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Multi-layer Energy Filter Produced by Stereolithography for Charged Particle Therapy

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Introduction.

Heavy charged-particle beam (proton or heavy ion) has characteristic advantage in its superior dose localization by one or a few directional irradiation. As a method to control spread of Bragg peak for conformation to the target in the irradiation, uneven ridge filter was proposed [1]. In the present work, the idea of the uneven filter is improved on the structure and the designing procedure by using the rapid prototyping technique; stereolithography. A new type of energy filter is developed, which realize conformal irradiation by using intensity modulation having lateral position dependence. The new energy filter achieves variable spread of the depth-directional peak in irradiated dose distribution by changing the thickness of the filter.

Structural feature of the new filter.

Traditional range modulation by a ridge-shape filter makes evenly spread-out peak in the dose distribution by mixing several beams having different residual ranges. To realize lateral changing of the spread, the concept of the energy mixing is improved in steps illustrated in figure 1. Similarity in the thickness pattern of the absorbing material for the traditional ridge remains with the miniaturized unit cell of the multi-layer filter. The energy filtering with many layers realizes easy controllability of the dose spread by changing the number of the layers. Furthermore, controllability of steep changing of the spread is achieved by the miniaturization of the pattern. Instead of the ridge, cone and pyramid are usable as the shape of the construction of the unit cell.

To make the structure of the new filter with sufficient accuracy, formative technique using hardening of epoxy resin with laser light scanning is adopted, that is stereolithography. The schematic drawing of a block having the miniaturized structure is shown in figure 2. The size of the unit cell is 4mm height and 4 or 5mm width in this work. The new filter can be set on the bolus (range compensator) close to the patient, because the spacing is large enough to reduce the dose fluctuation originates in the miniaturized pattern of thickness.

Three-dimensional conformal irradiation.

The lateral changing of the dose spread makes unevenness of the dose with dependence on the lateral position. In order to get a uniform field on the target region, lateral intensity changing should be combined with the method using the new filter. As one of simple methods to realize the intensity changing, an additional thin scatterer was used in this experimental demonstration. The

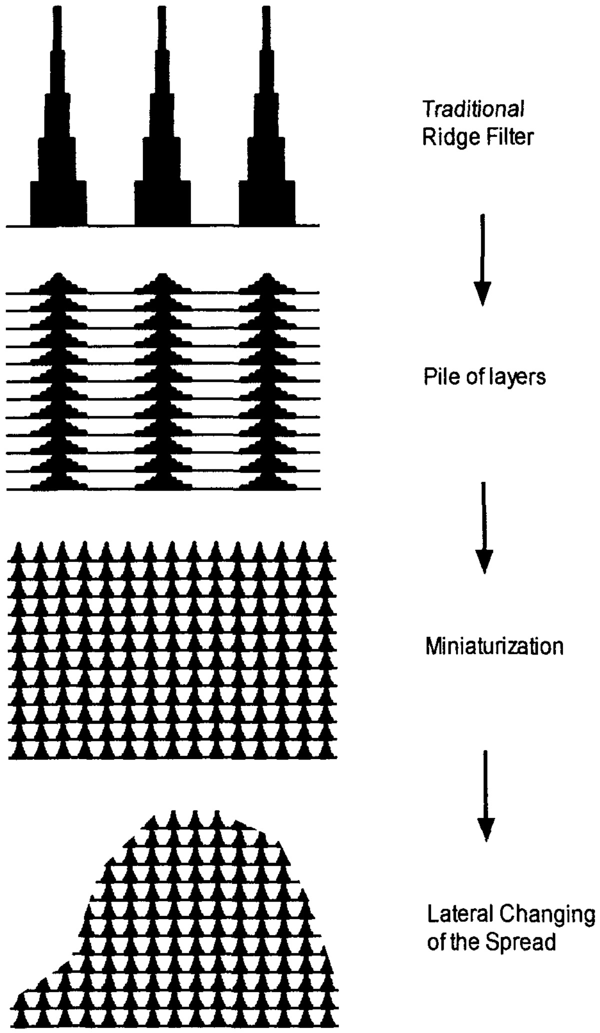

Figure 1. Conceptual changing of the structure and function from the traditional filter to the new filter.

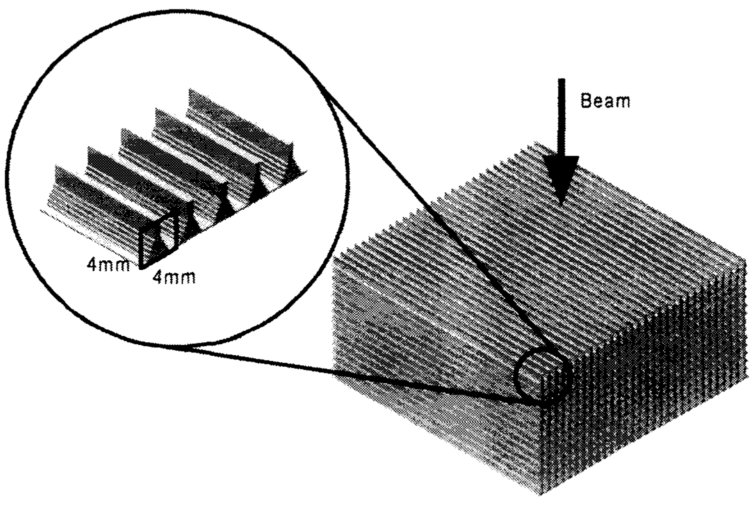

Figure 2. Schematic draws of a block including many layers of ridge-type filter.

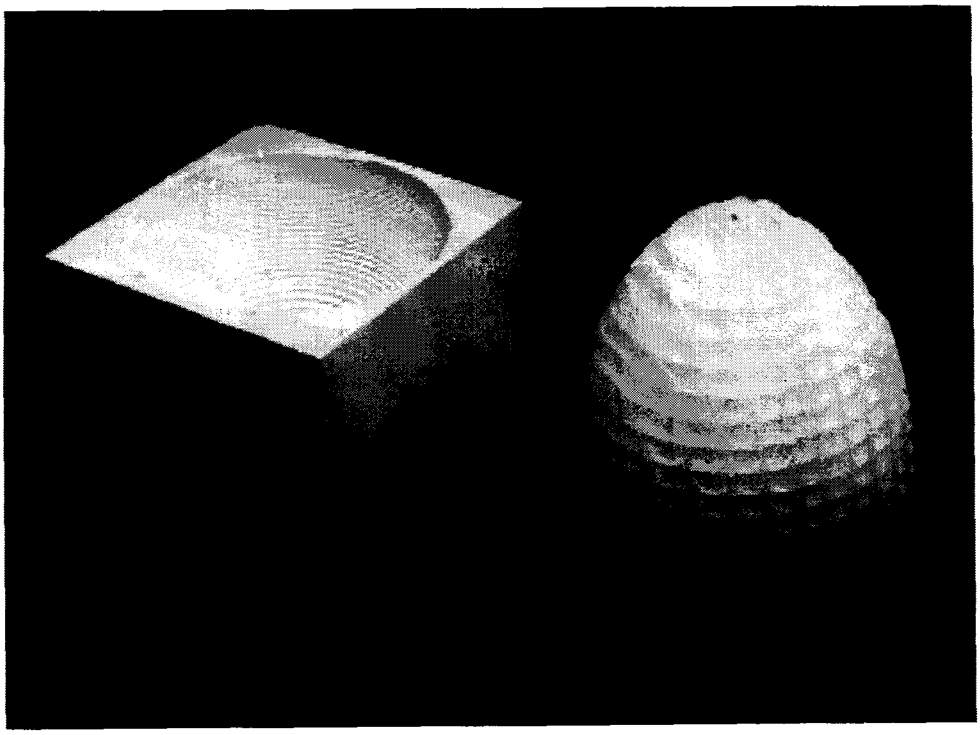

Figure 3, Picture of a set of the bolus and the new filter for the sphere target.

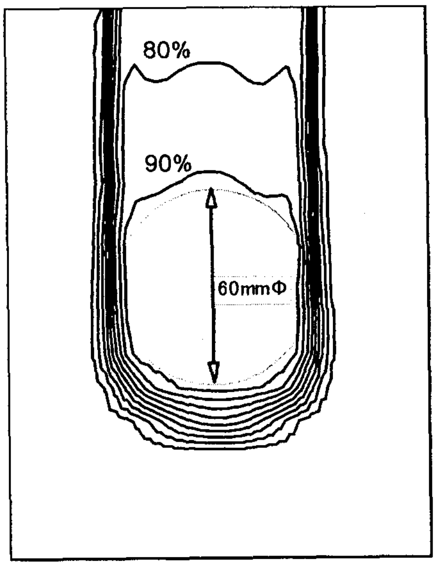

Figure 4. Experimental result of the conformal dose distribution on a plane along the beam axis
The cross section of the target is shown as a hatched region.

scatterer consists of a center region of low Z material and other region of high Z material. By the scatterer, intensity increase of about 5% was introduced on the center region of a sphere target assumed in the irradiated phantom. The diameter of the target is set to 60 mm.

The new energy filter designed for the sphere target is shown in figure 3, together with the bolus shaped to a half of the target. The outward form of the multi-layer filter is machined to follow the vertical thickness of the target. In the experimental setup, the position of the fine collimator was about 150mm upstream of the target. The set of the bolus and the new filter were put on the fine collimator. The broad beam with energy of about 180 MeV was formed by single scatterer in the vertical beam line of Proton Medical Research Center (PMRC), university of Tsukuba. The range shifter is set to 50mm in water equivalent length.

In order to measure three-dimensional dose distribution in the setup, a stack of imaging plates (IP) was applied. In the measuring system, the IPs (BAS-III 2025, Fuji Film Co., Ltd.) were sandwiched by the solid phantoms alternately. The experimental result given by proton irradiation of about 10mGy is shown in figure 4. From three-dimensional data of the dose distribution, two-dimensional data on a plane along the beam axis were picked up for the iso-dose drawing. For the drawing, the depth directional position of the measurement was converted to the water equivalent length. It is clarified that a dosed region conformed to the sphere target is realized by the multi-layer energy filter.

Conclusion.

The new energy filter for charged particle therapy controls the lateral changing of the depth-directional spread of the irradiation field by the thickness of the filter. By using outline data conformed to the target in the cancer treatment, the outward form of the filter can be designed easily. By using the filter, three-dimensional conformal irradiation was achieved for a sphere target with a diameter of 60mm.

Reference

1) Y. Hayakawa, Proc. of NIRS Int. Semi. on the Appli. of Heavy Ion Accel. to Radiation Therapy of Cancer in connection with XXI PTCOG Meeting (ed. by T. Kanai and E. Tanaka), 234-240(1994).

2) Rapid Prototyping Report 8(12), (1998).