PRESENT STATUS OF THE 3 MeV PROTON LINAC AT TSINGHUA UNIVERSITY*

Q.Z. Xing#, C. Cheng, C.T. Du, L. Du, T.B. Du, X.L. Guan, C. Jiang, C.X. Tang, X.W. Wang, H.Y. Zhang, S.X. Zheng, Key Laboratory of Particle & Radiation Imaging (Tsinghua University), Ministry of Education, Beijing 100084, China
B.C. Wang, Northwest Institue of Nuclear Technology, Xian, China
W.Q. Guan, Y. He, J. Li, NUCTECH Co. Ltd., Beijing 100084, China

Abstract

We present, in this paper, the present status of the 3 MeV high current proton Linac for the Compact Pulsed Hadron Source (CPHS) at Tsinghua University. The ECR ion source produces 50 keV proton beam which is accelerated to 3 MeV by the downstream RFQ accelerator. The RFQ accelerator has been conditioned to 50 Hz/500 μs with the input power of 442 kW. Proton beam with the peak current of 30 mA, pulse length of 100 μs and repetition rate of 50 Hz has been delivered to the Beryllium target to produce the neutron since July 2013. The status of the development of the Drift Tube Linac is also presented in this paper. The beam energy will be enhanced to 13 MeV after the DTL is ready in 2015.

INTRODUCTION

The CPHS (Compact Pulsed Hadron Source) linac at Tsinghua University, which began its construction in the year of 2009 [1], has achieved its mid-term objective: delivering the 3 MeV proton beam to bombard the Beryllium target [2]. Figure 1 shows the CPHS linac facility at Tsinghua University, which contains the ECR Ion Source (IS), Low Energy Beam Transport line (LEBT), a 4-vane Radio Frequency Quadrupole (RFQ) accelerator, and High Energy Beam Transport line (HEBT).

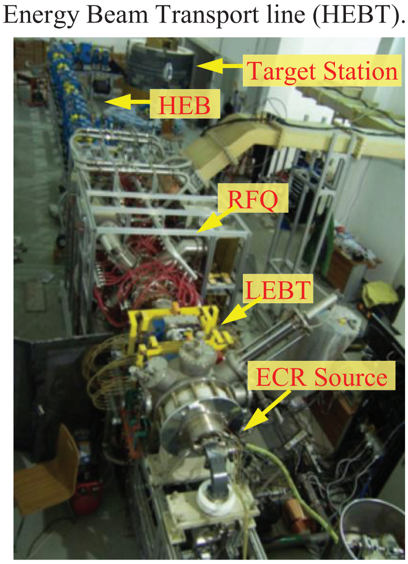

Figure 1: CPHS linac facility and the target station.

Table 1 shows the main designed and achieved parameters of the CPHS linac. The beam current of 23 mA is measured at the entrance of the target station after the 90-degree bending of the beam. The detailed information on the high power test and beam commissioning of the RFQ accelerator, and the characteristics of the 3MeV proton beam can be referred to [3] and [4]. In this paper, the development status of the beam measurement and the Drift Tube Linac (DTL) are mainly presented.

Table 1: Main Parameters of the CPHS Linac

Parameter	Designed	Achieved
Beam Energy	13 MeV	3 MeV
Beam Current	50 mA	23 mA
Pulse Length	500 μs	100 μs
Repetition Rate	50 Hz	50 Hz

OPERATION STATUS

Figure 2 presents the operation status of the CPHS linac in 2014. A stable beam current of 22 mA can be obtained before the target station (after bending). The RFQ suffers from a degradation of the transmission rate from its original 88% (with input peak current of 50mA at 50 μs/ 50 Hz). The reason may come from the unmatched beam from the LEBT, or the deformation of the RFQ cavity. In this year the field distribution of the RFQ is planned to be inspected and the beam emittance at the entrance of the RFQ will be measured.

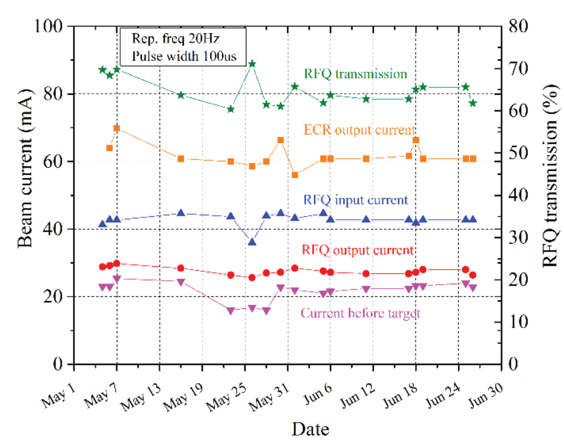

Figure 2: Operation history of the 3 MeV linac in 2014.

*Work supported by National Natural Science Foundation of China (Major Research Plan Grant No. 91126003 and 11175096)
#xqz@tsinghua.edu.cn

The neutron beam has been applied in the R&D of the He-3 detectors and B_4C-coated straw-tube-type detectors. The result of the position resolution measurement of the B_4C-coated straw-tube-type detector shows that the alignment of the neutron beam line is very good.

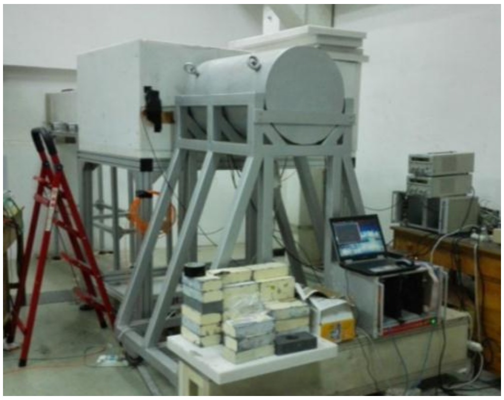

Figure 3: Position resolution measurement of the B_4C-coated straw-tube-type detector.

BEAM DIAGNOSTICS

2D beam profile measurement is under development based on the CT algorithm with rotatable multi-wires. Twenty carbon wires with the diameter of 30 µm are aligned and mounted on one board, as shown in Fig. 4. The primary experiment shows that the beam is asymmetric at the measurement position and wire current near the beam centre is 0.3 mA (while the estimated value is 0.4 mA). The following challenging work on the electronics system is to measure the current which is less than 1 nA near the beam edge.

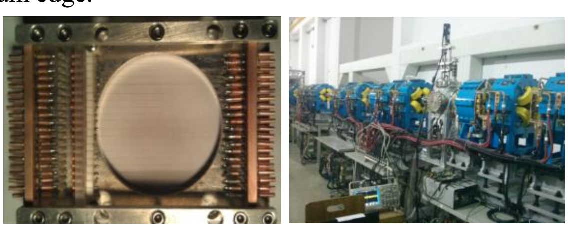

Figure 4: Rotatable multi-wires (left) and the 2D beam profile measurement system (right).

DRIFT TUBE LINAC DEVELOPMENT

Two test drift tubes for the DTL have been manufactured and the beam energy of the CPHS linac is expected to be enhanced to 13 MeV in 2015.

Permanent Magnet Quadrupole (PMQ)

The PMQ is used for beam focusing instead of usual electromagnets. It consists of 16 segments of SmCo permanent magnets and a stainless steel skeleton (1Cr18Ni9Ti), as shown in Fig. 5. The average integral gradient is about 3.3 T.

If the magnetized directions of some pieces among the 16 segments were considerably different from the designed direction, undesirable field components would appear. The test and screening procedure is necessary before assembling (Fig 6).

Figure 5: An experimental sample of PMQ.

Figure 6: The magnet segments after screening.

The proportion of the unwanted field component shall not exceed one percent inside a radius of 8 mm. CST software is adopted to simulate the magnetic field distribution affected by the deviation of the segments. The result shows that the magnetization-direction deviation of less than 3° and the remanence deviation of less than one percent are acceptable, which has been proven by experiments (Fig 7).

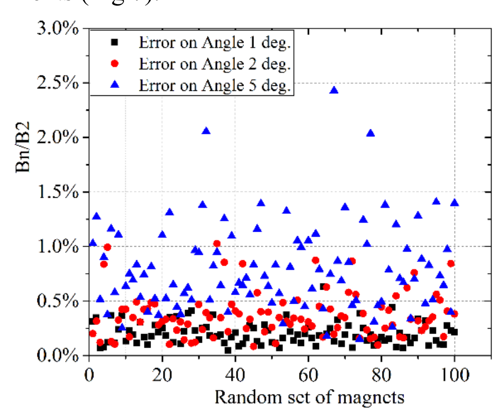

Figure 7: The proportion of the unwanted field component affected by different deviation of magnetization direction.

The measurement of PMQs is very important after assembling, which contains the measurement of the magnetic centre, the high-order field components and the integral gradient. The magnetic centre and high-order field components are measured by rotating coil equipment.

ISBN 978-3-95450-142-7

For a PMQ, its integrated gradient cannot be adjusted after it is installed into a drift tube, while for an electromagnet the gradient can be easily adjusted by changing the drive current. After detailed error analysis, we believe that hall probe equipment can meet our needs. We are now constructing such a suit of equipment, which can provide the integrated gradient with high accuracy.

Figure 8: The measurement of a PMQ.

Drift Tube

The processing experiment of the drift tube is in progress, which contains four main steps: 1) rough machining; 2) repairing of the magnetic centre; 3) welding and 4) machining after welding.

Up to now the positioning of the magnetic centre can be controlled within about 0.02 mm. The welding includes two times of brazing and electron beam welding. The design requirements can be met after the two brazing.

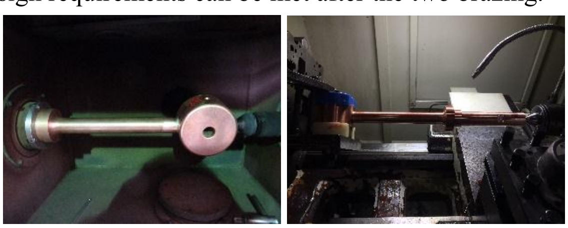

Figure 9: Electron beam welding (left) and finish machining after welding (right).

We use laser tracking for the collimating during the experimental installation. The experiment of the collimating installation of the drift tube mainly includes three steps: 1) establishment of the coordinate system for the drift tube itself (Fig. 10); 2) collimating installation of the drift tube on the base; 3) collimation installation of the drift tube inside the cavity. At present the drift tubes are being installed on the base, as shown in Fig. 11.

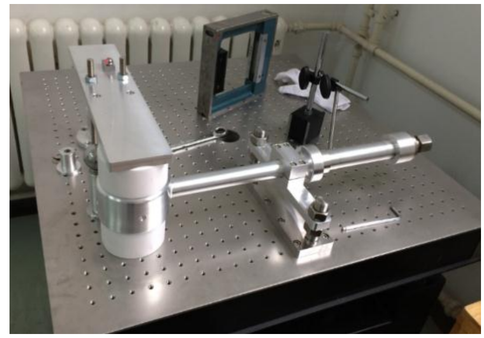

Figure 10: Establishment of the coordinate system for the drift tube.

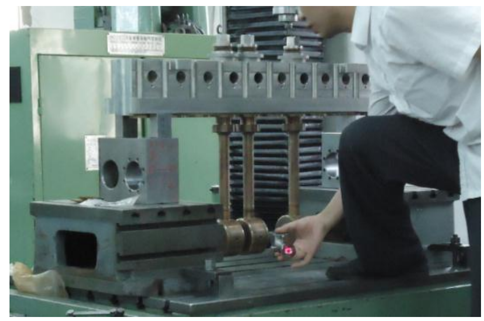

Figure 11: Collimating installation of the drift tube on the base.

CONCLUSION

The development of the drift tube for CPHS linac at Tsinghua University is on its way and the beam energy is expected to be enhanced from present 3MeV to 13 MeV in 2015. Presently the linac can provide the proton beam with peak current of 22 mA, pulse length of 100 µs and repetition rate of 50 Hz, and the neutron beam after the proton beam is delivered to bombard the Beryllium target.

ACKNOWLEDGEMENT

The authors would like to thank IHEP for the help of magnet measurement.

REFERENCES

[1] J. Wei et al., “The Compact Pulsed Hadron Source Construction Status”, IPAC’10, Kyoto, MOPEC071, p. 633 (2010); http://www.JACoW.org

[2] X.W. Wang, “Delivery of 3-MeV Proton and Neutron Beams at CPHS: A Status Report on Accelerator and Neutron Activities at Tsinghua University”, Physics Procedia, to be published.

[3] Q.Z. Xing et al., “High Power Test and Beam Commissioning of the CPHS RFQ Accelerator”, IPAC’13, Shanghai, THPWO050, p. 3884 (2013); http://www.JACoW.org

[4] Q.Z. Xing et al., “CPHS Linac Status at Tsinghua University”, IPAC’14, Dresden, THPME023, p. 3268 (2014); http://www.JACoW.org