BEAM COMMISSIONING RESULTS OF THE CSNS LINAC

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Abstract

The China Spallation Neutron Source(CSNS) accelerator systems is designed to deliver a 1.6GeV, 100kW proton beam to a solid metal target for neutron scattering research. It consists of a 50keV H^- Ion Source, a 3MeV Radio Frequency Quadrupole (RFQ), an 80MeV Drift Tube Linac (DTL), and a 1.6GeV Rapid-cycling Synchrotron (RCS). The beam commissioning has been started since April 2015. The Front End and three of the four DTL tanks have been commissioned, while the last tank and the RCS will be commissioned at the autumn this year. At the end of the DTL3, beam has been accelerated to 61MeV with nearly 100% transmission, other parameters such as peak current, transverse emittance and beam orbit have reached the design goal. Results and status of the beam commissioning program will be presented.

INTRODUCTION

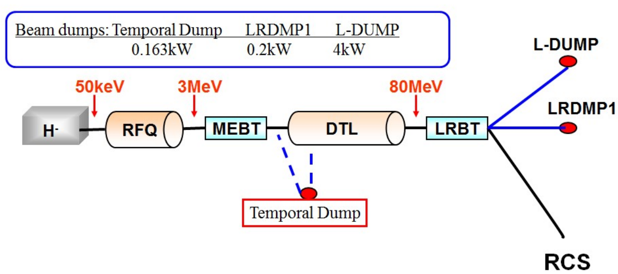

Figure 1: CSNS Linac layout.

The layout of the CSNS Linac is shown in Fig. 1. Details of the Linac design can be found in [1]. The DTL consists of four tanks, and each tank is fed by a 324MHz, 3MW klystron. However, since 3 of 4 klystrons are available at present, only tank 1to 3 have been commissioned and the beam was successfully accelerated to 61MeV. After that, the beam was transported through the last DTL tank and Linac to RCS Beam Transport (LRBT), and then directly to the LRDMP1. Until May 2017, four runs of Linac beam commissioning have been performed. In the first and the second runs, the Front-End and the DTL1 have been commissioned, with using a temporal dump [2]. In the third run, the DTL1 was re-commissioned and the 21MeV beam was transported to the LRDMP1 for the first time. In the fourth run, DTL tank 1 to 3 have been commissioned, and the 61MeV beam was firstly bent to the L-Dump. The commissioning in this run were performed with the peak current of 10mA, the pulse width of 100 μ s, and the repetition rate of 1Hz. Figure 2 shows an overlay of Current Transform signals along the Linac. The beam transmission of the RFQ is about 92% and that of the DTL is about 97%. Transverse matching in the MEBT has been performed. However, it made no improvement in beam transmission of the DTL.

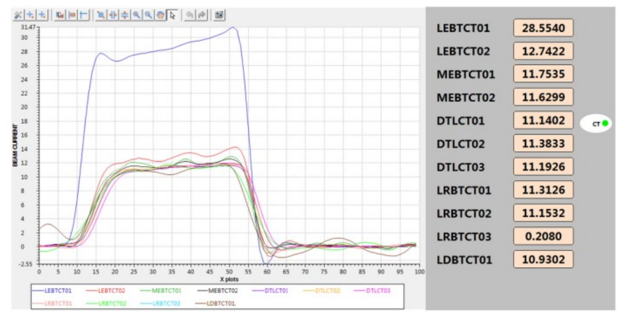

Figure 2: Current Transform signals along the Linac.

MEBT COMMISSIONING RESULTS

The MEBT is used for matching beam output from the RFQ into the following DTL transversely and longitudinally. It consists of 10 quadrupoles, 6 steering magnets and two 324MHz bunchers. Besides optic elements, there is a suit of diagnostics to monitor beam.

Transverse Twiss Parameters

Four wire scanners are located along the MEBT to measure the Twiss parameters of the RFQ output beam. Table 1 shows the comparison of the design values (with PARMTEQM) and the measured values. The Twiss parameters in the horizontal plane are agreed well with the simulated values, while those in the vertical plane are obviously deviated from the simulated values.

Table 1: Twiss Parameters at the MEBT entrance (I=10mA)

	α	β [mm/mrad]	Emittance rms, normalized [πmm mrad]
Horizontal			
Measured	-1.716	0.256	0.215
Simulated	-1.773	0.233	0.215
Vertical			
Measured	1.944	0.173	0.211
Simulated	0.639	0.074	0.212

*This work is supported by National Natural Science Foundation of China (11505101).
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ISBN 978-3-95450-182-3

RF Tuning of Buncher

There are two bunchers in the MEBT for longtidutinal matching. The phase scan method is used for finding the RF set points of two bunchers. The beam phase is provided by Fast Current Transforms (FCTs) which are located at the downstream of the measured cavity.

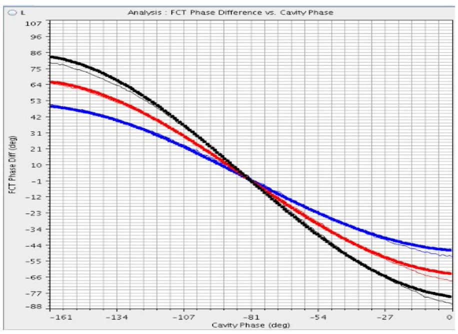

Figure 3: Measured phase differences (degrees) between two FCTs as functions of the buncher01 cavity phase.

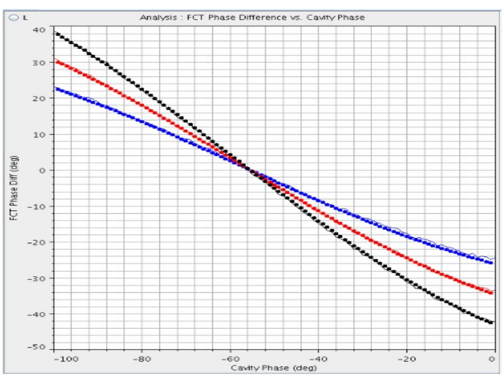

Figure 4: Measured phase differences (degrees) between two FCTs as functions of the buncher02 cavity phase.

As shown in Fig. 3 and 4, three sets of measured phase differences vs. cavity phase were recorded. Plotted are experimental data (solid lines) and simulation results (solid circles) for three different RF amplitudes. The red curve was taken at nominal RF amplitude, the blue one at 25% below nominal, and the black one at 25% above nominal. The bunchering phase is located at the intersection of the three curves. At this point, the amplitude of the FCTs' signal was observed maximum.

DTL COMISSIONING RESULTS

The DTL consists of four accelerating tanks with final output energy 80MeV. The transverse focusing was arranged in a FFDD lattice utilizing electric-magnet quadrupoles. Because no drift tube is empty, diagnostics have to be imbedded between tanks. After each tank, a FCT and a CT were installed to monitor beam phase and current. Between DTL 3 and DTL 4, a Beam Position Monitor (BPM) was added for monitoring beam orbit.

For DTL tanks, it is essential to find the correct tank RF field amplitude and phase to minimize energy spread and mismatch, which are highly required by the following RCS. A method called "phase scan signature matching" was adopted for determining the RF set points of DTL tanks [3]. The method involves varying an RF cavity amplitude and phase settings over a fairly large range and comparing the measured downstream beam phase response "signatures" to model predictions. A software application called PASTA was applied for phase scan and analysis [4]. The RF amplitude, relative phase of beam and the input energy were used as variables in model fitting.

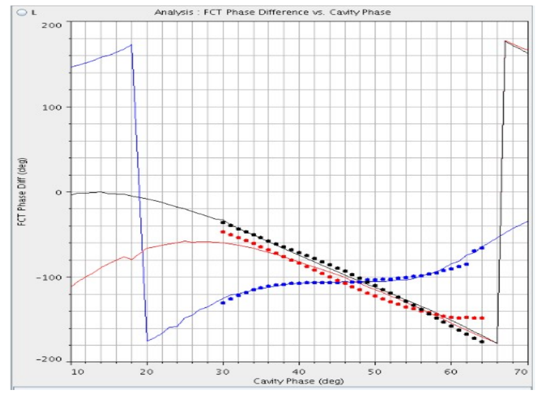

Figure 5: Plots of the DTL tank1 phase scan for nominal RF amplitude (red), 3% below nominal (blue) and 3% above nominal (black).

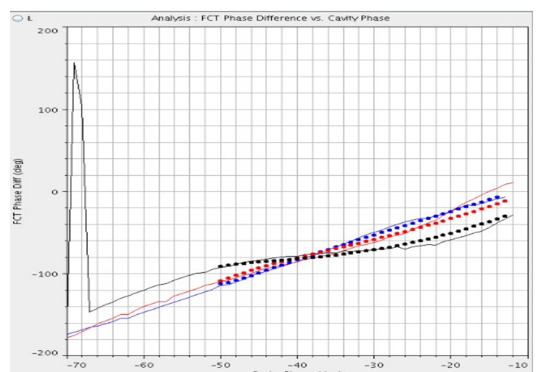

Figure 6: Plots of the DTL tank2 phase scan for nominal RF amplitude (red), 4% below nominal (blue) and 2% above nominal (black).

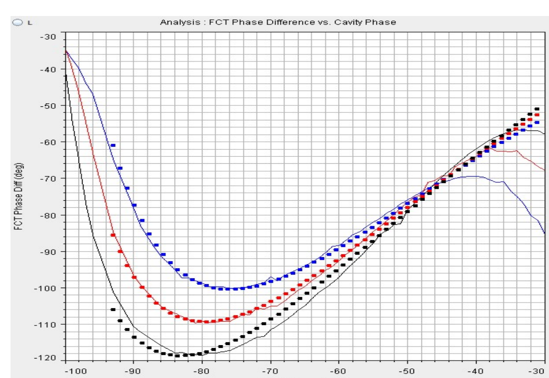

Figure 7: Plots of the DTL tank3 phase scan for nominal RF amplitude (red), 2% below nominal (blue) and 2% above nominal (black).

ISBN 978-3-95450-182-3

Figures 5 to 7 show the phase scan results for DTL three tanks. The solid lines represent the measurement data and solid circles represent the model fitted data. The vertical axis shows the phase differences between two FCTs downstream of the measured cavity. The horizontal axis is the phase of the tank RF field. The agreement between the measurement and the model fit is excellent.

Time of flight measurement was also performed. For each tank, three FCTs were used to form two short pairs and a long pair. The two short pairs were used to determine the number of integer periods and the long pair was used to calculate beam energy. The beam energy calculated with TOF and phase scan are summarized in Table 2. The deviation of measured beam energy from the design value is less than 1%.

Table 2: Beam energy from two methods

	TOF [MeV]	Phase scan [MeV]	Design [MeV]
RFQ	3.027 ±0.01	3.029	3.026
DTL1	21.685±0.01	21.802	21.669
DTL2	41.566±0.14	41.52	41.415
DTL3	61.09±0.34	60.917	61.072

CONCLUSION

The CSNS DTL1-3 have been fully commissioned, the primary design goals of peak current, and beam energy have been achieved. The last tank will be commissioned in autumn this year.

The beam loss of 2% in DTL and the difference between the design and the measured Twiss parameters of the RFQ output beam are still need further investigation.

ACKNOWLEDGEMENT

The beam commissioning of CSNS MEBT and DTL has been performed with the efforts of all the members of CSNS accelerator division. We would also like to acknowledge the help from the conventional facility division.

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ISBN 978-3-95450-182-3