THE UPGRADE PROJECT OF HEFEI LIGHT SOURCE (HLS)*

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Abstract

To enhance the performance of Hefei Light Source, which was designed and constructed two decades ago, an upgrade project is undergoing. The detail upgrade scheme was described in this paper. Firstly, the magnet lattice of storage ring should be reconstructed with 4 DBA cells, whose advantages are lower beam emittance and more straight section available for insertion devices. Secondly, the beam diagnostics, main power supply, transverse and longitudinal multi-bunch feedback, beam control and manipulation system would be upgrade to improve the beam orbit stability. Finally, the injection system of storage ring and injector, which is composed of electron linac and beam transfer line, would be updated in order to assure smooth beam accumulation process under new low emittance lattice. With above measures, it is hopeful to increase the brilliance of Hefei Light Source by two orders approximately.

INTRODUCTION

HLS is a dedicated second generation VUV light source, whose main body is composed of 800MeV electron storage ring, 200MeV linac and beam transfer line. HLS was designed and constructed in the late 1980s; ten years ago, Phase II Upgrade Project was carried out and more beamlines were built successfully. The main parameters of HLS were listed in table 1. There are two factors affecting light source performance: large beam emittance and less number of straight sections.

Table 1: Main Parameters of HLS

Injection/Operation Energy	200/800 MeV
Circumference	66.13m
Magnet Lattice	4×TBA
RF Frequency	204MHz
Transverse Tunes	3.54/2.60
Momentum Compaction	0.048
Energy Loss	16.3keV/turn
Beam Intensity	250~300mA
Beam Emittance	~160nm·rad
Parameters of straight section	3.36m×4 = 13.4m
Number of undulator	2

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the quantum control, catalysis, combustion and blame, high temperature super-conductivity, etc. Unfortunately, HLS can't meet the requirements of some advanced SR experiments due to lower brilliance.

There are three keys to improve HLS performance: increasing the number of insertion devices, lowering beam emittance and improving the beam orbit stability.

UPGRADE OF MAGNET LATTICE

Considering theoretical minimum beam emittance and number of straight section, separate function DBA was adopted as the standard cell of ring. Similar to many light sources, the length of straight section in the arc was increased to install undulators. The layout of new magnet lattice is showed in the Figure 1.

Two optional focusing parameters were designed, which is named as mode A and mode B. The mode A is an achromatic mode, whose dispersion in the long straight section is zero. In contrast, the mode B is a distributed dispersion mode, whose emittance is smaller than that of mode A. The Figure 2 and Figure 3 displayed the Twiss and dispersion function of two modes.

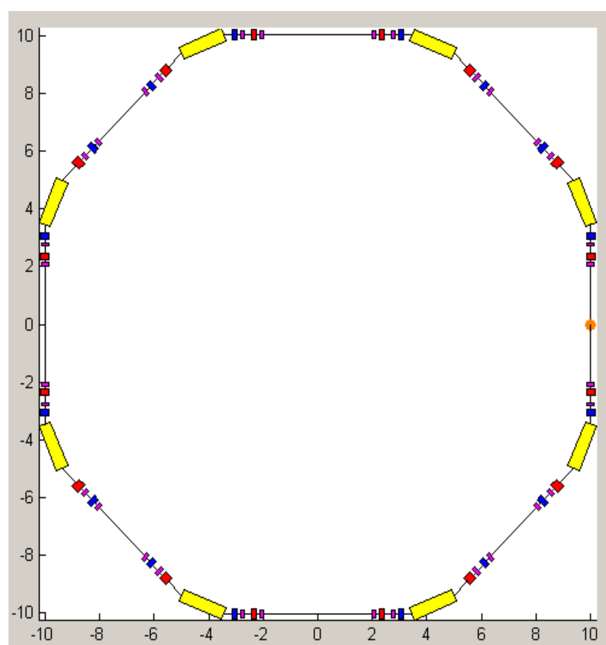

Figure 1: Magnet layout of HLS II storage ring.

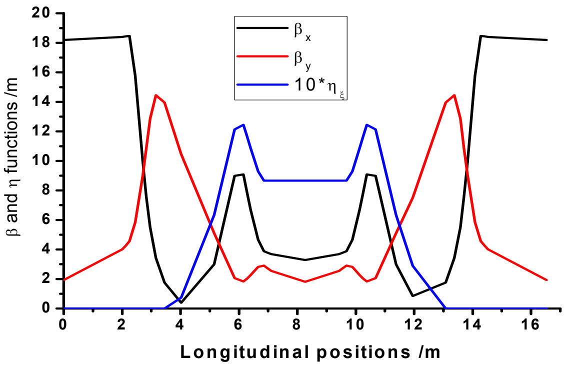

Figure 2: β and dispersion function of mode A.

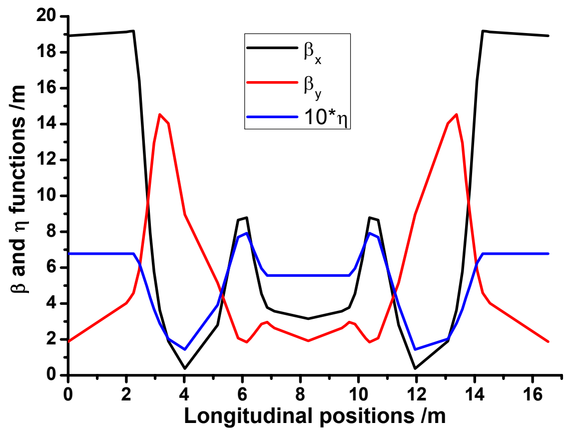

Figure 3: β and dispersion function of mode B.

Table 2: Main parameters of HLS II

	Mode A	Mode B
Operation energy	800MeV	
Circumference	66.13m	
RF frequency	204MHz	
Transverse tunes	4.41/3.21	4.44/3.20
Momentum compaction	0.0205	0.0183
Emittance	36nm.rad	20nm.rad
Radiation loss	16.74kev/turn	
Beam intensity	> 300mA	
Parameters of straight section	(4m + 2.3m)×4 = 25.2m	
Orbit shift	< 5μm	

After reconstruction of magnet lattice, the main properties of storage ring would be refined and listed in table 2. With careful choice of betatron phase advances between sextupoles, two families of sextupoles were used to compensate natural chromaticities and good on-momentum and off-momentum dynamic aperture were obtained for mode A and mode B. The dynamic aperture of mode A and mode B is showed in Figure 4 and Figure 5. Oscillation amplitude limitation due to vacuum chamber was considered in dynamic aperture tracking study.

The beam emittance is reduced to 36nm.rad and 19nm.rad, which is 1/5 and 1/8 of current value approximately. The number of straight section available for ID is increased by 2 times, which are 6.

Comparing the parameters of straight section and beam emittance, new lattice showed better properties than current HLS storage ring. Accompanying upgrade of magnet lattice, the vacuum chamber and support of magnets would be reconstructed also.

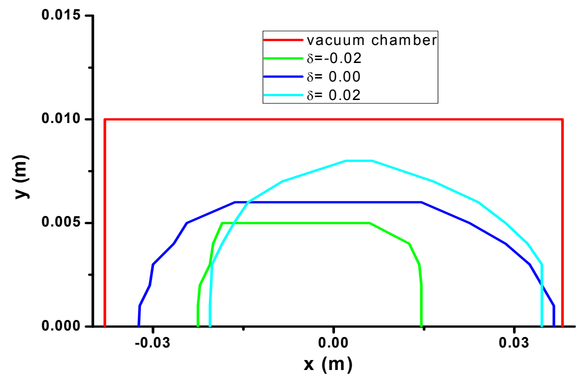

Figure 4: Dynamic aperture of mode A.

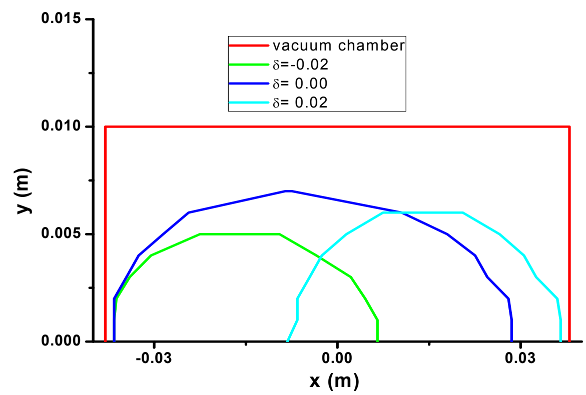

Figure 5: Dynamic aperture of mode B.

UPGRADE OF OTHER SUBSYSTEMS

To improve beam orbit reproducibility and orbit stability, several accelerator subsystems would be updated. The changes of BPM system include: the Q9 tie-in of bottom electrode would be replaced with SMA type to enhance the anti-interference capability; the number of BPM would be increased to 32. The quadrupoles will be powered by individual PS, and it is possible to make optics distortion correction. The resolution and stability of steering magnets will be improved by usage of new digital PS. The multi-purpose sextupole should be used in upgrade. The efficiency of orbit distortion correction is estimated by numerical simulation. The Figure 6 is residual orbit distortion. To improve orbit stability, except for slow orbit feedback, tunnel for storage ring would be built to control temperature variation. It is expected that orbit shifts are smaller than 10% beam sizes.

During HLS operation, multi-bunch instabilities were observed and maybe the main limitation of beam intensity. To overcome this obstacle, the digital transverse and longitudinal feedback system is in the upgrade proposal also. Of cause, DC clearing electrode and beam shaking is the main measure to fight ion trapping effects under low injection energy. With above measures, it is expected the instability threshold is higher than 300mA.

Low beam energy and beam emittance worsen the Touschek scattering effects. The momentum aperture from RF system and transverse off-momentum dynamics is similar, and then current RF system will be not changed. We have used ZAP and OPA to estimate the beam lifetime, which are about 6 and 3 hours for mode A and B respectively. To improve beam lifetime, passive 4th harmonic RF cavity was designed. The beam lifetime under mode A can meet requirements from all users, and mode A is standard operation mode. The mode B is prepared for some users requiring higher brilliance.

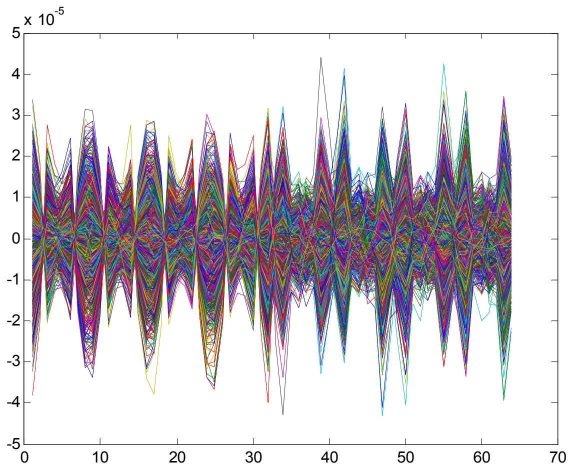

Figure 6: residual orbit distortion (unit: m).

UPGRADE OF INJECTORS

Poor lifetime under low injection energy makes the beam accumulation process more difficult. Improving injection efficiency is essential to obtain high beam intensity.

The injector of HLS was constructed twenty years ago, and poor beam properties cannot meet the requirements of high injection efficiency according to computer simulation of injection process.

Several measures were proposed. Using new thermal-cathode gun, the beam emittance and time structure would be better. Cooperating with new time system, bunch by bunch filling would be realized in the future. Reconstruction of beam trajectory monitoring system and steering magnet system would be helpful to control the position and angle of injected beam. Again, local orbit bump system would be renewed. Optimizing location of kicker, the deflection angle of kickers as well as its perturbation on beam would be decreased. Finally, phase feedback system of klystron would be installed to assure beam energy stability.

Simulation showed that the injection efficiency can be higher than 90% for standard operation mode.

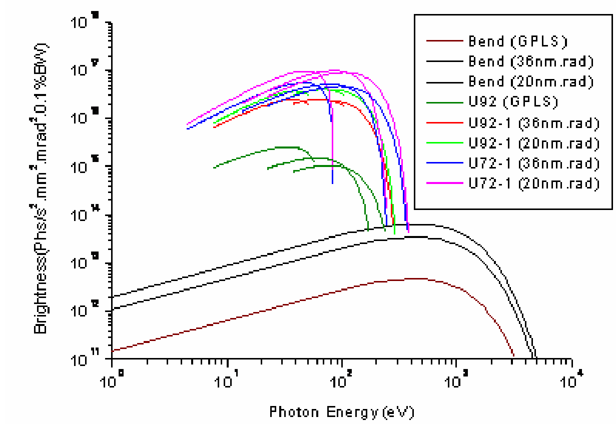

Figure 7: Brilliance curves (calculated by SPECTRA 8.0).

SUMMARY

With decreased beam emittance and new undulators, the brilliance of HLS would be increased by several ten times, as showed in Figure 7. Going with stability improvement, the HLS should gain more strong competence in VUV region.

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