INJECTOR DESIGN FOR ALBA

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Abstract

The storage ring ALBA is a 3rd generation synchrotron light source under construction in Barcelona (Spain). The facility is based on a 3.0 GeV storage ring of 268.8 m circumference with a beam emittance under 5 nm.rad. Top-up operation is foreseen from day one. The injector complex for ALBA will consist of a 100 MeV linac and a full energy booster. The linac will be a turn-key system which has already been ordered to the industry and delivery is expected in the second half of 2007. The full energy booster will be placed in the same tunnel as the storage ring and will have a circumference of 249.6 m. The lattice of the booster is a modified FODO lattice providing an emittance as low as 9 nm.rad. The magnet system comprises 40 combined magnets and 60 quadrupoles. Chromaticity correction relies on the sextupole component built-in the combined magnets and the quadrupoles. In this paper a description of the injector including the present status of the different components will be given.

INTRODUCTION

The injector for ALBA will consist of a 100 MeV electron linac followed by a full energy booster up to 3.0 GeV. The booster and the storage ring will share the same tunnel, with a simple transfer line connecting the two rings.

LINAC

The linac injector for ALBA is a turn key system provided by Thales Communications based on the specifications listed in table 1. It will work in single and multi bunch mode. Figure 1 shows schematically the linac.

Table 1: Technical Specifications at the Linac exit

Parameter	Unit	Single Bunch	Multi Bunch
Pulse Length	ns	1	2 to 1024
Charge	nC	2 nC	4 nC
Norm.Emitt.(1σ)	π mm rad	≤ 30	≤ 30
Energy Spread	%	≤ 0.5 (rms)	≤ 0.5 (rms)
Rep.Rate	Hz	3 to 5	3 to 5
Energy	MeV	≥ 100	≥ 100

The linac consists of a 90 kV dc thermoionic gun, a sub-harmonic pre-buncher (500 MHz), a pre-buncher (3 GHz) and a 22-cells standing wave buncher (3 GHz). The bunching system is designed to reduce the energy spread and to minimize the losses. Two travelling wave constant gradient accelerating sections increase the energy up to 125 MeV. Two TH2100 pulsed klystrons will feed the accelerating sections, and also the buncher at 3 GHz. The sub-harmonic prebuncher and the pre-buncher at 3 GHz will have an independent RF amplifier. The transmission from the gun to the linac exit has been estimated to be around 80%.

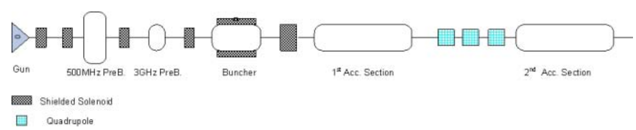

Figure 1:ALBA Linac layout

Beam focusing is ensured by solenoids up to the bunching section and a triplet of quadrupoles between the two accelerating sections. Beam dynamics simulations have been carried out for single bunch and multi bunch mode with the *GPT* code [1]. The expected performances are listed in table 2.

Table 2: Results from simulations

Parameter	Unit	Single Bunch	Multi Bunch
Norm.Emitt.(1σ)	π mm rad	15	10
Energy Spread	%	0.3 (rms)	0.4 (rms)
Energy	MeV	125	125

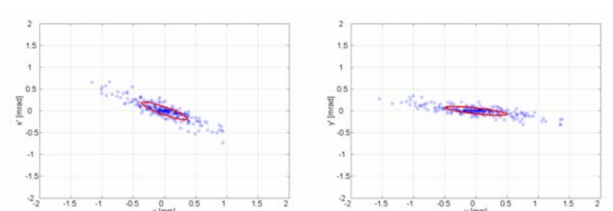

Figure 2: Transverse phase space at linac exit in single bunch mode

The diagnostic system is based on an extensive use of fast current transformers; a total of 7 will be installed, one after each active element, and three fluorescent screen monitors will be installed at the output of the buncher and the two accelerating sections.

BOOSTER

The Booster structure has a four-fold symmetry. Each quadrant arc has 10 cells: 8 regular cells – based on a modified FODO structure where vertical focusing is provided by a combined function bending dipole with a gradient of 23 T/m at 3 GeV and horizontal focusing by a quadrupole – and 2 matching cells, composed of a shorter combined function dipole and 3 quadrupoles. The resulting emittance of such a lattice is as low as 9 nm rad. Figure 3 shows the lattice and the optical functions for 1/4th of the Booster. The arcs are connected by four long straight sections (2.46 m) which will be used for the injection, the RF cavity and the diagnostics components. The main parameters of the booster are presented in table 3.

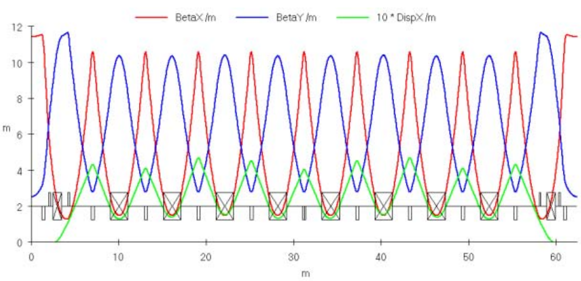

Figure 3: Lattice and optical functions

Table 3: Booster parameters

Parameter	Unit	
Maximum energy	GeV	3.0
Circumference	m	249.6
RF frequency	MHz	500
Maximum current	mA	5
Maximum repetition rate	Hz	3
Tune Qx, Qy		12.43 / 7.38
Natural chromaticity $\zeta_{x,}$, $\zeta_{y,}$		-17 / -10
Equilibrium values at 3 GeV		
Emittance	nm.rad	9.0
Radiation losses	keV/turn	0.62
Energy spread	%	0.001
Damping times	ms	4.5 / 8.0 / 1.8

Closed Orbit System

Orbit will be measured at 44 BPM's and corrected with 44 horizontal and 28 vertical steering magnets (4 correctors per betatron oscillation). Misalignments and roll angle errors up to 200 μm and 0.5 mrad can be compensated with a 200 μrad maximum strength in the correctors.

Non Linear Optics

The natural chromaticity of the Booster ring is relatively small, see table 3 and is corrected to $\zeta_{x,y}$ = +1 with a sextupole component built-in the combined function bending magnets and the quadrupoles pole profile (S = 18 T/m^2 and 44 T/m^2 at 3 GeV, respectively). Two families of 8 sextupole magnets add flexibility to the lattice and will be regularly used to correct the eddy current effects in the dipoles during the field ramping. The dynamic aperture, shown in figure 4, has been calculated for energy deviations up to 2 % and it is larger than the physical aperture of the ring. Furthermore the dynamic aperture was also calculated including the sextupole contribution generated by the eddy currents in dipoles at 200 MeV, where the eddy current effect is maximum, and switching on the 16 sextupole magnets needed to keep constant the chromaticity during the ramping both in a scenario with $\zeta_{x,y}$ = +1 and with $\zeta_{x,y}$ = +5. In all these studied cases the dynamic aperture is larger than the physical aperture of the booster.

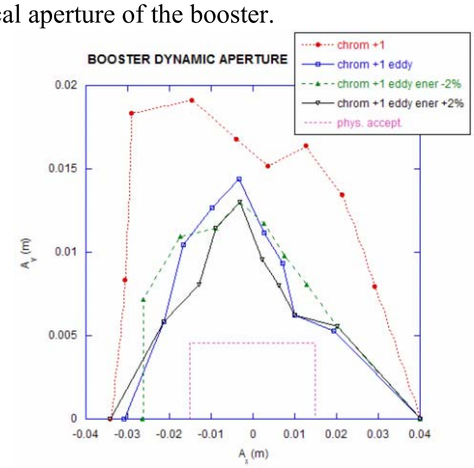

Figure 4: Booster dynamic aperture with $\zeta_{x,y}$=+1, with eddy currents at the dipole and off-energy particles

STATUS OF THE MAIN COMPONENTS

Magnets

The booster contains 40 combined function bending magnets, 60 quadrupoles, 16 sextupoles and 72 steerer magnets. The design of the magnets is finished and they will be ordered before the end of the summer.

With the small emittance of the booster we have designed magnets with small apertures, the quadrupoles have an aperture radius of 18 mm and the bending have a gap of 22 mm. Table 4 summarises the main characteristics of the magnets.

Table 4: Booster magnets parameters

Parameter	Unit	
# Dipole magnets		8 / 32
Maximum magnetic field	T	0.87
Bending angle	deg	5 / 10
Number of quadrupoles		36 / 16 / 8
Max. gradient	T/m	16
Sextupolar comp. d^2B/dx^2	T/m^2	44 / 0 / 0
Magnetic length	mm	360 / 200 / 360

Radius of aperture	mm	18
Number of sextupoles		16
Max. d^2B/dx^2	T/m^2	400
Magnetic length	mm	190
Radius of aperture	mm	18

Radiofrequency

The Booster's RF system shall provide enough voltage, at full energy, to compensate for the synchrotron beam losses and to provide enough quantum lifetime. A dynamic range of 23 dB is also needed to be able to reduce the voltage at injection to ensure a good injection efficiency.

The voltage will be produced by one 5-cell Petra type cavity, already ordered to ACCEL. This cavity will be feed with 40 kW to produce 1 MV of voltage at 500 MHz. In addition, a beam power of 3 kW is needed for a beam current 5 mA, which is the maximum the LINAC can deliver. To produce these 43 kW of power, an 80 kW IOT based transmitter has been chosen. This solution gives ample margin of power, and permits the standardisation of the transmitters of the whole facility, since the storage ring RF system will be based on the same units [2]. The transmitter and waveguide transmission line are in the tendering process. The Low Level RF is being developed in house [3].

Diagnostic

Table 5 below shows the diagnostic components to be installed in the booster and also on the transfer lines.

Table 5: Injector diagnostic components

Instrument	LTB	BO	BTS
Beam Position Monitors	4	46	3
Beam Charge Monitors	2	-	-
Fast Current Transformers	2	1	3
DC Current Transformers	-	1	-
Fluorescent Screens / OTRs	3	4	3
Synchrotron Rad. Monitors	2	3	2
Scrapers	1	-	1
Annular Electrodes	-	1	-
Striplines	-	2	-

Vacuum Chamber

The design of the vacuum chamber is now completed. The vacuum chamber profile will be elliptical (17.6 x 46 mm internal) at the dipoles and circular (ID=29 mm) at the quadrupoles. There will be a step transition between the two close to the vacuum pumps.

The thickness of the vacuum chamber will be 1 mm. This has been found to be a good compromise between the need of introducing ribs to increase the rigidity of the vacuum chamber and the attenuation effect of the eddy currents in the magnetic field.

20 l/s ion pumps will be installed at each side of the dipoles and in addition another pump will be installed at the beginning of the unit cell, see figure 5. In total around 130 ion pumps will be installed around the booster; with this arrangement a pressure in the 10^{-8} mbar range with beam will be achieved. Bellows will be installed at each side of the unit cell.

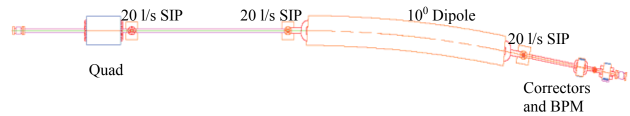

Figure 5: The unit cell of the booster.

TRANSFER LINES

Linac to Booster

The beam provided by the Linac at the energy of 100 MeV is injected in the Booster through transfer line of 14.5 m. The vacuum chamber has a radius of 20 mm as in the Linac. The line design consists of three quadrupole triplets alternating with two dipoles 0.3 m long. After the first quadrupole triplet an OTR screen is installed to perform emittance measurements of the linac beam. Flexibility of the line has been tested in order to match different initial optical functions from the Linac. The line terminates with a septum magnet 1 m long deflecting the beam trajectory by 13.5º (0.0781 T).

Booster to Storage Ring

The beam extracted at 3 GeV from the Booster is transferred to the Storage Ring through a line of 23.7 m. 7 quadrupoles and 2 dipoles with an angle of 10.55º are installed in the line. A section 4 m long has been left clear to allow people and small equipment to pass below the beam pipe to gain access to both the Booster and the Storage Ring. The vacuum chamber has the same dimensions as in the Booster.

CONCLUSIONS

The design of the injector for the ALBA Light source is now completed and the main components are in the process of being ordered.

The beam provided by the injector will be of low emittance and therefore shall provide the high injection efficiency required for top-up operation

REFERENCES

[1] http://www.pulsar.nl/
[2] F.Perez, B.Baricevic, H.Hassanzadegan, A.Salom, P.Sanchez and D.Einfeld, "New Developments for the RF System of the ALBA Storage Ring", this conference.
[3] H.Hassanzadegan, A.Salom and F.Perez, "Analogue and Digital Low Level RF for the ALBA Synchrotron", this conference.