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ACCEPTANCE ANALYSIS METHOD FOR THE SCHEME DESIGN OF MULTIPOLE KICKER INJECTION*

P. N. Wang, G. Liu†, L. Wang, W. Li
National Synchrotron Radiation Laboratory,
University of Science and Technology of China, Hefei, Anhui 230029, China

Abstract

Pulsed multipole kicker has zero magnetic field at the center, consequently, this injection scheme can be transparent to the stored beam and users. In general, multipole kicker injection schemes are derived from the method of phase space analysis. In this paper, a new method of acceptance analysis based on multi-particles tracking is proposed. Using this method, we can quickly obtain multipole kicker injection schemes and easily make adjustments to them. The details of this method are presented and we apply it to the HALF storage ring as an example. A series of tracking simulations are carried out and results are also discussed.

INTRODUCTION

The traditional injection for electron storage ring adopts a septum magnet and a pulsed local bump produced by several kicker magnets. This bump injection scheme is widely applied in most electron storage rings. However, a complete closed bump is difficult to be made due to field errors, timing jitters, and nonlinear elements [1]. The leakage of bump introduces adverse disturbance to the stored beam and leads to the perturbation to user's experiments. Therefore, the multipole kicker injection scheme has been proposed to improve this situation through not employing the bump at PF-AR in KEK [2].

In multipole kicker injection scheme, the pulsed multipole kicker kicks the injection beam into the acceptance of storage ring, and the stored beam passes through the center of the multipole kicker, where the field strength is almost zero. Thus, the scheme is transparent to the stored beam. Moreover, compared with the bump, the multipole kicker has simpler structure, requires less space and does not need to adjust the synchronization of all four pulsed magnets. These advantages make the multipole kicker injection more beneficial in design, construction and operation. The multipole kicker injection scheme has been developed in MAX IV [3], and the nonlinear kicker (NLK) injection scheme has also been proposed in BESSY II [4], which utilizes NLK to replace multipole kicker for better performance.

In this paper, a new acceptance analysis method based on multi-particles tracking for the scheme design of multipole kicker injection is proposed. Using this method, we can obtain several multipole kicker injection schemes and easily make adjustments to them, such as the positions of kickers and coordinates of the injection point. An optimal scheme can be found by comparing these schemes. The details of this method are presented and we apply it to the HALF storage ring as an example to verify its feasibility. A series of tracking simulations are carried out. The injection efficiency and stability are also discussed.

ACCEPTANCE ANALYSIS METHOD

The final goal of injection scheme is to inject beam into the acceptance of storage ring. In this paper, we have proposed a new method by which pulsed multipole injection scheme can be designed and the acceptance for injection can be easily enlarged. An application of this method is presented to the lattice of the HALF 2.2 GeV storage ring with numerical simulations to explore the feasibility of this method. HALF will be a fourth generation synchrotron radiation light source with low natural emittance. If the new method can be applied on HALF successfully, then the feasibility of the method can be proved. The relevant designed parameters of HALF are listed in [5].

In the simulation, NLK is adopted to replace multipole kicker because a well-designed NLK has a large and flat field far away from the center to kick the injected beam into the acceptance. The structure of the NLK is designed by W.B. Song in NSRL and calculated by OPERA [6]. The designed magnetic field of the NLK is shown in Fig. 1. More detailed parameters and others research results can be seen in [6].

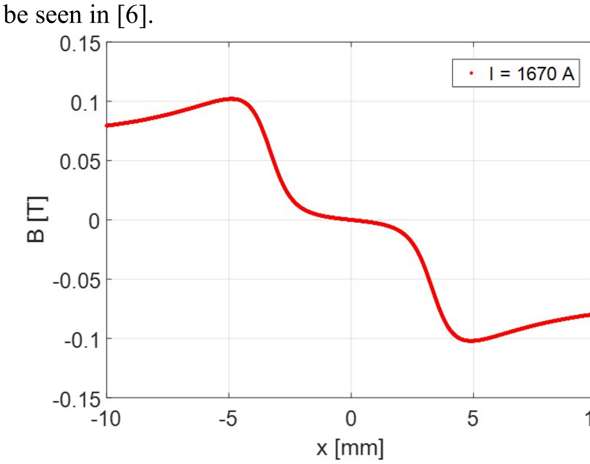

Figure 1: Field distribution of nonlinear kicker.

Detailed steps of the method are the following:

First, the locations where kickers may be installed need to be determined. The suitable positions for placing kickers must have high beta function and enough physical space. Considering above limitations, four possible positions are

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†hbwxlgw@ustc.edu.cn

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shown in Fig. 2 for installing kickers. To investigate these positions, acceptance of these positions is obtained through tracking with 5 mm initial amplitude, which is the maximum value within the allowable range of off-energy dynamic aperture. By comparing their acceptance in Fig. 3, it can be concluded that all of these positions have enough acceptance for installing kickers. Therefore, four corresponding multipole kicker injection schemes are obtained as alternative schemes.

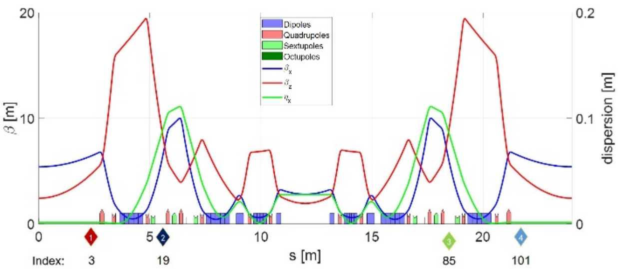

Figure 2: Lattice functions of the HALF 2.2 GeV storage ring and four possible positions to install kicker.

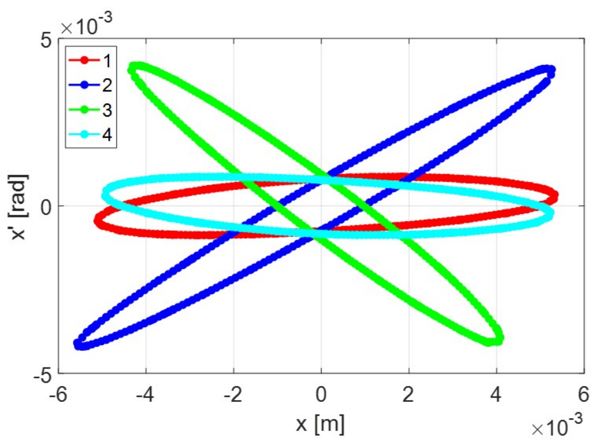

Figure 3: Comparison of the acceptance at different positions.

Second, in order to evaluate and optimize schemes, it is necessary to track from the position of NLK to the injection point and analyze the acceptance. Taking scheme 1 in Fig. 4 as an example, after obtaining the acceptance at position of kicker through tracking (left), the effect of the kicker enlarges this acceptance to a new one in which the beam can be kicked into the original acceptance (middle). Then acceptance at the injection point is obtained through conversely tracking (right).

Finally, by comparing results of four schemes in Fig. 5, we can choose the most suitable scheme from the alternative schemes. It is obvious that acceptance of scheme 3 is the smallest and even does not reach 10 mm. Though the acceptance of scheme 2 and 4 can meet the injection requirement, the injection angles of the injection beam are negative. As a result, the beam will continue to deviate from the equilibrium orbit, and it is likely to exceed the limitation of physical aperture after the injection. Even though the physical aperture is large enough, the good field region of magnet cannot be as large as the physical aperture, thus the beam will deviate from the designed trajectory and the injection efficiency will be affected. Therefore, the scheme 1 which has large space for injection and positive injection angle is the best choice.

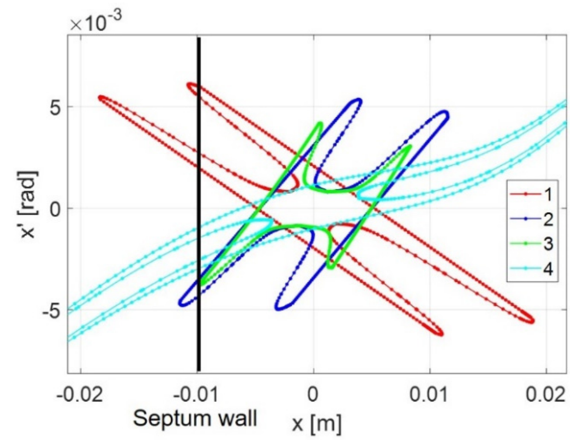

Figure 5: Comparison of acceptances of four schemes.

After above three steps, a feasible injection scheme is obtained. The trajectory of the injected beam in x direction is shown in the Fig. 6 and specific injection parameters are also marked.

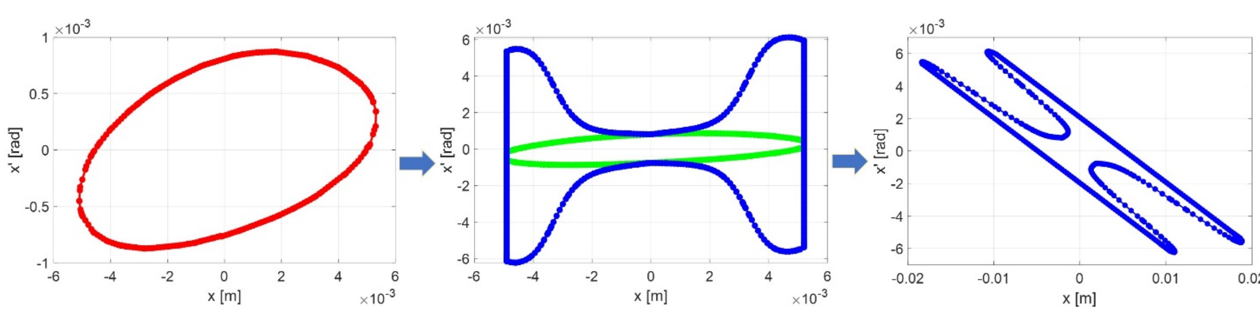

Figure 4: Acceptance at positions of nonlinear kicker and the injection point in scheme 1.

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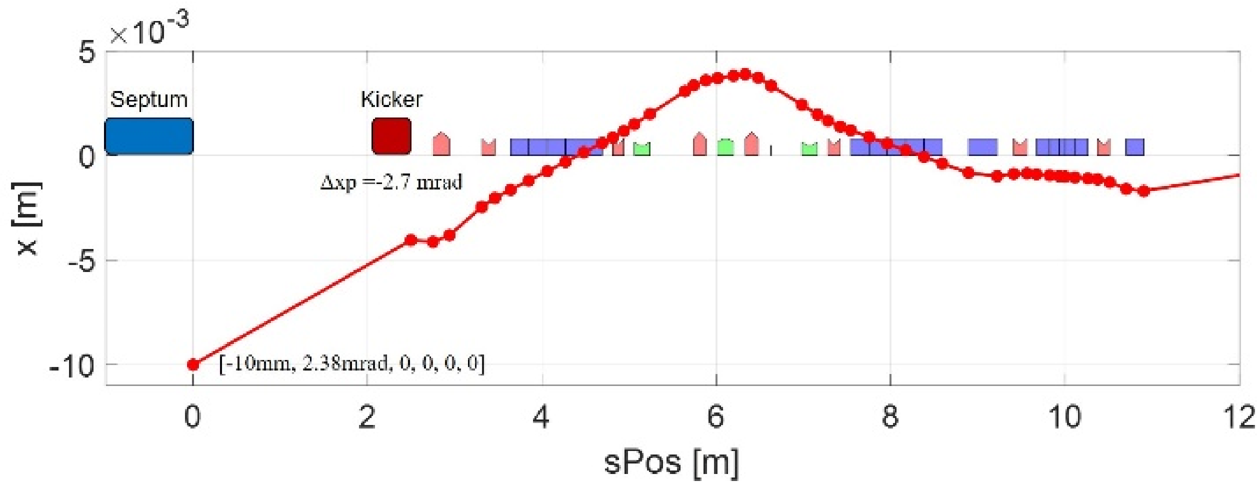

Figure 6: First turn trajectory of the injected particle and specific parameters of the injection scheme.

PROCESS OF INJECTION AND ACCUMULATION

To evaluate the injection efficiency of the injection scheme, it is necessary to simulate the process of injection and accumulation. The injected beam is tracked 50000 turns after the injection process. As shown in Fig. 7, almost all of the injected particles are successfully damped into the stored beam and the injection efficiency can reach nearly 100% without considering errors of bunch and storage ring. This result is a strong indication of the feasibility of this injection scheme.

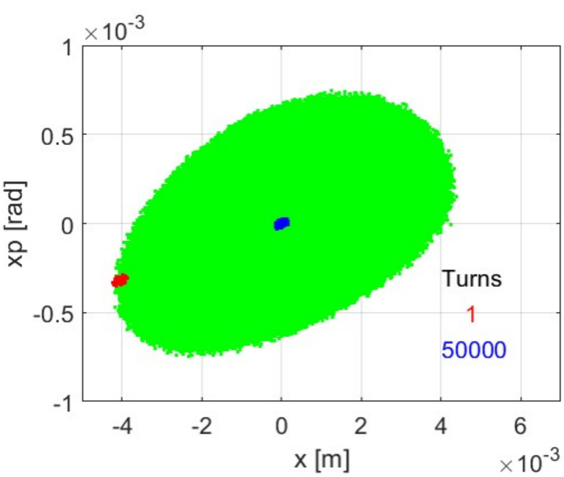

Figure 7: Injection beam distribution in the transverse plane.

CONCLUSION

We have presented a novel analysis method to obtain pulsed multipole injection scheme for small aperture electron storage rings. In this method, we got several alternative injection schemes through particles tracking, then selected the best one by acceptance analysis and verified its feasibility at last. Through this method, suitable pulsed multipole injection scheme can be easily obtained for not only existing storage rings but also the next-generation light sources. We applied this method on the lattice of HALF storage ting to get a multipole kicker injection scheme and verify that its injection efficiency is within our tolerance. Future studies of this method, mainly error analysis including bunch errors and storage ring errors, are in progress.

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