ENERGY DEPENDENT OF OSLDs COMPARED WITH TLD IN LOW AND HIGH ENERGY PHOTON BEAMS

By

MUHAMMAD HADZMI BIN YAHYA

issertation submitted in partial fulfillment of the requirement for the degree of Bachelor in

Health Sciences

(Medical Radiation)

JUNE 2016

CERTIFICATE

This is to certify that dissertation entitled

"ENERGY DEPENDENT OF OSLDs COMPARED WITH TLD IN LOW AND HIGH ENERGY PHOTON BEAMS"

is the bona fide record of research done by

MUHAMMAD HADZMI BIN YAHYA during the period

from February 2016 to June 2016 under supervision.

Supervisor

____

En. Mohd Fahmi Bin Mohd Yusof
Senior Lecturer,
School of Health Science
University Sains Malaysia
16150 Kubang Kerian,
Kelantan, Malaysia.

Date:

Co-Supervisor

____

Ahmad Bazlie Bin Abdul Kadir,
Penyelia Dosimetri Peribadi,
Makmal Standard Dosimetri Sekunder (SSDL),
Bahagian Keselamatan Dan Kesihatan Sinaran (BKS),
Agensi Nuklear Malaysia.

Date:

Co-Supervisor

____

En. Reduan bin Abdullah
Science Officer,
School of Health Science
University Sains Malaysia
16150 Kubang Kerian,
Kelantan, Malaysia.

Date:

Co-Supervisor

____

En. Syazwan bin Rosnan
Radiographer,
School of Health Science
University Sains Malaysia
16150 Kubang Kerian,
Kelantan, Malaysia.

Date:

DECLERATION

I hereby declare that this dissertation is the result of my own investigations, except where otherwise stated and duly acknowledged. I also declare that it has not been previously or concurrently submitted as a whole for any other degrees at Universiti Sains Malaysia or other institutions. I grant Universiti Sains Malaysia the right to use the dissertation for teaching, research and promotional purposes.

....

"MUHAMMAD HADZMI BIN YAHYA"

Date: ....

ACKNOWLEDGEMENT

In the name of Allah S.W.T, the Most Gracious and the Most Merciful. All praises to Him for His blessing and giving me an opportunity to complete my undergraduate research study about energy dependent of optically simulated limunescence dosimeter (OSLDS) compared with thermoluminescence dosimeter (TLD) at various energy and energy photon calibrated with Cs-137.

I would like to express the deepest appreciation to Prof. Ahmad Zakaria, dean school of health science, Universiti Sains Malaysia for encouragement to finish this study. I gratefully acknowledge and thank to my research supervisor, Mr. Mohd Fahmi bin Mohd yusof for guided me to finish this research project. Without his guidance and persistent help this dissertation would not have been possible. I like to wish my special thank to En.Ahmad Bazlie Bin Abdul Kadir for helping me in my data collection OSL dosimeters and give advices for my wring about this dosimeters.

Thank you to Mr.Reduan bin Abdullah and Mr.Syazwan bin Rosnan for helping me in collection data and research setup at high photon energy at radiotherapy department and radiology department, HUSM. I also would like to say thank you to Mr.Abdullah Waidi bin Idris dan Mr. Ahmad Zaky for helping me in writing my thesis.

For my friends, I would like to say thank you to accompany me doing writing thesis. Last but not least, I would like to thank my parent for giving me moral support and motivation to finish this research study.

TABLE OF CONTENTS

Contents

DECLERATION iv
ACKNOWLEDGEMENT v
TABLE OF CONTENTS vi
LIST OF TABLE vii
LIST OF FIGURE viii
LIST OF SYMBOLS AND ABBREVIATIONS x
ABSTRACT xii
ABSTRAK xiii
CHAPTER 1 1
1.0 INTRODUCTION 1
1.1 Background of the study 1
1.2 Objective of the Study 4
CHAPTER 2 6
2.0 LITERATURE REVIEW 6
CHAPTER 3 9
3.0 MATERIALS AND METHOD 9
3.1 MATERIALS 9
3.2 METHODS 21
CHAPTER 4 31
4.0 RESULT 31
CHAPTER 5 39
5.0 DISCUSSION 39
CHAPTER 6 43
6.0 CONCLUSION 43
REFERENCE 45
APPENDICES 47

LIST OF TABLE

Table 4.1: Half value layer (HVL) and Effective energy for Diagnostic X-ray by using plotted graph of HVL (ρAl = 2.804) ... 31

Table 4.2: Absorbed dose of parallel ionization chamber for X-ray by using Shadow Free Diagnostic Chamber (SFD chamber) (Nk value = 3.688 x 105 Gy/c). ... 31

Table 4.3: The average absorbed dose of TLD100 and OSLDs using Ionization Chamber as reference value ... 32

Table 4.4: Absorbed dose of TLD100 at 40 kVp, 81 kVp and 125 kVp X-ray energies ... 34

Table 4.5: Absorbed dose of OSLDs at 40 kVp , 81 kVp and 125 kVp X ray energies. ... 34

Table 4.6: The comparison value of error between TLD100 and OSLDs ... 35

Table 4.7: Comparison Chi square, X2 values of ionization chamber to TLD100 and OSLDs at 40, 81 and 125 kVp. ... 35

Table4.8: Average absorbed dose of 6 and 10 MV photon using OSLDs and TLDS100 ... 36

Table 4.9: Absorbed dose for TLD100 at 6 MV and 10 MV high energy photon. ... 37

Table 4.10: Absorbed dose, OSLDs after at 6 MV and 10 MV high energy photon. ... 37

Table 4.11: Error value, σ of TLD100 and OSLDs readings at 6 MV and 10 MV. ... 38

Table 4.12 Chi square, X2 of OSLDs and TLD100 to ionization chamber for 6 MV and 10 MV. ... 38

LIST OF FIGURE

Figure 1.1: The process of energy absorption, trapped electron and recombination hole pair during irradiation of OSL dosimeter. 2

Figure 1.2: The process of energy absorption, trapped electron and recombination hole pair during irradiation of OSL dosimeter. 3

Figure 3.1 OSLDs chips type nanodot.... 9

Figure 3.2 Li:Mg,Ti TLD100 chips with its capsules 10

Figure 3.3 Solid water phantom 30 cm x 30 cm.... 11

Figure 3.4 Bolus.... 12

Figure 3.5 TLD oven model PTW TLDO 1400 with TLD plate.... 13

Figure 3.6 Mobile OSLDs reader with computer control.... 14

Figure 3.7 Harshaw 3500 TLD reader.... 15

Figure 3.8 Shadow Free Diagnostic ionization chamber.... 16

Figure 3.9 Farmer chamber type 30013.... 17

Figure 3.10 UNIDOSE-E Universal Electrometer 18

Figure 3.11 Siemens Primus Linear Accelerator (LINAC) 19

Figure 3.12 Philips Optimum 80 General X-ray Machine 20

Figure 3.13 Set up for HVL measurement at diagnostic X-ray.... 22

Figure 3.14(a) TLD100 chips set up for irradiation at low energy X-ray 25

Figure 3.14(b) OSLDs chips set up for irradiation at low energy X-ray.... 25

Figure 3.14(a) TLD-100 chips set up for 6MV of photon energy 26

Figure 3.14(b) OSLDs chips set up for 6MV of photon energy.... 27

Figure 4.1 The comparison between TLD 100 and OSLDs to ionization chamber. 33

Figure 4.2 Average absorbed dose were measured by TLD 100 and OSLDs after exposed 36

LIST OF SYMBOLS AND ABBREVIATIONS

SYMBOLS/ ABBREVIATIONS	DEFINITION
%	Percentage
μ	micro
AAPM	American Association of Physicist in Medicine
AEC	Automatic Exposure
Al	Aluminium
Al_2O_3:C	aluminium oxide powder doped with carbon
C_f	Calibration factor
cm	centimeter
g/cm^3	Gram per centimeter cube
Gy	Gray
HUSM	Hospital Universiti Sains MAlaysian
HVL	Half Value Layer
Hz	Hertz
IC	Ionization chamber
kV	Kilovoltage
kVp	Peak kilovotage
mAs	mili ampere second
MeV	Mega electron Voltage
mGy	miliGray
Min^{-1}	Per minutes
MV	Megavoltage
nC	nanoCoulomb
Nk	Calibration factor for IC
nm	nanometer

OSLDs	Optically Stimulated Luminescence Dosimeter
PMT	photomultiplier tube
PTW	Physikalisch-Technische Werkstätten
RL	Radioluminescence
SD	Standard deviation
SFD	Shadow Free Dosimeter
SSD	Source to surface distance
TLD	Themoluminescent dosimeter
V	Voltage
W	Watt
X^2	Chi square value
ρ	densitiy
σ	Error

ABSTRACT

The aim of this study to investigate energy dependent of OSLDs and TLD100 at low energy and high energy photon beam. All dosimeters were calibrated using Cs-137 at Secondary Standard Dosimetry Laboratory (SSDL) at Malaysia Nuclear Agency. TLD100 and OSLDs dosimeter were irradiated using Philips Optimum 80 General X-ray machine with different energy of 40 kVp, 81 kVp and 125 kVp respectively. For high energy measurement, both dosimeters were placed in water phantom at d_{max} then were irradiated under high energy photon using 6 MV and 10 MV which were generated by Siemens Primus Linear Accelerator (LINAC). Both dosimeters showed energy dependent. The OSL dosimeters give reliable of result percentage different compare to TLD100 at high energy. The percentage different of OSLDs was less than 10% compared to TLD100 less than 19%. Chi square, X^2 values OSLDs to theoretical in low photon energy were 83.16, 125.03 and 156.16 compare X^2 values for TLD100 were 10.89, 4.13 and 8.69. In high energy photon, X^2 values for OSLDs 0.035 and 0.121 compare TLD100 were 1.989 and 3.845. For better result in dose measurement using TLD100 in high energy, we should calibrate it using high energy source such as Co-60.

ABSTRAK

Tujuan kajian ini untuk menyiasat tenaga bergantung oleh OSLDs dan TLD100 pada tenaga foton yang rendah dan tenaga foton yang tinggi. Semua dosimeter telah ditentukur bawah Cs-137 di Makmal Dosimeter Standard Kedua (SSDL) di Agensi Nuklear Malaysia. TLD100 dan OSLDs dosimeter telah diradiasikan dengan mesin Philips Optimum 80 Jeneral X-ray dengan tenaga yang berbeza masing-masing 40 kVp, 81 kVp dan 125 kVp. Untuk mengukur tenaga yang tinggi, kedua-dua dosimeter telah diletakkan di dalam fatom air pepejal di kedalaman maksima kemudian telah diradiasi bawah tenaga foton yang tinggi yang dihasilkan oleh Siemens Primus pemecut linear (LINAC). Bagi kedua-dua dosimeter telah menunjukkan bahawa ada tenaga bergantung. Dosimeter OSL memberi peratusan hasil berbeza yang dipercayai berbanding dengan TLD100 pada tenaga yang tinggi. Peratusan yang berbeza OSLDs adalah kurang daripada 10% berbanding dengan TLD100 kurang daripada 19%. Ujian ki-kuasa dua, nilai X^2 OSLDs kepada teori dalam tenaga foton yang rendah adalah 83,16, 125,03 dan 156,16 membandingkan nilai X^2 untuk TLD100 adalah 10.89, 4.13 dan 8.69. Dalam tenaga foton yang tinggi, nilai-nilai X^2 untuk OSLDs 0,035 dan 0,121 membandingkan TLD100 adalah 1,989 dan 3,845.. Untuk mendapatkan kesan yang lebih baik TLD100 pada tenaga yang tinggi, kita perlu kalibrasi dengan sumber tenaga yang tinggi seperti Co-60.

CHAPTER 1

1.0 INTRODUCTION

1.1 Background of the study

The use of has been increased and successfully replacing the (TLD) in application of personnel monitoring. Typical OSLDs are constructed using aluminium oxide powder doped with carbon Al_2O_3:C. The chip-shaped also known as nanodot has made OSLDs able to measure radiation doses from every direction. OSLDs provide fast reading dosimeter in comparison to other solid state dosimeters which is 13 seconds per OSL and 280 OSL in 1 hour. This device can be exposed and read repeatedly with good reproducibility rate of detection. OSLDs provided wide range of energy detection with 5 kV-10 MV photons and electron energy beyond 250 keV. OSLDs also give significantly good energy dependence of ± 10 % over diagnostic energy range 70 – 140 kVp , ± 5 % for photon and electron from 5 MeV – 20 MeV (Christopher et al ,2012) .

TLD and OSL dosimeter are handled and analyzed in which light is emitted from an irradiated insulator or semiconductor during exposure to a chosen light wavelength. Green light having wavelength of 532 nm is the specific insulator for OSL dosimeter. Irradiation on OSLDs ionizes of valence electron and electron-hole pair will be created with the valence electron trapped similarly to that in the TLDs as shown in Figure 1.1. The non-radiative transition allows the pre-existing defects within the material localization the free electron and holes pass through it. Subsequent illumination with light is used to free the trapped electron back to the valence band. Stored energy will be released in form of visible light formed by the recombination of the freed electrons with localized holes. This further result in radioactive emission and luminescence light equivalent to the amount of energy absorbed by the electron (Zeljka et al, 2013).

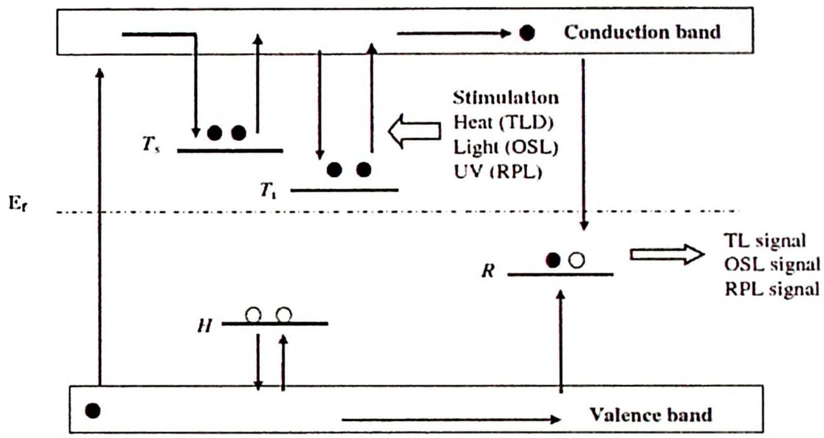

Figure 1.1: The process of energy absorption, trapped electron and recombination of electron-hole pair during irradiation of OSL dosimeter.

Dose of radiation measured by OSL dosimeter can be analysis by using microStar readers which are available in form of static and mobile unit. This portable reader was used in this study as it provides convenient and reliable analysis of the OSLDs. The reader only uses conventional electrical power source (110 – 240 V , a.5 amp , 50-60 Hz) made it very convenient to be used for small scale dosimetry works (Christopher et al, 2012).

During the analysis of the OSLDs, the element aluminium oxide, (Al_2O_3) in OSL dosimeter will be stimulated by light with 532 nm wavelength (green light) . This causes the sensor in OSL dosimeter to produce two type light emission with different wavelength for analysis data collection of 532 nm (green light) and 420 nm (blue light)., Only the 420 nm (blue light) wavelength was required for radiation dose analysis detected by OSLDs (Christopher et al, 2012) .

Discrimination filter known as the optic filter will be used to filter the light during dose analysis. It is placed between aluminum oxide (Al_2O_3) sensor and photomultiplier tube (PMT) as shown in Figure 1.2. The optic filter will filter out the green light while allowing the blue light to pass through this filter. PMT will detect the blue light and it will amplify the signal. Photon number produce in this process will calculate as radiation dose. Absorbed by the OSLD material (Christopher et al, 2012).

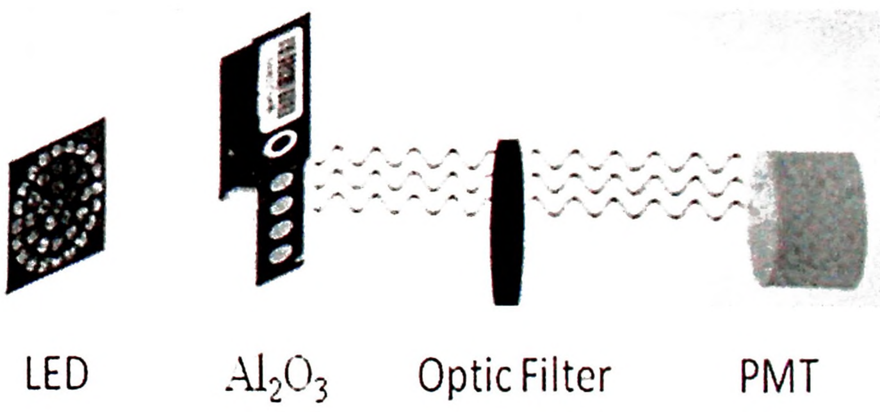

Figure1.2: The process of energy absorption, trapped electron and recombination of electron-hole pair during irradiation of OSL dosimeter.

1.2 Objective of the Study

1.2.1 Aim of thE Study

To study the response of OSLDs and TLD100 at low energy and high energy photon.

1.2.2 Objective

The objectives of this study are:

- To measure dose using OSLDs and TLD100 and compare with IC at low energy photon and high energy photon.
- To determine energy dependent of OSLDs and TLD100 at low and high energy photon.
- To investigate characteristic OSLDs and TLD100 in term of percentage error.

1.2.3 Research Question

1. What absorbed dose value of both dosimeter compare to IC at low energy photon and high energy photon?
2. How much energy dependent of both dosimeter at low energy and high energy photon?
3. How much value of percentage error for both dosimeter according Chi square?

1.2.4 Significant Study

Personal dosimeter is importance for radiation worker which is to measure radiation receive to our body. From this study, we conclude that both dosimeters which are calibration using Cs-137 source are not suitable for measuring absorbed dose at low energy photon. This is because absorbed dose given by this dosimeters have 20% of percentage error value. This cause our personal dosimeter give lower absorbed dose reading compare true reading. We suggest that TLD100 and OSLDs should calibrate using higher energy such Co-60.

CHAPTER 2

2.0 LITERATURE REVIEW

In 2013, Dunn *et al*, was conducted a study about Commissioning of optically stimulated luminescence dosimeters (OSLDs) for use in radiotherapy. This study was to replacement Thermoluminescence dosimeter (TLD) by OSLDs for used in the Australian Clinical Dosimetry Service. The dependent energy experiment was used OSDs nanodot, Linear accelerator type Elekta Synergy, and solid water phantom. This solid water phantom was used to build-up and back scatter for all irradiation. The energy dependent of OSL dosimeter in this study was measured for 6, 10 and 18 MV photons and 6, 8, 12, 15 and 18 MeV electrons. Elekta Synergy II linear accelerator was used to irradiate OSL nanodot with 1 Gy at reference depth, SSD in solid water and 10 cm x 10 cm field size for all exposures. Each exposure was repeated three – four times with separate dosimeter used for each instance. This measurement was repeated on separate day giving a total 6.8 OSLDs per energy.

Result from this study was shown that OSL dosimeters response a low energy dependence on high photon energy. The largest variation from dosimeter response to 6 MV photon and electron was 1.2 ± 1.1 % and 1.6 ± 1.6 %.

In a study was reported in 2009 by Reft, was conducted a study about the energy dependence and dose response of a commercial optically stimulated luminescent detector for kilovoltage photon, megavoltage photon, and electron, proton, and carbon beam. They were studies about dosimeters response to measure energy for absorbed dose. The method was the average of four consecutive detectors reading for each measurement in this study. All the dosimeter in this study were read out prior to and after irradiated and the difference were recorded. The relative sensitivity factors for each dosimeter was obtain to improve the measurement statistics. The dosimeters were irradiated with 0.5 Gy and they were optically bleached by illumination with a 22 W fluorescent lamp for approximately 24 h to remove the radiation effect of O.5 Gy dose. This procedure was repeated three times or more to get average sensitivity factor. Standard deviation for each dosimeters were calculated and that varied by less than 1 % at 1 SD. Dosimeter were irradiated on the surface of a solid water (RM1 451) phantom for kilovotage energy from 125 to 250 kVp using Philips RT-250. However, dosimeters were irradiated in both solid water phantom and water phantom using Varian CT 2100 for megavoltage photon and electron. The 6 MV and 18 MV were used at high photon and 6-20 MeV for electron energy. TG 61 AAPM protocol was used to calibrate output kilovotage energy and TG 51 AAPM protocol for megavoltage energy with Extradin A 12 ionization chamber which was calibrated chamber.

Result form study was concluded that output uncertainty for kilovoltage was 4.7 % and 2.5 % for megavoltage in OSL sensitivity 1 %. The increased respond for OSL dosimeters at low energy (X-ray) was attributed to increased photoelectric effect in the aluminium oxide which was 11.2. In megavoltage photon and electron, there was 4% different in dosimeter response for 6 MV and 18 MV. This different could be percentage different in phantom material used during irradiation.

Real-time optical-fibre luminescence dosimetry for radiotherapy: physical characteristics and applications in photon beams was determined by the method of Aznar *et al.* (2004). This previous study conducted a research study about dosimetry in vivo of radiation therapy. Method for reproducibility test was used in clinical photon beams of 6 MV and 18 MV in a water tank positioned at SSD 100 cm. 1 Gy delivered at 3 Gy min^{-1}, 10 cm x 10 cm field size and detector positioned at depth dose maximum. Both value of absorbed dose for OSLDs were determined by OSLDs dosimeter which were repeated 10 times in 6 MV and repeated 8 times for 18 MV. Result was showing that reproducibility signal OSLDs was 0.1% at 1 Standard Deviation. OSLDs was delivered 2 Gy absorbed dose by Elekta SLi Plus accelerator at a depth 10 cm in water, using 6 MV and 18 MV photon beam. The absorbed dose was determined using ionization chamber at Swedish secondary standard dosimetry laboratory. The reading of absorbed dose of dosimetry were normalized to the average radioluminescence (RL) or optically stimulated luminescence (OSL) signal, respectively for all measurement. The result of variation in outpun from this study of detector was 0.6% at 1 standard deviation for both RL and OSL dosimeters.

CHAPTER 3

3.0 MATERIALS AND METHOD

3.1 MATERIALS

3.1.1 Optically Stimulated Luminescence Dosimeter (OSLDs)

Optically Stimulated Luminescence Dosimeter (OSLDs) is constructed by doping carbon into aluminium oxide powder giving a formulation of $Al_2O_3:C$. This dosimeter provided fast dosimetry analysis as it can give reading in 13 seconds for each chip and 280 chips in 1 hour. OSLDs can also be read repeatedly with good reproducibility. Energy range can be detected by OSLDs chip was 5 kV – 10 MV photon and more than 250 keV (Christopher et al, 2012). Figure 3.1 shows a typical OSLDs chips type nanodot used for dosimetry.

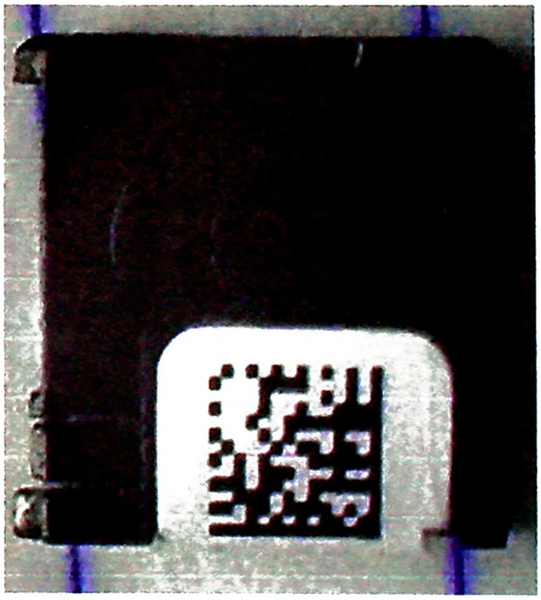

Figure 3.1 OSLDs chips type nanodot.

3.1.2 Themoluminescent dosimeter chips (TLD100)

Harshaw chemical company has developed a dosimeter called Themoluminescent dosimeter chips (TLD100). This dosimeter is made of Li:Mg,Ti which comprises of 180 ppm of Mg and 10 ppm of Ti to create crystal. Dimension of TLD chips was about 3.0 x 3.0 x 1.0 mm^3 (Tobergte & Curtis, 2013). 10 chips of TLD 100 were sent to Secondary Standard Dosimetry laboratory (SSDL) at Malaysian Nuclear Agency for calibration using 1mGy of Cs-137. Figure 3.2 shows a typical TLD100 chips used for dosimetry.

Figure 3.2: Li:Mg,Ti TLD100 chips with its capsules

3.1.3 Solid water phantom

A solid water phantom is a epoxy material with density 1.02 gg/cc and thickness tolerance ± 0.01 cm which was close to density value of water. This solid water phantom is used to calibrate photon and electron beam within o.5 % of true water dose with cost effectively and easy to move. This study used solid water phantom with dimension of 30 cm x 30 cm with thickness 5.0 cm, 3.0 cm and 1.0 cm. These solid water phantoms of 15 cm thickness were used to prevent backscatter reading (Fluke Biomedical,2016). Figure 3.3 shows a typical solid water phantom used for dosimetry in radiotherapy.

Figure 3.3: Solid water phantom 30 cm x 30 cm

3.1.4 Bolus

Bolus is made up with density 1.03 g/cm^3 which was solid, homogenous, tissue-equivalent gel. Bolus was available in shape and layered to obtain the desired effect. Bolus was used for high energy more than 1 MV which was additional tissue equivalent thickness was needed. For this research study, 0.5 cm and 1.0 cm of thickness bolus was used at the surface with combination of solid water phantom as shows in figure 3.4.

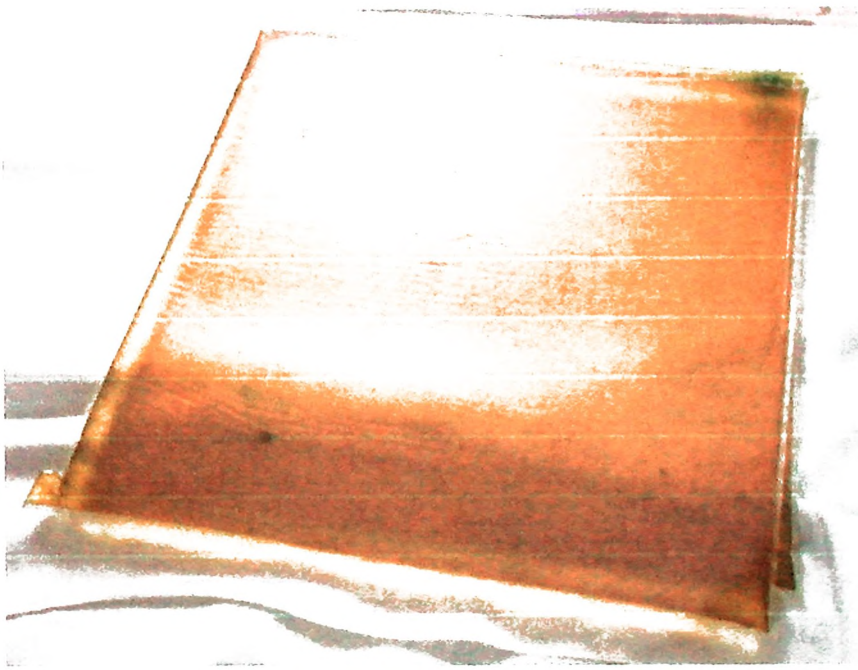

Figure 3.4: Bolus

3.1.5 TLD Oven and TLD plate

TLD oven was used in medical radiation lab for annealing TLD100 PTW TLDO 1400 manufactured by Physikalisch-Technische Werkstätten (PTW) in Germany. The annealing procedure for TLD 100 used two different temperature conditions which were 400 °C for 1 hour and 100°C for 2 hours. TLD 100 was placed onto TLD plate with specific arrangement according ID number (Tobergte & Curtis, 2013). Figure 3.5 shows a typical TLD oven and TLD plate used for this study.

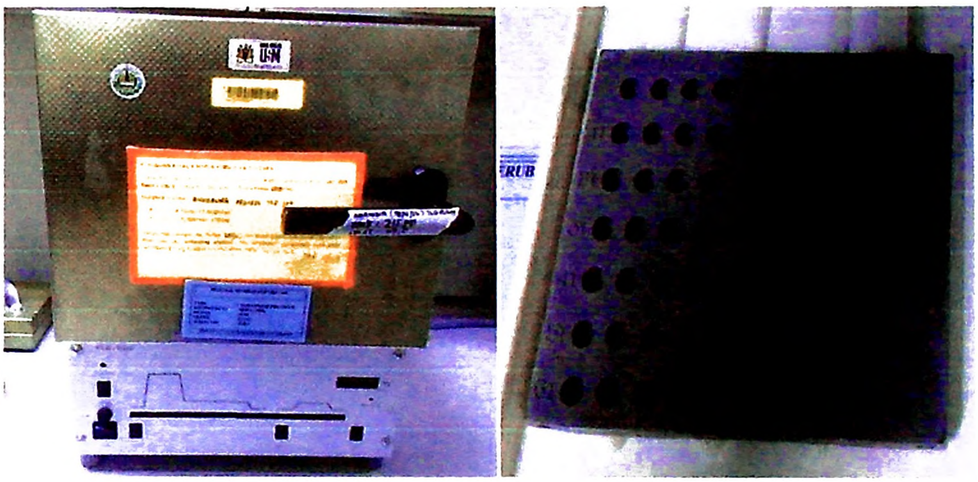

Figure 3.5: TLD oven model PTW TLDO 1400 with TLD plate

3.1.6 MicroStar reader

MicroStar reader is a mobile unit to measure dose radiation by OSL dosimeter type of nanodot. This reader used conventional electrical power source (110-240 V, 5 A, 50-60 Hz). The specification of electrical power gave benefit to small scale dosimetry works (Christopher, 2012). Figure 3.6 shows the mobile unit reader of OSL dosimeter reader used in the study.

Figure 3.6: Mobile OSLDs reader with computer control

3.1.7 TLD reader

Harshaw 3500 TLD reader is a device or machine to measure radiation absorbed dose by each TLD 100. A few special features were designed to provide cost effective measurement individual TLD chips. TLD reader provided sample drawer for single TLD chips. 600°C for maximum heating temperature capability during analyzed dosimeter, personal computer, dosimeter storage tray and PMT noise and reference light quality control check. Nitrogen gas was used for cooling annealing tray of TLD reader. TLD reader model Harshaw 3500 can measure radiation for photon with energy more than 5 keV and Electron energy more than 70 keV. It can measure in the range 1 μGy – 1 Gy in linear and 1 Gy – 20 Gy for supralinear (Thermo Scientific, 2007). Figure 3.7 shows a typical TLD reader used for measurement in this study.

Figure 3.7: Harshaw 3500 TLD reader

3.1.8 Shadow Free Diagnostic Chamber (SFD Chamber)

SFD Chamber is manufactured by Physikalisch-Technische Werkstätten (PTW) Freiburg in Germany. This parallel ionization chamber is 75 cm ^{3} sensitive volume for absolute dosimeter. This chamber does not significantly influence automatic exposure control (AEC). Air kerma rate and exposure rate were quantities using this chamber. Ion collection time for SFD ionization chamber type 34060 was 2 ms at 100 V chamber voltages (PTW, 2013). Figure 3.8 shows a typical SFD chamber used for dosimetry radiology and this study.

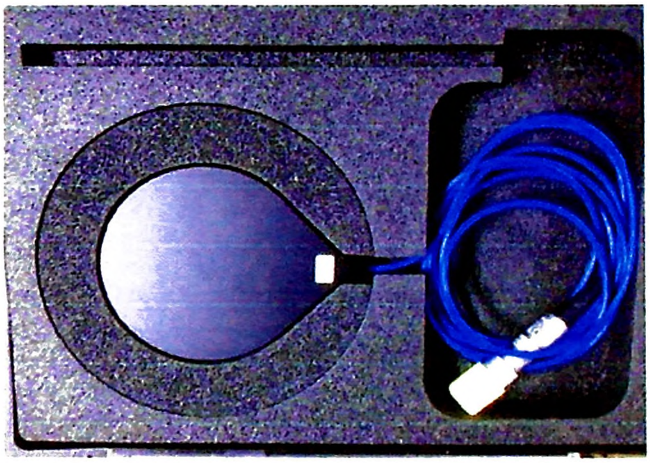

Figure 3.8 Shadow Free Diagnostic ionization chamber

3.1.9 PTW Farmer chamber type 30013

In this study, PTW farmer chamber type 30013 was used for this study at high energy photon 6 MV and 10 MV. The 0.6 cm^3 PTW farmer chamber type 30013 was a waterproof standard chamber for photon and electron dosimetry which was used in water or solid-state material. Energy range for photon was 30 kV to 50 MV and energy range for electron was 10 MeV to 45 MeV. This farmer chamber is made of aluminium element which is rugged construction with the wall material used graphite element with a protective acrylic cover (PTW, 2016). Figure 3.9 shows a typical farmer chamber used for this study in high photon energy.

Figure 3.9: Farmer chamber type 30013

3.1.10 UNIDOSE-E Universal Electrometer

Electrometer used in this study was UNIDOSE-E Universal Electrometer manufactured by Physikalisch-Technische Werkstätten (PTW) Freiburg in Germany. This electrometer was high–precision, field-class electrometer and suited for used in radiotherapy measurement and diagnostic radiology measurement. UNIDOSE-E electrometer was easily used by connecting to chamber especially in ionization chamber for this research study (PTW, 2016). Dose of radiation will be displayed in nanoCoulomb unit (nC) for radiotherapy and diagnostic radiology. This charge value will be converted into absorbed dose later in unit Gray (Gy). Figure 3.10 shows a typical charge electrometer used for this study .

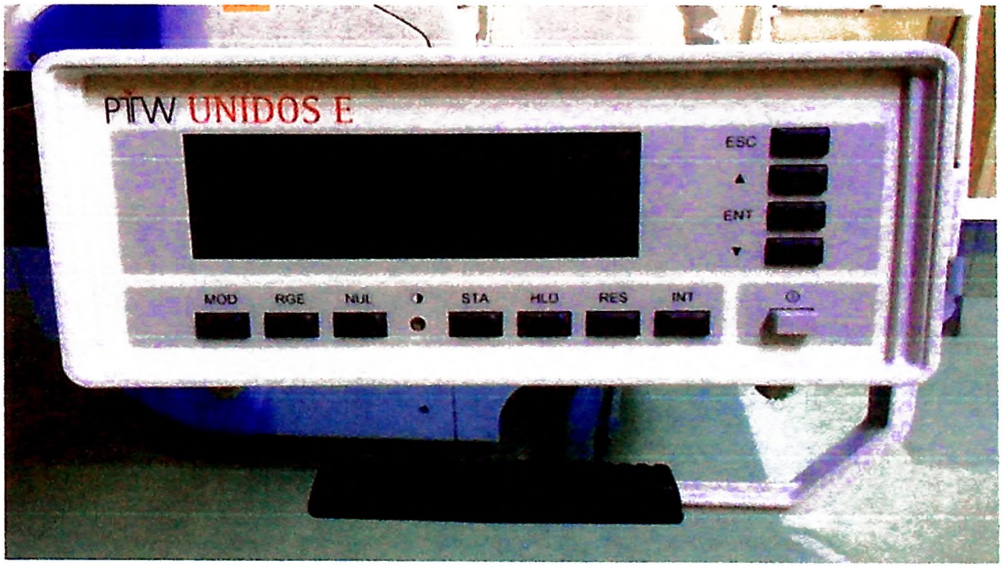

Figure 3.10: UNIDOSE-E Universal Electrometer

3.1.11 Siemens Primus Linear Accelerator (LINAC)

Linear accelerator machine is commonly used to treat patient with cancer using external beam radiation. In radiotherapy department of HUSM, linear accelerator machine is a machine model Siemens Primus Linear Accelerator. The high photon beam energy used in this research study were 6 MV and 10 MV photon beam. A Siemens Primus Linear Accelerator consists of Primus unit with tube, collimator, hand remote control and treatment couch as a complete unit to treat patient during treatment. Figure 3.11 shows a typical linear accelerator machine used for this dosimetry and radiotherapy treatment.

Figure 3.11: Siemens Primus Linear Accelerator (LINAC)

3.1.12 Philips Optimum 80 General X-ray Machine

X-ray machine used for this research study was Philips Optimum 80 which was used for daily X-ray radiography imaging in HUSM. This X-ray machine comprises of X-ray tube, table X-ray for patient set up, bucky for cassette, cassette image radiographic and control panel. This study used three exposure which were 40 kVp , 81 kVp and 125 kVp . Figure 3.12 shows a general X-ray machine used for exposure TLD100 and OSLDs.

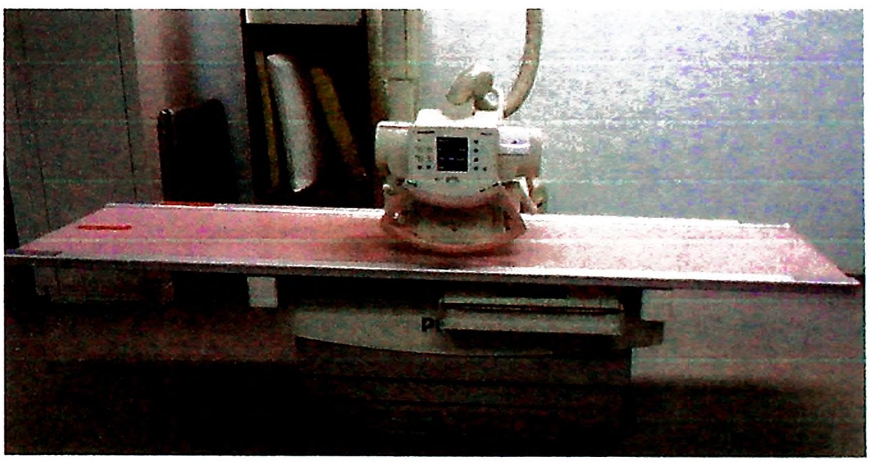

Figure 3.12: Philips Optimum 80 General X-ray Machine

3.2 METHODS

3.2.1 Measurement of Half Value Layer for Diagnostic X-ray beam

The HVL of diagnostic X-ray was determined using aluminium sheets with thickness 1.0 mm, 0.5 mm and 0.1 mm. This HVL measurement was done for 40 kVp, 81 kVp and 125 kVp with 12.5 mAs . Parallel ionization chamber was connected to PTW UNIDOSE-E electrometer to collect the charge value during radiation diagnostic X-ray. Distance X-ray tube to ionization chamber surface was 100 cm with 10 cm x 10 cm field size of X-ray beam. Firstly, exposure was done without aluminium sheet and repeated reading for three times. Then 0.5 mm aluminium sheet was placed under collimator X-ray tube with microfoam tape and charge value was recorded by ionization chamber. 0.5 mm aluminium thickness was added step by step until the electrometer reading one half of exposure without filter. Total aluminium filters were removed from X-ray tube and made final exposure without filter. The different value of final reading after removed aluminium filter compare initial reading before used aluminium filter must be less than 2 %. Graph of actual reading versus aluminium sheet thickness was plotted to get value HVL at 0.5 nC actual reading. Linear attenuation coefficient, μ values were measured using ln2 divided HVL value (ln2/HVL). Linear attenuation coefficient, μ values were divided by density of aluminium filter (2.804 g/cm^3) to get effective energy. The effective energy was calculated using the table of X-ray form factor, attenuation, and scattering tables . Figure 3.13 was shown a set up for HVL measurement at diagnostic X-ray machine.

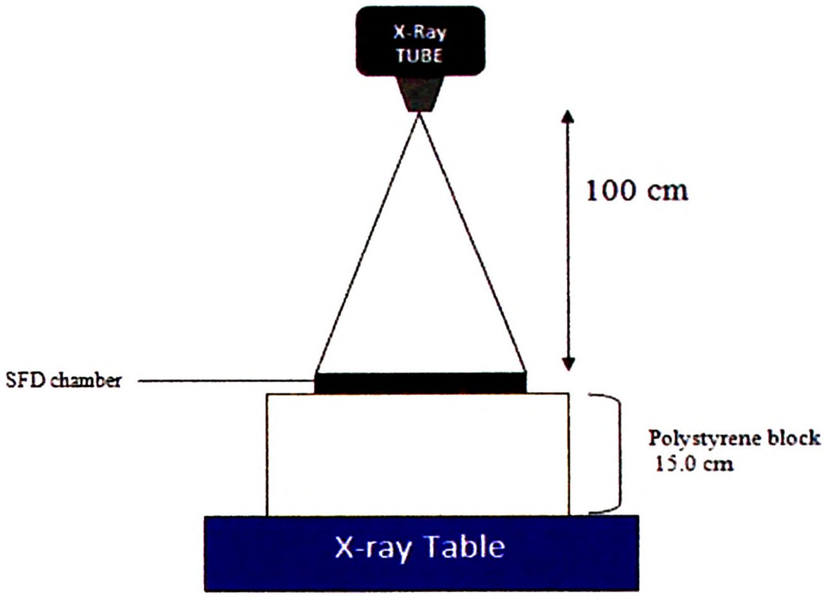

Figure 3.13: Set up for HVL measurement at diagnostic X-ray

3.2.2 Annealing TLD100 and OSLDs

Annealing procedure of LiF:Mg,Ti Themoluminescent dosimeter chips (TLD100) were done followed previous report using TLD annealing oven . TLD100 were annealed at the Medical Radiation Laboratory at Themoluminescent dosimeter room. Anneal TLD100 chips were done in two conditions which were anneal in two different degree of temperature 400°C in 1 hour then cooling down 30 minutes followed by second condition temperature which was 100°C in 2 hours . Last step in annealing procedure for TLD100 chips are cooling in room temperature for 1 hour minimum before exposed to next irradiation procedure (Jursinic, 2017). Optically Stimulated Luminescence Dosimeter (OSLDs) was a single crystal in a plastic holder, so it cannot be erase by high temperature. Annealing protocol for OSLDs was a simple way using optically illumination (bleaching) (Knežević , 2013).

3.2.3 Selection of TLD100

A group of LiF:Mg,Ti Themoluminescent dosimeter chips (TLD100) were selected to got high sensitivities dosimeters of TLD dosimeters. Selection of TLD 100 was followed protocol of Technical Report Series 457 (TRS 457) which was form International Atomic Energy Agency. Firstly, check physical damage of a group of TLD 100 and removed all damaged dosimeters. Mean value of background reading was measured from three background selected TLD100. Dosimeter were exposed using X-ray about 5 -10 mGy in free air geometry condition with capsulated in sachets. All dosimeters were read using TLD reader model Harshaw 3500 by WinREMS software. Mean values,M and standard deviation values,s(M_i) for background corrected reading were calculated using equation 3.1(mean value) and equation 3.2(standard deviation) in Technical Report Series 457 (TRS 457) for selection dosimeters . Lastly, TLD100 was selected according the interval (M - ± 3s (M_i)).

$$M = \frac{\sum_{i=1}^{n}(M_i - M_o)}{n} \quad (3.1)$$

$$s(M_i) = \frac{\sum_{i=1}^{n}(M_i - M_o)^2}{n-1} \quad (3.2)$$

3.2.4 TLD100 Calibration

10 chips of TLD100 were sent to Secondary Standard Dosimetry Laboratory (SSDL) at Malaysia Nuclear Agency for calibration procedure. I mGy of Cs-137 of gamma radiation was used to calibrate TLD100 for this study. This calibration protocol was done using air calibration follow International Atomic Energy Association (IAEA). TLD100 was exposed with 1 mGy of Cs-137 for 1.31 minutes at distance 1 meter form the source. TLD respond charge value was measured by TLD reader in unit nanoCoulomb (nC). This calibration factor (C_f) for each TLD was calculated using equation 3.3 in unit mGy/nC. This C_f value multiplied with each TLD reading after irradiated using diagnostic X-ray or radiotherapy to get absorbed dose in mGy.

3.2.5 Irradiation TLD100 and OSLDs at diagnostic X-ray

LiF:Mg,Ti Themoluminescent dosimeter (TLD100) and Optically Stimulated Luminescence Dosimeter (OSLDs) were irradiated using low energy photon beam of general X-ray in radiology department Hospital Universiti Sains Malaysia (HUSM). Both dosimeter chips were irradiated using three different exposure factors which were 40 kV & 12.5 mAs, 81 kV & 12.5 mAs and 125 kV &12.5 mAs. Both TLD100 and OSL dosimeter chips were placed on the surface of 15 cm thick polystyrene. They were exposed on polystyrene with standard field size set up 10 cm x 10 cm and the source to surface distance (SSD) of 100 cm to the polystyrene surface. The set up for both dosimeter chips were shown in figure 3.14(a) and figure 3.14(b)