BEAM COMMISSIONING PLAN FOR CSNS ACCELERATORS

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Abstract

The China Spallation Neutron Source (CSNS) is now under construction, and the beam commissioning of ion source will start from the end of 2013, and will last several years for whole accelerators The commissioning plan for CSNS accelerators is presented in the presentation, including the commissioning correlated parameters, beam instrumentation in used commissioning, the goal at different commissioning stages, and some key commissioning procedures for each part of accelerators. The detailed schedule for commissioning is also given.

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 related 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 onto 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.

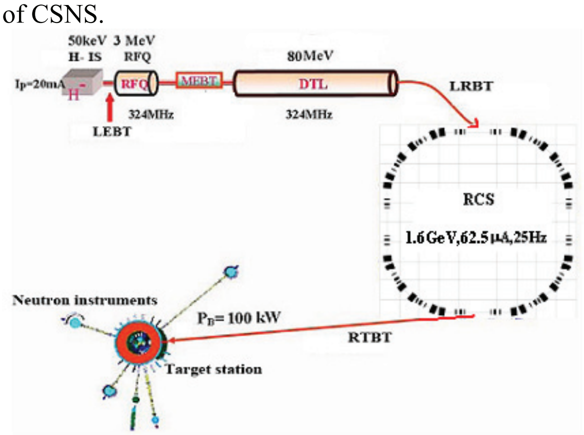

Figure 1: The Schematic Layout of CSNS

Table 1: The Main Parameters of CSNS RCS

	CSNS	Upgrade
Beam power (kW)	100	500
Repetition rate (Hz)	25	25
Target number	1	1
Average current (μA)	62.5	312
Proton energy (GeV)	1.6	1.6
Linac energy (MeV)	80	250

The construction of CSNS has been started in September 2011. The commissioning will start at the end of 2013. Starting from the ion source, the accelerators will be installed and commissioned sequentially.

THE COMMISSIONING SCHEDULE AND THE GOAL AT EACH STAGE

According to the commissioning goal, the commissioning can be divided into 3 stages: The first stage is from Oct. 2013 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 official acceptance; The third stage is from Mar. 2018 to Mar. 2021 to increase beam power to the design goal of 100kW. 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 will be done, and the measurement of the beam losses to determine the threshold of beam loss for MPS will be also done at this stage. Table 2 shows the planned commissioning schedule. Table 3 shows the beam dump will be used in the commissioning.

Table 2:. Planned commissioning schedule

Front end	Oct.18,2013-Apr.10,2014
RFQ,MEBT,DTL1	Jun.5,2014-Aug.27,2014
DTL2-4	Jun.302015-Nov.3,2015
LRBT+Linac	Nov.4,2015-Jan.6,2016
RCS	May13,2016-Mar.2,2017
RTBT	Mar.3,2017-Aug.24,2017
First beam on target	Aug.24, 2017
Beam power to 10kW	Aug.25,2017-Mar.3,2018
Beam power to 100kW	Mar.3,2018-Mar.3,2021

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Table 3: Beam dumps used in the commissioning

Beam dumps	Beam energy	Power limit
Linac-dump1	250MeV	4kW
Linac-dump2	250MeV	200W
Temp. dump	30MeV	160W
Inj-dump	250MeV	2kW
RCS-dump	1.6GeV	7.5kW

LINAC COMMISSIONING

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. Fig. 2 gives layout of MEBT. MEBT has all kind of beam instruments which will be used in the linac commissoning, 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 at the exit of DTL-1. 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 will be corrected to a proper value with BPMs and steering magnets.

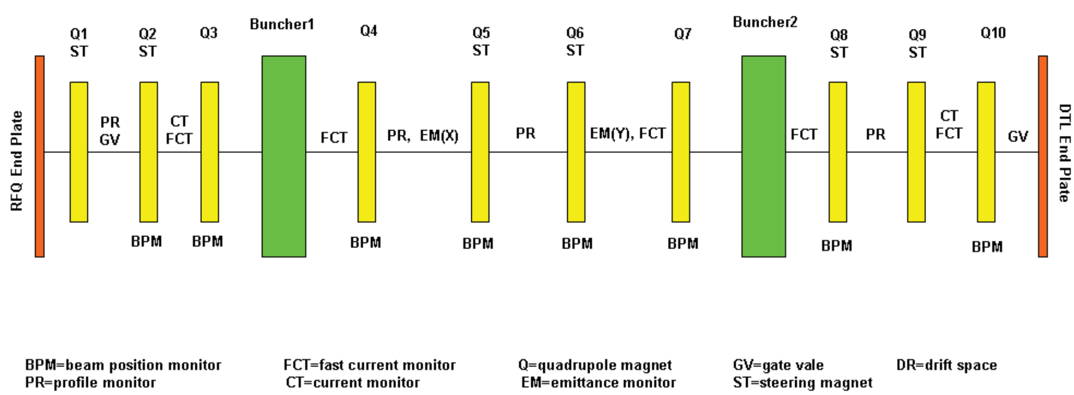

Figure 2: The layout of MEBT.

Table 4: The Main Parameters of DTL Tanks

Tank number	1	2	3	4	total
Output energy (MeV)	21.67	41.41	61.07	80.09	80.09
Number of cell	64	37	30	26	157
RF driving power (MW)	1.35	1.32	1.32	1.34	5.33
Total RF power (MW) (I=15mA)	1.63	1.62	1.62	1.63	6.5
Accelerating field (MV/m)	2.86	2.96	2.96	3.0	
Synchronous phase (degree)	-35 to -25	-25	-25	-25	

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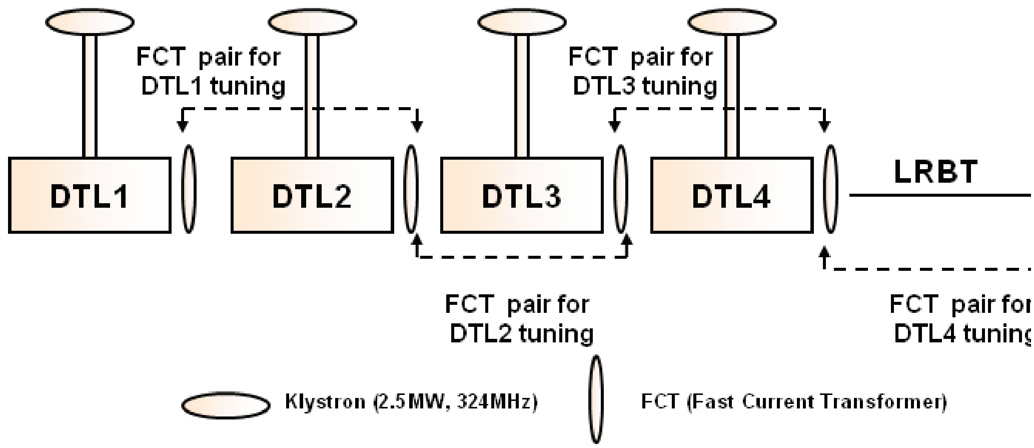

Figure 3: The RF driving and FCT on linac.

In the second phase of linac commissioning, DTL-1 will be tuned before the installation of other three DTL tanks. Table 4 shows the main parameters of DTL tanks. In the DTL-1 commissioning, a temporary test beam line, called 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 the transmission rate will be measured. By tuning the four matching quadrupoles of the MEBT, we will minimize the measured rms emittance.

For longitudinal tuning, the RF set point of DTL-1 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, since there is no bending 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 BEAM TRANSPORT LINE COMMISSIONING [4]

Two dumps at the end of straight section of LRBT and a dump at injection section will be used in the LRBT commissioning. Figure 4 shows the layout of LRBT and its branch LDBT, and Table 5 shows the beam diagnostics in LRBT and RTBT. There is a debuncher in LRBT, and its 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 instruments, 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 which can be used in the RCS commissioning: Inj-dump and RCS-dump, as shown in table 3. Table 6 shows the beam diagnostics in RCS.

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Table 5: The Beam Diagnostics in LRBT and RTBT

Section	CT	FCT	BPM	BLM	FBLM	WS	WCM	MWPM
LRBT	2	3	20	28		7	3	5
RTBT	4		33	50	2	8		2
Inj. Dump	1		2	3	1			1
R-Dump	1		2	6	1			1

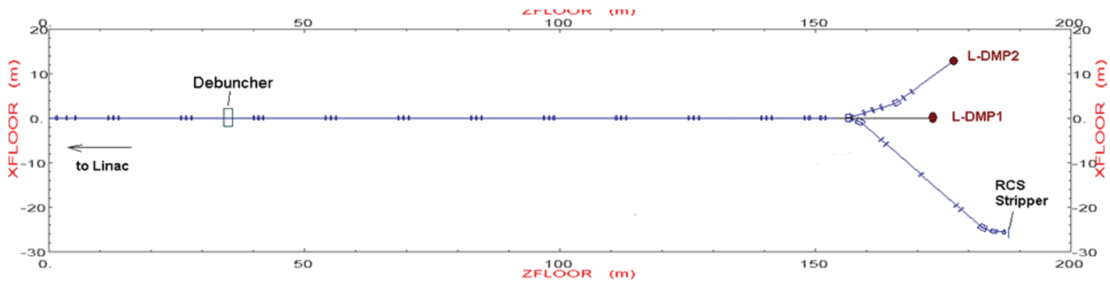

Figure 4: The layout of LRBT and its branch LDBT.

Table 6: Beam Diagnostics in RCS

	SCT	MCT	DCCT	FCT	WCM	BPM	BLM	FBLM	tune
RCS	1	1	1	3	2	32+3	72	9	2

For the injection beam commissioning, the injection beam is firstly directed to the injection dump by pulling 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 the 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 re-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 issues in the injection commissioning.

For multi-turn injection, firstly, it 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. The Debuncher parameters will be optimized according to the estimation of momentum spread and beam loss.

Based on the optimized DC mode with RF cavities, with the short injection pulse, AC mode commissioning can be performed. 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 will be measured 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 in the RTBT line up to dump will be commissioned, 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

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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, and the remain part of RTBT will be commissioned upon target condition. 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.

SUMMARY

The commissioning plan for CSNS accelerators is given, and the detailed schedule for commissioning is also described. The goal at different commissioning stages, and some key commissioning procedures for each part of accelerators are considered and presented.

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