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STUDY ON THE PHASE SPACE PAINTING INJECTION DURING THE BEAM COMMISSIONING FOR CSNS*

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Abstract

During the beam commissioning of China Spallation Neutron Source (CSNS), different injection methods were used in different periods. In the early stage, since the precise position of the injection point was unknown and the beam power was relatively small, the fixed point injection was selected. In the later period, in order to increase the beam power and reduce the beam loss, the phase space painting method was used. In this paper, the phase space painting in the horizontal and vertical planes is studied in detail and the beam commissioning results of different painting injection are given and discussed. In addition, different injection effects of the fixed point injection and painting injection are compared and studied.

INTRODUCTION

China Spallation Neutron Source (CSNS) is a high power proton accelerator-based facility [1] and its technical acceptance had been completed in March 2018. The accelerator consists of an 80 MeV H^- Linac and a 1.6 GeV rapid cycling synchrotron (RCS) with a repetition rate of 25 Hz which accumulates an 80 MeV injection beam, accelerates the beam to the designed energy of 1.6 GeV and extracts the high energy beam to the target. The design goal of beam power for CSNS is 100 kW and capable of upgrading to 500 kW [2].

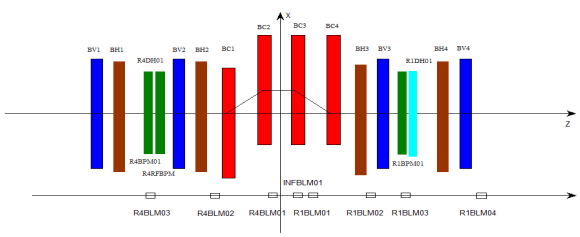

Figure 1: Layout of the CSNS injection system.

For the high intensity proton accelerators, in order to reduce the beam loss caused by the space charge effects, the phase space painting method is used for injecting the beam of small emittance from the Linac into the large ring acceptance [3]. For CSNS, the position painting was used in both horizontal and vertical planes. Figure 1 shows the layout of the CSNS injection system. It can be found that, there are four dipole magnets (BH1-BH4) used for painting in the horizontal plane and other four dipole magnets (BV1-BV4) used for painting in the vertical plane [4].

In the early stage of CSNS beam commissioning, since the precise position of the injection point was unknown and the injection beam power was relatively small, in order to inject the beam into the RCS as soon as possible, the fixed point injection method was selected. Latter, in order to increase the beam power and reduce beam loss, the phase space painting in the horizontal plane was used. Finally, the phase space painting in both horizontal and vertical planes was used, and the painting ranges and painting curves were studied and optimized.

In our early paper, we had studied and discussed the fixed point injection during the beam commissioning for CSNS [5]. In the following sections, the phase space painting in the horizontal and vertical planes during the beam commissioning will be studied and discussed.

HORIZONTAL PAINTING INJECTION

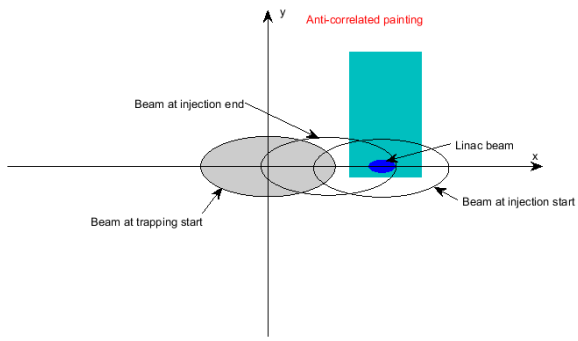

Figure 2: Positions of the ring acceptance ellipse during the horizontal painting injection.

In the middle of beam commissioning, in order to increase the beam power and reduce the beam loss, the phase space painting in the horizontal plane was used. Figure 2 shows the positions of the ring acceptance ellipse during the horizontal painting injection process. For CSNS, the fixed point injection was changed to the horizontal painting injection on Nov. 9, 2017. During the beam commissioning, by comparing the results of the fixed point injection and horizontal painting injection, it can be found that there are many advantages to applying the horizontal painting injection. Figure 3 shows the beam loss of the Linac and RCS while the fixed point injection and horizontal painting injection were used. It can be seen that the beam loss in the injection region while the horizontal painting was used is much smaller than that while the fixed point injection was used.

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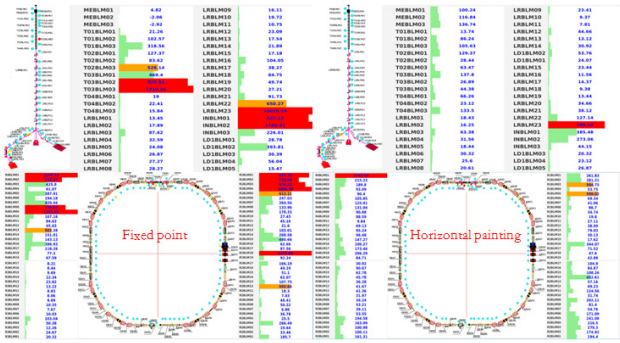

Figure 3: Beam loss of the Linac and RCS while the fixed point injection (left) and horizontal painting injection (right) were used.

While the fixed point injection was used, there was a suddenly beam loss during the injection process no matter the matching of the injection beam and circular beam [5]. However, while the horizontal painting injection was used, the suddenly beam loss during the injection process was gone. Figure 4 shows the RCS DCCT displays while the fixed point injection and horizontal painting injection were used. It can be found that, for the horizontal painting injection, the suddenly beam loss was gone and the injection efficiency had increased very much. Therefore, the beam power can be further improved.

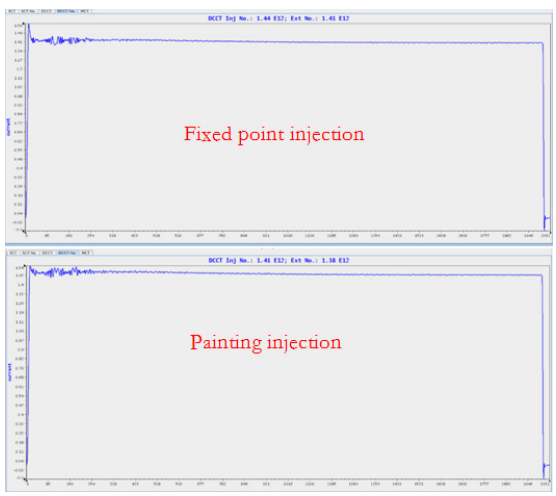

Figure 4: RCS DCCT displays while the fixed point injection and horizontal painting injection were used.

HORIZONTAL AND VERTICAL PAINTING INJECTION

In the process of further increasing the beam power, the space charge effects of cumulative beam would be increased so as to cause larger beam loss. Under the circumstances, the painting in both horizontal and vertical planes needs to be considered. Figure 5 shows the positions of the ring acceptance ellipse during the horizontal and vertical painting injection process. For CSNS, the horizontal and vertical painting injection were both used and optimized on Feb. 13, 2018.

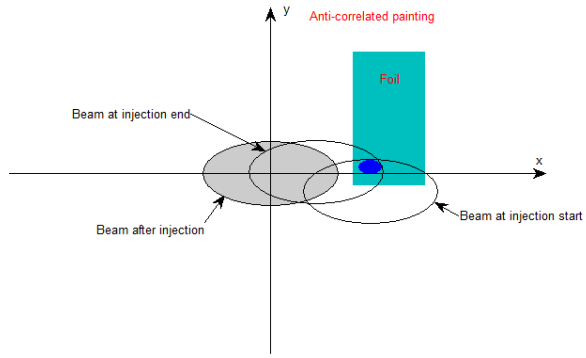

Figure 5: Positions of the ring acceptance ellipse during the horizontal and vertical painting injection.

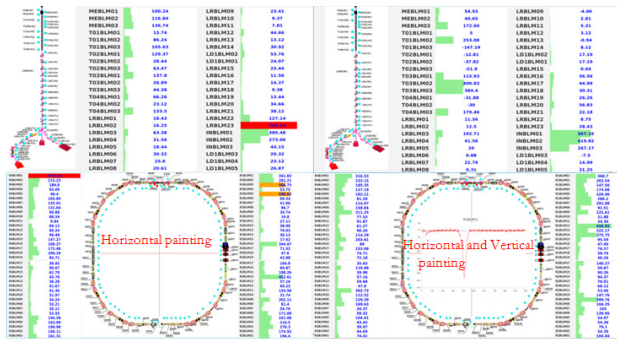

Figure 6: Beam loss of the Linac and RCS while the horizontal painting injection (left) and horizontal & vertical painting injection (right) were used.

During the beam commissioning, by comparing the results of the horizontal painting injection and horizontal & vertical painting injection, it can be found that there are some advantages to applying the phase space painting in both horizontal and vertical planes. Figure 6 shows the beam loss of the Linac and RCS while the horizontal painting injection and horizontal & vertical painting injection were used. It can be seen that the beam loss in the injection region while the phase space painting in both horizontal and vertical planes was used is smaller than that while only horizontal painting injection was used. In addition, the beam power had increased from 13 kW to 23 kW. In the future, in order to further improve the beam power, the painting curves and painting ranges in the horizontal and vertical planes need to be further optimized.

CONCLUSIONS

In the middle of CSNS beam commissioning, the fixed point injection was changed to the horizontal painting injection. The beam commissioning results showed that the beam loss in the injection region while the horizontal painting was used was much smaller than that while the fixed point injection was used. In addition, for the horizontal painting injection, the suddenly beam loss that appeared in the fixed point injection process was gone and the injection efficiency had increased very much.

In the latter period of beam commissioning, the

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painting in both horizontal and vertical planes was used for the beam injection. The beam commissioning results showed that the beam loss was much reduced and the beam power had increased from 13 kW to 23 kW. In the future, in order to further improve the beam power, the painting curves and painting ranges in the horizontal and vertical planes need to be further optimized.

ACKNOWLENDGMENTS

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