MAGNETS FOR THE STORAGE RING ALBA

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Abstract

The Storage Ring ALBA is a 3.0 GeV synchrotron light source under construction in Barcelona (Spain). The Storage Ring has a circumference of 268.8 m and comprises 32 combined magnets, 112 quadrupoles, and 120 sextupoles. This paper will describe the design and the present state of these magnets. The combined magnet has a central field of 1.42 T and a large gradient of 5.65 T/m, since most of the vertical focusing happens at these combined magnets. The 112 quadrupoles have been designed for a maximum gradient of 22 T/m. The bore diameter will be 61 mm and the lengths range from 200 to 500 mm. Each quadrupole will be individually powered. The 120 sextupoles are divided in 9 families. There are two lengths of sextupoles 150 and 220 mm and the maximum sextupole gradient is 600 T/m^2. The bore diameter is 76 mm. The sextupole magnets will also be equipped with additional coils for vertical steering, horizontal steering and quadrupolar skew correction.

DIPOLES

ALBA requires a total of 32 C-shape bending magnets. The cores will be laminated and the laminations will be stacked together along a curved line with uniform radius thus forming a curved magnet with parallel ends. The pole was designed using the OPERA 2D [1] software and it combines dipolar and quadrupolar fields. Table 1 summarizes the main dipole design parameters.

Table 1: Dipole design parameters

Magnetic proerties		
Central field	1.42	T
Field gradient	5.656	T/m
Effective length	1.384	m
Mechanical properties		
Bending radius	7.047	m
Bend angle	11.25	degrees
Central gap	36	mm
Length of the Fe yoke	1340	mm
Coil and conductor		
Number of coils	2	
Turns per coils	40	
Conductor size	16.3 x 10.8	mm^2
Cooling channel diameter	6.6	mm
Number of Amper turns per coil	21000	A.turns
Current	527	A
Cooling		
Maximum ΔT	8.6	^{o}C
Nominal imput temperature	23	^{o}C
Number of cooling circuits per magnet	2	
Maximum pressure drop per magnet	7	bar

Figure 1 shows the upper half of the dipole cross section. The result of the field uniformity is shown in Figure 2.

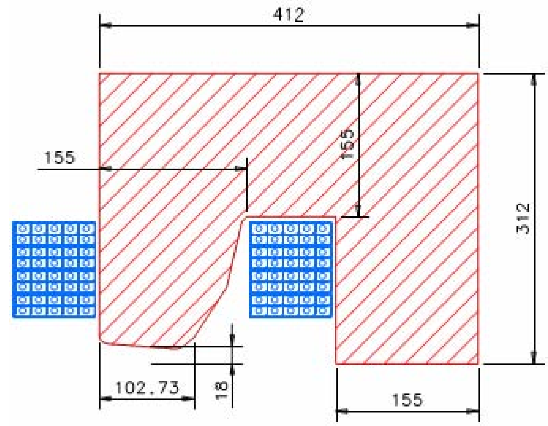

Figure 1: Upper half dipole cross section.

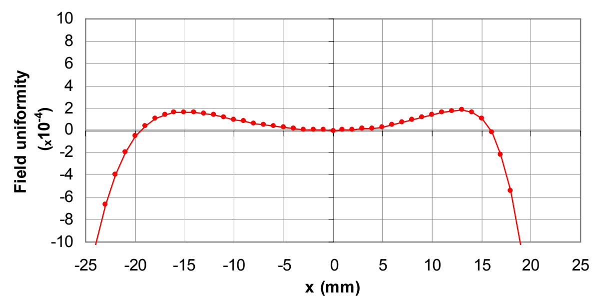

Figure 2: Field uniformity.

3D simulations were done in order to evaluate the multipoles along the beam trajectory. The 3D model was also used to predict the shape of the end chamfer, which is designed in order to have the same effective length along the transversal position. Figure 3 shows the effect of the applied end chamfer in the effective length of this magnet, defined as:

$$Leff(x) = \frac{\int B_y(x,s)ds}{B_y(x,s=0)} \quad (1)$$

where $B_y(x,s)$ is the vertical component of the magnetic field along the transversal (x) and the trajectory (s) axis.

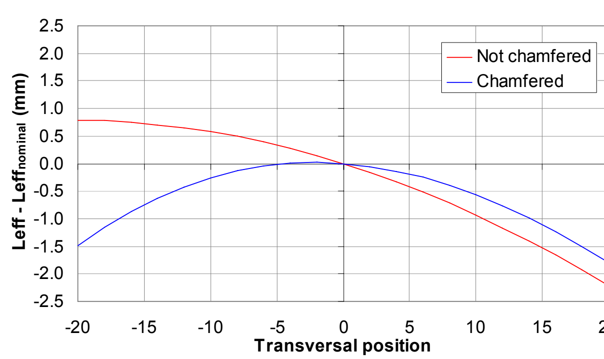

Figure 3: Leff-Leff$_{nominal}$ along the transversal position.

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QUADRUPOLES

ALBA requires a total of 112 quadrupoles. The quadrupoles are distributed in two main types (from the magnetic point of view): closed (CX) and opened (O); and in 4 different physical lengths: 200, 260 280 and 500 mm. Table 2 summarizes the main design parameters of the quadrupoles.

Table 2: Quadrupole design parameters

Quadrupole Name		Q500	Q280	Q260	Q200
Magnetic proerties					
Maximum field gradient	T/m	22.0	21.5	21.0	20.0
Magnetic field at pole tip	T	0.67	0.65	0.64	0.60
Effective length	m	0.530	0.310	0.290	0.230
Mechanical properties					
Aperture radius	mm	30.5			
Iron length	m	0.500	0.280	0.260	0.200
Coil and conductor					
Number of coils		4			
Turns per coils		46			
Conductor size	mm^2	8 x 8			
Cooling channel diameter	mm	5			
Number of Amper turns per coil	A.turns	8620	9180	8220	7717
Current	A	187.4	199.6	178.7	167.8
Cooling					
Maximum ΔT	°C	8			
Nominal imput temperature	°C	23			
Number of cooling circuits per magnet		4			
Maximum pressure drop per magnet	bar	7			

The O types are used in the places where it is necessary to accommodate the experimental beam lines. Therefore two types of non-magnetic spacers are used in ALBA: the OI (where the beam line passes inside de quadrupole) and OC (the beam line passes outside the quadrupole), as can be seen in figure 4. The use of non-magnetic spacers avoids asymmetries in the field distribution in quadrupole cores, which may reduce the gradient uniformity.

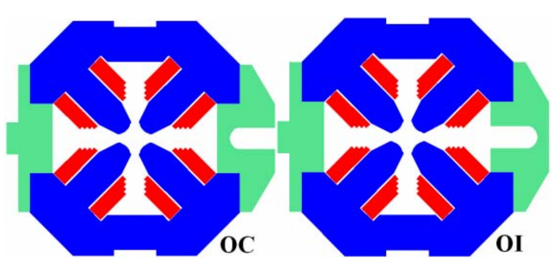

Figure 4: The two types of quadrupoles.

The geometry was optimized using OPERA 2D in order to have a good field region (GFR) better than $4 \cdot 10^{-4}$ within ±20 mm. The cross section of these magnets is shown in figure 5.

Simulations in 3D where done in order to evaluate the integrated GFR as well as the integrated multipoles. The 3D model also permits to predict the length of the 45 degree end chamfer. The end chamfer is designed to minimize the dodecapolar (n=6) component. Figure 6 shows the results of the integrated harmonic analysis for the different quadrupoles with the optimum end chamfer applied.

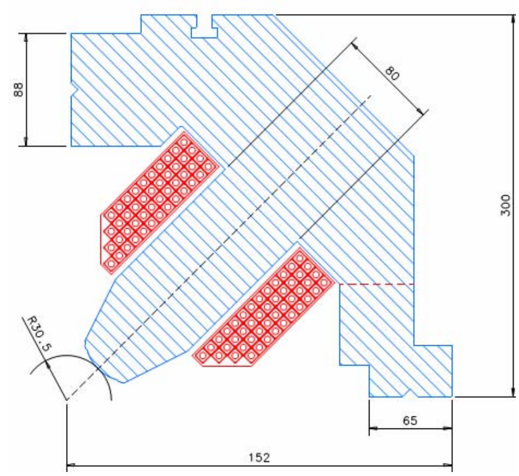

Figure 5: Quadrupole cross section (CX). The AA mark shows the limits of the O type cross section.

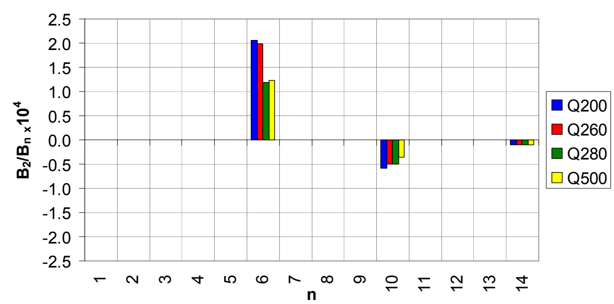

Figure 6: Integrated multipoles calculated in a reference radius of 20 mm with the optimum end chamfer applied. The quadrupolar component (n=2) is not shown.

SEXTUPOLES

ALBA requires a total of 120 sextupoles, distributed in two different physical lengths: 150 and 220 mm. Table 3 summarizes the main design parameters of the Sextupoles.

The geometry was optimized using OPERA 2D in order to have a GFR better than $4 \cdot 10^{-4}$ within ±20 mm. The cross section of these magnets is shown in figure 7.

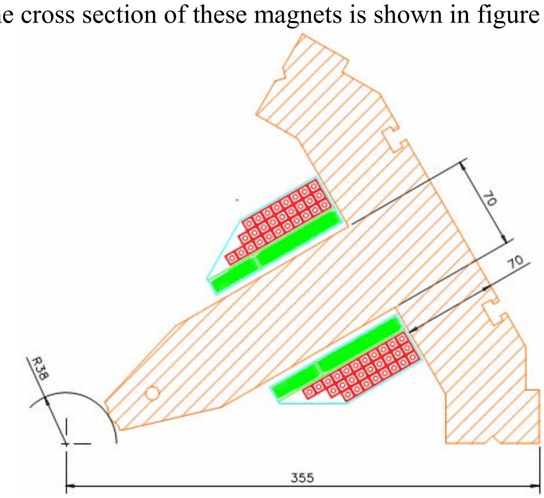

Figure 7: Sextupole cross section.

Table 3: Sextupole design parameters

Sextupole Name		S150	S220
Magnetic properties			
Maximum field gradient	T/m^2	600.0	600.0
Magnetic field at pole tip	T/m	0.51	0.51
Effective length	m	0.175	0.245
Mechanical properties			
Aperture radius	mm	38	38
Iron length	m	0.150	0.220
Coil and conductor			
Number of coils		6	
Turns per coils		28	
Conductor size	mm^2	7 x 7	
Cooling channel diameter	mm	3.5	
Number of Amper turns per coil	A.turns	5400	
Current	A	192.9	
Cooling			
Maximum ΔT	^{o}C	9	
Nominal imput temperature	^{o}C	23	
Number of cooling circuits per magnet		3	
Maximum pressure drop per magnet	bar	7	

Simulations in 3D where done in order to evaluate the integrated GFR as well as the integrated multipoles. The 3D model also permits to predict the length of the 45 degree end chamfer. The end chamfer is designed to minimize the 18-pole (n=9) component. Figure 8 shows the results of the integrated harmonic analysis for the different quadrupoles with the optimum end chamfer applied.

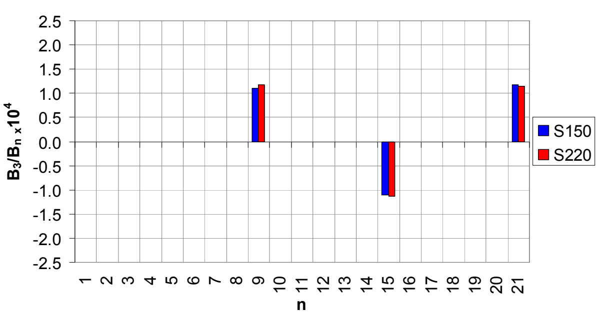

Figure 8: Integrated multipoles calculated in a reference radius of 20 mm with the optimum end chamfer applied. The sextupolar component (n=3) is not shown.

The sextupoles have additional coils (named as N1 and N2 in figure 7) for horizontal, vertical steering and quadrupole correction. The coils are powered according to figure 9 depending on the desired correction. Table 4 summarizes the main corrector parameters.

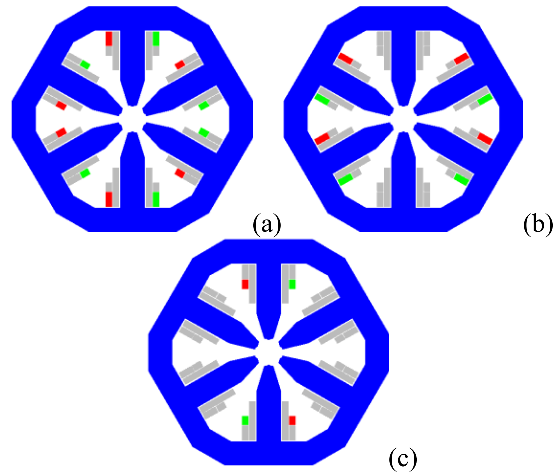

Figure 9: Coils configurations for (a) Horizontal steering; (b) Vertical steering; (c) Skew quadrupole correction. Green and red represent, respectively, the positive and negative current flux in each coil.

Table 4: Typical corrector parameters

Corrector Names		Horizontal	Vertical	Skew
Magnetic properties				
Maximum magnetic field	T	0.050	0.050	0.007
Coil and conductor				
Number of coils		6	4	2
Coils name		N1 and N2	N1	N2
Coil N1				
Number of turns		174	174	-
Conductor size	mm^2	4 x1	4 x1	-
Number of ampere.turns	A.turns	1400	1300	-
Current	A	8.0	7.5	-
Coil N2				
Number of turns		87	-	87
Conductor size	mm^2	4 x1	-	4 x1
Number of ampere.turns	A.turns	700	-	300
Current	A	8.0	-	3.4

PRESENT STATUS

The magnetic design of the magnets for the ALBA Storage Ring is finished and the magnets are now in the production phase.

Prototypes shall be available at the end of 2006 for checking the magnetic design and the production phase shall be completed in the first quarter of 2008.

REFERENCES

[1] Opera-2D©, Opera-3D© and Tosca©, Trademark from Vector Fields Limited, Oxford, England