FIRST RESULTS OF THE COMMISSIONING OF SOLEIL STORAGE RING

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Abstract

The commissioning of the SOLEIL storage ring started in May 2006. The objective was to reach, within a first phase of two months, stable beam conditions at 100 mA in the multi-bunch mode that can be used for the commissioning of the beamlines. This is a challenging objective especially because SOLEIL's ring is incorporating some innovative techniques such as the use of a superconducting RF cavity, NEG coating for all straight parts of the machine and new BPM electronics. Prior to starting the commissioning, 4 Insertion Devices and most of the IDs low gap vacuum vessels, including 10 mm inner vertical aperture vessels for the Apple-II type, were installed on the ring. We report here the main results of the first commissioning experiments.

THE SOLEIL STORAGE RING

The SOLEIL storage ring consists of 16 Double Bend cells and 4 super periods. The 2 central cells of these laters are modified to create 2 additional straight sections (3.6m) by drifting apart the two quadrupole doublets located in-between the two bending magnets of the cell [1]. The machine provides 24 straight sections (4x12m, 12x7m, 8x3.6m) with a circumference of 354.097m. The injection occupies one long straight and the SC RF cavities occupy two medium straights. The magnet structure is composed of 32 bending magnets, 160 quadrupoles with independent power supplies grouped into 10 families and 120 sextupoles in 10 families. The orbit correction is done using 120 BPMs and 56 correctors in each plane. The lattice is designed to achieve an emittance of 3.7nm.rad at 2.75GeV with distributed dispersion in straight sections. Figure 1 shows the optical functions of one of the four super periods and Table 1 lists the main parameters of the storage ring.

BEFORE BEAM STARTING UP

Before starting up, most of the available equipment were thoroughly verified and their control command tested and validated. The polarities of each DC magnets were checked (voltage and magnetic field orientation). A lattice modelling including additional focusing effects deduced from magnetic measurements (bending magnet fringing field, gradient due to curved trajectory and difference between entrance and exit edges) was prepared. Most of the application programs, needed for the first phase, were developed [2]. These checks allowed correcting several defects which would have otherwise complicated the commissioning.

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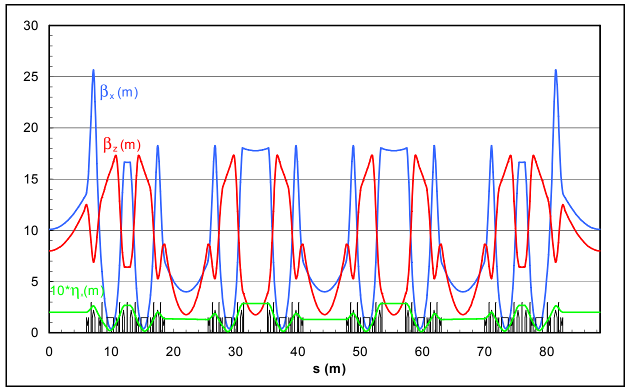

Figure1: SOLEIL storage ring optics.

Table 1: SOLEIL storage ring main parameters.

Energy	2.75	GeV
Circumference	354.097	m
RF frequency	352.202	MHz
Betatron tunes	18.20 /10.30	
Natural chromaticities	-53 / -23	
Momentum compaction	4.45×10^{-4}	
Radiation loss per turn	944	keV
Damping times	7, 7, 3.5	ms
Emittance	3.7	nm.rad
Relative energy spread	1.016×10^{-3}	
Natural bunch length	4	mm

FIRST BEAM INJECTION

On-Axis Injection for Storing

During all this first part of the commissioning, the movable injection septum was positioned at its inner location (15mm from the storage ring axis). In the beginning, only bending magnets were powered on to a field corresponding to 2.75GeV and the beam was injected on the central orbit of the ring by an on-axis injection. The first turn trajectory measured on several BPMs was used to determine the deviation between the energy of the injected beam and the storage ring bending magnet field. The minimization of the trajectory excursion in the first 20 BPMs corresponds to an energy deviation of –0.40% (as predicted also by the Booster and transfer line TL2). We have chosen to apply this correction to the storage ring bending magnets to avoid a re-tuning of injector parameters. The vertical angle of the injected beam was corrected using the 2 last vertical correctors of TL2. Then the quadrupoles were powered on to their theoretical values and scaled by the factor of –0.40%. Without any trajectory correction, the beam circulated for almost 3 turns. To increase the number of turns, we corrected step by step the first turn trajectory in both horizontal and vertical plane using the storage ring dipolar correctors and the BPMs in the first turn mode. The correction algorithm allowed either the use of one corrector and one or several downstream BPM readings or the use of any matrix composed of given correctors and BPMs. The inversion of the pre-defined matrix was performed using the SVD method. Figure 2 shows the result of the first turn trajectory correction. The maximum deviation is less than 2mm, with corrector strengths lower than 0.2mrad (H) and 0.1mrad (V).

Figure 2: Result of the first turn trajectory correction.
a: intensity seen by each of the 120 BPMs.
b: beam positions after the first turn correction
c: correctors values (H in red and V in blue).

The last vertical corrector was excited to kill the beam after the first turn, to ensure that all the BPMs read the same turn.

After this correction, the beam performed up to 50 revolutions in the ring, as shown on the FCT situated in the last quarter of the ring (Figure 3).

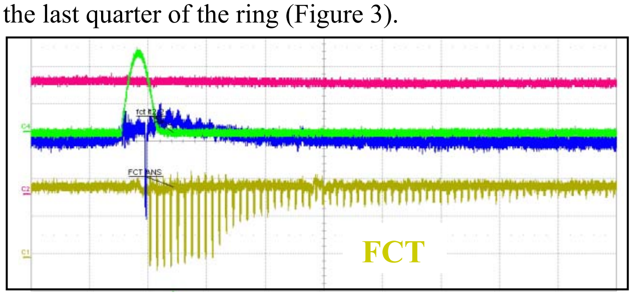

Figure 3: 50 revolutions in the ring.

We next switched on the sextupoles progressively from zero to their theoretical values and we happily observed the transmission improving and the number of turns increasing. Figure 4 illustrates the beneficial effect of the sextupoles.

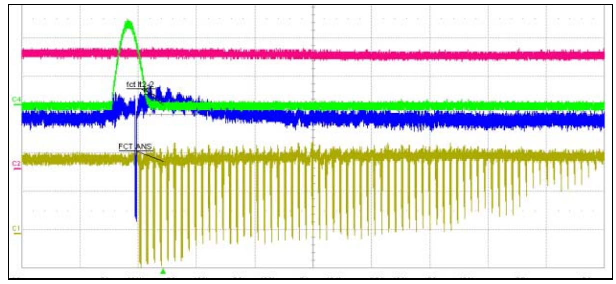

Figure 4: Revolutions after powering the sextupoles.

To get a stored beam, the RF was turned on; after optimisation of the RF-phase (between the Booster and the Storage Ring), centering of the horizontal orbit by varying the RF frequency, and decreasing slightly the horizontal focusing, the beam was stored. A beam current of 0.3mA was stored during 10 minutes with a beam lifetime of 20 minutes. Only one of the RF cavity was powered to simplify the phase tuning.

Off-Axis Injection for Accumulation

In order to accumulate the beam in the ring, we moved to the normal off axis-injection. The four kickers were then retuned but all the storage ring magnets kept their values determined during the on-axis settings. We could accumulate 8.35mA in 10 minutes. Due to a cooling problem of the vacuum vessels [3], the beam current was limited to 20mA during several days. Later on, we managed to increase the current step by step to reach a maximum of 85mA in 312 bunches, filling three quarters of the ring. Figure 5 shows an automatic injection of the beam every one second during ten minutes .

Presently, the highest possible current cannot be reproduced easily and this is not completely understood up to now; some observations showed that fast beam ion instabilities could be one of the reasons. Although the actual total beam time was reduced because of cooling repetitive interlocks due to the blocking of magnet filters (full of resin), the integrated dose of current has already reached 2.6 A.h.

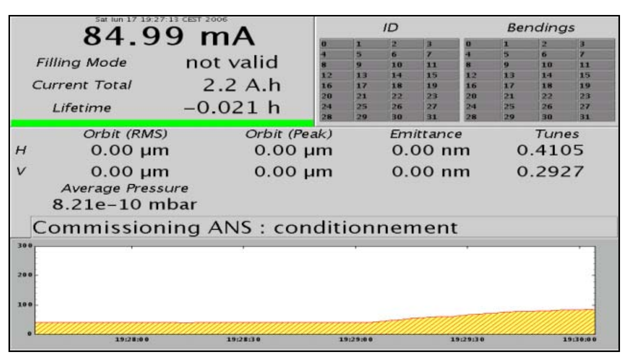

Figure 5 : Present maximum current reached.

A Few Machine Physics Studies Results

The single turn capability of the BPMs has been very helpful during this early commissioning part. In addition to the very successful first turn correction, one of these BPMs revealed via a significant decrease of the intensity (sum signal) a suspicion of an obstacle in the machine. Systematic orbit bumps were then performed in order to locate precisely this obstacle. The machine was then opened around the indicated location and a distorted bellows RF finger was found.

The natural closed orbit, i.e. the orbit with correctors powered off is compatible with an excellent alignment of the girders (50µm-rms) and the quadrupoles (20µm-rms). Figure 6 shows that the peaks are less than 5mm horizontally and 1.5mm vertically.

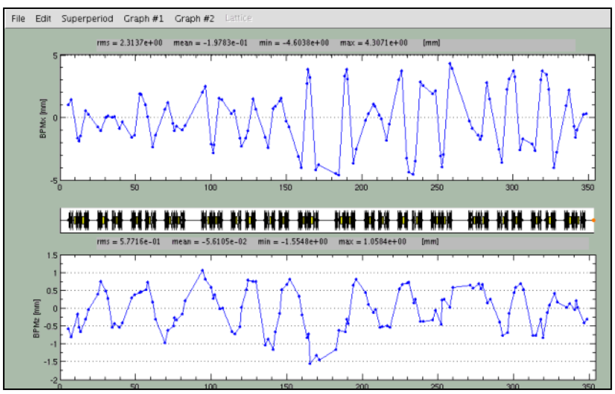

Figure 6: Measured closed orbit with all correctors off.

Furthermore vertical and horizontal orbit correction using SVD was successfully performed, reducing the maximum values around hundreds of microns before performing beam based alignment. Figure 7 shows the first corrected closed orbit using a theoretical matrix.

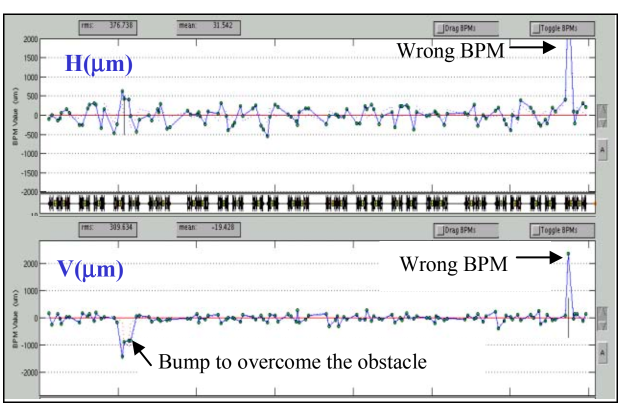

Figure 7: Closed orbit correction using a theoretical response matrix.

During beam storing tests, we had to vary the RF frequency by about -5kHz (-5mm in circumference) in order to center the horizontal closed orbit. This was confirmed later by tune variation versus RF frequency for different chromaticities.

The betatron tunes expected from the model are 18.20 and 10.30 and the measured ones were respectively 17.80 and 10.14. This deviation has to be understood. To obtain model values from measured values, the calibration of all the quadrupoles has to be increased by 8 x 10^{-3}. At present, the working point is around 18.40 and 10.30, optimised for injection efficiency and beam lifetime.

First measurements of the beta functions in all 160 quadrupoles have been performed as well as the horizontal and vertical dispersion. Characterisation and correction is under analyzing using LOCO [4].

The linear betatron coupling seems to be very low (0.17%) as determined by the closest tune approach ($\Delta\nu_{min}=3\times10^{-3}$) shown in Figure 8. Precise measurements of beam dimensions are under preparation.

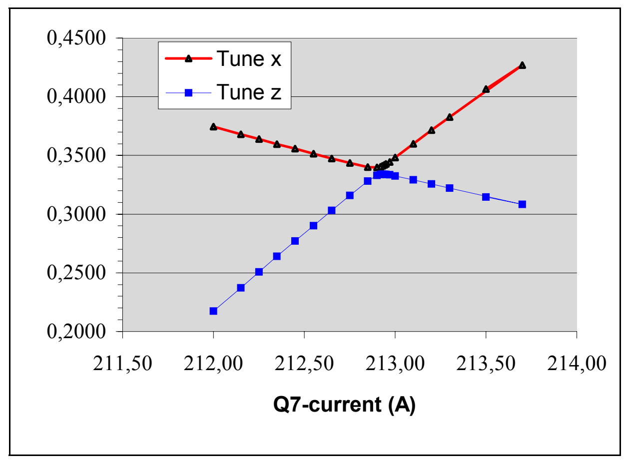

Figure 8: Closest tune approach.

CONCLUSION

After only three weeks, the first results of SOLEIL storage ring commissioning are very encouraging. The different steps of the first part were covered very quickly. The program of the following weeks will aim for stable operation conditions and a solid basic understanding of the machine. This will guarantee a stable photon beam for the beamlines commissioning foreseen to start by the middle of July 06.

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