

# RAMPING EFFICIENCY STUDIES IN THE LNLS SYNCHROTRON LIGHT SOURCE

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## Abstract

The 1.37 GeV LNLS UVX electron storage ring has a 120 MeV injector LINAC. Once stored, the electron beam must be ramped up to the nominal operation energy. In order to minimize current loss, orbit and tune corrections have been implemented along the energy ramp. In this report, we present a description of the energy ramping process, performance, orbit and tune corrections.

## 1 INTRODUCTION

The LNLS synchrotron light source is composed of a 1.37 GeV electron storage ring and a 120 MeV injector LINAC. Commissioning of the storage ring started in May 1996 and the latest results as well as other details on the machine are presented in a separate contribution to this conference<sup>[1]</sup>. Beam accumulation at injection energy and energy ramping have proven to be the most challenging part of the commissioning.

To achieve a ramping efficiency up to 80% it was necessary to implement a versatile ramping system which allows several ramp parameters to be easily changed by the operator. These parameters include:

- intermediate optical configurations;
- RF gap voltage ramp;
- varying ramping speeds along the ramp and
- varying energy step sizes along the ramp.

This report describes how the energy ramping process has been implemented and shows illustrative experimental results.

## 2 RAMPING SYSTEM

### 2.1 Hardware

During the energy ramp, 47 power supplies must have their current increased simultaneously. In order to achieve the necessary synchronism among power supplies during the ramp, it is not possible for the main control computer to control directly all ramped power supplies. Rather, during the ramp, control is temporarily passed on

to distributed local controllers that step along a precalculated table of set points as they receive trigger signals from a master clock. These trigger signals produce a hardware interruption in the local controller's CPU bypassing any other process that might be running at that time. The main control computer must calculate all set points along the ramp and send them to the local controllers' memory before the ramp is started. The ramp master clock is directly controlled by the main control computer and is used to provide different ramping speeds. A counter board connected to one of the three outputs of the master clock board is used to monitor the ramping progress.

The number of points in each ramping table was determined by a compromise between the desired resolution of the energy ramp, the amount of memory available in the local controllers for storage of the ramp tables and the time needed to send those tables to the controllers. At present the dipole, quadrupole and sextupole power supplies have 4096-point ramp tables whereas the orbit corrector power supplies have 1024-point tables and the total time to send a complete set of ramp tables to the local controllers is about 2 minutes.

### 2.2 Software

Figure 1 shows the main window of the ramping application. Intermediate optical configurations (sets of quadrupole, sextupole and corrector strengths) may be set up so that the ramping software interpolates linearly between those configurations. This allows the tune and orbits to be controlled along the ramp. Different ramping speeds may also be chosen. Three different RF gap voltage ramps may be used: no ramp (normally used when ramping to low energy, i.e. 300-400 MeV), linear ramp (with a given initial and final setpoints) and an arbitrary set of points given in a separate text file. The ramp software registers the beam current, beam orbits and possibly the beam tunes along the ramp for off-line analysis.

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Figure: 1 Main window of the ramping application.

### 3 EXPERIMENTAL RESULTS

Many different ramping parameters have been tried and these had to be changed often as the commissioning proceeded and higher beam intensities were stored at injection energy.

Due to the fact that the horizontal and vertical tunes at injection energy ( $\nu_x=5.05$  and  $\nu_y=2.09$ ) are different from the tunes at 1.37 GeV ( $\nu_x=5.27$  and  $\nu_y=2.17$ )<sup>[1]</sup>, it is necessary to find a suitable path in tune space from one point to the other. We have found it necessary to keep the tunes low up to until about 500 MeV when the beam is damped and rigid enough to withstand the change in tune. In order to keep the tunes constant up to 500 MeV, it is necessary, due to remnant field effects, to change quadrupole strengths and six intermediate optical configurations had to be set up. Figure 2 shows the tune variations during the ramp.

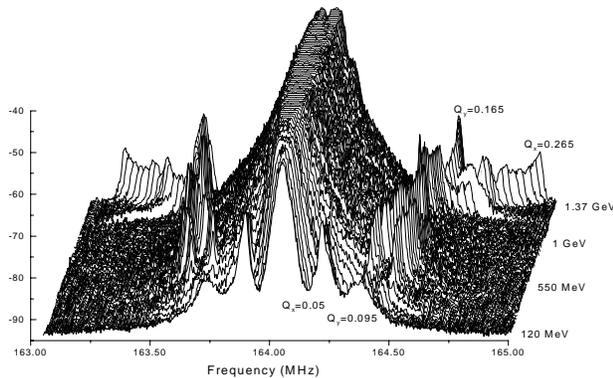


Figure 2: Tune variations during the ramp.

Figure 3 displays the difference between the initial and the six intermediate optical configurations of quadrupole and integrated sextupole strengths and figure 4 shows the strengths of correctors ACH07A and ACV07A along the ramp until 500 MeV.

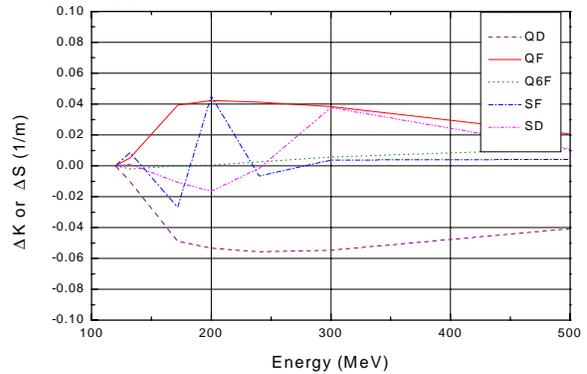


Figure 3: Variations of quadrupole and integrated sextupole strengths along the energy ramp.

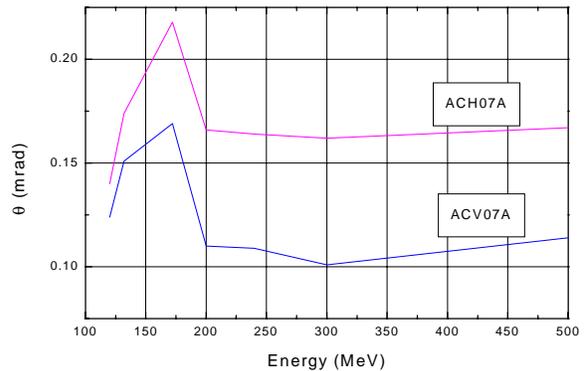


Figure 4: Strengths of correctors ACH07A and ACV07A along the energy ramp.

Orbit correction along the ramp is necessary partly due to remnant field effects but also because of the influence of the (DC) thin septum magnet leakage field on the stored beam orbit which is only properly corrected at injection energy. Orbit correction has been done with two different methods: (a) by ramping to an intermediate energy and correcting the orbit and (b) by acquiring orbit data dynamically along the ramp, calculating corrections off-line and then implementing corrections for the next ramp. The second method, although more laborious, takes into account the effect of Foucault currents on the orbit distortion. The difference between the orbit corrected with these two methods is around  $\pm 2$  mm in the horizontal and

$\pm 1$  mm in the vertical. Figure 5 shows the corrected orbits during the ramp.

The RF power must also be ramped since beam accumulation is only possible at 120 MeV with at most 60 kV gap voltage (this is due to the excitation of large energy oscillations as a result of the large phase spread of the injected beam). The start of the RF ramp is delayed to until 300 MeV to avoid the excitation of synchrotron oscillations (and corresponding current loss) and the gap voltage reference is taken to its full value at 500 MeV. The ramping speed is then decreased to allow for the cavity power in the cavity to stabilize at high level.

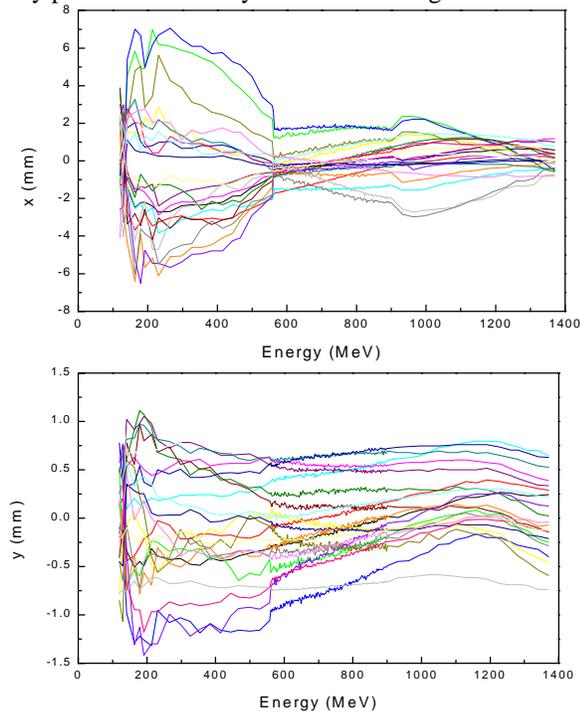


Figure 5 - Orbits during ramp.

The RF ramp has proved to be the most critical part of the ramping process. Initial conditions such as the cavity temperature and tuner positions play an important role in the determination of the overall ramping efficiency<sup>[2]</sup>.

Three different speed regimes (Table 1) are used during the ramp. In the low energy part, we proceed as fast as possible to avoid losses due to the low lifetime. At intermediate energies, we proceed slowly in order to allow the RF system to stabilize with RF power. Finally above 900 MeV we proceed quickly to the nominal energy. The total ramping time is about 4 minutes.

E (MeV)	v (MeV/s)
120 - 300	15
300 - 500	28
500 - 900	2.5
900 - 1370	28

Table 1: Values of ramping speed.

Ramping efficiency is lower for higher stored currents and some ramping parameters (especially in the RF

system) have to be changed according to the stored beam intensity.

Figure 6 shows the variation of current as function of energy during ramping process, where the speed of ramping is given in table 1 and figure 7 shows the variation of RF gap voltage and gap reference during the same ramping process, as function of the time.

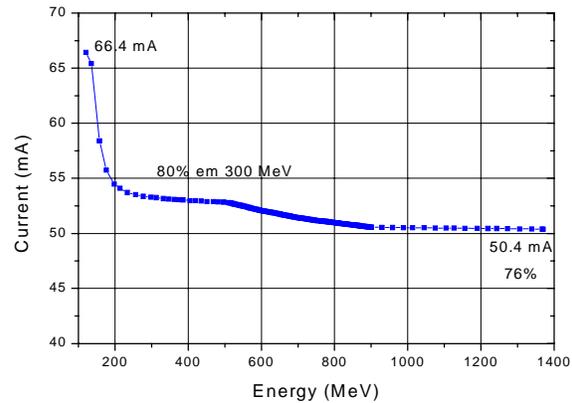


Figure 6: Current vs. energy during ramping process.

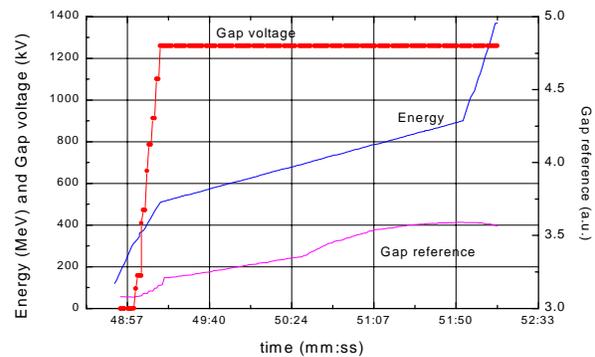


Figure 7: Variation of RF gap voltage, gap reference and energy as function of the time during ramp.

## 4 CONCLUSIONS

The energy ramping system of the LNS electron storage ring has proven to be capable of ramping electrons from 120 MeV to 1.37 GeV with an efficiency ranging from 65% to 80%, depending on the initial beam current.

Possible improvements include changing the cavity detuning during the ramp and implementing a feedback loop for the RF gap voltage.

## REFERENCES

- [1] A.R.D. Rodrigues et al., 'Commissioning and Operation of the Brazilian Synchrotron Light Source', these proceedings.
- [2] D. Wisnivesky et al., 'Operation of the LNS Storage Ring RF System', these proceedings.