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BEAM INJECTION WITH AN ANTI-SEPTUM INTO THE HALF STORAGE RING*

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Abstract

Compared to the conventional injection scheme, the three-kicker bump injection scheme with an anti-septum has two advantages. One is less requirement of dynamic aperture thanks to the thin blade of the anti-septum, the other is less installation space requirement of the injection system. Both are beneficial to the beam injection for the fourth generation light sources. In this study, the application of this injection scheme to the HALF storage ring is presented. The layout and parameters of the injection system are designed and the injection process is simulated. The results of the injection efficiency and the effect on the stored beam during beam injection is shown in this paper.

INTRODUCTION

The Hefei Advanced Light Facility (HALF) [1] is proposed to be a new VUV and soft X-ray diffraction-limited storage ring-based light source. After several years' research of the key physical and technical issues during a pre-research project, the HALF project has been approved officially and will start to be built in this year in Hefei province, China. The modified hybrid six-bend-achromat (H6BA) lattice has been fixed as the final lattice version of the HALF storage ring [2], which can achieve a natural emittance of 85.6 pm·rad at electron beam energy of 2.2 GeV with longitudinal gradient bends and anti-bends employed. The main designed parameters of the HALF storage ring are listed in Table 1 [3].

Table 1: Main Parameters of the HALF Storage Ring

Parameter	**Value**
Beam energy [GeV]	2.2
Circumference [m]	479.86
Number of cells	20
Natural emittance [pm·rad]	85.8
Transverse tunes	48.19/17.19
Momentum compaction factor	9.4×10^{-5}
Energy lose in one turn [keV]	181.4
Damping time [ms]	28.5/38.8/23.7
Natural energy spread	6.1×10^{-4}

This lattice is special designed with a long straight section and a middle straight section in a cell, which can install more beam lines and stations for users. The magnet layout and the linear optical functions are shown in Fig.1. Extra sextupoles and octupoles are employed in this lattice for the sake of increasing the dynamic aperture. Considering the magnet misalignment and field errors, the 6D dynamic apertures are calculated with 100 sets of errors. The result is present in Fig. 2 [4].

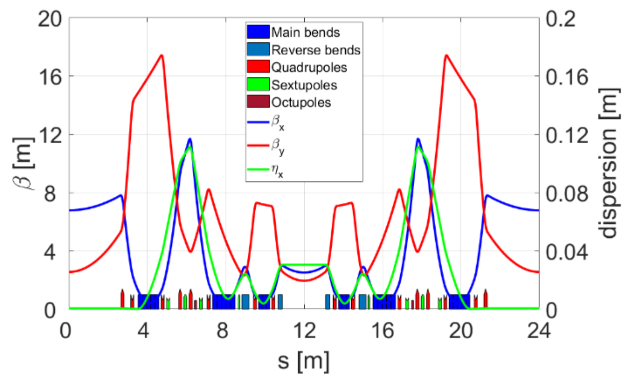

Figure 1: Magnet layout and linear optical functions.

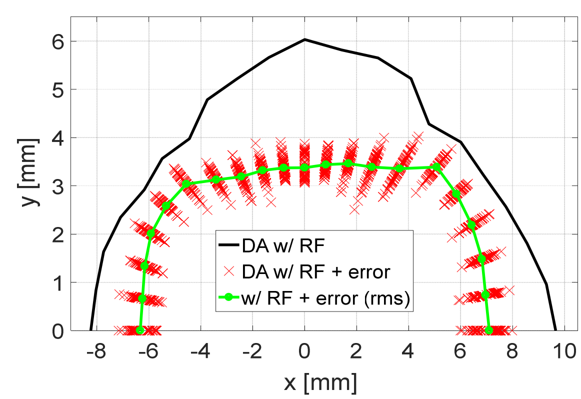

Figure 2: Dynamic apertures with 100 sets of errors.

According to the calculation results, the 6D dynamic aperture with errors is more than 6 mm, which make it possible to adopt the conventional off-axis injection for the beam injection. A three-kicker bump injection scheme is employed for the injection system of the HALF storage ring. One of the kickers is replaced for an anti-septum that can deflect the stored beam without affecting the injected beam [5]. Compared to the conventional four-kicker bump injection scheme, this injection scheme can reduce the requirement of the dynamic aperture thanks to the thin blade of the anti-septum (~1 mm), as well as the less installation space requirement of the injection system. The schematic layout of this injection scheme is shown in Fig. 3.

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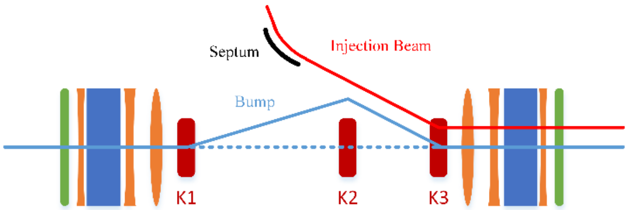

Figure 3: Schematic layout of the three-kicker bump injection scheme with an anti-septum (K2).

INJECTION SCHEME WITH AN ANTI-SEPTUM

The three-kicker bump injection scheme have been well designed to obtain the best layout and the exact parameters of the injection system. The whole injection system can be placed in a 5.3 m long straight section including two septums and three kickers. The whole length of the two septums is about 1.5 m, and the length of each of the kickers is 0.3 m. The anti-septum provides 5.576 mrad kick to the stored beam, which is equal to the sum of the kick angles of K1 and K2 to generate a 6 mm bump. The injected beam can go directly to the K3 without affected by K2 and is kicked into the storage ring with an off-axis distance of 3.8 mm due to that the blade thickness of the anti-septum is only about 1 mm. The schematic layout of the injection system is shown in Fig. 4. The positions of the septums and kickers in the straight section are marked, and the strengths of the kickers are presented either. Two injection methods with this injection system are used for different stages of beam injection. An on-axis injection of a single bunch just using the septums and K3 is adopted for the commissioning of the storage ring with the initial transverse coordinates of 13 mm and 5.2 mrad at the exit of the septum. The on-axis injection progress is indicated in Fig. 4 with the blue dotted line. The bump injection of the injected beam using the whole injection system is adopted for normal operation of the storage ring with the initial transverse coordinates of 11.8 mm and 3.2 mrad at the exit of the septum. The different coordinates of the injected bunch at the exit of the septum can be adjusted by the two septums.

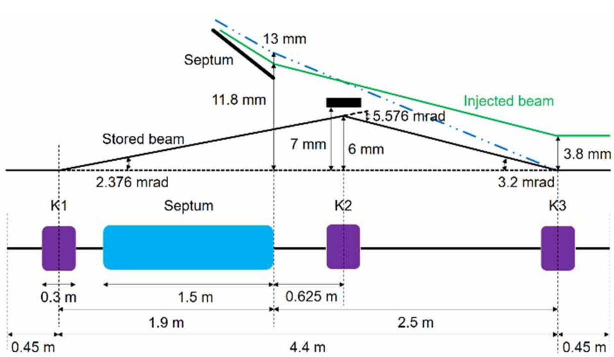

Figure 4: Schematic layout of the injection system with detailed parameters.

The beam injection progress is simulated with the parameters of the injected bunch, which are listed in Table 3. The result of the simulation is shown in Fig. 5. The black bar indicates the blade of the anti-septum. The different colors of bunches with digital identification mean the transverse phase space of the injected beam in the first 6 turns during injection. The black dotted circles are the injection acceptance at the position of K3 with bump. Because of the pules widths of the three kickers are about 5.6 μs, the bump will influence the injected beam one turn which is marked with "1" in Fig. 5. The result still shows that the injected beam is successfully captured by the storage ring after injection.

Table 3: Main Parameters of the Injected Bunch

Parameter	Value
Emittance [nm·rad]	12
Energy spread	5.0×10^{-4}
Bunch length [mm]	3
Number of particles	10000

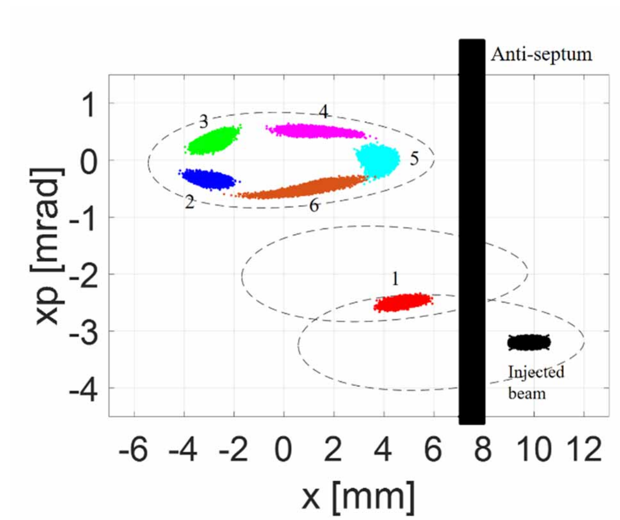

Figure 5: Transverse phase space of the injected beam.

INJECTION EFFICIENCY AND IMPACT ON THE STORED BEAM

The stability of the stored beam is very important for the storage ring, which determines the quality of the synchrotron radiation. In order to capture the injected beam, the injection bump will influence the injected beam one turn and the stored beam four turns at least due to that the pules widths of the three kickers are about 5.6 μs. Because of the special structure of the anti-septum, it is very hard to match the fields of the three kickers to close the bump very well, which may contribute errors to the injected and stored beams. The injection efficiency has been simulated with considering various factors including the injected beam errors, jitter of K3, leakage field effect of the septum and the bump errors. The injected beam errors are 100 μm/μrad in the transverse plane. And the jitter of K3 is about 0.1% of its kick. The leakage field effect of the septum is calculated with the leakage field distribution of the designed septum. The pulse width of the septum is about 60 μs which will affect the stored beam 38 turns. The bump errors depend

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on the uniformity of the three kickers. The simulation result of the injection efficiency with different bump errors is shown in Fig. 6, which tells that the injection efficiency can be up to 99% when the bump errors are 100 μm and 100 μrad. The impact on the emittance and orbit of the stored beam are also analyzed with the 100 μm/μrad bump errors, the results which are presented in Figs. 7 and 8. The emittance and orbit of the stored beam can return to the design value in about 80 ms.

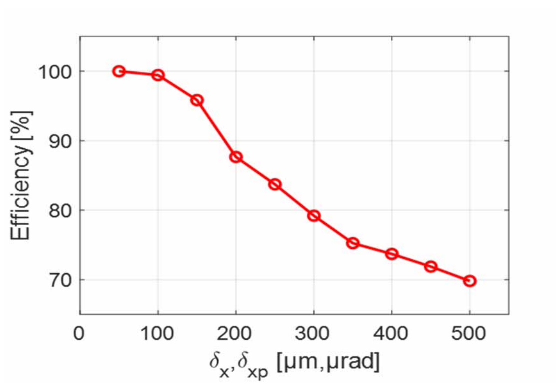

Figure 6: Injection efficiency with the bump errors.

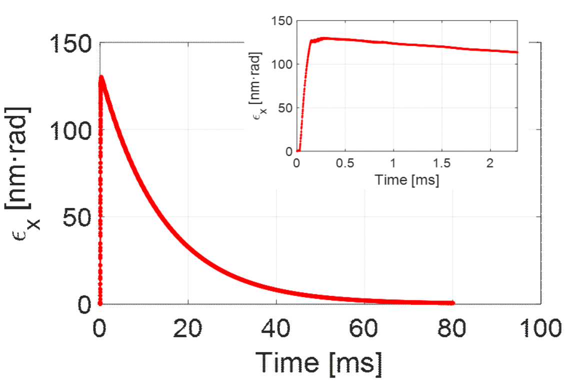

Figure 7: The impact on the emittance of the stored beam during injection.

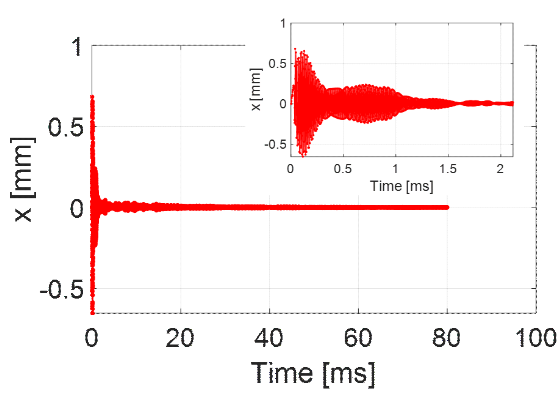

Figure 8: The impact on the orbit of the stored beam during injection.

SUMMARY AND OUTLOOK

The injection scheme with an anti-septum has been well designed for the HALF storage ring. The layout of the injection system in a straight section is presented. The injection progress is simulated with particle tracking. The injected beam can be successfully captured by the acceptance of the storage ring thanks to the thin blade of the anti-septum. The injection efficiency and the impact on the stored beam are also analyzed with simulation. If the bump errors mainly coming form the filed difference between the three kickers are kept at a small level, such as 100 μm/μrad. The high injection efficiency and low impact on the stored beam can be achieved with this injection scheme. The prototypes of the septum and kickers are under manufacturing. Further simulations of the injection scheme with the measured field data will be done.

REFERENCES

[1] Lin Wang *et al.*, “Hefei Advanced Light Source: A Future Soft X-ray Diffraction-limited Storage Ring at NSRL”, in *Proc. IPAC'18*, Vancouver, Canada, Apr.-May 2018, pp. 4598-4600. `doi:10.18429/JACoW-IPAC2018-THPMK120`

[2] Zhenghe Bai *et al.*, “A Modified Hybrid 6BA lattice for the HALF storage ring”, in *Proc. IPAC'21*, Campinas, Brazil, May 2021, pp. 407-409. `doi:10.18429/JACoW-IPAC2021-MOPAB112`

[3] Zhenghe Bai *et al.*, “Progress on the storage ring physics design of Hefei advanced light facility (HALF)”, presented at the 14th Int. Particle Accelerator Conf. (IPAC’23), Venice, Italy, May 2023, paper MOPM038, this conference.

[4] Penghui Yang *et al.*, “Error study on Hefei advanced light facility storage ring”, presented at the 14th Int. Particle Accelerator Conf. (IPAC’23), Venice, Italy, May 2023, paper WEPL080, this conference.

[5] A. Saa Hernandez and M. Aiba, “Investigation of the Injection Scheme for SLS 2.0”, in *Proc. IPAC’15*, Richmond, USA, May 2015, pp. 1720-1723. `doi:10.18429/JACoW-IPAC2015-TUPJE046`