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BEAM INSTRUMENTATIONS AND COMMISSIONING OF LINAC IN CSNS

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Abstract

China Spallation Neutron Source (CSNS), the biggest platform for neutron scattering research in China, will be finished built and run in the end of 2017. It mainly consists of an 80MeV H- linac and an 80MeV to 1.6GeV Rapid Cycling Synchrotron, two beam transport lines, one target station and relative ancillary facilities. The linac beam commissioning with beam loss monitors, current transformers, BPMs, beam profile monitors and beam emission measurement has been the main task since last year. Beam instrumentations, commissioning of the temporary 60 MeV linac will be discussed in this paper.

INTRODUCTION

Beam instrumentations distributed on the CSNS linac are presented in Fig. 1. After the 50keV H- source, there are 2 beam current monitors and an emission monitor installed on the low energy beam transport line (LEBT). At the middle energy beam transport line (MEBT) there are 2 self-made FCTs to monitor the beam current, 7 strip-line beam position monitors and 4 wire scanners to monitor the beam profile for measuring the Twiss parameters of the RFQ output beam. The 4-tank 324MHz drift tube linac (DTL) is designed to accelerate the H- beam from 3MeV to 80MeV. At the exit of the 4th tank of an 80MeV drift tube linac (DTL), 5 Bergoz FCTs are used to monitor the beam phase for energy measurement by means of TOF. At present commissioning period, only 3 of the 4 klystrons are available to feed 3MW power into the corresponding DTL tank, therefore tank 1 to 3 have been commissioned and the beam was successfully accelerated to 61MeV. After that, the beam was transported through the last DTL tank and the linac to RCS Beam Transport line (LRBT), and finally directly to the LRDMP1. Until May 2017, four runs of linac beam commissioning have been performed [1].

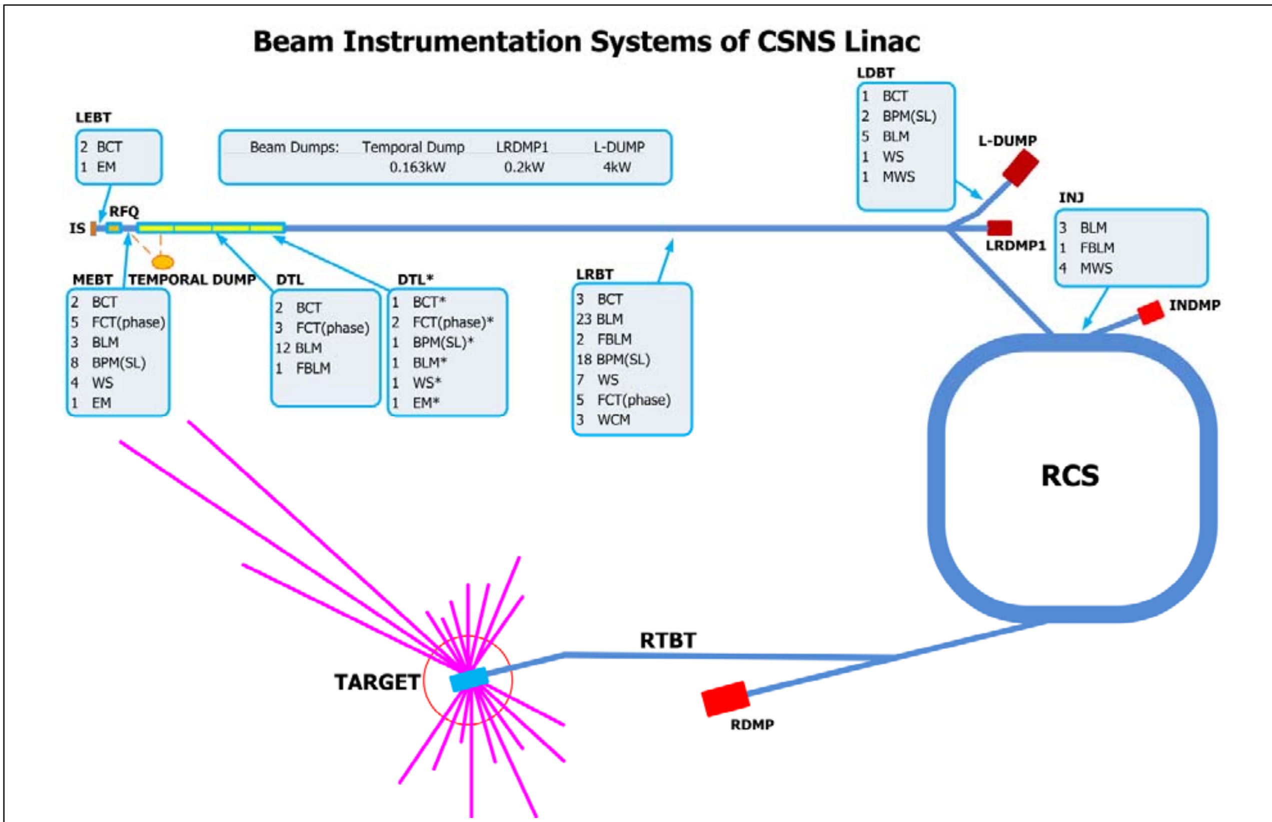

Figure 1: Layout of beam instrumentations on CSNS linac.

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BEAM TRANSMISSION IMPROVEMENT

The beam current transformers (BCT) were made by the BI group of CSNS, which consist of amorphous magnetic cores with high permeability and were winded up by 150 turns of varnished wires. During the 500µs pulse width, the BCT output droop is less than 1%. A Bergoz FCT located at the exit of DTL tank 1 can also work as a BCT for phase detection, by using an RF switch to connect it to different electronics. When working as a BCT, the electronics and the read out system hold and recover the waveform to the beam envelope, just like other BCTs which are showed in Fig. 2. The beam current flat was averaged to provide the EPICS broadcast PV value for calculating the beam transmission efficiency at concerned sections of linac.

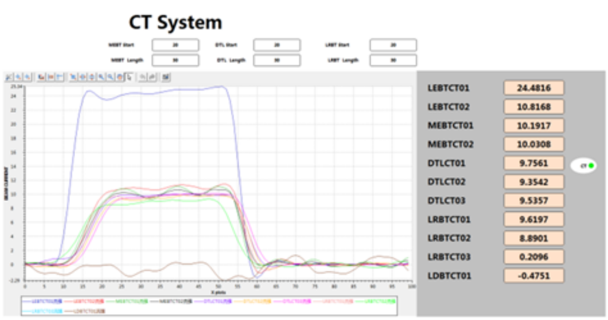

Figure 2: Beam current measurement results from the transformers along the LEBT, MEBT, DTL and LRBT

The plastic scintillators photomultiplier detector combination with a gain factor of 5×10^5 were adopted to monitor the beam loss on the MEBT, which are post-processed by Libera electronics. Two of the three sets were installed beside the bunchers and the third one at the end of MEBT. While ion chambers manufactured domestically with different gas filled were used to help improving the beam transmission. At the beginning of 20MeV beam (DTL1) commissioning, the sensitivity of original ion chambers (schematic drawing showed in Fig. 3) filled with 70%Ar+30%N_2 were not good enough to detect the beam loss, thus an instead plan B of filling with 90%Xe +10%CO_2, BF_3 or 90% Xe+10%Ar was tried and successful on detecting the gamma ray emission during the 20MeV beam commissioning (at the exit of DTL tank #1). When the beam current showed a decrease, the output of the ion chambers increased correspondingly. Commissioning by this method the beam transmission efficiency in DLT1 improved 2%. Readouts of the BLM electronics (designed by BI group) were shown as Fig. 4 on the screen in the accelerator control center. Finally, the beam transmission efficiency of the RFQ reached 80% and that of the DTL is about 97%.

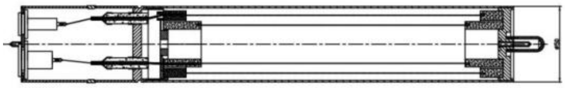

Figure 3: Schematic of ion chambers in CSNS.

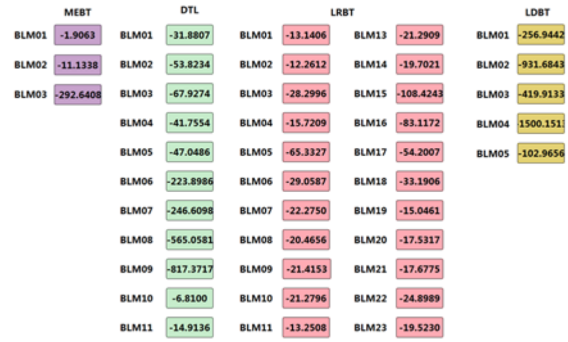

Figure 4: Readout value of BLMs in linac commissioning.

BEAM ENERGY MEASUREMENT

The H- beam energy was measured by means of Time of Flight (TOF) as illustrated in Eq. (1) and (2) . The beam phase is provided by Bergoz Fast Current Transforms (FCTs) which are located at the downstream of the measured cavity. Before the electronics of the phase detectors were manufactured and accepted by local test, wide bandwidth oscilloscopes such as Tektronix TDS7254B (2.5GHz, 10GSa/s, 250fs/pt) were used to measure the phases of FCT pairs. The sample rate of TDS7254B is suitable for a 324MHz RF signal and the phase measurement accuracy of TDS7254B achieved $\pm 1^{\circ}$.

When the electronics of FCT were available, with a phase resolution of 0.1° for a standard signal generator and a stability of 1° for the real beam, the beam energy were measured more accurately for DTL 1# to 3#. The details of the debuncher RF tuning using phase scan technique were presented in [1, 2]. A comparison of the designed energy and measurement is showed in Tab. 1. The deviation of measured beam energy from the designed value is less than 1%.

$$v = \frac{l}{nT + \frac{\Delta\emptyset}{360}T}, \quad where\ T = \frac{1}{324\text{MHz}} \quad (1)$$

$$E_k = m_0 c^2 \left(\frac{1}{\sqrt{1 - v^2 / c^2}} - 1\right), \quad (2)$$

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Table 1: Comparison Design and Measurement Results of CSNS Linac Beam Energy [1]

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

BEAM POSITION MONITORS

Due to the high space resolution of strip-line (SL) beam position monitors, there are 7 BPMs (SL) installed on the MEBT and 21 ones on the DTL and LRBT of CSNS. The electronics for linac BPMs were commercial products of Bergoz (MX-BPM-324MHz) and Libera separately.

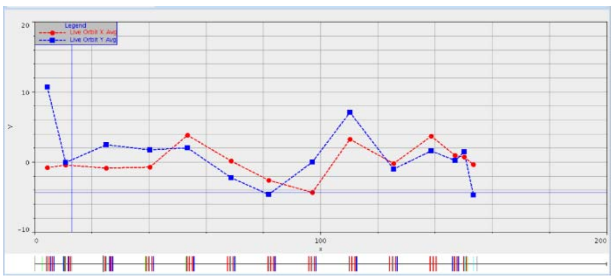

Figure 4: Beam orbit measured by LRBT BPMs.

An automatic BPM calibration system is showed in Fig. 5. The RF signal was generated by SRS382. The stepping motor was controlled by an NI PXI-7340 card and data acquisition by a PXI-6356card. The control program and data acquisition software were developed both for linac and RCS BPMs. A calibration accuracy of 0.1mm was achieved by trying different motor steps and moving ranges.

Figure 5: Automatic BPM Calibration System.

LINAC COMMISSIONING

In the commissioning of CSNS linac, the transverse matching includes RFQ to DTL (MEBT) and DTL to LRBT triplet section. There are four wire scanners (WS) on MEBT to measure the accurate beam size and emittance for Twiss parameters calculation [3]. Figure 6 gives a beam profile scanning results of MEBTWS03.

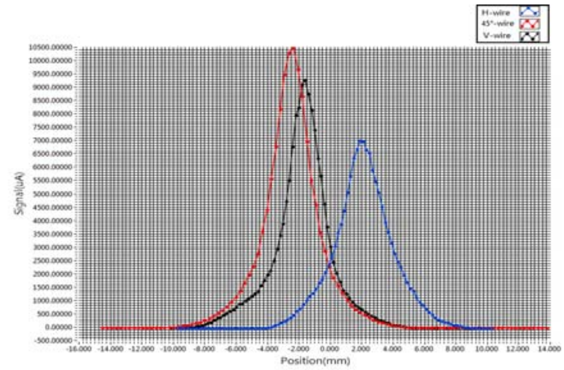

Figure 6: Beam profile measured by MEBTWS03.

Two bunchers were installed at the MEBT for longitudinal matching. The phase scan method is used for finding the RF set points of two bunchers [1]. Figure 7 gives the measured phase differences between two FCTs as functions of the buncher 01 cavity phase.

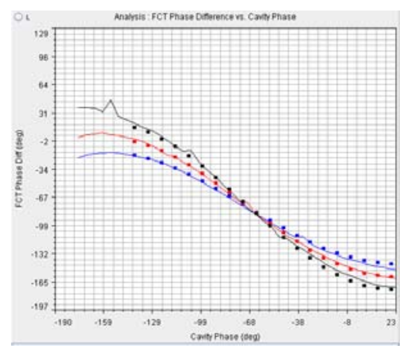

Figure 7: Measured phase differences (degrees) between two FCTs as functions of the buncher01 cavity phase.

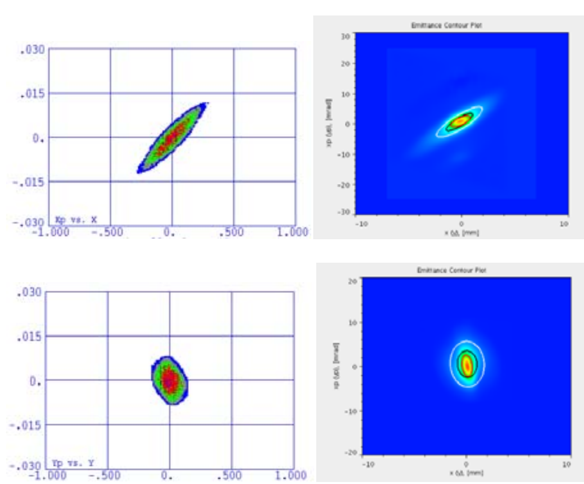

Figure 8: Comparison of the simulation and EM measurement of the beam distribution at the MEBT EM location.

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CONCLUSION

The beam instrumentations of CSNS linac were tested fully in the commissioning on RFQ, MEBT, DTL and LRBT. The beam peak current, and energy have been achieved to the design value. The beam transmission efficiency of DTL tank 1# to 3# reached nearly 100%. The last DTL tank will be commissioned in autumn this year.

ACKNOWLEDGEMENT

The beam commissioning of CSNS linac has been endeavored by all the members of CSNS accelerator division. We would also like to acknowledge the help from the conventional facility division and the corresponding technicians of domestic factories.

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