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Laser CT evaluation on normoxic PAGAT gel dosimeter

DS Kumar[1,2], EJJ Samuel[1] and Y Watanabe[2]
[1]Photonics Division, School of Advanced Sciences, VIT University, Vellore-632014, Tamil Nadu, India
[2]Department of Therapeutic Radiology, University of Minnesota, Minneapolis, (Twin cities), MN-55455, USA

E-mail: kalaimeenasen@gmail.com

Abstract. Optical computed tomography has been shown to be a potentially useful imaging tool for the radiation therapy physicists. In radiation therapy, researchers have used optical CT for the readout of 3D dosimeters. The purpose of this paper is to describe the initial evaluation of a newly fabricated laser CT scanner for 3D gel dosimetry which works using the first generation principle. A normoxic PAGAT (Polyacrylamide Gelatin and Tetrakis) gel is used as a dosimeter for this analysis. When a laser passes through the gel phantom, absorption and scattering of photon take place. The optical attenuation coefficient of the laser can be obtained by measuring its intensity after passing through the gel by a sensor. The scanner motion is controlled by a computer program written in Microsoft Visual C++. Reconstruction and data analysis on the irradiated gel phantom is performed by suitable algorithm using Matlab software.

1. Introduction
Modern radiation delivery techniques such as stereotactic radiotherapy, three-dimensional (3D) conformal radiotherapy and intensity modulated radiation therapy aim at precise delivery of radiation dose. These techniques are based on increasing complexity of radiation delivery methods and therefore necessitate verification of computer calculated dose distribution by an accurate dosimetric method. Gel dosimeters are capable of recording 3D dose distributions [1, 2]. Previously, magnetic resonance imaging (MRI) was the only available method for reading the dose distribution recorded in polymer gels [3, 4]. However, due to the cost and problem of availability, optical scanning of gel has been used by several researchers [5-9] in preference to MRI, x-ray CT [10-13], ultrasound [14-16] and vibrational spectroscopy [17, 18] readout. We present some initial investigations using normoxic PAGAT [19, 20] gel dosimeter with an in-house built laser CT scanner.

2. Materials and Method

2.1. Gel Preparation
The normoxic PAGAT gel described elsewhere [19] was prepared under normal atmospheric conditions. The gel preparation was carried out as follows: 5% gelatin was added to the magnetic stirred glass flask containing 89% of triple distilled water and allowed to swell for 10–15 minutes. Then the gelatin solution was heated to the temperature of 50 ^{0}C for complete dissolution of the gelatin. After obtaining the clear gelatin solution 3.5% BIS and 3.5% Acrylamide were added and stirred continuously until the mixture was dissolved homogeneously. The antioxidant 10 mM THP was added to the solution under stirring just before transferring the gel into polyethylene terephthalate

cylindrical containers of size 10 cm diameter and 13 cm long. All the cylindrical containers containing the PAGAT gel were sealed properly to avoid the further diffusion of oxygen and were kept in a refrigerator at 5ºC for one full night for gelling [21]. All chemicals were from Sigma Aldrich.

2.2. Gel Irradiation
To evaluate the dose response of polymer gel to gamma radiations, the polymer gel dosimeters were irradiated after complete gelation [19]. The polymer gel dosimeters were irradiated to 12 Gy with a square field size of 5 x 5 cm^2 using Co-60 gamma rays. The source-to-surface distance (SSD) was 100 cm. One dosimeter was kept unirradiated for background subtraction. The irradiated gel dosimeters were left in a refrigerator for one day before imaging to allow the complete post irradiation polymerization [22].

2.3. Laser CT scanning system

The Laser CT scanner was constructed on the principle of a first generation X-ray CT is shown in Figure 1. The construction part of this scanner was briefly explained and a single slice scanning has been reported previously using this scanner [23]. We extended the work to scan multiple slices on the PAGAT gel phantom for different depths. Figure 3 represents the multi slice scanning process.

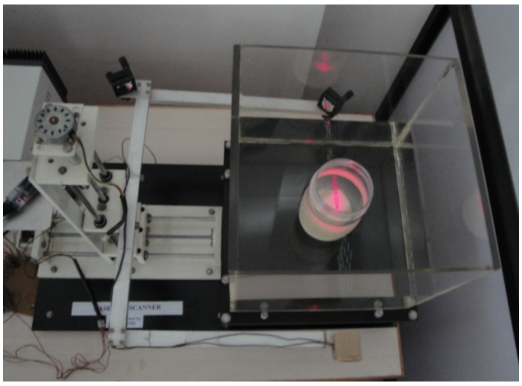

Figure 1: In-house fabricated Laser CT scanner.

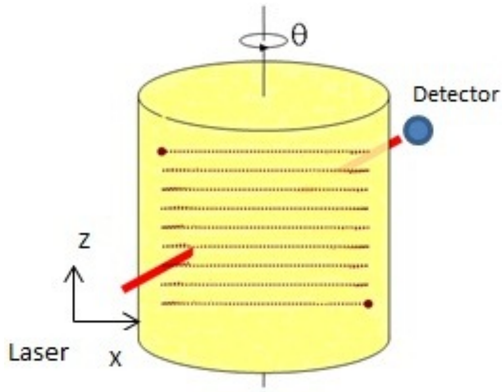

Figure 2: Multi-slice scanning process.

2.4. Scanner Control and Image Reconstruction
The software controls the scanner, acquires and stores the data and performs the necessary calculations for data procession and transformation [24]. The image reconstruction software converts the scanner data into 3-dimensional image data. The purpose of this software is to apply an Inverse Radon Transformation to the scanner raw data. Matlab readily provides the Filtered Back-Projection algorithm, an efficient algorithm for the Inverse Radon Transformation.

3. Results and Discussion

Figure 3 & figure 4 represents the top view of pre & post-irradiated gel phantoms. The pre-irradiation image was subtracted from the post-irradiation scan and the subtracted image were then analysed. The reconstruction for a single slice was undertaken using the Filtered Back Projection algorithm implemented in Matlab. Dose profiling the reconstructed slices and subtraction of post irradiated images from pre irradiated images was performed with in-house code developed in Matlab. Figure 5 represents the image of the pre irradiated gel slice. Figure 6, 7 and 8 represents the 2D reconstructed image slices of the post-irradiated gel phantom at 4, 6 and 8 cm depths. A line is drawn on the pre- and post-irradiated gel slice to get their corresponding dose profile. Figure 9 represents the dose profile for the pre-irradiated gel slice with distance across the gel dosimeter (mm) versus the optical density (cm^-

^{1}). Figure 9, 10, 11 and 12 represents their corresponding dose profile with distance across the gel dosimeter (mm) versus the optical density (cm^{-1}). From the distance versus optical density characteristics, it can be clearly observed that, as the distance across the gel phantom (mm) increases the optical density (cm^{-1}) also increases. The distance across the gel phantom has been plotted in the x-axis and the optical density has been plotted on the y-axis. The time taken for scanning and reconstructing single slice was ~ 10 minutes.

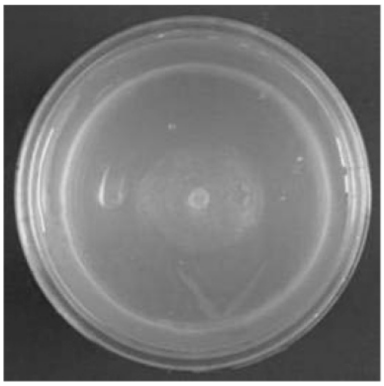

Figure 3: Top view of Pre irradiated Gel Phantom.

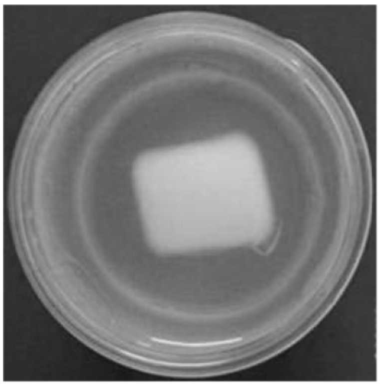

Figure 4: Top view Post irradiated Gel Phantom.

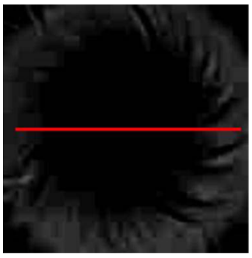

Figure 5: Reconstructed slice of the Pre-irradiated gel

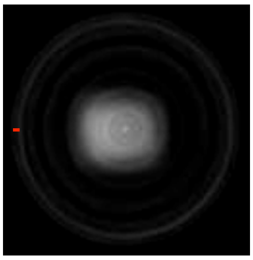

Figure 6: Reconstructed slice of the Post-irradiated gel at 4 cm depth

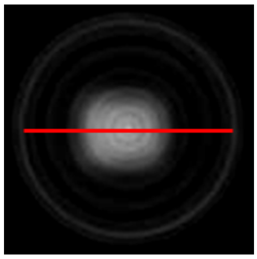

Figure 7: Reconstructed slice of the Post-irradiated gel at 6 cm depth

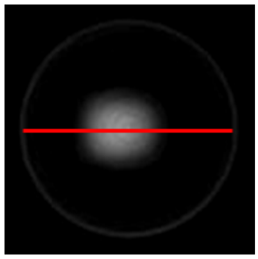

Figure 8: Reconstructed slice of the Post-irradiated gel at 8 cm depth

4. Conclusions

A laser CT scanner for reading the absorbed dose in a tissue equivalent gel was constructed for the total material cost of about $3,000 (US) and its initial performance for reading an irradiated gel dosimeter was investigated. The reconstructed image for the irradiated slice and its data analysis was performed with in-house code developed in Matlab. From the results, we conclude that the scanner is suitable for reading normoxic gels. However, the scanning time is relatively long and this has to be reduced in the future.

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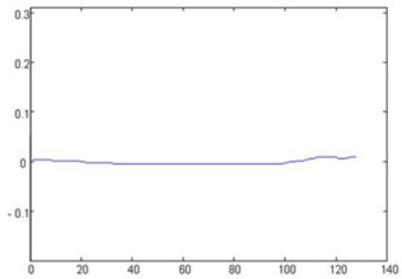

Figure 9: Dose Profile for Pre- irradiated gel slice (Distance across the gel phantom vs Optical Density).

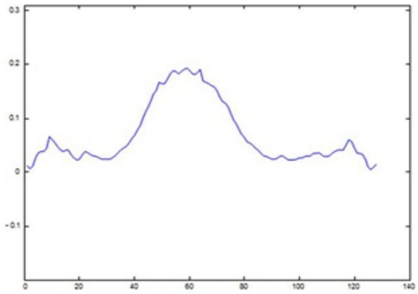

Figure 10: Dose Profile for Post- irradiated gel slice at 4 cm depth (Distance across the gel phantom vs Optical Density).

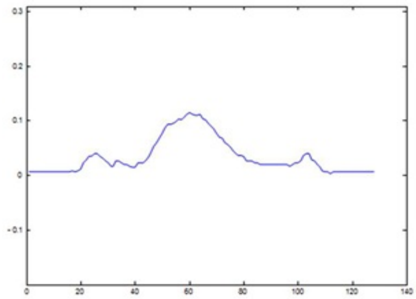

Figure 11: Dose Profile for Post-irradiated gel slice at 6 cm depth (Distance across the gel phantom vs Optical Density).

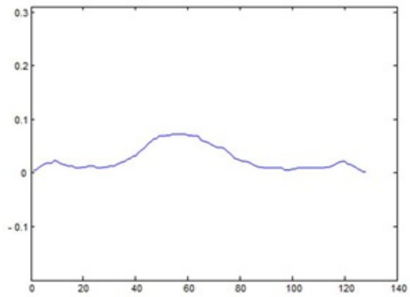

Figure 12: Dose Profile for Post-irradiated gel slice at 8 cm depth (Distance across the gel phantom vs Optical Density).

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