RESULTS OF THE HIGH-POWER CONDITIONING AND THE FIRST BEAM ACCELERATION OF THE DTL-1 FOR J-PARC

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Abstract

The first tank of the DTL for Japan Proton Accelerator Research Complex (J-PARC) was installed in the test facility at KEK. The DTL tank is 9.9 m in length and consists of 76 cells. The resonant frequency of the tank is 324 MHz. After the installation of the tank, the high-power conditioning was carried out deliberately. Consequently a peak rf power of 1.2 MW (pulse repetition of 50Hz, pulse length of 600 μsec) was put into the tank stably. (The required power is about 1.1 MW for the designed accelerating field of 2.5 MV/m.) Following the conditioning, An H^- ion beam, accelerated by the RFQ linac up to 3 MeV, was injected into the DTL and accelerated up to its design value of 19.7 MeV. The peak current of 30 mA was achieved with almost 100 % transmission in November of 2003.

INTRODUCTION

The construction of a high-intensity proton accelerator facility for J-PARC has been started at Tokai campus of JAERI. The accelerator consists of a 181-MeV linac (which will be extended to 400MeV in near future), a 3-GeV rapid cycle synchrotron and a 50-GeV synchrotron[1]. The 181-MeV injection linac is comprised of the an H^- ion source, an radio frequency quadrupole (RFQ) linac, a drift-tube linac (DTL), a separated DTL (SDTL)[2], and several beam transport lines. The resonant frequency of the RFQ, the DTL and the SDTL is 324 MHz.

The Alvarez-type DTL accelerates the H^- ion beam from 3 to 50 MeV. It consists of the three independent tanks of which the length is about 9 m. Furthermore each tank is comprised of three short unit tanks of which length is approximately 3 m. The inside diameter of the tank is 560 mm. Each drift tube (140 mm in diameter) accommodates the electro-quadrupole magnet. The DTL-1 has 77 magnets. The DTL-2 and -3 have 44 and 28 magnets, respectively.

HIGH-POWER CONDITIONING

The DTL-1 was assembled very precisely and the accelerating field was stabilized by the post-couplers [3]. After the tuning of the field, The DTL-1 was installed in the tunnel of the test facility at KEK for the beam acceleration experiment.

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Installed DTL-1 into the beam line is shown in figure 1. Left side component in the figure is the MEBT placed precisely in the area between the RFQ and the DTL. The properties of the beam ejected from the DTL are measured by the beam test line which has the current transformer (CT) , the beam position monitors (BPM), the transverse emittance monitor (EM) and the Faraday cup (FC) which works as a beam dump. The emittance monitor and the Faraday cup are installed in the area covered by concrete blocks for radiation shield. The blocks are seen at right side of the figure. The schematic view of the beam test line are shown in figure 2.
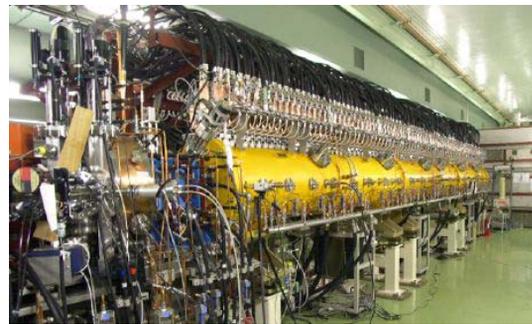

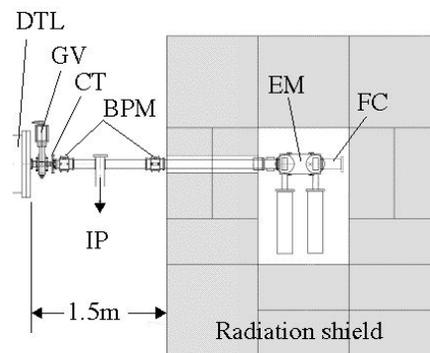Figure 1: DTL-1 in the beam line.

Figure 2: Beam test line.

A lot of black lines on the DTL shown in the figure 1 are the power lines for the quadrupole magnets. Each magnet is supplied the electric power independently. The power sources can supply both DC (600A in maximum) and pulse (1000A in maximum) currents to the magnet.

Adjustment of the input couplers

The rf power from the klystron is transferred in the WR2300 rectangular waveguide. The waveguide is converted to the WX203D coaxial one in the tunnel. The coaxial waveguide is connected to the input coupler.

The rf-power is fed into tank by two input couplers so that the load of each coupler is reduced by half. Furthermore the excitation of the TM_{011} and TM_{012} modes is suppressed since each coupler is located at one fourth of the total length from the end plate. The coupling constant of the coupler is tunable since the loop of the coupler is movable. The schematic view of the coupler is shown in figure 3.

Figure 4 shows the the relation between the coupler position and the value of the coupling constant. It also shows the loaded- (Q_L)and unloaded-Q (Q_0) values measured by changing the coupling constant (β_1 and β_2). Because the observed unloaded-Q value is 48700 and the calculated Q-value by the superfish without the effect of the post-couplers is 52900, the observed Q_0 is approximately more than 92 % of the theoretical value. Finally the coupling of the each coupler was adjusted to 0.5 so that the total coupling of the couplers is critical one. The reason why the critical coupling was chosen is described in the next section.
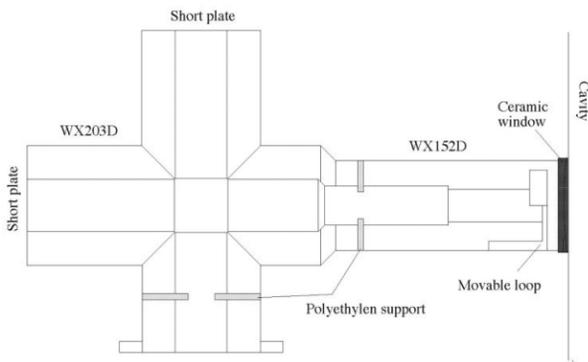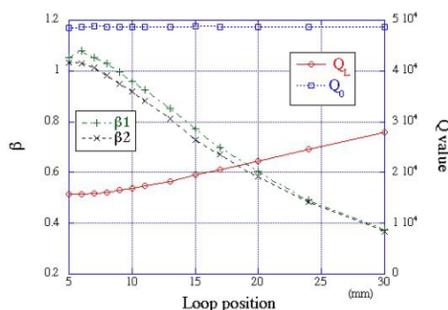

Figure 3: Design of the input coupler.

Figure 4: Measured Q-values and the coupling constants of the coupler.
 Abscissa shows the gap length between the loop and the window.

High-power conditioning

High-power conditioning has been done for the DTL-1 very carefully. The conditioning history is shown in figure 5. The coupling constant of each coupler was adjusted to 0.6 at the beginning of the conditioning. It means that the total coupling constant was 1.2 (over coupling) at first. The following items are the history of the conditining.
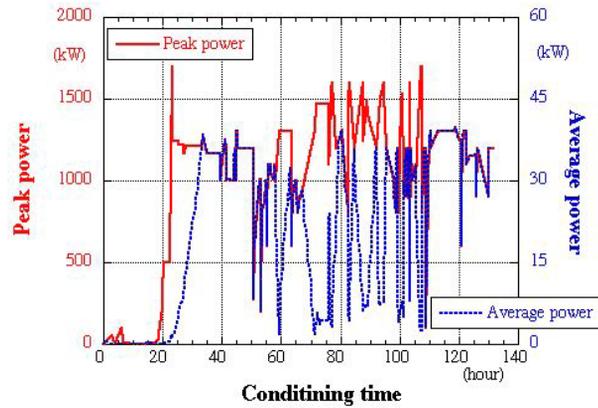

Figure 5: Conditioning history for DTL-1.

(1) 0 to 18 hours: In the beginning of the conditioning, almost input rf power was reflected from the coupler window. The rf pulse width was extended to 780 μsec with 50 Hz repetition in this period. Peak power was less than 6 kW. The conditioning in this period is considered as aging of the coupler window.

(2) 18 to 23 hours: When the rf power entered the tank through the window, real tank conditioning starts. During this period, the rf conditioning was done with the rf pusle of the low duty factor, (puse length of 100 μsec, repetition rate of $\le$ 10 Hz). It is the same procedure as the conditioning of the SDTL [4]. The input peak power was increased gradually up to 1.7 MW in maximum, which is approximately 1.5 times the desired value (the rf power of 1.1MW is required for the designed acceleration field of 2.5 MV/m) for the tank.

(3) 23 to 33 hours: After the achievement of the maximum value of rf power, the rf duty factor then has been extended gradually to the maximum value of 3% (600 μsec in the pulse length, 50 Hz in the repetition rate) with the peak power of 1.2 MW. The maximum duty was achieved soon. However the tank condition was not stable yet. Discharges happened frequently around the ceramic window. The rate of the discharge was approximately once per 5 minutes.

(4) 33 to 108 hours: The conditioning was being continued by changing the duty factor and/or the rf peak power. However the tank was still unstable.

(5) 108 to 120 hours: Finally we decreased the coupling constant of the coupler from 1.2 (figure 6 (a).) to 1.0 (critical coupling shown in figure 6 (b)) by removing the coupler loop from the window since the luminescence pattern on the window had the similar shape of the loop of the

coupler. As a result the tank became stable. (See figure 6 (b).)

(6) 120 to 130 hours: Because the tank achieved the stable condition, the tuning of the rf feed-back system was started for the beam acceleration.
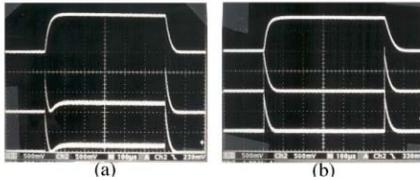

Figure 6: RF pulse shapes. (a) $\beta = 1.2$ (b) $\beta = 1.0$
Top: Tank rf level. Other lines:Reflection from the DTL.

FIRST BEAM ACCELERATION

The H^- ion beam was already accelerated by the RFQ linac up to 3 MeV [5]. Furthermore the MEBT line between the RFQ and DTL-1 was studied also by the beam from the RFQ [6]. The beam tuned by using the results of previous experiments was injected into the DTL-1 and accelerated up to its design value of 19.7 MeV. The energy was measured by the time of flight method with two beam position monitors, which works as a fast current transformer. The initial goal of the peak current of 30 mA was achieved after the tuning of the components in the MEBT. The observed current pattern is shown in the figure 7. Top of the figure is the beam current injected to the DTL-1 and bottom one is the beam from DTL-1. The beam pulse width is 20 μsec and the repetition rate of the beam is 12.5 Hz.

Quadrupole magnets in the DT were operated with DC current. The value of the current are shown in figure 8. The value of the current was fixed by using the previously observed transverse emittance of the RFQ. One of the main subject of the beam experiment is to find the reasonable operating condition of the quadrupole magnet in the DTL-1.

In the first beam acceleration, only the beam energy and the current were measured. The beam experiment is being carried out in order to study the beam properties (which are the emittance measurement, the bunch shape, the beam position, etc.). [7].

CONCLUSION

The high-power rf conditioning of the DTL-1 for J-PARC, which is installed in the test facility at KEK, was carried out deliberately. Consequently the peak rf power of 1.2 MW (pulse repetition rate of 50Hz, pulse length of 600 μsec) was put into the tank almost stably. (Recently the tank accepts stably the rf-power of 1.4 MW with the full duty factor.) Then H^- ion beam of 3 MeV energy was injected to the DTL. The beam which has 30 mA peak current was accelerated up to its design value of 19.7 MeV
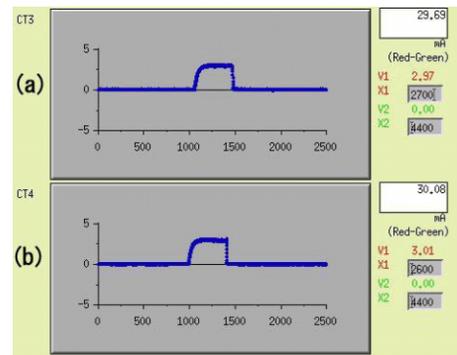

Figure 7: Output of the current monitor.
(a) Beam current at the end of the MEBT.
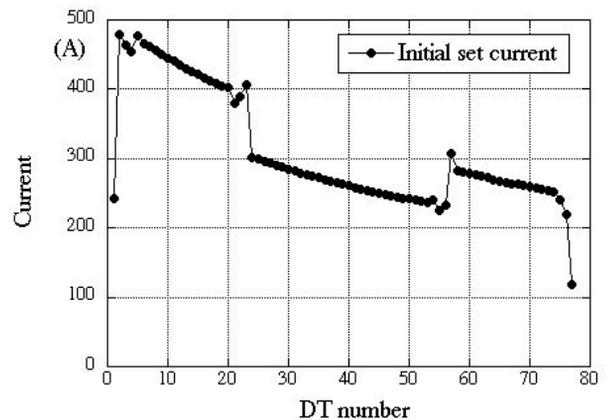(b) Beam current ejected from the DTL-1

Figure 8: The set DC current for DTQs.

with almost 100 % transmission. The beam experiment will be continued till the autumn of 2004.

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