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CPHS LINAC STATUS AT TSINGHUA UNIVERSITY*

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Abstract

We present, in this paper, the operation status of the 3 MeV high current proton Linac for the Compact Pulsed Hadron Source (CPHS) at Tsinghua University. 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 pulse length will be further increased to 500 µs. The proton beam energy is expected to be enhanced to the designed value of 13 MeV after the Drift Tube Linac is ready in 2015.

INTRODUCTION

The Compact Pulsed Hadron Source (CPHS) project was launched in 2009 at Tsinghua University, which contains mainly one 13 MeV proton linac, one neutron target station, and four experimental beamlines [1]. The accelerator system consists of the ECR Ion Source (IS), Low Energy Beam Transport line (LEBT), a 4-vane Radio Frequency Quadrupole (RFQ) accelerator, Drift Tube Linac (DTL), RF power supply and distributor, and High Energy Beam Transport line (HEBT). Fig. 1 shows the CPHS linac facility and the target station at present.

Figure 1: CPHS linac facility and the target station.

The first 3 MeV proton beam was obtained with the peak current of 44 mA, pulse length of 50 µs, and repetition rate of 50 Hz on March 2013. Since then, the mid-term task of delivering the 3 MeV beam to bombard the Beryllium target was undertaken and the first neutron beam was detected on July 2013. The neutron beam has been applied in the test of He-3 detectors and gadolinium-doped micro-channel plates [2]. On March 2014, the RFQ accelerator was conditioned to 500 µs at 50 Hz with the input RF power of 442 kW. Table 1 lists the main designed parameters of the CPHS linac and presently achieved performance.

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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

BEAM CHARACTERISTICS

There are three ACCTs to measure the beam current, which are located at the entrance and exit of the RFQ accelerator, and the entrance of the target station. Two faraday cups are adopted, in which one is pluggable and located at the exit of the ECR source, the other is located at the end of the straight beamline. Two solenoids and two steering magnets in the LEBT are adjusted during operation to obtain the matched beam at the entrance of the RFQ.

The ECR proton source is capable of delivering the beam pulse with the maximum width of 240 µs, as shown in Fig. 2. The particles in the 100 µs at the rear of the beam pulse with a current of 44.2 mA are accelerated by the downstream RFQ accelerator, while the other part of particles will be lost inside the RFQ.

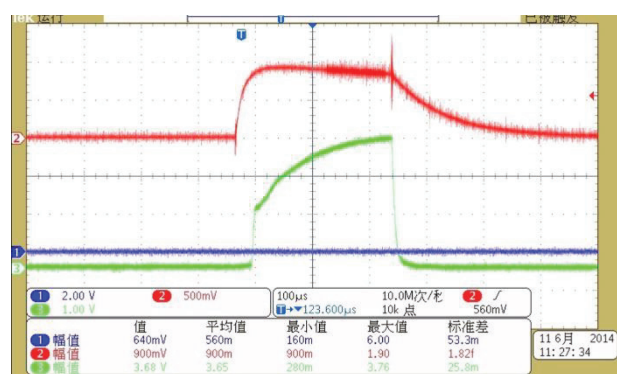

Figure 2: ACCT signal at the entrance of the RFQ (Channel 3).

While the construction of the DTL will be completed in 2015, five quadrupoles have been positioned instead of the 4.3-meter-long DTL. The other nine quadrupoles and

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two 45°-bending dipoles help to transfer the beam to the target station. The currents of the quadrupoles (mainly QD5, QF6, QF8 and QD9 as shown in Fig. 3) and dipoles are optimized to obtain a high beam transmission from the RFQ accelerator to the target station. The diameter of the round beam on the target is expected to be 20 mm by the TRACE3D code [3].

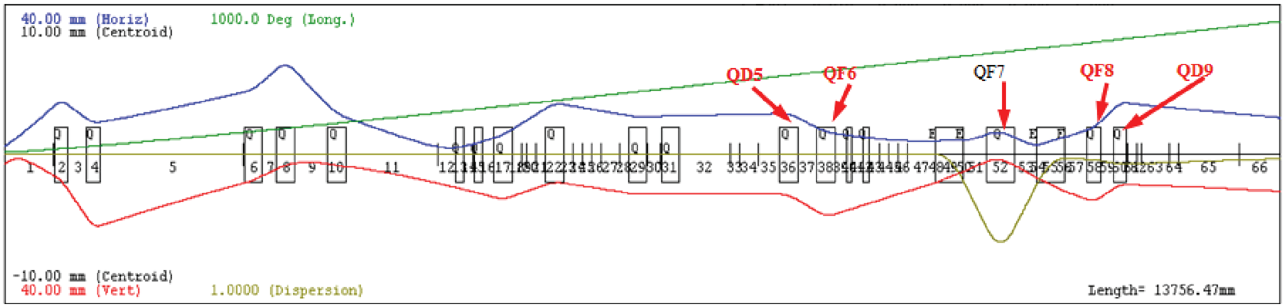

Figure 3: Beam envelop in the CPHS HEBT predicted by the TRACE3D code.

Fig. 4 presents the RF power and beam current during the recent operation, with the beam input at the entrance of the RFQ as shown in Fig. 2. The RF power fed to the RFQ cavity is 615 kW and the reflected power is 22 kW. The beam current at the exit of the RFQ and the entrance of the target station is 27.6 mA and 23.2 mA respectively. The beam profile on the Beryllium target is planned to be monitored by one infrared camera.

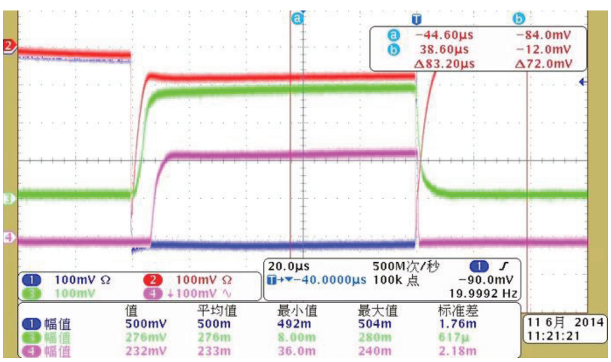

Figure 4: Channel 1: RFQ input power; Channel 2: RFQ reflected power; Channel 3: ACCT signal at the exit of the RFQ; Channel 4: ACCT signal at the entrance of the target station.

The RFQ cavity resonates at 325.130 MHz. Keeping constant the input power of 625 kW to the RFQ, Fig. 5 shows that few changes happen on the beam current at the exit of the RFQ and the entrance of the target station. The RFQ transmission rate is predicted to be 93.1% by the TRACK code with the nominal input power of 537 kW and input current of 50 mA, as shown in Fig. 6. The RFQ transmission increases with the cavity field amplitude until the relative field amplitude reaches 1.1. With the stable input beam of 42.2 mA unchanged, we measured the RFQ transmission rate, and the total transmission rate from the RFQ to target. The measured RFQ transmission exhibits the similar pattern, which decreases slowly until the relative field decays to 0.82. Meanwhile, The total transmission containing the 90°-bending of the beam goes down quickly when the field amplitude deviates from its designed value.

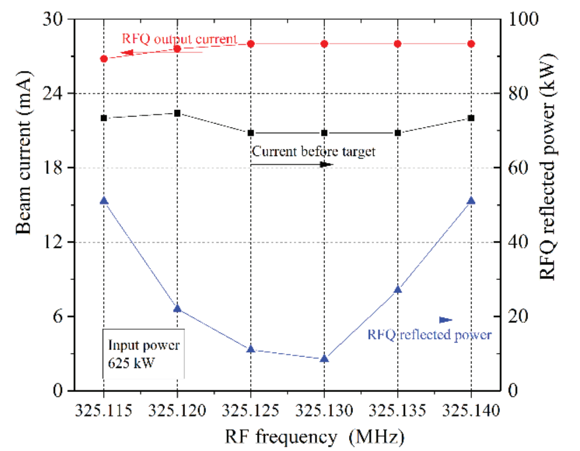

Figure 5: Beam current and the reflected power as a function of the RF frequency.

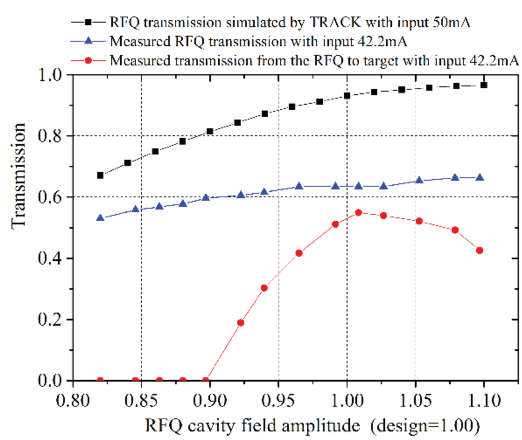

Figure 6: Beam transmission rate (RFQ, and from the RFQ to target) measured and simulated.

The degradation of the RFQ transmission from its original 88% (with input peak current of 50mA at 50 µs/50 Hz [4]) will be discussed in the following section.

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OPERATION HISTORY

The operation of the 3 MeV linac in the year of 2013 is recorded in Fig. 7. The maximum transmission of the RFQ accelerator is 88% at 50 µs (pulse duration) /50 Hz (repetition frequency). The output current of the RFQ is relatively stable (30 mA) near the end of 2013.

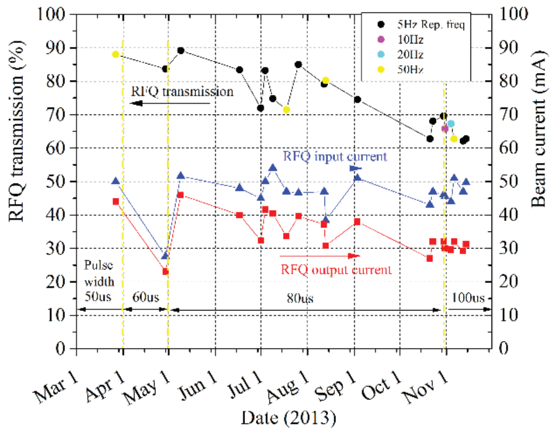

Figure 7: Operation history of the 3 MeV linac in 2013.

The RFQ suffers from a degradation of the transmission rate. 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.

Fig. 8 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).

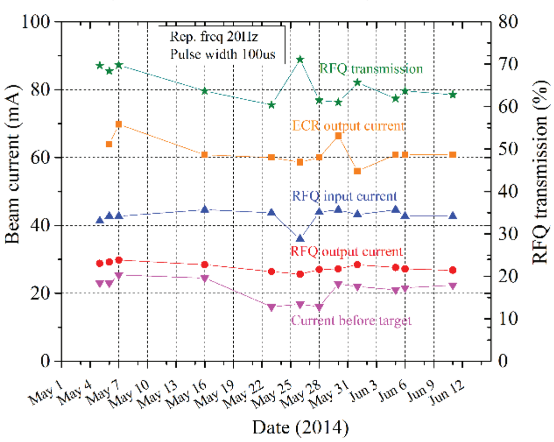

Figure 8: Operation history of the 3 MeV linac in 2014.

NEUTRON APPLICATION

Four neutron beamlines are planned in the CPHS project, among which two lines are being constructed for the Small Angle Neutron Scattering (SANS) and neutron imaging. Fig. 9 shows the test beamline, by which the flux of neutron below 1eV was measured to be 403 n/cm^2/s at the position 6.625 m away from the centre of the target station, which agrees with the value simulated within ±15%. Presently the neutron beam has been applied in the R&D of the He-3 detectors and gadolinium-doped micro-channel plates [2].

Figure 9: The test beamline.

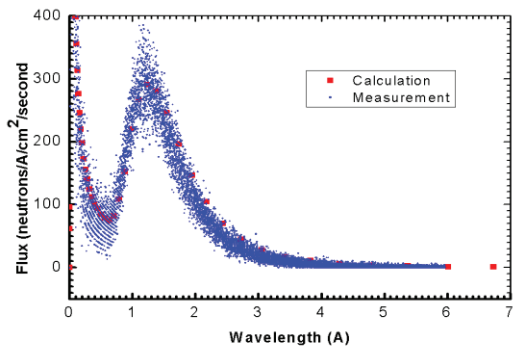

Figure 10: The wavelength spectra of the first neutron production.

FURTHER DEVELOPMENT

The CPHS linac is aimed at reaching its designed performance, stable operation, and providing the proton and neutron beams to the users. Two test drift tubes for the DTL have been manufactured and the CPHS linac is expected to be upgraded to 13 MeV in 2015. The control system for the CPHS is being upgraded to the EPICS system for more stable operation. The proton beam measurement is also under development, such as the 2D beam profile measurement based on CT algorithm with the rotatable multi-wires. Beyond these, the CPHS linac will be open and would like to provide the beam to all the possible users.

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] K.R. Crandall et al., “TRACE 3-D Documentation”, LA-UR-97-886.

[4] 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