ISBN: 978-3-95450-194-6 ISSN: 2226-0366 doi:10.18429/JACoW-LINAC2018-TUPO114

BEAM DYNAMICS STUDIES FOR THE CSNS DTL DUE TO A QUADRUPOLE FAULT

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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 3 MeV Radio Frequency Quadrupole (RFQ), an 80MeV Drift Tube Linac (DTL), and a 1.6 GeV Rapid-cycling Synchrotron (RCS). The DTL consists of four tanks. In 2017, three of four tanks have been commissioned successfully, and beam has been accelerated to 61 MeV with nearly 100% transmission. However, in July 2017, one quadrupole contained in the drift tube was found fault, the beam transmission decreased to 80%. A new lattice has been designed and the 100% transmission has recovered. In January 2018, the last tank of the DTL has been commissioned and accelerated the H- beam to the design energy of 80MeV for the first time. The commissioning progress and the measurement results before and after lattice adjustment will be presented.

INTRODUCTION

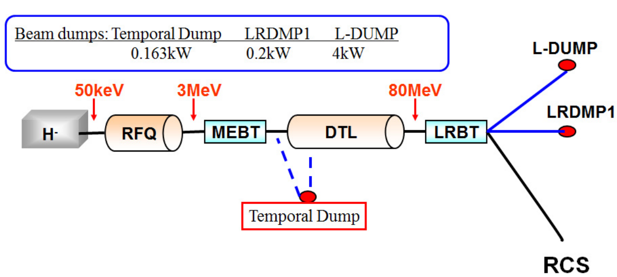

Figure 1: CSNS Linac layout.

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 accelerates H- beam from 3MeV to 80MeV. Each tank is fed by a 324MHz, 3MW klystron. From 2016 to 2018, the DTL has been commissioned tank by tank. In 2017，since only three klystrons were available, DTL1to3 have been fed and the beam was successfully accelerated to 61 MeV [2]. The last tank has been used as a beam line. Figure 2 shows the CT signals along the Linac. Beam transmission from the DTL to the LRBT (Linac to RCS Beam Transport) was nearly 100%. In May 2017, the vacuum in DTL1 became worse. And one month later, the beam commissioning was interrupted for the DTL vacuum checking. We found that the cooling channel of the EMQ13 in the DTL1 was leaking [3]. So we had to turn off the EMQ13 which made the beam transmission decrease to about 80%. Due to the tough arrangement of the commissioning timetable, beam commissioning has continued. A temporary lattice was used, in which the EMQ13 and EMQ 14 were turned off and the other quadrupoles' setting remained unchangeable. The beam transmission has been fluctuating from 96% to 98% during commissioning. In November 2017, we had two month interval for testing the klystron and RF conditioning of the DTL4. A new lattice for the DTL has been designed. According to this new lattice, every 2 of 4 quadrupoles after the EMQ13 had to exchange the polarities by modifying the cable connection mode. In January 2018, the last tank of the DTL has been commissioned and the H- beam to the design energy of 80MeV for the first time. With the new transverse focusing lattice, the beam transmission has recovered to 100%. Figure3 shows the CT signals along the linac with the new lattice.

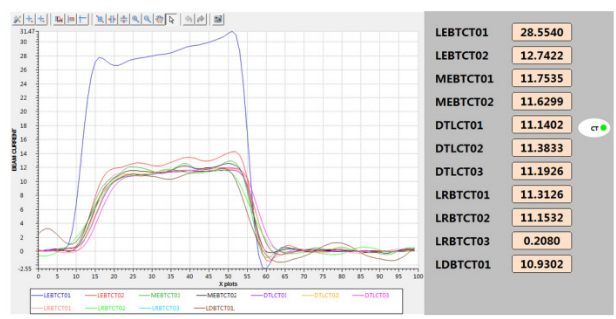

Figure 2: Current transform signals along the Linac with the old lattice.

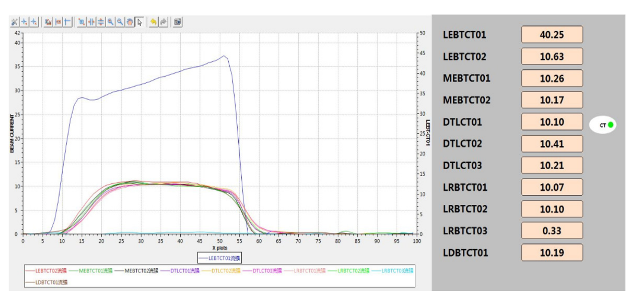

Figure 3: Current Transform signals along the Linac with the new lattice.

Old Lattice

The DTL uses Electrical Magnet Quadrupoles (EMQ) for transverse focusing and the focusing is done in a

*This work is supported by National Natural Science Foundation of China (11505101).
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DFFD lattice. The transverse lattice meets the following merits: [4].

1.$\sigma_{0t} \leq 90°/period$

2.$\sigma_{0t} \neq \frac{n\sigma_{0l}}{2}$ for n=1,3…

3. Equipartitioning ratio≈1.0 at full current.

Where σ_{0t} and σ_{0l} are transverse and longitudinal phase advances without space charge. There are total 161 EMQs in the DTL. The gradient of these EMQs are shown in Figure 4.

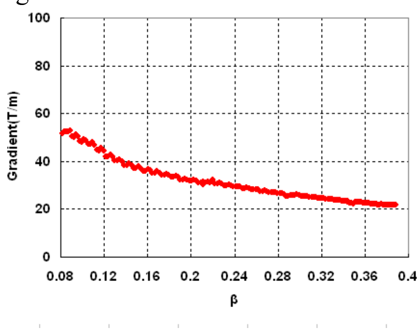
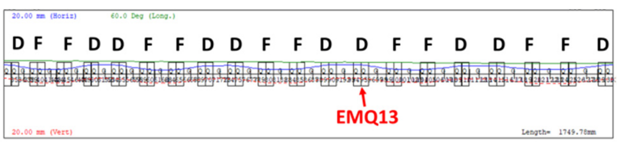
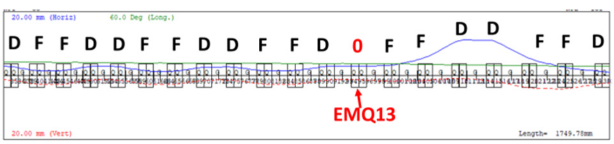


Figure 4: Quadrupole gradient.

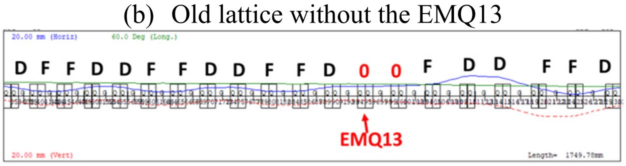
New Lattice



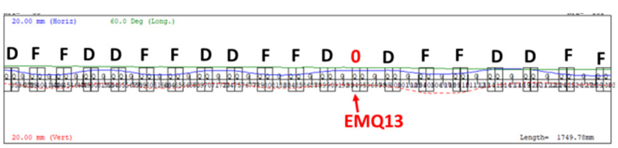
(a) Old lattice with the EMQ13



(b) Old lattice without the EMQ13



(c) Old lattice without the EMQ13、14



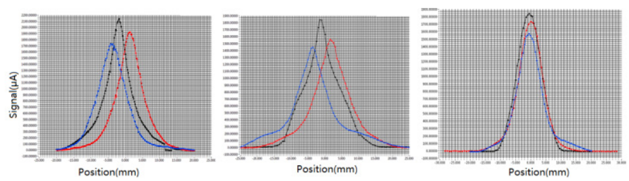
(d) New lattice without the EMQ13

Figure 5: Beam envelope in the DTL1(Blue line represents horizontal envelope, red line represent vertical envelope, green line represent longitudinal phase width).

The EMQ13 is a "D" quadrupole which stands for defocusing proton in the horizontal plane. Because of the fault of the EMQ13, there was a big envelope bump in the DTL1 which made beam lost. Figure 5 shows the beam envelope for the first five transverse periods in the DTL1 by Trace 3D [5].

A temporary lattice was adopted to continue the commissioning progress. As shown in Figure 5, the EMQ13 and EMQ 14 were turned off and the other quadrupoles' setting remained unchangeable. The temporary lattice has supressed the bump. However, there was about 4% beam loss along the linac. And the beam profile measurement showed that significant beam halo formation was observed downstream of the DTL, as shown in Figure 6.

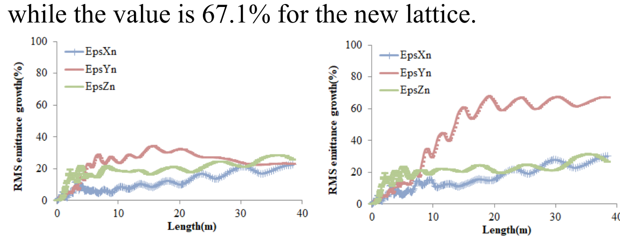
In November 2017, the fourth run of beam commissioning has completed and there was a two month interval to start the fifth beam commissioning. During the interval, a new lattice has been optimized. In the old lattice, the EMQ13 was the first quadrupole for a DFFD focusing period.In the new lattice, we start a DFFD focusing period with the EMQ14. The beam bump was eliminated. And the beam halo from the beam profile measurement was not observed.



(a) Old lattice (b)Temporary lattice (c)New lattice

Figure 6: Beam profiles measured for I_{peak}=10mA at the exit of the DTL.

In January 2018, the fifth beam commissioning has begun. The DTL4 has been fed for the first time. The nominal energy of 80 MeV has reached. The beam transmission along the DTL was nearly 100% with the new lattice. Although the beam transmission recovered, the beam emittance growth raised due to the discontinuity of the transverse focusing. Figure 7 shows the simulated RMS emittance growth for two lattices. At the exit of the DTL, the vertical emittance growth is 23.2% for the old lattice while the value is 67.1% for the new lattice.



(a) Old lattice (b) New lattice

Figure 7: RMS emittance along the DTL.

SUMMARY

Due to the fault of the EMQ13 in the DTL1, the beam transmission through the CSNS DTL decreased from 100% to 80%. With a new lattice, the beam transmission has recovered. No obvious beam halo was observed at the exit of the DTL although a EMQ was turned off.

REFERENCES

[1] J.Peng *et al*. "Design of 132MeV DTL for CSNS", in *Proc. Linac'06*, Knoxville, Tennessee USA, Aug. 2006, paper TUP069.

[2] J.Peng *et al.* "Beam Commissioning Results of the CSNS Linac", in *Proc. IPAC'17*, Copenhagen, Denmark, May 2017, paper TUOBA1.

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[3] H.C.Liu *et al.*, “Operation experience of the CSNS DTL”, presented at Linac’18, Beijing, China, Sep. 2018, paper THPO030, this conference.

[4] J. Stovall, Quadrupole Law and Steering Options in the Linac4 DTL, CERN LHC-Project-Note-0006, 2009.

[5] K. Crandall and D. Rusthoi, “TRACE 3-D Documentation”, LA-UR-97-886.

[6] Harunori T. PARMILA. LA-UR-98-4478, 1998, Revised July 26, 2005.