TOP-UP INJECTION WITH "ANTI-SEPTUM"

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Abstract

We present a novel improvement for injection into the very restricted machine aperture of future light source synchrotrons. A conventional injection scheme is based on a septum to deflect the injected bunch with a fast pulsed bump using kickers to bring the stored beam close to the septum wall. With the novel improvement, the bump kickers are fitted with a thin wall longitudinal metal plate which screens the injected bunch from deflection without changing the stored beam bump behaviour. This metal screen then forms the final septum, but inverted in function of the conventional approach, hence the name "anti-septum". The approach does not remove the need for the main septum magnet, but for modest cost it permits the injected bunch to be brought closer to the stored beam. Application of the anti-septum to the SLS-2 project and simulation results on a prototype are presented.

INTRODUCTION

Future light sources aim at an equilibrium emittance well below 1 nm-rad through a compact and tightly focusing lattice, namely a multi-bend achromat. Strong quadrupoles in the lattice may limit the physical aperture for given maximum pole tip field. At the same time, the need for strong sextupole magnets to correct chromaticity with limited dispersion function in the tight lattice causes a dynamic aperture restriction; this restriction is comparable to the physical aperture and is typically only a few millimeters and makes injection difficult.

Frequent top-up injection to keep the beam current approximately constant means the injection scheme should give minimal disturbance to the closed orbit. Several existing light source synchrotrons have moved towards using pulsed non-linear kicker (also termed pulsed multipole or pulsed sextupole) schemes to reduce this closed orbit disturbance [1, 2], although the experience at SLS indicates that ±0.1% tolerance on the kicker magnets and pulsers plus fine roll trimming of the kickers is sufficient to maintain closed orbit disturbance at low values.

However, the problem of injection into the small aperture remains. Schemes with beam manipulation [3] and on-axis beam injections [4-6] have been proposed.

We present a novel approach to modify the existing conventional top-up injection scheme to make it applicable to a storage ring with a limited aperture. An application to SLS-2 project, which is an upgrade of the Swiss Light Source (SLS), is presented as an example of the proposed approach.

CONVENTIONAL AND ANTI-SEPTUM SCHEME

The conventional injection scheme used at SLS [6] employs a septum and a symmetric four-kicker bump. At the time of injection, the septum is pulsed then the bump kickers are pulsed to give orbit bump which brings the stored beam into the vicinity of the septum wall. The septum wall is 3mm thick and uses eddy current screening in copper plus mu-metal screening to achieve near zero stray field for the stored beam. In Fig.1, the wall of the down-stream anti-septum however can be much thinner since its function is to delay the stray field in the injected beam channel only.

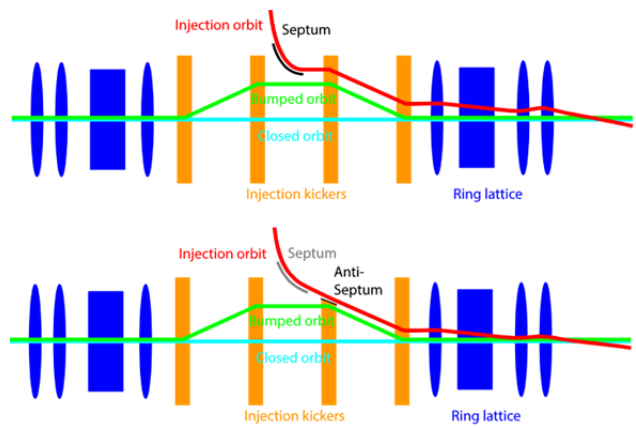

Figure 1: Schematic views of conventional top-up injection schemes with normal septum (upper) and anti-septum (lower).

In Fig. 1 (upper), both injected and stored beams are deflected with the third and fourth kickers. Also, the septum and the third kicker deflect the injected beam to opposite directions. Hence, if the septum and the third kickers are merged, the septum field is cancelled by the field of the kicker. Since this merged component needs to excite a field only for the stored beam, in contrast to the septum that excites a field only for the injected beam, it is called "anti-septum".

APPLICATION TO SLS-2

For the upgrade of SLS, the injector complex will be reused since it can generate injection beam with the rather small emittance of 9 nm. A new multi-bend achromat storage ring will have an injection straight section that is only half as long as for SLS. Table 1 summarises some injection parameters of SLS and SLS-2.

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ISBN 978-3-95450-182-3

Table 1: Parameters of SLS and SLS-2

Parameter	SLS	SLS-2
Beam energy	2.4 GeV	2.4 GeV
Straight section	11 m	~5 m
Dynamic aperture	~±15 mm	~±5 mm
Septum thickness	3 mm	1 mm
Emittance injected	~9 nm	~9 nm
Emittance Hor.	5.5 nm	<200 pm
Tune Hor.	20.74	37.22

In Fig. 2, the addition of an "anti-septum" screen in the kicker downstream from the septum permits the injected beam separation from the bumped orbit to be reduced to ~3 mm. Dummy anti-septum conductors are needed in the other kickers to give identical inductance and resistance, hence identical pulsed field waveforms. The blue areas are the pulsed dipole fields of four kickers. The dashed line shows the bumped orbit, the dotted line shows the injected electron beam.

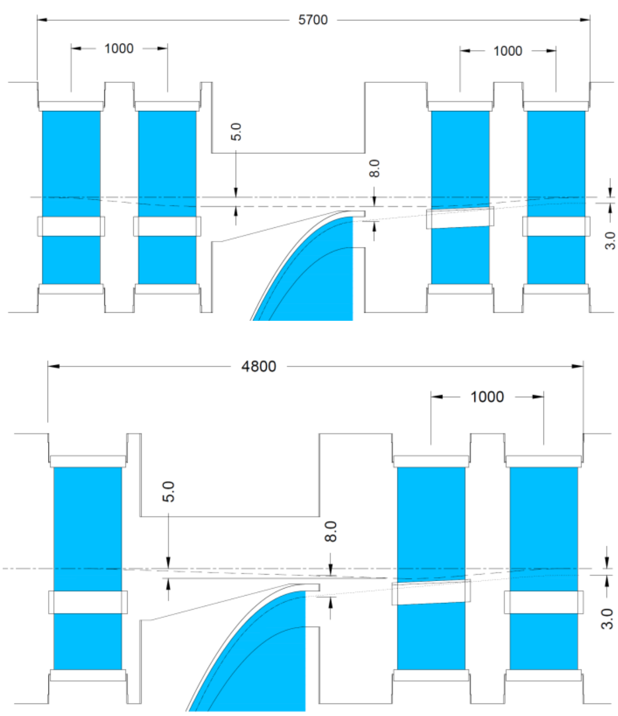

Figure 2: (a): Schematic plan view of the injection straight with a symmetric bump and the added anti-septum. (b): As for (a) but with three kickers of unequal strengths 1.6, 6.2 and 4.6 mrad.

In Fig. 2(b), the excellent orbit closure of Fig. 2(a) is compromised because of using unequal kicker strengths, but the injection elements require 1 m less length in the injection straight section.

PROTOTYPE ANTI-SEPTUM

Figure 3 shows cross section of the existing kicker magnet with the anti-septum conductor added. The bump of the stored beam is 5 mm, the separation stored beam – injected beam is 3 mm, and the anti-septum conductor is machined to give a narrow channel for the injected beam to pass. Preliminary measurements show that a round pipe as the anti-septum conductor severely affects the main field homogeneity whereas the vertical rectangular section conductor tends to leave the main field homogeneity in the range <1%. The field homogeneity of the latter configuration is examined with simulations in the next section.

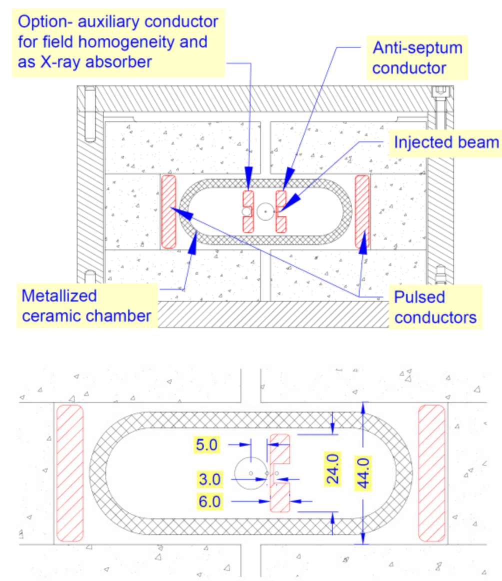

Figure 3: (a) Cross section of kicker and (b) dimension details of the anti-septum conductor.

SIMULATION RESULTS

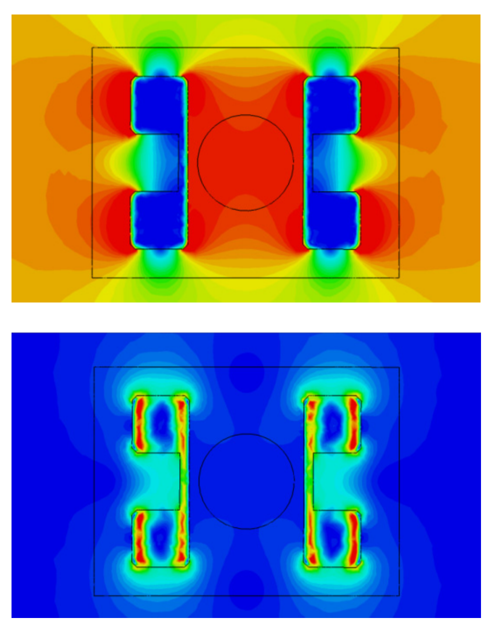

Figure 4: Simulation of the main field with symmetric conductors: (a) 66 mT at the peak of the current pulse; (b) ~800 μT at 3 μs after the current pulse.

ISBN 978-3-95450-182-3

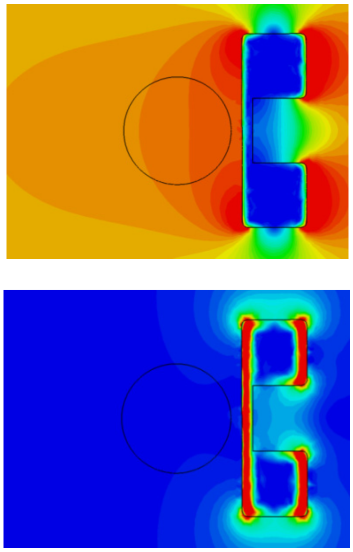

Figure 5: Simulation of the main field with a single (asymmetric) conductor: (a) 61mT at the peak of the current pulse; (b) ~800 µT at 3 µs after the current pulse.

Results from simulation with the CST LF solver are shown in Figs. 4 and 5 for a 6 µs half sine 2 kA excitation current and an anti-septum conductor width of 6mm. After the main excitation current pulse has disappeared, long term residual fields remain because of the eddy current flowing inside the conductors. However, these fields are fairly homogeneous, are at low level compared to main field and are proportional to the excitation current so they sum to zero through the three or four bump kickers.

The main concern then is with the homogeneity during the main pulse. Figure 6 shows the field along a horizontal line from beam axis to within 1 mm of the anti-septum conductor at the peak of the main pulse. For fully symmetric dual conductors, a more homogeneous field with ~500 µT change in ~66 mT is possible; but the fully symmetric configuration may not be practical because the outer conductor is subjected to high intensity X-radiation from the up-stream storage ring dipole. For a fully asymmetric single conductor, the peak field changes by ~2 mT in ~62 mT. However this modest inhomogeneity can be compensated by small geometry changes in the shape of the conductors, or in worst case by addition of a thin copper conductor outside the ceramic vacuum chamber. Work is in progress to find the optimum configuration.

CONCLUSION

The existing symmetric 4-kicker bump in the SLS gives low closed orbit disturbance due to the 0.1% tolerance on all pulsers and magnets. For an upgrade capable of injection into the restricted ±5 mm aperture of SLS-2, the "anti-septum" idea is proposed. The initial measurements and simulations show that a vertically oriented flat copper profile in a pulsed uniform field gives a large reduction of the field inside the injected beam channel and yet modest change to main field strength and homogeneity during the pulse. The residual eddy current fields after the pulse are low and cancel out. The scheme can be implemented with modest cost and in the restricted length of the injection straight section.

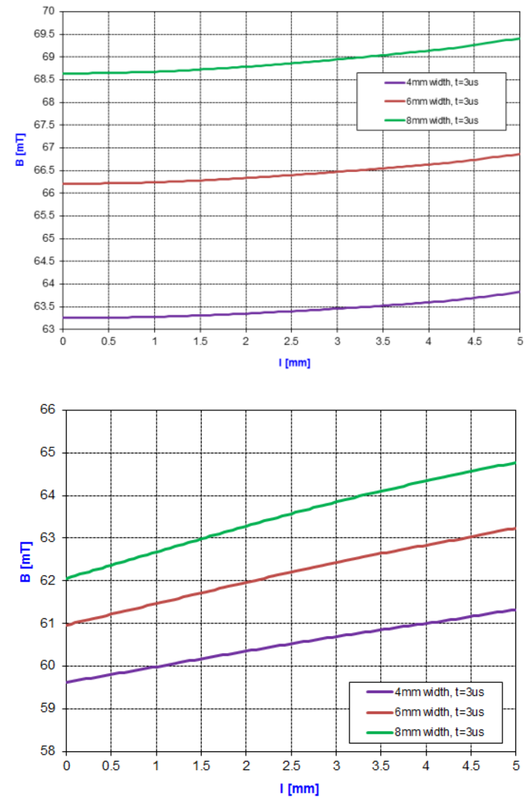

Figure 6: Main pulse homogeneity x=0 mm to x=5 mm for (a) dual (symmetric) conductors and (b) single (asymmetric) conductor, with conductor thickness 4, 6 and 8 mm.

ACKNOWLEGEMENT

The authors gratefully acknowledge the CST LF simulations by Dr Sladjana Dordevic.

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