GENERAL PERFORMANCES OF THE INJECTION SCHEME INTO THE SOLEIL STORAGE RING

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Abstract

The injection scheme of the electron beam into the SOLEIL Storage Ring is presented. It corresponds to the new SOLEIL optics : 12 meter long straight section, 2.75 GeV energy, with in addition, the requirement for top-up injection mode. Pulsed magnets are described, and in particular the eddy current septum magnet, the transverse position of which can be adjusted to optimise the Touschek beam lifetime. Tracking of particles has been performed over a large number of turns, taking into account the magnet errors, the high chromaticities and the physical apertures all along the machine (limited vertical apertures due to low undulator gaps). Statistical efficiency of the injection has been deduced. Specific requirements for top-up injection have been examined, such as a perfect closure of the injection bump, the residual vertical field and the leakage fields from septa.

INTRODUCTION

The use of top-up operation will provide the solution to face inevitable problems like Touschek limited beam lifetime, reduction of the gas scattering beam lifetime due to small gap in-vacuum undulators, and photon beam stability. The success of the top-up operation is strongly linked to a very good injection rate. This has been optimized for the case of multibunch mode (500mA in 416 bunches) approaching 100% efficiency. In this paper, the study will focus on the temporal structure mode (90mA in 8 bunches) where the Touschek effect is more pronounced and higher chromaticities are needed. This work takes into account the vacuum chamber dimensions, especially the in-vacuum undulator gaps, with a realistic residual closed orbit and different coupling values.

INJECTION SCHEME

TL2 transfer line

The 40 meter long Booster - Storage Ring (SR) transfer line (TL2) is made of 4 dipoles (same as those of the SR) fed by one power supply (independent of SR), 7 quadrupoles (same as those of the Booster). Two viewers, an emittance monitor, 3 BPMs, 2 Fast Current Transformers and 7 steerers permit to adjust the beam parameters at the injection point. Extra vertical correctors could be added if required and room is kept for possible collimators.

Injection scheme

Beam injection from TL2 to SR is made in the horizontal plane, in a 12m long straight section with finite dispersion [1]. The stored beam is bumped by four kickers to allow an off-axis injection. The injected beam is steered parallel to the stored beam thanks to two thick septa and an in-vacuum eddy current septum. Fig. 1 shows the injection point in the transverse x-x' phase space. Adjustment over 10 mm of the septum sheet position is foreseen: on one hand we have considered potential difficulties in reaching the maximum kicker current, on the other hand we would like to preserve possible enhancement of the machine performances through Touschek lifetime increasing.

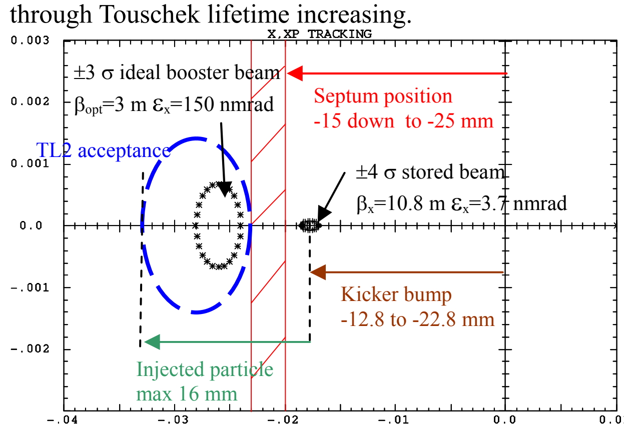


Figure 1: Injected and stored beam in the horizontal transverse phase space at injection point

Pulsed Magnets

The main characteristics of the pulsed magnets are given in Table1. Commercial solid state HV switch modules are used for kicker pulsers, based on many IGBT in series/parallel. They are located outside the tunnel via 15 coaxial cables (8 m long) in parallel to limit HV at 10 kV. The pulsers of the septum magnets use the classical scheme with up to date thyristors.

Table 1: Pulsed element characteristics

Pulsed element	Eddy ct septum	Thick septum	kickers
Lmag [m]	0.6	0.5	0.6
θ nom / max [mrad]	23.7 / 27.5	110 / 114	5.9 / 7.6
I max [A]	5 015	7 080	5 220
aperture H/V [mm]	18 / 15	21.2 / 15	80 / 25
τ ½ sine	60 µs	3.3 ms	6.5 µs

Injection straight section implementation

Fig.2 shows the injection straight section layout with the additional ring diagnostics placed there to take profit of the additional shielding (scraper) or due to the reasonable high β function in both plane (machine-study kickers). Vacuum chambers of the whole section have almost the same profile as the octagonal ceramic chambers of injection and machine-study kickers. Special chamber in the eddy current septum is connected through RF fingers for safe transverse displacement.

INJECTION TRACKING

Calculation assumptions

Injection has been performed using the SOLEIL BETA code (4D tracking) [2], for the SR nominal working point

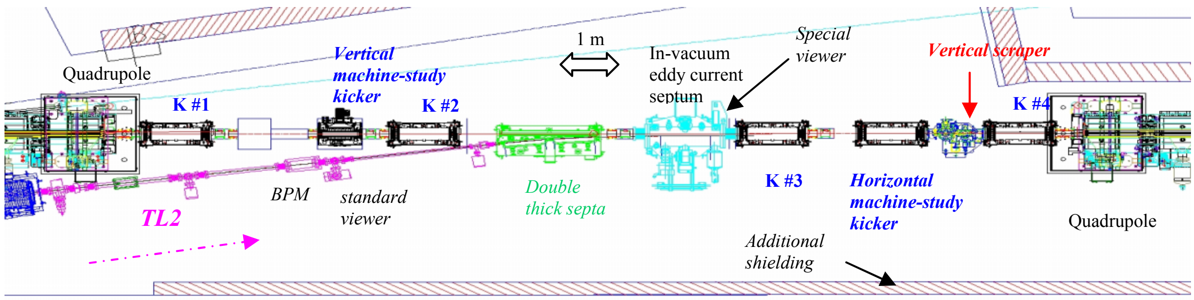


Figure 2: Injection straight section with pulsed magnets and diagnostics

[3] in the high chromaticity mode. A set of errors has been examined for statistical evaluation of the injection efficiency. 56 H/V dipolar correctors lead to a residual closed orbit of 30 μm rms value for both planes in the quadrupoles and sextupoles [3]. 32 skew quadrupoles are used for coupling correction [4]. The vacuum chamber apertures (Fig.3) includes the 5mm in-vacuum undulator gap and the vertical scraper in the injection section closed at ±3.5 mm, value which will be justified further in the paper (the non-linear equivalence of the ±2.5mm in-vacuum undulator gap being ±4.6 mm). No insertion device field nor decapolar field due to correctors are taken into account.

The TL2 acceptance has been considered, wich corresponds to a conservative increasing by 50% of the nominal 150 nm.rad booster emittance, assuming extraction-injection pulsed element instabilities. Natural coupling for booster is assumed to be less than 5%. 1500 particles were tracked over 1000 turns, before the transverse damping occurs.

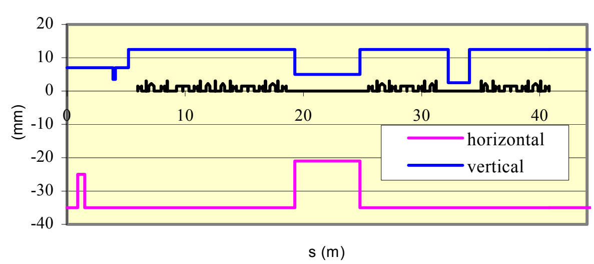


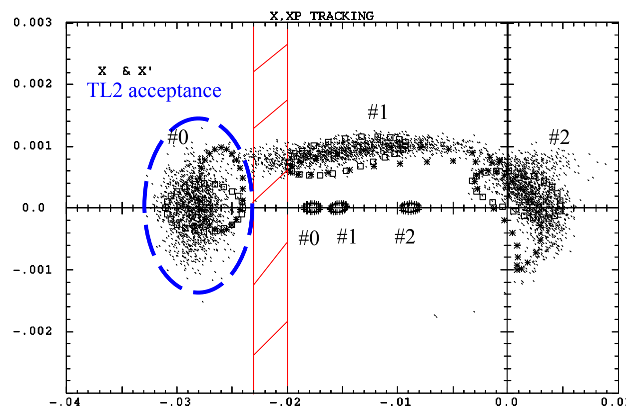
Figure 3: H/V vacuum chamber apertures for half a super-period

First turns

The low fractional part of the horizontal tune (.20) combined with the slow decreasing of the kicker strength, makes part of the beam hitting the septum sheet after one turn. As shown on Fig. 4, possible cures are either kicking the injected beam or increasing the β_{inj} from the optimal 3m (*) to 9m (□). In both cases the injected beam emittance is increased by around 30%. Particles with high negative divergence are lost on the septum.

Injection rate

A set of errors has been examined for the nominal working point (18.20-10.30) and the normalized chromaticities ξ_x=0.1 and ξ_z=0.8. No account of losses at 1st turn is taken here. Fig. 5 shows that an undesirable amount of particles is lost. If we consider 1% coupling as a reasonable goal after coupling correction, up to 60% of the beam could hit the vertical chamber aperture with no loss on horizontal chambers. Due to the vertical tune shift with the horizontal amplitude, the 4th order coupling resonance $3\nu_x+\nu_z=65$ is excited and induces losses on vertical limited apertures.



□ and* Ideal injected beam contour without any error in Booster–TL2
. Simulated injected beam for tracking with conservative distribution
+ Bumped stored beam

Figure 4: 1st and 2nd turns in the transverse phase space at injection point for injected and stored beam

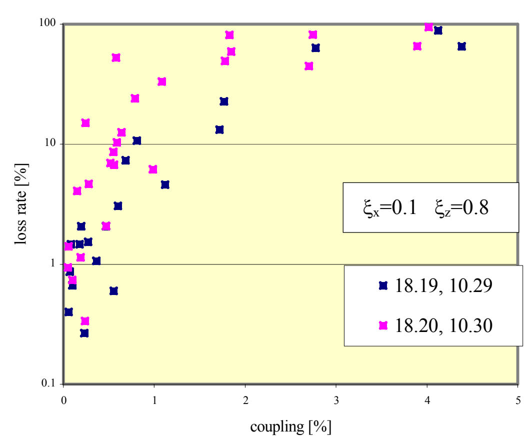


Figure 5: Loss rate for nominal and optimized working points

A re-optimization of the working point has been done at zero chromaticity. The chromaticity increasing was then adjusted with only two sextupole families [5]. Fig.5 shows that with the new working point (18.19-10.29) less than 10% losses of the whole conservative beam is expected at 1% coupling.

Dealing with Collimators

The issue of the loss location is of great importance for in-vacuum undulator protection. The error seed (with 1% coupling) studied in Fig. 6 and 7 opens a typical discussion. At nominal working point, the core of the x-x' injected beam distribution is lost vertically with no chance to be stopped by a possible horizontal collimator located on TL2 transfer line. Changing the working point, the situation is reversed and an H collimator in TL2, associated with the septum sheet (at first turn) acts efficiently. Such a result appears systematically for couplings lower than 1%.

On the other hand, Fig.7 evaluates the efficiency of the vertical scraper as possible alternative for collimation. From the strict point of view of the in-vacuum undulator, it acts more efficiently at the nominal working point. For the optimized one, closure down to ±2mm of the scraper will affect strongly the gas beam lifetime. Such behaviour is error seed dependent : skew quadrupoles distribution, that is first of all skew quadrupole relative phase advance, partly controls the vertical halo size for large horizontal amplitude at small gap locations.

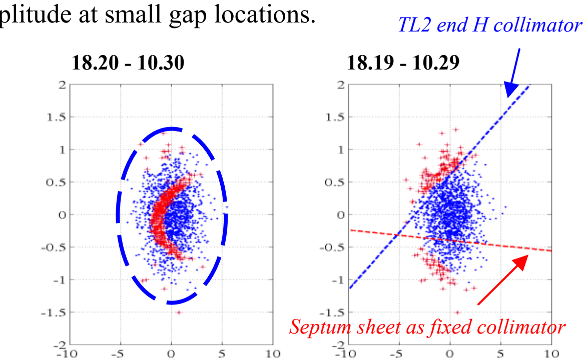


Figure 6 : Lost particles (red), injected particles (blue) projected in the x-x' phase space of injection point (mm.mrad)

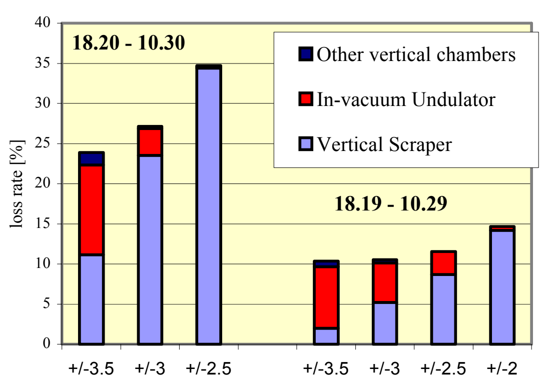


Figure 7: loss locations for nominal and optimized working points and different scraper apertures in mm

SPECIFIC REQUIREMENTS FOR TOP-UP

To fully satisfy the users community, top-up injection should be achieved while keeping the requirement on beam stability in both plane at the maximum of 10% of the beam size : typically 18 µm (H) and 0.8 µm (V) in the medium straight section. In addition, the possible lost particles should be collected at positions which minimize the radiation dose that could go through the open shutters. The following issues have therefore to be addressed:

Closure of the injection bump

Independent power supplies are foreseen for the kickers. Thanks to the IGBT's fast switching time, the identity between the 4 pulses should be better than 0.1%, with a jitter lower than 1 ns, after magnetic measurements and voltage adjustment. Pulse to pulse reproducibility is expected to be less than 0.1%. Nevertheless, the beam stability requirement would need to reduce these performances by a factor 2. Progress will be pursued after the machine commissioning.

Leakage field from septum magnets

Modelisation shows that an entrance and exit leakage field Bl_{max}=35G×2cm arises with the main field of the eddy current septum. Induced stored beam oscillation exeeds the requirement by a factor of 10. We are waiting for measurement on the real magnet for shielding optimisation. In the same idea, a delayed eddy current longitudinal leakage field has been seen, but already optimized down to $Bl_{max\ on\ SR\ axis}$=0.2G×60cm (τ=2ms).

During the design of the thick double septa, room has been kept for possible shielding.

No horizontal magnetic field

The 10 µrad alignement tolerance around the longitudinal axis for kickers is dramatically low. A precise mechanical system will enable a manual and step by step adjustement, using beam vertical orbit measurement.

CONCLUSIONS

The optimization of the working point of SOLEIL storage ring makes probable an injection rate better than 90%, for conservative injected beam and a machine including high chromaticities, errors and main non-linearities. Solution for capturing the lost particles is more delicate: a simple collimator in the transfer line would be efficient, but operation will give the real efficiency of the vertical scraper in the storage ring.

Work to fulfil the stability requirement for top-up operation is now under progress.

ACKNOWLEDGEMENT

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