THE ELETTRA BOOSTER MAGNETS CONSTRUCTION STATUS

D. Zangrando, D. Castronovo, F. Iazzourene and M. Svandrlik,
Sincrotrone Trieste, s.s.14, km 163.5, 34012 Trieste, Italy

Abstract

The third generation light source ELETTRA has been in operation since 1993. A new 2.5 GeV full energy booster injector has been approved for the first time in 2000 and finally founded last year. It will replace the existing linear injector limited to a maximum energy of 1.2 GeV. Once the specifications and the preliminary magnetic and mechanical design were completed last year, the orders for all the magnets were assigned to two European firms. The paper reports on the magnets construction status.

INTRODUCTION

Four years ago [1] we presented a magnet design of all the booster magnets based on the conceptual design described in [2]. In the mean time, in order to allow the injection of the electron beam in top up mode a booster lattice with a smaller emittance has been investigated and then developed [3,4]. The main upgrades with regard to the dipole magnets were an increase of the magnetic length to 2 m and a decrease of its gap to 22 mm. The new magnetic design carried out using Radia [5] and Poisson [6] was concluded in November 2004. It was based on the calculations described in [1] and [7] and adapted to meet the new optics requirements.

Following a tender exercise, a contract was subsequently placed with Danfysik in July of last year, for the detailed design, manufacture and magnetic measurements of the dipole, quadrupole and sextupole magnets. Another contract was placed with Tesla Engineering Ltd, in August, for the supply of the corrector magnets.

For all the magnets, but in particular for dipoles and quadrupoles, the magnetic design was carried out taking into account the resulting inductance in order to decrease as much as possible the total power requested to the power supplies for ramping at 3 Hz. Nevertheless, in order to operate with a voltage below 1 kV, all bending magnets will be powered by 2 power supplies: one dedicated to the upper coils and one for the lower coils.

The magnets of each quadrupole family (focusing: QF, defocusing: QD) and each sextupole family (focusing: SF, defocusing: SD) will be instead connected in series and powered by only one power supply per family.

The iron coercivity requested for all the magnets was 30 A/m however we agreed to construct all the magnets with EBG (Thyssen-Krupp) M270/50 that is a good compromise between our requirement and market availability, even if its coercivity could result a bit more than our specification (40 A/m). The thickness lamination is 0.5 mm for all magnets.

The prototype of each type of magnet will be ready this summer for testing. The series magnet construction will start immediately afterwords, and all magnets will be delivered to Sincrotrone Trieste by February 2007.

DIPOLES

With respect to the previous design [1] the gap has been reduced to 22 mm and the magnetic length increased to 2 m. The main dipole parameters are shown in Table 1. Fig. 1 shows the new dipole cross section agreed between Sincrotrone Trieste (ST) and Danfysik. The selected cross section will guarantee a systematic (due to the geometry) sextupole component less than 0.01% at r = 20 mm. The estimated magnetic field saturation at maximum field is about 1%.

Table 1: Booster Dipoles

Number of magnets	28	
Curvilinear magnetic length	2.0	m
Curvature angle	12.86	deg
Curvature radius	8912.68	mm
Gap height	22	mm
Max. freq. of operation	3	Hz
Cross section	H-type	
B at injection (0.1 GeV at I = 29 A)	0.037	T
B at extraction (2.5 GeV at I = 737 A)	0.936	T
Number of turns (total)	24	
Max. total power loss (at 3 Hz)	3.8	kW
Single coil resistance (at 40°C)	7.5	mΩ
Magnet inductance (coils in series)	7.5	mH
Magnet pressure drop	3.5	bar
Cooling water flow rate	9.3	l/min
Cooling water temp. rise	6	°C
Magnet weight	1500	Kg

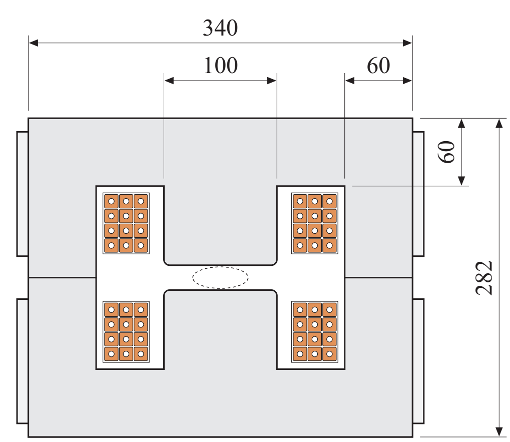

Figure 1: Dipole Cross Section

In order to evaluate the sextupole component induced by the dipole magnetic field variation in presence of the elliptical stainless steel vacuum chamber (50 mm x 20 mm; thickness 1 mm) with a finite relative permeability $\mu_r = 1.02$, we carried out some calculation using Elektra (a commercial software by Vector Field Limited) for a booster frequency of 3 Hz.

In fig. 2, the red curves show the sextupole component induced by eddy current only, with a dipole field ramped from 0.05 GeV(solid curve) and 0.1 GeV (dotted curve) to 2.5 GeV. The green curves show the overall sextupole component (eddy Current, relative permeabilty $\mu_r = 1.02$ and transverse finite size of the pole): the sextupole component due to the eddy current (~ 0.16% at r = 20 mm, starting the ramping at 0.05 GeV), is compensated by the other opposite sextupole components, so the overall sextupole at injection (green, solid curve) decreases to ~ 0.13% at r = 20 mm. At 2.5 GeV, the overall sextupole component is negative: - 0.04% (at r = 20 mm). With a ramping starting at 0.1 GeV (dotted curve), the maximum overall sextupole component is ~ 0.08% at 0.192 GeV (r = 20 mm).

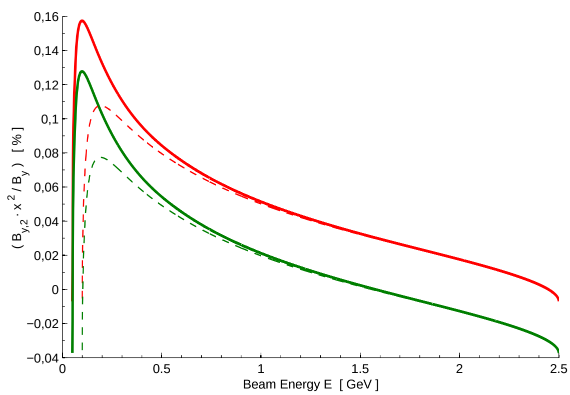

Figure 2: Sextupole field component [%] at r = 20 mm during energy ramping, due to eddy current only (red curves) and overall component (green curves) with an energy ramping from 0.05 (solid curves) and 0.1 GeV (dotted curves) to 2.5 GeV.

Dynamic aperture simulations have been performed. Fig. 3 shows the dynamic aperture for the low emittance optics at 2.5 GeV, assuming the above overall sextupole and assuming that all the dipole magnets have a sextupole component at r = 20mm of - 0.08%, i.e. defocusing (blue curves), + 0.08%, i.e. focussing (green curves), 0 (pink curves). All the above cases include the sextupoles SF and SD set to correct the chromaticities to zero in both planes. The computations are for on momentum particles (solid curves) and off-momentum particles (dashed or dash-dotted curves) for ± 0.036%, i.e., 5 sigma. Only in the worst case, where we assume that all the dipoles have the same sextupole component + 0.08% at r = 20 mm, allowed by our specifications, the correction of the chromaticity to + 5 is very demanding for SD in the low emittance optics at 2.5 GeV.

QUADRUPOLE MAGNETS

The main parameters of the quadrupole magnets are shown in table 2. The focussing (QF) and defocussing (QD) quadrupoles have the same cross section (fig. 4) but different magnetic length. The estimated magnetic field saturation with a gradient of 20 T/m is about 3%. At radius of 20 mm, the evaluated overall systematic harmonic contribution is about 0.04% and thus well below the specified 0.15%.

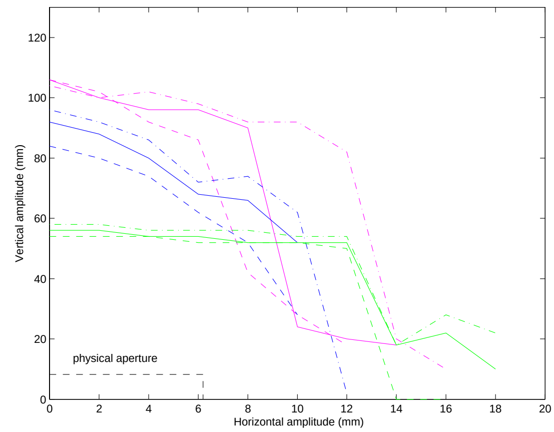

Figure 3: Dynamic aperture at 2.5 GeV for the low emittance optics for different sextupole components and energy spreads.

Table 2: Booster Quadrupoles

	QF	QD	
Number of magnets	18	18	
Bore radius	28	28	mm
Magnetic length	0.280	0.175	m
Nominal gradient at extraction (2.5 GeV)	18.65	18.95	T/m
Current at max. gradient (20 T/m)	378	382	A
Number of turns (per pole)	20	20	
Total power loss (at 3 Hz)	0.9	0.64	kW
Magnet resistance (at 40°C)	16	11.5	mΩ
Magnet inductance	3.65	2.3	mH
Magnet pressure drop	3.5	3.5	bar
Cooling water flow rate	1.2	1.4	l/min
Cooling water temp. rise	10.9	6.4	°C
Inlet water temperature	26	26	°C
Magnet weight	250	155	kg

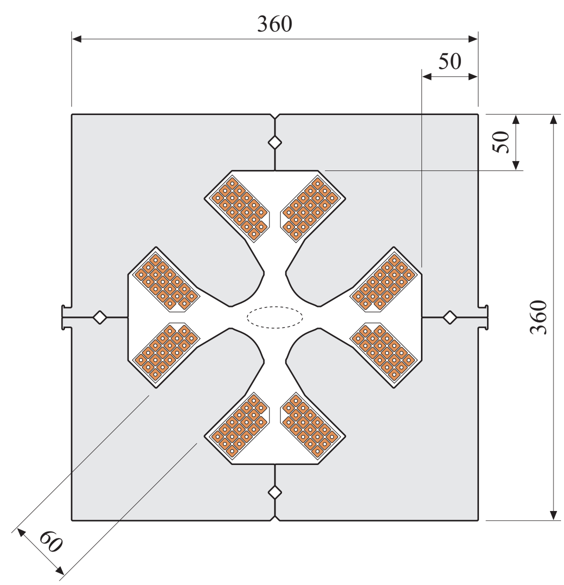

Figure 4: Quadrupole Cross Section

SEXTUPOLE MAGNETS

The main parameters of the sextupole magnets are shown in table 3 and the central cross section is shown in fig. 5. The calculated systematic harmonic contribution is less than 0.05% (about 10 times smaller than our specification). The estimated field saturation is less than 0.3% at maximum sextupole gradient.

Table 3: Booster Sextupoles

	SD	SF	
Number of magnets	12	12	
Bore radius	30		mm
Magnetic length	0.100		m
Max. sextupole gradient (at 61 A)	153		T/m^2
Number of turns (per pole)	18		
Total power loss (3 Hz)	0.1		kW
Magnet resistance (at 40°C)	34		mΩ
Magnet inductance	3.5		mH
Magnet pressure drop	10		bar
Cooling water flow rate	0.2		l/min
Cooling water temp. rise	12		°C
Inlet water temperature	26		°C
Magnet weight	90		kg

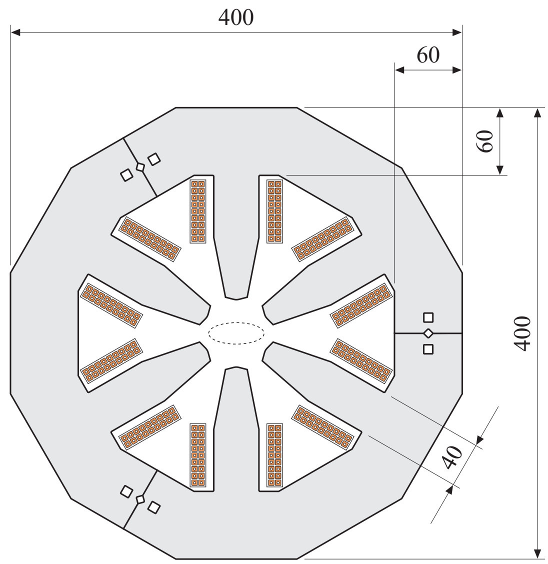

Figure 5: Sextupole Cross Section

STEERER MAGNETS

The horizontal and vertical steerer magnets have a different gap but the same air cooled coil and maximum current. This is possible because the requested correction angle for the horizontal plane (1.5 mRad) is about twice the specified vertical correction (0.8 mRad).

The main parameters are summarized in table 4. The cross section of the horizontal magnet is shown in fig. 6. The evaluated maximum transverse field variation at r = 20 mm, is about 0.8% (2.5%) for the horizontal (vertical) steerer, well within the 6% specified. The estimated saturation is less than 1%.

Table 4: Horizontal and Vertical Steerers

	STH	STV	
Number of magnets	10	12	
Gap	22	52	mm
Max. integrated field	125 (at 15 A)	68 (at 14 A)	G·m
Overall length	~150	~150	mm
Max. current	16		A
Number of turns	192		
Total power loss	15.6		W
Magnet resistance (at 40°C)	61		mΩ
Magnet inductance	38	29	mH
Magnet weight	27	26	kg

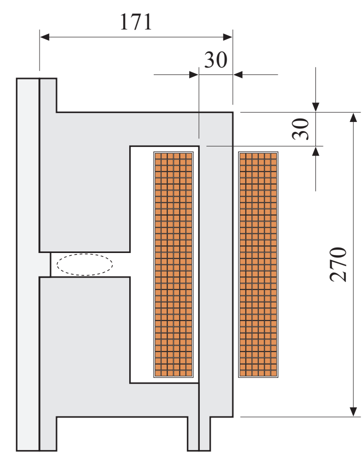

Figure 6: Horizontal Steerer Cross Section

Four additional horizontal steerer magnets will be operated as bumpers, with adequate power supplies to extract the electron beam from the booster, in combination with the kicker and septa magnets.

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