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THE INJECTION AND EXTRACTION DESIGN OF THE BOOSTER FOR THE HEPS PROJECT

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Abstract

The HEPS booster is a 1Hz electron synchrotron. It accelerates electron bunches from 500 MeV to final energy of 6 GeV. The vertical scheme was chosen for the injection and extraction system of the booster. What's more, an injection system from storage ring is required. The layout of the injection and extraction system were introduced in this paper. The parameter optimization and other considerations are presented in detail.

INTRODUCTION

The High Energy Photon Source (HEPS), a 6 GeV synchrotron radiation facility with ultralow emittance, is to be built in the suburbs of Beijing, China. A preliminary hybrid 7BA design for the HEPS, with a natural emittance of 34 pm·rad and circumference of about 1.3km has been made [1].

The HEPS booster is a 1 Hz electron synchrotron. It accelerates electron bunches from a 500 MeV linac to a final energy of 6 GeV, and then extracts and injects them into the storage ring through the booster-to-ring transport line. It is a 4-fold symmetric ring with 40nm·rad natural emittance for the beam energy of 6 GeV. Its circumference is 1/3 of the storage ring [2]. Four long straight section are used for injection, extraction and RF cavity, respectively.

For the storage ring, the on-axis swap–out injection scheme is adopted [3]. Two filling patterns are mainly considered: high-brightness mode (90% buckets uniformly filled by 680 bunches with beam current of 200 mA) and high-charge mode (63 bunches uniformly filled in the ring). For the latter filling pattern, 14.4nc charge to each bucket is needed, because of TMCI the booster cannot accumulate this high charge in the injection energy, so beam extracted from storage ring are injected to the booster again, as a result an injection system from the storage ring is required.

In the following, the design of the injection and extraction system is presented in detail, including the layout and parameters considerations.

INJECTION SYSTEM FROM THE LINAC

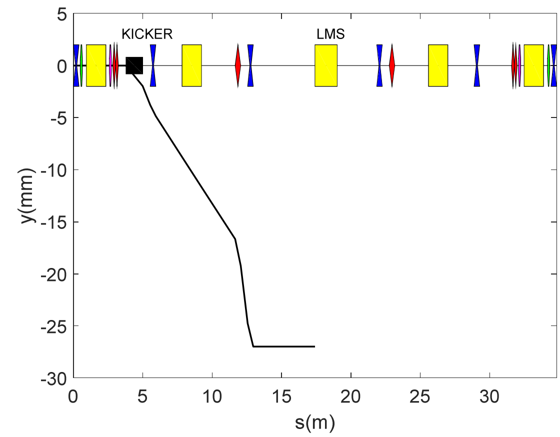

Figure 1: The schematic layout of the injection scheme of the booster.

The injection system from the linac is one-turn injection which consist of a kicker and a lambertson. It is vertical injection scheme. The schematic layout is shown in Fig. 1. Lambertson is placed in the middle of the long straight section. To ensure y'=0 in the injection point, the kicker is placed where the phase advance to the lambertson is π/2. The vertical separation between injection beam and storage beam is about 27 mm at the injection point.

Table 1: Main Parameters of Injection Elements

Specifications	unit	Kicker	Lambertson
Length	m	0.3	0.5
Deflection angle	mrad	3.3	210
Magnetic field	T	0.02	0.7
Repetition rate	Hz	50	DC
Aperture	mm×mm	36×30	25×12
Field uniformity	%	±1	±0. 05
Thickness of lambertson	mm	-	⩽10
Current pulse waveform		Half-sine	-
Pulse bottom width	ns	<300	-

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The electron beam of 500MeV from the linac is transported from the linac-to-booster transport line and get to the lambertson. The lambertson bend the beam 210 mrad in the horizontal plane while the kicker bend the beam 3.3 mrad in the vertical plane. The main parameters of the injection components are listed in Table 1.

EXTRACTION SYSTEM AND INJECTION SYSTEM FROM STORAGE RING

To keep the symmetry of layout, the extraction system and the injection system from storage ring are considered together: firstly, in order to simplify the design of transport line which link the booster and storage ring, they are located in two adjacent long straight section and both vertical scheme; secondly, the separation between the extraction or injection beam to the central close orbit stored beam are the same at the extraction or injection point; thirdly, for the extraction and injection beam y'=0 at extraction or injection point.

The injection from the storage ring is off-axis injection scheme which consist of two kickers and a lambertson. Lambertson is placed in the middle of the long straight section to deflected the incoming beam horizontally, while at a quarter betatron oscillation upstream and downstream of the injection point two kickers are located to form a local bump in the vertical plane. The height of the bump should large than $6\sigma_y$(injection beam)(2.8mm) +thickness of lambertson(6 mm)+margin(1 mm)~10 mm. where σ_y is computed with εy=10 nm, then the lambertson tip should be outside of the central closed orbit with a distance large than bump height+$5\sigma_y$(store beam)(2.3 mm). The schematic at the exit of lambertson and the layout of injection section are shown in Fig. 2 and Fig. 3.

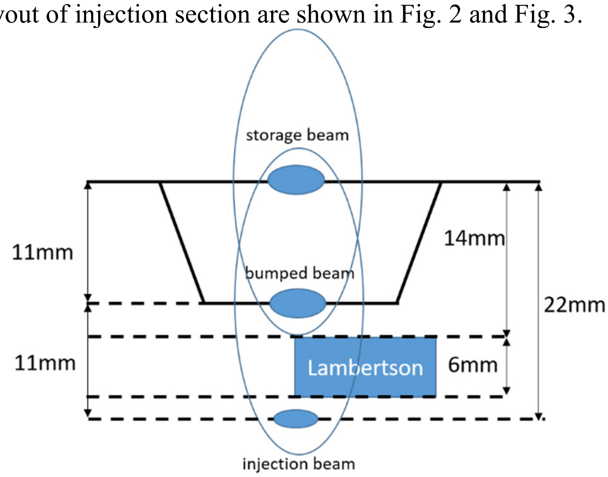

Figure 2: The schematic at the exit of lambertson for the injection system from the storage ring.

The extraction scheme consist of a kicker, four bumpers and a lambertson. Four bumpers are used to generate an 11 mm local bump in order to reduce the strength of the kicker. The location of the kicker is quarter betatron oscillation upstream of the extraction point. The beam is deflected by one extraction kicker, then it passes through several quadrupoles and a bend, reaches the entry of extraction lambertson with a displacement from the axis. The layout and beam trajectory in the extract section is shown in Fig. 4.

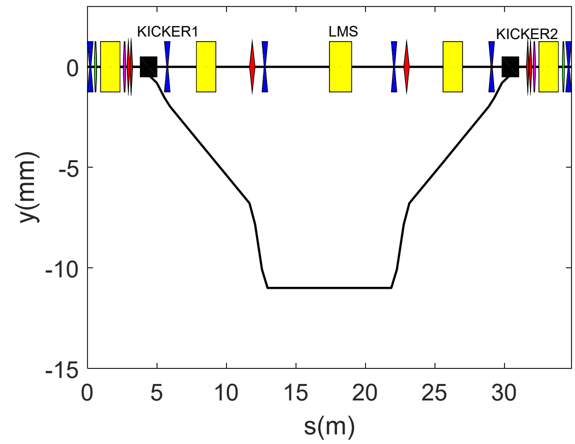

Figure 3: The layout and beam trajectory of the injection system from the storage ring.

The separation between the extraction beam and the bumped store beam should large than $5\sigma_y$(store beam)(2.3 mm)+$3\sigma_y$(extract beam)(1.4 mm)+thickness of lambertson(6 mm)+margin(1 mm)~11 mm. The schematic at the entrance of lambertson is shown in Fig. 5.

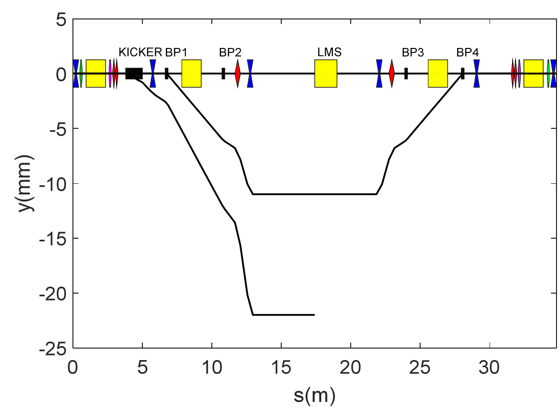

Figure 4: The layout and beam trajectory of the extraction system.

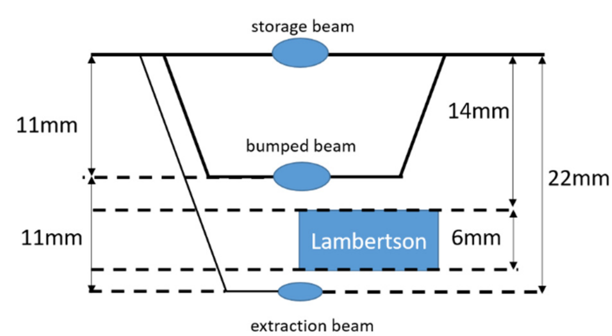

Figure 5: The schematic at the entrance of lambertson for the extraction section.

In addition, the maximum field that the kicker and bumper can reach should also be taken into account. To make the parameter of kickers the same for the extraction and injection from ring, the height of bump generated

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from the kicker for the injection system equals 11 mm is chosen. So the separation between the extraction beam and the bumped store beam is 11mm, too. Four bumpers contribute the 11mm local bump for the extraction system. Therefore the displacement of the extract and inject beam to the central storage beam is 22mm and y'=0 at the extraction and injection point. Lambertson tip is 14 mm outside of the central closed orbit. The main parameters of elements for the extraction and injection system are listed in Table 2.

Table 2: Main Parameters of Elements for the Extraction and Injection System

Specifications	**unit**	**Kicker (for injection and extraction)**	**Lambertson (for injection and extraction)**	**bumper**
Length	m	1.2	1.6	0.2
Deflection angle	mrad	1.3	80	0.66/1.6
Magnetic field	T	0.023	1	0.066/0.16
Repetition rate	Hz	50	DC	50
Field uniformity	%	±1	±0. 05	±1
Thickness of lambertson	mm	-	⩽6	-
Current pulse waveform		Half-sine	-	Half-sine
Pulse bottom width		<300ns	-	1ms

SUMMARY

As described above, the injection system from the linac and extraction system have been designed, the injection system from the storage ring are also presented. The design of the elements can also meet the requirements mentioned above. Moreover the simulation of the whole process of injection and extraction is on-going.

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