STATUS OF THE LNLS BOOSTER PROJECT

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Abstract

We present the status of prototype work on the main components of the LNLS 500 MeV booster synchrotron project. We present results of the characterization of the booster magnets and power supplies.

1 INTRODUCTION

The Brazilian National Synchrotron Light Laboratory, LNLS, is currently building a 500 MeV booster synchrotron to increase the injection energy into the UVX 1.37 GeV electron storage ring, which has been running routinely for synchrotron radiation research since July 1997. The decision to upgrade the injection energy arose from the need to install small gap insertion devices and also to further increase the stored beam current by improving the injection efficiency. Figure 1 shows the layout of the booster, which will be installed inside the storage ring. Table I shows the main machine parameters. A detailed account of the machine conceptual design and the rationale for the choice of the main parameters was given in previous work [1]. In this report, we concentrate on the first results from the booster magnet and power supply prototypes.

2 BOOSTER MAGNETS

The booster magnets are laminated and laser cut from 1.5 mm thick low carbon steel sheets and assembled without welding by using tie rods. This technique already proved to produce good quality magnets and provides very high flexibility in changing the lamination profile during the prototyping phase. The faces of the laminations were oxidized to minimize eddy current effects in the magnetic field. The Poisson 2D [2] code has been used to optimize the pole and coil shapes.

Prototypes of the dipoles, quadrupoles, sextupoles and corrector magnets have been built and characterized.

Table I: Injector ring main parameters.

Maximum energy	500	MeV
Injection energy.................................	120	MeV
Circumference..................................	34.0	m
RF frequency....................................	476.0	MHz
Horizontal tune..................................	2.27	
Vertical tune.....................................	1.16	
Horizontal natural chromaticity.........	-2.1	
Vertical natural chromaticity.............	-2.5	
Repetition rate..................................	0.2	Hz
Current (@ 500 MeV).......................	70	mA
Storage ring filling time (300 mA)....	2	min

2.1 Dipoles

Table II shows the main parameters of the dipole magnets, including some results of the first prototype. The basic constraints guiding the design were the maximum field, the small space available for magnet

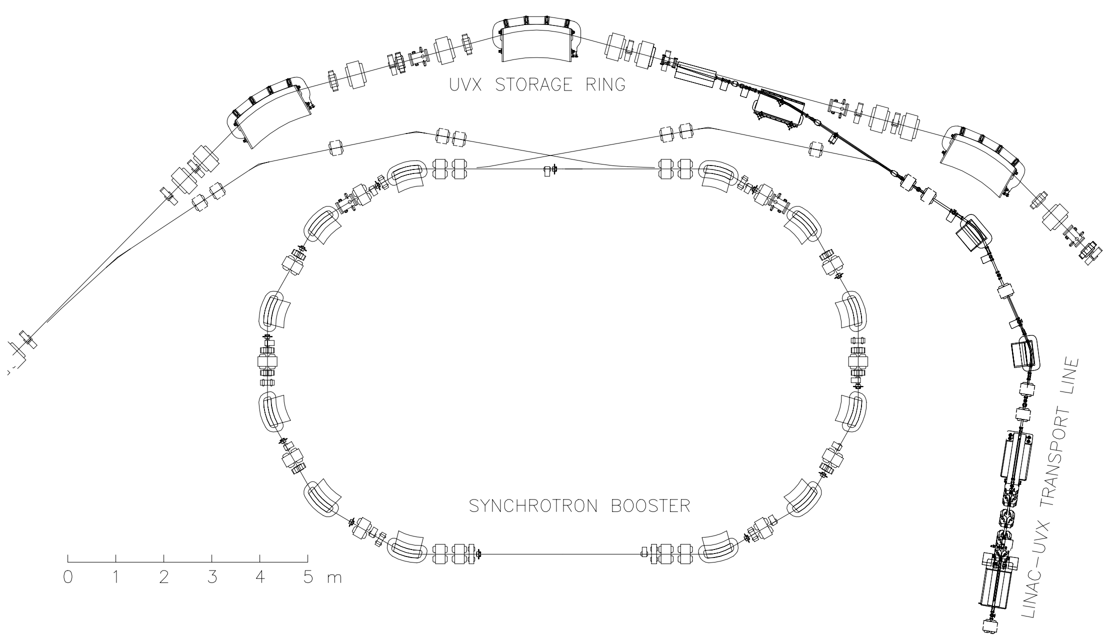

Fig. 1: Layout of the new injector for the LNLS UVX storage ring.

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installation, the working load limit of the crane available in the machine hall and a maximum time constant (inductance/resistance) of one second. These considerations led us to choose a water cooled rectangular C-shaped staggered magnet.

The field map on the symmetry plane of the magnet has been measured with a Hall probe and the results have been used to optimize the pole profile with shims. Figure 2 shows the resulting integrated field transverse profile.

Dynamic measurements (figure 3) have shown that the influence of eddy currents in the integrated field are less than 0.1% as could be anticipated from the rather low booster repetition rate (0.2 Hz) and correspondingly long ramping time (3 s).

Table II: Main parameters of the booster dipole magnets (* indicates maximum *measured* values).

Deflection	30	deg
Bending radius................................	1.026	m
Gap	36	mm
Required good field region:.............	1 10^{-4} ±10 mm	
....	1 10^{-3} ±25 mm	
Current*..	300	A
Current density*	4.55	A/mm^2
Voltage*	9.8	V
Power*..	8940	W
Magnetic Field*...............................	16770	Gauss
Inductance*	0.11	H

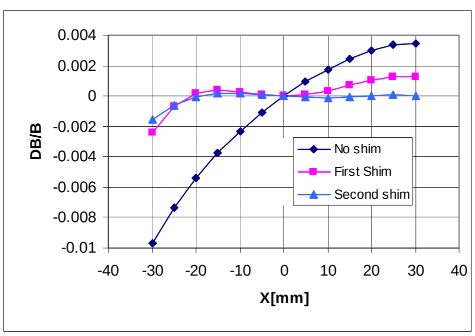

Fig. 2: Dipole magnet integrated field profile before and after shims were added (current = 180 A).

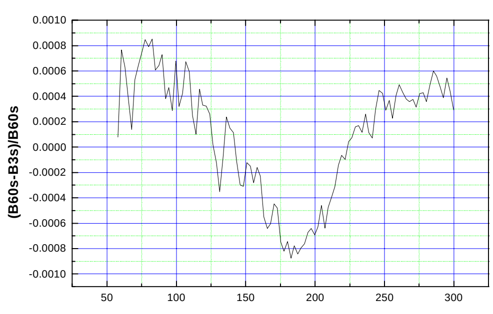

Fig. 3: Relative variation of the field in the centre of the dipole magnet as a function of ramping time. Two ramping times are compared (60 seconds and 3 seconds).

2.2 Quadrupoles

The main constraint to be observed in the quadrupole design was to achieve the required field gradient without water cooling the coils. Table III shows the main parameters.

The rotating coil method has been used to make the harmonic analysis and figure 4 illustrates the results obtained with this technique. The harmonic composition of the integrated field is not critically dependent on the excitation current. The field perturbation produced by eddy currents measured in the middle of the magnet and 10 mm far from its center, is about 1.5 Gauss.

Table III: Booster quadrupole magnet parameters.

Bore radius.......................................	27	mm
Core length.......................................	180	mm
Total length......................................	270	mm
Current*	10	A
Current density*...............................	1.06	A/mm^2
Voltage*...	10.39	V
Power*	103.9	W
Gradient*..	7.35	T/m
Inductance*	0.26	H
Coil temperature*.............................	46	ºC

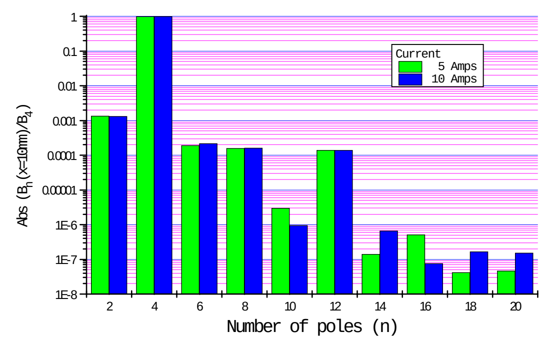

Fig. 4: Harmonic analysis of the integrated quadrupole field.

2.3 Sextupoles

The sextupole was divided into just two parts to guarantee radial symmetry of the poles (Table IV). For this design, the main difficulty comes from the small space available for the coils.

Table IV: Booster sextupole magnet parameters.

Bore radius.......................................	27	mm
Core length.......................................	100	mm
Total length......................................	150	mm
Current*	10	A
Current density*...............................	2.14	A/mm^2
Voltage*...	5.30	V
Power*	53	W
Gradient*..	224	T/m^2
Inductance*	0.023	H
Coil temperature*.............................	42	ºC

3 BOOSTER MAGNET POWER SUPPLIES

Table V shows the main parameters of the booster power supplies. Prototypes of all booster magnet power supplies have been built and tested. Except for the dipole power supply, all others have been tested under full load operation.

The dipole power supply is a combination of a 6-pulse thyristor power supply in series with Switch Mode Power Supply (SMPS) which works an active filter [3] to provide low ripple and tracking of the current reference during ramping (figure 5). The SPMS deals only with a fraction of the total power and provides for the fast response.

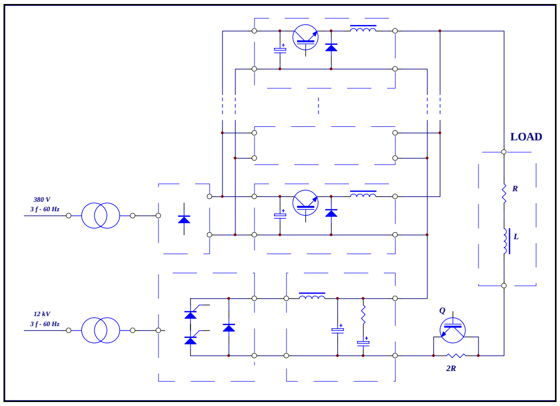

Fig. 5: Booster magnet power supply topology.

Up until now, this power supply has been tested with the first booster dipole prototype (time constant = 1 sec). In order to achieve the design repetition rate for the booster, we use a solid state switch in parallel with a resistor equivalent to twice the dipole resistance, so that when the current reference is reduced (nearly instantly) from the maximum value to the minimum at the end of each ramping cycle, the additional resistor is switched in, thus reducing the circuit time constant. Figure 6 shows a typical operation cycle for this power supply.

The power supplies for the quadrupoles and sextupoles consist of an off-line AC/DC converter followed by a chopper stage. Current regulation is accomplished by current limit modulation, which provides a fast and simple mode of operation.

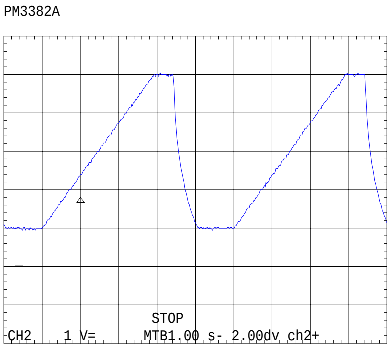

Fig. 6: Typical dipole current waveform in a cycle of operation (60 A/div, 1 sec/div).

4 OTHER COMPONENTS

Design and prototype work is also under way for various other booster components. The pulsed magnets (injection and ejection septa) have been designed and most components (ferrite blocks, high voltage power supplies, thyratrons, etc.) have been ordered from industry. These are all ferrite core magnets with thyristor or thyratron switched pulsers. The most challenging one is the ejection kicker, which must provide a very fast rise time (shorter than 20 ns) in order to guarantee a large transfer efficiency to the storage ring. The control system is basically the same as developed for the storage ring, with special care taken to guarantee the fast response needed to implement the energy ramp. The RF power requirements are sufficiently low (below 1 kW) that a solid state amplifier is being considered.

REFERENCES

[1] A.R.D.Rodrigues et at, *Design of a Booster for The Brazilian Synchrotron Light Source*, EPAC 98, Stockholm, Sweden.

[2] *Reference Manual for The Poisson/Superfish group of codes, Los Alamos* LA-UR-87-126.

[3] J. A. Pomílio, D. Wisnivesky and A. C. Lira, *A Novel Topology for the Bending Magnets Power Supply at LNLS*. IEEE–TNS vol.39 no. 5, oct/92. p. 1506-1511.

Table V: Booster magnet power supplies.

Magnet	# Mags. per supply	# Power supplies	Current Range (A)	Ripple ($\Delta I/I_{max}$)	Stability	L (H)	R (Ω)
Dipoles	12	01	58 – 300	10^{-4}	10^{-5}	1.44	1.2
Quads	02	09	0 - 10	10^{-4}	10^{-5}	0.12	0.25
Sext.	04	02	0 - 10	10^{-4}	10^{-5}	0.05	2.2