ATTENUATION MEASUREMENT ON CYCLOTENE (BCB PHOTO RESIN) POLYMER BASED SLAB WAVEGUIDE

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A project report submitted in partial fulfillment of the requirements for the award of the Degree of Master of Engineering (Electrical-Electronic&Telecommunication)

Faculty of Electrical Engineering
Universiti Teknologi Malaysia

MAC 2005

Dedicated to my beloved supervisor, wife and my two sons

KABILAN & MUGILAN

ACKNOWLEDGEMENTS

I would like to express deepest thanks to my supervisor, Associate Prof. Dr. Norazan Kassim for his invaluable guidance, support and encouragement in the completion of this project. Special thanks to Mr. Shi Yugang to be my working partner throughout this project. Without them, this work would not have been possible.

I would like to wish appreciation to members of the research group, especially to Mr. Hanif , Mr. Leow , Mr. Ahmad and Mr. Azrul for their support throughout this project.

ABSTRACT

Photonic switch /device are widely developed due to great requirement of all optical based network. The photonic device can be further divided into active and passive devices, in which for the former one, further light controlled using electric field or temperature variation is the actual characteristic. In this project, investigation of the thermo optic properties of the existing polymer in the photonic Lab was carried out. The investigation included with the literature study on the possible ways for characterizing both properties and further an experimental set-up was included in this project. Study on the attenuation and losses of light wave when it travels through polymer slab was introduced. An experimental set-up to identity the best technique to launch the light source into the wave guide by comparing the other method been done. New improved technique of the launching the light source into the fiber slab was introduced with taking into the account of attenuation and the losses at the minimum level.

ABSTRAK

Penyuisan Photonic merupakan keperluan utama dalam bidang rangkaian perhubungan optik. Keperluan optikal boleh dibahagikan kepada komponen aktif dan pasif. Di dalam projek ini, penyiasat terhadap ciri-ciri suhu, pengurangan isyarat atau kehilangan isyarat di kenal pasti melalui eksperimen di makmal "Photonic" . Dalam penyiasatan ini, kajian ilmiah dan cara – cara mengklasifikasikan komponen "Termo-Optic" di kenal pasti. Dalam masa yang sama eksperimen bagi mengenal pasti teknik bagi menghantar isyarat cahaya berbanding dengan cara-cara lain di kenal pasti. Di akhir projek ini, satu teknik bagi menghantar isyarat cahaya dalam pandu gelombang jenis "Slab" dengan mengambil kira kehilangan di kenal pasti.

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LIST OF SYMBOLS

c (m/s)	-	velocity of light in free space
B (W/m^2)	-	magnetic flux density
D (C/m^2)	-	electric flux density
E (V/m)	-	electric field intensity
H (A/m)	-	magnetic field intensity
k (m^{-1})	-	wave normal
m	-	mode number
N	-	effective index of a medium
n_1	-	refractive index of cladding region,
n_2, n_f	-	refractive index of guided wave region or film
n_3, n_s	-	refractive index of substrate layer
n_a	-	refractive index of air
n_p	-	refractive index of prism
W	-	beam width
t (μm)	-	optical guided layer thickness
t_{co} (μm)	-	cutoff thickness of waveguiding layer
v_p	-	phase velocity of an electromagnetic in a medium
β, β_m	-	z- directional component of wave vector for guided wave mode of order m
ε	-	permittivity of a medium
ε_0 (F/m)	-	permittivity of free space
θ_c (°)	-	critical angle of total internal reflection
θ_i, θ_m (°)	-	incidence angle with respect to normal
κ	-	coupling coefficient
λ	-	wavelength

μ	-	permeability of a medium
π	-	3.142
φ_{12}	-	Goos-Hänchen phase shifts for m^{th} mode, n_1-n_2 interface
φ_{32}	-	Goos-Hänchen phase shifts for m^{th} mode, n_3-n_2 interface
ω (rad/s)	-	angular frequency
∇	-	del operator
$\nabla\times$	-	curl operator

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LIST OF ABBREVIATIONS

2-D	-	Two Dimensional
3-D	-	Three Dimensional
BCB	-	B-Staged Bisbenzocyclobute
OEO	-	Optical-Electrical-Optical Switch
OOO	-	All Optical Switch
TE	-	Transverse Electric
TIR	-	Total Internal Reflection
TM	-	Transverse Magnetic
UV	-	Ultra Violet

CHAPTER 1

INTRODUCTION

1.1 Introduction

Demands of high bandwidth for present and future communication system, especially in multimedia communication have forced new technology to support these kinds of applications. Optical communication systems offer enormous potential bandwidth compared with other communication systems. Thus, optical integrated devices may play important role in networks switching to achieve 'All optical Network' (or sometimes referred to as OOO) as shown in Figure 1.1 which is subjected to replace OEO (Optical-Electrical-Optical) switching network in near future. Most curent optical switches use an electric core in switching. Advantages of OEO switch are flexible and well established but it suffers from electronic bottleneck, costly and high power consumption. Thus, the OOO technologies are becoming much more attractive than the OEO because of the avoidance of the electronic bottleneck, less expensive, low power switching and independent of data protocol [1,2]. Currently, there are few tehnologies of OOO including the thermo-optics and electro-optics which use optical waveguide as the basic components. Therefore, research in optical waveguide is still important and ongoing nowadays, in fact it is the first major step towards development of OOO technologies.

This project is mainly involved in-house fabrication and characterization of cyclotene polymer based optical slab waveguide. Slab waveguides were fabricated by deposition of polymer onto substrate to form a film layer and spinning the substrate on a spinner to spread the layer evenly. Different thicknesses of slab waveguide were realized by using different spin speed. The waveguide layers consist of the new type of polymer cyclotene 4024-40 as the waveguiding layer, microscope glass as the substrate and air as the cladding. These samples were then characterized in terms of refractive index and thickness using prism coupler measurement equipment. This technique was first successfull demonstrated in 1969 by Ulrich, Tien and Martin [3] which well explained of its basic principle.

Prism coupler is well established, versatile, accurate and reliable method and until now, many new configurations and modeling of this technique have been discussed in published journals [4,5,6] in optical measurement. It is much more interesting since this equipment is the first such system available in Malaysia. Therefore, this system need to be tested for further use in optical measurement. The next section in this chapter presents the objective, scopes and research methodology of this thesis. Description of thesis organization is presented at the end of this section.

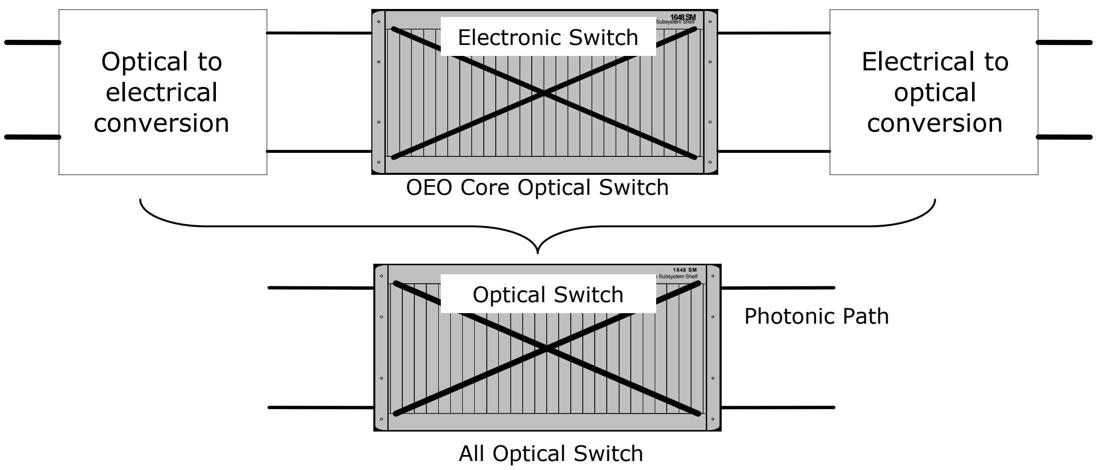

Figure 1.1: OEO and OOO switch [1]

1.2 Objectives

1) To establish the attenuation and the losses using polymer slab wave guide at various length & thickness

2) To establish the effect of rotation per minute (RPM) on the attenuation & losses for polymer slab wave guide.

1.3 Scopes of Research

i. To understand fundamentals of related areas including optical waveguide and optical measurement techniques and

ii. To study properties of cyclotene 4024-40 photo polymer from the given specifications.

iii. To understand and practice in house fabrication process of slab waveguide.

iv. To measure atenuation of the fabricated slab waveguides using prism coupler measurement equipment.

v. To make comparison between results obtained from prism coupler measurement and other measurement equipment.

vi. To analyse measured results.

1.4 Research Methodology

To achieve the objectives, the following steps as shown in Figure 1.2 has been taken:

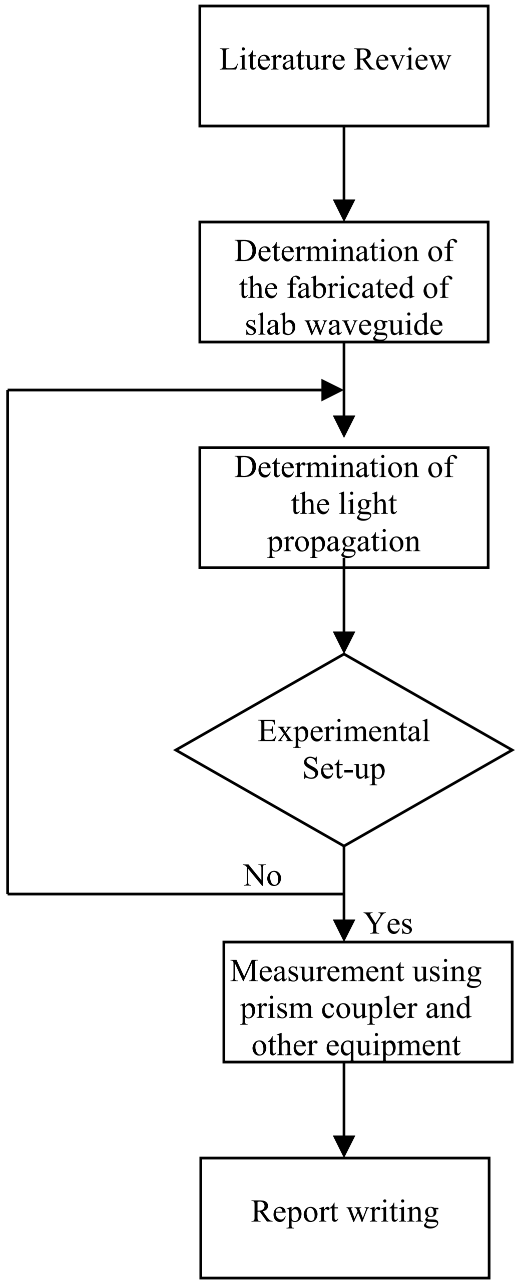

Figure 1.2: Flow chart of research methodology

This project started with literature review to understand fundamentals, requirements, problems and technology related to this topic by reviewed on published journals and books. These include fundamentals of optical waveguide, optical measurement technique, and technique of fabrication. The second stage was to determine the requirements of this project in terms of facilities, materials and equipment. Facility such as clean room for in house fabrication should be well equipped prior to the fabrication stage. A new polymer, the cyclotene 4024-40 was used in this experiment, Other equipments such the spincoater, oven, ultrasonic cleaner and hotplate were then prepared to their best condition. The third stage was examine the fabricated polymer on the light propagation with particular coated polymer. The fourth stage was to characterize the optical properties of the fabricated slab waveguide such as width of the propagated light and the attenuation using suitable set-up. All the results were collected during both stages. The final stage was to write report which is composed of all the findings, results and conclusion.

1.5 Thesis Organization

This thesis is organized into 5 chapters. Begins with Chapter 1 with explaination of motivation and importance of the project, objective, scopes and research methodology. Chapter 2 is the literature review part, presents related theories of dielectric slab waveguide which important in this research. These include the derivation of mode in slab waveguide using the ray optic and electromagnetic theory, the fabrication part, thermal effect and attenuation. In Chapter 3, presents various method used to measure attenuation, more focused on the prism coupler principle and prism coupler technique in optical measurement. This includes measurement of coupling angle in order to determine refractive index and thickness of waveguide. Measured results and analysis of data are presented in Chapter 4. Finally, Chapter 5 presents the conclucion based from all the works and results achieved throughout this research. Several recommendations for further works are also given.

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