RDMIS Radiation Detection and Medical Image Sensor laboratory

KAIST

Analysis of Beam Characteristics by Filter Design using Monte Carlo Simulation

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I. INTRODUCTION

- Charged Particle Therapy (CPT) or hadron therapy is one of external beam therapy to treat tumor.
- Application of He ions provides some clinical advantage than other particle therapy.
- In order to use low energy He ions in hadron therapy and achieve an acceptable homogeneity of the Spread Out Bragg Peak (SOBP) needs to be broadened at least few millimeters by means of a properly designed filter.
- In this study, we calculated depth-dose distribution for hadron therapy using the MC code and compared the Bragg peak in depth-dose distribution along the filter design of different shape and thickness.

II. MATERIAL & METHOD

◆ Monte Carlo simulation geometry

- We used Tool for Particle Simulation (TOPAS) which is MC simulation dedicated to proton therapy.
- The water phantom is placed center with 200 x 200 x 200 mm size and He ions is irradiated at a distance of 6 m from water phantom.
- The filter is placed in front of the water phantom as a distance of 300mm.

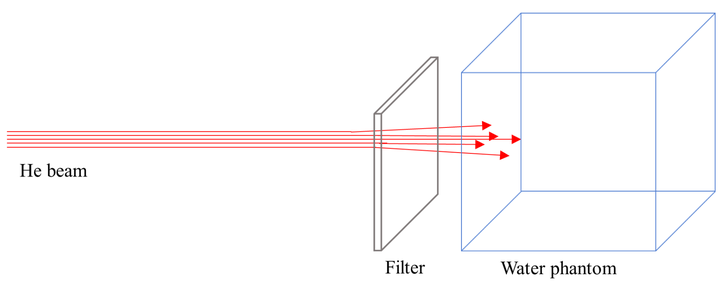


Figure 1. Schematic view of water phantom, beam and filter geometry.

- Before simulations, we calculated result of depth dose distributions for He ions beam with 10 MeV steps and energy range 160 ~ 690 MeV in the water phantom.

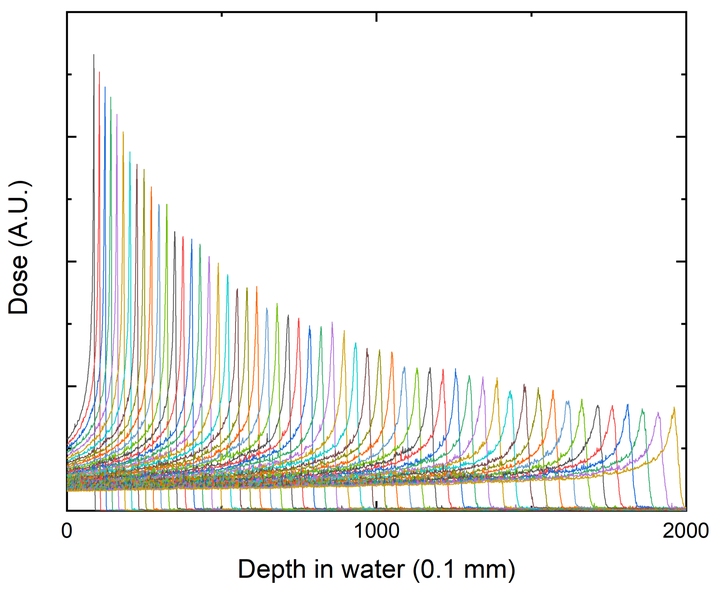


Figure 2. Pristine depth dose distributions in water phantom for He ions beam with energy range 160 ~ 690 MeV.

◆ Filter design modeling

- A certain amount of beam energy spread is need to uniformly give energy to the tumor.
- One of the methods to make beam energy spread is to penetrate the filter.
- Filter in our simulation, consisting of lung substitude material Gammex LN300, is used and has 260 x 260 x 2 mm and 260 x 260 x 3 mm size.

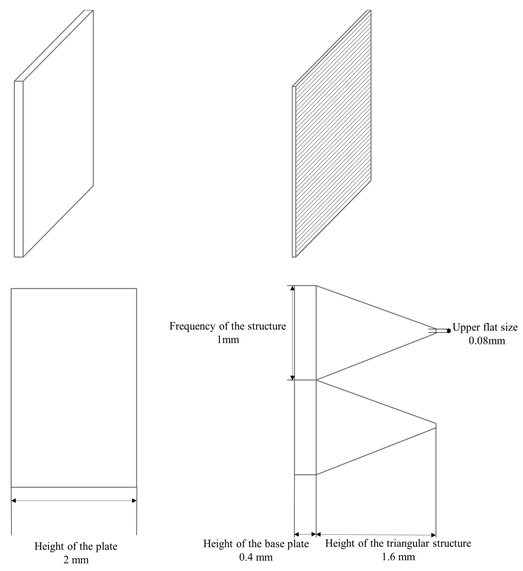
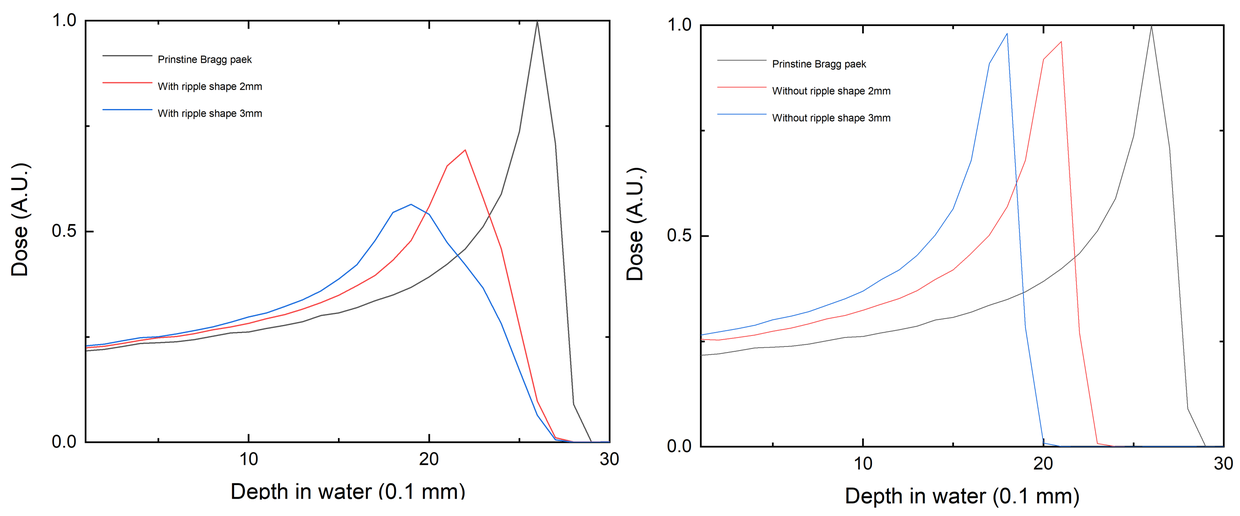


Figure 3. Schematic view of filter (a) with ripple shape and (b) without ripple shape.

III. RESULTS AND DISCUSSION

◆ Depth-dose distribution curve as filter design



(a) (b)

Figure 4. (a) Comparison with pristine Bragg peak (black) and without ripple shape filter (red and blue). (b) Comparison with pristine Bragg peak (black) and with ripple shape filter (red and blue). The thickness of filters is 2 mm and 3 mm, respectively.

- In Figure 4. (a), according to the thickness without ripple shape filter thicker, the depth of Bragg peak decreases 0.5 mm and 0,8 mm.
- Bragg peak width (BPW_{80}) without ripple shape filter is 2% and 5% wider than the pristine Bragg peak.
- Height of Bragg peak without ripple shape filter decreases 3.8% and 1.9%.
- In Figure 4. (b), according to the thickness with ripple shape filter thicker, the depth of Bragg peak decreases 0.4 mm and 0.7 mm, similar as without ripple shape filter.
- Bragg peak width (BPW_{80}) with ripple shape filter is 199%, 684% wider than pristine Bragg peak.
- Height of Bragg peak with ripple shape filter decreases 30.6% and 43.5%.

◆ Spread out Bragg peak homogeneity

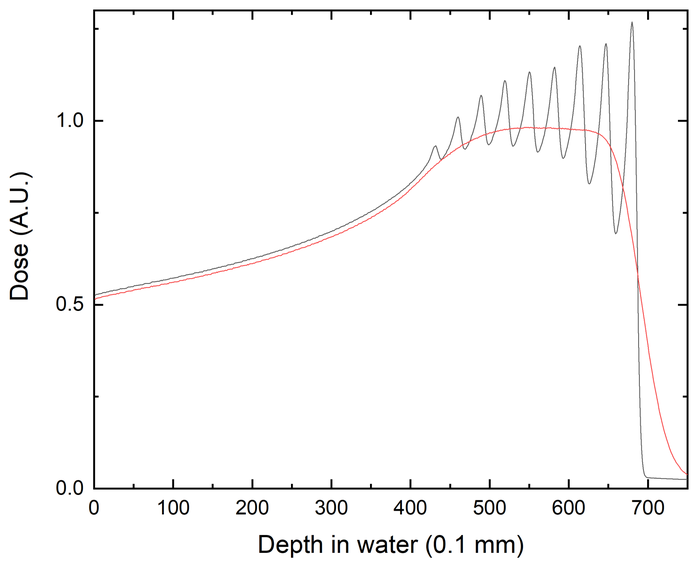


Figure 5. Effect of ripple shape filter on SOBP homogeneity and distal fall-off He ions beam.

- SOBP made by using a step of 3.7 mm the Bragg peak and gave different weights.
- Deviation of SOBP without ripple shape filter (black) has ±29.39%.
- Deviation of SOBP with ripple shape filter (red) has ±0.31%.

◆Discussion

- These Bragg peak property which result of filter 2 mm and 3 mm is because of multiple coulomb scattering.
- Depth of Bragg peak is similar both filter, but height and width of Bragg peak change significantly.
- SOBP plateau with ripple shape filter has more homogeneous, so using filter can deliver doses more evenly to cancer.

IV. CONCLUSION

- In this study, we analyzed beam characteristic by filter design.
- Multiple coulomb scattering occurs due to ripple shape, which results in beam energy spread.
- According to this beam energy spread, the homogeneity of SOBP increases, which can give tumor uniform dose.
- The proposed ripple shape filter is vital part of the beam modeling system for active beam scanning with synchrotron accelerators, but filter need to more optimization.