EXPERIENCE WITH THE SLS BOOSTER

M. Muñoz, SLS, Paul Scherrer Institut

Abstract

The Swiss Light Source (SLS) uses a new approach in the design of the booster synchrotron. The results of the commissioning and operation phases are described, and in particular some of the anticipated difficulties (effect in the storage ring, lifetime at low energy) and how they were solved.

1 INTRODUCTION

For synchrotron light sources, it is common to build a compact booster synchrotron in a small tunnel separate from the main tunnel of the storage ring. For the SLS, a novel expanded FODO design was used so that the booster could be built in the same tunnel as the storage ring. The modified FODO-like lattice uses 93 small combined function magnets to distribute the bending along as many magnets as possible and to correct locally the chromaticity.

This design offers a number of advantages over traditional approaches:

- Savings in space and shielding.
- Economical low field magnets with small apertures.
- Low power consumption
- Low emittance beam (~10 nm-rad at 2.4 GeV), allowing an efficient injection into the storage ring.

This last point is very important in the case of the SLS, where the top-up operation is the standard mode of operation (see reference [1]).

Table 1: SLS Booster Parameters

Maximum Energy	GeV	2.7
Circumference	m	270 = 3·90
Lattice		FODO with 3 straights of 8.68 m
Harmonic number		450=15*30
RF frequency	MHz	500
Peak RF voltage	MV	0.5
Maximum current	mA	12
Maximum rep. Rate	Hz	3
Tunes Q_x, Q_y		(12.39, 8.35)
Natural Chromaticity		(-1,-1)
Equilibrium values at 2.4 GeV		
Emittance	nm-rad	9
Radiation loss	keV/turn	233
Energy spread, rms		0.075 %
Partition numbers (x,y,ε)		(1.7, 1, 1.3)
Damping times (x,y,ε)	ms	(11, 19, 14)

The main parameters of the SLS booster are shown in Table 1. For a more in-depth description of the machine see reference [2].

At present, the operational energy is 2.4 GeV. However, top energies of 2.7 GeV have been reached in machine shifts.

A picture of the tunnel, showing both the storage ring (left hand) and the booster (right hand, mounted ih the wall) is show in figure 1.

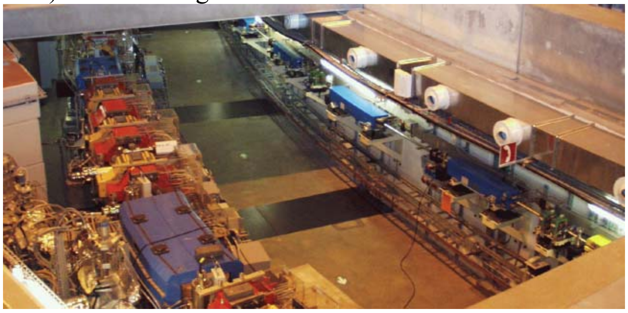

Figure 1:Picture of the tunnel.

2 COMMISSIONING OVERVIEW

The commissioning of the SLS booster took place between July 2000 and December 2000. The process went without any important difficulties. The milestones of the booster commissioning were:

- July 3: start of commissioning.
- July 11: first turn in booster, even without correctors.
- July 12: RF switched on, more than 100.000 turns.
- July 18: 40% of the injected particle survived until next injection (320 msec).
- July 27: ramping up to 1.5 GeV.
- Aug. 17: 80% of injected beam (400 pC) accelerated to 2.4 GeV (however one shot only, continuous operation with higher losses due to bad vacuum), tune measured and set to design value, measured betas agree to 10% with design.
- Aug. 23: Booster accepted: 1.1 nC before septum, 0.9 nC captured, 0.8 nC extracted at 2.4 GeV. These are values for first shot after a break of a few minutes; extracted charge in steady state is approx. 0.16 nC. Residual gas mainly CO, pressure 5.10-7 mbar.
- September 20: 1nC extracted at 2.4 GeV.

The following weeks were devoted to “laundry” of the vacuum chamber using the synchrotron light emitted by the electron beam. At the same time, we finished the commissioning of the hardware components, in particular of the digital BPM system, identical to the one to be used in the storage ring.

From December 11, the beam was extracted from the booster and the booster-to-storage ring transfer line was set-up. On 15 December, a beam of 2.7 mA was stored in the storage ring,

In the following section we describe some of the problems faced during commissioning and how we solved them.

3 PROBLEMS

3.1 Vacuum limitations

One of the possible limitations of the SLS booster is that at low energy (100 MeV) a good vacuum is required to ensure good lifetime and ramping efficiency, but the small dimensions of the vacuum chamber makes this difficult. The first step to solve this problem is to have a low emittance beam out the linac. However, at the start of commissioning,, the desorption induced by the synchrotron light in the vacuum chamber spoiled the vacuum and generated losses at low energy. Figure 2 shows the current along the ramp for this situation.

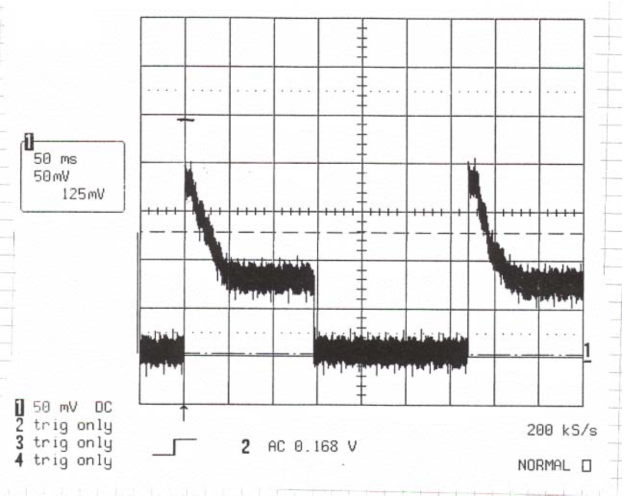

Figure 2: Losses due to bad vacuum during the ramp.

To solve this problem, the ramp was modified. The original idea was to have the energy during ramping following a sinusoidal shape, from the injection energy (100 MeV) to extraction (2.4 GeV). This implied that the beam would remain a long time at the bottom of the ramp, almost without an increase in energy, making it very sensitive to losses induced by residual gasses. The modified ramp follows also a sinusoidal shape, but the minimum energy corresponds to ~50 MeV, and the beam is injected in the slope, reducing the time that it remains at low energy. With this method, the losses due to gas desorption were reduced to almost zero.

3.2 Effect of the Eddy currents

The theoretical effect of the eddy currents is described in [3]. At the start of the booster commissioning no effect related to them was observed. However, when switching to very short pulses coming from the linac (in order to inject in a single bunch in the storage ring), sudden losses during the ramp were observed.

The behavior of the losses could be related to the charge density in the booster: for low charge, no losses were present. When increasing the charge, sudden losses (up to 10% of the beam in a few turns) appear. If the charge is increased further, the entire beam is lost. The time where the losses happen is where one has a maximum contribution to the chromaticity due to eddy currents (approximately 60 ms after the start of the ramp).

This effect can be explained by a fast head-tail instability induced by a negative chromaticity created by the eddy currents. In effect, the machine settings used at the time did not include any extra sextupolar correction. The only one are the sextupole component built in the combined function magnets, and they are set to compensate the natural chromaticity only. In addition, two families of sextupoles are available to compensate the sextupolar component induced by the eddy currents.

Following the procedure described in [3], we evaluate the currents required to keep the chromacticy constant at (+5,+5) during the ramp (including the contribution of the eddy currents). The power supplies installed in the SLS booster are fully programmable and allow for an arbitrary current shape during the ramps, so it is not a problem to follow a non sinusoidal ramp.

Once the sextupoles were active during the ramp, no more losses associated to charge density were observed.

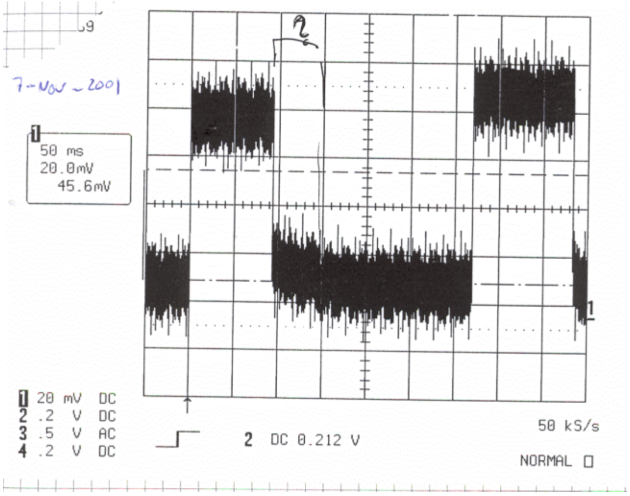
7-Nov-2001

Figure 3: Losses due to eddy currents during the ramp. It can be see that the losses are not constant between shots.

3.3 Overall ramp efficiency

After reducing the losses due to vacuum at low energy and to the eddy currents, we still observed a constant loss, independent of the charge, during the ramp. When we measured the tunes during the ramp, we observed that the tunes moved and that the horizontal tune crossed a third order resonance at the time of the losses. The ramp of the three extra quadrupole families was modified to keep the tune constant during the ramp. After that 100% ramp efficiency is reached.

The tune movements during the ramp are show in figure 4.

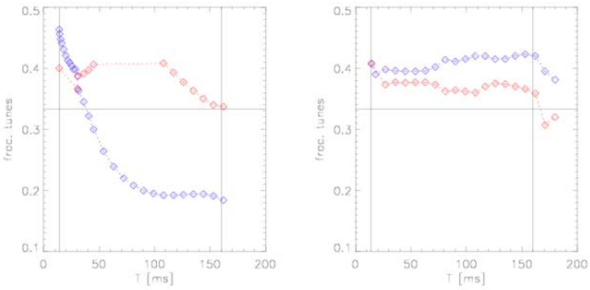

Figure 4: Fractional part of the horizontal (blue) and vertical (red) tune during the ramp, before (left plot) and after (right plot) optimisation. The crossing of the third order resonance is the cause of beam losses.

The main limitation of the overall efficiency is the injection into the booster. In regular operation the efficiency is about 60%, and can be raised to 80% after careful transfer line and injection settings optimization. Extraction from the booster reaches 100% efficiency regularly.

4 SUMMARY

The SLS booster was constructed and commissioned within schedule and below budget. All problems that were faced during commissioning were solved.

The overall performance of the system is according to the design specifications. The reproducibility of the booster is excellent: uploading a set of machine parameters using the control system reproduces the corresponding machine status without any further adjustements.

5 REFERENCES

[1] M. Muñoz, A. Ludeke, “Top-Up Operation at the Swiss Light Source,” these proceedings.

[2] W. Joho et al. “The SLS Booster Synchrotron”, EPAC’98, Stockholm, June 1998

[3] M. Muñoz, W. Joho, “Eddy currents effect in the SLS booster“, SLS-TA-1998-10