IMPLEMENTATION OF MMI STRUCTURE FOR OPTICAL DEVICE USING POLYMER MATERIAL

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To all my loving family members,

especially to my beloved PARENTS….

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In the name of Allah, the Most Beneficent and Most Merciful.

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ABSTRACT

Multimode interference (MMI) devices have been extensively studied and are of considerable interest as key optical components in photonic integrated circuit (PIC). The principle of the MMI devices is based on destructive/constructive interferences occurring in the MMI area with a large number of multimodes. Because of its unique properties, such as low insertion loss, large optical bandwidth, compactness, low crosstalk and excellent fabrication tolerances, the MMI devices has many potential applications such as couplers, splitters, combiners, filters and routers. Compared with silica, recently, polymeric material has lately attracted considerable attention for various waveguide devices, such as optical switches and variable optical attenuators, especially for its simple fabrication process.

ABSTRAK

Peralatan Gangguan Pelbagai Mod (MMI) telah dipelajari secara meluas dan dianggap sebagai komponen kunci/penting kepada litar fotonik (PIC). Pada umumnya, peralatan MMI adalah berdasarkan pada gangguan pemusnah/pembina yang berlaku di dalam kawasan MMI dengan jumlah nombor gangguan yang banyak. Disebabkan ciri-ciri unik seperti kehilangan penyelitan yang rendah, jalur optik yang besar, kepadatan, dan toleran pembuatan yang amat tinggi, peralatan MMI adalah berpotensi dalam aplikasi seperti pasangan, penggabung, penapis dan juga pembahagi. Berbanding dengan silika, sejak akhir-akhir ini, bahan polimer telah menarik minat ramai untuk digunakan dalam pelbagai peralatan waveguide, seperti suis optik dan atenuator optic boleh laras, terutama sekali kerana proses pembuatannya yang mudah.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

β	-	Propagation Constant
λ	-	Free Space Wavelength
c	-	Speed of Light in free space
E	-	Electric Field
H	-	Magnetic Field
n_c	-	Cladding refractive index
n_f	-	Core refractive index
ω	-	Angular frequency
n	-	Refractive index
t_g	-	Thickness of the waveguide
ε	-	Permitivity of material
ε	-	Permitivity of free space
σ	-	Conductivity of material
ρ	-	Free charge density
ψ	-	Electric or Magnetic field

LIST OF ABBREVIATIONS

PIC	-	Photonic Integrated Circuit
MMI	-	Multimode Interference
TE	-	Transverse Electric
TM	-	Transverse Magnetic
EIM	-	Effective Index Method
MZI	-	Mach-Zehnder interferometer
SiO2	-	Silica
SOS	-	Silica on Silicon
GaAs	-	Gallium Arsenide
BCB	-	Benzocyclobutene

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Fiber optics is a relatively new technology that uses rays of light to send information over hair-thin fibers at blinding speeds. These fibers are used as an alternative to conventional copper wire in a variety of applications such as those associated with security, telecommunications, instrumentation and control, broadcast or audio/visual systems.

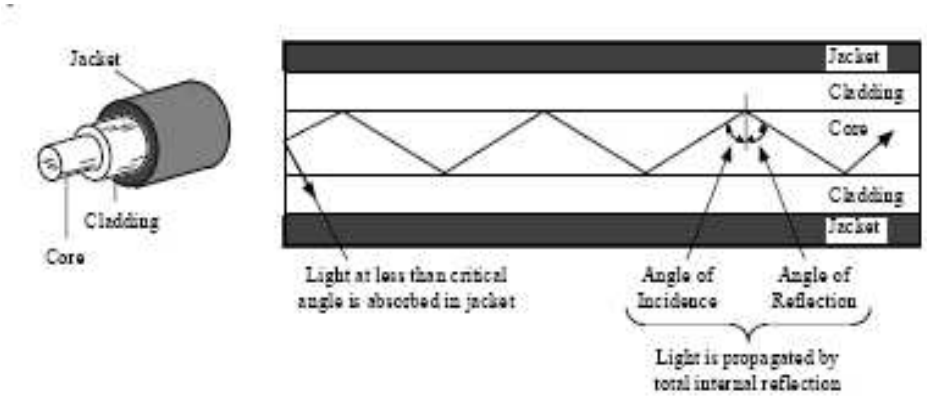

Figure 1.1 : Internal reflection in optical fibre

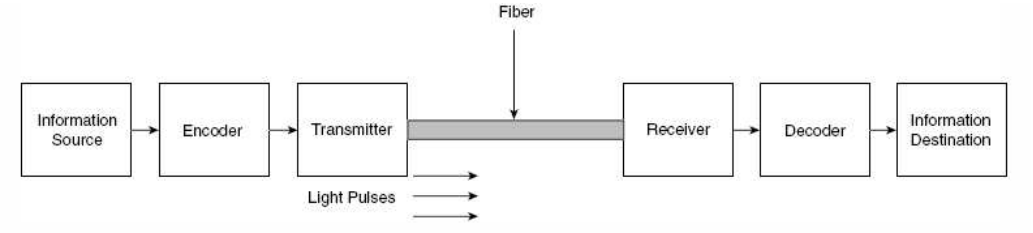

Figure 1.2 : Fiber optic communication system

One major reason for considering optical signal processing is its bandwidth (speed) advantage over electronic processors. With the increase in the transmission speed in modern optical communication systems, the application of optical signal processing in optical communication systems has been an active area of research.

As more communication capacity is demanded, more electronic components are being exchanged for optical components and many research efforts are going into integrating optical components into planar waveguide devices and photonic integrated circuit (PICs). PIC provides optical circuits connecting optical components such as optical filter, optical switches and optical amplifier.

In future, demand for application for PIC surely increase and also increased need of reducing the size of PIC. Thus, design and fabrication of ultra compact multimode interference (MMI) devices has gained more interests because of their importance in PIC.

Multi-mode interference (MMI) devices have been extensively studied and are of considerable interest as key optical components in photonic integrated circuits (PICs). The principle of the MMI devices is based on destructive/constructive interferences occurring in the MMI area with a large number of multi-modes. Because of its unique properties, such as low insertion loss, large optical bandwidths, compactness, polarization insensitivity, low crosstalk, and excellent fabrication tolerances, the MMI device has many potential applications such as couplers,

splitters, combiners, mode converters, filters, and routers. They can also be easily fabricated in more complex PICs such as ring lasers, optical modulators, MZI (Mach-Zehnder interferometer) switches, dense wavelength multiplexers, and wavelength converters.

1.2 CHALLENGES IN OPTICAL NETWORKING

The increase need for intercommunication have resulted in the intense demand for broadband services in the Internet. Currently, ongoing research is being carried out to introduce more intelligence system in the control plane of the optical transport systems, which will make them more reliable, flexible, controllable and open for traffic engineering.

In future, the critical challenges of optical networking may generally be classified into the following areas (i) Access Networks (ii) Core network architectures (iii) Integrated device and network research (iv) Network management & control (v) Robust and Secure optical networking and (vi) Application-driven optical networks.

(i) Access Networks

Efficient grooming, cross-connect and switching architectures for the optical Metro networks that can meet different (and time-varying) traffic granularity and QoS needs of users should be studied.

(ii) Core Network Architectures

One of the key issues in the design of core network architectures is how to transport data across a wide area in a cost-effective manner.

(iii) Integrated device and network research

It is evident that network architectures guide device and component technology development and at the same time, device and component capabilities influence network design. Tools for the design, modeling/simulation, and evaluation of optical devices, components and networks are of particular importance.

(iv) Network management & control

Rapid bandwidth provisioning is achievable in the next-generation optical network architectures. However, further research is required to develop the control software, physical layer modulation and signaling protocols, and mechanisms for monitoring, measurement, and fault-isolation.

(v) Robustness and security

With increasing line speeds, protection/restoration at the optical layer is clearly more attractive than restoration at higher layers in the event of fiber cuts and/or node failures. Efficient failure-resilient and survivable network architectures and protocols that take into consideration the interactions between multiple layers to achieve fast and guaranteed recovery without incurring excessive overhead should be investigated.

(vi) Application-driven optical networks

Both applications and optical networking technologies should be redesigned and existing protocols constantly improved to optimize for TCP/IP which is and will likely to remain the prevailing transport/routing protocols.

1.3 OBJECTIVES

The objective of this project is to understand the theory of Multimode Interference (MMI) structure, to identify the significant MMI structure easier to build using polymer material compared to silicon structure and also to do simulation on data measured.

1.4 SCOPE OF WORKS

The scope of works includes understanding the theory and concept of Multimode Interference (MMI) devices, the polymer-based MMI, advantages and disadvantages and also to justify the measured data.

1.5 OUTLINE OF THE THESIS

The thesis comprises of 5 chapters and the overviews of the chapter are as below:

CHAPTER 1 : This chapter provides the introduction, objective and scope of work involved in accomplishing the project.

CHAPTER 2 : The second chapter represents the literature review and explains the optical waveguide.

CHAPTER 3 : The third chapter is the overview and explanation of the multimode Interference.

CHAPTER 4 : The fourth chapter focus more on the polymer based multimode interference devices and also comparison with other material.

CHAPTER 5 : The fifth chapter concludes the thesis and suggestion for future works.