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Local Orbit Correction Application for CSNS/RCS High Intensity Commissioning

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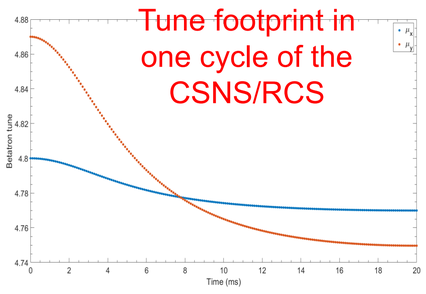
Abstract

The China Spallation Neutron Source (CSNS) is a high intensity hadron pulse facility which achieved the design goal in March, 2020. The Rapid Cycling Synchrotron (RCS) is the important part of the CSNS which accelerates the proton beam from 80MeV to 1.6GeV. During the high intensity commissioning of the RCS, an local orbit correction application was developed. Because of the good performance of the local orbit controlling at the ramping stage, the beam loss was optimized effectively in the process of the acceleration. In the paper, the efficiency of the beam loss optimization during the acceleration is given and the future plans were proposed.

INTRODUCTION

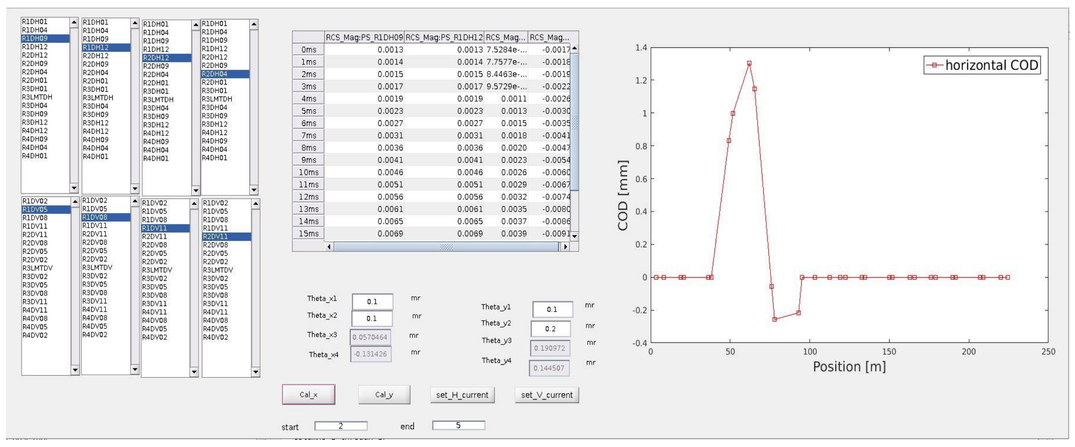
The China spallation Neutron Source (CSNS) is a high intensity hadron pulse facility with the repetition rate of 25Hz which aims to provide 100 kW proton beam at the first stage. The accelerator consists of an 80 MeV negative hydrogen Linac and a 1.6 GeV Rapid Cycling Synchrotron (RCS). The negative hydrogen beam is stripped to the proton beam and then injected into the RCS with the carbon foil. The proton beam is accelerated and accumulated to 1.6 GeV at RCS and then struck on the tungsten target. The beam commissioning of the RCS began from 2017, and the beam power is raised steadily in the following three years. At the high intensity beam commissioning, especially at 80 kW and 100kW beam commissioning, a novel local orbit correction method is adopted to increase the beam transmission rate and control the beam loss at RCS.

It is a tough journey for CSNS high intensity beam commissioning, and many aspects of the accelerator are carefully optimized, such as RF capture for larger bunch factor, injection painting for a reasonable emittance growth, working point investigation for avoiding the resonance lines. In order to alleviate the resonance effects caused by space charge, the working point investigation is crucial for high beam intensity commissioning. For better controlling of the beam loss, a novel orbit correction program based on accelerator toolbox is developed to correct the orbit at each trace of the orbit.

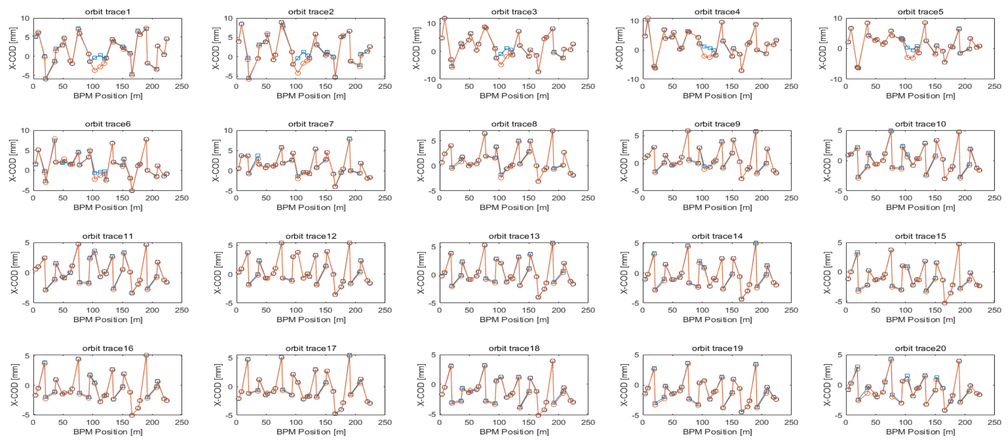


For high intensity beam commissioning, the hadron accelerators may choose a transverse tune variation scheme to optimize the ring's performance. In CSNS/RCS high intensity beam commissioning, the transverse tunes are carefully studies to minimize the space charge effects and coupling resonance. The figure above is the tune footprint in one cycle. The tunes starts from 4.80/4.87(H/V) and ends with 4.77/4.77(H/V).

RCS optics in one cycle



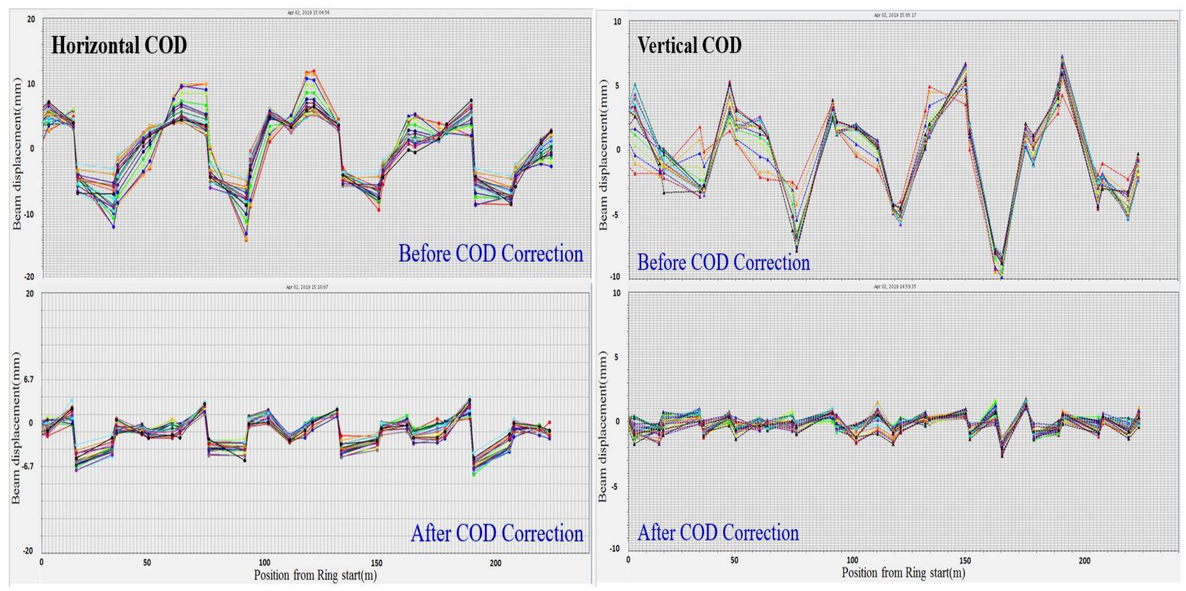
The novel local orbit correction is an APP based on accelerator toolbox.



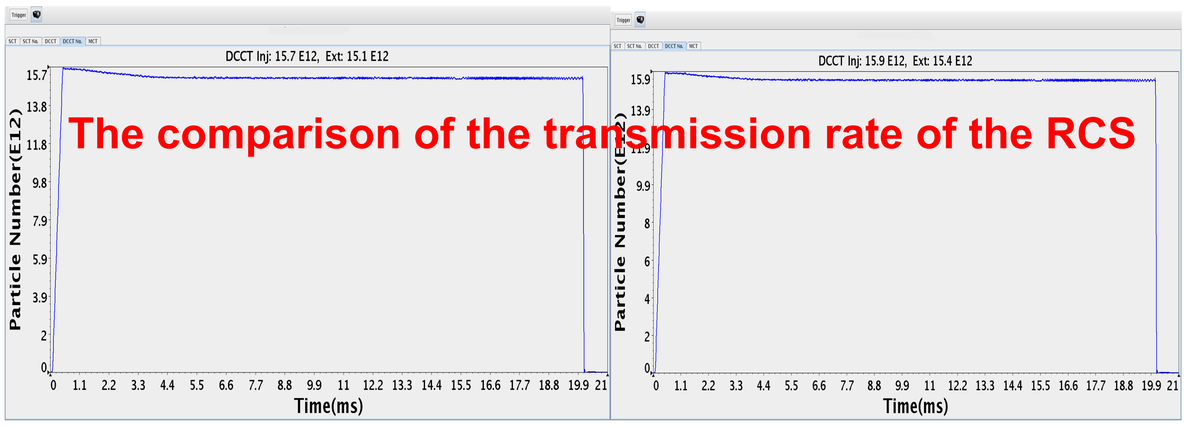
The horizontal orbits for 20 traces. The red circle represents the orbits before correction and the blue square represents the orbits after correction.

COD correction in RCS

The RCS of the CSNS is a key part of the accelerator which accelerates the beam from 80 MeV to 1.6 GeV with the repetition rate of 25Hz. 24 dipoles and 48 quadrupoles constitute a four folds super-period lattice based on the triplet structure. 17 horizontal correctors and 17 vertical correctors are used to correct the beam orbits at the 32 BPMs. As a rapid cycling synchrotron, the mismatch between magnets and RF cavities in the process of ramping can make the optics deteriorated from that of the design. And the magnetic field discretization of the 24 dipoles of the RCS can also lead to the orbit variation in the whole cycle. For better control of the beam orbit in one cycle, generally the orbit is often split into many traces. There are 20 orbit traces in one cycle corresponding to the ramping time 20 milliseconds, and the correctors with programmed power supplies can be used to correct every trace of the orbit at each second. the global orbit corrections applied at CSNS-RCS. The 20 traces of the horizontal orbit are corrected from ±15 mm to ± mm, and the 20 traces of the vertical orbit are corrected from ± 15mm to ± 3mm.

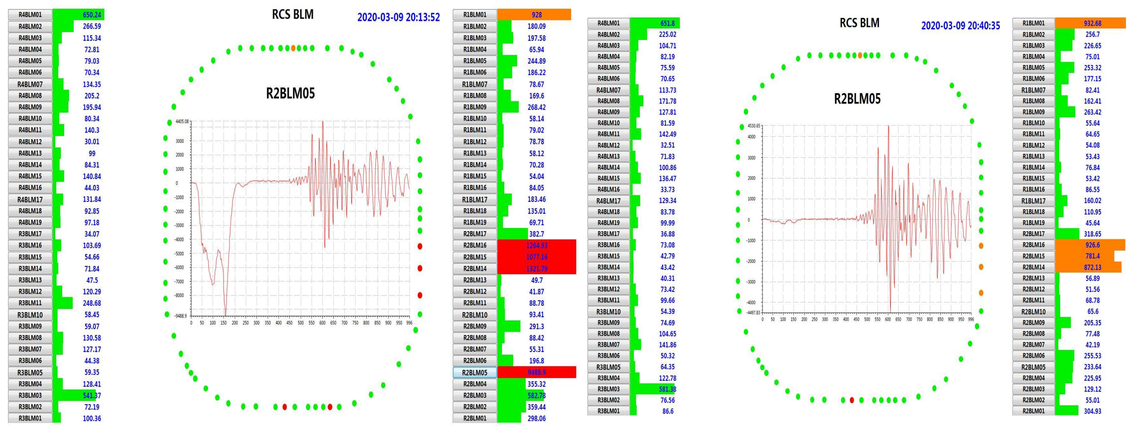


Global orbit correction applied at CSNS/RCS



The comparison of the transmission rate of the RCS

Before the correction the transmission is around 96.18% while the transmission rate can be raised to 96.86% after correction.



R2BLM05 beam loss optimization

By applying the local orbit correction, the beam intensity waveform at R2BLM05 is decreased. The maximum beam loss intensity at the R2BLM05 is 9488 before local orbit correction and that is minimized to 255 after local orbit correction. The waveform of the R2BLM05 in the second half is due to signal interference and the problem may be fixed in the future commissioning of the RCS.

SUMMARY

In order to mitigate the resonances which may cause space charge effects and collective instability, the tunes of the RCS is varied in one cycle. The optics of the RCS is well calibrated and the optics agreed well with that of the designed. Embedding the effects of the lattice variation in one cycle, a novel local orbit correction APP with the frame of accelerator toolbox is developed to optimize the beam transmission rate and minimize the beam loss. After a series of optimization and iteration applied to many BLMs, the beam loss is optimized well, and the beam transmission rate can be raised above 1 percent. Two factors may be summarized as follows. A rigorous constraint applied on the local bump area and very little orbit leakage can be used to find the golden orbit with the careful scan method. And also at the collimation area, the optimization of the beam directions may be better for the absorber of the secondary collimators.

The novel local orbit correction is well used for the CSNS/RCS commissioning, and the potentialities may be excavated more deeply with the upgrade of the correctors of the CSNS in the future.

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