CHARACTERIZATION OF A POLYMER OPTICAL MICRORING RESONATOR FILTERING FUNCTION FOR OPTICAL COMMUNICATION APPLICATIONS

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

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DECLARATION

I declare that this report entitled **"Characterization of Polymer Optical Microring Resonator Filtering Function for Optical Communication Applications"** is the result of my own work except for quotes as cited in the references.

Signature :

Author : Muhammad Syafiq bin Ramli

Date : 13th August 2020

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 : Dr Hazura binti Haroon

Date : 25/08/2020

DEDICATION

Dedicated to my beloved family, father and mother Ramli bin Amat@Jumat & Hamidah binti Rahmat as well as my supervisor, Dr Hazura binti Haroon.

ABSTRACT

Optical telecommunications are among the vital components in the field of modern communication in this day and age as it acts as the main backbone for many of the internet activities; social media, cloud services or even space engineering. It consists of several kinds of components that could help deliver the best services for the use of either corporate or consumer-level users. One of the essential components for data delivery connectivity is its filtering function. Optical Microring Resonator (OMR) is one of the optical telecommunications components commonly applied as wavelength filtering function. Hence, in this project, the Optical Microring Resonator (OMR) filter with polymer grafting material (PMMA) coating was designed and optimized to predict its potential as wavelength filtering devices. The optimization was focused on the design parameters such as its doped polymer thickness, the variation of gap separation, dissimilar bus and ring width waveguide combination to achieve the best output in terms of lower Insertion Loss (IL) and Extinction Ratio per cent (Through) for Wavelength-Division Multiplexing (WDM) applications specifically for the use of C-Band network. The OptiFDTD 15.0 software was employed in the design and the characterization process. Upon completion, it was found that the optimized design at the radius of 10 (um), 0.055 (um) thickness of PMMA applied and dissimilar width of 400 (nm) straight and 800 (nm) ring waveguide could be able to achieve 0.0099728 dB of Insertion Loss at 15° phase shift and 31.62% Extinction Rate.

ABSTRAK

Telekomunikasi optik adalah antara komponen penting dalam bidang komunikasi moden pada zaman ini kerana ia berfungsi sebagai tulang belakang utama bagi banyak aktiviti internet; media sosial, perkhidmatan awan atau bahkan kejuruteraan ruang angkasa. Salah satu komponen penting untuk penyambungan penghantaran data adalah fungsi penyaringannya. Optik Microring Resonator (OMR) adalah salah satu komponen telekomunikasi optik yang biasanya digunakan sebagai fungsi penyaringan panjang gelombang. Oleh itu, dalam projek ini, penapis Optik Microring Resonator (OMR) dengan lapisan bahan cantuman polimer (PMMA) dirancang dan dioptimumkan untuk meramalkan potensinya sebagai alat penyaringan panjang gelombang. Pengoptimuman itu difokuskan pada parameter reka bentuk seperti ketebalan polimer doped sendiri, variasi pemisahan jurang, kombinasi bus dan lebar pandu lebar lebar cincin untuk mencapai output terbaik dari segi penurunan Insertion Loss (IL) dan Ratio Extinction (Through) untuk aplikasi Wavelength-Division Multiplexing (WDM) khusus untuk penggunaan rangkaian C-Band. Perisian OptiFDTD 15.0 digunakan dalam reka bentuk dan proses pencirian. Setelah selesai, didapati bahawa reka bentuk yang dioptimumkan pada jejari 10 (um), ketebalan 0.055 (um) ketebalan PMMA yang diterapkan dan lebar yang berbeza dari 400 (nm) lurus dan 800 (nm) pada jejari pandu gelombang dapat mencapai 0.0099728 dB Kerugian Penyisipan pada pergeseran fasa 15 ° dan Kadar Kepupusan 31.62%.

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Praise be to Allah, His majesty for His innumerable blessings, His Wisdom and highest prayers and grace be to His strongest messenger Muhammad, his holy descendant, his relatives and noble companions.

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LIST OF SYMBOLS AND ABBREVIATIONS

OMR	:	Optical Microring Resonator
GaN	:	Gallium Nitride
SiO_2	:	Silicon Dioxide
Si	:	Silicon
FSR	:	Free Spectral Range
FDTD	:	Finite Difference Time Domain
PMMA	:	Poly(Methyl) Metacrylate
IL	:	Insertion Loss
ER	:	Extinction Rate
Q-factor	:	Quality factor
WDM	:	Wavelength-Division Multiplexing
ADI	:	Alternating Direct Implicit
Al_2O_3	:	Sapphire
BER	:	Bit Error Rate
MBE	:	Molecular Beam Epitaxy

CHAPTER 1

INTRODUCTION

This chapter describes the background study of the project through a specific parameter like research background, problem statement, research objective, the scope of research, methodology, its contribution, and thesis outline.

1.1 Research Background

Recently, the world of telecommunications has been dominated by the optical network infrastructure to deliver data over a concept of optical pulses in its best transmission condition. The optical network acts as the backbone for most of the telecommunication services, including satellite transmission, broadcasting, leased line, WDM (Wavelength-Division Multiplexing), cloud computing, Internet of Things (IoT) and upcoming 5G technology due to high-speed broadband networking requirements.

Photonic studies relate the study of optical communication by devising and analyzing data transmission capability by applying the fundamental concept of speed of light towards the data transmission. In the field of electrical and electronics, medical, image processing, and optical network communication are among the top applications of photonic studies. In optical network communication, more research work needs to be done for the use of short-haul or long-haul data transmission to determine the best options for achieving better connection stability and fast data throughput. This can be made possible by employing improvement in its development of high-performance optical devices such as a switch, amplifier, modulator, and filter.

Therefore, in this project, the Polymer Doped Optical Microring Resonator is proposed for network filtering purposes. The proposed design would employ the research studies on the Gallium Nitride (GaN) and Sapphire (Al_2O_3) as the add-drop filter of Optical Microring Resonator (OMR) through the concept of coupling between straight bus waveguide and ring waveguide. The silicon-based waveguide would then doped with the polymer grafting material (PMMA) on top of the design to enhance the device performance.

The motivation of this project is to design the add-drop filtering function device to have better performance; including transmission range, Insertion Loss (IL) ratio, Extinction Rate (ER), and Phase Shift (°) through variation of several parameters to contrast the conventional Silicon-based devices.

Mainly, Free Spectral Range (FSR) is a frequency spacing parameter that is relevant to each inverse round-trip-time of optical data transmission, either on its empty standing wave or standing wave of the length of a particular resonator mode design. Whereas, Q factor is a measurement of its specific characterization of the damping effect of each oscillation over the span. Extinction Rate (ER) in optical fiber communication is a correlation of efficiency power difference between the lower optical power and higher optical power over optical fiber channel. Besides, Insertion Loss (IL) is an evaluation of the lost (measured in dB) parameter between two points of optical network communication as data is transmitted from the light travelled in the straight waveguide to the ring waveguide. Also, finesse is the measurement of circulation power after one round trip of optical pulses between the straight and ring waveguide. In contrast, phase shift (°) is the phase difference between each wavelength produced from the Add-Drop filter Optical Microring Resonator (OMR).

1.2 Problem Statement

Conventional Silicon-On-Insulator fabrication would require Chemical Vapor Deposition (CVD), Electron Beam Lithography (EBL), or any plasma etching that could be the reason for the lower coupling efficiency issue, trigger high scattering losses and require much higher requirement of fabrication equipment requirements that could cost much higher in each of its production units. Using relatively simple equipment, thin polymer films can be deposited by spin or dip coating in a wide range of thicknesses. There is a range of channel waveguide fabrication techniques, ranging from microtechnology techniques, such as etching, to mass production methods developed explicitly for polymers, including molding and laser delineation. The simplicity, low cost, and flexibility of waveguide fabrication methods is the most attractive feature of polymer waveguide technology as compared to traditional CMOS fabrication technique.

Besides, an inorganic material such as the Si could not be able to offer a broad refractive index as much as polymer grating material could provide. The refractive indices of polymer materials can be precisely tailored and controlled to meet a specific design purpose in a broad refractive index range from n = 1.3 to 1.7. The birefringence present in the Silicon Resin based material is intended to be higher than in polymer-based material as it could be one of the factors that could cause excessive power penalties or high power consumption during data transmission. Due to the above-mentioned reasons, polymer technology is forecasted to have enormous potential in the development of optical devices.

Apart from that, the lower value of energy band gap offer in the inorganic material of Silicon Dioxide ($SiO2$) could only deliver much higher propagation losses and would apply high power penalties as it is due to 1.1 (eV).

1.3 Research Objectives

i. To design and analyze Polymer Doped Optical Microring Resonator Gallium Nitride/Sapphire for Add-drop filtering function using OptiFDTD 15 (FDTD Method).

ii. To analyze various filter design performance based on its Insertion Loss (IL), Phase Shift, and Extinction Rate (ER).

iii. To compare the proposed design with the conventional use of Silicon Dioxide/Silicon Optical Microring Resonator.

1.4 Scope of Research

Area of research would cover within the implementation of Doped Polymer Optical Microring Resonator (OMR) waveguide mechanism dedicatedly for its filtering function by implying much improvement technique through optimizing the polymerization approach (PMMA) as being doped on top of the base Gallium Nitride (GaN)/Sapphire and as a substitute towards the conventional use of Silicon-On-Insulator (SOI) approach. Micron sized OMR was considered and optimization course of action been taken as to focused on each of the parameter variation, like its variation of the polymer grafting material (PMMA) thickness, gap separation and straight-ring waveguide width are being analysed and being compared and analysed towards the conventional use of Silicon Dioxide (SiO_2)/ Silicon (Si) add-drop filtering function of Optical Microring Resonator configuration.

Apart from that, the primary intention of design work of the Doped Polymer Optical Microring Resonator would specifically serve a function as an add-drop filtering mechanism with a precise range of frequency being able to tolerate. As it is being implied towards the use of optical communication network specifically for the use of Wavelength-Division Multiplexing (WDM) network, the range of frequency may be capped at the telecommunication wavelength of range of 1550 nm wavelength yield accordingly the proposed design as of its ring radius or the characteristic properties of the doped polymer grating material.

Limitation of the research would correctly act out differently whenever the simulated proposed design is implemented to the real-life situation due to the fabrication process. Fabrication technique basically would be done with the help of machine construction, and it could trigger a slightly different result as the surface of the doped polymer may encounter a slightly minimal error that could trigger a more significant result difference. Due to that, the energy of optical pulses in a real-life application may be varied to the simulation.

1.5 Thesis Contribution

Proposed optimized design of the Doped Polymer Optical Microring Resonator regards the use of Doped Polymer of Poly(Methyl) Methacrylate (PMMA) on top of the Gallium Nitride (GaN) with the utilization of Sapphire (Al_2O_3) as the substrate based Optical Microring Resonator with the fundamental characterization of variation of its shape configuration parameter are meant to offer better critical parameter as being suggested. Each of the proposed optimized design would defer several critical parameters; its particular transmittance range, Insertion Loss (IL), Extinction Rate percentage (ER) and its analysis on Phase Shift.

As it is opposed, the implementation of Doped Polymer (PMMA) on top of the Gallium Nitride (GaN) based Optical Microring Resonator could be able to lower the energy consumption due to the polymer grafting material characteristic and utilization of inorganic material as it offers much higher power efficiency in term of delivering optical pulses.

Apart from that, as an apposed idea on this research quotes that the use of polymer grating material like Poly(methyl) Methacrylate (PMMA) is one of a kind of proposed material for the use of doped material on top of the Gallium Nitride (GaN) based Optical Microring Resonator that offers much lower refractive index compared to the silicon material as it can transmit higher optical pulses light through it.

1.6 Thesis Outline

This implementation research onward the design and analysis of Doped Polymer Optical Microring Resonator would be structured up of 5 Chapters that would cover Chapter 1 until Chapter 5.

Chapter 1 is an introduction that discussing on the fundamental of the basic application of proposed idea through identifying initial introduction of particular research background, analysing the research problem statements, initial methodology discussion, scope area of research and objective findings of the research itself.

Chapter 2 is a clarification of the rudimentary of fundamental properties of Doped Polymer Optical Microring Resonator through summarization of its particular properties of the material being targeted to be used as a dopant on top of the Gallium Nitride (GaN)/ Sapphire Optical Microring Resonator for the implementation of both straight and ring waveguide itself through analysation of its performance accordingly several parameters being set-up. All the parameters through the proposed design are meant to serve as an add-drop filtering function.

Besides, Chapter 3 is a review on the basis on implementing the proposed idea through some perimeters being applied as accordingly towards the design idea; variation of its parameters like its different polymer material thickness applied, gap separation and ring-straight waveguide width variation with the help of polymer dopant material on top of the Gallium Nitride (GaN)/ Sapphire. As an effort to improve the design work, all results are taken for the analysation method.

In Chapter 4, analysation is being discussed through result and discussion as of each data being taken into interpretation and comparison made fit into the OriginPro 2019b from the simulated design OptiFDTD 15 (FDTD Method).

In Chapter 5 would consist up of 3 subtopics that would be discussing on the research conclusion, its particular contribution of the research work and some recommendation for future implementation as well as the reference will be included at the end of the research thesis.

CHAPTER 2

LITERATURE REVIEW

This chapter describes the background study of the project where the references come from paper, previous journals, websites, and books as references in this project. All the references have been cited.

2.1 Doped Polymer Optical Microring Resonator Properties

Doped Polymer Optical Microring Resonator (OMR) could be able to perform several functions in an optical communication network specifically for the use of the Wavelength-Division-Multiplexing (WDM) network precisely for the C-Band network such as act as an optical signal processing, multiplexing, modulator [1] and optical channel dropping filtering purpose [1]. Implementation design of Doped Polymer Optical Microring Resonator (OMR) would be ranging from nanometer-size configuration due to its ring radius, gap separation between straight and ring radius, the waveguide width, core thickness, and targeted design of wavelength.

The definition of each of its specified critical parameters like the Q-factor brings the meaning of the time confined light in a cavity is accounted for. A high Q-factor allows light to be trapped in a cavity and interact with the analyte longer [2]. Cavity loss, its particular straight bus waveguide length, and gap separation would be related to the value of the Q-factor. As for the Extinction Rate (ER), coupling efficiency correlated to each other as the higher the depth of the dips of the resonance, the better the ER [2]. Apart from that, the radius of the width ring waveguide could affect the Q-factor as it could help easier and reduced losses of the sidewall [2].

Design of the Optical Microring Resonator (OMR) would be employing the polymer grafting material; PMMA Polymer [3] due to its characters like the low optical absorption loss and easiness and low-cost in term of its fabrication technique [4] as it would be applied on top of the waveguides.

All the parameters like its straight bus waveguide and ring waveguide width, the shape configuration of ring waveguide, characterization of the ring waveguide position, radii of the ring waveguide, gap width between the straight-bus and the ring waveguide, height of each waveguide and the type of polymer resonant waveguide grating [5] [6] would be take encountered to get the fully optimize the result. Polymer much implemented in the field of polymer optical fiber due to its low optical losses and easiness and low-cost fabrication process [15].

Other essential parameters of the Optical Microring Resonator (OMR) are the Free Spectral Range (FSR); that could help OMR support multiple resonances as it would be contingent on its resonator length [7]. As well as with the bend radii below five μm, an extreme compact ring could be designed even applied to the optical fiber application in telecommunication of FSR over 20 nm at 1550 nm wavelength [7]. As the primary purpose to serve as the spectral filter, the codirectional evanescent coupling between the ring and an adjacent bus waveguide would be designed [7] and yet OMR could also be used for banks of compact wavelength channel filters as a higher-order filter best suited and could provide a more uniform bandpass over a more extensive wavelength range [7]

2.2 Doped Polymer Optical Microring Resonator Structure

Optical Microring Resonator would be made off several desired designs and structures as each of the characteristic variations could serve a different kind of functions. Optical Microring Resonator could be able to serve functionality either as a multiplexer, switcher, modulator, or filter [1], different designs could have an impact on each of the result parameters like its own Q-factor and Free Spectral Range (FSR). Several findings stated that different parallel number of cascaded ring waveguide configuration designs would affect a particular FSR value up through some specified value. Flatter passband and steeper roll-off factor can occur as the number of ring order numbers increases [1]. The separation gap of each ring waveguide is being separated by theoretically Leff as the idea itself could serve the best condition for delay function or Butterworth-filter [1]. Designing the cascaded with the operation of Vernier (rings with different radii) may be used to eliminate non-sync ring resonances and extend the value of FSR [2], but somehow less suitable be able to be implied for the use of filtering function. The dissimilar or parallel cascaded design needs to consider its parameter as the bending loss of 7 dB/90° foreseen for the second-order mode of the TE was sufficient to suppress its resonance but was too low to prevent the fundamental resonance in the couplers [2]. As a solution, the resonant frequency mismatch further lowered this to 7.5 dB. These factors can be compensated with broader in-band rejection to produce symmetric responses [2]. More than just one individual resonator, multiple coupled rings can increase its filter efficiency with greater band rejection and flat passband [3]. MRR has a higher contrast ratio for higher-order [4].

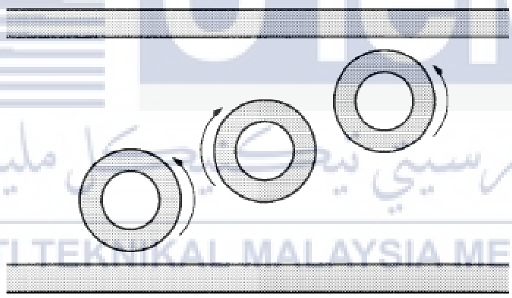

Figure 2.1 Parallel cascaded optical microring resonator

Apart from that, gap separation between waveguide could affect the performance of one's waveguide as the separation distances widen, Q-factor increases [4]. One approach to improve the Q-factor is to increase the separation distance but also to reduce the output power [4].

Also, an additional proposed idea onto implementing the Doped Polymer Optical Microring Resonator is to stack the ring waveguide like through double-layer implementation vertically. Vertically-stacked to each other as it could be able to tune to a much finer degree [10]. Due to the application in the Wavelength-Division-Multiplexing network, It would be best applicable to the multimode nature of waveguide only [10], and it could help in fabricating the Doped Polymer Optical Microring Resonator in nanometer range much more accurate [10].

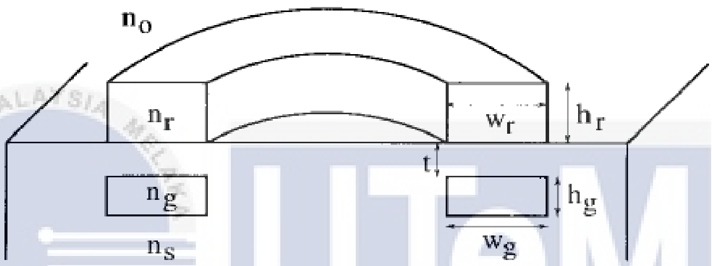

Figure 2.2 Vertically-stacked ring waveguide

Apart from that, the polygonal characteristic of the cavity inside of the as being compared towards the use of traditional circular microring resonator, it is found that it could be able to offer much higher possibilities of coupling efficiency even there would be higher gap separation between the waveguide. Coupled wavevector propagation direction crucially depends on the waveguide width yet with the length of straight waveguide [12]

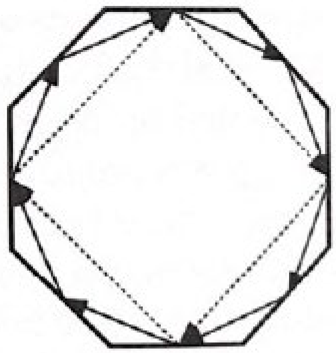

Figure 2.3 Ortogonally-cavitied of the Optical Microring Resonator

2.3 Material Selection for Waveguide Construction

Implementing of Polymer material onto the fabrication of Doped Polymer Optical Microring Resonator as a substitute method of traditional Silicon application on top of the Silica-based Optical Microring Resonator could be able to offer many capabilities like it could be able to achieve Q-factor score up to 105 range unit [7], low-cost, high optical transmittance, simple fabrication technique, low loss and high-electro-optic coefficient [8].

The selectivity of material Poly(methyl) Methacrylate (PMMA) could be able the best selection out of any other polymer grafting material as PMMA is a kind of established polymer grafting material being implied in the field of Polymer Optical Fibre (POF) manufacturing for optical communication use. Generally, much application of polymer grafting material being implied in the design of Optical Microring Resonator as being implied and studied in the study of synthesization and characterization Sm3+-doped polymer optical waveguide amplifiers [9], the study of the effect of neutron irradiation on the optical properties of PMMA/RhB used in optical fiber amplification and study of the effect of rare earth elements on the structural and optical properties of PMMA for possible uses in polymer optical communications [10].

PMMA doped with Rare Earth Elements (REEs) of 5wt.% of Neodymium(III) chloride (NdCl3) could be able to act at the highest value of Urbach's energy (Ee) as being quoted in [10] among many other REEs. Urbach's energy is related to the absorption coefficient of particular polymer grafting. RE chlorides need to be doped with the PMMA films as it could be implied towards any optical fiber use [10].

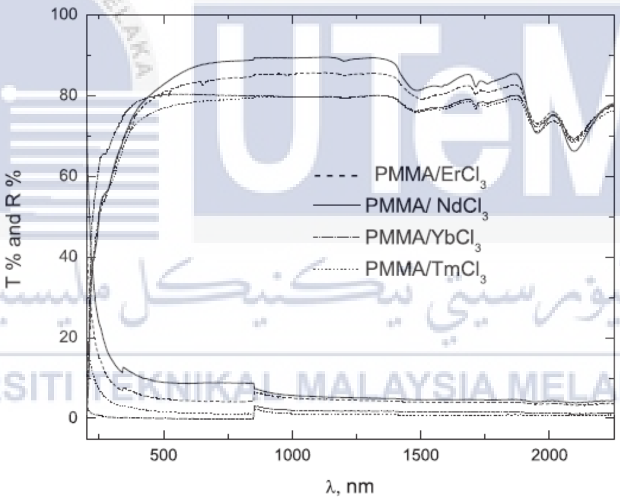

Figure 2.4 Correlation of PMMA with 5wt.% of Erbium (III) Chloride, Neodymium (III) Chloride, Yttebium (III) Chloride or Thulium (III) Chloride

Apart from that, the utilization of PMMA could be able to help develop 0.427 dB/m absorption loss due to the sixth harmonic vibration of the C-H bond present in the Polymethylmethacrylate [11].

Utilizing the Polymethylmethacrylate (PMMA) could do something more significant in the field of optical communication as compared to the non-linear grafting material like the Silicon (Si). To achieve matching and to achieve the most efficient and highest bandwidth as such could be able to reduce power penalties and achieve compact devices, PMMA available as one of the products that the Poly(methyl) Methacrylate (PMMA)-coated microphone microwire As2Se3 [12]. Most of the usage of PMMA being applied could offer the best result of its particular DFWM processes [12].

The analyzed output in the research [12], wavelength bandwidth could be gain up to 190 nm and performance up to 21 dB at an only maximum low input power of 70 mW. Apart from that, The full nonlinearity of the FWM chromatic dispersion and the sufficient long length (due to low absorbency loss $\alpha < 1$ dB / m) of the hybrid microwire make them the most power-efficient FWM devices for the net broadband gain in the end for details of FWM performance comparison of various materials including Silica, Bismuth, Silicone and Calcogenides [12].

Apart from that, polymer material itself could be able to dismiss or limit the TE and TM polarization mode and be able to avoid any unacceptable power penalties or high power consumption [9].

2.4 Fabrication Technique

Fabricating the Doped Polymer Optical Microring Resonator of proposed idea polymer doped (PMMA) onto the Silicon Dioxide base would need to be taken into account of its fabrication technique to reduce its scattering loss and to increase its coupling efficiency. Apart from that, applying the fabrication technique of Chemical Vapour Deposition (CVD) or plasma etching is a high-cost technique as it could trigger lower coupling efficiency and high scattering loss [5].

Nano-Imprint Lithography (NIL) could be done throughout any other process like thermal-NIL, UV-NIL, and other types of NIL. Nano Imprint Lithography (NIL) able to fabricate the polymer waveguide at a lower cost as a result of high throughput [6]. NIL attracted significant attention because, with simple processes, it can achieve high resolution and high yield at the same time [7]. The diffraction limit, which is inevitable in UV lithography and attains a high resolution, can be avoided with a mechanical imprint system. The reliability of the master mold is paramount because it is based on replication technology [7]. To print the soft mold, which is replicated from the hard mold as soft mold typically has low surface energy, and the process of the reproduction will not harm the hard mold, and demolding can also be much easier [7]. The basic structure of the soft mold would utilize the Polytetrafluoroethylene (PFPE) due to its properties of lower surface energy and able to reach 20 nm of fabrication resolution [7].

The photoinitiator Irgacure 2022(BASF) with the FluorolinkMD 700 (Solvay Solexis) should be made by mixing in the ratio of 1:20 before processing [7]. Later on, For improving the structural stability, a polystyrene foil must be placed on the top of the PFPE acrylate. A roller was then used to press the foil to ensure a complete filling of the hard mask with PFPE acrylate, and that patterns could be repeated correctly. As the substrate, the SiO2 wafer was used on the top. The thickness of the SiO2 layer of 3 µm was the lower cladding, which was thick enough to avoid the light out of the waveguide [7].

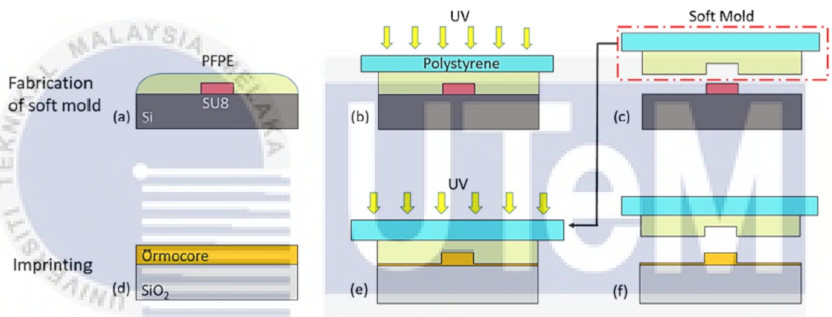

Figure 2.5 Soft UV-NIL fabrication steps with the use of Ormocore as doped polymer waveguide

With the use of UV-NIL fabrication, there would be no use of plasma etching that could trigger much loss due to its less smooth or roughness increase [8, 7]. In contrast, GaN Molecular Beam Epitaxy (MBE) is a process where the Ga vapour beam from the effusion cell is directed towards a heating substrate and the activated nitrogen (N) beam from the plasma source. Under appropriate conditions, it is possible to deposit Ga and N atomic. MBE is done in a high-vacuum environment, which minimizes image leakage. and able to create heterostructures with robust interfaces [31]

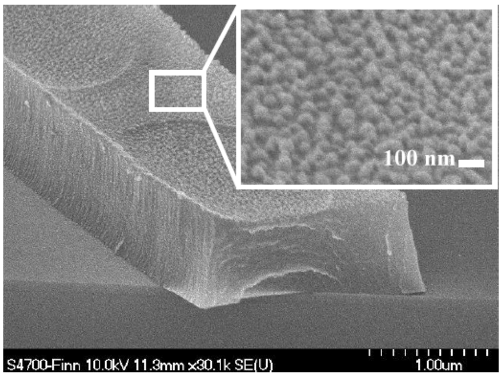

Figure 2.6 Rough surface due to plasma etching fabrication technique

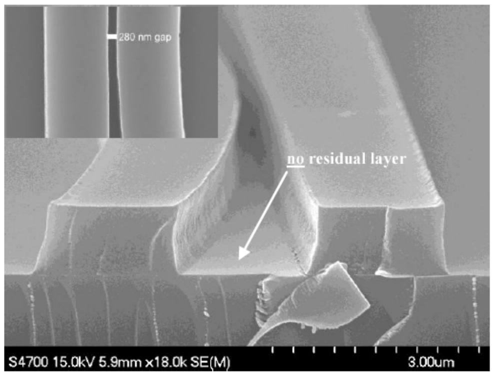

Figure 2.7 No residue accordingly to its UV-NIL fabrication

2.5 Doped Polymer Optical Microring Resonator (OMR) Theory & Operation

Fundamental of Optical Microring Resonator act as any of the function would work if the optical pulses could be able to couple from one waveguide to another as it is coupled from single straight bus waveguide onto the ring waveguide due to its resonance ability which related to the design parameter and material being applied as its core and cladding. If there would not be any coupling that happened between the waveguide, it is known that the waveguide did not become resonant with each other.

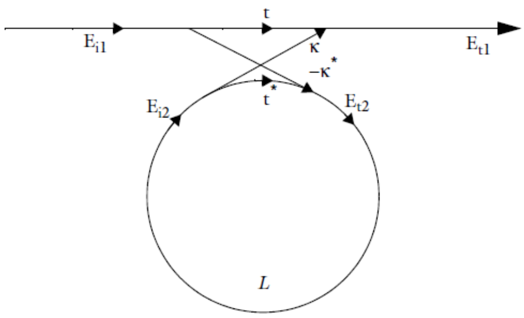

Figure 2.8 Coupling region on basic structure of Optical Microring Resonator

Once the optical pulses being resonant and coupled into the ring waveguide, the optical pulses would travel along the Et2, the optical pulses that left into the drop port, or Et1, would be the desired design wavelength of the Optical Microring Resonator. The value of k is the coupling efficiency that could be affected by the core material, core size, or gap separation between the waveguide. Thus, the optical pulses at Et1 would be lower as being analyzed in any simulation technique rather than the input optical pulses at Ei1.

Each of the design configurations would differ from each other if being compared to the implementation of add-drop filtering OMR. Add-drop filter OMR would consist of two straight waveguides as it could be added for another channel input. Fundamentally, the Notch filter would consist of 2 port, Port 1 for the input power, while the Port 2 as the drop port. As for the add-drop filtering function, it would consist of 4 port as Port 2 (Through port), Port 3 (Add port) would be implied towards another channel input, and Port 4 (Drop port) is the resonant optical should be flowing into.

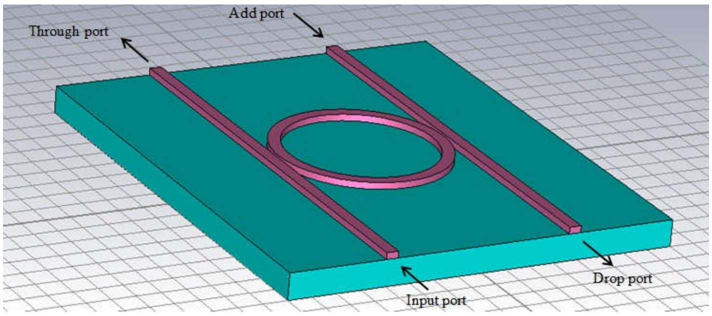

Figure 2.9 3D structure of Optical Microring Resonator

2.6 Performance Analysis

A most critical parameter in designing the Optical Microring Resonator regardless it's own parametric, or refractive index of its core and cladding, Extinction Rate (ER), Insertion Loss (IL), Free Spectral Range (FSR), Quality factor (Q-factor) or Full-Width-at-Half-Maximum (FWHM) are being analyzed and computed theoretically as to opposed the best design for particular function primarily for the filtering function that could serve well for the particular band (C-band or Ku-Band) for Wavelength-Division Multiplexing network. Most of the design could be simulated and calculated either through finite difference time domain (FDTD), analysis variance (ANOVA) [5] or software package FIMMWAVE/FIMMPROP [5].

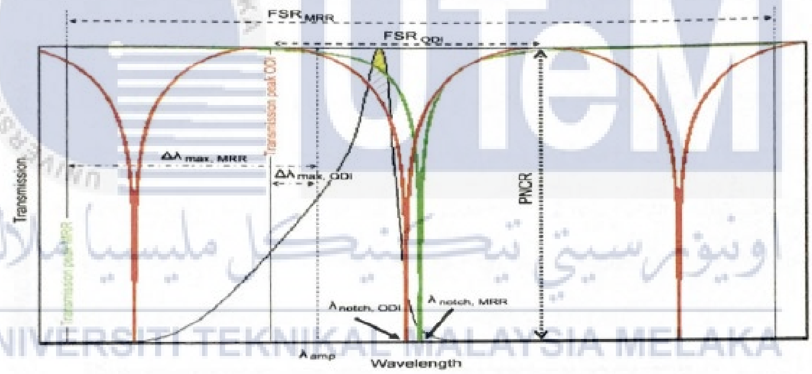

Figure 2.10 Spectrum graph of Optical Microring Resonator

Notably, the FSR of a particular OMR could be calculated between the peak of the highest between the spectrum graph. The best range of transmittance could be recognized as its transmittance could reach up to 1. Each of the configuration design could trigger much difference even in the slightest small changes in its parametric up to µm. Ranges of Q-factor as to get the best design of OMR should be able to reach up to ranges of 104 or 105.

In some findings, the higher number of channels could affect the value of Q-factor by susceptible to crosstalk caused by signal leaks between channels, thereby leading to the degradation of system performance [6]. Higher the Q-factor, it is advisable to have a lower number of channels. Instead, Bit Error Rate and Q-factor correlated to its value of data-rate [6].

Apart from that, the performance analysis of devising the best design parameter could be either done through the Taguchi Method or Response Surface Methodology (RSM) [14]. The result of Insertion Loss (IL) then could be submitted to the MINITAB software to analyze the result based on the orthogonal analysis, which would be resulting in the S/N ratio of the smaller signal to noise ratio, the better the IL [14]. Influence of each parameter of its ring radius, gap sizes, particular waveguide annulus, and core thickness is then be analyzed to not be less than the 95% of the level of confidence that be done through implementing the Fisher's F test as it in design optimization of Central Composite Design (CCD) in the MINITAB software [14].

2.7 Properties of Gallium Nitride (GaN) and Sapphire (Al_2O_3).

Gallium Nitride could be able to substitute the most conventional use of Silicon Dioxide (SiO_2) as in much of any other kind of electronic industry as it could be able to offer much better output and usage and far much more efficient as compared to the use of Silicon Dioxide as much of large companies like Anker or even Texas Instrument start to roll-off the research department onto the utilization of the Gallium Nitride (GaN) in much of its product. Gallium Nitride could excel much due to its vast features of χ (2) and χ (3), stunning warm properties and a moderately large bandgap [29], Mechanical hardness, high-temperature dependability and fantastic communicating range lucidity [30]. When it comes to implementation in photonic research, it is found that small significant transmission error occurred in buffer layers of Gallium-Nitride (GaN) with Aluminum-Nitride / Gallium-Nitride (AlN / GaN) on Sapphire nanostructures [30], GaN-based optical power splitter architecture has also been demonstrated for underwater optical wireless communication [30].

Due to its characteristic of lower energy bandgap of 3.4 (eV), as compared to Silicon Dioxide of only 1.1 (eV) it will serve as the key material for the next generation network of high-frequency, high-power transistors able to work at high temperatures, including the form of light-emittance diodes (LEDs) and laser diodes [31].

2.8 Design Doped Optical Microring Resonator (OMR) using Finite-Difference Time-Domain Method (FDTD) of OptiFDTD 15

Design and analysis work is done by using the OptiFDTD 15 utilizing the Finite Difference Time Domain with the Wave Optic Module that specifically tailored for the use of either through the 2D or 3D design work. The procedure is straightforward and can be defined in the following steps: define the sizing domain, select the components, select the correct principal meshes value, define the analyze plane of XZ and XY, define the Observation Point, select the APML solver and visualize the effects. The OptiSolver 15 accesses all these steps. The solution selection stage is usually performed automatically using default settings for each as it would calculate the theoretical part by combining Allen Taflove’s algorithmic in the background. Apart from that, the main functionality help serves to determine the coupling and propagation studies.

As in the result part, the simulated design could be easily tailored to its ranges of parameters being set-out in the Simulate 3D part with a specific value of mesh set and analyzed using the OptiAnalyzer 15 that could give out results of Power Spectrum (Pz), from XZ-Plane and current travelled over each Observation Point accordingly to time-domain.

The optimized design of Add-Drop filtering function of Optical Microring Resonator could be able to achieve the transmission rate of approximately near to 1 with the best resonance coupling between the straight bus waveguide and ring waveguide due to the refractive index of the core of 2.279 and substrate of 1.76 with a core thickness of 400 nm/ 800 nm of straight-ring waveguide and separation gap of 125 um.

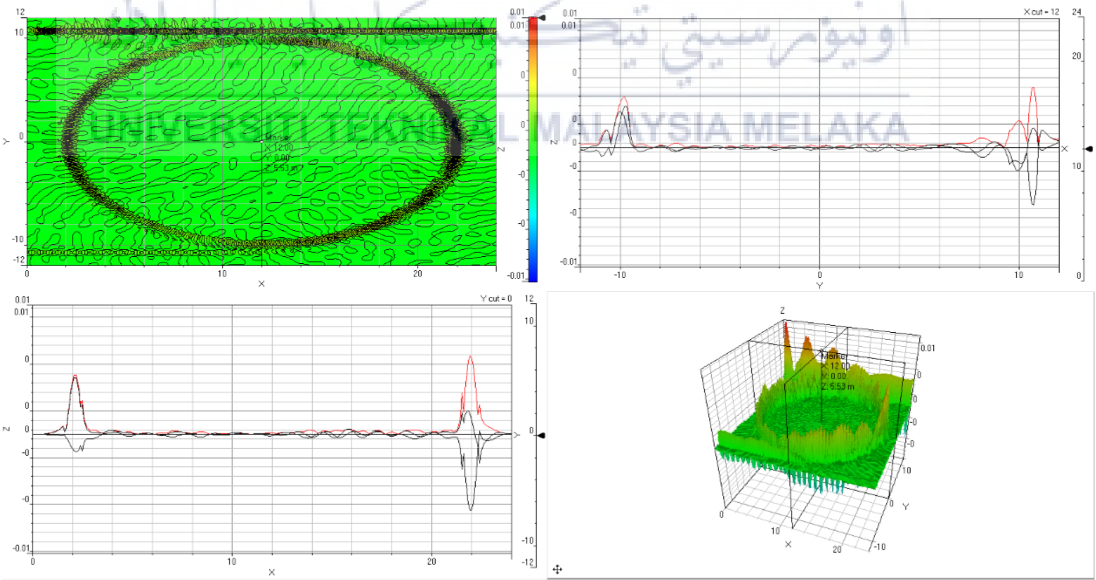

Figure 2.11 Optimized design of Add-drop filtering function OMR

2.9 Summary

Currently, photonic studies had done much research on implementing the polymer grafting material for the use of optical communication as many industrial companies start implementing the Plastic Optical Fiber as the main optical fiber cabling due to the conscious benefit of polymer over typically silicon optical fiber. Implementing design accordingly to specified parameter through devising and onto the Optical Microring Resonator in the optical network could be able to do much benefit as much new knowledge and research need to be done.

CHAPTER 3

METHODOLOGY

This chapter review on the overall progress of this research project specifically on the device design and performance analysis by using the OptiFDTD 15.

3.1 Methodology

Doped Polymer Optical Microring Resonator designing and characterization work starts with the background study through regarding the particular fundamental concepts of its polymer grating material specifically Polymethyl Methacrylate (PMMA) and Gallium Nitride (GaN)/ Sapphire (Al_2O_3) characteristic as comparison towards the conventional Silicon on top of the Silica-based Optical Microring Resonator with the doped polymer grating material. The study characteristic of the polymer grating material would then be suggested as the suitable polymer candidate for the implementation of dopant material on top of the silica base OMR. Apart from that, the study on basic configuration due to its different parameter variation, the thickness of the polymer grafting material (PMMA), gap variation of the ring and straight bus waveguide as well as the width of both ring and straight waveguide need to be done as to remodel the best design accordingly to its add-drop filtering function.

Subsequent the best of choices of study onto each characterization of each proposed design characteristic had been done, design work of basic sketch accordingly to the basic configuration of Gallium Nitride/Sapphire Optical Microring Resonator has to be start as a benchmark parameter for the future use of implementation of Doped Polymer on top of Silica-based Optical Microring Resonator. All the simulation work need to be done by using the OptiFDTD 15 (Finite-Difference Time-Domain Method). Comparison and analysation need to be done between both done design work.

Next, alteration towards the pattern done in the second stage of research work needs to be remodelled by doping the polymer grafting material on top of the Optical Microring Resonator. Both of the straight and ring waveguides are being configured with the polymer on top of the Optical Microring Resonator.

As some analysis work has the need to be done onto the altered doped polymer pattern of Optical Microring Resonator, collection of data like the Reflectance at Port 1, the transmittance at both Port 2 and Port 3, Total Reflectance and Transmittance, Loss and other parameters like its particular Free Spectral Range (FSR), Q-factor, Insertion Loss, Extinction Rate (ER), Refractive index contrast and Full Width at Half-Maximum (FWHM) need to be analysed and compared towards the basic pattern of Silica-based pattern design. Performance analysis has to be repeated through the calculation from the graph analysation after each polymer doping and different topology design work being done.

Onwards, different kind of topology studies and design work been done by simulating various kind of idea onto the straight and ring waveguide either through the implementation of various parameter variation. Each of design properties like its own of range unit of width of straight bus waveguide and ring radius, both range variation of micrometer of straight and ring waveguide thickness of polymer grafting material doped, range gap between the coupling waveguide. Preferably, range of design work of Doped Polymer Optical Microring Resonator is within the range of tens of nanometers until hundreds of micrometers. All the design work being done by using the OptiFDTD 15 (Finite-Difference Time-Domain Method).

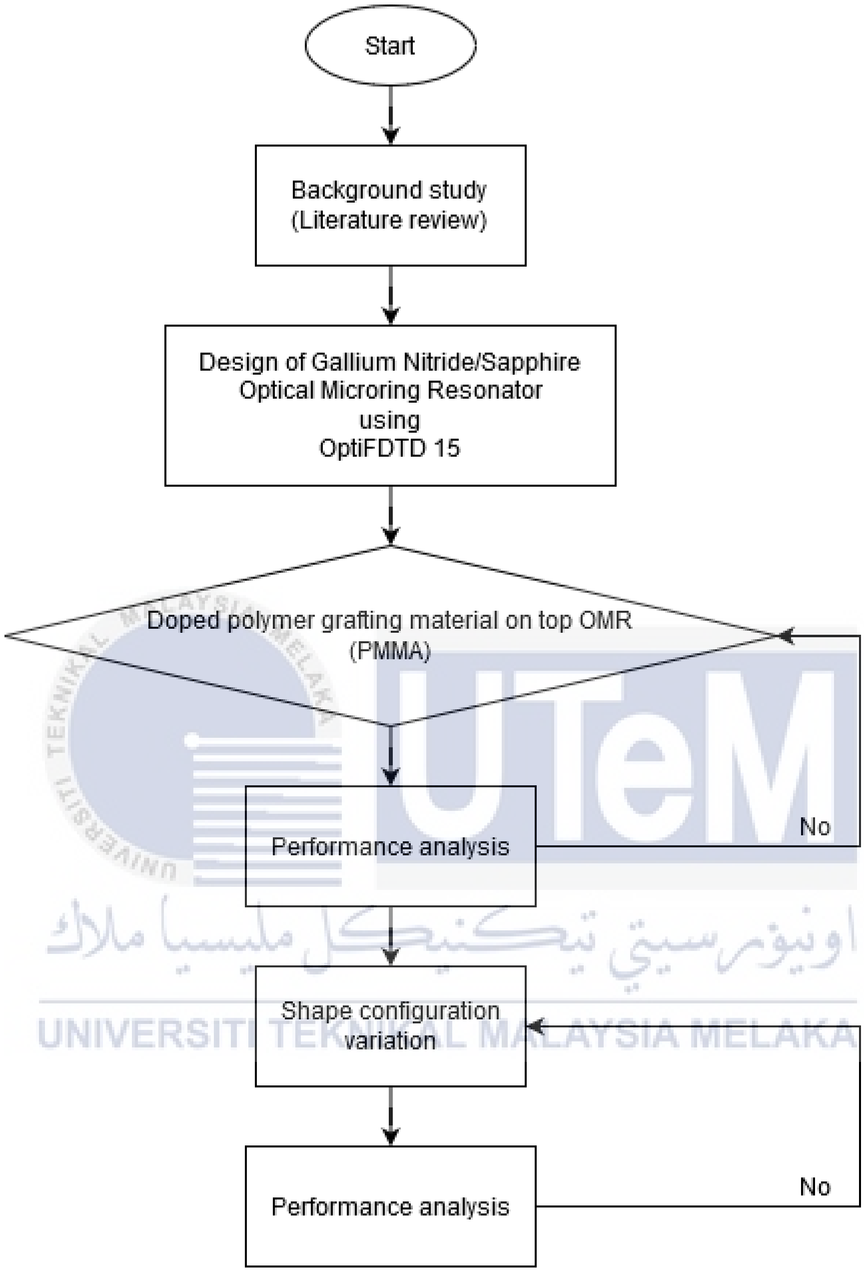

Figure 3.1 Overall flowchart of the research project

3.2 Software Configuration

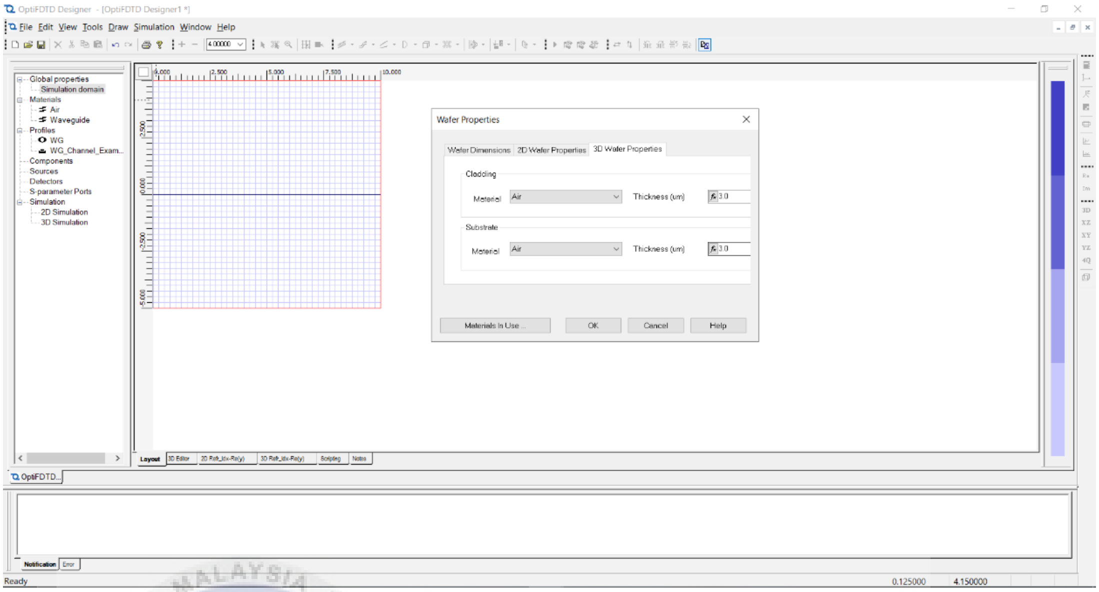

Figure 3.2 Wafer domain configuration

The initial stage of the design process would require a proper configure on the main size domain that would be implemented as the sizing of the wafer that on the Optical Microring Resonator design as it is would affect the duration of the simulation. Most of the time, the sizing would be configured up to micrometer range through applying its length and width. Also, configuring 3D Wafer properties through its Cladding and Substrate material for the designated application.

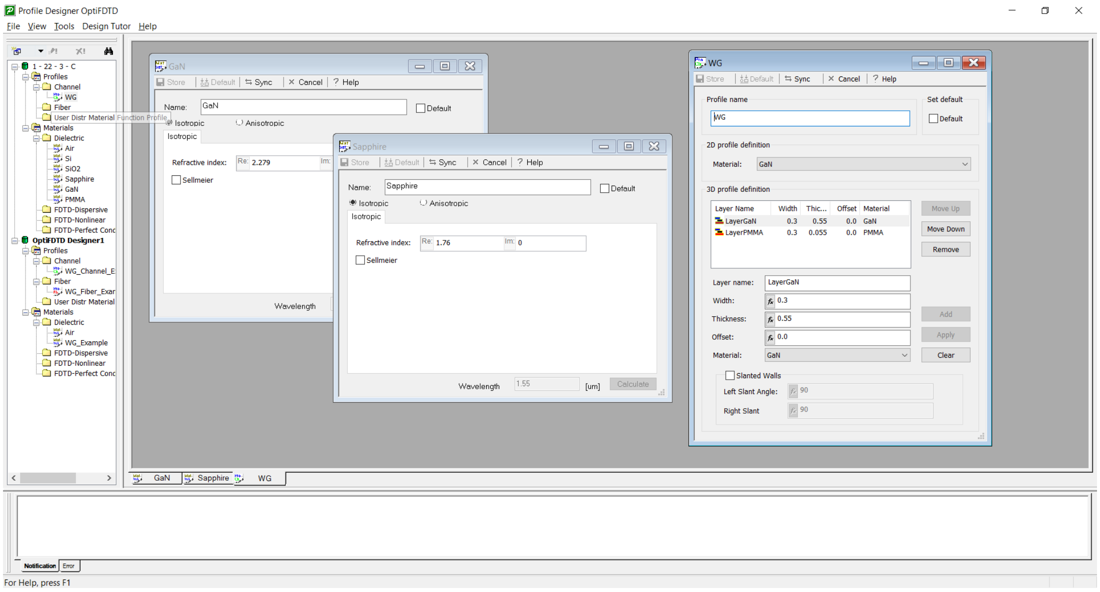

Figure 3.3 Profile designer configuration for material utilization

The second step would require proper attention towards the use of material that would be utilized onto the waveguide and as the substrate by devising through the actual value of the refractive index. The configuration could be made through clicking up the "Material in use" as it would directly refer to the Profile Designer OptiFDTD as in this Profile Designer any update towards the utilization should be made before each simulation attempt. Apart from that, the Profile of the Channel should be devised carefully as it would be the main configure of the waveguide parameter properties as it would need detail attention towards its width, thickness, offset of the Profile on the 3D axis and material used.

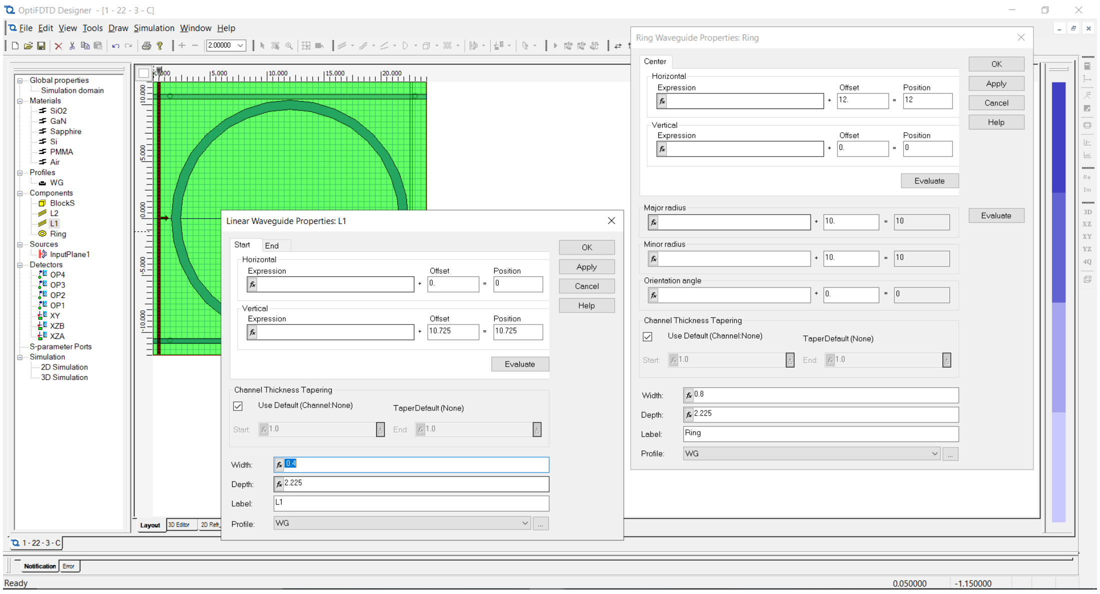

Figure 3.4 Component configuration

Moving on to step three that would require the user to configure the particular design of the waveguide by setting out its length, width and depth for the straight waveguide as it would set accordingly to the profile set-up from the previous steps, as of for the ring shape configuration same as the straight waveguide instead additional set-up on its radius. Apart from that, adding up the block as another substrate would need detail attention towards its positioning; orientation, through vector value.

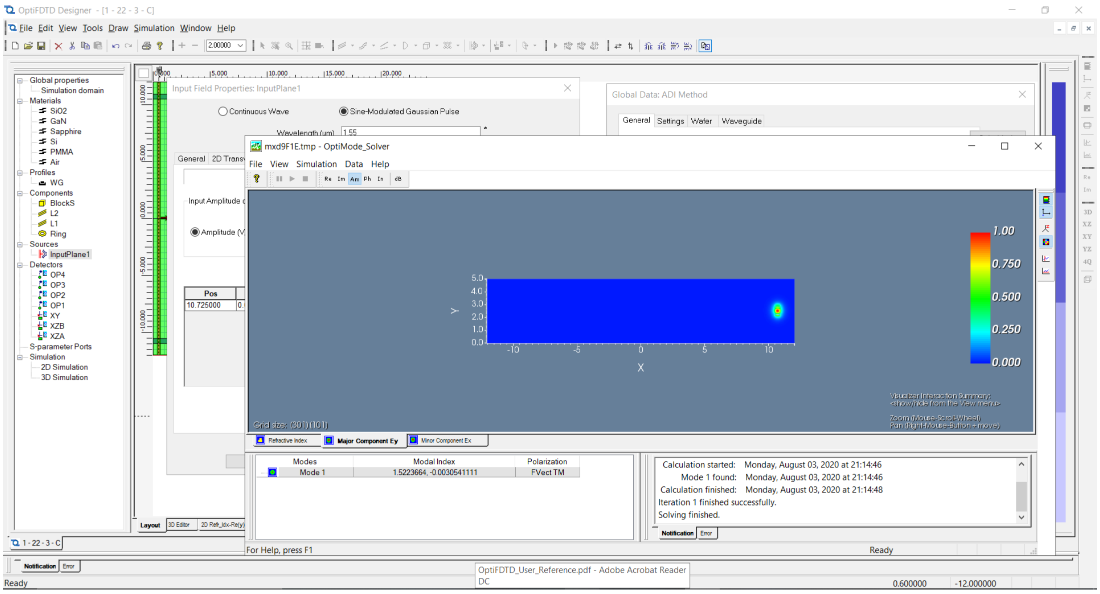

Figure 3.5 Input plane set-up using OptiMode Solver

Configuring the input plane for the wave excitation need to be done through proper positioning as into the middle of the 3D shape of the design as it would utilizing the Sine-Modulated Gaussian Pulse and targeted to be excited only through the first straight waveguide as it is excited along the Y-axis through complex solver on the mode of Full-Vector (ADI-Method). The OptiMode Solver itself would configure and analyse the optical pulses excitation along the straight waveguide as it would be ready to be coupled into the ring waveguide.

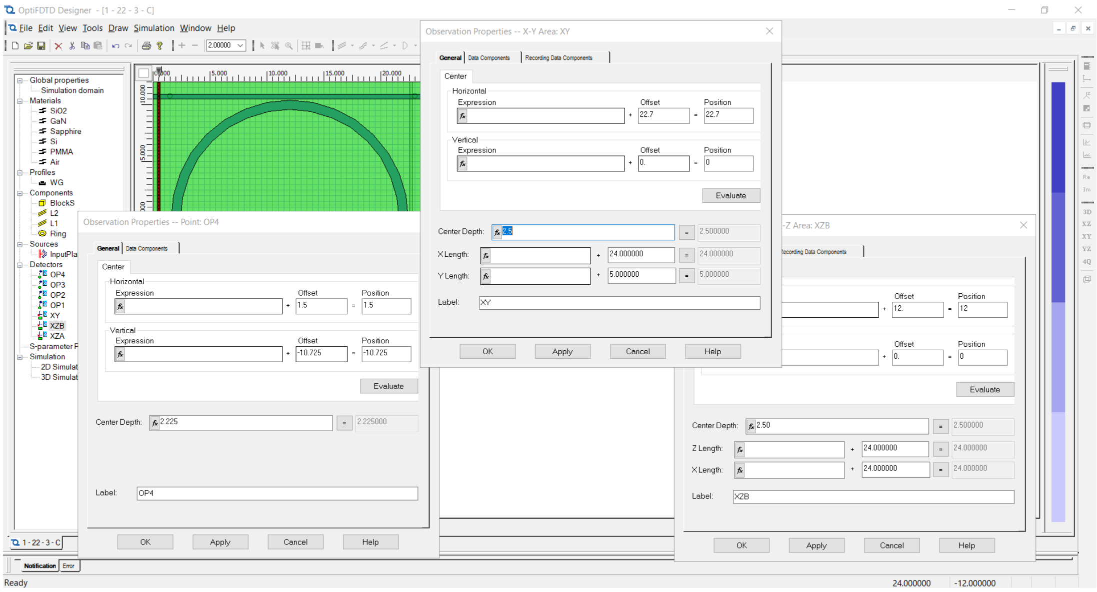

Figure 3.6 Analyzation point and plane of the design

As of for analyzation steps, some point of observation should be added into each point of the straight waveguide as to diagnose its power spectrum accordingly to the 4 points of the waveguide. As for the wave optical excitation analyzation, some observation plane is being added onto the design accordingly to the XY-axis and XZ-axis.

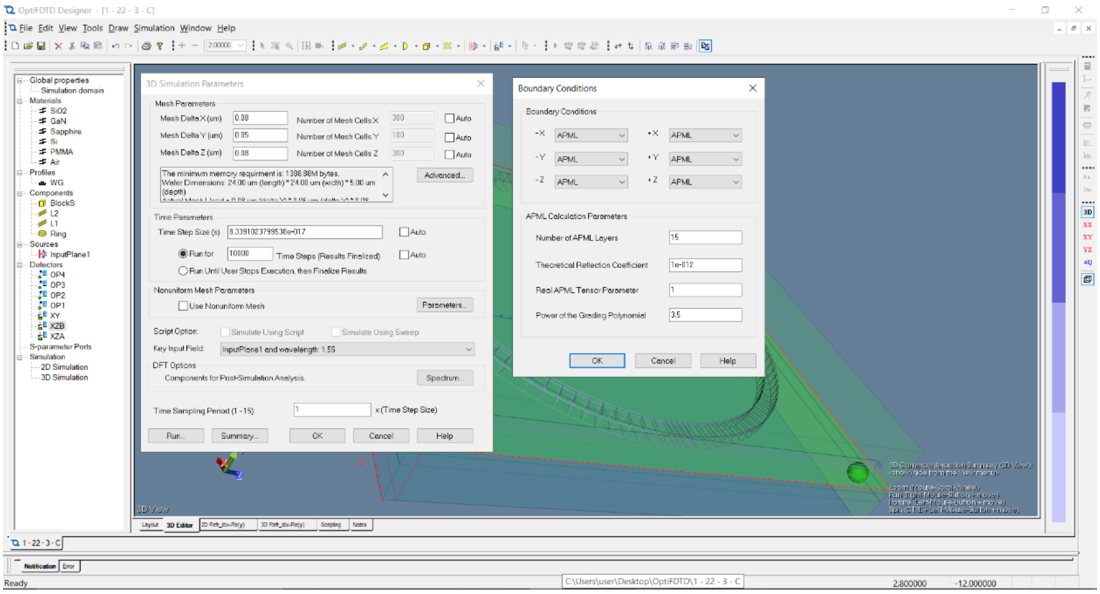

Figure 3.7 Running the simulation

As for the final steps before devising the design output through some study analyzation, some tweaks onto the mesh of the simulation need to be configured on its Mesh Delta X, Y, and Z-axis as each value could affect the output result. Also, the value of its own APML Calculation Parameters like its Theoretical Reflection Coefficient needs to take account as it would affect the results. At last, the simulated design would be executed through the OptiFDTD Simulator, and next could be reviewed through the OptiFDTD Analyzer.

3.3 Design and Model Doped Polymer Optical Microring Resonator

Design of the Optical Microring Resonator is related to its parameter characteristic as it is being designed with the radius that could be capped for the filtering function as its wavelength at optical communication wavelength of around 1550 nm for the use of C-Band Network. It is known that smaller bend radii of a particular ring waveguide could able to affect its losses, much dense channel could be fit through spacing in its spatial domain [1]. Grafting material selection for the core and cladding of the particular waveguide essential as its own particular refractive index contrast could affect the transmission of data, coupling and resonance of optical pulses between the waveguide. There is a reflection, and the ray is fully reflected the higher index medium if the refraction index of the second medium is lower. The incidence angle is higher than the other medium [2].

As in the initial modelling of the basic structure of using the Gallium Nitride (GaN)/Sapphire as the core of Add-drop filter of Optical Microring Resonator, the boundary state of field continuity guarantees that there is the tangential components of the electrical and magnetic fields at the boundary are continuous amid the phase jump [3], thus, the wave or optical pulses could be able to couple from the straight waveguide onto the ring waveguide due to its resonance ability.

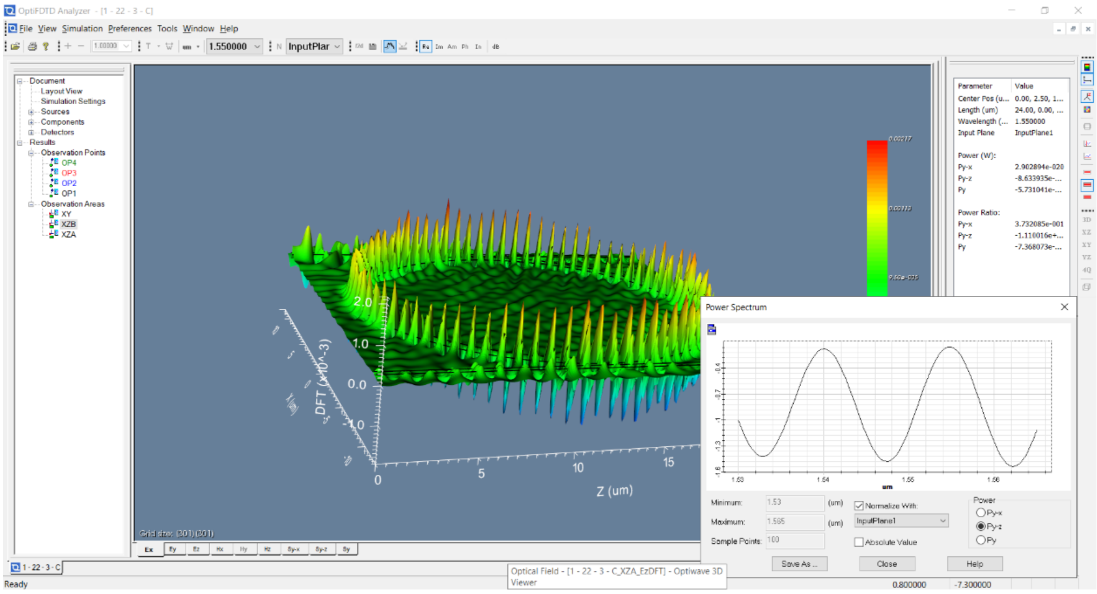

Figure 3.8 Analyzed plot of the optical pulses coupled of resonance design of Optical Microring Resonator

The analyzed of primary structure add-drop filter Optical Microring Resonator (OMR) varied the most at the coupled region with a lowest and highest transmitted wavelength that optical pulses being capped at specific wavelength accordingly to its radius parameter design that results in the desired optical pulses wavelength at the drop port.

3.4 Summary

This chapter able to clarify and guide the basic configuration of designing the Optical Microring Resonator by using the OptiFDTD 15 (Finite-Difference Time-Domain Method). This design and analysis work will be recorded, and optimization through improvising parametric study would be done as to reap best results.

CHAPTER 4

RESULTS AND DISCUSSION

Outcome results are being discussed and analyzed throughout the whole chapter based on any other parametric studies being done for the research studies.

4.1 Introduction

As of in Chapter 3 explaining more onto about several steps and techniques that should be done as to refine the studies of the different characterization and implementation of the 3D design of Doped Polymer Optical Microring Resonator (OMR) by using the OptiFDTD 15 (FDTD Method), some several design specification through variation of parameter show some effect onto the design development.

As to refine the studies in the whole of the research project, several discussion and analyzation are being separated into several points inside of this chapter 4 due to several parametric studies are being done through decent explanation and result analyzation. In line with the chapter's purpose, section 4.2 would be discussing and explaining the fundamental characteristic parameter or study range implementation of 3D design of the Polymer Core Optical Microring Resonator (OMR). Bullet list example.

4.2 Fundamental Characteristic of Design

Each of the design or shape configuration being varied is being based on the fundamental value of frequency of optical pulses being injected of the speed of light over the input wavelength that would yield around only 193.414 THz as of the fundamental concept of light travelled around the speed of light being analyzed around the range of C-Band network at the wavelength of 1550 nm. Apart from that, input wavelength being capped and analyzed at 1550 nm with some of the parameter sweep done around the range of 1530 um till up to 1565 um with the Spectral DFT parameter sample size study of 100 steps. Besides, the mesh of the studies being done are set-out at 1/10 of minimum wavelength that yield value of Mesh Delta X, Y, and Z of 0.08 (um),0.05 (um) and 0.08 (um) As of for the input port inside of the design structure, only the unidirectional input being set-out at the first port with its own 90° phase angle of the first wave. Apart from that, its time steps size are being lowered to $8.339102e^{-17}$ as to achieve much better simulation results with 10000-time steps.

Table 4.1 Design specification

Parameter	Value	Description
f0	193.414 THz	Frequency
wl0	1550 (um)	Input wavelength.
GaN	2.279	Refractive index of Gallium Nitride
Sapphire	1.76	Refractive index of Sapphire
time_steps	$10e^5$	Time steps of study analyzation.
time_size	$8.339102e^{-17}$	Time size
r0	10 (um)	Radius of ring waveguide
w_core	400 (nm)	Straight waveguide width
w_ring	800 (nm)	Ring waveguide width
dx	125 (um)	Gap separation of waveguide

Variation of the design implemented that varied at its own basic parameter like its own gap size (in nm) between the straight and ring waveguide, ring size (in nm), core size (in nm), and among many other characteristics.

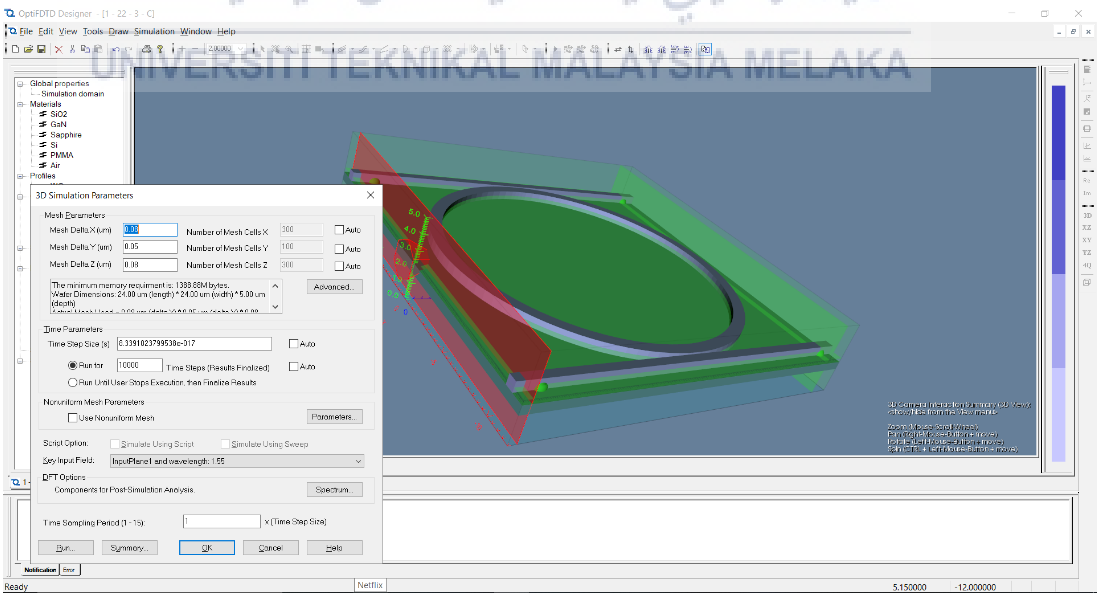

Figure 4.1 Design environment of OptiFDTD 15 (64-bit)

Variation of each of the parameter could have yielded the result onto its reflectance, transmittance and loss and simulated 3D plot of optical pulses that could be seen with the help of height expression of optimization of OptiAnalyzer 15 as with the help of Finite Difference Time Domain Method.

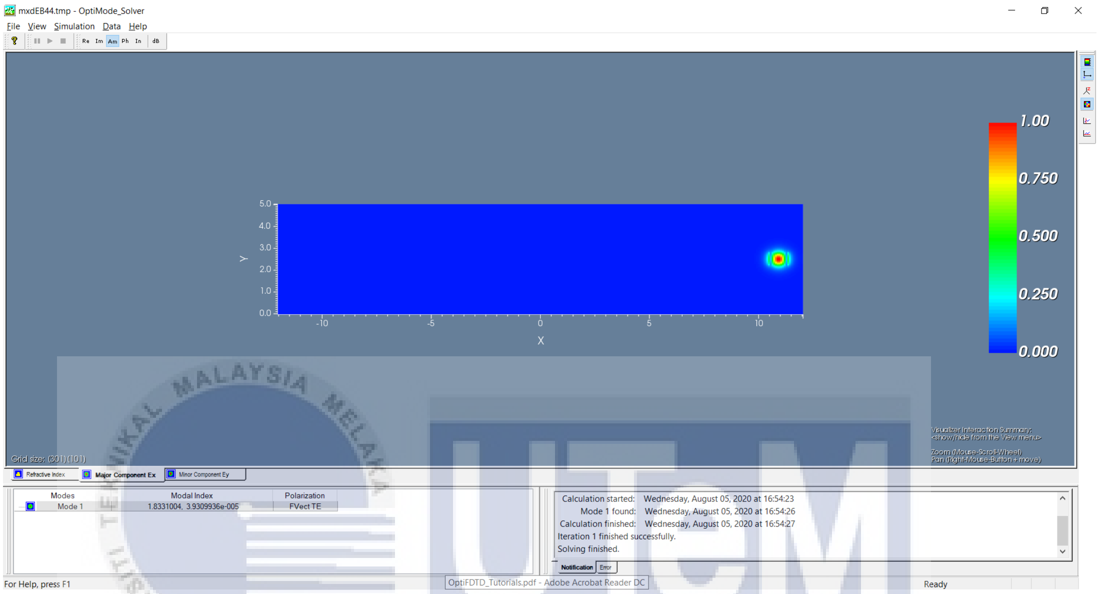

Figure 4.2 OptiMode Solver for wave excitation analyzation.

The wave excited along with the L1 of the straight waveguide by implying the ADI-Method that would be generated by the OptiMode Solver that would yield Model Index of $3.9371e^{-5}$ by optimizing the Sine-Modulated Gaussian Pulse at 73.5452 THz FWHM of $4.5e^{-14}$ second time delay.

4.3 Effect of variation of parametric design on the λ, Q-factor and Insertion Loss

Different kind of variation of its parameter like the thickness of polymer grafting material (PMMA) doping configuration, straight-ring waveguide width dissimilarity, size core size as well as the gap separation size between both of the straight and ring waveguide are among of the dependent variable that is varied as to observe its phase shift difference, Insertion Loss (IL) and Extinction Ratio (ER) with among of other vital parameters

4.3.1 Effect of the different material applied to the design on the filtering performance of Optical Microring Resonator (OMR)

Since different kind of refractive index could have a different refractive index difference when it comes to the internal reflection coefficient of the optical wave travelled inside the core itself could yield different coupling coefficient.

Some analyzation had been done as to make a comparison between the use of inorganic material of Silicon Dioxide (SiO2) pair with the Silicon (Si) and Gallium Nitride (GaN)/ Sapphire as to make a clear comparison due to this ability to transmit the data as its round trip losses and coupling coefficient within the same shape configuration of ring size 10 (um), ring waveguide width 800 (nm), straight waveguide width (400 nm) and gap separation of 125 (um).

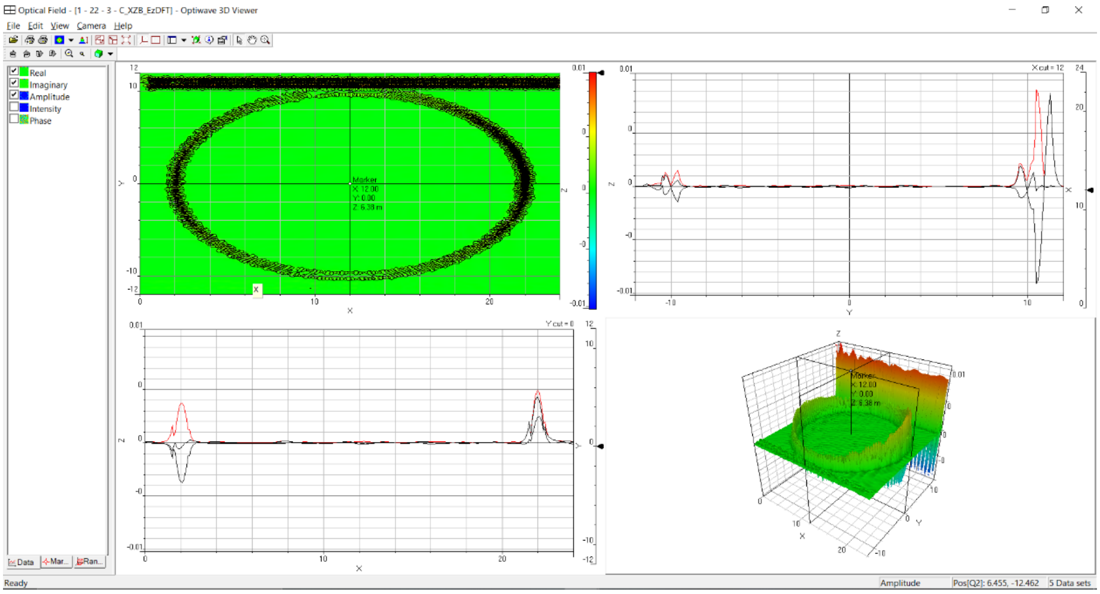

Figure 4.3 Coupling efficiency offered by Silicon Dioxide/Silicon

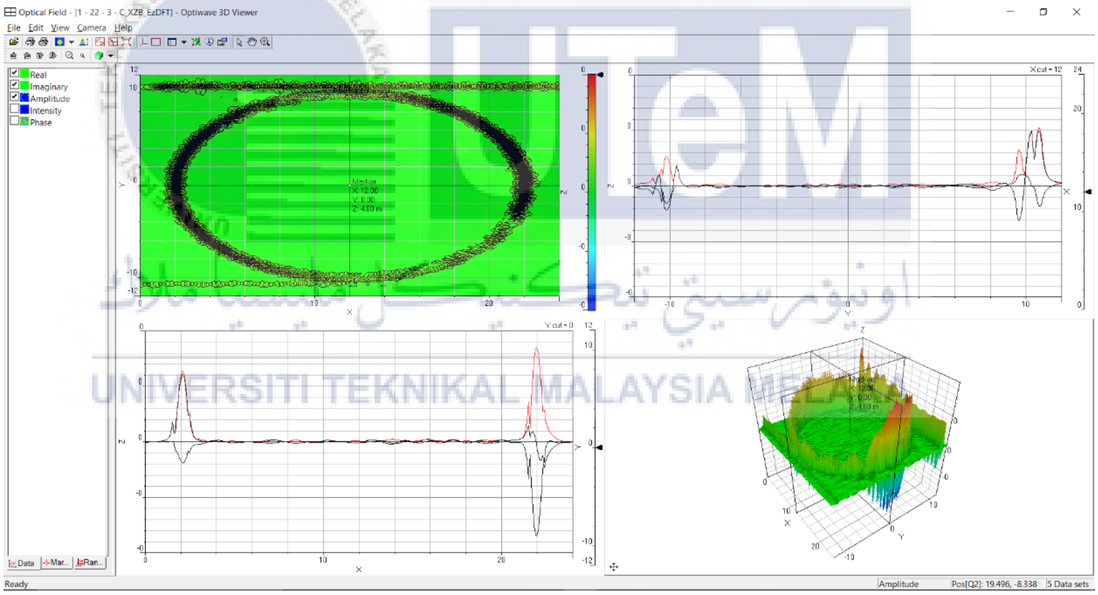

Figure 4.4 Coupling efficiency offered by Gallium Nitride/Sapphire

The coupling coefficient offered by the paired material of Gallium Nitride and Sapphire offers much better as compared to the standard pair of Silicon Dioxide and Silicon due to the fact it could couple much higher possibilities of the optical pulses from the bus waveguide onto the ring waveguide. Apart from that, the frequency of wavelength travelled coupled to the use of C-Band network also much better in terms of its lower Insertion Loss (IL) much better in pair of Gallium Nitride and Sapphire as compared to Silicon Dioxide and Silicon.

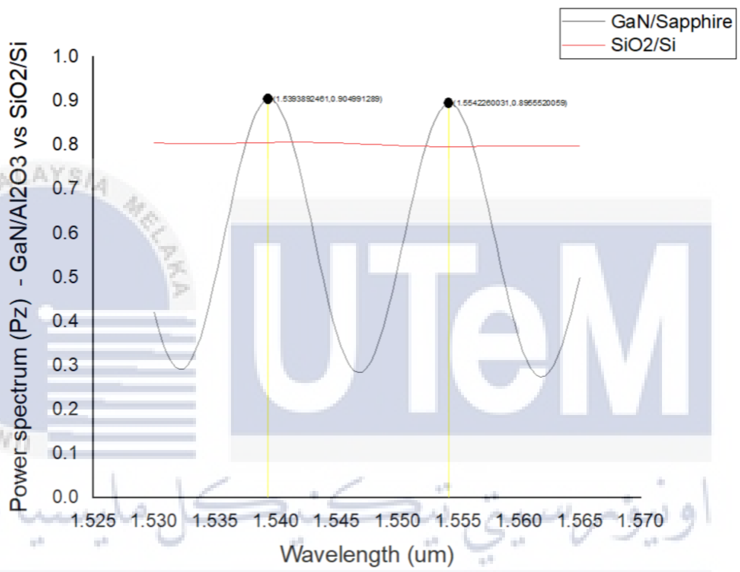

Figure 4.3 Frequency travelled throughout inside of the waveguide

With the same shape configuration, the input frequency capped around 1550 nm and analyzation been done for the C-Band network (1530 nm – 1565 nm) could be easily being analyzed for its phase shift difference, Extinction Ratio (ER) or even Insertion Loss (IL). Pair configuration of Gallium Nitride excels in the range of shape configuration as preferred.

With the preferred material used combination; Gallium Nitride (GaN) as the core of the waveguide, and Sapphire (Al_2O_3) could be able to yield much lower Insertion Loss of 0.099728353 dB at the wavelength of 1.539389 (um) and 1.554220 (um) while 0.192454 dB of utilizing the Silicon Dioxide (SiO_2) as the core waveguide as within the same shape configuration; thickness polymer applied, same gap separation and same width combination. The output yield of the optical pulses would act like the OFF-Resonance with the utilization of the Silicon Dioxide as it could not filter many wavelengths onto the ring waveguide as compared to utilization of the Gallium Nitride,

4.3.2 Effect of the thickness of polymer grafting material (PMMA) on the filtering performance of Optical Microring Resonator (OMR)

A variation on the thickness of the doped polymer grafting material (PMMA) on top of the Gallium Nitride (GaN)/Sapphire (Al_2O_3) could yield some difference in term of its essential values like on its phase shift difference, Insertion Loss (IL), or even Extinction Ratio (%). It is noticeable that since it could yield a different resonant wavelength as it would show some frequency shift as the different thickness of polymer doped onto the Optical Microring Resonator.

The study analyzation being done are based on its particularly on the Amplitude value tab from the OptiAnalyzer 15 as the data curve being exported at around Power Ratio (Pz) of $8.0011267e^{-1}$.

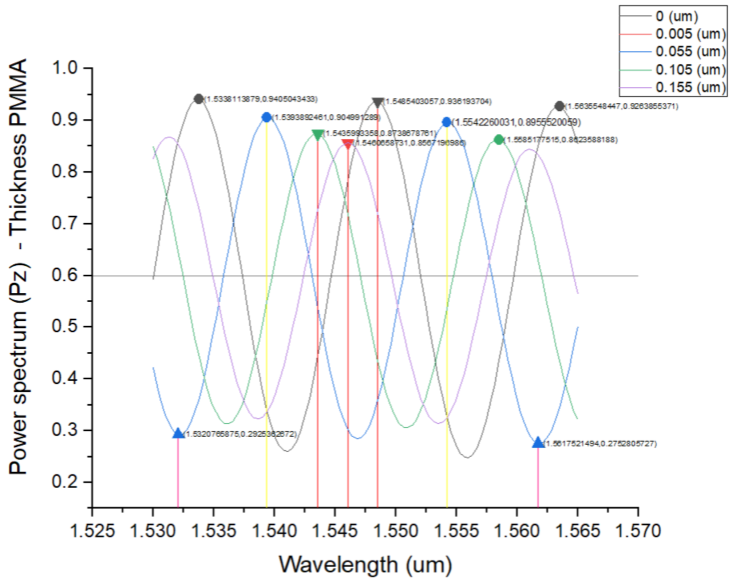

Figure 4.4 Wavelength representation of different thickness applied onto top of the OMR

Comparison on the thickness of the polymer grafting material (PMMA) applied on top of both straight bus, and ring waveguide varied with the trend of increment of 50 (um) varied from 0 (um) up to 0.155 (um) as to discover its properties. No polymer grafting material applied as its reference point to which on how it would turn out if different thickness act on the performance of the Optical Microring Resonator (OMR). Wavelength shift occurs if the different thickness applied that could yield a study analyzation possibilities; its phase shift difference It is found that the larger the phase shift difference could help deliver best modulation process for the use of Dense Wavelength-Division Multiplexing (DWDM) Network.

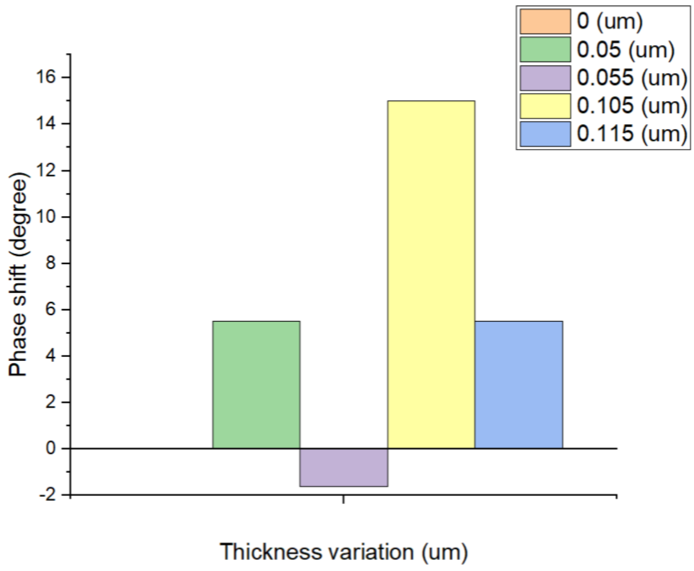

Figure 4.5 Phase shift comparison of different thickness of PMMA applied

It is found that with the thickness of 0.105 (um) it could offer much highest phase shift difference at around 15° as compared to the other thickness variable at only around 5.512 ° for both of the 0.05 (um) and 0.055(um). The variation shows that the same value of both the 0.05(um) and 0.055(um) due to the fact of its polymer properties that would act out offer the same power output around the same variation. The value of the phase difference being calculated by making the 0 (um) as the reference point and ratio of the θ_1 of the variation 0.155 (um) towards reference 0 (um), θ_2 variation of 0.105 (um), θ_3 of 0.055 (um) and is calculated by making ratio respect to 360°.

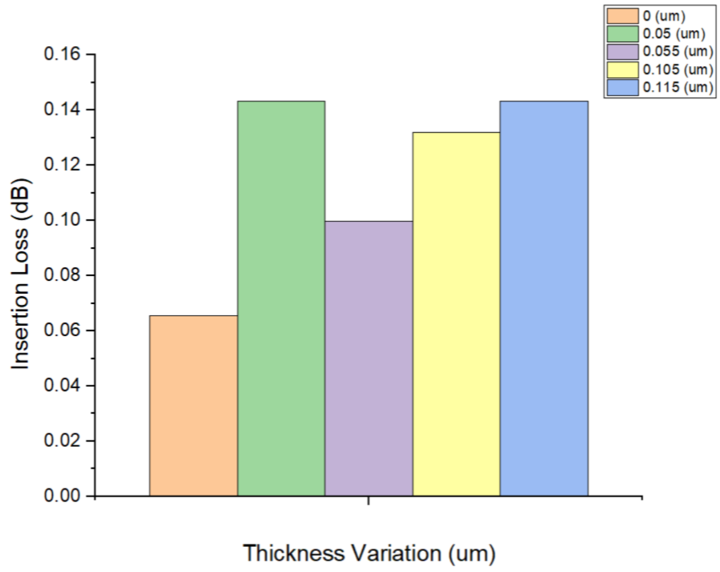

Figure 4.6 Insertion Loss of thickness PMMA applied

As it would appear in the graph above the preferred polymer thickness of 0.055 (um) could offer much lower value of its Insertion Loss of 0.0675 dB as compared to any other kind of thickness variation due to its ability to transmit much higher power as received from the Input port. The analyzation being done at the Through port. The trend could be seen as the higher the thickness of polymer applied, and it could be seen the higher its Insertion Loss which would yield much lower transmitted at the Through port.

In brief, it is concluded that the thickness variation at 0.055 (um) could offer much better performance due to its ability to transmit at lower Insertion Loss and trigger higher data Throughput of the Optical Microring Resonator (OMR).

4.3.3 Effect of the gap separation between the straight and ring waveguide core waveguide.

Gap separation between the straight waveguide and ring waveguide would give out much significant difference if there is many changes even in minimal changes that could affect the Insertion Loss and Extinction Ratio (ER) of the performance of Optical Microring Resonator (OMR).

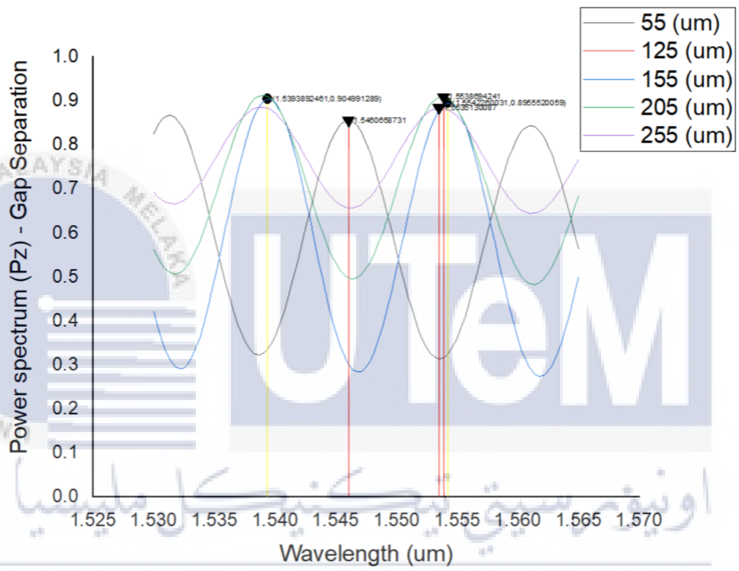

Figure 4.7 Effect of gap separation variation on the OMR

The comparison is made as the variation starting from the 55(um) with the range of increment of 50 (um) up till to 255 (um) as to show the trend of the minimal changes towards the device performance. It shows the minimal changes could affect its wavelength shift and diverse Extinction Rate (ER).

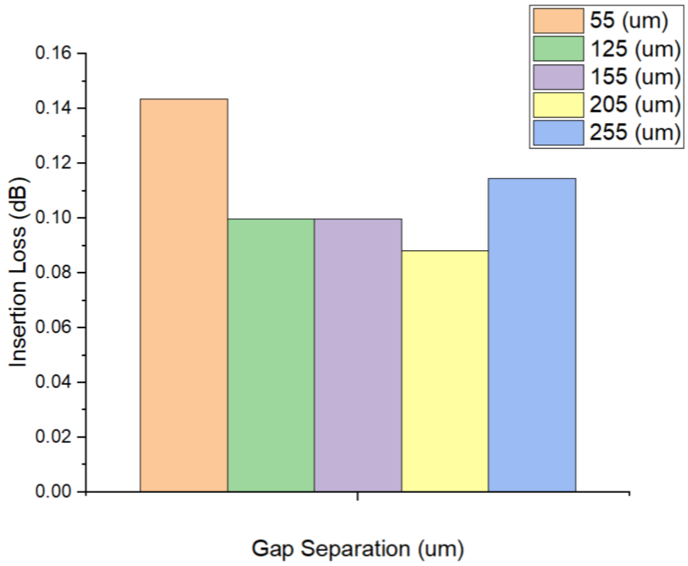

Figure 4.8 Insertion Loss affect the device performance OMR

With the same shape configuration of ring size 10 (um), thickness polymer PMMA applied of 0.055 (um) it could be seen that the gap separation at the 125 (um) and 155 (um) is the best configuration as it could offer much lower value of Insertion Loss of 0.099728352 dB as the highest Insertion Loss occur at 55 (um) due to the fact that its coupling ability to degrade at that gap separation. The value yields the same value as the 155 (um) because the best variation would be yield around a particular range of distance.

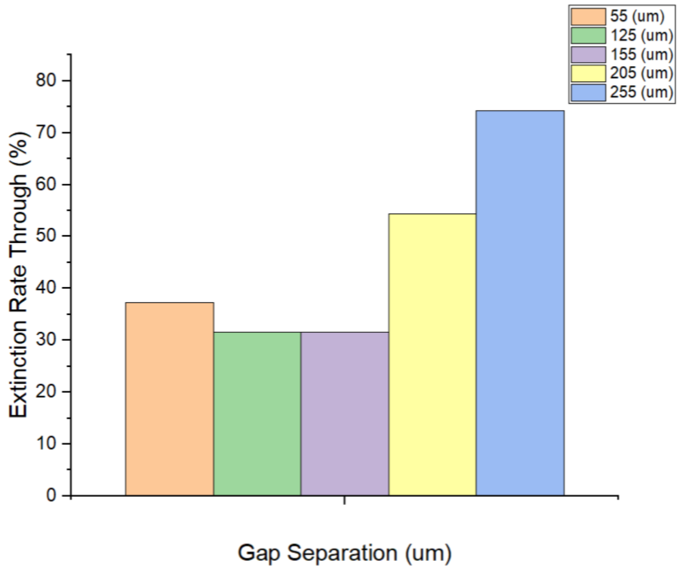

Figure 4.9 Gap separation effect on the performance of OMR

As it turns out the Extinction Rate being analyzed at Through port yield, the result of 31.5314 % for the gap variation of 125 (um). The lower value percentage of the Extinction Rate would be preferred to its best ability to maintain its own constant Bit Error Rate (BER) of the optical pulses going through the device. The Extinction Ratio percentage being calculated and analyzed concerning the ratio of average three or two-point lowest peak over the average of highest peak respect to the percentage calculation.

4.3.4 Effect on the dissimilar straight-ring waveguide width

Some series of studies onto the implementation of different width size between the straight and ring waveguide is done as it would show different characteristic offered for the performance evaluation of the Optical Microring Resonator.

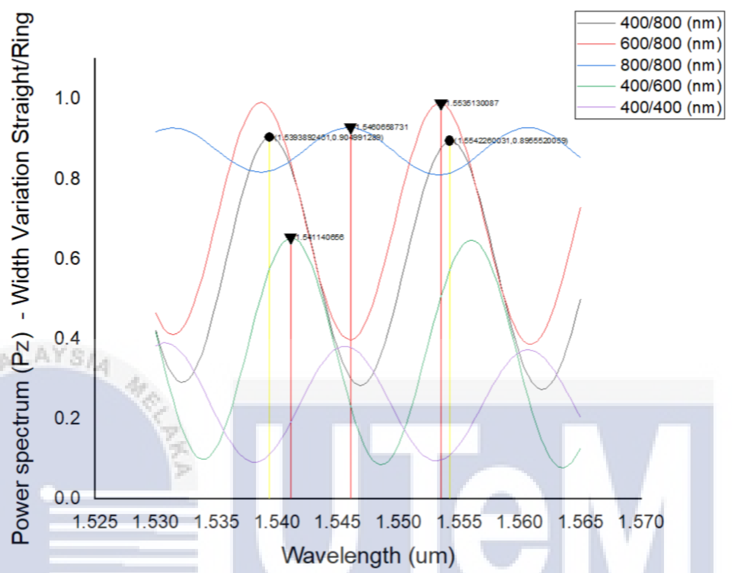

Figure 4.10 Waveguide width effect on the Optical Microring Resonator performance.

It is noticeable that the better pair of different width of the waveguide could yield better result as it shows that the pair of the 400 (nm) and 800 (nm) could yield much reasonable output power as compared to the others that could only serve much lower Extinction Ratio and wavelength shift occurred.

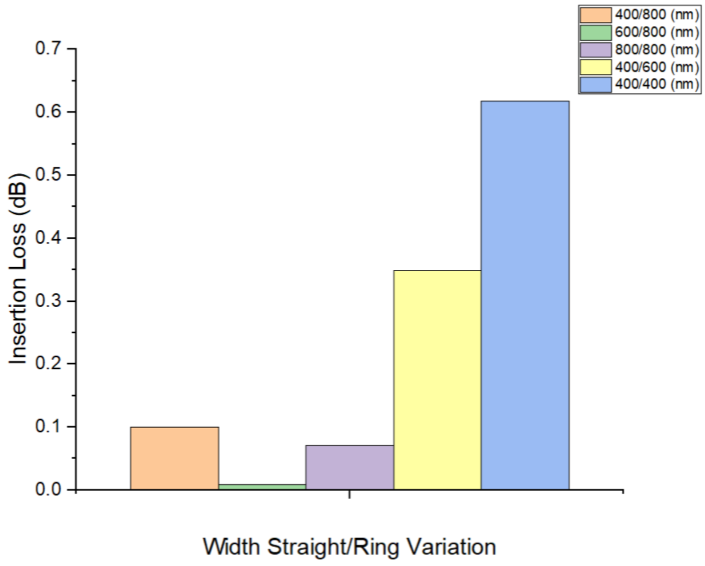

Figure 4.11 Insertion Loss of dissimilar combination of straight-ring width

The selection of dissimilar width for the straight and ring waveguide at the parameter of 400 (nm) and 800 (nm) due to the ability to make sure the light could be able to couple easily from the straight bus waveguide onto the ring waveguide and to lessen the round-trip losses within the ring waveguide and to make sure the optical pulses could be able to circulate much longer inside of the ring and filter the wavelength.

As in the graph above, the variation combination of 400 (nm) for the straight waveguide and 400 (nm) of the ring waveguide shows much of highest value of Insertion Loss at around 0.61771 dB as compared to the selection of 400 (nm)/800 (nm) at only 0.09973 dB.

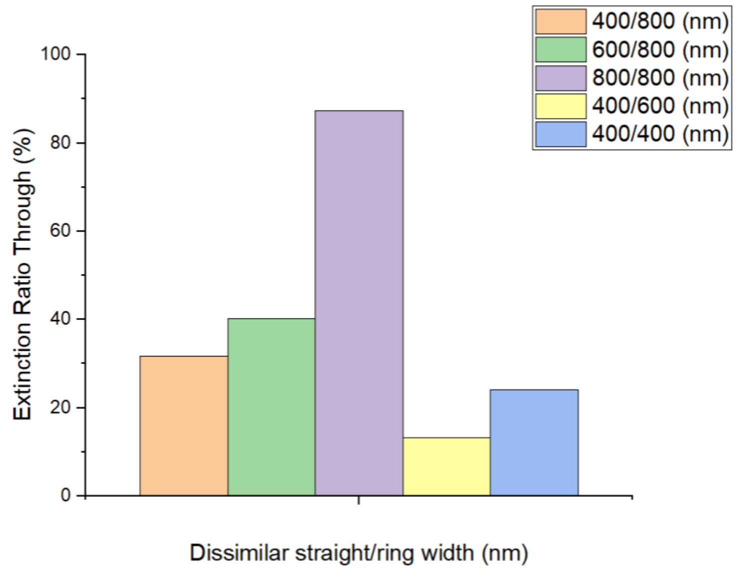

Figure 4.12 Extinction Rate of different width applied

The selection of the value of dissimilar of straight-ring waveguide width at the value of 400 (nm)/800 (nm) yield the average value as compared as to another kind of value as it would yield the result at around 31.6238 %. As we could analyze the highest Extinction Rate yield at around 87.3203 % for the dissimilar combination of 800 (nm) for its straight waveguide and 800 (nm) as the preferable value need to be at the lower as possible, it could give.

4.4 Performance of preferred optimized design

Much of testing with different parameter variation being done in previous study yield some of the among of the best result for the best configuration so far which yield the result of the best configuration by utilizing design as followed.

Table 4.2 Preferred design specification

Parameter	Value
Ring size	10 (um)
Ring waveguide width	800 (nm)
Straight waveguide width	400 (nm)
Core Refractive Index (GaN)	2.279
Cladding Refractive Index (Al_2O_3)	1.76
Wafer size	24x24 (um)
Gap separation	125 (um)
Thickness of PMMA applied	0.055 (um)

The proposed design has been tuned in towards the better data throughput regardless of its Power Spectrum analyzation and the selection of the parameter being done as it would take a proper conscious towards many drawbacks of its phase shift difference, Insertion Loss (IL) and Extinction Rate (ER).

CHAPTER 5

CONCLUSION AND FUTURE WORKS

Summarization of the whole research project would be concluded in this chapter as of it would cover the whole topics regarding the future implementation due to research's inabilities and conclusion on research works.

5.1 Conclusion

As many studies onto the different shape configuration characterization particularly its thickness of polymer grafting material applied on top of the Gallium Nitride (GaN) waveguide of the substrate of Sapphire (Al_2O_3) and so forth yield much different kind of resonant wavelength. It could be concluded that the optimized design yield much better result with the utilizing of 0.055 (um) polymer grafting material Poly(methyl) Methacrylate (PMMA) doped on top of Gallium Nitride (GaN), gap separation of 125 (um) between the waveguide and 400 (nm) of straight and 800 (nm) of ring waveguide dissimilar width structure of 10 (um) ring size and 0.55 (um) thickness of both the Gallium Nitride (GaN) and Sapphire (Al_2O_3) substrate by taking consideration of its phase shift difference (°) and lower Insertion Loss (IL) and Exticntion Rate (ER) as compared to the other variation of parameter of the design. Utilization of material Gallium Nitride (GaN)/Sapphire could give out much different result as compared to the conventional use Silicon Dioxide (SiO2)/Silica regardless same shape configuration; gap separation size, thickness of doped polymer, and dissimilar core size core being implemented on the design. The matched design of utilization of a different kind of material would differ from each other as to cap the filtering function around 1550 nm for the best value of phase shift difference, Extinction Ratio (%) and Insertion Loss (IL) as for conventional implementation of the optical communication network environment.

5.2 Research contribution

Simulating and analysing the 3D design of various parametric variation had been done using the OptiFDTD 15 software as to observe the effect of minimal changes variation towards its performance. Varying its different dissimilar size core and gap size with the optimization of different thickness of doped polymer grafting material on top both of the straight and ring waveguide of the Optical Microring Resonator (OMR) for the function of add-drop filtering with a different style of parametric study as to analyze the effect on the targeted result of the implemented application.

Implying new the study on the various parameter variation as its dissimilar width variation could yield much new conscious on the idea of improving the performance of the Optical Microring Resonator (OMR) as well as the effect of the thickness of polymer (PMMA) applied on its performance. Apart from that, utilizing the Gallium Nitride (GaN) could be able to help conserve much power penalties due to its 1% power loss resulting in much more efficient power transmission.

5.3 Recommendation

Future implementation research and analyzation of the Optical Microring Resonator (OMR) could be improved with the implementation study of implementing the design with using the 3D design as it should have been done to study different design characteristic like as of its effect on using the different multiple stacked topologies or even considering the effect on the study of implementing the micro wheel structure inside of the ring waveguide, different shape; racetrack shape, multiple numbers of ring topology itself. Considering the particular higher number of meshes to get a much more precise and more accurate result of the design should have been done in future works.

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