COMMISSIONING PLAN FOR THE CSNS LINAC*

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Abstract

The linac of the China Spallation Neutron Source (CSNS) will be commissioned from October 2013. The linac will be commissioned in three phases. The delivery of beam to the RCS is planned for October 2015. This paper describes the commissioning plan for the linac. Techniques for finding the RF set-point, matching and steering are presented, as well as codes to assist in the beam commissioning.

INTRODUCTION

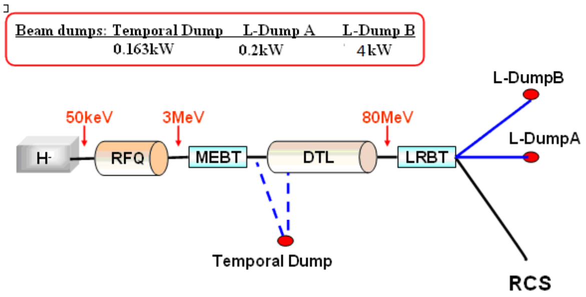

Figure 1: CSNS Linac layout.

The layout of the CSNS linac is shown in Fig. 1. The linac comprises a volume-production type H^- ion source, a 3 MeV Radio Frequency Quadrupole (RFQ), an 80MeV Drift Tube Linac (DTL) and several beam transport lines. Operation frequency is 324MHz for the RFQ and DTL.

The required beam current for the RCS at 80MeV is 15mA at 0.5msec, 25Hz. The 0.5msec long macro-pulses are chopped at the RCS revolution frequency into intermediate pulses of 489ns duration with 489 nsec gaps. The electro-static pre-chopper in the Low Energy Beam Transport (LEBT), which is between the ion source and the RFQ, chop the beam in the rise and fall times of 15~20ns.

The CSNS linac will be commissioned in 3 phases: Front-end, DTL1 and DTL2-4 commissioning. During the commissioning of Front-end and DTL1, a temporal beam diagnostic system will be used, which is installed after the DTL 1st tank. This temporal dump is available with the maximum power of 0.163kW. Once DTL1 commissioning is finished, the temporal beam diagnostic system will be replaced by DTL2 and DTL installation and testing will be completed.

During the third phase, DTL2 to 4 will be commissioned one after the other with the same in-line diagnostics that will be used during operation. For DTL4, the diagnostics is placed in the LRBT. There are two beam dumps for DTL2-4 commissioning, which are L-Dump A and L-Dump B in Fig.1.The maximum power of L-Dump A is 0.2kW and the maximum power of L-Dump B is 4kW.

COMMISSIONING GOAL

The primary goal set out for linac commissioning is to deliver $2.34*10^{14}$pps (particles per second) at the correct energy to the RCS. Typical beam parameters for the beam commissioning are summarized in Table 1.

Other commissioning goals are achieving the design beam quality, measuring the pulse to pulse jitter in beam parameters (e.g. beam centre), quantifying beam loss and achieving the maximum beam transporting rate possible. After the beam is successfully accelerated to 80MeV, a single shot operation is required for the RCS commissioning. In this mode, one macro-pulse is injected into RCS only when a request is placed, which is realized by the ion source and pre-chopper. It can produce a beam pulse of 150ns~420 μ s when the beam request is placed.

Table 1: Typical Beam Parameters for Commissioning

	Peak current	Pulse width	Repetition
Low-current	5mA	0.05msec	1Hz
Normal-current	15mA	0.05msec	1Hz
Long-bunch	5mA	0.5msec	1Hz
Commissioning goal	15mA	0.5msec	5Hz
Single shot	5mA	150ns~420 μ s	Sporadic

FRONT END

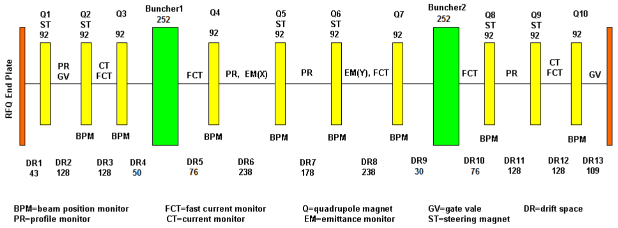

Figure 2: Layout of the CSNS MEBT.

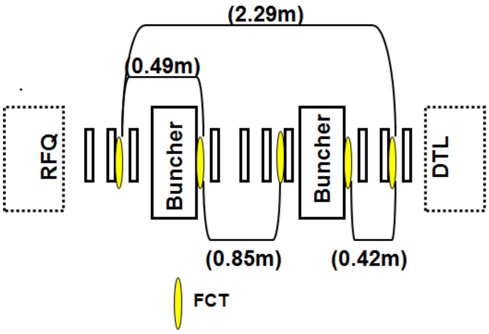

Figure 3: Schematic of FCT layout for the RF tuning of bunchers.

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The commissioning of the Front end will start from October 2013 and last about 120days. The MEBT is a complex beam transport line as shown in Fig 2. Its main role is to perform transverse and longitudinal matching to the succeeding 324MHz DTL. The MEBT includes ten quadrupole magnets (Q1~Q10) for transverse matching, two 324MHz buncher cavities for longitudinal matching, and various beam diagnostic instrumentation for beam diagnosis. We also have 6 two-plane steering magnets for beam steering.

First up, we use the low-current mode for linac commissioning, as shown in Table 1. The output energy of RFQ will be measured by a time-of-fight technique with 3 FCT's in the MEBT [1], as shown in Fig 3.

The transmission ratio through the MEBT will be measured with two CT's (Current Transformers), while the bunchers are turned off. We will use several steering magnets to achive nearly 100% beam transmission efficiency.

Then the RF set point of bunchers will need to be determined, this is done by means of a phase scan method: one observes the beam induced phase difference between two FCTs after each buncher, which is a function of RF phase and refer to as a "phase scan curve". The phase scan measurement is repeated with different tank level to compare with the PARMILA numerical model [2-3]. Then the tank amplitude is determined by the way that the difference between the measured phase scan curve and the simulated one minimum. The FCT pairs used for the RF tuning of bunchers are shown in Fig. 3.

For longitudinal matching, typically the two bunchers will be used. For transverse matching, mainly the last four quadrupoles in the MEBT will be used. The strategy of the MEBT matching is as follows [2]:

1. We first fit Twiss parameters ($\alpha_x, \alpha_y, \beta_x, \beta_y$) and emittance ($\varepsilon_x, \varepsilon_y$) at the entrance of the MEBT to the measured beam RMS widths at 4 wire scanners and transverse emittance and Twiss parameters at a double-slit emittance monitor with a Trace3D model.
2. Secondly, using the fitted Twiss parameters and emittance at the entrance of the MEBT, we will calculate the gradients of four matching magnets, the electric field and phase settings of buncher 1 and 2 to fulfil the matching conditions with a Trace 3D model. Since lacking of diagnostic to measure longitudinal Twiss parameters and emittance, simulated results from PARMTEQM are used for matching calculation.

Then we gradually increase beam current from 5mA to 15mA with step width of 5mA. Since the beam Twiss parameters and emittance changed as current, we need find RF set-point for bunchers and do matching again. With low current of 5mA, we will extend slightly the pulse length from 50 μs to the design value 500 μs and increase the repetition from 1Hz to 5Hz. During this process, the beam transmission ratio should be surveyed carefully.

DTL

The DTL consists of 4 tanks operating at 324MHz with final output energy of 80MeV.The accelerating field is stabilized by post couplers. The transverse focusing is arranged in an FFDD lattice utilizing electro-magnet quadrupoles. The main parameters of the DTL are shown in Table 2.

Table 2: Main Parameters of the CSNS DTL

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)	1.62	1.62	1.62	1.63	6.49
Accelerating field (MV/m)	2.86	2.96	2.96	3.0	
Synchronous phase (degree)	-35 to -25	-25	-25	-25	

DTL1

The commissioning of the first tank will start from January 2014 and last about 60days. A temporal beam diagnostic system will be positioned directly after the first tank. A full suite of beam diagnostic instrumentation is planned, including profile, current, phase, energy, and emittance measurements. DTL1 commissioning can then proceed with the measurements as listed in Table 3.

Before commission the first tank, we need measure the transmission rate to check the alignment, while the RF of DTL1 is turned off and the electro-magnet quadrupoles in DTL1 are set to 3MeV beam transport mode.

In DTL commissioining, finding a correct RF set-point is an essential procedure in avoiding excess beam quality deteriorioration. The basic idea of the RF tuning is based on the phase scan method. Each DTL tank has an FCT at its exit as shown in Fig4. The output energy from each tank is measured with two downstream FCT's based on the TOF (Time of Flight) method. Fig 5 show the phase-scan curves for DTL1 obtained with PARMILA simulations. To enable effective matching, a typical scanning range adopted is about ±30°.

Table 3: DTL 1 Measurements with Temporal Beam Diagnostic system

Measurement	Technique	Diagnostic
Profile(transverse)	Validate algorithm	Wire scanner
RF ϕ & amp	time-of-fight phase scan	2 FCT
MEBT matching (transverse)	validate algorithm	Quad & Emittance monitor
MEBT matching (longitudinal)	transmission	CT
steering	validate algorithm	BPM & steering magnet

The quadrupole setting for the DTL1 is from physical design. After the beam is successfully accelerated to the design value at the end of DTL1, we will turn to optimize the transverse matching of the MEBT. By varying the last four matching quadrupoles of the MEBT, we will minimize the RMS emittances measured from emittance scanner at the end of DTL1 [5].

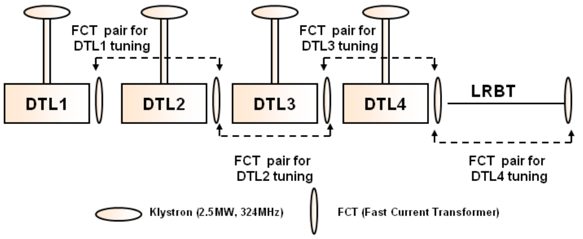

Figure 4: Scheme of the FCT layout for the DTL tuning.

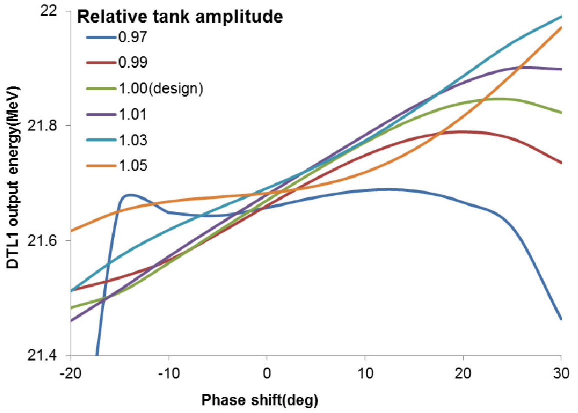

Figure 5: Phase scan curves for the DTL1 (simulated).

DTL2-4

The commissioning of the DTL2-4 will start from January 2015 and last about 90days. The RF tuning procedure will be same as the DTL1. Since the space between two tanks equals $1\beta\lambda$, the cavity phase of tank2-4 can be set at the point same as DTL1.

The quadrupole setting for the DTL2-4 is from calculation according to equipartitioning requirement.

CONCLUSION

The commissioning plan for the CSNS linac is presented. In the DTL commissioning, the phase scan method will be used to find the correct RF set-point. The Twiss parameters matching combined with minimum emittance scan method will be used to realize beam output from RFQ smoothly transporting into DTL.

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