Performance Evaluation of CT Using Visible Scintillation Light

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ABSTRACT

We propose the use of visible scintillation light for monitoring the X-ray CT in the gantry of a diagnostic CT for its performance test and maintenance works. We placed a disk of bare plastic scintillator disk in the gantry opening area of a helical X-ray CT. When we operated the CT, we could observe the emission of blue scintillation light from the scintillator in a dark room. Visible light was identified under all scanning conditions of diagnostic uses. As a result, we observed the direction and the spread of the incident X-ray in the scintillator. We also observed the change of the part of the scintillator where visible light was generated, and the move that took place associating with the rotation of the X-ray tube during one CT scan. On the basis of the observation, we examined the usefulness of the visible scintillation light as a convenient performance-evaluating tool as well as a maintenance tool of the CT.

Keywords: Plastic scintillator, Scintillation light, X-ray CT

1. INTRODUCTION

Usually, optically shielded scintillator attached to a photomultiplier is used to detect the X-ray. One might be able to observe the emission of scintillation light by naked eyes when one irradiates intense X-rays. In this study, we succeeded in observing blue scintillation light from a disk of plastic scintillator during one CT scan, and in recording the light with a digital video camera. The change of the emitting part of visible scintillation light was associated with the rotation of the X-ray tube during one CT scan. The recorded animating images can be analyzed in the direction, the spread and the uniformity of the incident X-rays in the scintillator. From the results, we examined whether the present method is useful as a performance-evaluating tool as well as a maintenance tool of the CT.

Not only scintillator but also a sheet of fluorescent screen converts X-rays into lights. Therefore, we carried out similar measurements with the fluorescent screen. And, we compared the result of scintillator with that of the fluorescent screen.

2. MATERIALS AND METHODS

A disk of plastic scintillator used in this study (300mm in diameter and 12.5mm in thickness, BICRON BC-400) is shown in Fig. 1. Reflective material was attached on the rear side of the scintillator in order to increase the amount of visible scintillation light. Arrangement of equipment of this experiment is shown in Fig. 2. We placed the scintillator in the gantry opening area of an X-ray CT (GE Yokogawa ProSeed Accell Ver.4.0). We used the CT under the scanning conditions listed in Table 1.

For recording the scintillation light, we used a digital video camera (Canon DM-FV30). The recorded images (30 frames/second) were divided into frames for frame-by-frame analyses on a Personal Computer (DELL DIMENSION 4300S). Then, we analyzed the spread of the incident X-ray using the digital image editing software (Adobe Photoshop 6.0).

Table 1 Scanning conditions.

Parameter	Measured Range
Tube voltage	80~140kV
Tube current	60~250mA
Scan time	1~3s
Slice thickness	10.0mm

In order to measure the brightness due to the X-ray irradiation in each frame, square regions (10x10 mm^2) were selected in the following way, i.e. the outmost part of the region were 5mm inside of the circumference of the disk. There are 36 pixels in each region. The mean value and the standard deviation of the data of the pixel were calculated to determine the average brightness of the region. In order to measure the attenuation of the X-rays on the radial direction, the average brightness were obtained along the X-ray axis in a similar way as stated above.

We performed a similar measurements with a sheet of fluorescent screen (KYOKKO P-4, Size: 36 cm x 36 cm) .

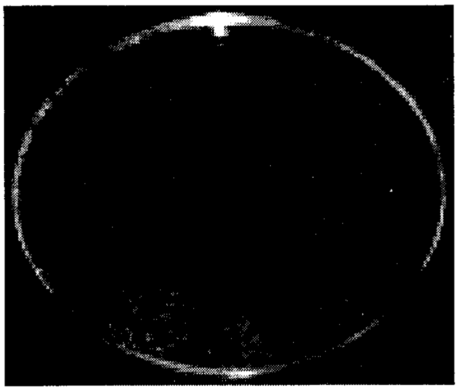

Fig. 1 The disk of plastic scintillator.

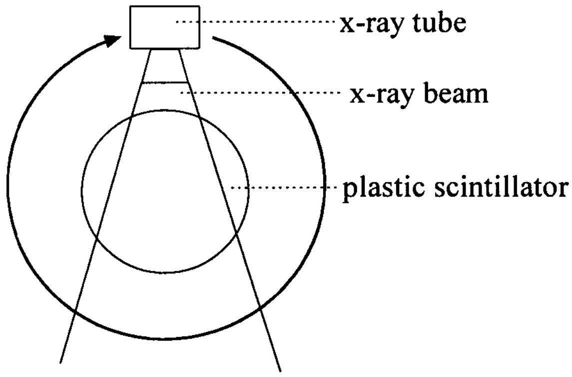

Fig. 2 Arrangement of equipment of this experiment.

3. RESULTS AND DISCUSSION

Visible scintillation light was identified under all scanning conditions. A part of recorded images of the emission of scintillation light are shown in Fig. 3, where scanning conditions were the tube voltage at 140kV, the tube current at 250mA and scan time of 1s. One can observe the brightest part of the scintillator disk rotates from the top, right, bottom, to left. This move associates with the rotation of the X-ray tube in one CT scan.

The obtained brightness were digitized to determine the irradiated area by the X-ray. The angular spread of the X-ray beam can be calculated by the use of the irradiated area and the distance to the X-ray source. The angular spread, the mean value and the standard deviation of brightness are listed in Table 2. Thus, we could measure the uniformity and the spread of the incident X-ray beam.

The attenuation curves of the brightness that are the light output along the X-ray beam axis are shown in Fig. 4. The curves show that the brightness attenuates exponentially. According to the differences in the attenuation curves for different tube voltages, one can say that the change in the X-ray energy is measurable.

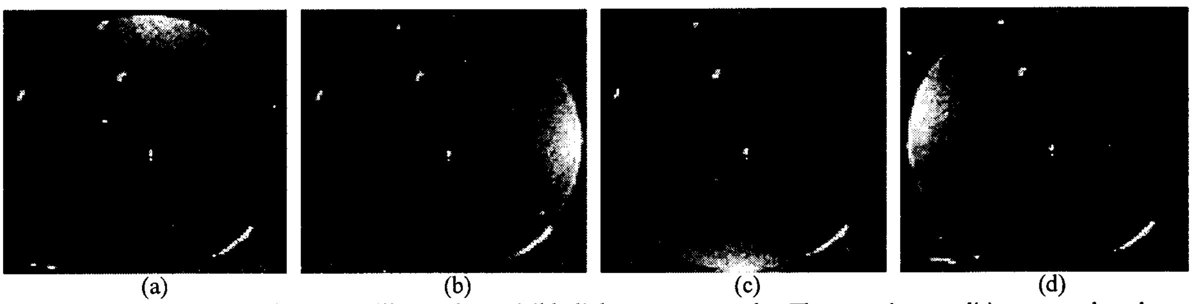

Fig.3 The motion of the part of plastic scintillator where visible light was generated. The scanning conditions were the tube voltage at 140kV, the tube current at 250mA and scan time of 1s. Image (a) is 1^{st} frame, (b) is 8^{th} frame, (c) is 17^{th} frame and (d) is 25^{th} frame of 30 frames per second. The contrast of the frame has been enhanced in this diagram. Several bright spots appeared in the images are reflection of illuminating lamps of the equipment in the room.

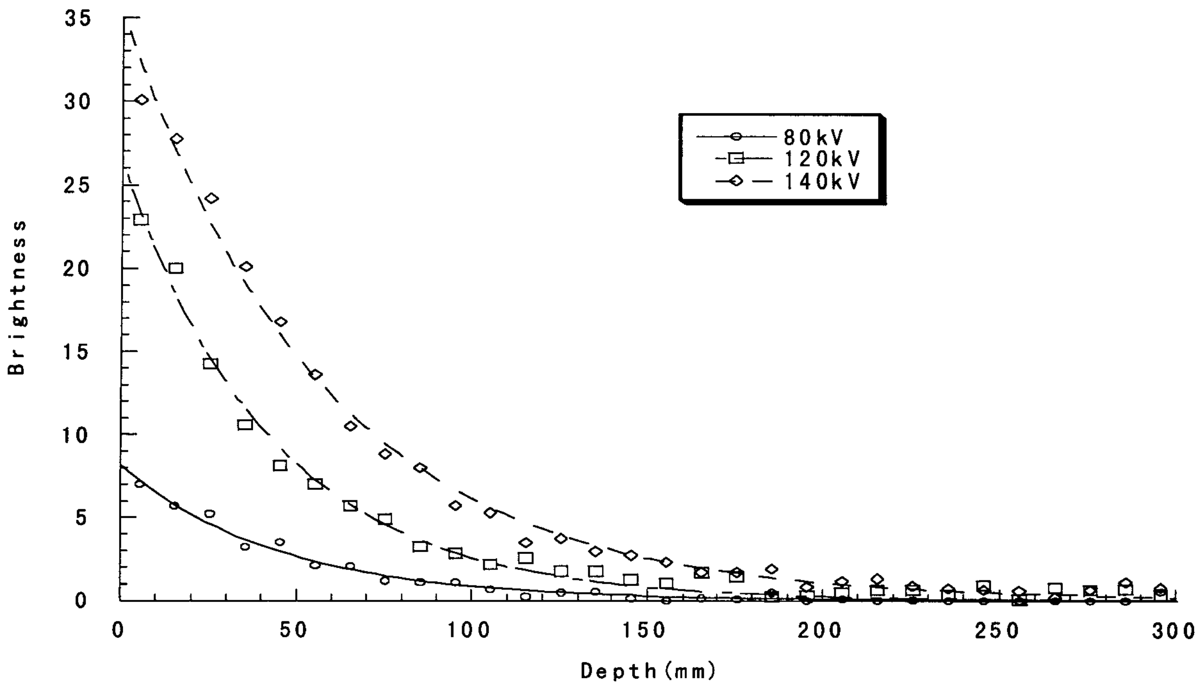

Fig. 4 The attenuation curves of the brightness. The curves are reproduced by exponential functions.

Table 2 The angular spread of the X-ray beam and the mean value and the standard deviation of brightness. The scanning conditions were the tube voltage at 120kV, the tube current at 250mA and scan time of 1s.

	The angular spread of the X-ray beam	Brightness	
		The mean value	The standard deviation
1st frame	30.4°	36.25	4.40
8th frame	29.8°	39.49	3.23
17th frame	30.8°	34.25	3.10
25th frame	29.4°	36.14	3.33
Back ground		10.47	1.42

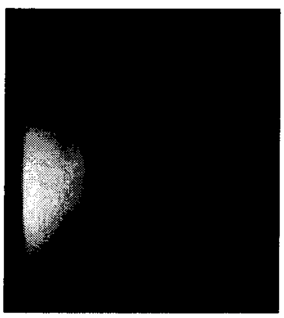

Fig.5 The X-ray irradiates on a fluorescent screen from left. The scanning conditions were the tube voltage at 120kV, the tub current at 250mA and scan time of 1s.

The result of fluorescent screen with CT scanning is shown in Fig. 5. The light output from the fluorescent screen is much larger than that from the plastic scintillator. However, it is difficult to analyze the spread of the incident X-ray and the brightness, because the visible light was scattered by the structures such as indented surface on the fluorescent screen. In addition, the fluorescent screen is not transparent as plastic scintillator. That is the reason why this method using the fluorescent screen cannot be applicable to a helical CT scanning.

4 . CONCLUSION

By irradiating a disk of plastic scintillator placed in the opening area of the CT gantry, we could observe visible scintillation light by naked eyes under all available scanning conditions. The light was able to record with a digital vide camera. As a result of the analyses of the recorded images, we found that following measurements are possible. At first, it was possible to measure the angular spread of the incident X-ray beam by analyzing the shape of the part where visible light was generated. The second, one could measure the uniformity of the incident X-ray by analyzing the mean value and the standard deviation of brightness. Finally, by analyzing the attenuation of the light output, the change in the X-ray energy was measurable. Therefore, we conclude that the present method is useful as a performance-evaluating tool as well as a maintenance tool of CT.

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