Commissioning of an Optically-Stimulated Luminescence (OSL) system for remote dosimetry audits

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Purpose

For 30 years the Radiological Physics Center (RPC) has used TLD dosimeters for remote audits of beam output of photon and electron beams and energy checks for electron beams. Acrylic blocks with capsules containing TLD powder are sent for each beam. The powder is used as a disposable dosimeter. The RPC has previously described the use of the remote audits to identify units with beam measurements exceeding 5% and 5 mm. The system uncertainty is 1.5% (1 standard deviation) indicating high confidence in the 5% threshold for acceptability.[1,2]

Optically-Stimulated Luminescence (OSL) dosimetry with aluminum oxide doped with carbon has been extensively used to monitor personal occupational radiation dose and the use of OSL dosimeters for dose measurements at therapeutic levels has been studied in the last few years.[3,4] The RPC performed a promising initial evaluation of a commercial system using the microStar System™ with InLight™ dosimeters[5] and decided to purchase and commission dosimeters and instrumentation with the goal of implementing an OSL-based system into its remote audit program. The system was available with the InLight nanoDot™ dosimeter.

Materials

OSL reader microStar System™ (2 units)
InLight nanoDot™ dosimeters
Annealing light box from Landauer
Cobalt beam
6 – 18 MV photon beams
5 – 20 MeV electron beams
Photon mini-phantom blocks for in-air irradiations of dosimeters
Electron phantom blocks for full phantom irradiations of dosimeters

Methods

The following properties weredetermined as part of the characterization of the system:

READER
- Stability
- Reading cycle

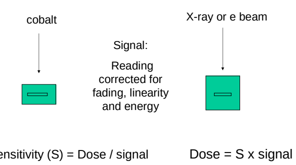
DOSIMETER
- Depletion rate
- Dependence of depletion rate with reader
- Cumulative dose limit
- Number of readings per dosimeter
- Relative dose response or element correction factor (ECF)
- Variability of ECF with reader
- Variability of ECF with dose
- Dose linearity correction
- Signal fading correction
- Energy/block correction

ANNEALING
- Optimal annealing time and recommended instrumentation.
- Variability of ECF with annealing

Dose Determination Algorithm

The response of an OSL dosimeter is quasi linear with dose for any energy. Small deviations from linearity are corrected together with loss of signal from the difference in time between irradiation and reading as well as corrections for energy/block and position of the OSL in the beam.

Methodology



Formulism

$$\text{Dose} = S \cdot \text{signal} \cdot \text{ECF} \cdot \text{DCF} \bullet K_L \cdot K_F \cdot K_E$$

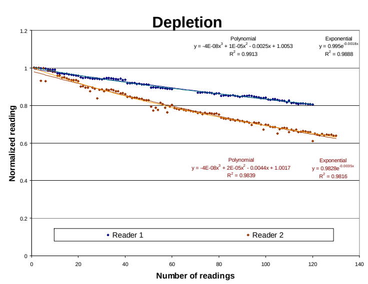
ECF: Element correction factor
DCF: Depletion correction factor
K_L: Supra linearity correction
K_F: Fading correction
K_E: Energy/block correction

Results

SIGNAL CAPTURE

A reading time of 7 seconds was adopted from studies by Homnick[5]. The reference dose was 100cGy.

Repetitive readings of a single dosimeter with two different readers showed predictable behavior that was reader-dependent and represented a loss of around 0.2% per reading. This study led to the conclusion that more than one reading was needed and that three readings provided acceptable confidence. The spread over three readings was such that no depletion correction was needed. The graphs below show the differences in quality of the signal between two readers.



ELEMENT CORRECTION FACTORS (ECF)

A set of dosimeters went through a series of 100 cGy irradiations, reading and annealing cycles and the relative signal factors were calculated and compared with the average signal. The factor for each dosimeter was constant within a standard deviation of 0.3 to 1.3%. See Table 1.

The exercise was also performed with doses of 25 and 300 cGy. In addition, readings were performed on the second reader without any significant change.

Results (cont'd)

ELEMENT CORRECTION FACTORS (ECF)(cont'd)

Table 1: Average ECF after nine cycles

Dosimeter ID	AVG ECF	STDEV
DN09305639P	1.035	0.34%
DN09307843U	0.950	0.50%
DN09307865O	0.989	0.83%
DN09307916P	0.974	0.85%
DN09308972Q	1.045	1.34%
DN093090941	0.997	0.24%
DN09309159T	1.010	0.60%
DN09309249S	1.030	0.48%
DN09309355X	1.012	0.39%
DN09309697J	0.989	0.96%

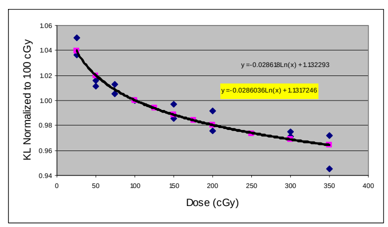
SIGNAL REPRODUCIBILITY

When dosimeters were irradiated and read as described earlier, the corrected readings demonstrated a standard deviation of 0.8%.

NON LINEARITY

Dosimeters irradiated at doses between 25 cGy and 350 cGy showed supralinear responses. A correction was applied to compensate for this supralinearity. That correction was:

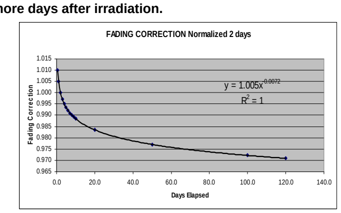
$$K_L = \frac{(\text{cGy/Signal})_{\text{DoseD}}}{(\text{cGy/Signal})_{100\text{cGy}}}$$



The K_L function was determined from multiple irradiations of a single dosimeter and was reproducible as long as the cumulative dose to the dosimeters did not exceed 1000 cGy. Consequently, 1000 cGy was identified as the limit of cumulative dose.

FADING

Dosimeters were irradiated at different dates to a dose of 100 cGy and read in one session. Up to 4% of the signal was was lost over a period of 120 days with the decrease being more pronounced in the first few days. In practice, dosimeters will be read approximately 7 days after irradiation. The graph below shows K_F values normalized at two days. The tests reported here used a delay of 2 or more days after irradiation.



Results (cont'd)

ENERGY/BLOCK CORRECTION

Preliminary results showed that the signal per unit dose was largely independent of energy when irradiations were performed in a full phantom.[5] Dosimeters in acrylic blocks were irradiated with different beam energies to a measured dose of 100 cGy and read in one session together with standards irradiated in the cobalt beam at the same dose level. Some energy dependence combined with a correction for reduced backscatter was determined as:

$$K_E = \frac{(\text{cGy/Signal})_{\text{energyE}}}{(\text{cGy/Signal})_{\text{Cobalt}}}$$

The signal was corrected for fading, linearity and the sensitivity of each dosimeter (ECF). K_E for any energy E relative to a cobalt beam is shown below:

Energy	K_E
6 MV	0.992
15 MV	1.028
18 MV	1.044
5e	1.036
6e	1.027
7e	1.026
8e	1.033
9e	1.019
10e	1.023
12e	1.017
15e	1.025
16e	1.014
20e	1.019

Conclusions

1. The measurements reported here demonstrate that OSL dosimetry is an acceptable alternative for remote dosimetry of teletherapy beams.
2. The reproducibility reported here was achieved by irradiating two dosimeters at each point and taking three readings from each dosimeter. The standard deviation of the three readings should be better than 1.5%; if not, more readings can be taken and depletion corrections applied.
3. The response of the dosimeters used for this study deviated from the average by up to 8%. A relative dose response correction was found necessary for each dosimeter.
4. It was observed that the characteristics of individual dosimeters were independent of the number of irradiation/anneal cycles as long as the cumulative dose was less than 1000 cGy.
5. The need to apply ECF corrections and the limit on cumulative dose for each dosimeter required tracking the dose received by each dosimeter.
6. Uniformity of the dosimeter response and depletion rate of the signal can be affected by the characteristics of each reader. The methodology used here achieved a distribution in the measurements of less than 1% (SD) after the necessary corrections. This may be a criterion for acceptance of a reader.

References

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[2] Kirby TH, Hanson WF and Johnston DA. Uncertainty analysis of absorbed dose calculations from thermoluminescence dosimeters. Med Phys 1992; 19:1427–1433.
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[5] J. Homnick. G. Ibbott, A. Springer, J. Aguirre. "TH-D-352-05:Optically Stimulated Luminescence (OSL) Dosimeters Can Be Used for Remote Dosimetry Services". Med Phys 2008; 35:2994–2995.

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