Measurement of Depth Dose Distribution Using Plastic Scintillator

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ABSTRACT

We examined a possibility to use inorganic plastic scintillator, which has the effective atomic number close to that of human soft tissue, for the measurement of dose distributions in a shorter time period. The method was to irradiate a block of plastic scintillator as a phantom, and to measure the distribution of the scintillation light by a wave length analyzer through a thread of plastic optical fiber. By irradiating the diagnostic x-ray, we observed the emission spectrum of the scintillation light from the scintillator. It showed a peak at around 420nm with a full width of 140 nm. The emission spectrum was integrated to determine the total number of photons. The dependences of the amount of photons on the irradiated dose were measured. The results of the experiment show that the amount of emission light is in proportional to the irradiated dose. From this fact, we conclude that the present method can be used for the measurement of the depth dose distribution of the diagnostic x-rays.

Keywords: Plastic scintillator, Scintillation light, Depth dose distribution

1. INTRODUCTION

There are various methods to measure the depth dose distribution of the treatment x-ray. The ionization chamber or the semiconductor dosimeter is most frequently used. These dosimeters controlled by a computer are installed in a water phantom and measure the depth dose distribution in two or three dimensions. The measurement procedure is time-consuming[1)]. The film dosimetry is very simple in principle and is used well. The measurement procedure is to put several sheets of film into various parts of phantoms, and to obtain the data of the depth dose distribution by one irradiation. The film dosimetry has to take into account the characteristics of film such as dose linearity and energy dependence. Other less frequently used methods such as TLD[1)], the CR dosimetry[2)], the device that uses plastic fiber scintillator are on the market[3)]. We examined another possible method that might be able to measure the depth dose distribution in a shorter time period with less investment. The method is to irradiate x-rays on a block of plastic scintillator as a phantom, and to measure the distribution of the scintillation light from outside. In this study, we measured the scintillation light from one side of a block of plastic scintillator.

2. MATERIALS AND METHODS

In order to measure the depth dose distribution by using plastic scintillator (Bicron, BC-400 5 5̃ 3̃0cm^3), it is desirable that the amount of emission light from the scintillator is in proportional to the absorbed dose. Moreover, the amount of emission light must be measured efficiently. In this photometry study, we used a plastic optical fiber as a light guide from the scintillator to the wave length analyzer (Ocean Optics, USB2000) of which sensitivity is 86 photons/counts. First, we measured the effective view of the plastic optical fiber. Then, we measured the dose dependence of the amount of emission light in the following way. By irradiating x-rays on the fixed plastic scintillator, we moved the fiber along the surface of the block to measure-emission light. And we determined the relation between the amount of emission light and the depth of the plastic scintillator. Finally, the calibration of the dose to the JARP level dosimeter (PTW-FREIBURG, 0.6cc type, wall material is PMMA.) in the Tough Water phantom (Kyoto Science Corp., 30cm 3̃0cm) was done.

2.1. Measurement of the effective view

A schematic layout of experimental equipment is shown in Fig. 1(a). A laser beam (655nm) was incident on the block of plastic scintillator from left side. We measured scattered photons of the laser beam from one side by using the plastic optical fiber that was adjusted in vertical position for each measurement. We measured the laser beam for 1000msec and used a Z axis translation stage (Sigma Koki Corp., Σ-303) for vertical movement. The distances between the tip of the optical fiber and the path of laser beam were 15mm, 20mm and 25mm. The fiber was fixed at 20mm in depth from the laser beam incident surface. The count of the wavelength distribution decreases when the laser beam is out of the effective view as shown in Fig. 1(c). From the result, the angular range of the effective view was determined to be 7.68° ±0.72°. Consequently, the volume of the effective view in the scintillator is approximately 0.590cm^3, and the value is equal to the volume of the JARP level dosimeter of 0.6cc type.

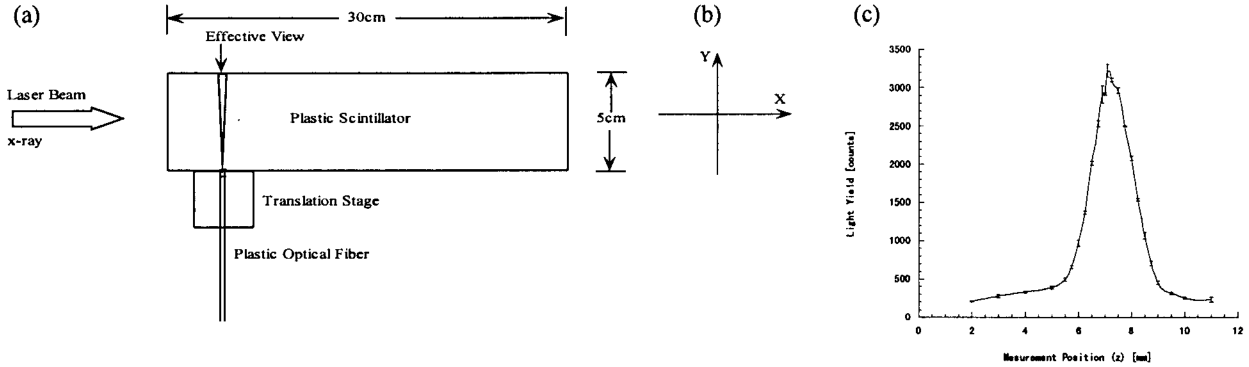

Fig. 1. (a) Experimental equipment. A thread of plastic optical fiber is mounted on a stage that can move along vertical (*z*) direction as well as in horizontal direction (*x*). (b) Definition of our left-handed coordinates. (c) Distribution of light yields in vertical direction at a distance of 15mm.

2.2. Measurement of the dose dependence

In Fig. 1, the x-rays were incident on the block of plastic scintillator from left side (SSD=80cm, surface field size=2.5 × 2.5cm^2). The fiber fixed at 10mm in depth from the x-ray incident surface and at the center in the vertical direction. We measured scintillation light for 1000msec under the following conditions: the tube voltage of 100kV and the irradiation time of 500msec. We measured the light yields at several tube currents. In this study, we used the x-ray tube of Toshiba DRX-3724HD, the beam limiting device of Toshiba Model TF-6Tl-6 and the power source of Toshiba Model KXO-80G. Fig. 2 shows an example of the measured wavelength distribution.

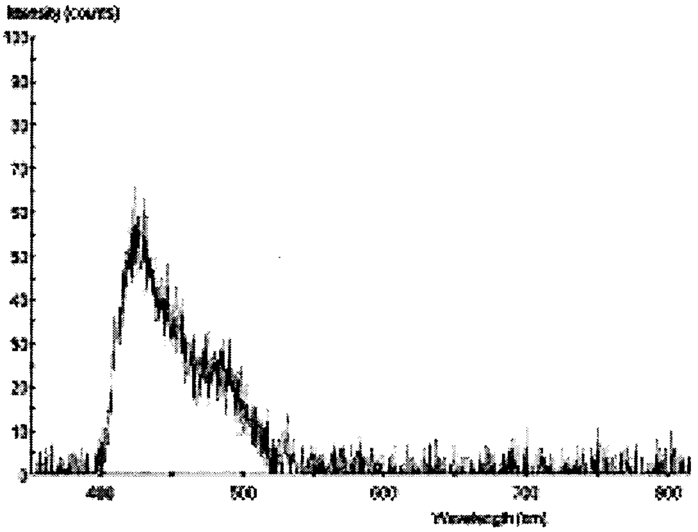

Fig. 2 The wavelength distribution of the scintillation light at a tube current of 500mA (Light yield is the integral of the spectrum).

2.3. Measurement of the depth dose

Measurements of the light yields at various depths were performed under the similar geometrical conditions in the former subsection, where the tube current and irradiation time were fixed at 250mA and 500msec, respectively. The tube voltages were set at a voltage between 60kV and 120kV in 20kV step. In order to calibrate the light yield to the absorbed dose, a JARP level dosimeter was placed in the plates of tough water phantom. The thickness of the phantom in front of the dosimeter was changed. The same irradiation conditions such as the surface field size and SSD were used in the measurements of the light yield from the scintillator.

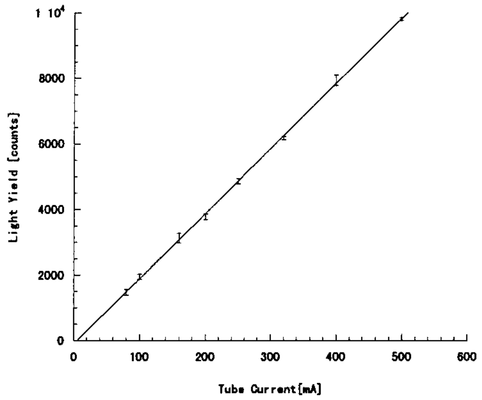

Fig. 3 Current dependence of light yields.

3. RESULTS AND DISCUSSION

Fig. 3 shows the relation between the tube current and the light yield. The light yield is in proportional to the irradiated dose, i.e. the amount of emission light is in proportional to the absorbed dose. Fig. 4 shows the depth dependence of light yields at various tube voltages. The light yields rise from the surface to the depth of 1mm to 4mm depending on the tube voltage. The rise can be interpreted to be a buildup of light yields in the shallow area. One reason of this buildup is that the effective view of the plastic optical fiber is not in the block of scintillator when the tip is close to the incident surface. In the deeper region above the peak, the yields decrease. The fall can be approximated by an exponential function corresponding to the attenuation of the x-rays. It should be pointed out that the observed buildup of light yields has structures with a few mm widths. This indicates good position resolutions of the present method in the measurement of the depth dose distribution. We tried to reproduce the light-yield curves by a superposition of two exponential functions expressed as follows,

$$y = A_1\exp(-\mu_1 x) + A_2\exp(-\mu_2 x), \qquad (1)$$

where y is the light yield [counts], x is the depth [mm], and A_1, A_2, μ_1, μ_2 are constants to be determined. All the four curves are reproduced well by eq. 1 as shown in Fig. 4. Fig. 5 is a comparison of the depth curve at 120kV and the data obtained by the dosimetr in the Tough Water phantom. Both data are normalized at the depth of 50mm. The behaviors of two sets of data are similar in shape. The ionization chamber gives a steeper decrease than the present method. One cause of this is the difference in the materials used in two measurements, i.e. the attenuation in the tough water phantom is larger than that in plastic scintillator. And also, the wave length analyzer does not have a capability for gating, the data might include noise contributions in the smaller signal region. A more careful calibration has to be made to establish the comparison with the absolute dose.

4. CONCLUSION

By measuring the scintillation light from outside by a thread of optical plastic fiber and a wave length analyzer, we could measure light yields from inside of the block of plastic scintillator. The observed light yield is in proportional to the irradiated dose. The depth dependence of the light yields can be expressed by a superposition of two exponential functions that show a buildup in the shallow region, a peak at 1~4 mm, and a decrease in the deeper region. It is proved that depth dose measurement for the diagnostic x-rays is possible by the present method. In the future, a more refined calibration of the dose with the JARP level dosimeter will be carried out. We plan to use another plastic scintillator that has characteristic of human soft tissue. Another plan is to irradiate the therapeutic x-rays to determine the relation between the light yields and the irradiated dose at higher dose rates.

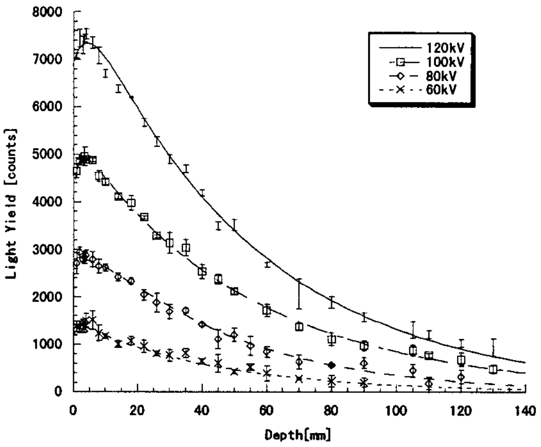

Fig. 4 Depth dependence of light yields.

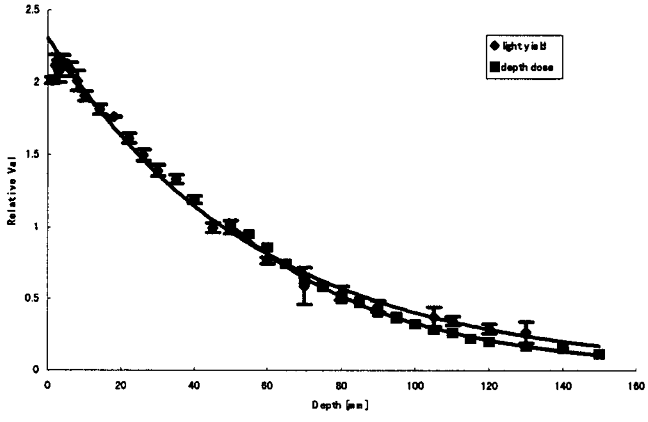

Fig. 5. Comparison of depth distribution by the present method and that by the ionization chamber.

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