THERMOLUMINESCENCE DOSIMETRY SYSTEM

LAB REPORT

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Date of experiment: 13-10-2023

Date of submission: 09-11-2023

Aim:

1. To study the characteristics of $CaSO_4 : Dy$.
2. To calibrate the TL 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:

Principle of thermoluminescence dosimetry

Thermoluminescent dosimetry (TLD) is based on the ability of solids to absorb and store the energy of ionizing radiation, which upon heating is emitted in the form of electromagnetic radiation, mainly in the visible wavelength region. These materials are known as phosphor and 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. 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.

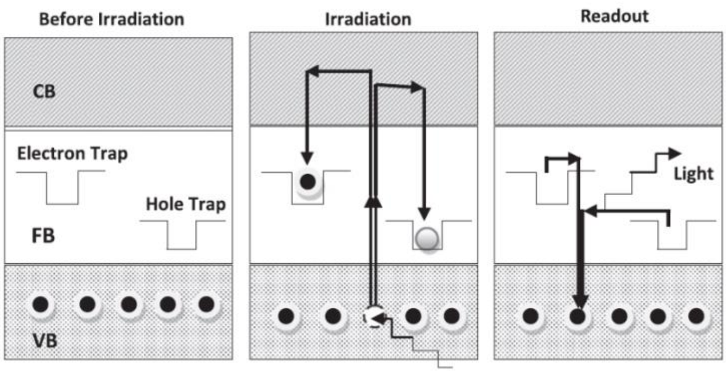

Fig. 1. Mechanism of Thermoluminescent phenomenon

The electrons cannot escape the traps at room temperature but when a sufficient heat is provided, they escape the traps and recombine with the holes to produce light. The light emitted is then detected and correlated to the absorbed dose received by the TL material.

To enhance the TL sensitivity, dopants are added e. g. Dy in $CaSO_4 : Dy$. 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.

Specifications and properties of the $CaSO_4: Dy$ disk used

The discs are made from a homogeneous mixture of $CaSO_4: Dy$ phosphor (grain size < 75 um).

The amount of Dy added to $CaSO_4$ is 0.05 mole % by weight, which is 500 ppm.

Diameter- 13.3 mm, thickness- 0.8 mm, weight- 280 mg, $Z_{eff} = 15.6$, Fading < 5 % per year, Dose range: 10 mR – 1000 R.

TL Disk reading process and setup

After the TLD disks are irradiated, they are taken to the TLD disk reader setup and supplied with heat (contact heating, gas heating, etc.) at a particular rate, generally from $30^o\ C\ (\sim room\ temp.)\ \ to\ 280^o\ C$, because we observe the maximum peak in the glow curve of a disk of this particular dimension between $170^o\ C$ and $230^o\ C$. A temperature profile is set and glow curve for each disk is obtained which is nothing but the relation between the intensity of light produced by electron-hole recombination at a particular temperature and the heating time/ temperature. Using the information produced in the form of glow curves of the TLD disks with known doses, a calibration curve is produced which is used to evaluate the unknown doses received by other irradiated disks.

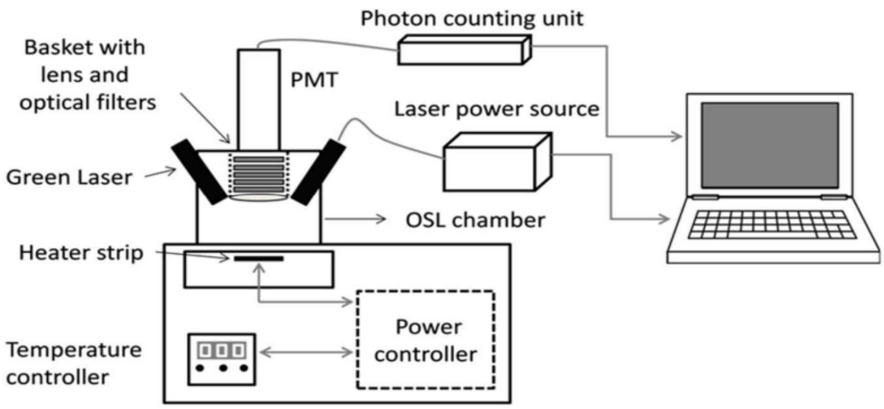

Fig. 2. Schematic diagram of the semi-automatic TLD disk reader system used in the experiment

Fig. 3. TLD disks

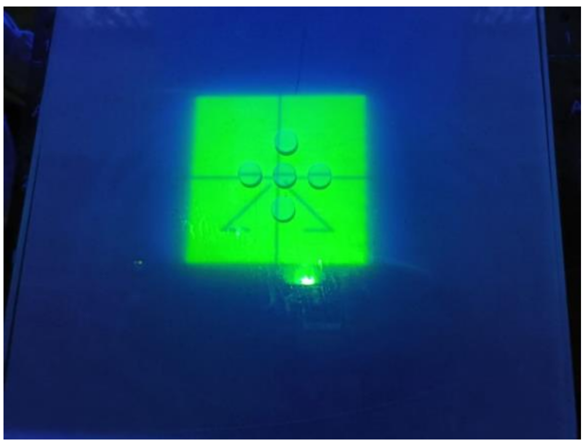

Fig. 4. 5 TLD disks placed on top of a plastic phantom, aligned with the radiation field of LINAC

Observations:

Irradiation

Specifications and parameters used during irradiation,

SSD: 100 cm, Buildup: 2 cm, Field size: 10 × 10 cm^2, X-ray energy: 6 MV.

Monitoring Units	Dose (Gy)	Dose type
51	0.5	Known
101	1	
152	1.5	
203	2	
254	2.5	
305	3	
508	5	
183	?	Unknown
325	?	

Table. 1. TLD irradiation data

SSD stands for the Source to surface distance. It is the distance between X-ray Source and the surface of the phantom.

Since the depth of maximum dose deposition (d_{max}) for 6 MV photon beam is about 1.5 cm. So, we measure dose at any depth above the d_{max} because dose delivered at any depth below the d_{max} (buildup region) is subject to perturbations due to electron contamination by the MLCs (Multi Leaf Collimators). This is the reason behind taking a buildup of 2 cm.

Dose reading

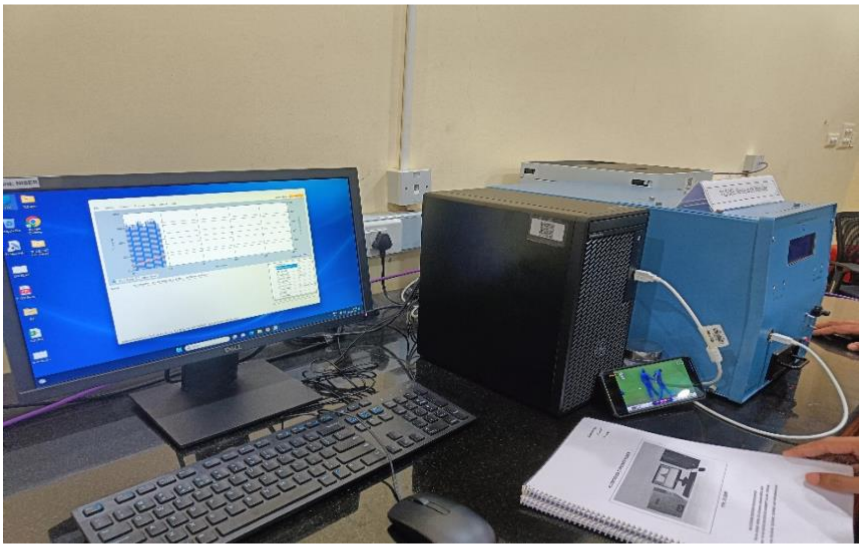

Fig. 5. Semi-automatic TLD reader setup

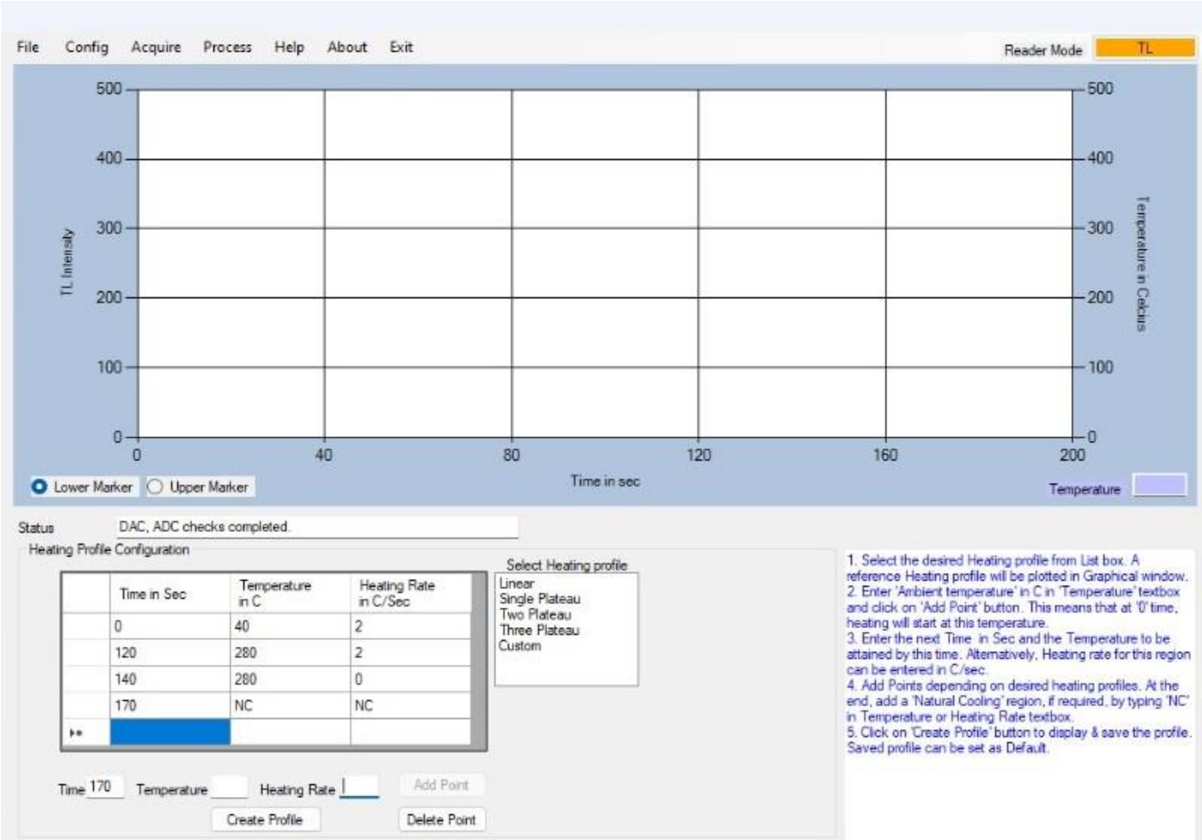

Fig. 6. Temperature profile set before dose reading

Dose (Gy)	D1 integral counts	D2 integral counts	D3 integral counts	Avg. integral counts	Net integral counts
Bkg.	172118	104737	197447	158100.6667	
0.5	27685313	27441284	24972088	26699561.67	26541461
1	45636139	44368076	44029536	44677917.00	44519816.33
1.5	59685310	54687281	52110209	55494266.67	55336166.00
2	67625374	69546650	72355920	69842648.00	69684547.33
2.5	70730261	66074327	76762681	71189089.67	71030989.00
3	78983926	83909592	86003773	82965763.67	82807663.00
5	112610845	111264415	105078964	109651408.0	109493307.3
Unknown 1	79908110	84830198	89575253	84771187.00	84613086.33
Unknown 2	61568766	65472536	65327732	64123011.33	63964910.67

Table. 2. Data obtained from the TLD reading process for various disks irradiated at various doses

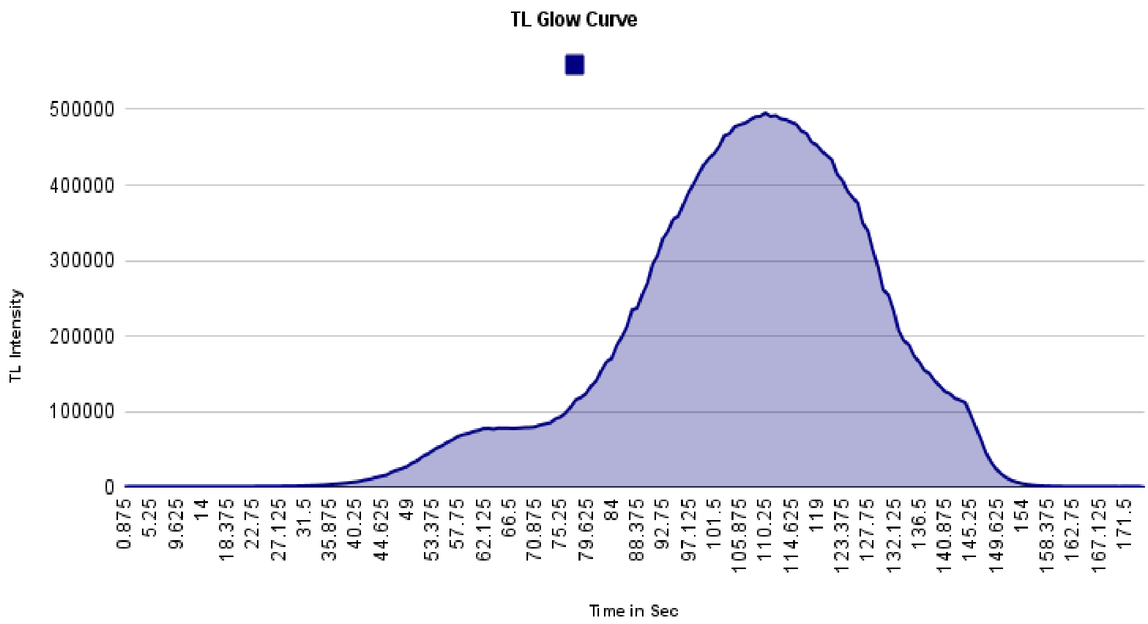

Fig. 7. Observed glow curve of one of the TLD disks

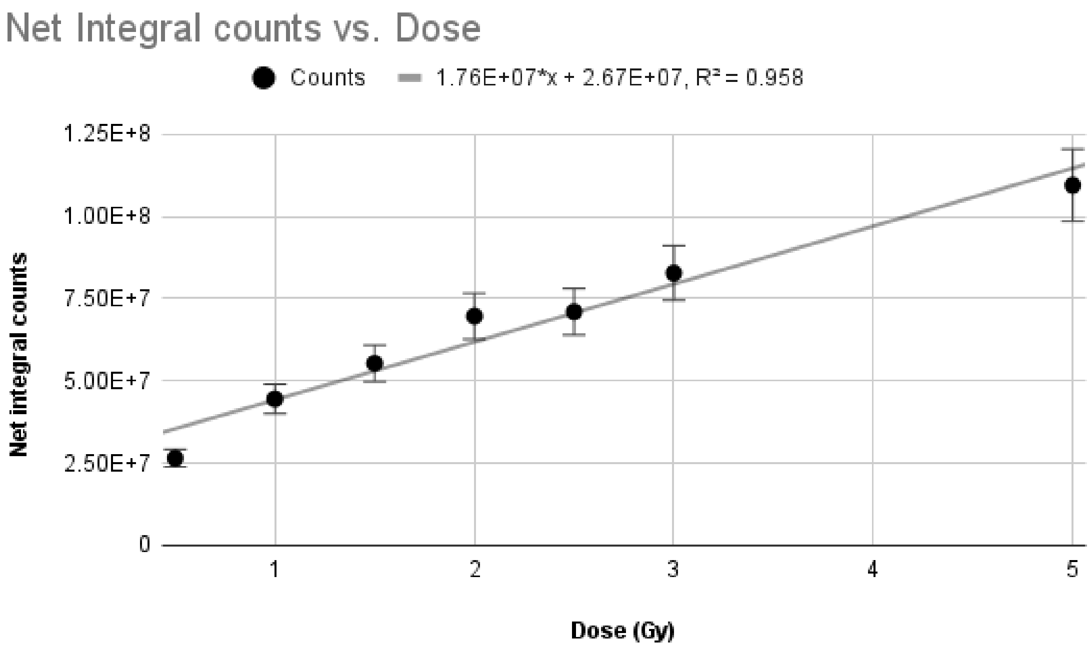

Fig. 8. The Dose calibration curve obtained from the TLD disks reading data

The above calibration gives us a straight line relating counts with the dose with a linear regression of 0.958.

Calculations:

From the above dose calibration curve obtained from the known doses data, we get an equation of a straight line,

$$I\ (Intensity) = (1.76\,x + 2.67)\ 10^{7}$$

Here, 'x' denotes dose and unit is Gray (Gy).

$$x = \frac{I \times 10^{-7} - 2.67}{1.76}$$

Finding out the unknown doses,

$I(Unknown\ 1) = 84613086.33,$

$$x(Unknown\ 1) = \frac{84613086.33 \times 10^{-7} - 2.67}{1.76} = 3.29\ Gy$$

$I(Unknown\ 2) = 63964910.67,$

$$x(Unknown\ 2) = \frac{63964910.67 \times 10^{-7} - 2.67}{1.76} = 2.117\ Gy$$

Result:

The two unknown doses were found to be 3.29 Gy and 2.117 Gy which were deposited by giving the monitoring units 325 and 183 respectively.

Conclusion:

The TLD reading process is an effective process and with the advent of advance computing, the reading time has been significantly reduced and possibility of human error is minimized.

The semi-automatic reading setup was used in this experiment and the heating mode was contact heating which leads to some dose error due inhomogeneous heat distribution across the TLD disk.

Precautions:

1. Read the TLD disks soon after the irradiation to avoid any possibility of fading.
2. Do not open the disk holder midway while the heating and reading process is going on.
3. Take the integral counts from the glow curve within the same temperature range for all the disks.

References:

- CMRP Lab manual (3rd semester)
- Rivera, T. (2012). Thermoluminescence in medical dosimetry. *Applied Radiation and Isotopes*, *71*, 30-34. https://doi.org/10.1016/j.apradiso.2012.04.018
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