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PHYSICAL DESIGN OF HEPS LOW ENERGY TRANSPORT LINE*

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Abstract

The High Energy Photon Source (HEPS), a kilometre-scale storage ring based light source, with emittance less than 60 pm.rad, will be constructed in Beijing, China. It consists of a 500 MeV linac, a 500 MeV low energy transport line, a full energy booster synchrotron, two 6-GeV transport lines, a 6 GeV ultra-low emittance storage ring, and the beam line experimental stations. The low energy transport line connecting the linac and the booster. Based on the construction layout restrictions, the beam envelopes of the linac and the booster should be matched, and the beam produced by the linac is high efficiently transmitted to the booster injection point. HEPS low energy transport line has three functional sections, the achromat injection matching section, the optics matching section and the output matching section. In order to correct the error effects on the beam, 8 BPM are set in the low energy transport line. There are also 6 horizontal correctors and 6vertical correctors for beam trajectory correction. This paper will show the detailed design of HEPS low energy transport line.

INTRODUCTION

HEPS is an ultra-low emittance synchrotron light source will be constructed in Beijing, China. The circumference of storage ring is about 1.36 km [1-3]. For getting low emittance and enough dynamic aperture, many advanced accelerator technologies and methods are adopted in HEPS storage ring lattice design, contains: hybrid-MBA cell [4, 5] which first proposed by ESRF, longitudinal gradient dipoles [6, 7], combined function dipoles , anti-bend dipoles [8] and so on.

HEPS injector consists of a 500MeV linac with a thermionic gun, a 500 MeV low energy transport line (LB), a full energy booster which ramping the beam energy from 500 MeV to 6 GeV and 2 high energy transport lines for “high energy accumulation” scheme [9]. The layout of HEPS injector is shown as Fig. 1.

LB is a transport line connecting the linac and the booster. Besides the construction layout restrictions, the beam envelopes of the linac and the booster should be matched, and the beam produced by the linac is high efficiently transmitted to the booster injection point. So the LB design should match the booster low energy injection system, it also should adjustment the optics flexibly.

In this paper, first is the introduction of the booster low energy injection system design scheme, then present the LB lattice design scheme, and the error effect study of LB is shown in the last.

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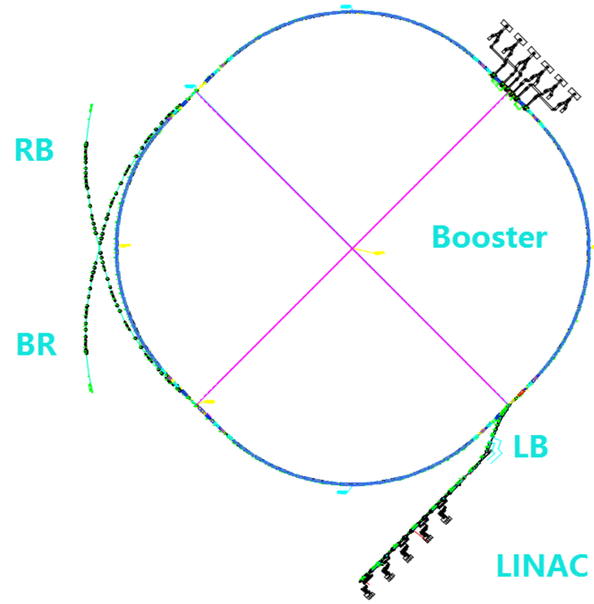

Figure 1: Layout of HEPS injector.

DESIGN OF LB TRANSPORT LINE

LB is the low energy transport line of HEPS connecting the linac and the booster. In the survey design, HEPS linac is parallel to the long straight section of booster. The main function of LB transport line is to transport the 500- MeV electron beam from the linac to the booster with high efficiency. Its design need considerate the beam transportation, beam parameters measurement, energy control, optical matching, on-axis booster injection and tuning flexibility. The optics parameters at the linac exit point and booster injection point are presented in Table 1. The dispersion is free both at the linac exit point and booster injection point.

Table 1: Beam Parameters at the Linac Exit Point and Booster Injection Point.

Parameters	Linac end	Injection point
β_x(m)	7.90	6.18
α_x	-0.74	0
β_y(m)	7.86	18.97
α_y	-1.01	0

For keep the linac and the booster nearly on a plane, the low energy injection of HEPS booster adopt vertical injection scheme. The low energy injection system consists of a 0.8 m kicker bending the beam to right 9.1 mrad vertically and a 0.5 m Lambertson septum for bending the beam to left 200mrad horizontally. The layout of low energy injection system is presented in Fig. 2.

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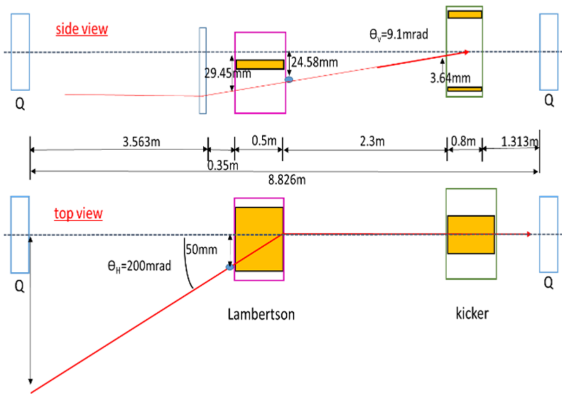

Figure 2: Layout of low energy injection system.

The LB is designed with three function sections: the linac to achromatic section, the achromatic section and the injection-matching section.

The linac to achromatic section is from the linac end to the "achromatic section". At the beginning of this section are three quadrupoles for beam envelope adjusting, and then is a DBA cell which consists of one quadrupole and two dipoles with each bend the beam to the right 200 mrad. The beam is achromatic at the end of this section.

The achromatic section consists of six quadrupoles, the beam is achromatic in this section. The emittance measure element is placed in this section. Through changing these quadrupoles' strength, the optics parameters are adjusted without change the dispersion.

The injection-matching section consists of three quadrupoles, a horizontal dipole and a Lambertson septum. Each of the dipole and the septum bend the beam to the right 200 mrad.

Two vertical dipoles with bending angle 5.1 mrad are placed upstream the Lambertson septum in the LB transport line for minimize the height difference between the linac and the booster.

The length of LB transport line is 25 m，envelope functions are restricted less than 30 m, the dispersion less than 0.7 m. Figure 3 presents the lattice layout and the optics parameters of LB transport line.

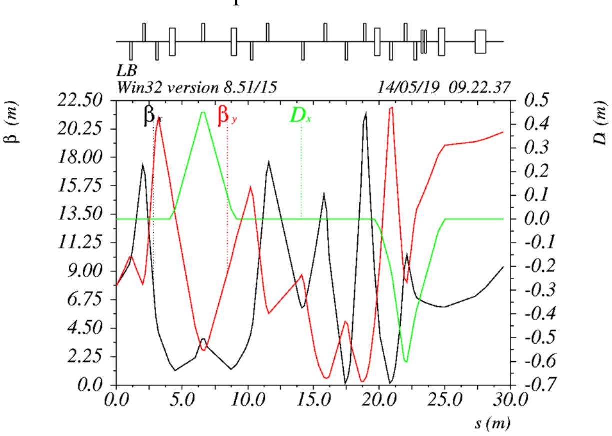

Figure 3: Lattice layout and optics parameters of LB transport line.

The beam stay clear (BSC) which determines the vacuum chamber size is defined as the sum of 3σ of the beam size, 4 mm tolerance for the trajectory distortion. The beam emittance and beam energy given by the linac is 40-nm.rad and 0.005, respectively. The aperture requirements are ±15 mm in the horizontal plane and ± 8 mm in the vertical plane.

ERROR STUDY

Error study is aim to evaluate the LB transport line performance in presence of various errors to check the robustness.

At present, the HEPS LB transpot line error study only covered the static errors, which is independent of time or has very slow changes over a long period of time.

The field error and misalignments of dipoles will effect on beam orbit and dispersion. The field error and misalignment of quadrupoles may change the optics and beam orbit. 8 BPM are set on the LB transport line for measuring the orbit.

Error Setting

In HEPS LB error study, the field error and misalignment setting like Table 2. The error setting as Gaussian distribution and cut off with 3σ.

Table 2: Error Settings (3σ, Gaussian distribution)

Element	Error	Units	Value
Dipole	shift(x/y)	mm	0.2
	shift (z)	mm	0.2
	Roll	mrad	0.2
	Field error	%	0.1
Quadrupole	shift (x/y)	mm	0.1
	shift (z)	mm	0.2
	Roll	mrad	0.2
	Field error	%	0.1
Lambertson	shift (x/y)	mm	0.1
	shift (z)	mm	0.2
	Roll	mrad	0.2
	Field error	%	0.05
BPM	uncertainty	mm	0.1

The long term beam stability parameters at the end of the linac are listed in the Table 3. The error is also setting as Gaussian distribution, but cut off with 1σ.

Table 3: Beam Stability Parameters at the End of the Linac

Parameters	Units	Values
Beam position	mm	0.5
Beam angle	mrad	0.2
Energy deviation	%	0.25

Orbit Simulation with Errors Before Correction

The simulation results with 100 random seeds are shown in Fig. 4. The maximum beam orbit is 18 mm in the horizontal plane and 15 mm in the vertical plane,respectivly.

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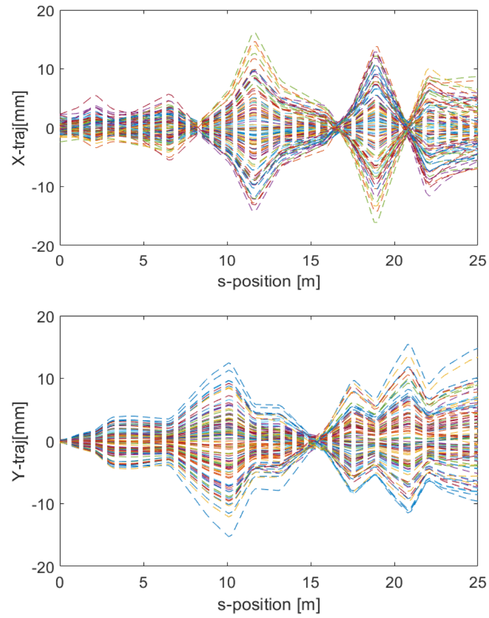

Figure 4: Beam orbit without correction. Top: Beam orbit in the horizontal plane. Bottom: Beam orbit in the vertical plane.

For beam orbit correction, 6 horizontal correctors(HC) and 6 vertical correctors(VC) are used in the HEPS LB transport line. Distribution of the BPM and correctors are presented in Fig. 5. The simulation result of the beam orbit after correction is shown in Fig. 6. Both of horizontal and the vertical plane, the maximum beam orbit are less than 2 mm. The results are shown in Fig. 5.

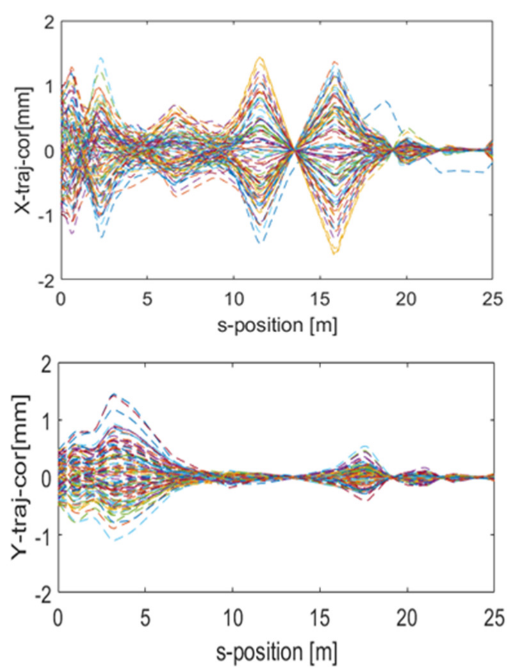

Figure 5: Beam orbit with correction. Top: Beam orbit in the horizontal plane. Bottom: Beam orbit in the vertical plane.

The beam position and dispersion at the injection point are also analysed, and the results are shown in Fig. 6 and Fig. 7 respectively. The maximum orbit deviation at the HEPS booster low energy injection point is less than 0.22 mm in the horizontal plane and less than 0.05 mm in the vertical plane, respectively. The dispersion are less than 2 cm both in the horizontal plane and in the vertical plane.

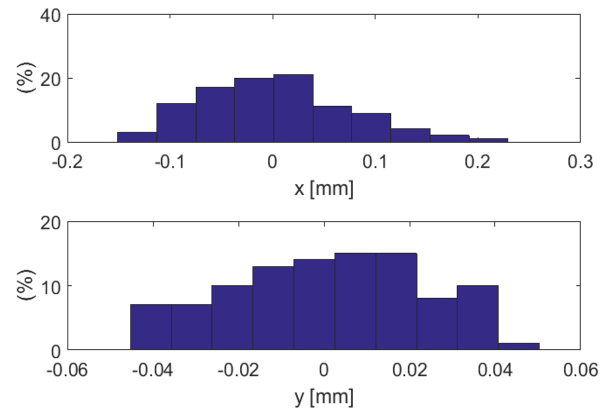

Figure 6: Distribution of beam position at booster injection point.

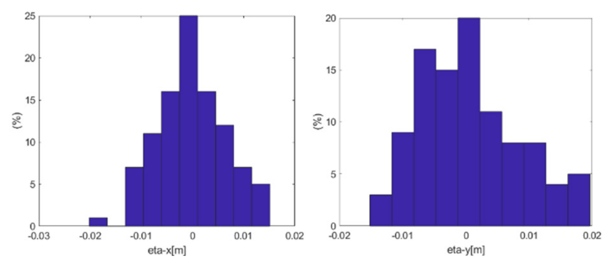

Figure 7: Distribution of dispersion at booster injection point. Left: dispersion in the horizontal plane. Right: dispersion in the vertical plane.

CONCLUSION

This paper presents the design of HEPS LB transport line. For keep the linac and booster nearly on a plane and use the mature Lambertson septum, HEPS booster use vertical injection as its low energy injection scheme. The LB transport line use vertical dipoles in the horizontal bending region, and the LB is designed with three function sections for flexible adjusting. Error study is also contained in this paper, 8 BPM, 6 HC and 6VC are placed in the LB transport line for orbit measure and correction. After correction, the beam orbits are less than 1.5 mm in the LB transport line.

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