Spot-beam Scanning Technique Developed at the CYRIC Proton Therapy Facilities

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IV. 3. Spot-beam Scanning Technique Developed at the CYRIC Proton Therapy Facilities

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Conventional irradiation techniques in charged-particle therapy such as wobbler and scattering methods spread the dose of a pencil beam from the accelerator over a target volume, and provide an appropriate dose distribution in a tumor with an energy filter, a bolus and a collimator. However, the maximal dose of the so-called spread-out Bragg peak (SOBP) is given to normal tissue outside the tumor because the SOBP is designed to cover the maximum width of the target volume in the beam direction.

A scanning method of the pencil beam can provide a conformal dose profile in the target volume without high dose in the surrounding normal tissue. Unfortunately, the scanning technique is applied to limited cases$^1$ in actual treatments because patient safety concerning the beam delivery and the treatment plan has not fully been established at present. In this report we will describe preliminary results for beam tests of the scanning technique developed using the horizontal beam course of the proton therapy system$^2$ at CYRIC.

Figure 1 illustrates the spot-beam scanning method. The pencil beam from the AVF cyclotron is scanned in the lateral directions by magnetic deflection whereas the beam energy is changed with a range shifter for the scan in the depth direction. The dose control has been performed by means of a discrete beam-scanning technique in which the pencil beam is delivered into the target volume spot by spot to generate a designed dose distribution for the tumor.

Test experiments for the discrete beam-scanning technique were successfully
performed using an 80-MeV proton. Figure 2 shows the lateral dose distributions measured with the imaging plate\textsuperscript{3} (IP) concerning the conformal irradiation (Fig. 2(b)) and the intensity modulated irradiation (Fig. 2(c)), together with the spot beam profiles (Fig. 2(a)). The spot-beam size is currently more than 10 mm (FWHM) in diameter. We plan to reduce the beam size up to about 5 mm in diameter by improving the beam transport optics upstream of the irradiation system.

In order to provide the SOBP with the scanning technique, the energy scanning with the range shifter was performed using a 70-MeV proton based on the SOBP designed with 11 depth-dose profiles of mono energy protons (Bragg peaks : BP) measured with the IP. Figure 3 shows the depth dose distribution measured with the ionization chamber\textsuperscript{4} and the designed SOBP. The experimental result does not agree with the designed SOBP at the end of the range. This discrepancy is probably ascribed to the energy dependence\textsuperscript{5} in dose measurement with the IP.

References
4) The 0.6 cm\textsuperscript{3} PTW Farmer chamber type 30013, PTW, Freiburg, Germany, http://www.ptw.de/
Figure 2. Lateral intensity distributions using the spot-beam scanning method.

Figure 3. Depth dose distribution generated in PMMA with the scanning method based on the SOBP designed from each Bragg peak. Depth in PMMA is converted to the water-equivalent depth.