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BEAM TRANSFER LINE OF WUHAN ADVANCED LIGHT SOURCE

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Abstract

Wuhan Advanced Light Source (WALS) is a fourth-generation diffraction limit synchrotron radiation facility, which is composed of a full energy 1.5 GeV LINAC, a 1.5 GeV Storage Ring and 10 beamlines for its phase I project. The LINAC is 6 meters lower than the storage ring, which is connected by a 46 meters beam transfer line. The beam transfer line includes three parts, one vertical line between two horizontal lines. Four achromat sections are used, the first three are 30 degrees with exact same settings and the last one is matched with the storage ring injection septum and non-linear kicker. In this paper, the optic and error correction results are described in brief, especially the dispersion correction. Since there are horizontal and vertical dispersions at the same time, the correction process must correct both of them at the same time.

INTRODUCTION

Wuhan Advanced Light Source (WALS) is a fourth-generation diffraction limit light source [1], which consists of a 180 m storage ring (1.5 GeV), a 1.5 GeV linac working as its injector, the beam transfer line (BTL) and eight beamlines, as shown in Fig. 1. By using 3.5 T superB magnet, the photon energy of the storage ring is extended to hard X-ray region.

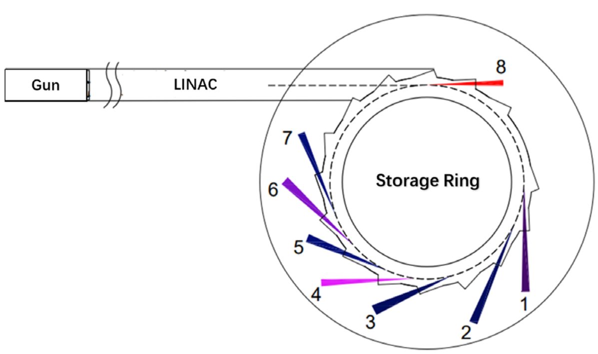


Figure 1: Layout of Wuhan Advanced Light Source.

The beam transfer line is used to delivered the 1.5 GeV electrons from LINAC, which is 6 meters underground, to storage ring. Like many fourth-generation light sources, the dynamic aperture of WALS 1.5 GeV storage ring is only about 8-10 mm in horizontal and a pulsed non-linear magnet will be used for the off-axis injection [2], so the acceptance of the storage ring injection system is very small. To ensure the efficiency and the stability of the machine, the error analysis is carefully studied, especially the dispersion correction. A multi-objective optimization algorithm is used during the beam transfer line optic correction.

In the following sections, the design of the WALS beam transfer line will be described briefly.

1.5 GeV BTL OPTICS

Figure 2 shows the schematic diagram of WALS beam transport line. The whole line is divided into three sections by two blue dots in the top view drawing of Fig. 3, two in horizontal plane and one in vertical. The two red points are where the beam pass through the storage ring basement.

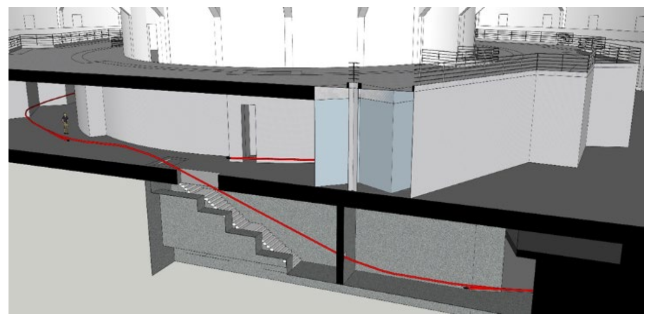
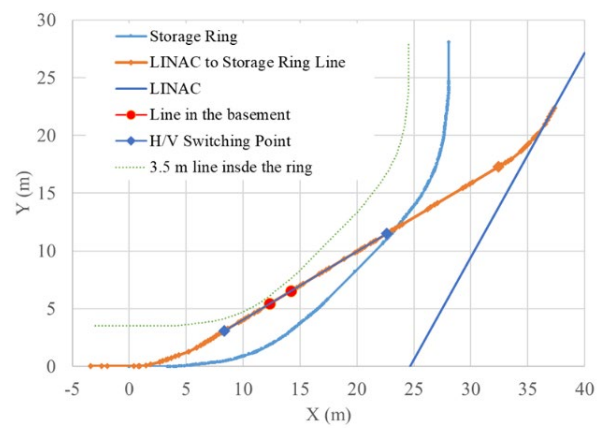
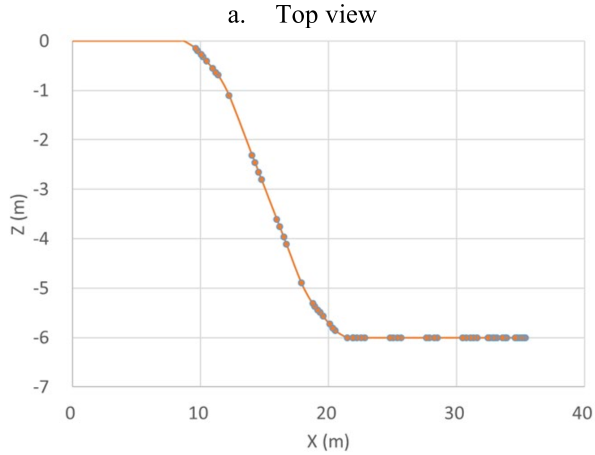


Figure 2: Schematic diagram of WALS beam transport line.



a. Top view



b. Side view

Figure 3: Layout of WALS beam transport line.

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Four achromats, two in horizontal and two in vertical, are used to deliver the beam from LINAC exit to storage ring entrance. The first three achromats are exactly the same, with two 15 degrees dipoles and three quadrupoles. The last one is same structure but the dipole angle is only 10.5 degrees, the inject septum and kicker are also included in the beam optics matching process. Another 18 quadrupoles in the dispersion free section are used for the twiss parameter control of the beam transfer line. The whole length of the BTL is about 46 m. Fig. 4 shows the twiss parameters of the BTL and Fig. 5 is the beam size distribution when the normalized emittance of the LINAC is 2 mm·mrad and energy spread is 0.2%, respectively [3].

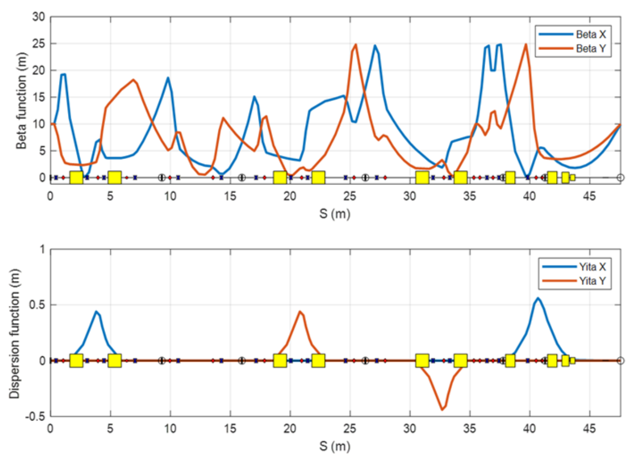

Figure 4: Twiss parameters of WALS BTL.

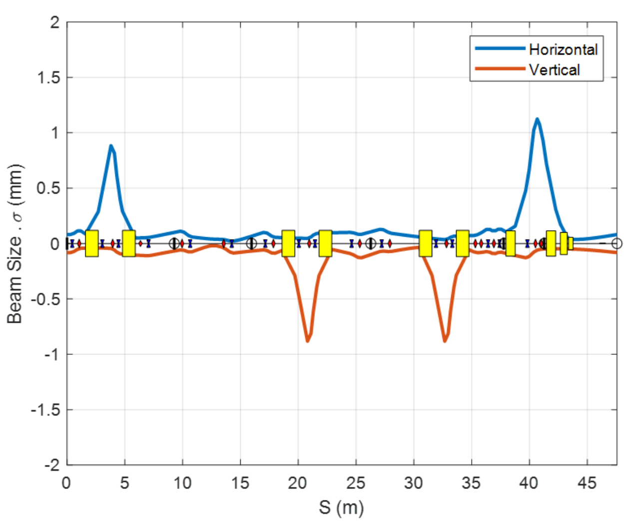

Figure 5: Beam size distribution of WALS BTL.

ERROR ANALYSIS

The acceptance of WALS injection system is very small due to the small dynamic aperture of the four-generation light source and the off-axis non-linear kicker injection scheme. The field and alignment errors of the magnets will cause the orbit and beam size distortion, and this distortion might affect the injection efficiency a lot, especially the orbit distortion and the horizontal dispersion at the injection point. Table 1 shows the alignment and field tolerance requirement of the magnets in WALS BTL and the beam parameters errors at the exit point of the LINAC.

Table 1: Tolerance Requirement of WALS BTL

Dipole	
Shift along x/y/z	0.5 / 0.2 / 0.5 mm
Tilt around x/y/z	0.5 / 0.5 / 0.2 mrad
Field error	0.1 %
Quadrupole	
Shift along x/y/z	0.2 / 0.2 / 1.0 mm
Tilt around x/y/z	0.5 / 0.5 / 0.5 mrad
Field error	0.2 %
Beam parameters at LINAC exit	
Orbit shift x/y	0.5 / 0.5 mm
Orbit angle x/y	0.3 / 0.3 mrad
$\Delta\beta_x/\beta_x$ & $\Delta\beta_y/\beta_y$	30%
$\Delta\alpha_x$ & $\Delta\alpha_y$	0.3
$\Delta\eta_x$ &$\Delta\eta_y$	0.03 m

As shown in Fig. 4, 6 pairs of BPM and HVC are used for the orbit correction, the small cycles in the upper plot are the BPM positions and the H/V correctors are set at the same position as BPM except the one at the end, which moves to the beginning point of the BTL. Fig. 6 shows the simulation result of the orbit correction, by using 100 seeds. The orbit distortions are well corrected from maximum 20 mm to less than 3 mm in both horizontal and vertical planes. At the injection point, the orbits are corrected to almost 0 from about 20 mm for all seeds. The maximum corrector strength is less than 2 mrad in both planes.

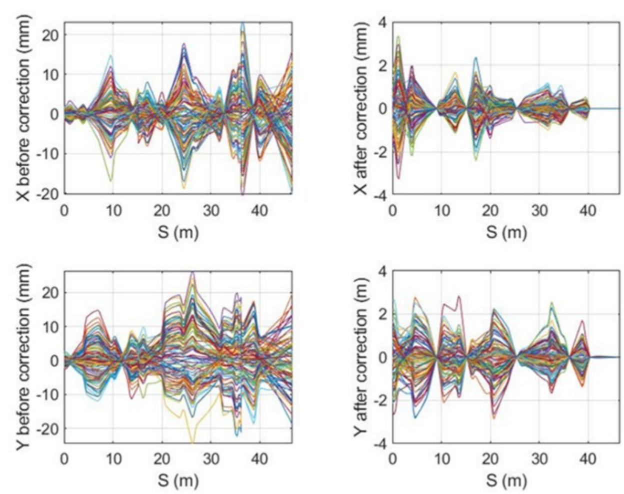

Figure 6: Orbit correction simulation results (100 seeds).

The optic correction of WALS BTL is much more complicate than the orbit correction or the optic correction in other facilities, because it deflects the beam in both horizontal and vertical planes and the matching must be done by using 4-D transform matrix instead of 2-D. Fig. 7 shows the optic function distribution before correction with 100 seeds, the maximum beta is changed to about 150 m and the maximum dispersion at the end is about 0.5 m, which

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is not acceptable for the storage ring injection. Although it is still possible to do the optic correction section by section by using some match software, but it will take a long time to finish all seeds and very difficult to do it automatically.

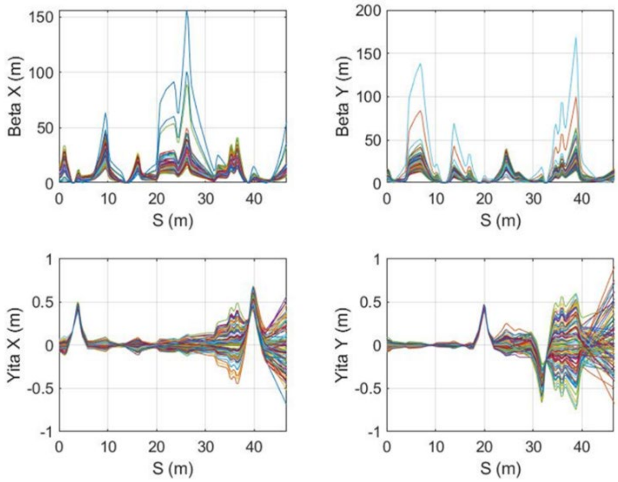

Figure 7: Twiss parameters along the WALS BTL before optic correction (100 seeds).

A new method is developed for the BTL correction. It is a global correction and it will correct the orbit and the twiss parameters at the same time. The idea is to apply several sets of changes to the chosen quadrupoles, usually 30-50 sets, and keep the one better than the original as the new seeds, repeat the upper steps until all optimum goals are achieved, such as the twiss parameters at the end, dispersion functions at some measurement point like profile, maximum beta function along the line, etc. Fig. 8 and Fig. 9 show the simulation results of the BTL optic correction. The maximum beta function is well corrected to less than 35 m in both planes, and the dispersion functions are almost corrected to the designed values, especially at the ending point of the BTL, the dispersion functions are corrected to only few mm, which is neglectable for the storage ring injection system. The beta function errors are not very important because the emittance is very small for the full energy LINAC.

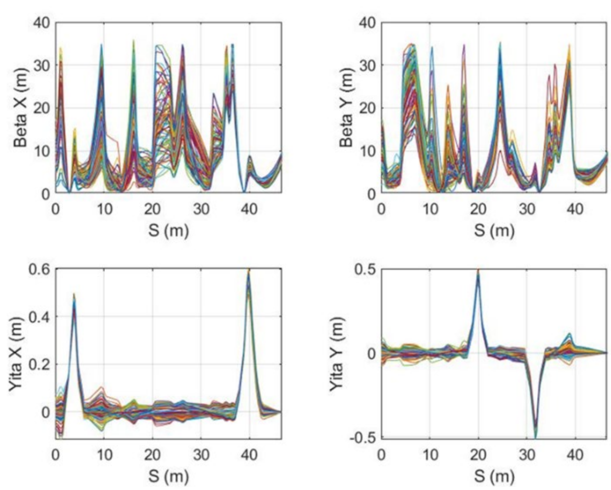

Figure 8: Twiss parameters along the WALS BTL after optic correction (100 seeds).

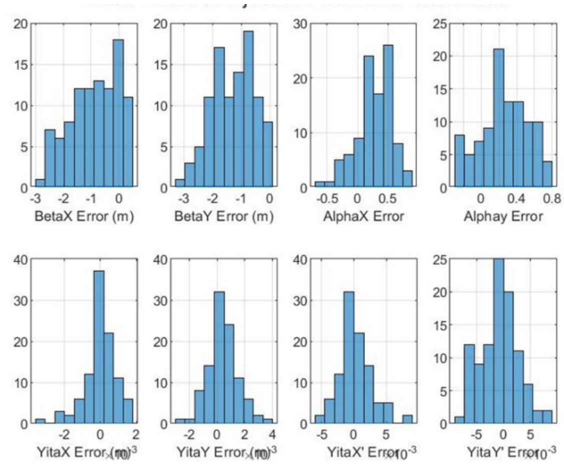

Figure 9: Twiss parameter errors at the injection point.

FUTURE PLAN

The BTL is well designed for the WALS, and the error analysis shows there is no unsolvable problem in the present design. The next step is for the future beam commissioning. Although the simulation shows the orbit and the optic can be well corrected, but how to correct them by using only 6 BPMs and 3-5 profiles during the future beam commissioning is still a question need to be answered.

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