PTTL METHOD APPLIED TO UV RADIATION DETECTION DURING REFRACTIVE SURGERY USING EXCIMER LASER

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The method of phototransferred thermoluminescence (PTTL), using CaSO₄:Dy pellets produced at IPEN as sensitive material, was used to detect the spread laser radiation inside the surgery room during refractive surgical procedures using ArF excimer lasers. The purpose of this work was to study the viability of performing the ultraviolet radiation (UVR) exposure detection of patients and the hospital's surgical staff during a refractive surgery. The CaSO₄:Dy pellets were positioned at different distances from the laser source inside the surgery room: patient's (≥0.15 m), surgeon's (≥0.5 m) and nurse's (≥1.0 m) foreheads, lateral (≥1.5 m) and back (≥4.0 m) walls. The measurements of PTTL were carried out at two different conditions: five surgeries, each one taking ~10 min, and during a period of 4 h (cumulative), when several operations were performed. The detectors positioned as far as 4.0 m from the UV laser source were sensitised, making the UVR detection feasible at large source–detector distances. The absorbed energy was detected in the range from 40 µJ to 30 mJ during a surgery. This result indicates that the method studied can be used to detect the spread UVR.

INTRODUCTION

Ultraviolet radiation (UVR) has been widely used for medical applications, but there is no practical and cheap method to detect the spread UVR in the surgery room environment and the exposure of the hospital’s surgical staff.

Refractive surgical operation, a corneal surgery to correct myopia, hyperopia and astigmatism, is a procedure that is frequently used ~100,000 surgeries are performed in Brazil every year. The equipment often used to apply this technique is the ArF excimer laser system. The analysis of the risks associated with these surgeries becomes very interesting, since there are reasons to presume¹,² that the spread laser radiation can cause diseases and burns on the surgeon’s and nurse’s eyes and skin.

The method of phototransferred thermoluminescence (PTTL), using CaSO₄:Dy pellets produced at IPEN as sensitive material, was previously studied for UV and laser UVR detection. PTTL is the thermoluminescence due to the light incident on a material that was exposed earlier to ionising radiation and partially annealed, leaving some residual charge carriers trapped in the deep traps which are localised in the band gap due to impurities and lattice defects³. The CaSO₄:Dy pellets showed high sensitivity and reproducibility, linear response and good signal resolution for a wide range of absorbed energy (0.01–40 mJ) and gamma doses (5–100 Gy)⁴,⁵.

In partnership with the Bioengineering Department from the Universidade Federal de São Paulo (UNIFESP), a methodology was developed to detect the spread UVR into refractive surgical rooms using the PTTL technique.

METHODS

The CaSO₄:Dy/teflon pellets are manufactured at IPEN and have the following dimensions: 6 mm diameter, 50 mg weight and 0.8 mm thickness. The samples were always annealed at 300 °C for 15 h before gamma irradiation and subjected to heat treatment at 300 °C for 15 min before laser exposure, using a microwave furnace MAS 7000 from CEM Co.

A ⁶⁰Co panoramic source (50 TBq) was used for gamma irradiations. The pellets were irradiated in air, between 3 mm Lucite plates that guarantee electronic equilibrium condition.

The TL measurements were performed using a 5500 TL reader from Harshaw.

The laser source was an ArF excimer laser, model Autonomus Ladarvision, with the following characteristics: oscillating mode 10 ns, wavelength 193 nm, beam diameter 0.9 mm, frequency 10 Hz, energy per pulse ~3 mJ and tracker in the IR region (905 nm).

To perform the measurements, groups of three detectors were prepared at IPEN and sent to UNIFESP using an express current mail service, Sedex. Each detector comprises three pellets of CaSO₄:Dy sealed in an antistatic plastic film (polyethylene). The detectors were defined as:
analysis detector—used to measure the UVR; control detector—used to detect any spurious signal accumulated during the IPEN–UNIFESP–IPEN transportation; this detector was not exposed to the laser radiation, it just accompanies the analysis detectors; proof detector—is kept in the lead shield, at room temperature, at IPEN, to be compared with the control detector, and is used to confirm that there is no influence of spurious signals. These procedures are described in the literature(6,7).

The \( \text{CaSO}_4: \text{Dy} \) PTTL response was studied under surgery conditions to determine their behaviour when exposed to the excimer laser radiation. The PTTL response was measured for different number of laser pulses (1–20) and a wide range of gamma doses (5–100 Gy). The samples were placed 20 cm straight from the laser source and the dosemeters were centred using the tracker before shooting the laser pulses.

To measure the spread radiation inside the surgery room, the analysis detectors were positioned at different distances from the laser source: patient’s (\( \geq 0.15 \) m), surgeon’s (\( \geq 0.5 \) m) and nurse’s (\( \geq 1.0 \) m) foreheads, lateral (\( \geq 1.5 \) m) and back (\( \geq 4.0 \) m) walls. The PTTL measurements were carried out for two different conditions: five surgeries, each one taking \( \sim 10 \) min, and during a period of 4 h (cumulative), when several operations were performed. After exposure, the pellets were sent back to IPEN by current mail service for evaluation.

RESULTS AND DISCUSSION

The typical \( \text{CaSO}_4: \text{Dy} \) PTTL glow curve obtained after heat treatment at 300°C for 15 min before laser exposure and heat treatment at 100°C for 15 min after UV exposure and 24 h after UV exposure is presented in Figure 1. The temperatures of the dosimetric peak are 230 and 210°C, respectively, similar to the TL \( \text{CaSO}_4: \text{Dy} \) glow curve.

The \( \text{CaSO}_4: \text{Dy} \) PTTL responses as a function of the radiant energy (laser pulses) and the gamma dose are shown in the Figures 2 and 3, respectively. The PTTL response is linear as a function of the radiant energy and the gamma dose in the range studied. This behaviour shows that the excimer laser can detrapp carrier charges from the deepest traps created through the previous irradiation using the high gamma dose. Figure 3 also compares the \( \text{CaSO}_4: \text{Dy} \) PTTL response of UVR (18 mJ cm\(^{-2}\)) and excimer laser (180 mJ cm\(^{-2}\)) for gamma doses between 5–100 Gy.

The PTTL responses of the control and proof detectors was the same, indicating that there was no detection of any influence of spurious signals.
The analysis detectors were evaluated and compared according to their positioning for each surgery. The PTTL responses obtained for the five surgeries are shown in Figure 4. It can be observed that the surgeries did not have the same parameters; for instance, the number of laser shots on the patient and the spread laser radiation that the hospital’s surgical staff and environment are exposed to.

According to IRPA publication (1996) (8), the upper exposure limit depends on the exposure time, wavelength and also the laser oscillation mode. For exposure times between $10^{-9}$ and $3 \times 10^{8}$ s (8 h 20 min) the upper exposure limits are $3 \times 10^{5}$ J cm$^{-2}$ and 30 J cm$^{-2}$, respectively. Considering that the samples have 6 mm diameter, the upper exposure limit range is between 84 kJ and 8.4 J. These values present the close relationship with the results obtained for cumulative measurements, presented in Figure 5.

Figure 5 presents the spread laser radiation detected, measured for the hospital’s surgical staff and environment for a period of 4 h inside the surgical room. The reference values presented are the data obtained from surgery 5, given in Figure 4, normalised to the exposure area of the CaSO$_4$:Dy pellet. The upper exposure limit for the hospital’s surgical staff, for a period of 4 h, was very small. The surgeon was exposed to 12.2 $\mu$Jh$^{-1}$ of radiant energy inside the surgery room.

The results obtained indicate that the detectors positioned as far as 4 m from the laser source were sensitised to the UV laser radiation. The spread UVR measured for a period of 4 h indicated a substantial increase of the accumulated exposure.

CONCLUSIONS
CaSO$_4$:Dy pellets manufactured by IPEN are very sensitive PTTL materials and can be used for the detection of the spread excimer laser. The detectors present a linear response as a function of the radiant energy and the gamma dose for a large range. As expected, the PTTL response presents an exponential decay as a function of the laser source-detector distance.

It was demonstrated that the hospital’s staff and environment are below the exposure limit of the spread laser radiation and that the upper exposure limit was not exceeded during the studied period (4 h).

The results show that the PTTL technique using CaSO$_4$:Dy detectors is a relatively cheap, efficient and feasible method to control UVR and its related occupational exposure risks in a refractive surgical environment.

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