FIRST BEAM STUDY FOR THE 432-MHZ DTL

F. Naito, K. Yoshino, T. Kato, Z. Igarashi, M. Kawamura, E. Takasaki,
Y. Morozumi, C. Kubota, T. Kubo, M. Ono, S. Anami and Y. Yamazaki
KEK, High Energy Accelerator Research Organization
1-1 Oho, Tsukuba-shi, 305-0801 JAPAN

Abstract

The first beam extraction from the 432-MHz DTL has been carried out in the test stand of KEK. Both MEBT and HEBT were assembled in the beam line for the beam test. The DTL has accelerated the 3-MeV H^- ion ejected from the RFQ up to 5.47 MeV. The measured ratio of the beam transmission is 91 %.

1 INTRODUCTION

The low-energy part of the 1-GeV linac for the Japanese Hadron Project (JHP [1]) has been constructed in order to establish the construction techniques and study the beam properties. (The scheme of the JHP is different from that of the Japanese Hadron Facility (JHF [2]) which was proposed recently as the modified version of the JHP.)

The test linac system consists of the H^- ion source, the radio frequency quadrupole (RFQ) linac and the short Alvaretz-type drift-tube linac (DTL). The beam-transport lines connect them. The high-power test of the DTL was completed in summer of 1994. The preparation for the beam study of the DTL was started since 1997, because the beam study of the RFQ had been completed.

2 SETUP FOR THE BEAM STUDY

The components of our linac system are as follows: 1) the H^- ion source; 2) the low-energy beam-transport line (LEBT); 3) the radio frequency quadrupole (RFQ) linac; 4) the medium-energy beam-transport line (MEBT); 5) the Alvaretz-type drift-tube linac (DTL); 6) the high-energy beam-transport line (HEBT). The layout of the linac system from the RFQ to the HEBT is shown in figure 1.

2.1 Ion source, HEBT and RFQ

The volume-productive ion source [3] supplies the H^- beam of the maximum 16-mA peak current. The extraction voltage of the ion source is 50 kV. The LEBT is composed of two solenoid magnets. The RFQ has the four-vane type structure. It accelerates the H^- ions from 50 KeV to 3 MeV. The resonant frequency of the RFQ is 432 MHz. The accelerating field of the RFQ is stabilized by the pi-mode-stabilizing loop. [4]

2.2 MEBT

The MEBT [5] consists of eight quadrupole electromagnets (Q-magnets [6]), a buncher and two steering magnets. All components of the MEBT are aligned on the same table. Thus, the alignment of the MEBT has been done by tuning the position of the table.

The buncher is a single-cell reentrant cavity. The gap length is 8.99 mm. The resonant frequency and measured Q_0 value of the buncher are 432 MHz and 21700, respectively. The maximum rf-power of 10 kW is supplied by the solid state power amplifier through the WX39D coaxial waveguide. The buncher is set in the middle of the MEBT. Two small steering magnets are installed between the QD1 and QF2.

2.3 DTL

The DTL has 18 drift tubes (DTs). The total length of the DTL is about 1.2 m. A permanent quadrupole magnet (PQM) is installed in each DT. The average field gradient of the PQM is 211 ± 1.3 T/m, which is about 20 % stronger than the design field (175 T/m). [7] The observed Q_0 value is 43500. It is about 90 % of the calculated value. The Q_0 value is sufficiently high. The measured

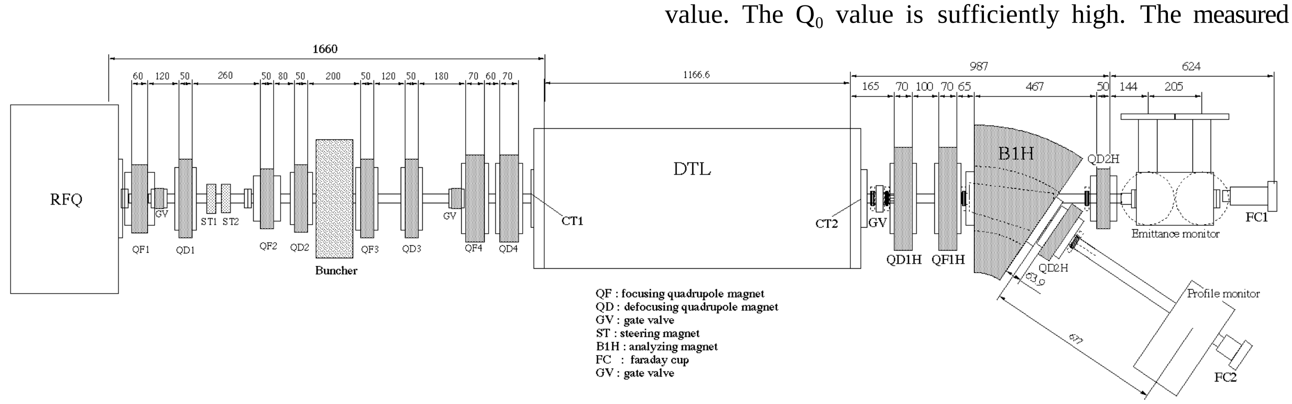

Fig.1 Setup of the DTL beam experiment

shunt impedance (Z) is 82 MΩ/m. It suggests a peak power of 128 kW for the 3-MV/m accelerating field. Thus rf-power of about 150 kW is required for the acceleration of 10-mA beam. The maximum electric field on the drift tube corresponds to 75% of Kilpatrick's limit. [8]

The accelerating field is stabilized by the eight post couplers. The field distribution stabilized by post couplers is sufficiently uniform (± 0.3%) and stable.

The current transformers (CT1, CT2) for the beam current measurement are installed in each end plate of the DTL.

2.4 HEBT

The HEBT consists of four Q-magnets, a bending magnet [9], a profile monitor, a transverse emittance monitor and two faraday cups. (We did not use the QD2H magnet between the bending magnet and the profile monitor.) The bending angle of the bending magnet is 34 degrees. The momentum distribution is measured by using a set of the bending magnet and the profile monitor. The effective area size of the profile monitor is 16 mm x 16 mm. The beam distribution is read by tungsten wires (0.1 mm in diameter) of 1-mm pitch.

The faraday cups (FC1, FC2) measure the total beam current. The FC1 works as the beam dump and the FC2 measures the beam current of the selected momentum.

3 MEASUREMENT

Because this study is the first beam acceleration by the DTL, the average beam current is reduced in order to minimize the beam loss. Then, the pulse length of the beam is reduced to 50 μsec, which corresponds to the rf-pulse length of the RFQ. The repetition rate is 10 Hz. Thus, the duty factor of the beam is 0.05 %. (The designed duty factor is 3 %.) The rf-pulse length of the DTL and the buncher are 200 and 140 μsec, respectively. The peak current of the beam, comes from the ion source, is about 13mA during the study. The coupling constant of the input coupler to the DTL tank has been increased from 1.0 to 1.25 (over coupling) against the beam loading by rotating the coupling loop before the beam experiment.

The DTL, MEBT and the HEBT were aligned in the RFQ beam axis by using a laser alignment system.

3.1 Tuning of the Parameters

The main parameters to be tuned are as follows: 1) The field strength of the Q-magnets of the MEBT; 2) The level and the phase of rf-field in the buncher; 3) The level and the phase of rf-field in the DTL; 4) The strength of the steering magnets. These parameters were tuned in order to maximize the beam transmission in the DTL and minimize the momentum spread of the beam ejected from the DTL.

The buncher requires the rf-power of 5.6 kW. The rf-power in the RFQ was adjusted to about 480 kW, which is an adequate power level for the standard operation of the RFQ. The rf-power level of the DTL is adjusted to 170 kW by parameter survey. Figure 2 shows the rf-field patterns for the DTL and the buncher

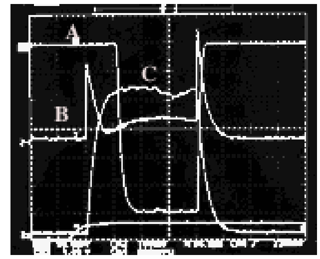

Fig. 2 Tank rf-field.
A: RF-field in the Buncher
B: Reflection from the DTL
C: RF-field in the DTL
(Abscissa: 50 μsec/div)

3.2 Beam Transmission

Figure 3 shows the output signals from CT1 and CT2. The upper line ("A" line) shows the beam current at the entrance of the DTL and the lower ("B" line) the output beam current from DTL. One vertical division corresponds to the current of 2 mA. It shows that the input and the output beam currents are 10.7±0.13 and 9.7±0.13 mA, respectively. Thus, the transmission of the DTL is 91 ± 2 % in this stage. Because the beam current from the ion source is 13±0.9mA and the transmission of the RFQ is 82.5%, the estimated beam current from the RFQ is 10.7±0.7 mA, which consists with the input beam current in the DTL. The reason for the missing beam of about 9 % is still unknown. We will check the followings in order to find its origin; 1) Transverse mismatching at the DTL entrance due to a 21-% excess in the strength of the PQM; 2) Alignment of the total accelerating system, especially, the Q-magnets of the MEBT; 3) a fraction of particles other than H^- ions.

3.3 Beam Energy

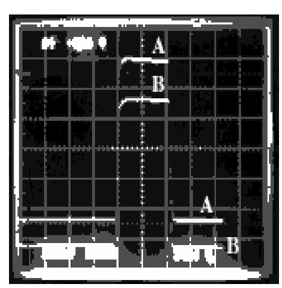

Fig. 3 Current monitor signal.
A: Incident beam into the DTL
B: Output beam from the DTL

Abscissa: 20 μsec/div
Ordinate: 2 mA/div

The beam momentum is measured on the profile monitor by changing the excitation current of the bending magnet in the HEBT. The beam momentum has been calibrated by using the beam from the RFQ without the acceleration in the DTL since the beam energy from the RFQ was already measured. The results (figure 4) include three kinds of data taken by changing the excitation current of the bending magnet. The abscissa is the energy of the beam. The Gaussian distribution curve has been fitted to the data in order to estimate the center value and the width of the kinetic-energy distribution. The averaged center value and the full width at half maximum of the fitted curves are 5.47 and 0.21 MeV, respectively. The width of the distribution will be checked by the simulation.

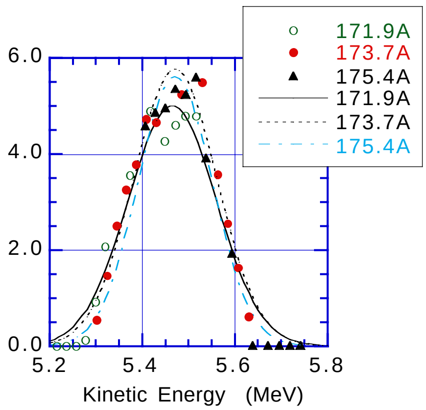

Fig. 4 Energy distribution of the beam from the DTL. Markers indicate the measured data. Gaussian curves are fitted to the data. The figures (171.9, 173.7 and 175.4) are the excitation current of the bending magnet used for the data taking.

3.3 Phase Dependence of the BeamTransmission

Figure 5 shows the variation of the beam transmission measured by changing the rf-phase of the DTL relative to that of the RFQ. The beam is measured by the FC2 after the bending magnet, which is adjusted by changing the excitation in order to collect the beam in the faraday cup FC2. The ordinate values are normalized at the maximum point. The width of the flat top of the plot is about 30 degrees. It is reasonable value, because the longitudinal bunch length of the beam from the RFQ is about 50 degrees and the acceptable longitudinal phase of the DTL is about 90 degrees.

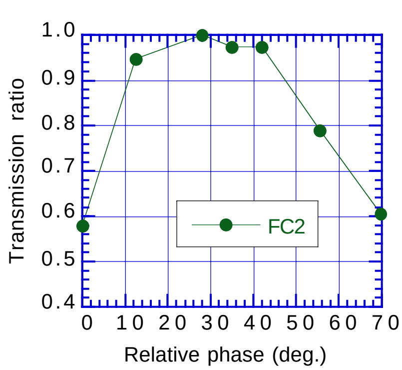

Fig. 5 Relative phase dependence of the beam transmission.

4 CONCLUSION

The first experiment of the beam acceleration by the 432-MHz DTL has been successfully performed in the test stand of KEK. The DTL accelerates the 3-MeV H^- ion ejected from the RFQ up to 5.47 MeV. Both MEBT and HEBT, assembled for the beam test, worked well. After the survey of the Q-magnet strength and the rf-pulse parameter for the tanks, the transmission of 91 ± 2 % has been obtained. The measurement of the beam emittance will be done soon.

5 ACKNOWLEDGEMENTS

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