SIMULATION OF HEFEI ADVANCED LIGHT SOURCE (HALS) INJECTION SYSTEM*

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Abstract

The Hefei Advanced Light Source(HALS) is a super low emittance storage ring and has a very short beam life time. In order to run the ring stably, top-off injection will be necessary. The design of injection system will greatly affect the quality of beam. This article first gives a physical design of the injecting system. Then under different injection system's errors, tracking studies are done to simulate the responses of storage beam and injecting beam.

INTRODUCTION

The Hefei advance light source (HALS) is a super low emittance storage ring. It will be one of the most advanced VUV and soft X-ray light sources in the world, with higher brilliance, better coherence, more insertion devices than these of the current Hefei Light Source (HLS). HALS's circumference is 396m long. It has 18 super periods. Each cell is a FBA lattice. 18 long straight sections in the ring can be used to install undulators, wigglers, injection system, RF system and so on. Except the sections used for injection and damping wiggler, there are more than 12 long straight sections for 6m long insertion devices installation.

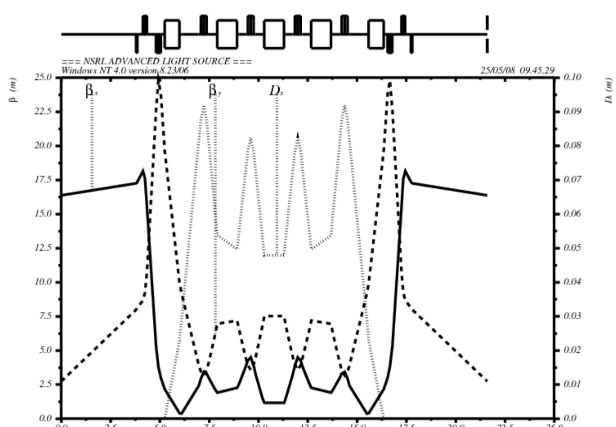

Figure 1: β and dispersion functions of one cell.

Figure 1 is beta and dispersion functions of one HALS cell. Table 1 gives the main parameters of HALS. More detailed descriptions can be found in other publications [1-3]. HALS's emittance will be less than 0.2nm·rad after the damping wiggles are installed. The emittance of HALS is so small that the ring has a very poor beam life time. Its beam life time is less than 1 hour without 3rd harmonic cavity. In order to run the ring stably, top-off injection will be necessary. To minimize the disruption to the user operations, the design of injection system will be very important. It also should be capable of filling the beam from empty to full charge in a reasonable time.

Table 1: Main Parameters of HALS Storage Ring

Parameters	Values
Circumference	396m
Energy	1.5GeV
Lattice structure	FBA
Super-period number	18
Straight section length	7.6m
Emittance of bare lattice	0.27 nm·rad
Emittance with damping Wigglers	<0.20 nm·rad
Transverse tunes	29.32/10.28
Natural chromaticities	-55/-51
Momentum compaction factor	0.00047
Energy spread	0.00022
Harmonic number	660

PHYSICAL DESIGN OF HALS INJECTION SYSTEM

To maintain high quality of the HALS ring, the injection system should obey the following demand. First, the ring runs in top-off operation mode. In this mode, we require that the injection efficiency to reach 100% almost. Electrons should be lost in the injection process as small as possible because of the problem of radiation protection. This also gives a requirement to the beam from booster or LINAC. Second, the disturbance of injection to the stored beam must be small. The synchrotron users should not see the injection process and their experiments can go on without interruption. And in order to reduce the dependence on the lattice, the HALS injection system will be placed in one straight section. So the local bump can be compensated perfectly.

The whole HALS injection system is located in a 7.6m long straight section. It includes four kickers with separated power supplies. The four kickers are distributed symmetrically in the section. Each kicker is 0.3m long. The space between kicker1 and kicker2 and also kicker3 and kicker4 is 1.3m and the space of 3.2m between kicker2 and kicker3 is used to place septum magnets.

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Septum is split into two parts for the convenience of installation. Table 2 give out the parameters of injection system.

Table 2: The Parameters of the Injection System

element	l(m)	Angle (mrad)	B(T)	rising time(μs)
K1	0.3	6.25	0.1043	1.15
K2	0.3	-6.25	0.1043	1.15
K3	0.3	-6.25	0.1043	1.15
K4	0.3	6.25	0.1043	1.15

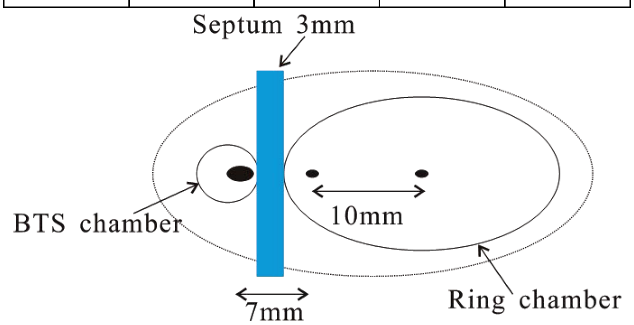

Figure 2: Setup of bump and septum.

The magnetic field waveform of kickers is a 2.3μs sinusoidal waveform. The injection time is at the peak of waveform. The pulse length is about 1.7 times longer than the revolution time. So the injection beam will see the kicker's magnetic field one times only. The kickers are set to produce a max bump height of 10mm in a single turn. The max kick angle is about 6.25mrad. The height of septum is 13mm and the thickness of septum is 3mm. The beam from booster is 17mm high. Fig 2 shows the receiving space of the HALS injecting system and show the positions of kicked and unkicked stored beams, as well as the position of the injected beam at the injection point. To increase the injection efficiency, the stored beam should be bumped as high as possible, so that at the injection point, the injected beam and the stored beam can be as close as possible, but at the same time, the space between the septum and beams should be large enough to prevent electrons from any scraping.

TRACKING OF HALS INJECTION SYSTEM

Elegant[4] was used to track the injection process. Elegant is a particle tracking code from APS. Elegant stands for "ELEctron Generation ANd Tracking", which is a 6D accelerator program generating particle distributions and tracking them.

Tracking of Injected Beam

By tracking the injected beam, we can determine the minimum acceptance required by the injection process, we simulated the electron distribution in x,x' phase space after the injection. The quality of the injected beam may play an important role in the efficiency of transport and injection which in turn, affects the radiation environment in the machine. We have begun to study the injection efficiency by tracking particles through the existing HALS lattice for a few turns. Description of the injection parameters is as the previous section. Figure.3 illustrates the results of the tracking in the horizontal phase space where the injected beam's emittances are 1nm·rad, 5nm·rad, 20nm·rad and 50nm·rad separately. Each beam was tracked 5 turns. At the injection point, the injected beam's emittance affected the injection efficiency always. By simulation, the injected matched beam which emittance smaller than 20nm·rad can fulfill HALS's demanding on the injection efficiency. A booster with emittance smaller than 20nm·rad can be realized easily.

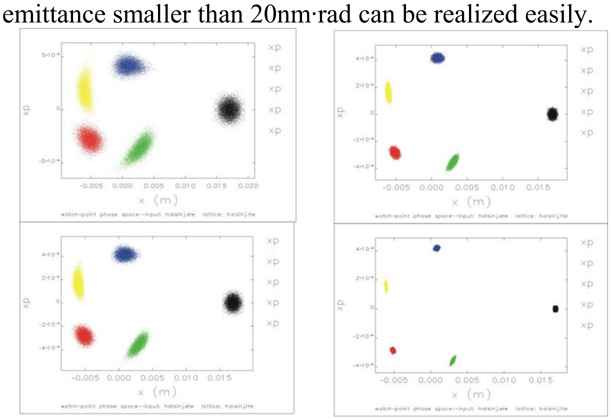

Figure 3: Particle tracking for the different emittance injected beams. Left up: 50nm·rad, left down: 20nm·rad, right up: 5nm·rad, right down: 1nm·rad.

Errors can affect the performance of injection system. There are two kinds of injection errors mainly. One is the errors from injected beam, for example, the mismatching of the injected beam. This kind of error influences the injection efficiency, but does not affect the stored beam. Our attention was mainly paid to the errors from the elements of injection system.

Errors from the elements of injection system include errors of peak field of kickers, the installation errors, the alignment errors and time errors of kickers, and also the residual field of septum. These errors will affect not only the motion of injected beam but also the motion of stored beam. So user's experiment is possible to be interrupted by the injection system errors.

Table 3: Errors of the Injecting System and Injection Beam

Error	Kickers(rms)	septum
peak field	0.5%	
Time offset	0.5ns	
Rotation	0.5mrad	
residual field		0.1%(10mm height)
	injection beam	
Dx and dy	0.5mm	
Dx and dyp	0.5mrd	
Dp	0.2%	

The errors of the injection system are given in the Table 3. Errors are considered as follows in the tracking. For kickers, the rms peak field error, the rms time offset error and the rms rotation error are considered. To the four kickers, there is no correlation for the different kicker's errors because of the separating power supplies. A residual field of septum causes a 0.1mrad (about 0.1% of septum strength) angle kick at the bump height of 10mm is included in the tracking. The injection beam's errors from booster are given in the table 3 also. Rms position error, rms divergence error and rms energy error are considered.

We simulation the injection process while errors of the injection system are considered, the beam's emittance is set to 20nm·rad. Comparing with tracking of no errors, errors distort the injected beam's distribution in the phase space and increase the residual oscillation of the central trajectory. The magnitude of residual oscillation is increased from 5mm to 8mm. This would reduce the efficiency of injection.

We tracked the injection process with 1000 random seeds. For each tracking, 1000 electrons are used to simulate the injection process and the injected beam is tracking 50 turns each time. Trackings show there are no electrons lost for the 990 random seeds tracking. To the other 10 random seeds the injected beams lost electrons from 1 to 78. Most ones are small than 10. It is a small number. So the injection efficiency is above 99%. And it can fulfill the needing of top-off injection.

Tracking of the Stored Beam

For the ideal injection, the perfect bump would exist in the injection straight section. There was not affection to the electron's trajectory in the other part of the ring. But while the injection system's errors are included, the status change. The injection process can excite oscillations of electrons in the other part of the ring especially in the long straight section. It will cause decrease of brilliance of undulators.

So the disturbance of the injection system to the stored beam in the ring must be considered in the tracking. Injection process should not disturb the experiments of synchrotron radiation users. The residual oscillation of storage beam caused by the errors of injection system should not be too large.

Different storage beam bunches would undergo different kicker fields. About half of bunches would see kickers' field two times and the others see it only one times but undergo the largest field.

After errors were added, perfect bump disappeared. A residual oscillation would disturb the motion of stored beam. Figure 4 shows the excitation amplitude of oscillation in x plane and in y plane at the center of long straight section. It is tracking result of the storage bunch undergoing the largest bump height. We track the process with 1000 random seeds and get the result at the long straight section located at the injection section's opposite side.

It shows the amplitudes of oscillations are smaller than 6mm in x plane and 0.06mm in y plane. It would require a damping time of about 0.06s to be damped by synchrotron radiation.

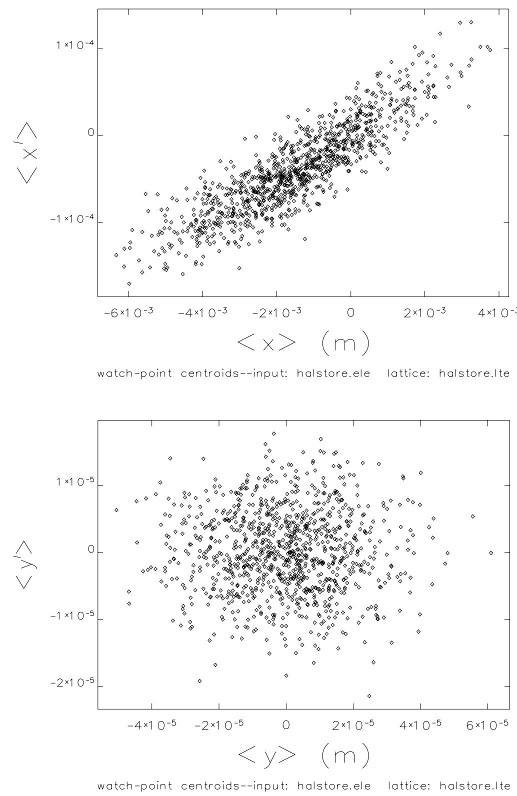

Figure 4: Particle tracking of storage beam under different injection system errors for the 1000 random seeds.

CONCLUDING REMARKS

Simulation shows that the matched beams emittance smaller than 20nm·rad can reach 99% injected efficiency. But the disturbance to the stored beams is large still. In order to reduce the residual oscillation of stored beam, we need to decrease the bump height in the future work and decrease the errors of injection system. The time structure of kickers will be studied also in future. The errors of other system of ring, the lattice errors and disturbed close orbits are also our future works.

REFERENCES

[1] Li Wei-Min, Wang Lin, Feng Guang-Yao, et. al., EPAC2008, 2136-2138

[2] Wang Lin, Feng Guang-Yao,Zhang Shan-Cai, et. al., EPAC 2008, 2142-2144

[3] Feng Guang-Yao,Wang Lin,Zhang Shan-Cai, et. al., EPAC 2008, 2016-2018

[4] M. Borland "elegant: A Flexible SDDS-Compliant Code for Accelerator Simulation," Advanced Photon Source LS-287, September 2000.