) would be comparable with the one observed in the previously presented lattices, but with the advantage of not requiring any intervention on the sextupole scheme.

Magnetic Chicane

A magnetic chicane is a device composed by four dipole magnets all having the same strength, the same size and the field aligned on the same axis but pointing in the direction such that electrons will follow a trajectory as depicted in Fig. 4. In the chicane electrons with higher energy will travel

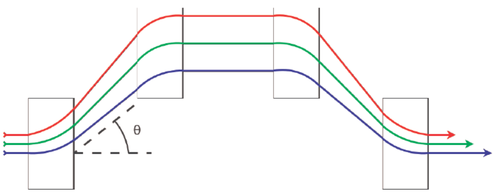

Figure 4: Three electrons with different energy travel along paths whose length depends on the energy.

through shorter paths than electrons with lower energy, giving rise to a negative momentum compaction factor. The bending angle of such chicane has to be properly tuned in order to introduce the right amount of negative momentum compaction factor to zero the positive one produced in the rest of the lattice. A chicane composed by four sector type bending magnets with transverse gradient has been simulated, a quadrupole has been fitted in the chicane arms in order to compensate for the focusing fringe fields of the dipoles and keep the lattice functions equal to the nominal one. For the same reason the two quadrupole triplets close to the long straight section have been tuned. The modified lattice and functions, close by the chicane, is depicted in Fig. 5.

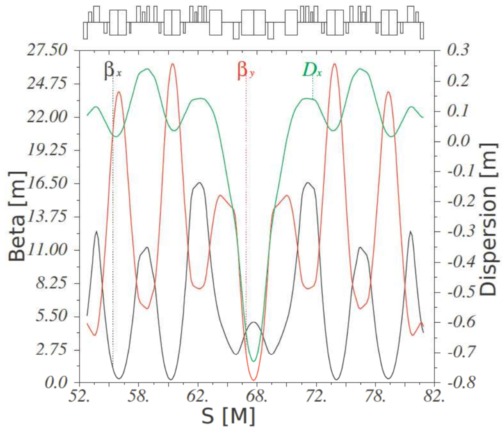

Figure 5: Lattice function of the ring close by the chicane.

Because of the strong detouring introduced by the chicane, the beam trajectory will be shifted by almost 50 cm, thus a bypass beam-pipe should to be inserted to accommodate the beam when the chicane is switched off.

CONCLUSION

A low alpha linear lattice for the ALBA storage ring has been investigated. Some major difficulties were found during this process because of the lack of flexibility imposed by the ALBA optics. A first attempt of a working sextupole configuration has also been described, but still some improvement on the dynamic aperture is needed. For this purpose a different optimization approach where the dynamic aperture is directly used as optimization variable will be tried. An initial study to investigate the microwave instabilities threshold is going on but a definitive result has still to be found.

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