THE INJECTION SYSTEM OF THE SSRF STORAGE RING

H.H. Li, G.M. Liu, W.Z. Zhang, Y. Xu, X.Y. Sun, B.C. Jiang, X.M. Zhou

Shanghai Institute of Apply Physics, PO.Box 800-204, Shanghai, 201800, P. R. China

Abstract

A multi-turn injection scheme with four kickers and two septa is used for injection into SSRF storage ring. The 3.5GeV electron beam from the SSRF booster is injected with 6.3 degrees horizontally. All injection elements are set in one 12m long straight section for the requirement of the top-up operation. Simulation and commissioning results will be presented in this paper, such as the injection efficiency and the disturbance on stored beam.

INTRODUCTION

Shanghai Synchrotron Radiation Facility (SSRF) is a 3rd generation light source, which consists of a 150MeV LINAC, a full energy booster synchrotron and a 20-DBA storage ring. It will provide 4nm·rad nature emittance electron beam at 3.5GeV[1][2].

LAYOUT OF THE INJECTION SYSTEM

Like most of 3rd generation light source, multi-turn injection method is used in SSRF storage ring. [3][4][5] The injection system of SSRF is composed of four fast kicker magnets and two septum magnets, all kickers are placed symmetrically in a 12m long straight section, as shown in Fig. 1. By putting all injection elements into a single straight section, the injection progress became straightforward both technically and operationally. And the most important, this system satisfies the demands of top-up injection mode. Table 1 shows the main parameters of the injection elements.

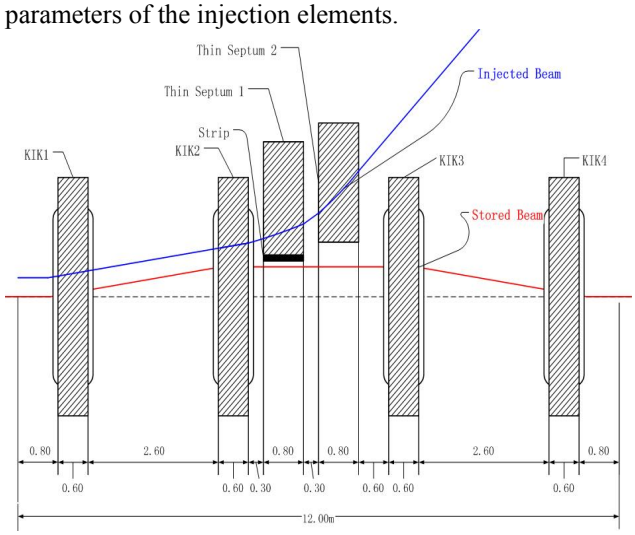


Figure 1: Layout of the injection elements

Table 1 Main parameters of kickers and septa magnets

	kicker	Septum I	Septum II
length	0.6 m	0.8 m	0.8 m
Strength	4.83 mrad	55 mrad	55 mrad
Field	0.094 T	0.802 T	0.802 T
Waveform width	3.8±0.2 μs	60±0.5 μs	60±0.5 μs
Reproducibility	±0.5Gauss·m	±1Gauss·m	±1Gauss·m
Homogeneity with chamber	2% ±20×±5 mm^2	0.5% ±14×±5 mm^2	0.5% ±14×±5mm^2
Leakage	——	< 0.1%	< 0.1%
Jitter	±5ns	±100ns	±100ns

PARAMETERS CHOICE

The injected beam will be deflected 6.3 degrees horizontally through two septum magnets from inside of the ring to SSRF. Four fast kicker magnets will bump the stored beam during injection, in order to move the beam acceptance to include the injected beam inside it at the exit of the first septum, as shown in Fig. 2.

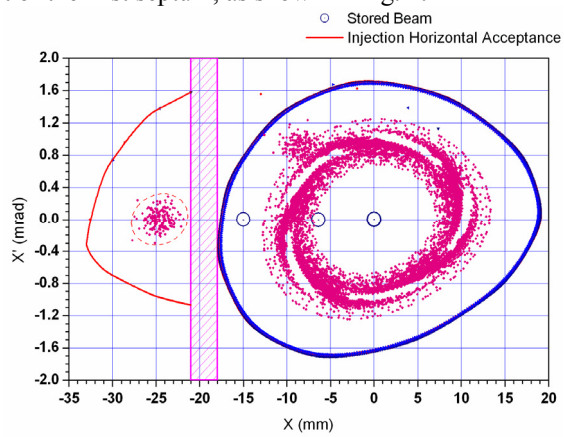


Figure 2: Stored beams, injected beams and injection acceptance at the exit of SEP1 (tracking 50 turns)

At the end of septum 1, the horizontal injected beam size is about 3~7mm, according to the beta function. By considering about the optimal matching, the momentum acceptance and the dynamic aperture, the stored beam will be bumped about 14.5mm, the distance between injected beam and bumped orbit is about 10mm, and the septum strip will be set between 18.5mm and 21.5mm inside the SSRF storage ring.

The minimum strength of two septa is to ensure the injected beam will not hit on fast kicker magnet KIK3. In SSRF, the injected beam will be about 195mm far from the stored beam at KIK3 exit. This value gives enough space for mechanical installation.

The distance between KIK1 and KIK2 has been maximized in order to reduce the kicker strength. The

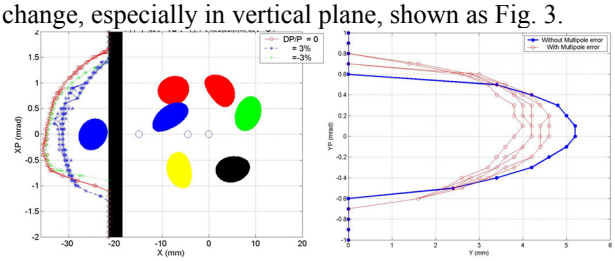
maximum strength of the kickers should be able to bring the stored beam as close as allowable to the maximum septum position.

EFFECTS OF ERRORS

There are several different error sources will affect the injection process, such as injection elements' error, injection beam mismatching, multipole field errors and misalignment of the storage ring magnets, etc.

Multipole Field Errors and Misalignment

Multipole field errors and misalignment of the storage ring elements will reduce both dynamic aperture and the injection acceptance. From the simulation results, in most cases, all injected electrons will lose if there has no closed orbit correction for magnets' misalignment. With multipole field errors, the injection acceptance will change, especially in vertical plane, shown as Fig. 3.

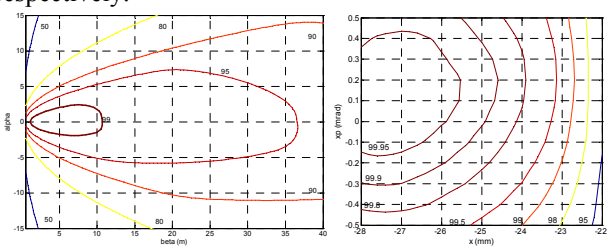


a) Horizontal b) Vertical

Figure 3: Acceptance with multipole field errors (5 seeds)

Injection Beam Parameters

The injection efficiency is dependent on injection beam position and its twiss parameters. Fig 4 a) and b) show the effects of injection twiss parameters and position, respectively.



a) With twiss parameters b) With injected position

Figure 4: Injection efficiency depends on injection beam twiss parameters and its position

Kickers' Errors

Because the emittance of the stored beam is only 4-10 nm·rad, much smaller than the injected beam, which is about 110 nm·rad, the errors of the kicker magnets will effect the stored beam mostly, especially when the machine is running in the top-up injection mode. The main errors of the kickers are composed of timing jitter, the field homogeneity, reproducibility, and its mechanical misalignment, etc.

Firstly, timing jitter and field reproducibility of the kicker will cause an extra oscillation of the stored beam. From simulation results, the oscillation amplitude due to the jitter, less than 2ns (RMS), is about four times larger than the amplitude due to the field reproducibility, less than ±0.1%. Table 2 shows the stored beam disturbance by kicker's jitter. Fig.5 shows the position of the stored beam center after the injection period, both timing jitter and field reproducibility was taken into account.

Table 2 Stored beam disturbance by kicker's jitter

Timing Jitter (RMS 2ns)	Horizontal disturbance	
	RMS(μm)	MAX(μm)
1σ	70	440
2σ	110	750
3σ	130	840
4σ	130	860
5σ	130	880
6σ	130	920

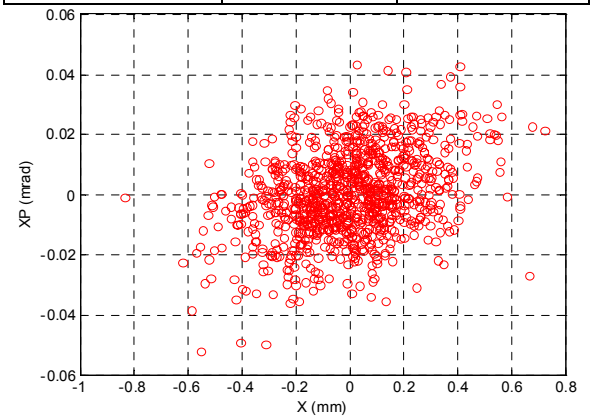


Figure 5: The stored beam center after the injection period (RMS jitter 2ns, reproducibility 0.1%, 3σ, 1000 seeds)

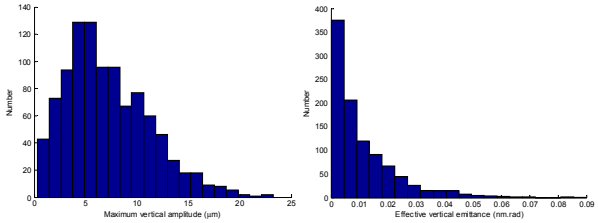
Metallic ceramic vacuum chamber is used for the injection kicker. Due to the eddy current effect, the field homogeneity in vacuum chamber will become worse, and this will cause the disturbance different with the bucket. As shown in table 3, the average disturbance could be 0.8mm with only 2% field inhomogeneity. To reduce this effect, an easier way is to modify the strength of the kickers. For instance, the disturbance is reduced to only 2.5% of the initial by changing the strength of KIK2 and KIK3, shown in table 3.

Table 3 Stored beam disturbance by eddy current effect of the metallic ceramic vacuum chamber

a	Disturbance		KIK2 (mrad)	KIK3 (mrad)
	before compensate	after compensate		
1%	0.4mm	11μm	-4.925	-4.725
2%	0.8mm	20μm	-5.02	-4.62
5%	2.0mm	47μm	-5.305	-4.305
10%	4.0mm	128μm	-5.78	-3.78

The alignment error of the injection kickers is composed of displacement and roll. For the displacement error, it is convenience to correct or compensate by adjusting the strength of the kickers. For the tilt of the kickers, it will affect the beam in vertical, and there has no good way to reduce this effect except mechanical realignment. Fig. 6 shows the vertical beam disturbance and the effective vertical emmittance after the injection,

the RMS tilt angle of the kickers is 0.2mrad, total seeds number is 1000.



a. vertical disturbance b. effective vertical emmittance

Figure 6: The vertical disturbance and emmittance after injection period (RMS tilt 0.2mrad, 3σ, 1000 seeds)

COMMISSIONING RESULTS

Commissioning of the SSRF storage ring was started at the evening of Dec. 21, 2007. The first turn was gained three hours later. After about 3 days, the electrons were successfully stored and accumulated in the ring. [6]

Injection Efficiency

Fig. 7 shows a typical injection rate plot when the stored beam current was increased from 0mA to 100mA. The maximum rate is about 1.05mA/s, corresponding to 0.76nC per shot, almost 100% injection efficiency. [7] There are some points that the rate is 0, because it needs time to change buckets and modify the timing setting.

Stored Beam Disturbance

After a detailed scan of the kickers' strength and timing, the horizontal disturbance was reduced to less than 100μm. The vertical vibration was reduced to 30μm by adjusting the kickers' tilt angle. The 2-D strength scan of KIK1 and KIK4 is shown in Fig. 8, the color bar means the disturbance amplitude in mm.

CONCLUSIONS

The design, manufacture, installation and tuning of the SSRF injection system are successful, the results from commissioning are well match with the simulation. For the future, the tilt angle of the kickers will be adjusted carefully to make the vertical orbit disturbance reach the expected value, less than 10μm.

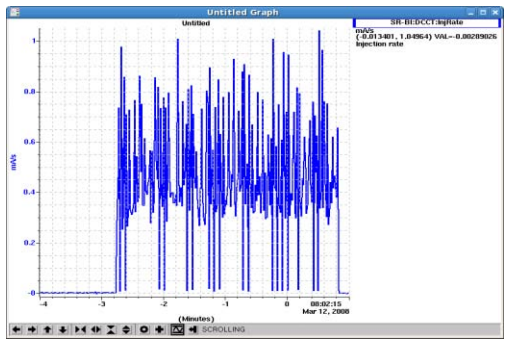
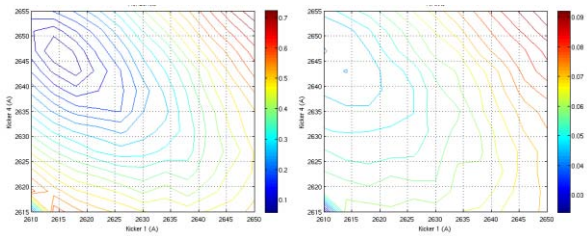


Figure 7: Injection rate (max: 1.05mA/s, mean: 0.6mA/s)



a) Horizontal b) Vertical

Figure 8: Orbit oscillation caused by injection kickers

REFERENCE

[1] G.M. Liu, Z.M. Dai, H.H. Li et al, "Lattice Design for SSRF Storage Ring", Chin. Phys. C, 30(S1) (2006) p.144

[2] Z.T. Zhao, H.J. Xu, "Progress of the Shanghai Synchrotron Radiation Facility", APAC 2004, Gyeongju, March 2004, MOM101, p.1

[3] H.L. Owen, S.L. Smith, "Optimising the injection scheme for DIAMOND from a 3GeV booster synchrotron", EPAC 1996, Sitges, June 1996, MOP038G

[4] M. Munoz, "Simulation of the injection in the SLS storage ring", SLS-TME-TA-1999-0013

[5] M-A. Tordeux, P. Lebasque, P. Gros, et al. "General performances of the injection scheme into the SOLEIL storage ring", EPAC 2004, Lucerne, July 2004, WEPLT082, p.2044

[6] G. M. Liu, H.H. Li, et al. "Commissioning of SSRF storage ring", in this proceeding

[7] H.H. Li, Q. Gu, D.M. Li, "Commissioning of the SSRF booster", in this proceeding