DOUBLE LOW BETA STRAIGHT SECTION FOR DUAL CANTED UNDULATORS AT SOLEIL

A. Loulergue, C. Benabderrahmane, F. Bouvet, P. Brunelle, M-E. Couprie, J-C. Denard, J-M. Filhol, C. Herbeaux, P. Lebasque, V. Leroux, A. Lestrade, O. Marcouillé, J-L. Marlats, F. Marteau, T. Moreno, A. Nadji, L. Nadolski, F. Polack, A. Somogyi, M-A. Tordeux,
Synchrotron SOLEIL, GiF-sur-Yvette, France.

Abstract

SOLEIL is the French 2.75 GeV high brilliance third generation synchrotron light source delivering photons to 20 beamlines with a current of 400 mA in multibunch or hybrid modes, and 60 mA in 8 bunch mode. Already 17 insertion devices are installed and 9 others are planned in the next two coming years. Among them, two canted in-vacuum insertion devices, for the Nanoscopium and Tomography beamlines, will be accommodated in a 12 m long straight section, with a 6.5 mrad separation angle. These ~150 and ~200 m long beamlines will exploit the high brilliance and coherence characteristics of the X-ray (5-25 keV) beam, both for diffraction limited focusing and for phase contrast imaging. To provide low vertical beta functions at each undulator, an extra triplet of quadrupoles was added in the middle of the section. We present here the lattice implementation footprint, the different working points under investigations as well as the first results of the measurements on the machine performance.

INTRODUCTION

Beside the optimisation of the SOLEIL accelerator system, implemented in parallel with the installation of new insertion devices [1], further developments such as short bunch operation in low-alpha mode, ultra-short pulses with the femto-slicing project [2], and the challenging long canted beam-lines [3] are either in progress or under construction. Installation of a dedicated optics for the canted long beamlines is planned for mid 2011 together with the in-vacuum insertion devices. The first photons are planned to be delivered to Nanoscopium beamline for the summer of 2011. The scope of this paper is focused on the beam dynamics studies in presence of the additional quadrupole triplet and its first tests on the storage ring.

SECTION LAYOUT

One of the four 12 m long straight sections will be dedicated to the two canted in-vacuum Insertion Devices (ID) for Nanoscopium and Tomography long beamlines. In order to achieve the double low vertical beta functions of about 2 m at each ID, an extra quadrupole triplet is located in the middle of the section. The optical functions for the nominal long straight and for the modified one are respectively plotted in figure 1 and 2. The canted geometry is achieved by four permanent dipole magnets of 0.5, 5.38, -11.88, and 6 mrad. The resulting separation between the two beam-lines is then of 6.5 mrad.

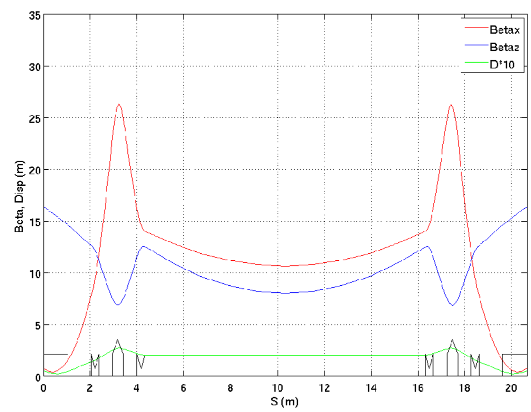

Figure 1 : Nominal long straight section optical functions.

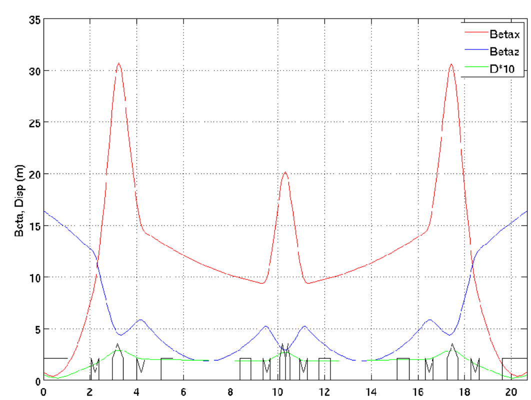

Figure 2 : Modified long straight section optical functions with the vertical double low beta.

BEAM DYNAMICS STUDIES

Inserting the extra quadrupole triplet breaks the present four-fold symmetry of the storage ring optics and consequently may spoil the beam dynamics in terms on beam lifetime as well as injection efficiency [4]. The goal is to be able to restore the injection efficiency and the beam lifetime presently achieved during user operation, as listed in table 1, with chromaticities set to 2 in both planes for the bare lattice as well as with the main set of IDs. It has to be pointed out that the energy acceptance for the nominal bare machine is large and reaches about 4%. The only limitation at +4% is the well known second order momentum compaction factor effect [5]. In counter part, the presence of IDs spoils this large acceptance and the lifetime is reduced by a factor of about two by off momentum resonance excitations [6].

In order to minimize this non-linear optics perturbation, we apply the well know "pi-trick" phase advance along the section based on +0 and +0.5 additional phases respectively in the horizontal and vertical plane. These set

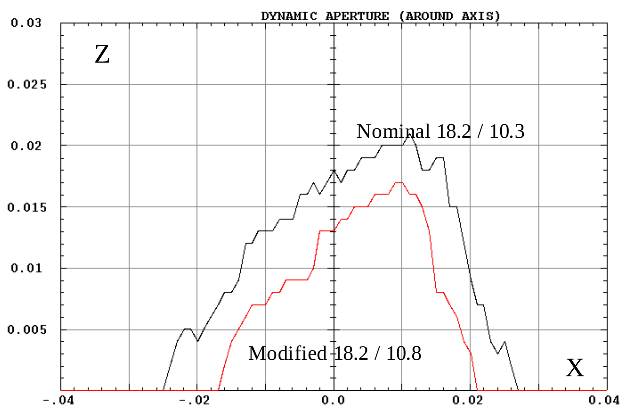

Figure 3 : DA comparison, black curve for the present nominal machine and red curve for the modified one.

of additional phase step preserves the sextupoles tuning in both plane and so the Dynamic Aperture (DA). In addition, it is well adapted to retune the optics from the large vertical beta function of 8 m to the double low waist of 2 m (figure 1 and 2). This optics retuning is done by means of the additional triplet and the two already existing flanked triplet of quadrupoles using the BETA code [7]. Unfortunately, based on the nominal storage ring configuration, 3 points have to be faced:

1) Four Sextupoles are present in between the two flanked triplets. The phase tuning is then not preserved any more for these concerned sextupoles.
2) Sextupoles are not powered individually, but in families with respect to the present four-fold symmetry.
3) The nominal present working point is 18.202 in horizontal and 10.317 in vertical plane. Applying the "pi-trick" moves the new Working Point (WP) directly on the unstable coupling sum resonance $\nu_x+\nu_z=29$.

The simulated DA reduction induced by the change of the betatron functions within the four sextupoles is shown in figure 3. In both cases, the chromaticities are 2 in both planes, the sextupoles tuning is identical without any skew errors. There is a slight DA reduction but the injection efficiency should stay the same. Nevertheless, as expected, when adding some skew quadrupole errors components, the modified lattice is unstable and the DA drops to zero very fast. The second step, for the new optics tuning, has been to shift the working point away from this strongly unstable resonance. We then started to investigate a set of working points around the nominal one. The linear and non linear optics were optimized with the BETA code and both quadrupole and sextupole settings are affected. Increasing by one unit the horizontal or vertical tunes drastically limits the DA optimization. On the contrary, reducing by one unit the vertical tune relaxes the DA but does not lead to beta functions low enough at the ID locations. We then restricted the working point investigation to : 18.2-10.7, 18.2-10.3, 18.8-10.7 and 17.8-10.7 regions. The two last ones are known to be more sensitive to the resistive wall instability but the transverse feedback [8] should enabled to overcome it. The WP 18.2-10.7 may be less favourable regarding the off momentum dynamics being to close to the coupling sum resonance together with positive chromaticities.

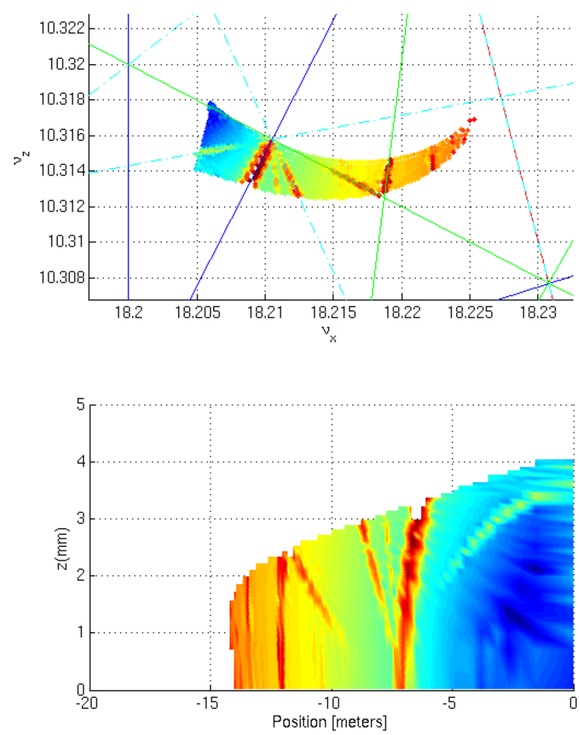

Figure 4 : Simulated on momentum FMA for the modified bare lattice on 18.207-10.317 WP. Red lines for order 4 resonances, Blue lines for order 5, green for order 7 and dashed light blue for order 8.

The transverse DA optimization is straightforward with BETA code. An example of Frequency Map Analysis (FMA) is plotted on figure 4 for the WP 18.2-10.3. Tracking is performed using the Tracy II 4^{th} order integrator code [9]. The modelled colour code is related to particle tune diffusion rates [10]. Unfortunately, the off momentum dynamics is more difficult and clearly suffers from the four-fold symmetry break (figure 5).

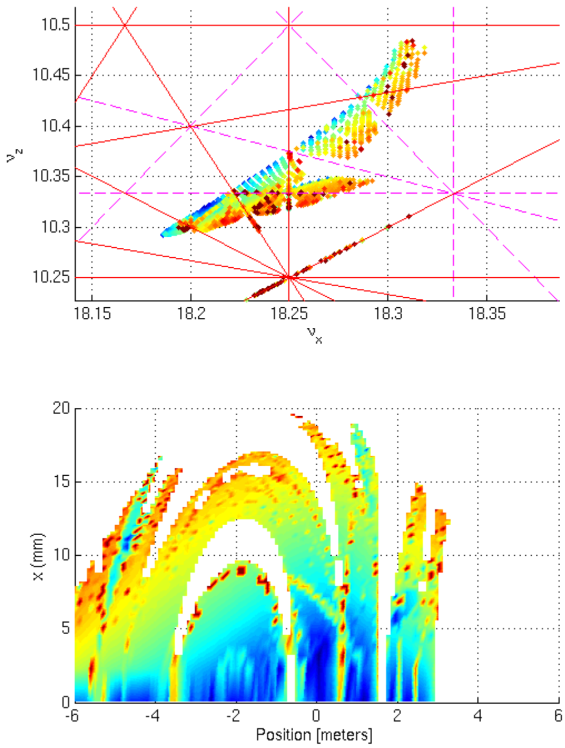

Figure 5 : Simulated off momentum FMA for the modified bare lattice on 18.207-10.317 WP. Dashed magenta lines for order 3 and red lines for order 4 resonances.

The main off momentum DA reductions are induced by the systematic resonances of order 3 : $\nu_x+2\nu_z=39$, $2\nu_x+\nu_z=47$ and of order 4 : $3\nu_x+\nu_z=65$, $2\nu_x+2\nu_z=57$ and $4\nu_x=73$. The off momentum acceptance is then reduced from 4 down to 3%. It should be noticed that these resonances are the same than already observed on the nominal lattice in presence of IDs [6,11,12,13]. These IDs also break the lattice symmetry.

EXPERIMENTAL TESTS

The final installation of the canted section is planned for mid 2011. In order to experimentally investigate the impact of the additional quadrupoles, we took an opportunity to install a set of three spare quadrupoles during the summer 2009 shut-down. Since then, we dedicated three machine shifts for testing the various WP mentioned above. On the first run, the first approach was tested near the WP 18.2-10.8, keeping the rest of the lattice unchanged. As expected it was initially impossible to inject. We had to scan the tunes for obtaining a maximum efficiency of 80% on the 18.26-10.80 WP with a quite large coupling of 2.6%. On the second run, we tested the 18.2-10.3 WP and we got the best solution so far, with an injection efficiency of 90% and a beam lifetime of 6 h for the bare lattice at 400 mA in multi-bunch mode (table 1). The WP was then optimized at 18.207-10.317. The main feature of this new lattice lies in its low sensitivity to the IDs, the beam lifetime staying the same at about 6 h. It corroborates the previous off-momentum simulations that exhibit the effects of the broken symmetry, which are finally similar to the IDs effects on beam dynamics. In addition, the reduction of the beam lifetime by a factor of two is coherent with the energy acceptance reduction from 4 to 3%. On the third run, we tested both 17.8-10.7 and 18.2-10.7 WP. In both cases, the beam lifetime was only 2.7 h at 400 mA in multi-bunch mode and the injection efficiency was 70 % at best.

Table 1: Lifetime and injection efficiency comparisons for the nominal and modified lattices at 400 mA in multibunch filling mode.

	Bare	**With IDs**
Nominal	14 h / 90 %	6 h / 45%
Modified (best)	6 h / 90 %	6 h / 55%

CONCLUSIONS

The optimum tuning of the new optics providing the double low vertical beta in one long straight section is still under investigation. The presence of the quadrupole triplet strongly affects the energy acceptance and hence the beam lifetime, in the same manner as the IDs [12], via similar systematic resonances.

REFERENCES

[1] J-M. Filhol et al, "Operation and Performance Upgrade of the SOLEIL Storage Ring", These Proceedings.
[2] A. Somogyi, F. Polack, and T. Moreno, Nanoscopium: A Scanning Hard X-ray Nanoprobe Beamline at Synchrotron Soleil, SRI 2009 AIP Conference Proceedings 1234, p. 389.
[3] A. Nadji et al, "SLICING at SOLEIL, These proceedings.
[4] A. Ropert L. Farvacque, EPAC08 Proc. pp. 2106-2108.
[5] A. Nadji et al. "The Effect of Nonlinera Synchrotron Motion on the SOLEIL Energy Acceptance", PAC99 Proceedings.
[6] P. Brunelle et al., , These proceedings.
[7] J. Payet, Beta Code, CEA, SACLAY.
[8] R.Nagaoka et al "Development and Status of Transverse Bunch by Bunch Feedback System at SOLEIL", PAC'09, Vancouver, May 2009,
[9] L. S. Nadolski, Soleil version of Tracy II code.
[10] J. Laskar, "Fequency Map Analysis and Particle Accelerators", Portland, PAC'03, 2003, pp. 378-382.
[11] P. Brunelle et al., WEPC048, EPAC08 Proceedings.
[12] L. S. Nadolski et al. THPC063, EPAC08 Proceedings.
[13] M-A. Tordeux et al., THGPFP095, PAC09 Proceedings.