COMMISSIONING AND OPERATION OF THE BRAZILIAN SYNCHROTRON LIGHT SOURCE

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Abstract

The Brazilian National Synchrotron Light Laboratory, LNLS, operates a 1.37 GeV electron storage ring with a 120 MeV injector Linac. Commissioning of the storage ring at low energy started on May 1996 and now, an year later, we can store 120 mA at 120 MeV and ramp more than 75 mA to 1.37 GeV. A summary of the latest commissioning results and a description of the present operational performance of the LNLS Synchrotron Light Source facility is presented.

1 INTRODUCTION

The Brazilian National Synchrotron Light Laboratory, LNLS, sponsored by the National Council for the Development of Science and Technology (CNPq), operates a 1.37 GeV electron storage ring with a 120 MeV injector Linac. Commissioning of the Linac started in December 1995 and after almost simultaneous completion of all sub-systems on April 1996, commissioning of the storage ring at low energy started on May 1st. The first stored beam was observed a month later, on May 30. Some weeks later we could capture a current of 3 mA (after one damping time, or 10 s) with the one-shot on-axis injection. The off-axis accumulation process (with 3 kickers producing a closed bump) was still very difficult and the accumulated current saturated at about 0.3 mA. Our efforts at this time split roughly into two main tasks: accumulation at 120 MeV and energy ramping. While energy ramping evolved quickly with a rather systematic approach, accumulation turned out to be much more challenging. The first stored beam at 1.15 GeV was observed in July 96 but only in October have we succeeded in accumulating 20 mA at 120 MeV. The quality of the magnets allowed us to extend the planned 1.15 GeV operating energy to 1.37 GeV. This is the usual operating energy since October 96. Since then the accumulated current both at injection and operating energies increased steadily with small adjustments in many parameters and hardware improvements, such as an increase in the gun pulse length to allow operation in the beam-loading steady state regime (where energy dispersion is small). At present (May 97) we can store 120 mA at 120 MeV with about 90 seconds lifetime for an average pressure of about 7 x 10^{-10} Torr. The lifetime is limited by elastic scattering on the residual gas. At 1.37 GeV we can store more than 75 mA with 1.5 hour (instantaneous) lifetime. As the current decreases to 20 mA, the lifetime reaches 3.5 hours. A more relevant figure of merit for the lifetime (as far as users are concerned) is the time it takes for the current to fall to 1/e of its initial value. This is about 2.2 hours.

Table I shows the specified and achieved values of the main performance parameters. Fig. 1 compares the flux expected from the nominal machine parameters with the flux obtained from the achieved machine parameters.

Table I: Specified and achieved performance parameters.

Parameter	Specified	Achieved	
Energy	1.15	1.37	GeV
Current	100	75	mA
Lifetime	7	2.2	hours

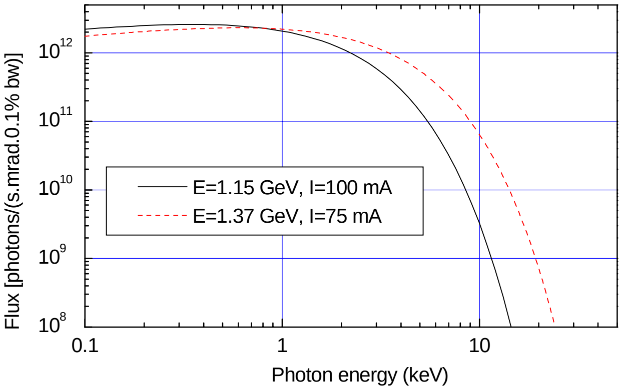

Figure 1: Comparison between the flux expected from the specified and achieved machines.

2 THE LNLS SYNCHROTRON LIGHT SOURCE

The LNLS Synchrotron Light Source [1,2,3,4,5,6,7,8] is composed of a low energy injector Linac, a transport line and the UVX storage ring. The Linac is a standard SLAC-type, with four 3 m long accelerating sections which are powered by two 25 MW klystrons reaching a maximum energy of 125 MeV. The RF frequency is 2856 MHz. The Linac is being operated at a repetition rate of 0.5 Hz, gun pulses of 4 µs in length and gun currents varying from 0.5 to 1.7 A. Beam loading effects are very noticeable and have a large impact on the current pulse length and shape at the end of the transport line. By adjusting gun current, synchronism and RF phases, the pulse at the end of the transport line has been optimized both for higher charge

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per pulse and lower energy dispersion. At present, we get typically pulses of 150 to 200 ns and 100 to 140 mA (current in the macro pulse), of which about 40 % is accepted by the storage ring.

The storage ring consists of 6 double-bend achromatic arcs, with a circumference of 93.2 m (311 ns). The 12 dipoles operate at 0.15 T at 120 MeV injection energy and 1.67 T at 1.37 GeV operation energy. There are 36 quadrupoles, 18 sextupoles and 29 orbit correctors. The theoretical emittance for the standard operation mode is 99.8 nm.rad at 1.37 GeV and the nominal tunes are ν_x=5.27 and ν_y=2.17.

The beam diagnostic system of the storage ring includes 24 stripline type beam position monitors, a betatron and synchrotron tune measurement system, a visible light beam line for transverse and longitudinal beam profile measurement, a beam current monitor (DCCT) and beam scrapers for aperture measurements.

The 476 MHz RF frequency is a sub-multiple of the Linac frequency.

2 COMMISSIONING RESULTS

2.1 Low Energy Injection and Accumulation

In order to optimize (and in fact make possible) accumulation at 120 MeV, we have performed a thorough scanning of the tune space looking for points of higher beam lifetimes. The best machine working point has found to be very close to the integer resonance, ν_x=5.05 and ν_y=2.09. With the present beam lifetime at low energy (90 s) the Linac pulses are injected every 2 seconds, about a fifth of the radiation damping time.

The three kicker parameters have also been scanned to find the optimum compromise between higher injected charge and smaller current loss per Linac pulse. In order to guarantee that the kicker bump is local, beam lifetime (with the kicker bump on) was maximized as a function of relative kicker strengths and timing.

Since the first successful accumulation of 20 mA in October 96, the accumulated current has increased continuously mainly due to adjustments in the injector, which increased the current and decreased the beam energy spread at the end of the transport line. Also, improvements in the injector stability (with reduction of energy drifts and fluctuations) were essential to allow optimizations in the storage ring parameters to take place. Other adjustments and hardware developments were important as well, such as reduction in the quadrupoles power supply ripple and reduction of leakage field from the septum magnets by addition of magnetic shielding, The average pressure is also improving slowly with washing with high energy photons. At the moment of this writing we can accumulate 120 MeV at 120 mA. The injected current varies from 20 to 30 mA per pulse depending on the injector state and it takes about 15 to 20 pulses to reach the saturation current.

Further improvements of the accumulated current are expected with the upgrade of the injector energy to 170 MeV, and the replacement of the present DC septum by a thinner pulsed septum.

2.2 Ramping Process

Energy ramping from 120 MeV to 1.37 GeV can be optimized for minimum loss during ramp by setting up intermediate configurations with corrected orbits and tunes and varying ramping speed, energy steps and RF gap voltages at different energies. The beam losses occur mainly at the very beginning of the ramp (up until 300 MeV) and are probably mainly due to the excitation of large amplitude longitudinal oscillations as well as the poor lifetime.

The machine working point is kept close to integer resonance (ν_x=5.05, ν_y=2.09) up to 500 MeV, after which it is brought to the nominal value of ν_x=5.27 and ν_y=2.17 at 1.37 GeV. Ramping takes about 4 minutes.

Eddy current effects on the magnetic fields have visible effects on the orbit and tunes during the ramp. An off-line correction of these effects (using saved parameters during ramping) have been implemented in the intermediate configurations.

The ramping efficiency varies according to the initial accumulated current, being less efficient for higher currents. For 120 mA the present ramping efficiency from 120 MeV to 1.37 GeV is 64%. 90% of the losses occur from 120 to 300 MeV.

2.3 Beam Characterization

The machine has been characterized at injection and operation energies. Betatron and dispersion functions show good agreement with theoretical values. The chromaticity can be corrected by setting the sextupoles to calculated values. The results are shown in figures 2 to 4. At 120 MeV, the beam horizontal size, as seen and measured on a synchrotron light monitor, is compatible with the expected from intrabeam scattering effects whereas the vertical size is larger than predicted from coupling effects. At 1.37 GeV, the measured beam emittance - 98 nm.rad - (from beam size measurement and knowledge of betatron functions) is very close to the nominal value. This is another indication that we have a reliable model for the machine first order optics. The small coupling measured at 1.37 GeV (smaller than 0.3%) attests a careful alignment procedure for the magnets.

2.4 Orbit Correction

Orbit correction algorithms can be applied successfully both at low and high energies. At high energy (1.37 GeV) the machine optics model can be derived either from the implemented quadrupole strengths or by fitting the strengths to reproduce the measured tunes. At low energy, however, the fitted model is required. This is expected since remnant field contributions cause the excitation curves to be less precise at low energy. Localized beam bumps using 3 correctors have also been produced either to move the photon beam in an experimental station or to scan the vacuum chamber aperture during commissioning.

Orbit reproducibility from fill to fill is better than 60 μm and long term orbit drifts can be kept below ± 30 μm by means of an automatic periodic correction.

2.5 Observation of ion trapping

Ion trapping effects have been observed as a vertical expansion of the beam seen in the synchrotron light monitor when excitation by kickers are produced. The enlarged beam persists even when the excitation is turned off. The beam can be made flat again by applying appropriate voltages to the clearing electrodes. This effect has been observed for energies up to 900 MeV, where the present maximum kicker excitation is needed.

BEAMLINES STATUS

Seven beamlines have been built in parallel with the synchrotron light source: X-ray absorption fine structure XAFS, Soft X-ray Spectroscopy (SXS), Small Angle Scattering (SAXS), X-ray Optics (XRD), Protein Crystallography and two VUV beamlines with thoroidal grating (TGM) and spherical grating (SGM) monochromators, respectively. The SAXS and XAFS beamlines are operational and the others are been commissioned. Access by external users should start in July 1997.

CONCLUSIONS

The LNLS synchrotron light source has been commissioned and achieved most of its specified performance figures. Further improvements in the stored beam current are expected to be achieved when the injector energy is upgraded to 170 MeV, whereas beam lifetime should improve as the vacuum pressure decreases with washing by synchrotron radiation photons. Even with present parameters the photon flux delivered by the source is above the specification over most of the harder photon spectrum.

The machine operation reliability is increasing. From January to April 1997, 500 hours were scheduled for user's shifts. The machine was not operational during about 10% of this time. This percentage falls to 2% if we take only the last month. In the same period of 4 months, 675 hours were dedicated to commissioning sessions and 150 hours to maintenance or improvement of the equipment.

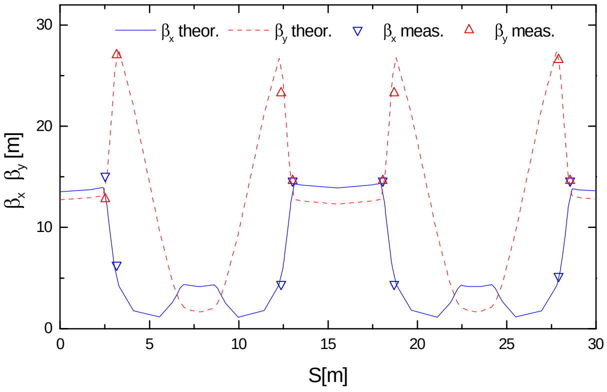

Figure 2: Theoretical and measured betatron functions.

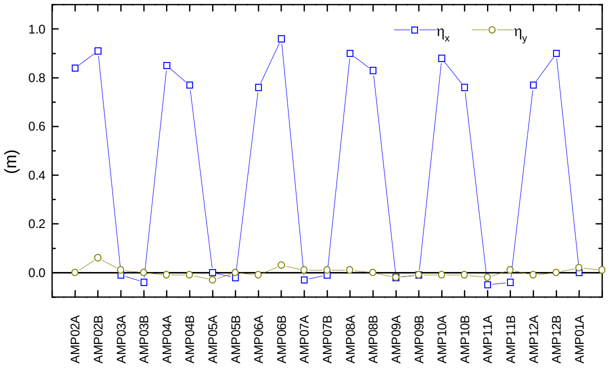

Figure 3: Horizontal and vertical dispersion functions for E=1.37 GeV. Theoretical value at even BPMs is 0.90 m.

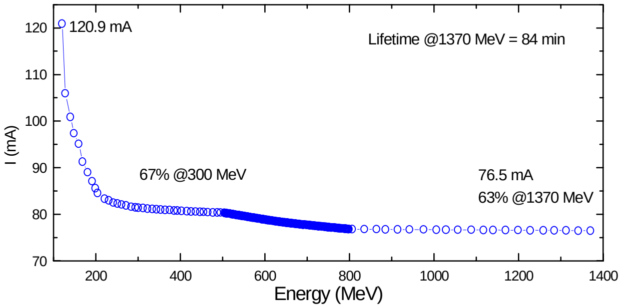

Figure 4: Beam current decay during energy ramping.

REFERENCES

[1] R.H.A.Farias et al 'Optical beam diagnostics for the LNLS synchrotron light source', these proceedings.

[2] R.H.A.Farias et al 'Orbit measurement and correction in the LNLS synchrotron light source', these proceedings.

[3] R.H.A.Farias et al 'Ramping efficiency studies in the LNLS synchrotron light source', these proceedings.

[4] A.R.D.Rodrigues et al 'Pulsed septum for the LNLS injector', these proceedings.

[5] D.Wisnivesky et al 'Operation of the LNLS storage ring RF system', these proceedings.

[6] D.Wisnivesky et al 'Upgrading of the LNLS injection system', these proceedings.

[7] D.Wisnivesky et al 'Commissioning and first year operation of the LNLS magnets power supplies', these proceedings.

[8] M.J.Ferreira, 'LNLS Vacuum System Commissioning', these proceedings.