RECENT ACTIVITIES AT THE J-PARC RFQ-TS*

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Abstract

The Japan Proton Accelerator Complex (J-PARC) linac delivers the negative hydrogen (H^-) ion beam with a peak current of 50 mA to the Material and Life science experimental Facility (MLF) and the Main Ring synchrotron (MR) through the Rapid Cycling Synchrotron (RCS). The Radio-Frequency Quadrupole linac Test Stand (RFQ-TS) in the J-PARC linac building is utilized for the evaluation of the beam quality and the tests of apparatuses by the 3-MeV H^- ion beam. Some studies were carried out in the RFQ-TS such as the low-level RF system, the novel magnet, and the beam monitors. Recently, the performance estimation of some linac apparatuses was carried out with a higher repetition than normal operation. In this sense, the points of the improvement were checked for the ion source, magnets, cavities, RF source, beam monitors, and the control in the RFQ-TS. The results of the beam test were reported in the paper.

INTRODUCTION

The Japan Proton Accelerator Research Complex (J-PARC) linac [1] accelerates the negative hydrogen (H^-) ion beam with a peak current of 50 mA to the subsequent synchrotron, which is the Rapid Cycling Synchrotron (RCS) for the Material and Life science experimental Facility (MLF) and the Main Ring synchrotron (MR).

The Radio-Frequency Quadrupole linac Test Stand (RFQ-TS) in the J-PARC linac building is mainly utilized to prepare the spare equipment and investigate the performance of the instrumentation and the beam quality of the front-end for the accelerator science. Some studies are carried out in the RFQ-TS, such as the low-level RF (LLRF) system [2], the novel magnet [3], the laser instrumentation [4], and the beam monitors [5, 6].

The beam repetition is 25 Hz in the current normal operation of the J-PARC linac. Recently, as one of the performance estimation of the linac apparatuses, some apparatuses were operated with a repetition of the 50 Hz, which is twice the normal repetition, in the RFQ-TS, to use the additional 25 Hz for the plan of the proton irradiation facility at the J-PARC [7]. The results of the preliminary beam test are reported in this presentation.

EXPERIMENTAL SETUP

Figures 1, 2, and 3 show the experimental setups of the RFQ-TS, which are the overall view of the RFQ-TS, the H^- ion source (IS), the Low-Energy Beam Transport (LEBT), and the Medium-Energy Beam Transport (MEBT), respectively. The H^- ion source [8] produces the pulsed H^- ion beam accelerated to 50 keV with a peak current of 60 mA and a repetition of 25 Hz in the normal operation. The 50-keV H^- ion beam is transported with the LEBT including two solenoids into the RFQ. Subsequently, the H^- ion beam is accelerated to 3 MeV with the RFQ [9, 10]. The 3-MeV H^- ion beam is transported with the MEBT into the Faraday cup as the beam dump. The MEBT contains many components such as the three quadrupole magnets, the bending magnet, and the beam instrumentation. The typical peak current at the MEBT was 54 mA.

50 HZ BEAM TEST

In this time, as one of the performance estimations of the linac apparatuses, the 3-MeV H^- ion beam is accelerated with a repetition of 50 Hz. Since the normal repetition of the apparatuses is 25 Hz, the points of the improvement were checked. The 50 Hz beam test was carried out including the performance estimation of the particle counter system and the measurement of the gamma rays and neutrons around the RFQ-TS to confirm the operation environment.

Ion Source, Magnets, and Beam Monitors

As for the 50 Hz beam test, the ion source can be operate with a repetition of 50 Hz [8]. The static solenoid and quadrupole magnets work without any problem under the 50 Hz operation. The beam monitor system is also capable of operating without issues at the 50 Hz.

Cavity and RF

Table 1 shows the RF gate width and the typical RF power of the RFQ for the 25 Hz and 50 Hz operation. The RFQ is driven by a 324-MHz Klystron and the dedicated LLRF system [2], which are capable of operating with 50 Hz when provided with the 50 Hz trigger signal. Considering the heat loading of increasing the repetition, the RF gate width in the 50 Hz operation was set to slightly shorter than the half of the 25 Hz operation.

Figure 4 shows the typical waveform of the RFQ in the 50 Hz operation. No frequency shift affected the RFQ operation. Figure 5 shows the typical waveform of the trigger signal, the RFQ and the SCT signal in the 50 Hz operation. The beam was successfully accelerated with a repetition of 50 Hz in the RFQ-TS.

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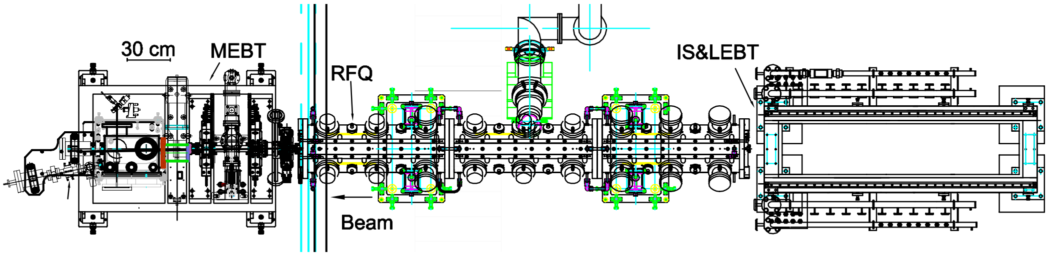

Figure 1: Overall view of the RFQ-TS setup.

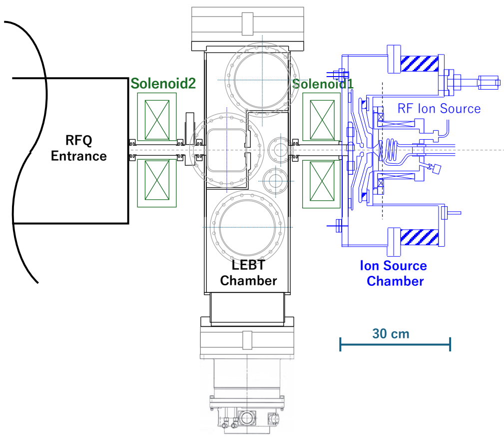

Figure 2: Schematic drawing of the H^- ion source and LEBT in the RFQ-TS.

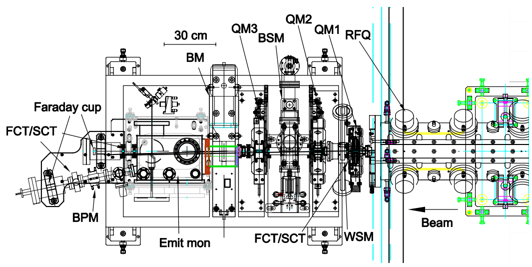

Figure 3: Schematic drawing of the MEBT in the RFQ-TS. QM, BM, FCT, SCT, BPM, Emit mon., WSM, BSM mean the quadrupole magnet, the bending magnet, the fast current transformer, the slow current transformer, the beam position monitor, the emittance monitor, the wire scanner monitor and the bunch shape monitor respectively.

Table 1: RF Gate Width and Typical RF Power of the RFQ

Repetition	**25 Hz**	**50 Hz**
RF gate width	600 µs	235 µs
Duty	1.5%	1.175%
Typical forward power	440 kW	
Typical reflected power	35 kW	
Typical RF power in tank	380 kW	

Control Including the Particle Counter System

Using the 50 Hz H^- ion beam, the performance evaluation of the particle counter system was carried out, which is one of the important apparatuses to operate accelerators safely with the high intensity. The particle counter system measures the number of accelerated H^- ion particles by processing the waveform signal from the SCT [11]. Figure 6 shows the measurement result of the number of particles with the particle counter system in the 50 Hz beam operation. The result shows the good linearity. The number of particles at the beam pulse width of 0 µs may show the number of the leakage particles from the ion source.

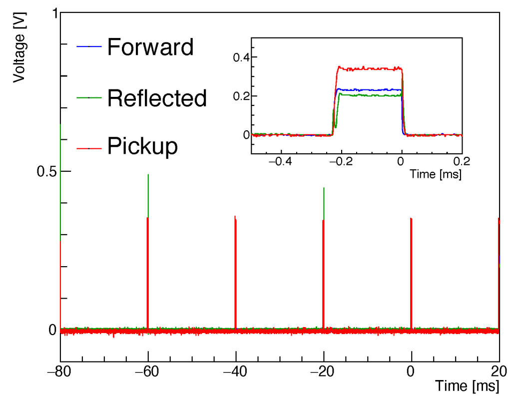

Figure 4: Typical waveform of the RFQ in the 50 Hz operation. Upper right window shows the zoomed waveform.

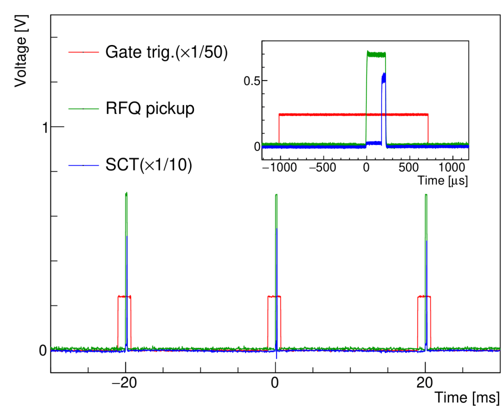

Figure 5: Typical waveform of the trigger signal, the RFQ and the SCT signal in the 50 Hz operation. Upper right window shows the zoomed waveform. Beam width was 50 µs.

Radiation Measurement

The radiation levels of the gamma rays and the neutrons were measured with the 50 Hz beam operation to confirm the

Table 2: Result of the neutron measurement. The measurement points are shown in Fig 7. Unit is µSv/h. BG means the background level.

Beam repetition	Beam pulse width	①	②	③	④	⑤
25 Hz	50 µs	0.50	0.20	0.20	BG	BG
50 Hz	10 µs	0.06	0.06	0.08	BG	BG
50 Hz	50 µs	0.75	0.48	0.42	BG	BG

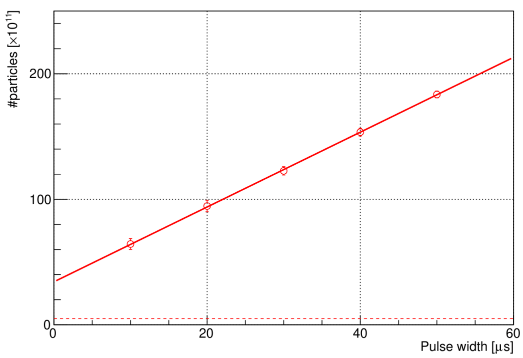

Figure 6: Measurement result of the number of particles with the particle counter system in the 50 Hz beam operation. Dotted line is the data without the beam.

experimental environment. Figure 7 shows the schematic drawing of the RFQ-TS to identify the measurement points for the radiation measurement. The detectors were AE-133V/Λ1 for the gamma rays and TPS-451C for the neutrons, respectively. In the gamma-ray measurement, the radiation level was at background levels. The radiation level of the neutrons was much smaller than the J-PARC regulatory standard. Table 2 shows the result of the neutron measurement.

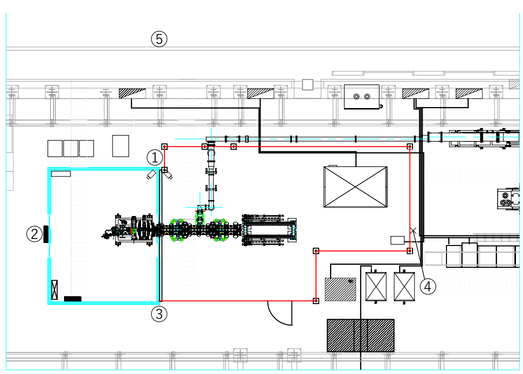

Figure 7: Schematic drawing of the RFQ-TS to identify the measurement points for the radiation measurement.

SUMMARY

The RFQ-TS is utilized to prepare the spare equipment for the J-PARC linac and investigate the performance of the instrumentation and the beam quality of the front-end for the accelerator science. The 50 Hz beam acceleration was demonstrated in the RFQ-TS to confirm the performance estimation of the linac apparatuses. The successful beam test with a repetition of 50 Hz will give us the various fruitful prospects for the future studies.

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