

## Thermoluminescence Dosimetric Characteristics of Fabricated Germanium (Ge) Doped Optical Fibres for Electron Beams Dosimetry: A Preliminary Study

(Pencirian Dosimeter Pendar Gerlap Terma terhadap Gentian Optik Dop Germanium yang Difabrikasi bagi Pengukuran Dos dalam Pancaran Elektron: Sebuah Kajian Awal)

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### ABSTRACT

*The basic dosimetric favourable responses of tailored fabricated germanium (Ge) doped cylindrical optical fibres, make use of 2.3% mol have been extensively studied with clinical electron beams irradiation in terms of dose linearity, reproducibility, fading signals, minimum detectable dose (MDD), energy- and field size dependence. The irradiation was performed at the Radiotherapy Unit, Advanced Medical and Dental Institute (AMDI), which utilizes Elekta Synergy® linear accelerator (LINAC) at 6-, 9-, 12- and 15 MeV electron beam energies at specific doses ranging from 1 to 5 Gy. Thermoluminescence (TL) signals exhibited a linear dose-response overdose ranges, mean reproducibility with a coefficient of variation (CV) of better than 10% and no dependency with different field sizes at  $p > 0.05$ . The MDD values were typically 3.51 to 4.13 mGy. The minimum TL fading of the fabricated Ge-doped cylindrical optical fibres was reported favourably for 9 MeV electron beam at day of 74.*

*Keywords: Dose linearity; optical fibres; thermoluminescence (TL)*

### ABSTRAK

*Pencirian asas yang sesuai terhadap tindak balas germanium (Ge) dop gentian optik yang berbentuk silinder dengan kepekatan 2.3% mol telah dikaji secara meluas dengan penyinaran pancaran elektron klinikal daripada segi kelinearan terhadap dos, kebolehulangan semula, kemerosotan signal, kebolehkesanan dos radiasi minimum (MDD) dan kebergantungan kepada saiz medan dan tenaga. Penyinaran ini telah dijalankan di Unit Radioterapi, Insititut Perubatan dan Pergigian Termaju (IPPT) dengan menggunakan pemecut linear Elekta Synergy® dengan tenaga pancaran elektron iaitu 6-, 9-, 12- dan 15 MeV pada dos tertentu dengan penjumlahan daripada 1 hingga 5 Gy. Signal pendar gerlap terma (TL) telah menunjukkan gerak balas dos yang linear terhadap julat dos, min kebolehulangan semula dengan pekali variasi (CV) lebih baik daripada 10% dan tidak bergantung kepada perbezaan saiz medan pada  $p > 0.05$ . Nilai kebolehkesanan dos radiasi minimum biasanya daripada 3.53 hingga 4.13 mGy. Kemerosotan signal yang minimum bagi gentian optik telah dilaporkan oleh pancaran elektron yang bertenaga 9 MeV pada hari yang ke-74.*

*Kata kunci: Gentian optik; kelinearan dos; pendar gerlap terma (TL)*

### INTRODUCTION

Electron beams have eagerly been used in radiotherapy treatment for superficial tumours for the last two decades (Nascimento et al. 2018). Currently, the use of LINAC Accelerator typically delivers several electron beam energies in the dynamic range of 4 to 22 MeV used for radiotherapy treatment. The prime focus of present work was to establish the characteristics of tailored fabricated Ge-doped cylindrical optical fibres on electron beam dosimetry, although in many current researches, examples of other forms of radiation sources such gamma (Fadzil et al. 2018), photon (Lam et al. 2017; Noor et al. 2016) diagnostic radiology, UV dosimetry system and food

irradiation industry. Different time-temperature profile (TTP and proton (Hassan et al. 2017) dosimetry have been established in their characteristics.

In many productive years, an impressive number of independent research groups have scientifically investigated the key characteristics of dosimeters in electron dosimetry such as in commercial optical fibres (Rahman et al. 2014), Metal Oxide Semiconductor Field Effect Transistor (MOSFET) (Amin et al. 2011), including the location of d(max, ionization chamber (Followill et al. 2003), Optically Stimulated Luminescence (OSL) (Ponmalar et al. 2017) and radiochromic film (Sipilä et al. 2016). With the remarkable achievement of the

characteristics with other dosimeters in electron beam dosimetry, this comparative study has progressively extended to the fundamental discovery of instantly establishing characteristics of fabricated Ge-doped cylindrical optical fibres.

## MATERIALS AND METHODS

### FABRICATED GERMANIUM (GE) DOPED CYLINDRICAL OPTICAL FIBRES

This extensive study was focused on tailored fabricated germanium (Ge) doped cylindrical optical fibres, concentration of 2.3% mol germanium which were made by Modified Chemical Vapour Deposition (MCVD) technique.

### PREPARATION OF FABRICATED GERMANIUM (GE) DOPED CYLINDRICAL OPTICAL FIBRES

In a proper preparation for irradiation, the fabricated Ge-doped optical fibres were carefully cut into approximate length of  $6.0 \pm 1.0$  mm using a diamond-cutter (Thorlabs, USA). Then, the vacuum tweezer was carefully used in the handling of the fabricated Ge-doped optical fibres and placed them in a brass container covered with aluminium foil to prepare for annealing. Subsequently, the fabricated Ge-doped cylindrical optical fibres were annealed in an oven (Carbolite Gero Limited, UK) at  $400^\circ\text{C}$  for 1 h and left inside in an oven for 16 h to naturally keep the fabricated Ge-doped optical fibres back to their ordinary temperature and minimize thermal stress inside the fibres. Under those circumstances, the fabricated Ge-doped cylindrical optical fibres were grouped and later encapsulated in gelatin capsules to ensure proper preparation for the next irradiation procedure.

### IRRADIATION OF FABRICATED GERMANIUM (GE) DOPED CYLINDRICAL OPTICAL FIBRES

The annealed fabricated Ge-doped cylindrical optical fibres were carefully arranged at the center of  $10 \times 10$  cm field size for irradiation setup. The fabricated Ge-doped cylindrical optical fibres were sandwiched with 1.0 cm bolus and preferred depths of solid water phantom (Polymethylmethacrylate, PMMA) with its specific dimension of  $30 \times 30 \times 30$  cm to create build up thickness and placed at the center perpendicularly to the electron beam axis at the desired depth of dose maximum. The fabricated Ge-doped cylindrical optical fibres were then exposed to 6-, 9-, 12-, and 15 MeV of electron's energies at specific doses range from 1 Gy up to 5 Gy using an Elekta® synergy linear accelerator, located at Radiotherapy Unit, Institut Perubatan dan Pergigian

Termaju (IPPT), Bertam, Pulau Pinang. The specific dose rate of 600 cGy/min, focus to surface distance (FSD) of 100 cm and a 15 cm backscatter thickness were prominently used for all irradiation setups.

To instantly show the linearity signal of the fabricated Ge-doped cylindrical optical fibres for electron beams over a dose range of 1 Gy up to 5 Gy, the standard measurements were done precisely at different electron beam energies of 6-, 9-, 12-, and 15 MeV. The reproducibility characteristic of the fabricated Ge-doped cylindrical optical fibres was evaluated by preferentially using the same set (re-used) of fabricated Ge-doped cylindrical optical fibres which have been exposed to different electron beam energies of 6 up to 15 MeV at a set dose of 2 Gy. The repetition processes of the re-used fabricated Ge-doped cylindrical optical fibres were annealing, irradiation, and read-out. Two repetition of irradiations were typically made. To properly obtain the field size characteristics, the fabricated Ge-doped cylindrical optical fibres were exposed to different field sizes of  $6 \times 6$  cm up to  $25 \times 25$  cm at a dose range of 1 Gy up to 5 Gy. The possible response of TL signal fading for the fabricated Ge-doped cylindrical optical fibres was accurately assessed by reading out the decreased TL signals over a storage period at day 5, 7, 20, 34, and 74. Throughout the storage period, the fabricated Ge-doped optical fibres were preserved in a black container at room temperature to minimize the released of trapped electrons.

### READOUT MEASUREMENT

The signal responses of the fabricated Ge-doped optical fibres were precisely measured by using a Harshaw 3500 TLD reader, located at Pusat Pengimejan dan Diagnostik Nuklear (PPDN), UPM. WinREMS software was used as a supported software. The following time-temperature profile (TTP) was used: Pre-heat at a temperature of  $80^\circ\text{C}$  for 10 s; acquisition temperature of  $400^\circ\text{C}$  for 16.7 s; heating rate at  $30^\circ\text{C/s}$  and an annealing temperature of  $400^\circ\text{C}$  for 10 s.

## RESULTS AND DISCUSSION

### DOSE LINEARITY

Figure 1 shows the TL dose response of fabricated Ge-doped cylindrical optical fibres to different electron energies of 6, 9, 12, and 15 MeV. The graph also displays that TL signal has a good linearity with doses range of 1 Gy up to 5 Gy with the coefficient of determination ( $R^2$ ) approximately to 0.98 of all specific energies. This result is in support of recent proton studied by Hassan et al. (2017) showing the same linearity pattern for 2.3% mol Ge-doped concentration for proton beam measurement.

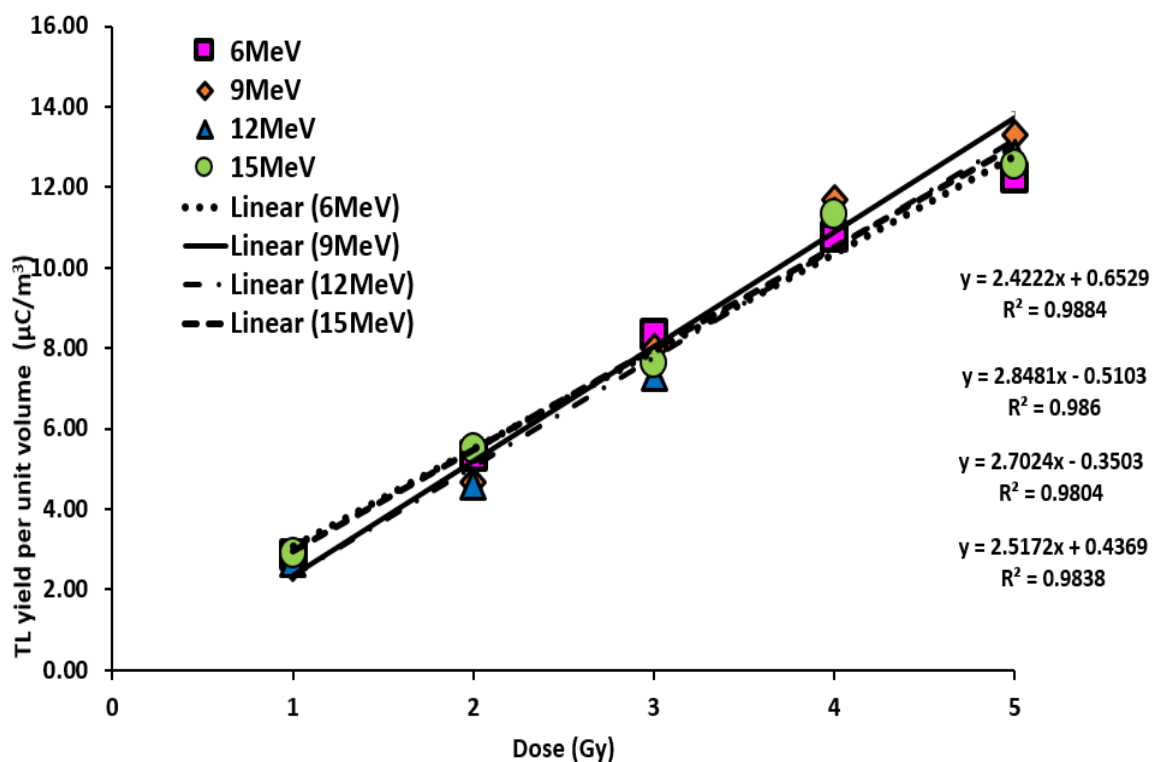


FIGURE 1. Linearity of the TL response of the fabricated 2.3% mol cylindrical Ge-doped optical fibres for doses ranging from 1 Gy to 5 Gy for megavoltage electron energies

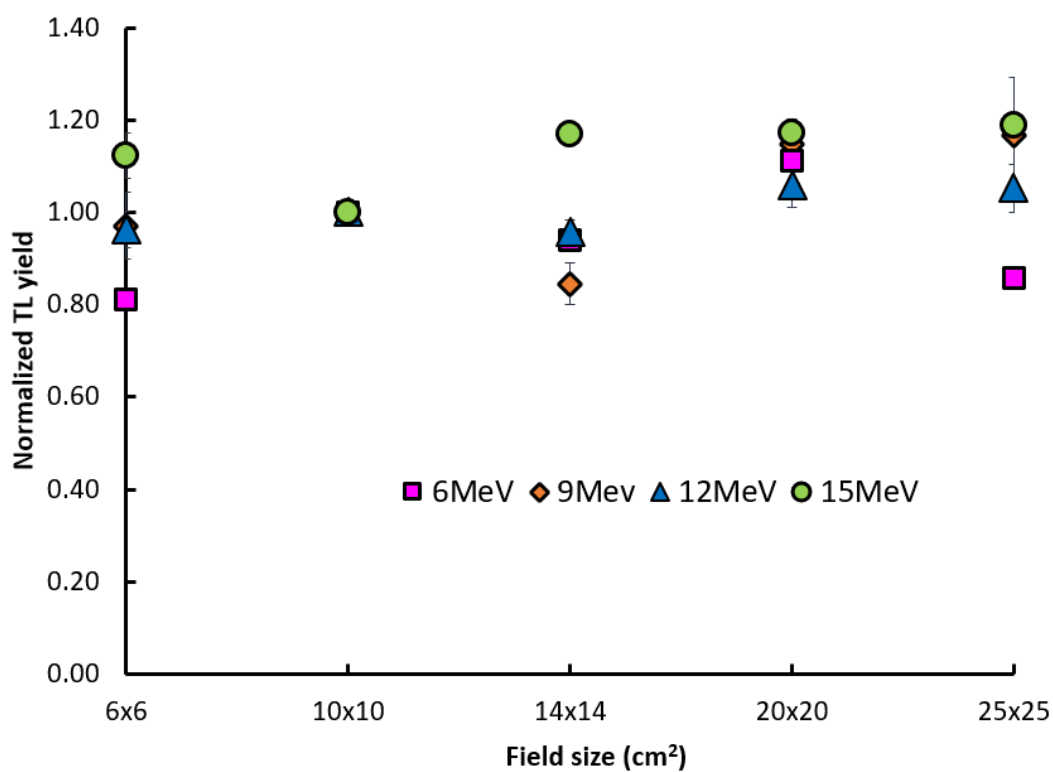


FIGURE 2. Field size dependency for 6, 9, 12, and 15 MeV electron beam energies

#### REPRODUCIBILITY

The reproducibility characteristic of the fabricated Ge-doped cylindrical optical fibres falls between 0.80 and 9.65%. This satisfactory result indicates precisely that the fabricated Ge-doped cylindrical optical fibres comprise a reusable dosimetric material.

#### MINIMUM DETECTABLE DOSE (MDD)

The MDD represents the measurement of the low dose that can be detected (Hashim et al. 2015). The MDD for 6, 9, 12, and 15 MeV are 4.13, 3.51, 3.7, and 3.97 mGy, respectively.

#### FIELD SIZE DEPENDENCE

Figure 2 shows the TL signal as a function of field sizes

for different energies (6, 9, 12, and 15 MeV). The results extracted from One-Way ANOVA analysis, showing there was no significant difference of TL signal between different electron energies nor between the TL signals of different field size at  $p > 0.05$ .

#### TL SIGNAL FADING

Figure 3 displays the TL signal for fabricated Ge-doped cylindrical optical fibres that was normalized to day five of post-irradiation. The minimum signal fading of the fabricated Ge-doped cylindrical optical fibres as notable at day 74 was reliably found to be approximately 9% at energy of 9 MeV.

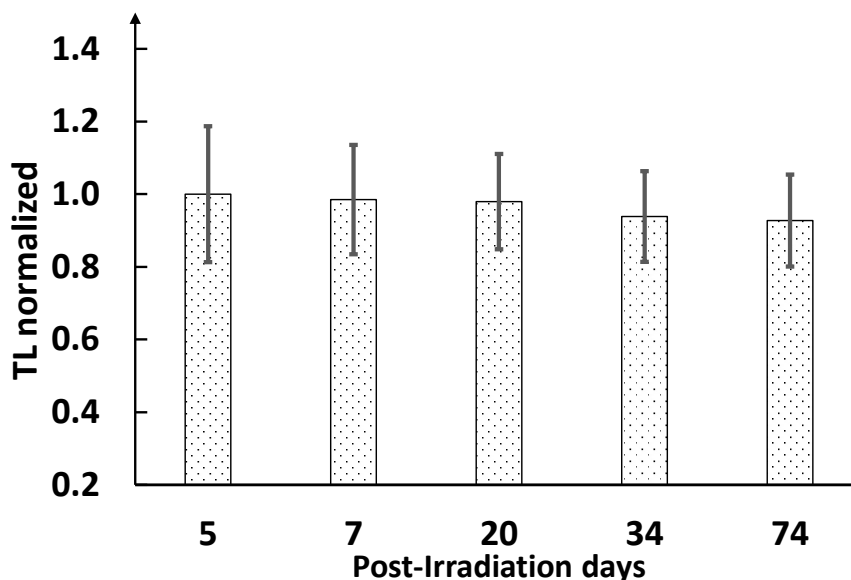


FIGURE 3. TL normalized versus post-irradiation days for 9 MeV electron beam

#### CONCLUSION

Present work has pursued to establish the key characteristics of fabricated 2.3% mol Ge-doped cylindrical optical fibres. The results have shown that new fabricated 2.3% mol Ge-doped cylindrical fibres offer a suitable potential as a new dosimeter for electron beams dosimetry. Forthcoming work is intended to analyse the glow curves behaviour of this fibre.

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