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Combination of Longitudinal and Transverse Dose Distributions by Using a Range-modulating Propeller and a Rotatable Sample Stage

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1. Introduction

In the applications of the energetic proton beam, both the transverse and the longitudinal uniform doses are required at the same time in order to get uniform irradiation effects over the large volume of a target.

Recently, we have developed a range modulating propeller to obtain the longitudinal uniform dose distribution, and a rotatable sample stage to achieve the transverse uniform dose distribution in the target. If the effects of the two devices are combined together in the beam irradiation sample, we should determine the appropriate operation mode since the working principles of both devices are time-dependent.

2. Methods and Results

2.1 Longitudinal Uniform Dose Distribution

In order to obtain the longitudinal uniform dose distribution, a range modulating propeller has been designed and fabricated.[1,2] The range modulator is composed of 4 periodic blades and each blade has 27 steps with different thicknesses and opening angles. The different thicknesses of the blade take a role of the energy modulation of proton beam, so the traversing beams are distributed to various depths in a target. The different opening angles do a role of the beam allocation to the specific depths. The ratios of the angles are determined by a simulation code "SRIM" so that the uniform dose distribution is formed in a water-equivalent sample.[3,4] Figure 1 shows the beam allocation ratios, so called "beam weights" for each target depth. In this Process the stopping powers and ranges for various proton energies are calculated with the help of SRIM.

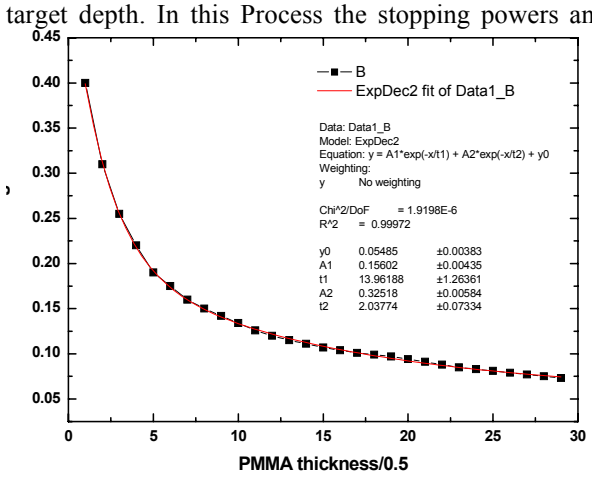

Figure 1. The determined beam weights.

Figure 2 shows the designed range-modulating propeller made of Polymethyl Metacrylate (PMMA). The maximum thickness of the propeller is 13.5mm, which coincides with the range of 42MeV proton. Every step thicknesses in a blade are a multiple of 0.5mm. The maximum beam acceptance is 170mm, corresponding to the maximum beam size on the beam transfer line. Each blade has a saw-tooth shape in azimuthal direction so as to fit for combining the longitudinal and transverse dose distributions.

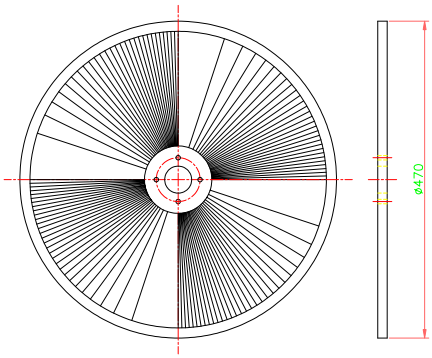

Figure 2. The designed range modulating propeller with different thicknesses and opening angles.

We measured the longitudinal dose profile formed by the fabricated range-modulating propeller as shown in Figure 3. The width of uniform dose region is 10mm in PMMA, and its uniformity is about 96% on the flat top.

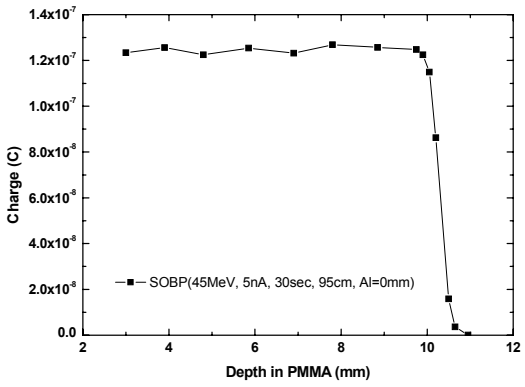

Figure 3. The measured longitudinal dose distribution for 35.5MeV proton beam by using the range-modulating propeller.

2.2 Longitudinal Uniform Dose Distribution

Using a rotatable sample stage, the wide and uniform dose distribution can be formed on the surface of an irradiation sample. We developed the two methods, one is a mechanical wobbling method and the other is a spiral scanning method. The first scans the sample in a circular direction by rotating the stage on axis and off axis with the same revolution speed. On the other hand, the second scans the sample in a spiral direction.

The transverse dose distribution was measured by using a dosimetry film, and the measurement result is shown in Figure 4. The width of uniform dose region is more than 20cm, and its uniformity is about 92% on the flat top.

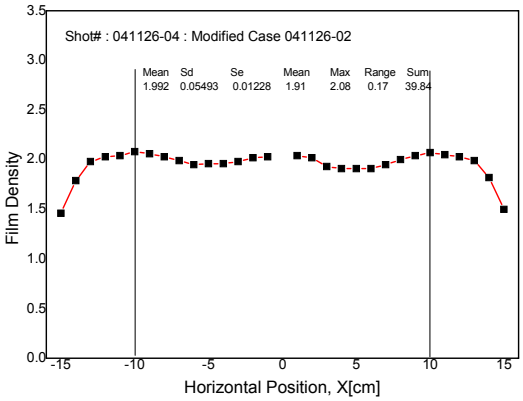

Figure 4. The measured transversel dose distribution formed by using the rotatable sample stage.

2.3 Combination of Two Dose Distributions

In mutation breeding or other irradiation experiments, we want to expand the wide and uniform dose distribution on the sample surface to a deep region. For this purpose, the range-modulating propeller and the rotatable sample stage should work together. The principle of the combination is shown in Figure 5. The separate working of the range-modulating propeller and

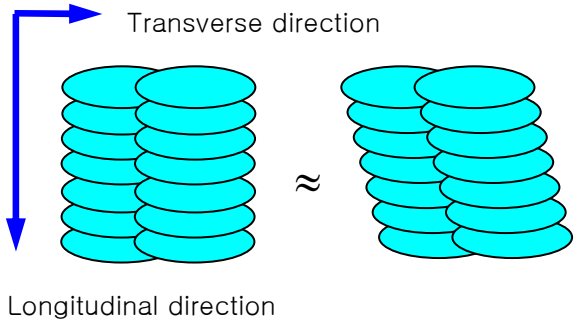

Figure 5. The combination principle of the range-modulating propeller and the rotatable sample stage.

the rotatable sample stage is equivalent to the simultaneous working of them in the viewpoint of the uniform dose.

When the combination of both devices is considered, the ratio of the numbers of revolution should be a multiple during the irradiation time. In this way we could determine the appropriate operation mode of both devices.

3. Conclusion

A rotating range modulator was designed and fabricated for longitudinal uniform dose profile and a rotatable sample stage was developed for transverse uniform dose profile. In order to achieve the uniform dose in a sample volume we devised the combination of both devices and tested the dose uniformity in the volume when the devices were working at the same time.

REFERENCES

[1] J. P. Biersack and L. Haggmark, Nuclear Instruments and Methods, Vol.174, p.257, 1980.
[2] J. F. Ziegler, J. P. Biersack and U. Littmark, The Stopping and Range of Ions in Solids, by Pergamon Press, New York, 1985 (new edition in 2003).
[3] W. T. Chu, B. A. Ludewigt, and T. R. Renner, Instrumentation for Treatment of Cancer Using Proton and Light-ion Beams, Rev. Sci. Instrum., Vol.64, p.2055, 1993.
[4] A. M. Koehler, R. J. Schneider, and J. M. Sisterson, Range Modulators for Protons and Heavy Ions, Nuclear Instruments and Methods, Vol.131, p.437, 1975.