CONCEPTUAL DESIGN OF INJECTION SYSTEM FOR HEFEI LIGHT SOURCE (HLS) UPGRADE PROJECT*

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Abstract

In order to obtain more straight sections for insertion devices and higher brilliance synchrotron radiation, an upgrade project of Hefei Light source (HLS) is undergoing. A new injection system has been designed to improve injection efficiency and keep the machine running stably. Four kickers will be used to generate a local injection bump. Effects of injection system to injecting beam and stored beam have been simulated considering errors. Finally, ELEGANT code was used to simulate the injection process with new designed bump system. The simulation results show that the injection efficiency would be higher than 99% and perturbation on stored beam would be small enough, which are benefit to full energy injection and top-up operation of HLS in the future.

INTRODUCTION

Hefei Light Source (HLS) of National Synchrotron Radiation Laboratory is a dedicated second generation light source [1,2]. In order to obtained synchrotron radiation with high brightness in the VUV and soft X-ray range for synchrotron radiation users, A plane of building a new machine named HLSII storage ring has been brought forward. Considering the required low emittance and the straight sections' number and length, A DBA lattice structure with 4 super-periods has been chosen for HLSII. There are 8 straight sections along the ring. Four short straight sections about 2.3m in chromatic arcs can be used besides four 4.0m long achromatic straight sections. Two operation modes (mode A and mode B) have been optimized. Mode A is an achromatic mode, whose dispersion in the long straight section is zero. Mode B is a distributed dispersion mode, whose emittance is smaller than that of mode A. β and dispersion functions of the two modes are shown in Fig. 1 and 2. Table1 gives main parameters of the storage ring.

Table 1: Storage Ring Parameters

	Mode A	Mode B
Energy [GeV]	0.8	
Circumference [m]	66.13	
DBA cells	4	
Bending radius [m]	2.1645	
RF frequency [MHz]	204.0	
Energy spread	0.00047	
Emittance [nm·rad]	36	20
Beam current	>300mA	
Momentum compaction	0.0205	0.0184
Tunes: ν_x, ν_y	4.44/2.81	4.44/2.81
Natural chromaticity: ξ_x, ξ_y	-9.89/-4.67	-10.8/-4.64
Maximum dispersion [m]	1.2	0.75
Radiation loss [keV/turns]	16.74	
Dipole critical energy [eV]	525	

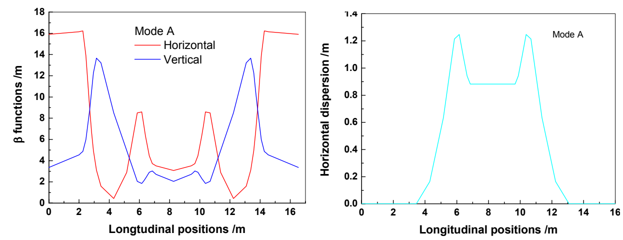

Figure 1: β and dispersion function of mode A.

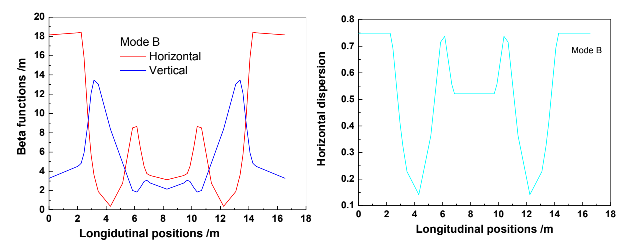

Figure 2: β and dispersion function of mode B.

PHYSICAL DESIGN OF HLSII INJECTION SYSTEM

For the current storage ring, main body of injection system is composed of one septum, four kickers, power supplies, et al. four ferrite-core window-type kicker magnets were installed on one 3m straight section. Figure 3 shows the layout of current injection system [3]. One can see that there are no quadrupoles between kickers, which means form of the local bump only depends on angle of each kicker. Table 2 presents main parameters of current local bump system. Advantage of the current injection system is that there is no dependency between the local bump form and storage ring lattice parameters. However, there are some problems with the current injection system. For example, the kick angle is so large that leads injection process sensitive to errors of injection system and other related systems of the ring. In addition, it is not possible to implement full energy injection because of magnetic saturation in ferrite core of kickers.

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For the upgrade project, an ns DC gun system will be installed which means bunch by bunch filling pattern should be adopted for HLSII. In order to improve the injection efficiency and reserve the potential of full energy injection, a new injection system will be installed to match the project.

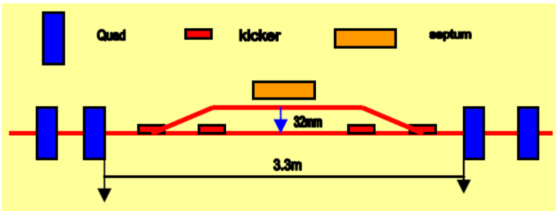


Figure 3: Layout of current injection system.

Table 2: Main Parameters of Current Bump System

Kick angle of each kicker	52 mrad
Deflecting angle of septum	105 mrad
Height of local bump	32 mm
Effective length of kicker	~300 mm
Magnetic field of kicker (200MeV)	~1160 Gauss

Considering the system sensitive effects to injection efficiency, it is a good idea to decrease the kick angle while keeping the height of local bump in the same level like current condition. Equivalently, to reduce the requirement on kicker strength, a distributed local bump system is adopted: four kickers are installed on arcs and straight sections, shown in Fig 4.

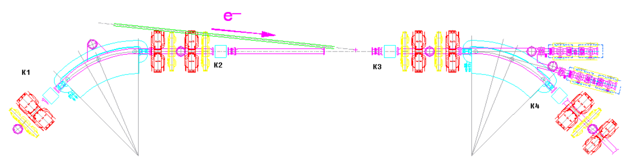


Figure 4: Arrangement of kickers for the new system.

Parameters of new injection system have been optimized. For increasing the injection efficiency, the stored beam should be bumped as high as possible, so that injecting beam and stored beam can be as close as possible at the injection point. At the same time, the space between the septum and beams should be large enough to prevent electrons from scraping. Space between septum and central trajectory is chosen 29mm, which is restricted by storage ring's physical aperture and beam lifetime [4]. Considering factors about closed orbit distortion and beam size, height of local bump is selected 24mm. Figure 5 shows the receiving space of the new injecting system. Positions of kicked and unkicked stored beams, as well as the position of the injected beam at the injection point, are also shown.

The requirements on kickers are listed in table 3. The kick angles of first and last kickers on arcs, where beta function is small, are relatively large. Figure 6 shows local bump on the long straight section for Mode A, from which one can see that extremes of local bump are located at the quadrupole's position on straight section but not injection point. Calculation result shows the local bump form of Mode B is very similar to Mode A.

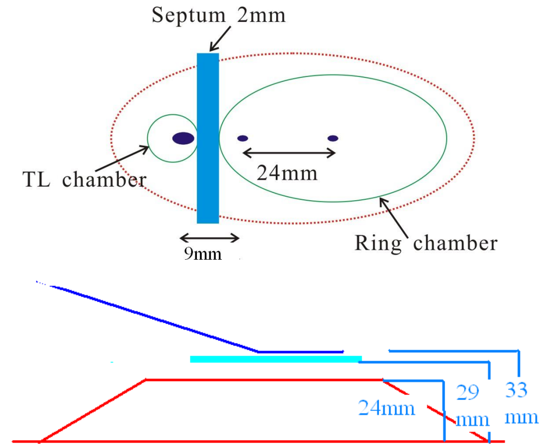


Figure 5: Receiving space of new system and position relationship of beams

The pulsed magnetic field waveform of kickers is a 1.32μs half sinusoidal waveform. The injection time is at the time of 0.88μs. In this way, the local bump can vanish at the time of second turns. A bunch by bunch filling pattern is adopted for the project.

Table 3: Requirements on Kickers

	Mode A	**Mode B**
Kick angle of 1and 4 kickers	6.3mrad	6.3mrad
Kick angle of 2 and 3 kickers	3.843mrad	3.755mrad
Deflecting angle of septum	105mrad	
Height of local bump	24mm	
length of kickers	200mm	

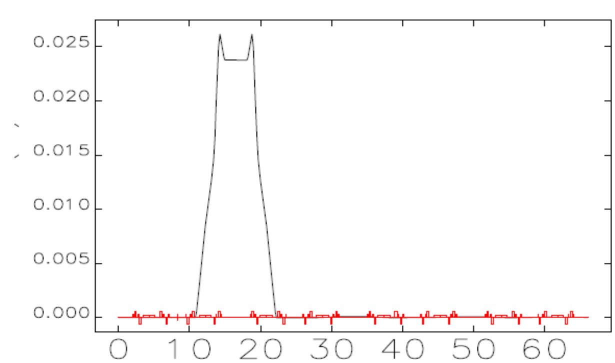


Figure 6: Local bump on long straight section.

Errors of injection system would lead to leakage of local bump. It maybe be reduce the injection efficiency, at same time, it would perturb the stored beam and results in centre-mass emittance growth even in stored beam loss. Table 4 gives errors of the new injection system.

Table 4: Errors of New Injection System

Time jitter of kickers	<2ns (3σ)
Amplitude variation of kickers	<1.5‰ (3σ)
Alignment error of kickers	0.2mm(3σ)
Rotation error of kickers	0.5mrad(3σ)
Position jitter of injection beam	0.2mm (3σ)
Angle jitter of injection beam	0.2mrad (3σ)
Energy jitter of injection beam	5‰ (3σ)
Energy spread of injection beam	5‰ (3σ)
Length of injection beam	1ns
Emittance of injection beam	76nm.rad

Elegant code was used to simulate the injection process, which is a particle tracking code developed by APS [5]. Initial physical parameters of injecting beam are decided by beam transport line: β_x=16.034m, β_y=5.6165m, α_x=0.0, α_y=-0.096, $\eta_x=\eta_x'$=0.0, $\varepsilon_x=\varepsilon_y$=76nmrad, σε=0.005, which matches with storage ring lattice. In numerical simulation, the injecting and stored beams were composed of 1000 macro-particles. Errors of injection system, nonlinear fields, and focusing errors of lattice are also included during simulation. To obtain more believable conclusion, 300 seeds simulation were made using random errors and the injecting beam was tracked 30 turns each time.

Figure 7 gives the horizontal and vertical trajectories of stored beam during injection process. Figure 8 shows particle tracking results in horizontal phase space for Mode A, and Fig. 9 Mode B.

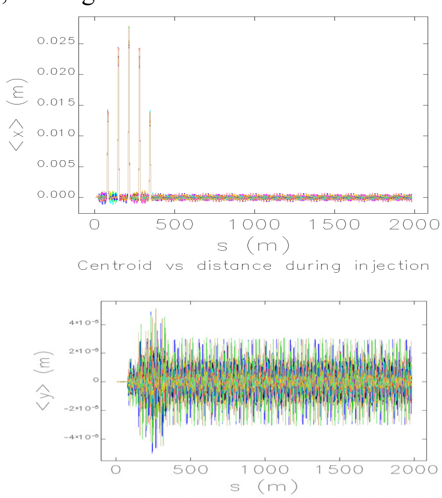
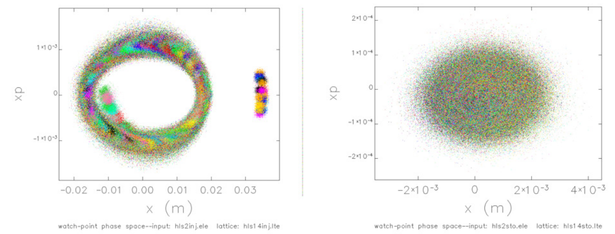


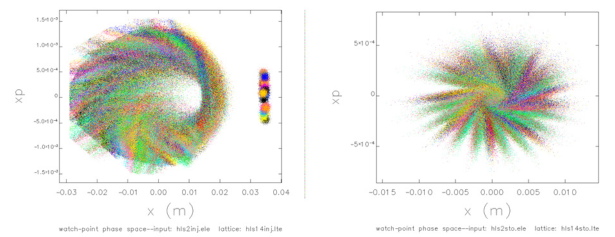
Figure 7: Horizontal and vertical trajectories of stored beam.

Simulation results prove that the injection efficiency is above 99% in Mode A, and it can satisfy the requirement of top-off injection mode in the future. About 76% injection efficiency was obtained in Mode B. Numerical simulation indicates that injecting beam energy stability and energy spread are the main reasons to restrict the injection efficiency. From Fig. 1, 2 and Table 1, one can see that there are same tunes in the two operation modes although their beam emittances are quite different. This means one can easy get Mode B from Mode A by quadrupoles strength tuning.



Injecting Beam Stored Beam

Figure 8: Particle tracking in phase space (Mode A).



Injecting Beam Stored Beam

Figure 9: Particle tracking in phase space (Mode B).

SUMMARY

A new injection system has been designed to improve injection efficiency and keep the machine running stably. Four kickers will be used to generate a local injection bump. Effects of injection system for injecting beam and stored beam have been simulated considering errors. The simulation results show that in Mode A, the injection efficiency would be higher than 99% and perturbation on stored beam would be small enough. Mode B can be gotten from Mode A by lattice tuning.

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