MEASUREMENTS OF THE BEAM ENERGY AND BEAM PROFILE OF 100 MeV PROTON LINAC AT KOMAC*

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Abstract

The linac for generation of the 100 MeV proton beam is operating in Korea Multi-purpose Accelerator Complex (KOMAC), Korea. The 100 MeV proton beam is applied in the industrial and the scientific fields such as improvement of the material characteristics and production of the isotope. The accurate measurements of the proton beam energy and profile are necessary for increasing the efficiency of the application and minimizing the inadequate radioactivation in linac structure caused by the beam loss. The proton beam energy and beam profile are measured by using the time-of-flight (TOF) method with a BPM (beam position monitor) and the ion chamber array, respectively. The detailed measurement setup and the measured results will be given in this paper.

INTRODUCTION

The proton linac with 100 MeV beam energy consists of a 50 keV injector with microwave ion source, a 3 MeV four-vane type radio frequency quadrupole (RFQ) and a 100 MeV drift tube linac (DTL) at KOMAC. The schematic diagram of the linac at KOMAC is shown in Fig. 1. As shown in Fig. 1, the 100 MeV DTL can be divided into two parts: a 20 MeV DTL with assembled 4 tanks and a 100 MeV DTL with assembled 7 tanks. The operating frequency of the RFQ and the DTL tanks is 350 MHz [1].

This work presents the beam energy and the beam profile of the linac at KOMAC. The beam energy is measured by two methods for validation of the measured beam energy. At first, the beam energy is calculated roughly by measuring the length of the beam penetration through the aluminium block with various thicknesses. And, the beam energy is measured more accurately by the TOF [2]. The beam profile is measured by 2D ionization chamber array.

MEASUREMENT SETUP

Figure 2 shows the experimental setup of the beam energy measurement by beam penetration through the aluminium block. The aluminium pieces with thickness 0.2 mm are added at the surface of aluminium cube. Therefore, the thickness of the aluminium block ranges from 30 mm to 34.2 mm. The green paper of which colour is changed by impingement of proton beam is attached in the opposite side of aluminium block. And it is located at 1.7 m away from the AlbeMet beam window of which thickness is 0.5 mm in a target room 103 (TR103).

The schematic diagram of the experimental setup for measuring the beam energy by TOF is shown in Fig. 3. The proton beam energy is measured at two positions. First, the energy of the accelerating proton to DTL107 is measured by TOF. And the other, the energy of the accelerating proton to DTL106 is measured by TOF. To measure the beam energy by TOF, two BPM signals are used. The time difference of the each peak value at the two BPM positions is calculated for the beam drift between two BPM positions. The time difference can be converted into phase difference between two BPM positions.

The beam profile is measured by using 2D ionization chamber array. The 2D ionization chamber array specifications are described in Table 1.

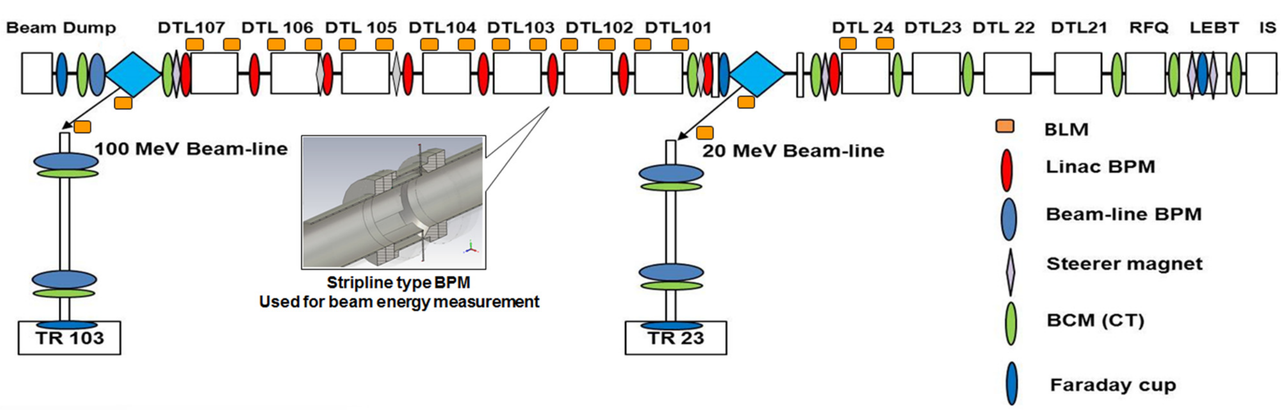

Figure 1: Beam diagnostic layout of the proton linac at KOMAC.

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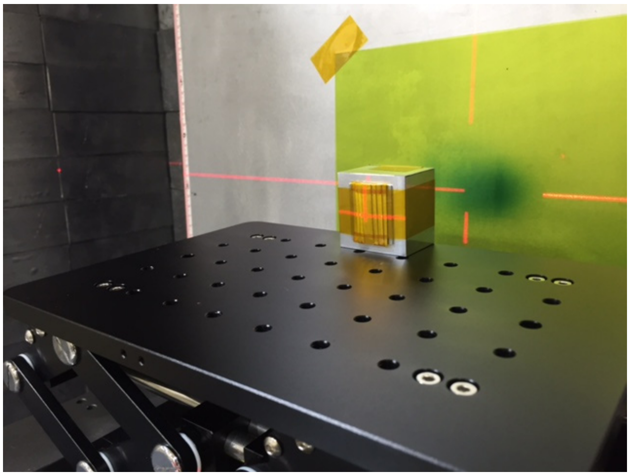

Figure 2: Experimental setup of the beam energy measurement by the beam penetration through the aluminium block.

Figure 4: Experimental setup of the beam profile measurement by using 2D ionization chamber array.

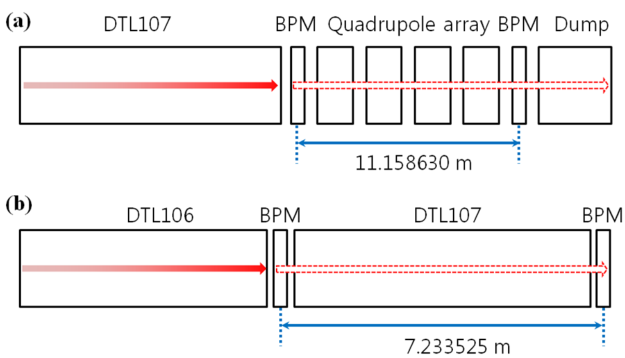

Figure 3: Schematic diagram of the experimental setup for measuring the beam energy by TOF. (a) after acceleration to DTL107, (b) after acceleration to DTL106.

Table 1: 2D Array Specifications

Parameter	Value
Manufacture /Model	PTW / 2D-array XDR
Detector type	Ionization chamber
Number of detector	729
Spatial resolution	10 mm
Effective area	270 mm X 270 mm

Figure 4 shows the installation of the 2D ionization chamber array in front of the beam window. The 2D ionization chamber array is located at 1.6 m away from the beam window. The beam profile is measured by this equipment with 100 MeV proton beam energy.

MEASUREMENT RESULTS

Beam Energy

The proton beam energy is calculated by measuring the beam penetration thickness of the aluminium. The results of the changing green paper colour by the impingement of the proton beam is shown in Fig. 5. The dark green region of the paper is the region of the proton collision, whereas the proton does not penetrate in the light green region. The beam energy is estimated from the thickness of the beam penetration with considering beam energy loss by the beam window and air. In Fig. 5 (a), the minimum thickness of the proton penetration is approximately 34.2~34.4 mm. Therefore, the calculated beam energy is estimated at 97.6 ~98.2 MeV. In Fig. 5 (b), the minimum thickness of the proton penetration is approximately 30~30.2 mm. The proton beam energy after acceleration to DTL106 is derived at 91.1~91.5 MeV.

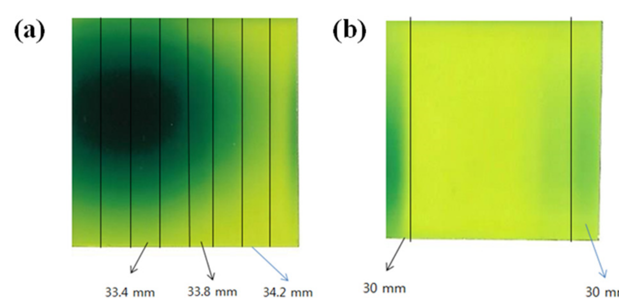

Figure 5: The results of the beam energy measurement by the beam penetration through the aluminium after acceleration to (a) DTL107, (b) DTL106.

To obtain the more accurate proton beam energy, the method of TOF is adopted. The experiments using TOF are carried out with changing the RF phase in DTL106, 107. And, the proton velocity is calculated by Eq. (1) [2]. Finally, the proton beam energy calculated by using the calculated proton velocity and Eq. (2).

$$v = \frac{L_{12}}{T_{12}} = \frac{L_{12}}{T_{acc}\left(N+\frac{\varphi_{12}}{360}\right)} = \frac{360 \cdot L_{12} \cdot F_{acc}}{360 \cdot N + \varphi_{12}} \quad (1)$$

φ_{12}: phase difference between two BPM positions.
L_{12}: Length between two BPM positions
F_{acc}: Accelerator frequency
N: Bunch number between two BPM positions
v: Beam velocity

$$\mathrm{K.E.} = (\gamma - 1)mc^2 = \left(\frac{1}{\sqrt{1-v^2/c^2}} - 1\right)mc^2 \quad (2)$$

The calculated beam energy after acceleration to DTL107 is shown in Fig. 6. When the RF phase is -30°, the proton beam energy is approximately 98 MeV. This value is identical to the value of beam penetration method.

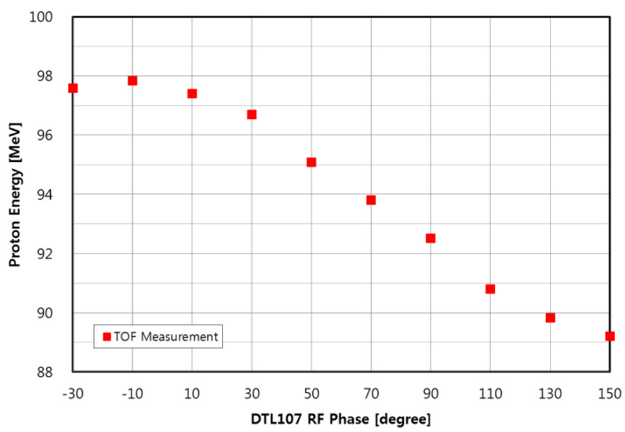

Figure 6: The calculated beam energy with various DTL107 RF phase.

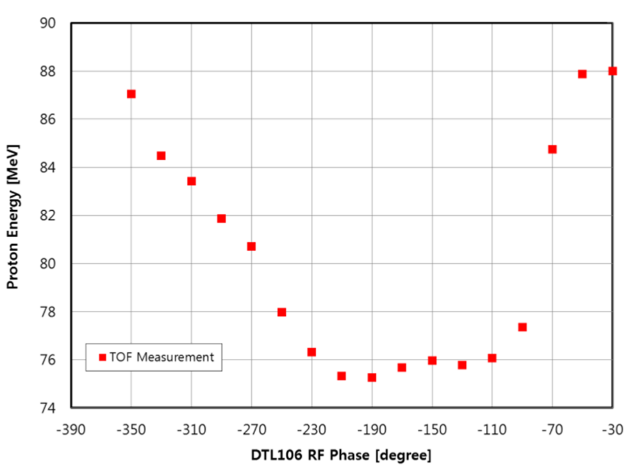

Figure 7: The calculated beam energy with various DTL106 RF phase.

Figure 7 shows the proton beam energy with various DTL106 RF phase. The beam energy with -30° RF phase is approximately 88 MeV lower than the value of beam penetration method.

The maximum beam energy in Figs. 6 and 7 is lower than design value of linac. Above experimental results are obtained by RF tuning test. In future, we will conduct precise experiments.

Beam Profile

The 2D plot of the beam intensity with 100 MeV proton beam energy is shown in Fig. 8. The 100 MeV beam irradiates in the middle of 2D ionization chamber array. The horizontal FWHM beam size is 44.9 mm, and the vertical FWHM beam size is 17.6 mm, respectively. The beam shape is stable.

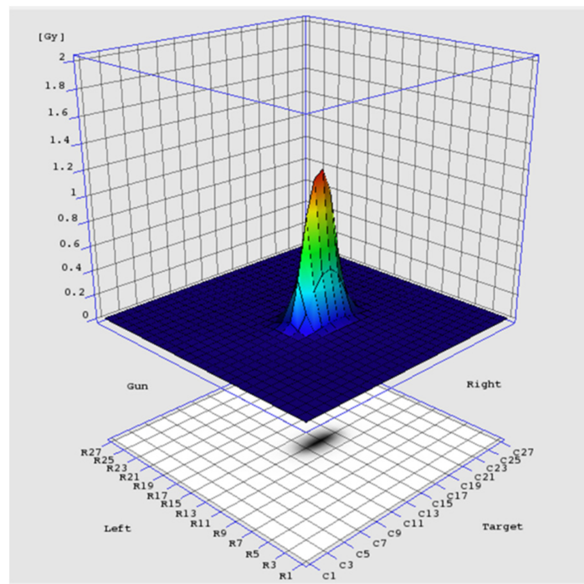

Figure 8: Beam profile after DTL107 (100 MeV).

CONCLUSION

The first attempt of the beam energy measurement by using TOF is carried out. The accuracy of the proton beam energy measurement by TOF is confirmed through those experimental results. In future, we will accomplish the beam tuning.

ACKNOWLEDGEMENT

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