PROGRESS WITH NSLS-II INJECTION STRAIGHT SECTION DESIGN*

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Abstract

The NSLS-II [1] injection straight section (SR) consists of pulsed and DC bumps, septa system, beam trajectory correction and diagnostics systems. In this paper we discuss overall injection straight layout, preliminary element designs, specifications for the pulsed and DC magnets and their power supplies, vacuum devices and chambers and diagnostics devices.

INJECTION STRAIGHT SECTION

The storage ring's injection straight section consists of a DC pre-septum, a pulsed septum, and four kickers located in the 9.3 meter long high beta straight section of the storage ring.

The four kicker magnets, IS-BU1SE to IS-BU4SE, are placed symmetrically in the straight section. There are no multipoles between the kickers, so the closed bump does not depend on the machine optics (non-interleaved scheme). When the injection beam arrives, the first and second kickers kick the stored beam 15 mm towards the septum knife, where there is 2.5 mm "safety" distance between the stored beam orbit and the septum knife. The stored beam and the injected beam merge at the exit of the septum. The third and fourth kickers kick both beams, so that the stored beam returns to its designed orbit, and the injected beam trajectory is 9.5 mm away from the stored beam orbit at the exit of the straight section.

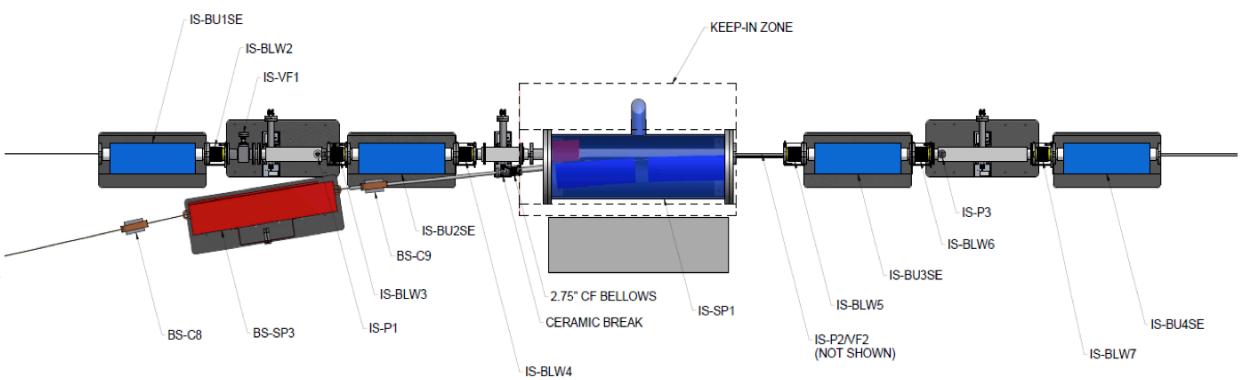

Figure: 1: Schematics of the storage ring injection straight section.

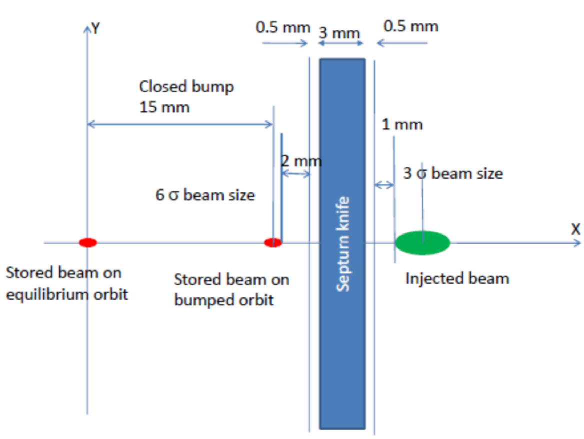

Figure 2: Geometry of the injected and stored beams at the septum exit.

PULSED MAGNET SPECIFICATIONS

The design parameters for the pulse kickers and pulsed septum are listed in Tables 1 and 2. The kicker waveform is a half-sine with 5.2 µs pulse length, which is equivalent to two consecutive storage ring revolutions, so every stored bunch goes through the closed bump only twice during one injection cycle. The pulse septum's waveform is a full-sine, so that the effects from the magnet leakage fields are minimised.

The magnet error specifications [3] are based on the tolerances for residual oscillations of the stored beam during top-off injection. After analysing experience in ALS, DIAMOND, SLS and SPEAR, we specified tolerances for the pulsed magnets in the injection straight section in such a way that the acceptable oscillation amplitude of the stored beam at the injection point is below 100 µm (i.e. 0.7 σ_x in the horizontal plane and 2.5 σ_y in the vertical plane). In order to minimise the vertical orbit transient caused by the magnet errors and

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misalignments every kicker will be placed on a remotely adjustable support.

Specifications for the kicker and septum parameters are presented in Tables 1 and 2.

Table 1: Kicker Specifications

Parameter	Unit	Value
Maximum Field	mT	131
Magnet Yoke Length	mm	650
Maximum Bend Angle	mrad	7.85
Magnet Aperture X x Y	mm	90 x 41
Pulse Length	µs	<5.2
Maximum Repetition Rate	Hz	2
Field Waveform Variation	%	<0.1%
X/Y Good Field Region	mm	±20 / ±10
Field quality inside GFR	%	±.5
Magnet Total Inductance	µH	2.2
Maximum Current	A	4700
Vacuum (with beam)	Torr	$< 1 \times 10^{-9}$

Table 2: Septum Specifications

Parameter	Unit	Value
Maximum Field	T	0.85
Magnet Yoke Length	mm	1300
Maximum Bend Angle	mrad	100
Magnet radius of curvature*	m	13
Magnet Aperture H x V	mm	24 x 10
Field quality inside GFR	%	0.1
Pulse Length (full sine)	µs	<200
Leakage Field at SR orbit	µT-m	<30
Timing Jitter	ns	<10
Field Amplitude Stability	%	0.01
Magnet Total Inductance*	µH	4.1
Maximum Current*	kA	7.41

The pulsed magnets, their supports, vacuum chambers, power supplies will be procured according to our specifications.

We considered both options of in-vacuum and out-of-vacuum septa and will choose the actual configuration based on the analysis of the received proposals. At this point the straight section design affords the opportunity to support either option.

For the DC pre-septum we will use an exact replica of the extraction DC septum for the NSLS-II booster ring.

Considerations for the NSLS-II kicker power supplies, together with analysis of an option for driving them in parallel, are presented in [6].

DC BUMP

The designed emittance of the ring results in extremely small beam sizes and even a small disturbance, induced by the SR pulsed magnets, will excite the stored beam betatron oscillation and perturb user experiments. As a consequence, the ring kickers have tight requirements on the magnets mechanical alignment, pulse-to-pulse stability and magnet-to-magnet reproducibility of the waveforms.

Experience shows that the performance of pulsed magnet power supplies is more stable at lower voltage operation. We proposed to implement a DC local bump [2] in addition to the fast bump to reduce the kicker strength, and thus the kicker power supply voltage, by 30%. This DC bump is comprised out of two ring corrector magnets together with an additional magnet near the pulsed septum magnet. As a side benefit, the DC bump can be used to study the effects of the reduced SR aperture on the stored beam lifetime.

Fig. 3 shows arrangement of the three DC bump correctors. The middle corrector is integrated into the pulsed septum upstream end. Two other correctors are located on the storage ring girders before and after the injection straight section. In between them, there are two quads and two sextupoles, which induce small but appreciable tune shift when the DC bump is on.

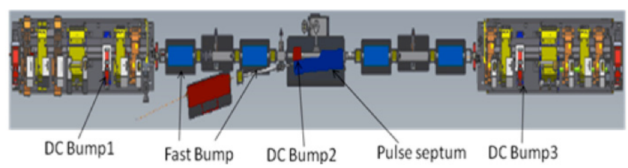

Figure 3: Layout of the DC bump.

Fig. 4 shows the stored beam trajectory through the injection straight region in different scenarios of the DC bump. The black line shows the beam trajectory with the DC bump on and the kickers off. The green line corresponds to the beam trajectory with the fast bump on and the DC bump off. The red line, DCfs1, is the beam trajectory with the both bumps on. There the kicker strengths are optimised so that the beam trajectory along the septum is parallel to the septum knife. The blue line, DCfs2, corresponds to the situation when four kickers have the same strength.

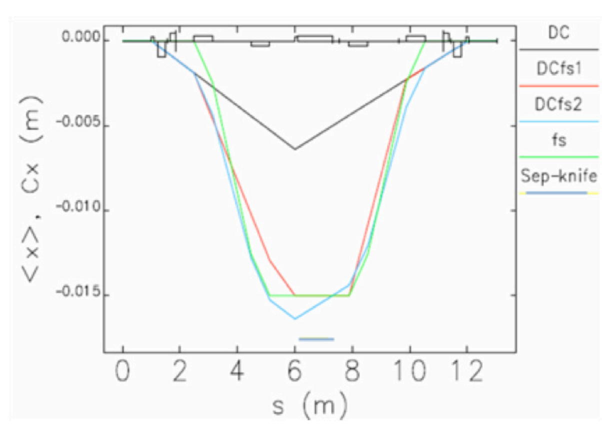

Figure 4: Beam center for different scenario of bump.

The DC bump amplitude is 5mm in order to maintain high injection efficiency and preserve the stored beam lifetime. Simulations using Elegant [4] show that the injection efficiency could be maintained at 99.7% while allowing a stored beam lifetime greater than 3 hours. The required strength of the middle magnet is 2.5 mrad and the outer corrector strength is 1.2 mrad.

BEAM DIAGNOSTICS

The injection straight diagnostics [5] includes four BPMs and two beam flags with the OTR screens (Fig. 5). The first flag is located before the upstream end of pulsed septum and will be used for beam shape and position measurements prior to injection into the storage ring. The second flag is placed between first and second kickers and will be used to observe the beam after the first turn in the storage ring.

One BPM is mounted on the round vacuum chamber immediately after the DC septum. Two other BPMs between the kickers will be used to measure the position of the circulating beam with the bumps on and off. Their measurement range is ±12.5 mm in the horizontal plane and ±10 mm in vertical plane. The middle BPM is located after the pulsed septum to monitor the bumped beam (15 mm inwards) and injected beam (24.5mm inwards). This BPM is shifted 17mm inwards with respect to the SR beam orbit, so that the orbits fall inside its linear region.

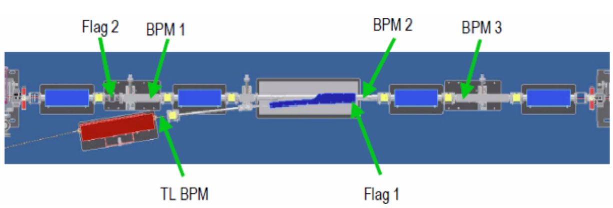

Figure 5: Injection straight section diagnostics layout.

IMPEDANCE ANALYSIS

The NSLS-II storage ring specifications require the ability to store stable high current electron beams with different bunch patterns. To inject the beam from the booster ring into the storage ring a low-impedance septum vacuum chamber has been analyzed and optimized with an injection septum angle of 100 mrad.

The cross-section of vacuum components has been specified with the same shape and size all the way through the injection straight section. It therefore avoids chamber transitions between the vacuum elements, keeping more space available for machine components. The design of the diagnostic devices such as the flags and the BPM assemblies has been optimized so their contribution to the storage ring impedance is insignificant.

The main issue for the BPM buttons is heating due to trapped modes. To reduce heating, the NSLS-II BPM button is designed with a diameter of 7 mm with the thickness of 2 mm. It produces a smaller loss factor compared with larger diameter button. RF shielding is applied around the BPM flange to eliminate trapped modes between the housing and the BPM flange.

CONCLUDING REMARKS

Prior to selecting the current “conventional” design of the injection straight section we analysed an option of injection via pulsed multipole pioneered at PF-AR [7].

We found [8, 9] that this promising approach was not suited to the NSLS-II storage ring optics, since it would require a impractically compact arrangement of the injection straight section components and a complex modification of the transport line optics due to the strong focusing of the injected beam passing off the pulsed multipole axis. In addition, the requirement for a small injection transient of the stored beam orbit severely constrains the vertical alignment tolerance of the pulsed multipole.

The design of the NSLS-II injection straight section is now completed with exception of transition chamber details, which will be adjusted to accommodate the actual layouts of the pulsed magnets.

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