COMMISSIONING OF THE SOLEIL BOOSTER

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Abstract

SOLEIL is a 2.75 GeV third generation synchrotron radiation facility under commissioning near Paris [1]. The injection system is composed of a 100 MeV electron Linac pre-accelerator commissioned in July 2005. It is followed by a full energy (2.75 GeV) booster synchrotron that has been commissioned in October 2005. A 75 % efficiency, at full energy, has been reached with 12 mA stored in the booster in October 20 2005.

INTRODUCTION

The booster lattice is based on a 22 cell FODO structure with missing magnets. With 2 super periods, the circumference is 156.6 m and low field magnets (0.74 T max), the emittance is of 130 nm.rad at 2.75 GeV. Injection and extraction scheme are inserted in the two long free drift sections. The main parameters are summarized in table 1.

Injection / Extraction energy	0.1, 2.75 GeV
RF Frequency	352.202 MHz
Circumference / Period	156.6 m / 2
Cycling frequency	3 Hz (340 ms)
Horizontal emittance	1.3 10^{-7} m.rad
Energy spread	6.6 10^{-4}
Energy losses by turn	409 keV
Betatron tunes (ν_x , ν_z)	6.6 , 4.6
Momentum compaction	3.19 10^{-2}
Natural chromaticities (ξ_x , ξ_z)	-1.14, -1.32
Damping times (τ_x , τ_z , τ_s)	6.3, 5.7, 2.7 ms
Number of dipoles / Length	36 / 2.16 m
Dipole Field min/max	0.027 / 0.74 T
Number of Quadrupoles	44 / 0.4 m
Maximum gradient	12 T/m
Number of Sextupoles	28 / 0.15 m
Max Sextupole Strength	16 T/m^2

Table 1 : Main parameters of the booster

Beside, a flexible and economic ramping switched mode procedure for the main booster power supply cycled up to 3 Hz and a 35 kW-352 MHz solid state amplifier powering the RF system are used.

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COMMISSIONING

On July 23rd 2005, the first beam at the energy of 110 MeV was injected in the booster. All the equipment necessary for these tests were made operational just in time for that day and have all been running with a good stability. Unfortunately, the BPMs didn't work at the beginning of the run and the beam showed some reluctance to make the first turn, then to make 4 or 5 turns. We finally stored about 10 % of the injected beam (figure 1). Off line analysis showed that the tunes were Q_x=5.95 and Q_z=3.83.

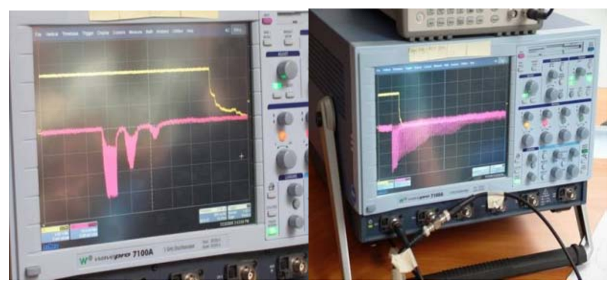

Figure 1: 3 first turns and first stored beam in the booster

The next runs, in October 2005, were focused on optics improvements at constant energy of 110 MeV. All the 22 BPMs were working enabling on line orbits read out, correction and tunes measurement. Rapid improvements of the booster injection efficiency were done.

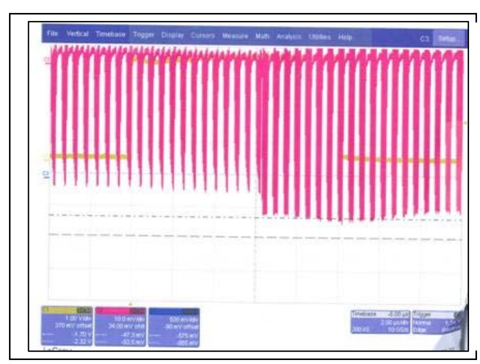

Figure 2: 80 % stored beam at 110 MeV

Increasing from 10 % to about 50 % efficiency was obtained by correcting the orbits (mainly the vertical one) and the chromaticities. A further injection efficiency increase, reaching about 80 %, was achieved by improving the beam matching from TL1 into the booster (figure 2). A search for the optimum tunes was performed. At present time, Q_x=6.6, Q_z=4.6 is a good working point region at 110 MeV. The comparison between measured tunes and quadrupoles current settings at 110 MeV showed a quite good agreement with the model based on the magnetic measurements. Beside, the stored current exhibits a slow decrease compatible with a vacuum beam lifetime of 1 to 2 s with a 10^{-7} mbar mean pressure.

For the energy ramping, the power supplies generate a 3 Hz sinus excitation of the magnets. After a final current tracking adjustment achieved for the four 3Hz booster power supplies [2], the deviation from a proportional variation between each PS current was kept below 2 $\pm 10^{-3}$.

$$\Delta Q_{x,z} \approx 10 \times \Delta I / I$$

Following the previous relation, the induced tune variation (Qx and Qz) were then kept below ±0.02 in each planes and we were ready to accelerate beam in the booster.
The few first trials were not successful. On October 13th, 2005, we succeeded to accelerate the beam up to 2.75 GeV for the first time in the booster. The efficiency from TL1 to 2.75 GeV was rather small, about 2.5 %.

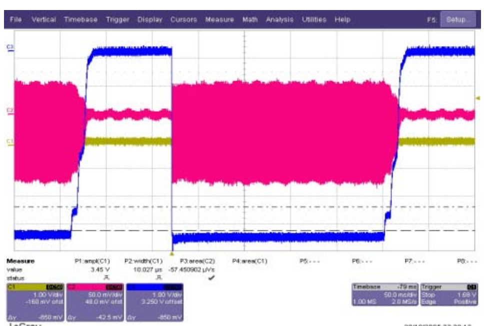

Figure 3: 75 % accelerated beam to 2.75 GeV.

Since we were not yet able to measure the tune by means of our strip-line during the energy ramp, we proceeded by iterative trials starting from theoretical current settings. In the following runs we improved the efficiency at 2.75 GeV up to 75 % from TL1 pulse charge. This efficiency was obtained on October 20th , 2005 with 12 mA current in the booster. It should be noticed that a premature losses appeared at high energy (~1.5 GeV) in the decelerating phase of the ramp, probably due to a resonance crossing. These losses are localised in one booster region inducing high activation of the vacuum chamber. They have been eliminated later on with a better tuning.

The orbits and chromaticities were corrected in DC mode at injection only. In AC mode, the horizontal orbit is slightly different than in DC mode and the chromaticities are almost cancelled at the same energy. These perturbations are induced by the Eddy currents in the dipole vacuum pipe.

The extraction process, based on combination of a fast kicker [4] and an orbit bump followed by an Eddy current and an active septums [5] has been commissioned in May 2006 just before the beginning of the storage ring commissioning [6].

BOOSTER FIGURES

The magnetic measurement [3] at low field exhibits a spread of 150 µm for the quadrupoles magnetic center. The relative spread of the dipole integrated field is ±0.5 % also at low field. These spreads are dominated by the presence of remnants component not negligible at low field. They are in accordance with the natural orbits measured at injection. They reach a maximum of ±6 mm in both planes (figure 4). A set of 22 DC correctors in each planes are used to correct these orbits down to 1 mm only at the injection energy. The magnetic measurement done at high field gave better results, respectively 100 µm and ±0.15 %, for quadrupole center and dipole spread. The natural orbits at maximum energy is then reduced down to 2 mm (figure 5). It confirms the choice that correcting the orbit is only required at injection.

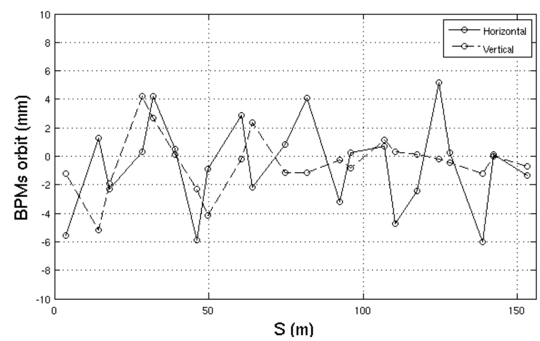

Figure 4: Natural orbits at injection.

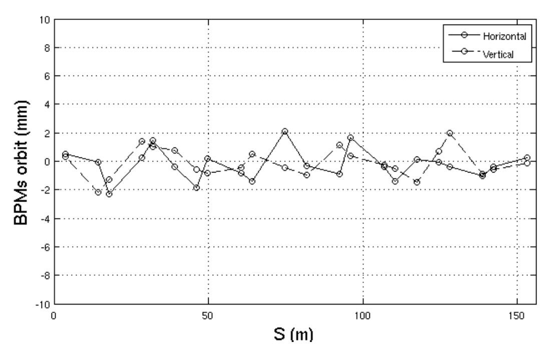

Figure 5: Natural orbits at 2.75 GeV.

Later on, further improvements have been done when we were able to measure the tunes through the ramp. The tunes are measured by means of a shaker (stripline) inducing a resonant excitation of the betatron oscillations. The frequency is scanned over a range covering the possible fractional tune of the booster. This operation is done at each new ramp with different delay following then the beam through the acceleration and deceleration phases.

The figure 6 depicts the measured tune through the 340 ms ramp for the present nominal working point Q_x=6.6, Q_z=4.6. It exhibits a small variation of ±0.05 from injection to the end of the cycle. The relevant parameters are the injection and ramping efficiencies as well as keeping the beam down to the lowest energy in the decelerating phase.

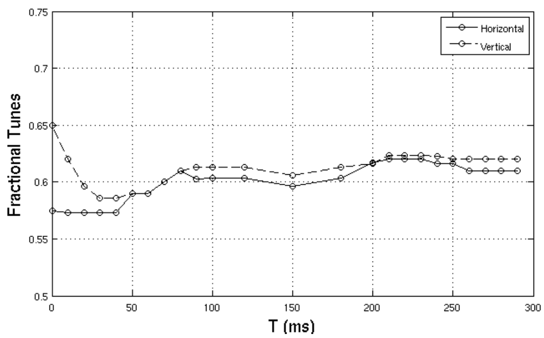

Figure 6: Booster fractional tunes through the ramp.

With the present working point, we obtained more or less an efficiency of 90-95% from the transfer line up to the maximum energy. Figure 7 depicts the charge coming from TL1 and the charge ramped up to 2.75 GeV recorded over 300 successive injections. They are very close to each other. It should be noticed that these good efficiencies are mainly due to the beam characteristics coming from the Linac. The injected normalized emittance are in the region of 50 mm.mrad (4βγε) in both plane, four times smaller than specified. By means of beam loading compensation, the energy spread is also lower than the ±1.5 % specified. It reaches ±1 % with a pulse charge of 3 nC and a minimum of ±0.5 % with a pulse charge of 8 nC [7][8].

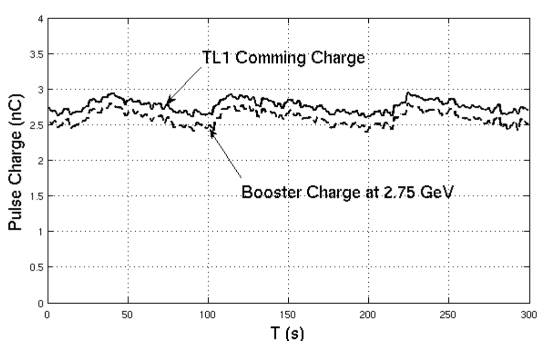

Figure 7: TL1 and Booster charge for 300 successive injections at 1 Hz.

To improve the efficiency stability as well as to ease the tune measurements, the sextupoles are ramped up to mid-energy. Losses in the decelerating phase happen between the energy of 140 and 100 MeV (figure 8). They are low enough to minimize the activation in the tunnel when the booster is run without beam extraction.

The RF voltage is also ramped with a 3 Hz sine wave. The DC Voltage is tuned in the region of 100 to 150 kV at 3 nC pulse charge and up to 200 kV at 8 nC to compensate the beam loading. At the maximum energy, the voltage reaches 900 kV.

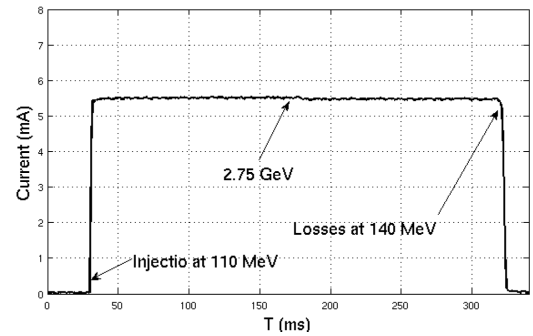

Figure 8: Booster current along the 340 ms ramp.

The booster is mainly working on coupling except at injection. The emittance has not yet been measured; it should be around 130 nm.rad. In a near future, the booster working point will be increased toward Q_x=7.3, Q_z=5.2 so as to reach a minimum emittance of 100 nm.rad at the maximum 2.75 GeV energy.

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REFERENCES

[1] JM. Filhol, Overview of the Status of the SOLEIL Project, this proceeding.
[2] P. Gros et al., The 3Hz Power Supplies of the SOLEIL Booster, this proceeding.
[3] A. Loulergue, Status Of the SOLEIL Booster, PAC 2005.
[4] P. Lebasque et al., Fast Kicker Systems for the SOLEIL Booster Injection and Extraction, this proceeding.
[5] P. Lebasque et al., Eddy Current Septum Magnets for Booster Injection and Extraction and Storage Ring Injection, this proceeding.
[6] A. Nadji, First Results of the Commissioning of SOLEIL Storage Rings, this proceeding.
[7] B. Pottin et al., Commissioning of the 100 MeV Preinjector HELIOS for the SOLEIL Synchrotron, this proceeding.
[8] M.A. Tordeux et al., Metrology for the Beam Emittance Measurement of the SOLEIL Injector, this proceeding.