THE UNIVERSITY OF TEXAS
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Analysis of Uncertainties for the RPC Remote Dosimetry Using Optically Stimulated Light Dosimetry (OSLD)

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Purpose:

In June 2010 the Radiological Physics Center (RPC) implemented a switch from Thermoluminescent Dosimetry (TLD) for its remote mailed dosimetry audits to Optical Lumunescent Dosimetry (OSLD). The irradiation procedures as well as the steps and factors for the calculation of dose with OSLD were designed to follow those already in use with TLD including the use of similar acrylic mini-phantoms and irradiation instructions. The OSLD system calibration factor was referenced to Co-60, and corrections for linearity, individual dosimeter response, fading, use of mini-phantoms and energy were determined for the OSLD. The analysis of the overall uncertainty of the OSLD dose measurement under Co-60 reference conditions and megavoltage beam audits is presented based on the individual uncertainties of all the factor used in the measurement and calculations.

Materials:

The RPC's OSLD system consists of Landauer's InLight nanoDot™ OSL dosimeters and a microStar reader System™. The OSLD/block system is used as a relative dosimeter referenced to absorbed dose measurements with Farmer-type ionization chambers in a water phantom using the AAPM TG-51 protocol for beam calibration. Photon beams from cobalt 60 to 23 MV and electron beams from 5 to 20 MeV are monitored and were initially used for the commissioning of the system.

Methods:

The OSLD dosimeters are read in sessions that include OSLD standards irradiated by an in-house cobalt unit used to calibrate the system, and dosimeters irradiated by a second cobalt unit, read interspersed throughout the session, for the purpose of monitoring fluctuations in the sensitivity of the system as well as serving as verification that the system operated well and customer irradiated dosimeters. The dosimeters used for standards and those for the customers are irradiated to 100 cGy and the controls to 90 cGy.

Calculation of absorbed dose

The absorbed dose D to the reference medium (water or muscle) at the location of the OSLD sample in a block can be calculated from the optically stimulated luminescence measured in the reader as

$$D_{sample} = S \bullet M_{sample} \bullet K_{Fsample} \bullet K_{Lsample} \bullet K_{Esample}$$

Methods, continued:

Where

D_{sample}	Dose at the OSLD location
S	System sensitivity
M_{sample}	Reading of sample signal
$K_{Fsample}$	Correction for loss of signal since irradiation
$K_{lsample}$	Correction for lack of linear response
$K_{Esample}$	Correction for differences in energy

The system calibration factor is the optically stimulated luminiscence response of the OSLD dosimeter system per unit dose that is determined from standards irradiated to 100 cGy under a cobalt-60 beam.

$$S = D_{std}/(M_{std} \bullet K_{Fstd} \bullet K_{Lstd})$$

The dose to a sample can be written as

$$D_{sample} = (D_{std}/ M_{std}) \bullet M_{sample} \bullet (K_{Fstd}/ K_{Fsample}) \bullet (K_{Lstd}/ K_{Lsample}) \bullet K_{Esample}$$

The dose to a sample can then be interpreted as the product of six components, the dose to the standards, the reading from the standards, the reading from the sample, and the relative lack of linearity the relative fading as well as the relative response between the dosimeters irradiated in cobalt and the sample irradiated in a given energy. These six components are independent of each other.

Uncertainty in the dose

The standard uncertainty in the dose measured by an OSLD dosimeter as determined from luminescence measurements using eq. (3) can be taken as the combination of the uncertainties of all six quantities related to the reading of the OSLD dosimeters..

The combined uncertainty in the dose to the samples is then the square root of the sum of the squared individual relative uncertainties.

$$uc(D_{sample})^2 = u(D_{std})^2 + u(M_{std})^2 + u(M_{sample})^2 + u(K_F)^2 + u(K_L)^2 + u(K_E)^2$$

The uncertainty in the determination of the dose rate of the cobalt-60 beam is in the set up error during calibration using an ionization chamber in a water phantom under fixed geometric conditions. Irradiation of the OSLD standards using a rigid attachment that fits the blocking tray slot makes the contribution to uncertainty negligible. It is estimated to be 0.6% for one standard deviation.

The uncertainty in the reading has been derived from readings of standards irradiated to the same dose and read every session showing 0.8% for one standard deviation. (Figure 1).

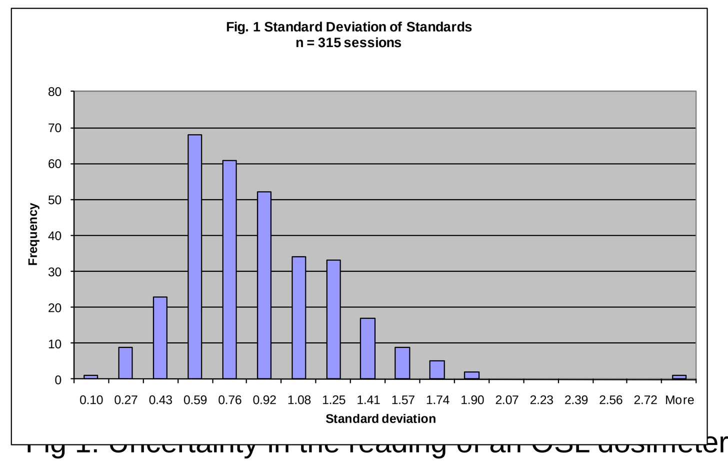

Fig 1: Uncertainty in the reading of an OSL dosimeter

Methods, continued:

The uncertainty in the correction for linearity is based on the uncertainty in the slope of the line that defines K_L. The best-fit line was determined for the calibration that define K_L (Figure 2). The 95% confidence interval on the slope of the best-fit line was determined using linear regression. At 25 cGy, the uncertainty in K_L was 0.2%; at 350 cGy, the uncertainty in K_L was 0.6%. For doses between 90 and 110 cGy the uncertainty was considered to be 0.1%.

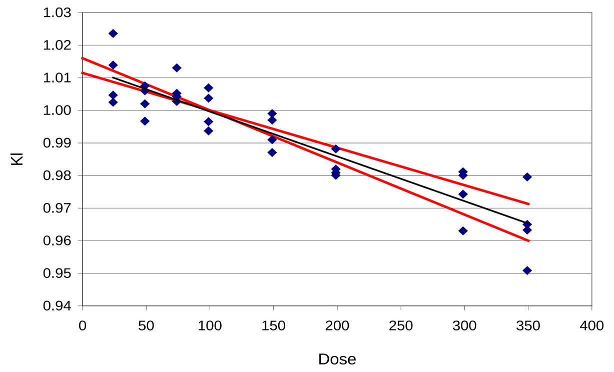

Fig 2: Uncertainty in the linear regression of dose dependence

The uncertainty in the correction for fading was calculated in a similar manner to that for linearity. For up to 2 weeks difference, the uncertainty in K_F (2 sigma) remained below 0.3%.

The uncertainty in the correction for different response of the OSL dosimeters depending on the energy K_E was determined from measurements done during commissioning when blocks irradiated at different energies at known doses. Repeated derivations of the energy/block correction factor yielded an average standard deviation of 0.9%.

Results:

Uncertainty budget for the OSLD calculation

Table 1 lists the various contributions from each parameter to the uncertainty budget for the calculation of dose with the OSLD mailable system. The uncertainties are expressed as fractional variance and are done for a measurement was done at a point using two dosimeters for the sample, four dosimeters for the standards and three readings for each dosimeter. The values correspond to one standard deviation.

Table 1: Uncertainty budget for dose calculations

Parameter	Relative standard uncertainty (1 std dev in %)
Dose to standards	0.6
Reading standards (n = 4)	0.4
Reading sample (n = 2)	0.57
Energy correction	0.9
Linearity correction	0.3
Fading correction	0.1
Total for controls	0.9
Total for institution sample	1.3

The total uncertainty of a sample has been calculated for two different circumstances, one is the irradiation of samples by institutions at the various photon and electron energies and the other one for samples irradiated at the RPC location in a cobalt beam and used as quality assurance controls during every session.

Results, continued:

Statistical variance of OSLD field measurements

The field measurements performed by the RPC are of two types: those done on controls irradiated at the headquarters under controlled conditions in a cobalt beam and those done at institutions that are monitored once a year on the standard output for both photons and electrons. Figures 3 and 4 are histograms of the results for the ratio of measured to stated dose for all the beams monitored since the inception of the OSLD program. The results show a standard deviation of 0.8% for controls and 1.8% for institutional results for both photons and electron beams.

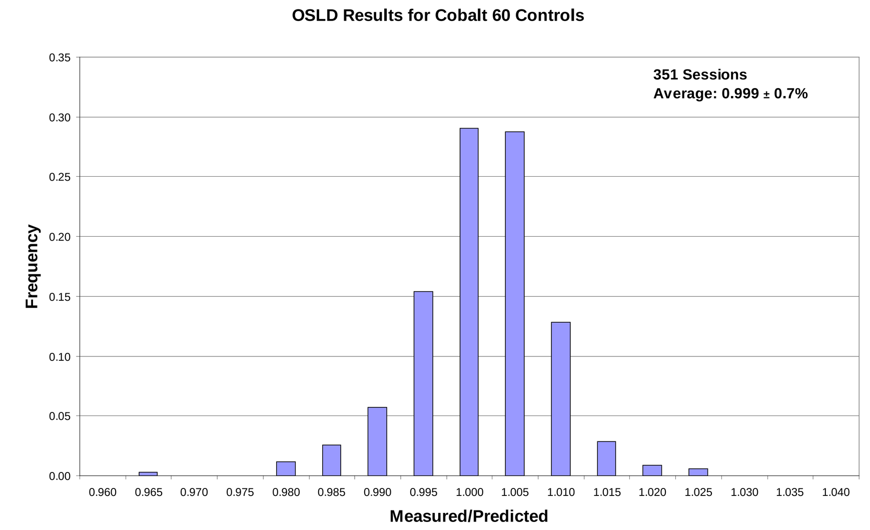

Fig 3: Results from irradiation of control OSLD

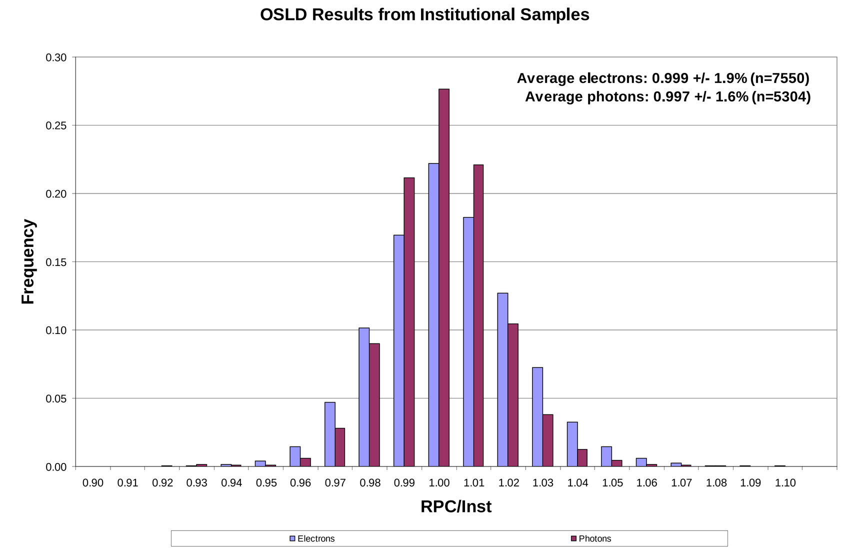

Fig 4: Results from institutional verifications

Conclusions:

The total uncertainty of the measurement of dose using OSLD dosimeters has been described and the individual components of that uncertainty have been detailed. When these expected uncertainties are compared against the results from a significant number of sessions and beams both for controlled as well as institutional results these compare very well. For a 95% confidence level the results suggest 3.4% standard deviation; the RPC uses a 5% criterion, well within that level.

Support:

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