Investigation of an in-house laser CT scanner for reading normoxic gel

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1. Introduction
New radiation delivery techniques that aim at precise delivery of radiation dose such as Stereotactic Radiotherapy, 3D Conformal Radiotherapy (3DCRT) and Intensity Modulated Radiotherapy (IMRT) are more commonly used at present. These advanced techniques based on increased complexity of radiation delivery methods necessitate verification of computer calculated dose distribution by an accurate dosimetric method. Gel dosimeters are capable of recording dose distributions in 3D. To date, magnetic resonance imaging (MRI) has been most extensively used for the evaluation of absorbed dose distributions in gel dosimeters. However, due to the practical problems of availability, cost and artifacts, optical scanning of gel has been used by several researchers as an accurate and practical alternative to MRI [1-4]. In this paper we discuss the construction of an in-house laser CT scanner and its performance for evaluating normoxic gel dosimeters.

2. Material and Methods
2.1. Laser CT Scanner
A laser CT scanner (Fig.1) based on the principle of a first generation X-ray CT was constructed. This scanner consisted of an aquarium, a turntable with angular graduation, a red diode laser (~633 nm) as light source, light dependent resistors (LDR) in series with a resistor as detectors. A Pentium PC controlled the translate-rotate motion and also served as the data acquisition system. The aquarium of size 26 x 26 x 20 cm³ was fabricated using Perspex with wall thickness of 3 mm on the laser transmission sides. The turntable fixed in the aquarium was rotated using a 4-pole stepper motor. Reduction gears were used such that the turntable rotated 0.35° for each pulse sent to the stepper motor. The linear motion of the source and the detector was achieved with two parallel ‘gear and belt’ arrangements driven by a single DC motor. The DC motor used for the linear motion and the stepper motor for the rotational motion were driven by the PC through the parallel port. The laser beam was tilted to a small angle (~ 5°) to avoid reflected light falling on the detector [5]. The position of the detector was determined by a 10-turn 20K linear potentiometer. A regulated 10 Volt DC was applied to the potentiometer and the LDR. The change in resistance was measured as the variation in the voltage and fed to the PC through a DT 9812 ADC (Data Translation, USA).
2.2. Normoxic Gel Preparation and Irradiation
The gel used for this study was the normoxic PAG gel named as PAGAT, which has been previously evaluated with X-ray CT and MR [6,7]. The components used for the preparation of this gel were 5% gelatin, 3.5% BIS, 3.5% AA, 88% distilled water and 10 mM THPC as the antioxidant. The gel was prepared as per the procedure discussed elsewhere [6] and poured into plastic containers of outer diameter 9.5 cm and height 15 cm and left in the refrigerator. For optical scanning the gel was placed in the aquarium filled with refractive index matching solution (glycerol mixed with distilled water). A pre-irradiation scan was carried out. The gel was then irradiated 3 hours post manufacture to a dose of 4 Gy at 7 cm depth using 6 MV photons from a PRIMUS linear accelerator with a field size of 4 x 4 cm$^2$. The gel was imaged 15 hours after irradiation since it is considered that the post-irradiation polymerization saturates after a period of about 12 hours [8]. The scans were performed for every 0.7° rotation and 514 projections were obtained.

2.3. Reconstruction
The ratio of the post and pre scan data were obtained and the CT reconstruction of the optical attenuation data was performed with Matlab ‘iradon’ function with ‘Hann’ filter and spline interpolation.

![Figure 2. (a) Repeated projection profiles showing reproducibility of scanner. (b) Projection profiles of blank gel and irradiated gel.](image-url)
3. Results and Discussion

The performance of the laser CT scanner with respect to positional accuracy and reproducibility were checked by obtaining repeated measurements of a blank gel. The profiles obtained for two projections of irradiated gel are overlapped in figure 2a. The profiles overlap indicating that the positional and the laser transmission signals from the CT scanner are reproducible.

The pre and post irradiation projection profiles of the gel irradiated for 4 x 4 cm² are shown in Figure 2b. Using this projection data, the optical attenuation coefficient was obtained by taking the negative log of the ratio of post and pre irradiated data. This was reconstructed using the ‘iradon’ function implemented in Matlab and is shown in figure 3. The measured diameter of the container from the reconstructed image was 9.5 cm which is the actual diameter of the plastic gel container. The diagonal of the irradiated area (4 x 4 cm²) measured from the reconstructed image (5.6 cm) was equal to that of the radiation field.

![Image](image.png)

**Figure 3.** Distribution obtained from gel for 4 x 4 cm² 6 MV beam.

4. Conclusion

A laser CT for reading gel has been constructed and its performance for reading normoxic gel has been investigated. From the results we conclude that the scanner is suitable for reading gel for clinical dosimetry.

5. References

[1] DOSGEL 1999 Proceedings of the 1st International Workshop on Radiation Therapy Gel Dosimetry eds Schreiner L J and Audet C (Lexington, KY, USA)
[2] DOSGEL 2001 Proceedings of the 2nd International Conference on Radiation Therapy Gel Dosimetry eds Baldock C and De Deene Y (Queensland University of Technology, Brisbane, Australia)
[3] DOSGEL 2004 Proceedings of the 3rd International Conference on Radiation Therapy Gel Dosimetry eds De Deene Y and Baldock C (Ghent University, Ghent, Belgium)
[4] Xu Y, Wuu C-S and Maryanski M J 2004 Performance of a commercial optical CT scanner and polymer gel dosimeters for 3-D dose verification Med. Phys. 31 3025-3033
[5] Gore J C, Ranade M., Maryanski M J and Schulz R J 1996 Radiation dose distributions in three dimensions from tomographic optical density scanning of polymer gels: I. Development of an optical scanner Phys. Med. Biol. 41 2695-2704
[6] Brindha S, Venning A J, Hill B and Baldock C 2004 Experimental study of attenuation properties of normoxic polymer gel dosimeters *Phys. Med. Biol.* **49** N353-N361

[7] Venning A J, Hill B, Brindha S, Healy B J and Baldock C 2005 Investigation of the PAGAT polymer gel dosimeter using magnetic resonance imaging *Phys. Med. Biol.* **50** 3875 – 3888

[8] De Deene Y, Venning A., Hurley C, Healy B J and Baldock C 2002 Dose-response stability and integrity of the dose distribution of various polymer gel dosimeters *Phys. Med. Biol.* **47** 2459-2470