Design of the Ridge-Filter Type Modulator for TR103 of PEFP

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1. Introduction

The PEFP (Proton Engineering Frontier Project) plans to start the beam service from 2013. We will provide proton beam to the users at the user facilities, TR103 and TR23. The user facility consists of energy degrader, flux controller, scatterer, ridge-filter type modulator, target stage, diagnostic system, collimator and so on. In this study, we designed a ridge-filter type modulator for the uniform depth-dose distribution with high LET (linear energy transfer) value. Currently, there are two types of range modulator for SOBP (spread-out Bragg peak). One is a propeller type, and the other is a ridge-filter type modulator. A propeller type modulator is not suitable for a pulsed beam because it has time-dependent property. So, it is difficult to apply a short pulsed beam of the PEFP because the range of pulse length is 0.1 ~ 1.33 msec. for 103-MeV. Unlike a propeller type one, ridge-filter type modulator has no restriction [1-3]. For these reasons, we choose the ridge-filter type modulator for the energy modulation. The aluminum was selected a s a material of modulator, because it can be cooled-down in the very shorter time after proton beam irradiation compared to graphite, another candidate. So we selected aluminum as a material of a ridge-filter type modulator.

2. Simulations and Results

The PEFP plans to construct 10 user facilities for 20/100-MeV proton beam utilizations. By the end of this year, we will install two irradiation facilities, TR23 and TR103, at the first time, and another two user facilities will be installed every year during next four years. Every user facility has its own dedicated utilization field. Before, the completion of the total user facilities construction, TR23 and TR103 have to meet all experimental requirements from the user in the field of NT, BT, IT, ST, medical science, nuclear physics, material and environmental science as possible as they can. Therefore, we designed ridge-filter type modulator which can be applied to every field and covering 8-cm flat-topped depth-dose distributions in 103-MeV proton beams for the water target. The minimum thickness was decided to be 2-mm for the mechanical support and maximum thickness was decided to be 40-mm for 103-MeV proton beam. Ridge interval and the drift distance was correspond to 8-mm and 30-cm, respectively.

To calculate the depth-dose distribution, we used SRIM (the stopping and range of ions in matter) Monte Carlo simulation code [4]. The SRIM code is effective to calculate the deposited energy distribution to the target depth. SRIM simulations were performed by varying the thickness of the aluminum from 2-mm-thick to 40-mm-thick with 1-mm-thick increase for 103-MeV proton beam energy. To obtain uniform depth-dose distribution, we regulated the weight of each energy distribution peaks (Bragg-peak) for 39 thickness conditions of aluminum in the range of 2 ~ 40-mm-thick. Figure 1 shows results of SRIM calculation and fabricated SOBP (spread-out Bragg peak).

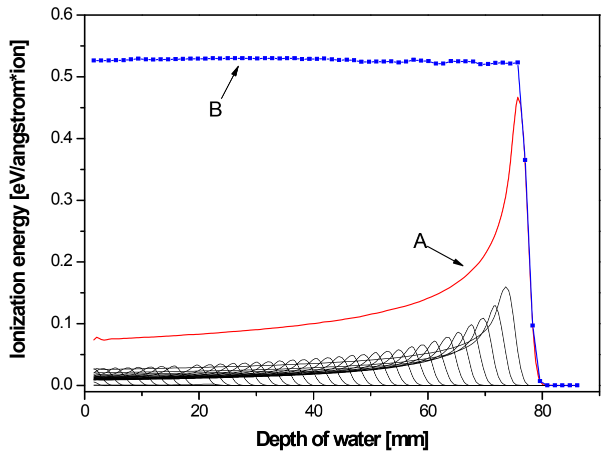

Fig. 1. Results of SRIM code simulation. (A) modulated Bragg peak with different weight according to the aluminum thickness. (B) depth-dose distribution.

As a result, we can obtain 8-cm SOBP region from the surface with the error less than 1%.

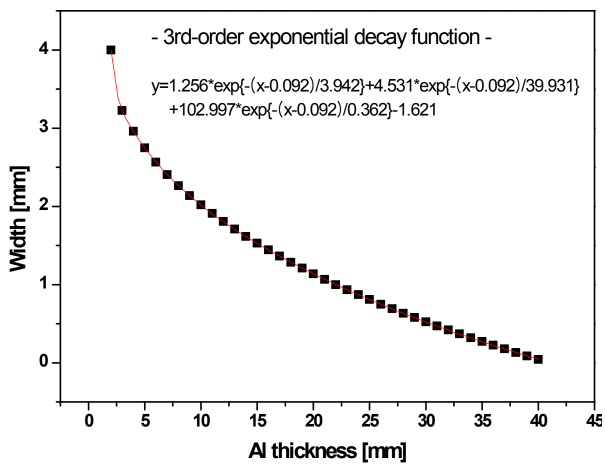

Fig. 2. Design ridge shape for 103-MeV proton beam.

From the calculated weighting values, we designed the ridge-filter shape as shown in figure 2.

The figure 3 shows the photograph of the proto-type ridge to verify the manufacture process. As a result, we can identify that 20-cm long, 4-cm high ridge shape with 8-mm interval can be using wire-cutting method.

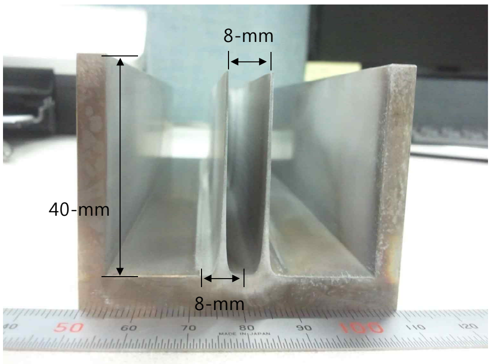

Fig. 3. The photograph of the proto-type for ridge-filter type modulator.

3. Conclusions and Discussions

We designed a ridge-filter type modulator using SRIM code simulation and the manufacturing process was verified by proto-type fabrication. In order to confirm two-dimensional dose distribution, we will perform MCNPX code simulations. In addition, on the basis above results, we will design a ridge-filter type modulator having a 2-cm-thick SOBP region in specific depth for the R&D experiment for cancer treatment of deep-seated tumor of small experimental animals.

ACKNOWLEDGEMENT

This work was supported by the Proton Engineering Frontier Project in the Ministry of Education, Science and Technology of the Korean government

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