THERMOLUMINESCENCE DOSIMETRY SYSTEM

Aim:

1. To study the characteristics of $CaSO_4$: Dy.
2. To calibrate the TL/OSL research Reader in terms of absorbed dose and find out the unknown dose from a sample.

Equipment Required:

1. Annealed TLD samples ($CaSO_4$: Dy)
2. Radiation-generating equipment
3. Slab phantoms
4. TL/OSL Research reader
5. TLD Annealing Oven

Theory:

Thermoluminescence (TL) is a phenomenon of emission of light from a material (insulator/Semiconductor) called phosphor during heating, which has already been exposed to ionizing radiations (x, β, and γ rays). These materials consist of a crystalline dielectric material with a trace amount of an activator. The impurities create crystal-lattice imperfections inside the phosphor material and form a metastable energy level in the forbidden region (Fig. 1). When these phosphors are irradiated by ionizing radiation the electron-hole pairs are generated. These electron-hole pairs moving randomly in the phosphor can be trapped at these metastable energy levels. The number of traps in the phosphor material is directly related to the amount of radiation given to the material.

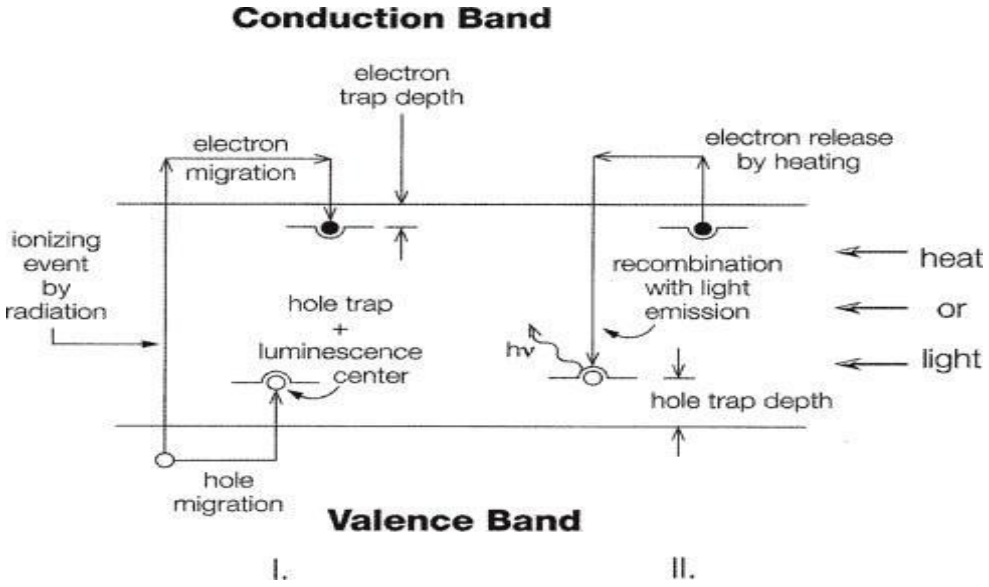


Figure 1

At normal room temperature, these electrons cannot escape the trap centres. But when sufficient energy is provided in terms of heat these electrons escape the trap centre and recombine with the holes to produce light. The wavelength of light emitted by the phosphor during heating lies in the visible region in general. This emitted light is sent to the PMT for the purpose of counting.

To enhance the TL sensitivity, dopants are added e. g. Dy in $CaSO_4$. Dysprosium is one of the rare earth metals that is commonly used as a dopant in Thermoluminescence materials. The activators/ dopants e.g., Dy, introduced into the phosphor, enhance the number of electrons and hole traps inside the forbidden band. This $CaSO_4$:Dy is known to have high sensitivity, slow fading, good thermoluminescence efficiency, wide dose range, and good thermal and physical stability.

The plot of light output with time or temperature is called the glow curve. There can be many glow curves having different glow peak temperatures, and different heights/amplitudes in a phosphor. This is decided by the nature and population of various traps. Each glow peak has a maximum and its value depends on the heating rate (°C/s) used. The light output/area under the glow curve in the TL-time plot can be taken as a measure of dose. By suitable calibration of the TLD reader, we can estimate the unknown doses.

After the readout process, there are always some residual traps inside the TL phosphors. To eliminate the effects of previous exposure, annealing of the TL phosphor is done without causing any damage to the phosphor and to stabilize the electron traps in order to use it again. Annealing is done in an annealing oven, where the TL samples are given a thermal treatment of 400°C for 1 hour.

In India, $CaSO_4$: Dy is used as TLD Badge in the countrywide personnel monitoring programme. It is designed to measure x, γ and β radiations. Even though it is not tissue equivalent but many advantages like high TL sensitivity, cheap, easy manufacture and simple annealing procedure etc. make it a good phosphor for personnel monitoring. The amount of Dy added to $CaSO_4$ is 0.05 mole %, which is 500 ppm. The TL glow curve of $CaSO_4$: Dy is shown in Fig. 2.

About The TL/OSL Research Reader and Software:

The TL/OSL research reader is manufactured by Nucleonix (Figures 2a and 2b). It is a compact integral unit which can be operated and controlled by computer software. Both Thermoluminescence and Optically Stimulated Luminescence phosphors can be read out with the instrument.

This system has precisely designed stimulation & detection optoelectronics, a photon counting module with appropriate filters, focusing lenses & sample drawer assembly with heating arrangement all enclosed in a single mechanical chamber. This system facilitates loading of the TL/OSL samples onto the Kanthal strip. TL/OSL data acquisition & analysis is controlled by PC software.

In the case of OSL, optical stimulation by BLUE & GREEN LEDs provided are also controlled by PC software and electronic circuits & embedded code in the microcontroller. This system can be operated in TL or OSL modes as required by the user. The Photon counting module acquires luminous intensity data for both TL & OSL samples. Two modes of OSL stimulation have been provided in this system namely, CW - OSL (Continuous wave OSL) and LM - OSL (Linearly modulated OSL).

The TL / OSL reader system operates through PC-controlled user-friendly software. The software has the facility to perform Self-diagnostics of the system & report faults. This software facilitates one to choose TL or OSL mode for sample data acquisition and allows the user to configure the required heating profile in TL mode & other parameters as required in OSL mode. Once data is acquired, acquired data can be saved or further processed depending upon the requirement.

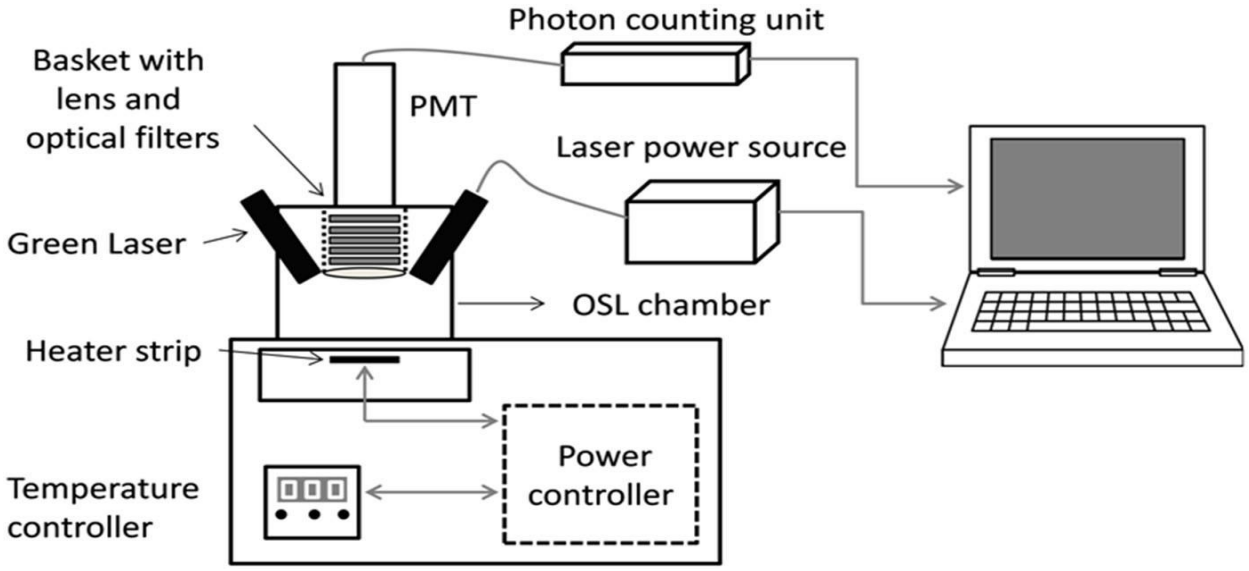


Figure 2a

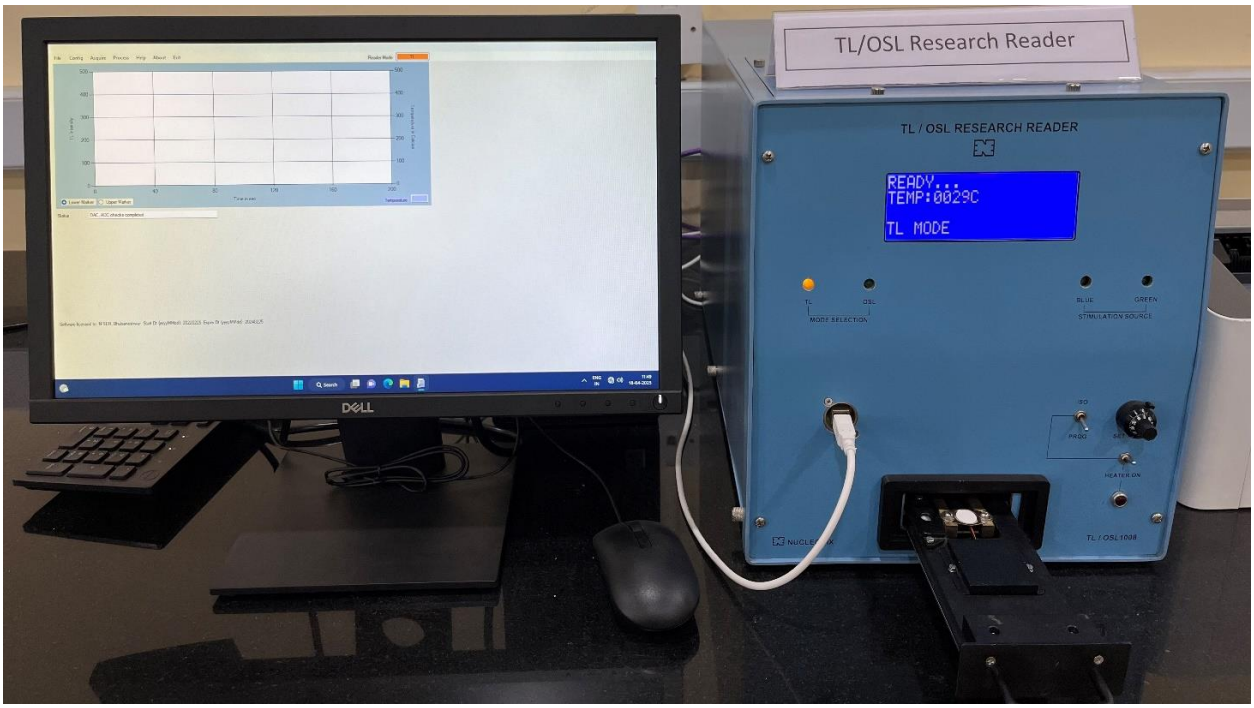


Figure 2b

Procedure:

The process of irradiation of TL samples and the readout process is described below.

1. **Irradiation of annealed samples**:
   - Place the fresh TLD samples inside the slot made in the slab phantom.
   - Keep the TL sample along with the slab under the radiation-generating equipment (Medical Linac or Telecobalt unit).
   - Irradiate the samples to various doses, e.g., 48 cGy, 72 cGy, 96 cGy…. etc.
   - For validation of calibration, Irradiate three samples with dose in between the calibration points.

2. **Readout process & Study of the Glow Peak:**
   - Switch on the reader unit and the computer. Wait at least 15 minutes for warmup and stabilise the reader unit.
   - Open the TL/OSL research reader application on the desktop.
   - First, place a freshly annealed sample on the sample holder in the TL reader and turn on the heater.
   - Acquire the background reading by clicking Start in the Acquire menu. Save this glow curve with an appropriate name (Ex. Bkg 1). Later, Select this file for background subtraction.
   - Pull the drawer assembly & allow the TLD holder temperature to reduce to 40°C. Now place the exposed/irradiated $CaSO_4$: Dy disc sample at the centre of the holder one at a time.
   - Click on the configure menu, create a profile (or load a profile previously saved, if any) by entering the parameters such as time, temperature, or heating rate to get the proper glow curve.
   - Now start acquisition by clicking on the "Acquire" menu and clicking on the "Start" button shown below. This initiates the plotting of the glow curve in the TL Research Reader software visually.
   - After completion, save the glow curve from the "File" menu.
   - To find the area under the glow curve, select the Lower marker (at the left bottom of the plot) to select the start point of ROI (Region of Interest) and the Upper marker to select the terminating point of ROI. Selected ROI will be turned into Red colour, and integral TL intensity will be displayed in the parameters table.
   - Find the temperature corresponding to the maximum TL intensity in the glow curve. This is the glow peak. This temperature is called peak temperature and is characteristic of that Tl material.
   - Repeat this procedure for various heating rates (by creating new heating profiles) and observe the effect on Peak temperature and integral output from the TLD.

3. **Calibration procedure and determination of Unknown dose:**
   - Obtain the glow curves for samples irradiated to known doses.
   - Find out the integral TL intensity (Counts) of the samples, i.e., the area under the glow curve (Example shown below).
   - For accurate results and minimal error, take the average of at least three samples for this calibration process.

- Plot a graph of TL intensity/counts vs Dose. The plot should be linear. Find the equation of the curve from the plot.
- Place the sample for validation in the sample holder and obtain the average TL intensity from the glow curve in a similar manner.
- From the equation, find the Dose and calculate the error in the measurement.
- This method can be applied to find the unknown dose in the calibration range.

4. Annealing Procedure:

- Place all the TL samples on the annealing tray.
- Insert the annealing tray into the TLD annealing oven.
- Set the temperature to 380°C for 6 hours and allow them to cool to room temperature.
- These TLDs can be used further as fresh samples.

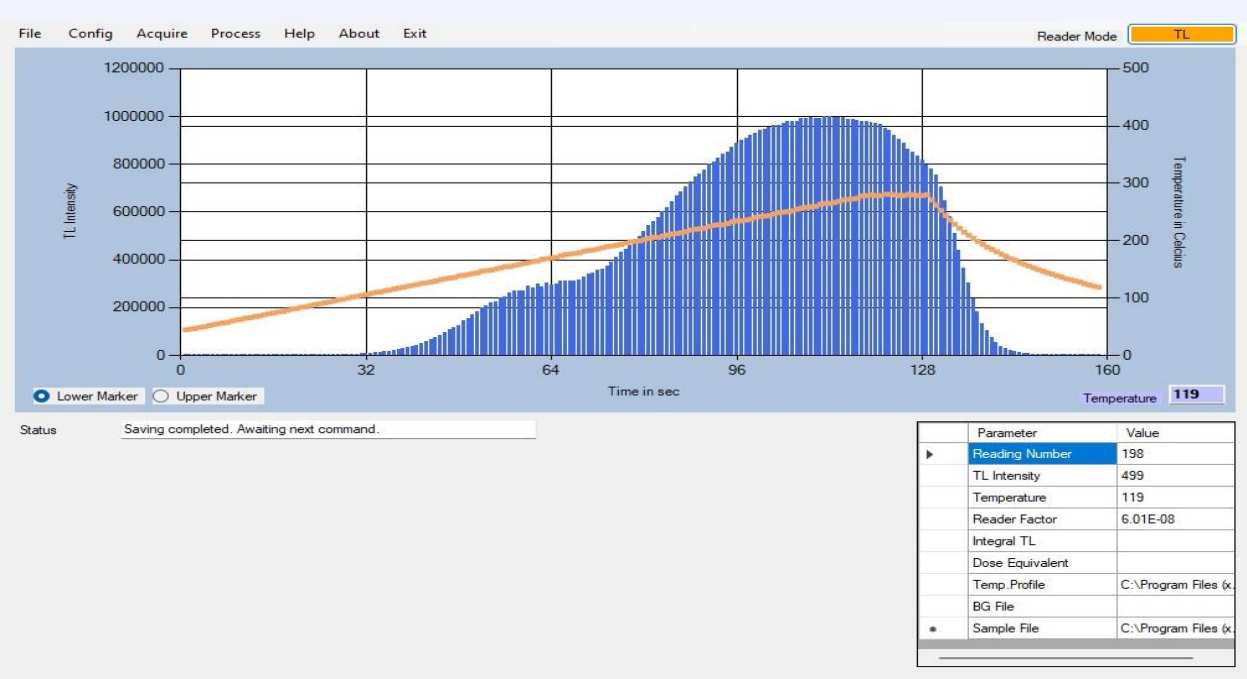
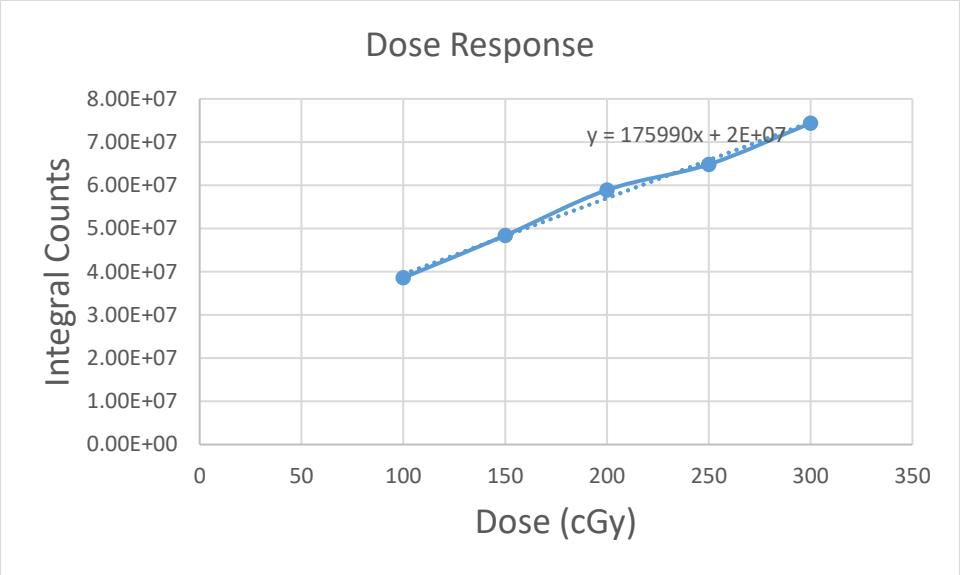


Figure 3

Tabulation:

	TL Intensity (I) in Counts		
Dose (cGy)	**Counts1**	**Counts2**	**Average**
100	39969288	37225881	38597584
150	48073656	48708257	48390956
200	60308674	57510360	58909517
250	65630105	64053086	64841595
300	75059011	73680601	74369806



Calculations & Results:

The plot of Dose Vs Counts was found to be a straight line given by

$$y = 175990x + 2 \times 10^7$$

Validation of unknown dose:

TL intensity from unknown sample = 47475030 Counts

Dose of unknown sample:

$$D_m = \frac{(4.75 \times 10^7 - 2 \times 10^7)}{175990}$$

$$= 156.12 \text{ cGy}$$

Actual Dose given (D_0) = 150 cGy

$$\text{Error} = \frac{156.12 - 150}{150} X\ 100 = -4.08\%$$

Conclusion:

Precautions:

- Do not increase the PMT voltage beyond 1000 Volts.
- Please ensure the correct mode (TL/ OSL) is selected.
- Do not open the drawer while the measurement is going on.
- Do not touch the planchet/ sample holder immediately after the readout. Wait for the temp. to reduce below 40°C.
- Switch on the TL/ OSL Reader power button after turning on the main supply.
- Before placing the annealing tray inside the annealing oven, ensure that the unit is switched off.
- Ensure that the door of the annealing oven is locked properly.
- Do not open the door of the oven immediately after switching it off. Wait for the temp. to reduce below 40°C.
- Always wear gloves while handling the samples during the measurement and the annealing procedure.