LNLS COMMISSIONING AND OPERATION

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Abstract

The commissioning of the Brazilian synchrotron light source has begun, with the successful operation of the LINAC injector and the first thousands of turns of the coasting beam in the storage ring. In this report we describe the first results of the commissioning. A brief description of the development of beam lines and the users' program is also presented.

1 INTRODUCTION

The National Synchrotron Light Laboratory (LNLS) is funded by the Brazilian National Council for Scientific and Technological Development (CNPq). It is located in Campinas, state of São Paulo. Since 1987, CNPq has invested the relatively modest sum of US$ 50.000.000 in the design and construction of the light source and of the first seven beam lines. This low cost could be achieved thanks to the decision to build in-house as much as possible of the storage ring and of the scientific instruments for the light source. Magnets, power supplies, vacuum chambers, control hardware and software, beam position monitors were designed and built mostly by LNLS. Large mechanical parts (i.e. racks, girders, etc.) and all of the conventional engineering (i.e., cooling plant, air-conditioning, power station) were contracted out to local industry, which also supplied the materials (steel, copper, etc.) used in the construction of the magnets, vacuum chambers, etc. The 476 MHz RF cavity for the storage ring was purchased from Sincrotrone Trieste. For more details about subsystems see refs. [1, 2, 3, 4, 5, 6,] and [7] in these Proceedings.

Funding problems faced by LNLS during the early nineties delayed the original schedule for completion of the storage ring by approximately three years. However, since the experimental hall became occupational in mid-1995, work on the light source has proceeded at a fast pace. By October 1995, the dipole magnets were in place. In parallel, the LINAC injector was assembled and successfully operated on December 22, 1995. Early in 1996, the transport line was completed. By March, all of the magnets were in place, connected to the power supplies, and the vacuum chambers installed and pumped down to the nTorr pressure range. Figure 1 shows a picture of the storage ring hall by mid-March. On May 4, the beam was at the end of the transport line. On May 22, the first turn was observed and on May 29, 1996, the first thousand turns (one kicker on, no RF, all corrector magnets in the ring switched off) were observed.

At the moment of this writing (June 1996), the RF system is being switched on and the ring optics is being optimized for storing the beam at low energy.

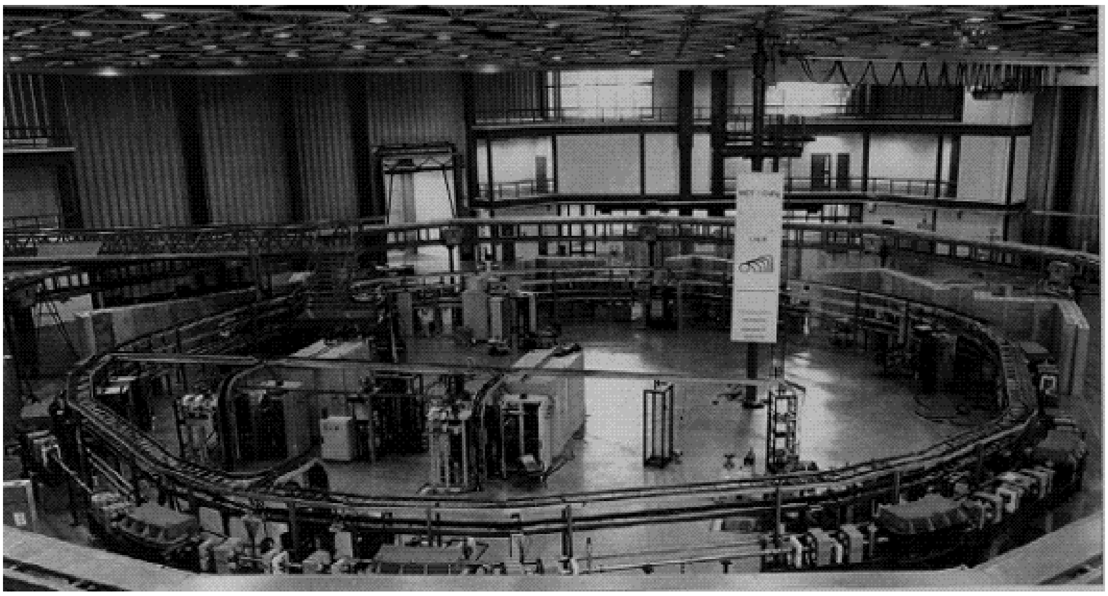

Figure 1: View of storage ring hall by mid-March.

2 LINAC

The LINAC injector is a standard SLAC-type, with four 3m long accelerating sections, powered by two 25 MW klystrons, reaching a maximum energy of 120 MeV. The RF frequency of the storage ring is a sub-multiple of the 2856 Mhz frequency of the injector. The LINAC is being operated at a repetition rate varying from 0.5 to 15 Hz (max.), with 100 ns pulses, and with gun currents ranging from 300 to 1400 mA. Beam loading effects are very noticeable at high gun currents. They are monitored by measuring the energy dispersion in a spectrometer installed at the end of the LINAC and by the current pulse length and shape at the end of the transport line. The 100 ns gun pulse can be reduced to a few nanoseconds pulse at the end of the transport line, for gun currents exceeding 1 A. For injection, the gun current may be reduced, in order to minimize beam loading effects and increase the pulse length at the end of the transport line. By adjusting the synchronism of the gun with respect to the RF, the amount of charge per pulse injected into the storage ring may be optimized.

3 TRANSPORT LINE

The transport line consists of two vertically deflecting dipoles (the LINAC is underground), two horizontally deflecting dipoles, 12 quadrupoles, one 15 degree deflection (thick) septum and one 3 degree (thin) septum. The septa are DC magnets, with a steel vacuum chamber for injection. Vertical and horizontal dispersions can be adjusted independently. It is also possible to independently adjust the vertical and horizontal position and angle of injection of the beam into the ring. For injection with a single kicker (the first kicker downstream from the injection point), it is found that the vertical angle of injection is extremely critical. Variations of ±0.25 mrad around the optimum vertical angle result in loss of the beam. The horizontal injection angle is slightly more tolerant: ± 1.25 mrad around the optimum. At present, there is no way of realiably measuring the absolute value of the optimum angle of injection.

4 STORAGE RING

Energy	1.15	GeV
Injection energy	.1	GeV
Magnet lattice	6-fold symmetric DBA	
Dipoles	12 (1.4 T)	
Quadrupoles	36	
Sextupoles	18	
Correctors	30	
Circumference	93.212	m
RF frequency	476	MHz
Natural emittance	70.3	nm.rad
Horizontal betraton tune	5.27	
Vertical betraton tune	2.17	

The main parameters of the electron storage ring are shown in Table 1 above.

The magnet lattice and power supplies are sufficiently flexible to allow operation of the storage ring in 6-fold, 3-fold and 2-fold symmetric modes. “Exotic” modes include a low vertical beta function for insertion devices with small gaps and a quasi-isochronous mode.

5 COMMISSIONING

The main result achieved thus far in the commissioning is the successful injection of the beam, which coasts without RF. Figure 2 shows the observation of the first turn. The time interval between the two successive passages of the current pulse is 310.7 ns, consistent with the value expected from the circumference of the ring (310.6 ns).

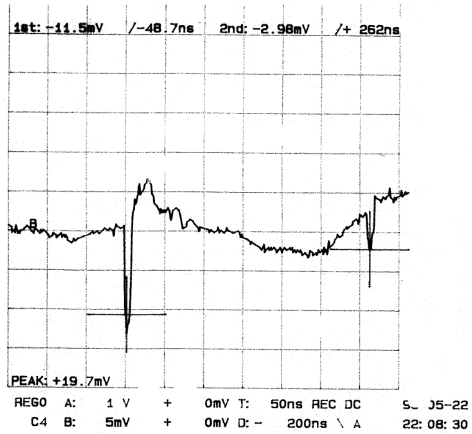

Figure 2: Observation of the first turn.

More than 3000 turns have also been repetitively observed during different injection working sessions. One millisecond after injection the beam position monitor AMP06 is still detecting a signal, as shown in Figure 3. Since the BPM is sensitive to pulses with a short rise time, as the coasting beam debunches, detection of its passage becomes more difficult. The visible synchrotron light signal being monitored by a TV camera installed in the 4 degree beam port of dipole 1 becomes very intense, as the beam starts to complete many turns, even though injection is at 110 MeV and the bending field is only 0.12 T. Under these conditions, the critical wavelength of the synchrotron radiation spectrum is 1.28 microns, in the infrared part of the spectrum.

The intensities of the synchrotron light and current signals improve significantly when the horizontal correctors in the storage ring are set to the values calculated to offset know errors in the bending magnets. The mean value of the correctors is practically zero (3 μrads), with a standard deviation of 180 μrads. The maximum value is 0.45 mrads. No vertical correctors have been used thus far.

Cycling of all the magnets is essential for reproducibility of the results. This is expected, having in view the low energy of injection and the large dynamic range of the magnets. It is reassuring, however, that remnant fields do not pose a serious problem.

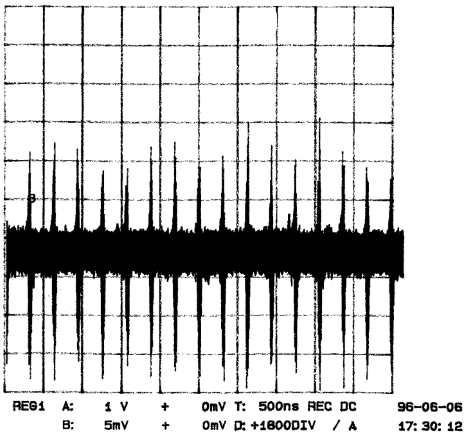

Figure 3: Observation of 3000 turns detected by the beam position monitor AMP06. Time delay is 1 millisecond.

6 BEAM LINES

As the only synchrotron light source in Latin America and as a national facility for materials research, LNLS is responsible for providing external users with beam lines and scientific instrumentation for synchrotron light. Attendance at the Annual Users' Meeting has been increasing since 1991, reaching more than 200 participants in 1995. There are users' from all of the main research Universities in Brazil, with about 10% coming from Argentina.

Thus far, seven beam lines have been built or are under construction and two more are funded. These are listed in Table 2 below.

Beam Line	Location	Spectrum
Toroidal Grating Monochromator	D6B*	12 - 300 eV
Spherical Grating Monochromator	D5B	200 - 1500 eV
Soft X- Ray Spectroscopy	D7B	.8 - 4 keV
EXAFS	D11A	2 - 11 keV
X-Ray Diffraction	D9B	2 - 18.5 keV
Small Angle X-Ray Scattering	D11A	6 - 12 keV
Protein Crystallography	D9A	6 - 12 keV
X-Ray Fluorescence	D9B	2 - 11 keV

* - Ports A are at 4 deg. and ports B are at 15 deg.

The central components of these beam lines (mirrors, monochromators, detectors) have been or are being built in-house. For further information, see ref.[8]

The storage ring has four 3 m long straight sections for insertion devices. These are still in the planning stages.

7 CONCLUSION

LNLS has designed and built the first large particle accelerator in the Southern Hemisphere, which is now in the process of being commissioned. It consists of a 100 MeV LINAC injector and a 1.15/1.37 GeV (nominal/maximum energy) electron storage ring to be used as a synchrotron light source. Independently of the technical achievement, the successful injection and the observation of the first thousands of turns in the electron storage ring of LNLS is a very significant event in the history of Brazilian science and technology. For the first time, a large civilian scientific project is carried out completely from the design to the operational phase. We hope that this will lead to a strengthening of the research and development effort in Brazil, not only in the field of accelerator physics, but also in materials science.

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8 REFERENCES

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[6] The LNLS RF System, D. Wisnivesky *et al.*, these Proceedings.
[7] The LNLS Vacuum System, M. J. Ferreira *et al.*, these Proceedings.
[8] Outline of LNLS Beamlines and Workstations, LNLS, NT - 01/94, available from, biblio@lnls.ansp.br.

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