

A Progress Report on the Laboratório Nacional de Luz Síncrotron (Brazil)

A. R. D. Rodrigues^(a), C.E.T. Gonçalves da Silva^(b), and D. Wisnivesky^(b)

Laboratório Nacional de Luz Síncrotron
Cx. P. 6192 Campinas 13083 SP BRAZIL

Abstract

We present a progress report on the design and construction of the Brazilian synchrotron light source facility, which is based on a 1.15 GeV (nominal energy) electron storage ring. To date, the first part of the LINAC injector (50 MeV) has been completed and is in operation. Prototypes for all the ring main components - magnets, vacuum chambers, kickers and septa, power supplies, control system, beam position monitors, RF cavity - have been developed in-house and characterized. An update of the production of these components, which is already under way, is presented here. A report will be given on the experience acquired with laser cutting technique for the production of laminated magnets, pioneered by LNLS.

INTRODUCTION

The Brazilian synchrotron light source is based on an electron storage ring, the main parameters of which are listed in Table I.

Energy	1.15 GeV
Injection energy	0.1 GeV
Nominal current	100 mA
Circumference	88.804 m
RF frequency	476 MHz
Natural emittance	65.3(34.1) nm·rad
Horizontal betatron tune	5.27(5.72)
Vertical betatron tune	2.17(1.85)
Synchrotron tune	9.420 1/1000
Momentum compaction	$8.72 \cdot 10^{-3}$
Energy spread	0.059 %
Horizontal chromaticity	-8.17(-18.71)
Vertical chromaticity	-9.70(-9.23)

TABLE I - Main parameters of the UVX ring normal mode of operation (low emittance mode in parentheses).

Thus far five different modes of operation have been studied. In three of these modes the six-fold symmetry is preserved, but, by using different quadrupole and sextupole excitations, the natural emittance can be varied (130, 60 - shown above - and 30 nm·rad). In a two-fold symmetric mode, a very small vertical betatron function value is obtained in the middle of a straight section. The minimum physical aperture at this point can reach 6.8 mm. The operation of a small gap insertion device is envisaged in this mode. Finally, the fifth mode is three-fold symmetric and allows the operation of the ring in a quasi-isochronous mode, with a momentum compaction factor two orders of magnitude smaller than in the normal mode¹.

MAGNETS

The dipoles are curved C-type laminated magnets, with the staggered laminations held together by tie-rods, not welded. The laminations are laser cut from low carbon steel sheets of 1.5 mm thickness. By the end of the process 11,112 laminations will have been cut with the required tolerances and reproducibility. The last laminations are to be cut on June 4, 1993. Six core are already assembled and the remaining six will be assembled by the end of June, 1993. Fully assembled cores show measured standard deviation from the design gap smaller than ± 25 microns.

Figure 1 shows the results for the transverse field measured at the central longitudinal point of the dipole, for various excitation currents.

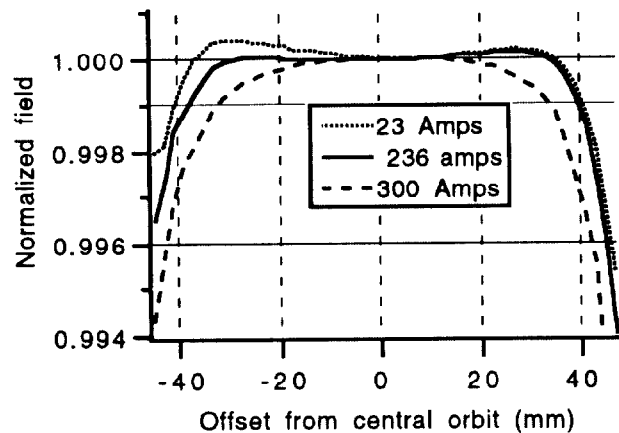


FIGURE 1 - Transverse profile of the field (dipole center).

Figure 2 shows the results for the longitudinally integrated field as a function of the transverse position (0 is the ideal orbit).

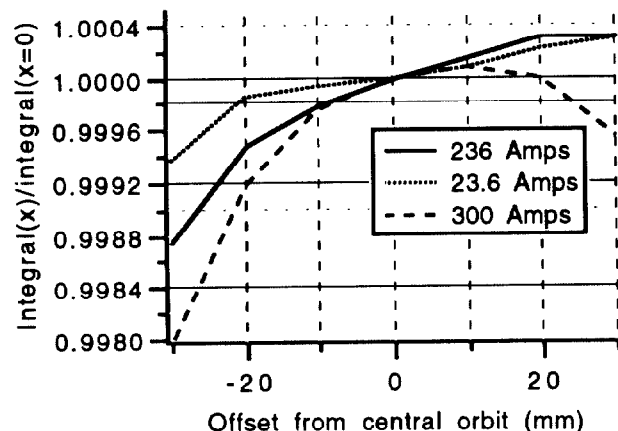


FIGURE 2 - Integrated longitudinal field at different transverse positions.

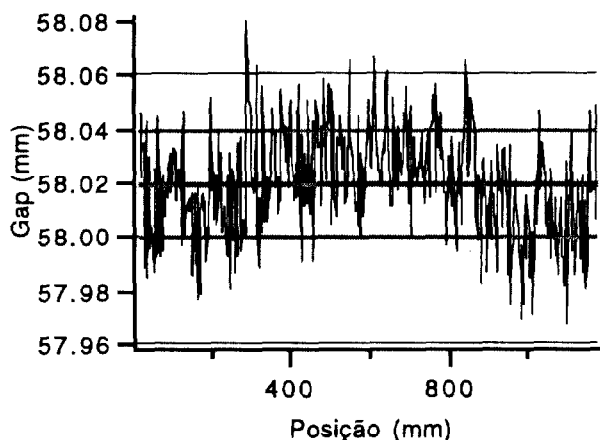


FIGURE 3 - Gap measurements for dipole #2. The average value is 58.0194 mm (middle thick straight line), with a standard deviation of 19.7 μm (the upper and lower thick lines indicate the average plus and minus one standard deviation, respectively).

Figure 3 shows the results of the dipole gap measurements for dipole #2.

Although the magnets were designed to operate at 1.4 T, it turns out that they can be run at higher fields, pushing the ring energy up to about 1.35 GeV. This is very desirable for the X-ray community, which can make use of radiation from the bending magnets, without waiting for the installation of the planned wiggler insertion.

Prototype work has already been done for quadrupoles and sextupoles, with production scheduled to begin immediately after the dipole laminations have been cut. The prototypes were characterized by the standard rotating coil set-up. A second measurement system, based on an integrator, is being developed.

VACUUM CHAMBERS

The standard bending magnet vacuum chambers are produced from 316 L steel and have light ports at 4 and 15 degrees. The parts are laser cut and TIG welded. The chamber has the following characteristics: (i) a copper water cooled absorber on the outer (radiation) side, with slits for extraction of synchrotron light; (ii) a permanent NEG strip on the inner side and a removable NEG cartridge on the outer side (placed in between the copper absorber and the chamber outer wall); (iii) metal-coated ceramic (vertical) clearing electrodes on the inner side. Thus far, LNLS has closed, baked and pumped-down six of the twelve vacuum chambers. The NEG strips have not been activated yet. They are all under vacuum better than 10^{-9} mbar.

There will also be non-standard vacuum chambers with ports at 0 and 15 degrees for insertion devices and bending magnet radiation, respectively, and one chamber with a backport for studies of X-ray scattering at $\pi/2$ Bragg angle. They are under construction.

Figure 4 shows the pump-down and bake-out curves for the bending magnet chamber #6.

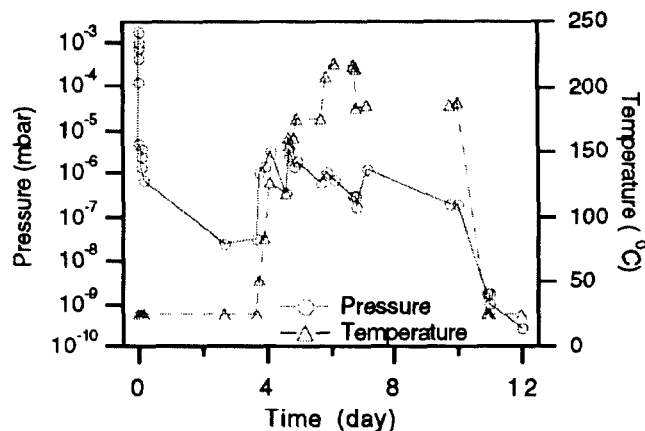


FIGURE 4 - Pump-down and bake-out curves (pressure and temperature) for bending magnet chamber #6.

RF CAVITY

The RF system is designed to supply 56 kW CW to the cavity, sufficient to supply the required 5.6 kW per 100 mA of stored current at 1.15 GeV. The RF power is produced by a 62 kW CW klystron. The 160 kW transmitter, including the main power supply and all auxiliary controls and power supplies, have been completed. The transmitter has been tested with a resistive load. The high power klystron is specified and in the process of being procured. The klystron pre-amplifier, as well as the cavity control system, are completed and tested.

LNLS is developing a single cell RF cavity for use in its storage ring. All the cavity designs were evaluated using the code URMEL-T². A scaled down version (1.2 GHz) in Al has been fully characterized. In this Conference, preliminary results for the Al prototype of the 476 MHz cavity are being reported for the 476 MHz cavity which is under development³. A first prototype was built, based on the proposed design for the PEP II B factory. It uses wave guide suppressors, which couple to HOM. Measurements indicate that there is a very strong reduction of the Q value and shunt impedance of the HOM which could cause multibunch instabilities. The cavity which will be effectively used in the ring will be made of Cu and the first full scale prototype will be built in the second Semester of 1993.

OTHER COMPONENTS

The transport line from the LINAC to the ring consists of a quadrupole doublet immediately after the LINAC at underground level, a vertical achromatic system to transfer the beam to the hall level and a horizontal achromatic arc leading to the injection point. The whole line uses 11 quadrupoles and 3 dipoles. No hardware development has as yet taken place.

The injection will be performed by thick and thin septa, in the transport line, and three kickers in the ring. The kicker developed and built to date have ferrite core inside the vacuum chamber and provides pulses with 150 ns of rise-time, 200 ns duration and 200 ns fall-time. A prototype for the thin

septum has been built and operated with 30 μ s sinusoidal pulses peaking at nominal field.

The 24 beam position monitors will be of the stripline type and their acquisition electronics, still under development, will allow both circulating beam and single shot readouts. The ring current is to be measured by a commercial DCCT monitor.

The control system consists of a few serial networks of local controllers, at the level of the ring equipments, connected to a parallel (SCSI) network of commercial desktop computers via a concentrator. The hardware and software library have been developed and tested.

The high precision power supplies for the storage ring magnets have been developed at LNLS using high power switching IGBTs⁴. Extensive performance tests of this new type of power supply have been made with excellent results on stability (8 ppm/K), ripple (5 ppm on the magnetic field), and reproducibility of the current (0.01 %). The power supply has a dynamic range of 1 - 100 and can be ramped, without tracking error, to the maximum current. A single power supply, 300 A, 1000 V, is used for the 12 dipoles. The 36 quadrupoles are arranged in three families. Nevertheless, to gain flexibility, every 2 quadrupoles belonging to the non-dispersive straight sections have a separate power supply, while the 12 remaining quads have a single power supply. Thus a total of thirteen power supplies are required for the quadrupoles. In-house production is under way and is scheduled to be completed by the end of 1993. Power supplies for the sextupoles, steering coils and transport line magnets have been prototyped and production is scheduled to start in the second Semester of 1993. In all, 75 different power supplies, with power ranging from 350 W to 300 kW, are being produced and expected to be finished in the first Semester of 1994.

INSTRUMENTATION

In parallel with the construction of the storage ring, LNLS has developed instrumentation for the beamlines.

A toroidal grating monochromator beamline, covering the spectral range from 12 to 300 eV photon energy has been designed, built and tested in Campinas. It is now installed on the storage ring of the Center for Advanced Microstructures and Devices (CAMD) of Louisiana State University. It will return to LNLS upon completion of the UVX ring⁵. A spherical element monochromator beamline is under development.

Two- and 4-crystal X-ray monochromators of original design⁶ have been built and successfully tested at DCI (LURE, France)⁷. The 4-crystal monochromator has performed exceptionally well, with an energy resolution of $8 \cdot 10^{-6}$ at 10 keV.

Two beamlines for X-rays, one for small angle scattering (SAXS) and another for EXAFS, are in advanced stages of construction. The former uses a one-bent-crystal monochromator, the third type of X-ray monochromator

developed by LNLS. Additional beamlines are being designed.

In total, six beam lines will be operational at LNLS when the storage ring is completed: two for VUV radiation and four for X rays.

CONCLUSION

Construction of the storage ring building has started, early in 1993, with the LINAC tunnel. The tunnel will be completed in June 1993, when construction of the main storage ring and experimental hall is scheduled to begin.

In spite of severe financial constraints over the past three years, specially in the last eighteen months, the LNLS project has moved ahead, in the construction of the light source, scientific instrumentation, and buildings. There are indications that financial constraints will be alleviated in the near future, allowing the speedy conclusion of the storage ring.

Innovative designs and developments for storage ring components and beam lines have been pursued with success. The relative isolation of LNLS, imposed by both geography and finances, has been a spur to try new designs and concepts, ranging from magnet production to power supplies to scientific instruments, which emphasize low cost, high quality and superior performance. Commissioning of the storage ring, expected to start in late 1994, will be the crucial test of these new developments.

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- (b) Also at State University of Campinas (UNICAMP).
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