

**THE PERFORMANCE CHARACTERISTIC OF A ROD WIRE
PARALLEL HOLE COLLIMATOR FOR GAMMA CAMERA**

LOOI HONG MING

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

**THE PERFORMANCE CHARACTERISTIC OF A ROD
WIRE PARALLEL HOLE COLLIMATOR FOR GAMMA
CAMERA**

LOOI HONG MING

**This report is submitted in partial fulfilment of the requirements
for the degree of Bachelor of Electronic Engineering with Honours**

**Faculty of Electronic and Computer Engineering
Universiti Teknikal Malaysia Melaka**

2019

BORANG PENGESAHAN STATUS LAPORAN
PROJEK SARJANA MUDA II

Tajuk Projek : THE PERFORMANCE CHARACTERISTIC OF A
ROD WIRE PARALLEL HOLE COLLIMATOR
FOR GAMMA CAMERA

Sesi Pengajian : 2018/2019

Saya LOOI HONG MING mengaku membenarkan laporan Projek Sarjana Muda ini disimpan di Perpustakaan dengan syarat-syarat kegunaan seperti berikut:

1. Laporan adalah hakmilik Universiti Teknikal Malaysia Melaka.
2. Perpustakaan dibenarkan membuat salinan untuk tujuan pengajian sahaja.
3. Perpustakaan dibenarkan membuat salinan laporan ini sebagai bahan pertukaran antara institusi pengajian tinggi.
4. Sila tandakan (✓):

SULIT*

(Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysia seperti yang termaktub di dalam AKTA RAHSIA RASMI 1972)

TERHAD*

(Mengandungi maklumat terhad yang telah ditentukan oleh organisasi/badan di mana penyelidikan dijalankan).

TIDAK TERHAD

Disahkan oleh:

(TANDATANGAN PENULIS)

(COP DAN TANDATANGAN PENYELIA)

Alamat Tetap: 45, Taman Mawar
Titi, 71650 Jelevu
Negeri Sembilan

Tarikh : 31 May 2019

Tarikh :

*CATATAN: Jika laporan ini SULIT atau TERHAD, sila lampirkan surat daripada pihak berkuasa/organisasi berkenaan dengan menyatakan sekali tempoh laporan ini perlu dikelaskan sebagai SULIT atau TERHAD.

DECLARATION

I declare that this report entitled “THE PERFORMANCE CHARACTERISTIC OF A ROD WIRE PARALLEL HOLE COLLIMATOR GAMMA CAMERA” is the result of my own work except for quotes as cited in the references.

Signature :

Author :

Date :

APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Bachelor of Electronic Engineering with Honours.

Signature :

Supervisor Name :

Date :

DEDICATION

I dedicate this to my parents for their loves and kindness, my friends for their care and help and my supervisor for her care and her help to me along the project is being done.

ABSTRACT

Gamma camera or gamma detector is a device to capture the image of gamma radiation emitting radioisotopes. The gamma camera is the imaging technique used to carry out functional scan of the organ in the patient's body such as brain, thyroid, lungs, liver and others to detect the abnormal cells like a tumour or cancer. It contains of four main part, which is collimator, scintillator, photomultiplier and computer. The collimator will be the target of this project where it acts as a filter of the gamma camera. The problem with the collimator is its weight and difficult to handle. In this project is to propose the design of the rod collimator made from a series of tungsten wire with lighter weight and have a comparable performance compare to the standard parallel hole collimator. Since gamma camera involves nuclear energy radiation, preliminary work on designing the component of the device must be using simulation tools rather than real experimentation as it is involving a nuclear radiation. A low energy general purpose rod collimator was designed and simulated using MCNP5 software. Hole size, septa thickness and collimator thickness are the parameters that are needed to consider for designing of the collimator. The simulation results was then processed by MATLAB software for the image processing step. In this project, a software called MCNP5 was used to construct the gamma camera and the rod wire collimator to run

the simulation using a low energy point source. The output PTRAC file was processed by the Matlab software to generate the image and improve the image quality. The results given by the rod wire collimator is surprisingly well in which its weight reduce by 72.9% from 42kg to 11.4kg with comparable performance in term of resolution. Since the weight is reduced with comparable resolution, this collimator can be applied in the portable gamma camera

ABSTRAK

Kamera gamma atau detektor gamma adalah peranti untuk menangkap imej sinaran gamma dari radioisotop. Kamera gamma adalah teknik pengimejan yang digunakan untuk mengendalikan imbasan fungsi organ di tubuh pesakit seperti otak, tiroid, paru-paru, hati dan lain-lain untuk mengesan sel yang tidak normal seperti tumor atau kanser. Ia mengandungi empat bahagian utama, iaitu kolimator, scintillator, photomultiplier dan komputer. Kolimator akan menjadi sasaran projek ini di mana ia berfungsi sebagai penapis kamera gamma. Masalah dengan kolimator adalah berat dan sukar untuk dikendalikan. Projek ini membina reka bentuk kolimator batang yang diperbuat daripada siri wayar tungsten yang lebih ringan dan mempunyai prestasi berbanding berbanding dengan kolimator standard. Oleh kerana kamera gamma melibatkan sinaran tenaga nuklear, kerja awal untuk merancang komponen peranti mesti menggunakan alat simulasi dan bukan percubaan sebenar kerana ia melibatkan radiasi nuklear. Kolimator batang tujuan umum yang rendah akan direkabentuk dan disimulasikan menggunakan perisian MCNP5. Saiz lubang, ketebalan septa dan ketebalan kolimator adalah parameter yang perlu dipertimbangkan untuk mereka bentuk kolimator. Hasil simulasi akan diproses oleh MATLAB untuk langkah pemrosesan imej. Dalam projek ini, satu perisian yang bernama MCNP5 telah diguna

untuk membina struktur gamma kamera dan kolimator untuk diuji dengan satu titik sumber yang mempunyai tenaga yang rendah. Hasil daripada ujian MCNP5 telah diproses oleh Matlab untuk menghasilkan gambar sumber tersebut and meningkatkan kualiti gambar. Hasil daripada reka bentuk kolimator telahpun mengurangkan berat sebanyak 72.9% iaitu dari 42kg kepada 11.4kg dengan prestasi yang standing dengan standard. Berat kolimator telahpun dikurangkan dengan prestasi yang setanding, oleh itu kolimator ini boleh digunakan dalam kamera gamma mudah alih.

ACKNOWLEDGEMENTS

I would like to express my special thanks of gratitude to my supervisor, Madam SITI AISAH BINTI MAT JUNOS@YUNUS who gave me the golden opportunity to do this wonderful project on the topic ‘The performance characteristic of a rod wire parallel hole collimator gamma camera’. Madam Aisah also helped me with some Research and I came to know about so many new things, that make me really thankful to them.

Secondly, I would also like to thank my parents and friends who helped me a by giving me a lot of courage and care during the whole project.

TABLE OF CONTENTS

Declaration	
Approval	
Dedication	
Abstract	i
Abstrak	iii
Acknowledgements	v
Table of Contents	vi
List of Figures	x
List of Tables	xiii
List of Symbols and Abbreviations	xiv
List of Appendices	xv
CHAPTER 1 INTRODUCTION	1
1.1 Project Overview	1
1.2 Problem Statement	2
1.3 Objective	3
1.4 Scope of Work	4

1.5	Organization of the thesis	5
CHAPTER 2 BACKGROUND STUDY		6
2.1	Overview	6
2.2	Introduction of medical imaging technique	7
2.2.1	Radiography (X-ray imaging)	7
2.2.1.1	Conventional Radiography	8
2.2.1.2	Computed or Digital Radiography	9
2.2.2	Computed Tomography (CT)	9
2.2.3	Ultrasound Imaging (US)	10
2.2.4	Scintigraphy (Nuclear Imaging)	10
2.3	Introduction to the gamma camera	11
2.3.1	Collimator	12
2.3.2	Detector	18
2.3.3	Photomultiplier Tubes (PMTs)	18
2.3.4	Computer	19
2.4	Design Concept and Parameters	19
2.4.1	Septal Thickness	20
2.4.2	Geometry of Collimator Holes	21
2.5	Previous Design Configuration of Parallel Hole Collimator	22
2.5.1	Wire Collimator	23

2.5.2	Variable Sensitivity and Resolution Collimator	24
2.6	Simulation Environment	26
2.6.1	Cell Cards	28
2.6.2	Surface Cards	29
2.6.3	Data Cards	31
2.7	Resolution and Sensitivity	31
2.8	Portable gamma camera application	35
	CHAPTER 3 METHODOLOGY	36
3.1	Overview	36
3.2	Methodology of The Research	37
3.2.1	Literature Study	38
3.2.2	Model Gamma Camera using MCNP5	39
3.2.3	Simulation Test	39
3.2.4	MATLAB Image Processing	40
3.2.5	Results Analysis	40
3.3	Design Configuration	40
3.4	Wire Collimator Design	44
3.5	MATLAB Image Processing	48
3.6	Point Spread Function (PSF)	50
3.7	Image Enhancement	51

CHAPTER 4 RESULTS AND DISCUSSION	52
4.1 Overview	52
4.2 MCNP result	53
4.3 Matlab result	55
4.3.1 Data Selection	55
4.3.2 Point Spread Function Implementation	57
4.3.3 Image filter	59
4.4 Calculation of the rod collimator weight	61
CHAPTER 5 CONCLUSION AND FUTURE WORKS	63
REFERENCES	65
APPENDICES	69
Appendices A: MCNP5 collimator design coding	69
Appendices B : Matlab main function	71
Appendices C: Matlab PTRAC filter	72
Appendices D: PSF implementation	75
Appendices E: Matlab Resolution	78
Appendices F: Image Enhancement	79

LIST OF FIGURES

Figure 2.1: Gamma Camera	12
Figure 2.2: Different types of collimator: (a) Parallel hole Collimator hole collimator (c) Converging Collimator (d) Diverging Collimator Collimator	(b) Slant (e) Pinhole 15
Figure 2.3: Gamma rays process without the collimator	16
Figure 2.4: Gamma rays process with the collimator	16
Figure 2.5: Close-up image of parallel hole collimator	17
Figure 2.6: Photomultiplier Tube's structure	18
Figure 2.7: Entrance and Exit walls design by Ogawa and Kato[9, 10]	23
Figure 2.8: a) Wire Mesh Collimator b) Wire Mesh Collimator with entrance and exit walls [9,10]	24
Figure 2.9: a) Schematic of the variable sensitivity and resolution collimator b) Top view of the variable sensitivity and resolution collimator c) Side view of the variable sensitivity and resolution collimator [13]	25
Figure 2.10: a) Alignment of the collimator in high resolution mode b) Top view of collimator in high resolution mode c) Side view of the collimator in high resolution mode	26
Figure 2.11: Input file format of MCNP	27
Figure 2.12: Format of defining cell cards	28
Figure 2.13: Format of the Surface Cards	29
Figure 2.14: The arrangement of the rods to form the collimator	30

Figure 2.15: Energy spectrum from PTRAC file	32
Figure 2.16: Point Source image from Chamberlain design	33
Figure 3.1: Flowchart of the research flow	37
Figure 3.2: Normal Rod Collimator design a) x-z direction b) y-z direction	41
Figure 3.3: Design of whole gamma camera system using MCNP	43
Figure 3.4: Flowchart of Gamma Camera design using MCNP5	44
Figure 3.5: Surface Card coding	45
Figure 3.6: Cell cards coding	46
Figure 3.7: Data Cards coding	47
Figure 3.8: Flowchart for generating image using Matlab	49
Figure 3.9: An example of the effect of fspecial function	51
Figure 4.1: The first part of the PTRAC file	53
Figure 4.2: The history of the photons	54
Figure 4.3: Final history of the simulation	54
Figure 4.4: Matlab codes to select the data	55
Figure 4.5: The output image and energy spectrum graph from the data selection	56
Figure 4.6: Matlab codes to implement the Point Spread Function	57
Figure 4.7: The image and energy graph after blurring	58
Figure 4.8: Result of original image resolution from Matlab	58
Figure 4.9: Matlab codes for fspecial	59
Figure 4.10: The output image after filter	59
Figure 4.11: Result of output image resolution from Matlab	60
Figure 4.12: The parameters of the rod collimator	61

LIST OF TABLES

Table 2.1: Radiographic densities with color	8
Table 2.2: Previous design for parallel collimator	22
Table 3.1: Parameters use in the project	41
Table 3.2: Simulations of components in the realistic gamma camera	42

LIST OF SYMBOLS AND ABBREVIATIONS

- LEGP : Low Energy General Purpose
- MCNP5 : Monte Carlo N-Particles version 5
- PSF : Point Spread Function

LIST OF APPENDICES

Appendix A: MCNP5 collimator design coding	69
.....	
Appendix B: Matlab main function	71
.....	
Appendix C: Matlab PTRAC filter	72
.....	
Appendix D: PSF implementation	75
.....	
Appendix E: Matlab Resolution	78
.....	
Appendix F: Image Enhancement	79
.....	

CHAPTER 1

INTRODUCTION

This chapter discusses about the project background, problem statement, objective and scope of work.

1.1 Project Overview

Gamma camera is a device that is able to image the gamma radiation that emitted by tracer introduced to patient's body. Gamma camera is applied in Scintigraphy technique among the medical imaging. In the gamma camera, the collimator will be the first component that is facing the patient's body to collect and filter the gamma

radiation[1–4]. The most common used collimator is called parallel hole collimator. However, there were still other types of collimator such as converging, diverging and pinhole collimators. Converging collimator which provided the best combination of image resolution and sensitivity in a specific distance range, but the distance of this collimator is limited to a certain distance. Then, diverging collimator offered a larger imaging area but in the exchange of resolution and sensitivity. Another type of collimator is pinhole collimators that gave a very good resolution and reasonable sensitivity to the user. The problem with this collimator is that it loses its sensitivity very fast with distance. Comparing with other collimators, parallel hole collimator had a better stability, the resolution and sensitivity are higher than diverging and pinhole collimators[3]. To design a parallel hole collimator, there are a few parameters need to consider such as hole diameter, septal thickness and collimator thickness. Different combination of parameters results in different models of collimator such as low energy high resolution (LEHR) collimator and low energy general purpose (LEGP) collimator. In this project, the design will be a focus on low energy general purpose collimator.

1.2 Problem Statement

The collimator is one of the parts of the gamma camera that is used to filter the undesirable gamma ray to improve the image quality and make sure the position of the organ is correct. There are many types of the collimator in the market where the most

common collimator is called parallel hole collimator. Since collimator is dealing with radioactive material, the wall of the collimator that absorb and attenuate those gamma rays need to have a relatively large density and atomic number so that it can perform a good work[3]. The requirement of high-density material as collimator walls make collimator must face to the problem that collimator is very bulky, weighting about 40kg and more which results in the difficulties to handle this component[5]. There was some other design to replace conventional parallel hole collimator but the problem is that the lacking of sensitivity or resolution as a trade-off for the reduction of weight[6]. A bulky collimator will cause it to a situation that it is very hard to handle. This kind of hard handling collimator will not very suitable to be applied in a portable gamma camera. The reason is that a portable gamma camera will need to change its collimator's model due to the requirement of usage, the collimator will be damaged very easily if the collimator is too hard to handle. A collimator that is too heavy is not reasonable to apply in portable gamma camera and this portable gamma camera is playing a significant role in the medical field.

1.3 Objective

This project aims to propose the optimum configuration of the low energy general-purpose wire collimator gamma camera that is a lighter and comparable performance with the standard parallel hole. In order to achieve that, the following objectives have been set: