PRESENT STATUS OF THE HIGH CURRENT LINAC AT TSINGHUA UNIVERSITY AND ITS APPLICATION*

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Abstract

The CPHS (Compact Pulsed Hadron Source) linac at Tsinghua University, is now in operation as an achievement of its mid-term objective. Presently the RFQ accelerator is operated stably with the beam energy of 3 MeV, peak current of 26 mA, pulse length of 100 μs and repetition rate of 20 Hz. After the maintenance the transmission rate of the RFQ accelerator had been recovered from 65% to 91%. The applications of the proton and neutron beams are introduced in this paper.

INTRODUCTION

Since the first 3 MeV/44 mA proton beam of the CPHS (Compact Pulsed Hadron Source) linac at Tsinghua University was achieved in March 2013, the proton beam has been delivered to bombard the Beryllium target to produce neutrons for various applications [1][2]. The whole linac contains the ECR Ion Source (IS), the 4-vane Radio Frequency Quadrupole (RFQ) proton accelerator (shown in Fig. 1), RF power supply and distributor, and beam transport. In the first half year of 2017 the Drift Tube Linac (DTL) is expected to be installed downstream the RFQ accelerator to upgrade the beam energy to the designed value of 13 MeV.

Figure 1: 3MeV RFQ accelerator at Tsinghua University.

Based on the proton and neutron beams, various applications mainly includes the development of the neutron detectors (B_4C-coated straw-tube and gadolinium-doped Micro-Channel Plate (MCP)) and biological dosemeters, and neutron imaging. Furthermore, a proton irradiation station is being planned to provide the 13 MeV proton beam with a flux of 10^8~10^9 p/cm^2/s for the experimental simulation of the space radiation environment.

OPERATION STATUS OF THE HIGH CURRENT 3MeV PROTON LINAC

The operation time of the CPHS facility in 2016 was ~300 hrs. The present main parameters together with the designed values of the proton beam are listed in Table 1. The RFQ accelerator is operated stably with the beam energy of 3 MeV, peak current of 26 mA, pulse length of 100 μs and repetition rate of 20 Hz. The peak current is measured near the outside surface of the target station. The current of the proton beam at the entrance of the RFQ has decreased from 60 mA (year 2013) to 44 mA (year 2016).

Table 1: Main Parameters of the Proton Beam Passing into the Target Station

Parameter	Designed Value	Present Value
Beam Energy (MeV)	13	3
Peak Current (mA)	50	26
Beam Pulse Width (μs)	500	100
Repetition Rate (Hz)	50	20

Neutrons are produced by proton beam bombarding the 1.2 mm-thick Beryllium target. The Be target has been redesigned to be mounted on a 2 mm-thick aluminium plate since it had broken twice after only several-hour operation on the repetition rate of 50 Hz. The possible reason of the crack was evaluated to be the thermal stress under high repetition rate. The new target with Al plate mounted had worked well in 2014 with the repetition rate of 20 Hz. Increasing the repetition rate to 50 Hz to test the new target with the proton beam will be carried out in the future.

MAINTENANCE AND UPGRADE OF THE 3MeV LINAC

The maintenance and upgrade of the CPHS linac are carried out as the following, among which the first five has been accomplished:

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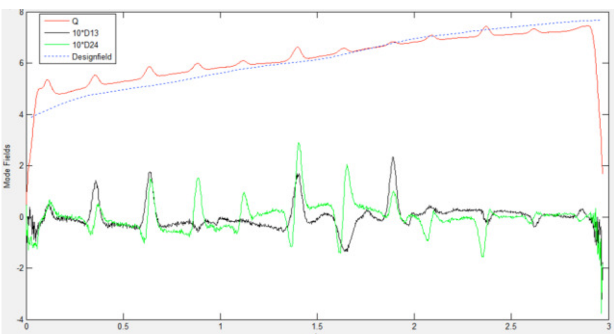
1. Field retuning of the RFQ accelerator to enhance the transmission rate.
2. Insert one chopper into the LEBT to decrease the rising and falling time of the beam pulse.
3. Re-layout of the power source supply of the IS/LEBT to avoid the sparking.
4. Upgrade the control system by adopting the EPICS environment.
5. Adopt parameter scanning during beam commissioning.
6. Monitor the temperature distribution of the Be target.
7. Upgrade the beam energy to 13MeV by the DTL accelerator.
8. Recovery of the output current of the proton beam to ~60mA at the exit of the ECR source.

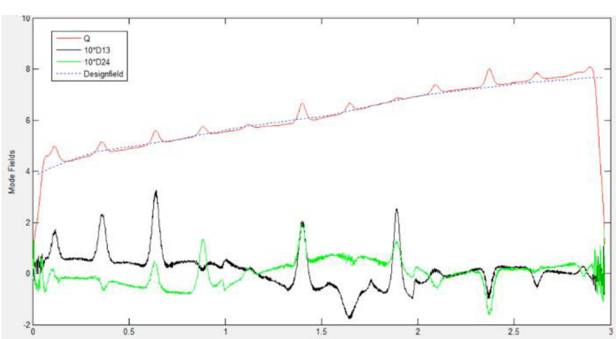
Re-tuning of the RFQ Accelerator

In order to deal with the transmission rate degradation of the RFQ accelerator, the field distribution inside the RFQ cavity was checked, and the field tuning was performed and the relative error of the quadrupole field was reduced from 7.3% to 2.6% (Fig. 2).

The resonance frequency of the RFQ was adjusted to 325.01 MHz from 325.12 MHz. After the RFQ was re-commissioned, the transmission rate of the RFQ raised to 91% by the end of 2015.



(a) Before re-tuning



(b) After re-tuning

Figure 2: Field distribution of the CPHS RFQ.

LEBT Chopper

One electrostatic chopper has been added at the end of LEBT. The rising and falling time of the beam pulse with the chopper had been decreased to 1~3 μs. The chopped particles are mostly lost before entering into the RFQ cavity.

Parameter Scanning

The measured currents from the ACCT and Faraday cups have been sampled and hold, then acquired by the EPICS system. Multi-dimensional parameter scanning has been achieved on the currents of the two solenoids and four steering magnets. Figure 3 shows the transmission rate of the CPHS RFQ (in different color) changes with the currents of the two solenoids.

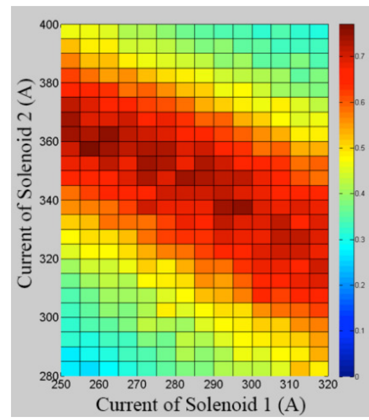


Figure 3: Transmission rate of the CPHS RFQ with the currents of the two solenoids.

Monitoring the Be Target

In order to obtain the profile of the proton beam bombarding on the target, the temperature distribution of the Be target had been monitored by one infrared camera, as shown in Fig. 4. One mirror will be added to prevent the camera from the damage of the neutrons. More study will be carried out on the relationship between the beam profile and the accelerator parameters.

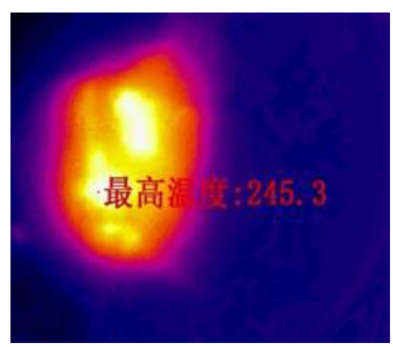


Figure 4: Temperature distribution of the Be target with the proton beam bombarding on it.

DTL Development

The CPHS DTL is under development. Ten test drift tubes (five aluminium tubes and five copper ones) were fabricated, and the alignment experiments are being carried out with the test drift tubes, as shown in Fig. 5. It is expected to finish the formal manufacture by the end of 2016 and finish the installation of the DTL by July 2017.

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Figure 5: Alignment experiment with the test drift tubes.

PROTON APPLICATION

Development of 2D Profile Measurement

Based on the CT algorithm, 2D profile measurement of the proton beam is under development by the rotatable multi-wires [3]. Twenty carbon wires with the diameter of 30 μm are aligned and mounted on one board. The development of the electronics system for the measurement of the twenty wires simultaneously has been completed. With the position step of 0.1 mm and angle step of 5°, the 2D profile of the proton beam has been acquired in 20 minutes at the position of about six meters downstream the RFQ accelerator, as shown in Fig. 6. The dynamic range of the measurement in one-dimensional can reach ~10^4.

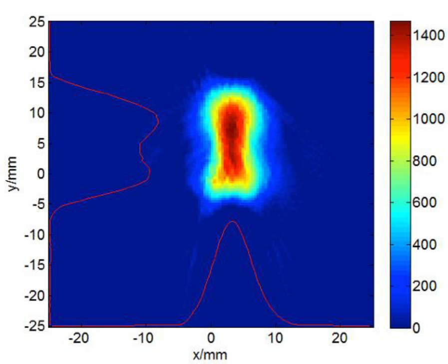

Figure 6: 2D profile of the proton beam downstream the CPHS RFQ measured by the rotatable multi-wires.

Proton Irradiation Station

A proton irradiation station is been planned to provide the future 13 MeV proton beam with a flux of 10^8~10^9 p/cm^2/s for the experimental simulation of the space radiation environment. The main objective is to decrease the flux by 10^6~10^7 by adopting one collimator (Fig. 7) and adjusting the currents of the solenoids and quadrupoles. The irradiation station will be located at the end of the straight line of HEBT.

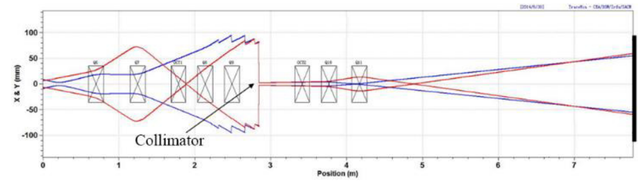

Figure 7: Beam profile in the HEBT for proton irradiation.

NEUTRON APPLICATION

The application of the neutrons mainly consists of the neutron imaging, and the development of the neutron detectors (B_4C-coated straw-tube and gadolinium-doped Micro-Channel Plate (MCP)) [4]. Furthermore, experiments related to biological dosemeters has been carried out based on the CPHS facility. Figure 8 shows the neutron imaging line and neutron beam test line.

Figure 8: The neutron imaging line (left) and neutron beam test line (right).

CONCLUSION

CPHS facility at Tsinghua University can provide 3 MeV proton beam and corresponding neutron beam to users. The beam energy will be enhanced to 13 MeV in the year of 2017. A proton irradiation station is planned at the end of the straight line of HEBT.

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