THE COMMISSIONING PLAN AND PREPARATION FOR CSNS ACCELERATORS *

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Abstract

The China Spallation Neutron Source (CSNS) accelerator consists of an 80MeV H- lianc and an 1.6GeV proton rapid cycling synchrotron, and it provide 100kW beam to the neutron target. At present, the most of the element of accelerator is under mass production and test. The installation and beam commissioning will be started from Ion Source, and done section by section. To make the beam commissioning smoothly and successfully, many preparation works on both accelerator physics and hardware have been doing. In this paper, the summary on the preparation work for beam commissioning is given, including the commissioning schedule, detailed commissioning plan, the development of the commissioning software, and etc.

INTRODUCTION

The China Spallation Neutron Source (CSNS) is a high intensity proton accelerators based facility [1]. Its accelerator consists of an 80MeV H^- linac, an 1.6 GeV Rapid Cycling Synchrotron (RCS) and correlated beam transport line. The 50keV H- beam is accelerated to 3MeV by RFQ, and the 3MeV beam is matched into Drift Tube Linac (DTL) through Medium Energy Beam Transport (MEBT). The beam is accelerated to 81MeV at the end of DTL. The 81MeV H- beam is transported to the injection point of RCS through Linac to Ring Beam Transport (LRBT) line. By using stripping painting, 81 MeV H- beam is stripped into proton and accumulated in the RCS. The proton beam is accelerated to 1.6GeV at repetition rate of 25Hz. The 1.6GeV beam is extracted in single-turn extraction. The 1.6GeV proton beam is transported through Ring to Target Beam Transport (RTBT) line on to the neutron target. The designed average beam power is 100kW, and is capable of upgrading to 500kW. Figure 1 gives the schematic layout of CSNS, and the Table 1 shows the primary parameters of CSNS.

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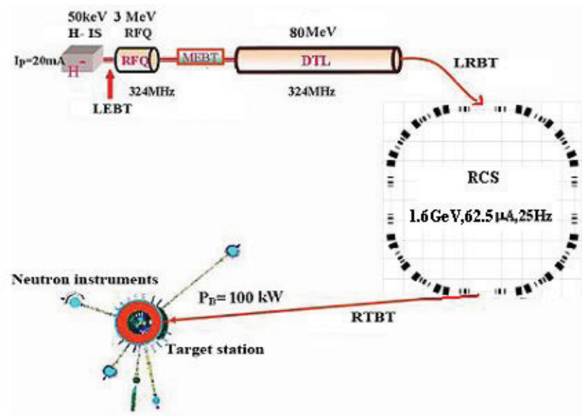

Figure 1: The schematic layout of CSNS.

Table 1: The Primary Parameters for CSNS

	CSNS	Upgrade
Beam power/kW	100kW	500kW
Repetition rate/Hz	25	25
Linac energy/MeV	80	250
RCS energy/GeV	1.6	1.6
Average current/μA	62.5	312.5
Target number	1	1

THE CONSTRUCTION STATUS OF CSNS

The civil engineering for the CSNS facility has been started from the May 2011. Up to now, about 70% has been completed. The two test halls have been put into use, and the tunnel for the linac and RCS will be available soon. The installation of the front end will start soon. The mass production of the accelerator and target components

Figure 2: The components in the test hall.

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are now under way, and the main components has been tested in the test hall of CSNS site. Figure 2 shows the components in the test hall.

THE COMMISSIONING SCHEDULE

The beam commissioning of the CSNS accelerator is planned to start from the ion source and Low Energy Beam Transport (LEBT) commissioning on Nov. 15, 2014. According to the commissioning goal, the commissioning can be divided into 3 stages: The first stage is from NoV. 2014 to Aug. 2017, to commission the low intensity beam to the target; the second stage is from Aug. 2017 to Mar .2018 to increase the beam power to 10kW for the official acceptance; the third stage is from Mar. 2018 to Mar. 2021 to increase beam power to the design goal of 100kW. The detailed beam commissioning schedule is listed in the table 2.

Table 2: The Commissioning Schedule

IS+LEBT	Nov. 15, 2014-Dec.31, 2015
RFQ+MEBT	Feb. 15, 2015-Mar. 31, 2015
DTL1	Aug. 1, 2015-Sep. 30, 2015
L2-4+LRBT	Jul. 1, 2016-Sep. 30, 2015
RCS	Oct. 1, 2016-Jul. 31, 2017
RTBT	Aug. 1, 2017-Aug. 31, 2017
First beam on target	Aug. 1, 2017-Aug. 31, 2017
Beam power to 10kW	Aug. 1, 2017-Dec. 31,2017
To the acceptance goal	Dec. 31, 2017
Official acceptance	Mar. 2018
Beam power to 100kW	Mar.1,2018-Mar.1,2021

THE COMMISSIONING PLAN

The first stage is the most important for the commissioning. In the first stage, the front end, linac, LRBT, RCS, and RTBT will be brought into beam operation, and the primary beam parameters will be characterized with low intensity, and establish and validate the whole commissioning procedures which will be used for the high intensity normal operations. The study of various error effects on the beam, and the dependence of beam performance on various tuning parameters will be done. The study on the beam loss, and measure the beam losses to determine the threshold of beam loss for MPS will be also done at this stage.

Linac Commissioning Plan

Linac commissioning can be divided into 3 phases: MEBT, DTL-1 and DT2-4 commissioning. The MEBT will be commissioned with a temporary movable beam dump put at the end of MEBT. MEBT has all kind of beam instruments in the linac, also two bunchers which are RF components. The beam test in the MEBT is not only for itself, but will also contribute to the whole linac on the commissioning of beam instrument, control system, power supply and RF system.

In longitudinal tuning, we will find the RF set point of buncher cavities with a phase scan method, which will also be adopted in the RF tuning of DTL. The RF amplitudes of two bunchers are determined finally by the beam transmission rate. In transverse tuning, based on the measured beam parameters, calculate the emittance and Twiss parameters at the exit of RFQ, and then the quadrupole strength is set based on the calculated emittance and Twiss parameters. The orbit of will be corrected to a proper value with BPMs and steering magnets. Figure 3 shows the RF driving and FCT on linac.

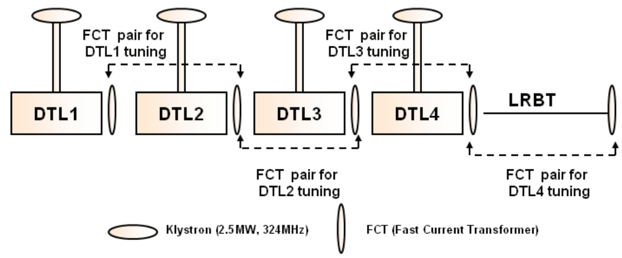

Figure 3: The RF driving and FCT on linac.

In the second phase of linac commissioning, DTL-1 will be tuned before the installation of other three DTL tanks. In the DTL-1 commissioning, a temporary test beam line: D-plate will be adopted, which is consisted of BPM, BCM, FCT, EM (emittance measurement), wire scanner and a beam dump. D-plate will be installed just after DTL-1, and used for performing the necessary beam diagnostic for DTL-1 commissioning. The commissioning will start from the low peak beam current, low repetition rate and short pulse length, and then increase the average beam current to the designed peak current and pulse length in the commissioning of first stage.

In the transverse commissioning, the RF of DTL-1 is turned off and the quadrupole setting is 3MeV beam transport line mode, and measuring the transmission rate. By varying the four matching quadrupoles of the MEBT, we will minimize the measured rms emittance.

Longitudinal tuning, the RF set point of DTL1 will be searched with phase scan method [2,3]. The tuning goal of the RF set point is 1deg in phase and 1% in amplitude. The phase scan curve obtained with a numerical model for the design RF set-point is adopted as the reference curve, and the reference curves is shifted to fit the measured phase scan curves under various RF amplitude settings. The deviation between the measured phase scan curve and the fitted phase scan curve is fitted using a 2nd order polynomial function with respect to the tank amplitude so as to find the optimum tank level. The accuracy of the RF tuning is determined by the phase scan step.

After the commissioning of DTL-1, the D-plate will be removed, and DTL2-4 will be installed together. The beam instruments in the LRBT will be used for the commissioning of three DTL tanks. The three tanks will be commissioned one by one. When the upstream tank is commissioned, the downstream tank will be set as transport line. The tuning procedure for each tank is similar to the DTL-1. Before the fine longitudinal tuning, only the linac-dump2 can be used, for there is no bending

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for beam to reach it. Due to the power capacity limit, the commissioning with linac-dump2 can be performed only with low beam power.

RCS and Transport Line Commissioning Plan

Two dumps at the end of straight section of LRBT and a dump at injection section will be used in the LRBT commissioning. There is a debuncher in LRBT, and the RF set-point should be tuned firstly in the LRBT commissioning, and then the transverse tuning based on the design optics will be done. The optics model can be re-calculated and calibrated based on the measured emittance, twiss parameters and the beam profiles as constraints.

The beam diagnostic devices, BPMs, BCMs, and WSs will be commissioned, and then measure the beam energy, emittance, trajectory and optics. In the beginning, the beam can be tracked by both BPM and BLMs, and The transport efficiency will be measured by using BCMs. The beam orbit can be corrected by correctors to minimize the beam loss. The dispersion in LRBT can be measured by adjusting the linac energy via the accelerating phase of the last cavity. Beam based alignment for BPMs and quadrupoles offset are considered. Before injection into the RCS, chopping tuning will be performed.

There are two dumps can be used in the RCS commissioning: Inj-dump and RCS-dump. For the injection beam commissioning, the injection beam is firstly directed to the injection dump by pull out the main stripping foil, and with the second stripping foil, the beam will be directly transport the injection dump. By using three Multi-wire Profile Monitors (MWPM) near the stripping foil, the position and angle of injection beam can be measured, and also the twiss parameters of injection beam can be evaluated by three MWPMs and other profile monitors in LRBT.

The RCS will be commissioned firstly with DC mode and single shot pulse. The transverse secondary collimators can be used as beam dump. By using turn by turn BPM and BLM to track the beam, perform the storage of the first beam, and wall current monitor (WCM) can be used to measure the beam current. After the beam has been stored, the injection bump orbit need to be precisely tuned. By using one turn by turn BPM, with a single short mini-pulse injection beam (less than 150ns), the relative injection orbit height can be precisely measured. The precise measurement of relative injection orbit height is one of the most important issue in the injection commissioning.

For multi-turn injection, firstly, can be performed with fixed injection point, and then the phase space painting will be performed first in one plane, and then in both plane. The painting beam will be extracted immediately after painting, and the painting beam distribution can be measured by using wire scanner in the RTBT beam line.

With the stored beam, closed orbit distortion, linear optics can be measured and corrected. Beam loss and collimation study should be carefully studied for high intensity and AC mode commissioning.

Based on the optimized DC mode with RF cavities, with the short injection pulse, AC mode can be commissioned. The lowest frequency will be set according to the measured energy of injection beam. Check the tracking among 5 families Q power supply and 1 family dipole power supply based on the tune and twiss parameter measurement. The COD and optics parameters during the different stage of a RCS cycle by ICA method using turn by turn BPMs. 8 cavities will be firstly independently commissioned with beam, and then commissioned together. For AC mode, the voltage curve should be optimized based on the beam.

Extraction will be commissioned for both DC and AC mode. The diagnostics will be commissioned in the RTBT line up to dump, and the extracting beam will be firstly directed to the RCS dump through the RDBT dump line. The kicker should be checked independently with small amplitude, and the timing of kicker should be adjusted. In the beginning, BLMs in RCS and RTBT will be the tool to track the extraction procedure, and the extraction condition will be established by tuning the timing and amplitude of kickers. The Interlock between RF phase and LEBT chopper will be checked, as well as the interlock between RF phase and extraction kickers. The emittance of extraction beam can be measured with wire scanners in RTBT.

The optics of RTBT line up to dump will be corrected based on beam measurement, The orbit and optics will be corrected based on beam measurement and beam loss. The effect of octupoles will studied with low intensity beam. The beam loss on the 3-collimators in front of the target will be measured to determine the local optics.

THE DEVELOPMENT OF APPLICATION SOFTWARE

The high level application software has been developing based on the XAL, an application software package developed by SNS. Some application software has been transplanted, and some new function has been developing. All the application software will be available before the commissioning of the corresponding part of accelerators.

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