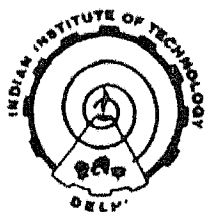


A STUDY OF THE PROPAGATION CHARACTERISTICS OF RECTANGULAR CORE OPTICAL WAVEGUIDES AND DEVICES

by
RAVINDRA KUMAR SINHA

Thesis submitted in fulfilment
of the requirements for
the degree of
DOCTOR OF PHILOSOPHY



Department of Physics
INDIAN INSTITUTE OF TECHNOLOGY, DELHI
NEW DELHI-110016, INDIA
1989

CERTIFICATE

This is to certify that the thesis entitled "A STUDY OF THE PROPAGATION CHARACTERISTICS OF RECTANGULAR CORE OPTICAL WAVEGUIDES AND DEVICES" being submitted by Mr. Ravindra Kumar Sinha to the Indian Institute of Technology, Delhi for the award of the degree of DOCTOR OF PHILOSOPHY, is a record of bonafide research work carried out by him. Mr. Ravindra Kumar Shina has worked under our guidance and supervision and has fulfilled the requirements which to our knowledge have reached the requisite standard for the submission of this thesis. The results contained in this thesis have not been submitted in part or full to any other University or Institute for the award of any degree or diploma.



(Arun Kumar)
Assistant Professor



(B.P. Pal)
Assistant Professor

Department of Physics,
Indian Insitute of Technology, Delhi,
New Delhi - 110 016
INDIA

ABSTRACT

In recent years single mode fibers have attracted a great deal of attention due to their many facet applications in optical communications and network. Lately, new applications of fiber optics are emerging in the scene such as fiber optic sensors, coherent optical communications and integrated optics. Most of these new applications require the waveguide structures such as integrated optical waveguides, high birefringent fibers, directional couplers etc; which are either rectangular in cross-section or could be modelled as rectangular core waveguides.

The present thesis is devoted to characterisation methods for rectangular core waveguides and to the study of multiport waveguide couplers formed out of rectangular core waveguides.

In the first part of the thesis, methods for characterising various rectangular core waveguides from the measurement of their far-fields are developed. The simplest optical waveguide is a planar waveguide which is a limiting case of a rectangular core waveguide for large aspect ratio. A method involving the measurements of the three angles at which the far-field intensity drops to 10%, 25%, and 50% of the maximum value is proposed to characterise an asymmetric planar waveguide. A simple method is then developed to

characterise both the symmetric and the asymmetric rectangular core waveguides. Since it is known that the elliptical core fibers could be modelled as rectangular core waveguides for estimating their birefringence, the above method was used to experimentally estimate the aspect ratio of an elliptic core fiber.

The second part of this thesis is devoted to a detailed study of multiport waveguide couplers, which are extensively used in coherent communication systems and fiber optic sensors. In chapter 4 of this thesis, a method to understand the coupling characteristics of an eight-port coupler, which can be fabricated either by (i) fusing four identical fibers or (ii) polishing the surfaces of two dual core fibers or (iii) using integrated optical channel waveguides with square cross-section, is discussed. The propagation constants of various guided modes and coupling characteristics of such eight-port couplers are discussed. A simple LP mode classification of various scalar modes and their spectral response are also presented. The method is applied to describe the various supermodes and the coupling characteristics of circular or highly elliptical core fibers arranged in a rectangular cross-section. The effect of aspect ratio of the rectangular arrangement as well as the aspect ratio of the individual waveguides on the coupling characteristics have been studied. It is observed that the

polarisation birefringence of various supermodes of a 4 X 4 coupler is of the same order as that of the individual elliptic core waveguides. Finally in the last chapter, transmission characteristics of a 4 X 4 coupler homodyne PSK receiver have been obtained. It is shown that the best performance is obtained if power is equally split in the output ports. Further, it is also shown that 90° hybrid is not a necessity for a PSK demodulation.

ACKNOWLEDGEMENTS

It is my proud privilege to have been a member of optical waveguide group (OWG) under the dynamic leadership of Professor A.K.Ghatak, who has been a source of inspiration and encouragement for my research endeavours. I am indebted to Professor I.C.Goyal for the many fruitful suggestions, I had in the early stages of this work.

Words fail to express my deep sense of gratitude to my supervisors, Dr. Arun Kumar and Dr. B.P.Pal, who have supervised this research work with utmost patience and care. Even though, at times, I let myself get involved in other activities, I admire the way they guided me through.

I would like to acknowledge my gratitude to Dr. K.Thyagarajan for constructive suggestions to improve the quality of my research papers. I take this opportunity to thank Dr. R.K.Varshney with whom I have worked endlessly. It is a pleasure to acknowledge the help he has provided to me. I also take this opportunity to thank Dr. S.I.Hosain for his active involvement in my research work during his short visits to I.I.T., Delhi. I thank Mr. P.C. Subrahmaniam for enhancing my knowledge on Communication theory.

I would like to thank Dr. Anurag Sharma who helped me in one or other way during my stay at I.I.T., Delhi. I would also like to thank Dr. Ajit Kumar, Dr. B.D.Gupta and Dr. Enakshi K. Sharma for readiness to help me in many ways.

I gratefully acknowledge the help of Dr. S.N. Sarkar, Dr.A.N. Kaul, Dr.P.K. Mishra and Mr. M.R. Ramdas in the early stage of my research work with OWG. My heartfelt thanks go to Dr. M.R. Shenoy and Dr. Ramanand Tewari, for their advice and suggestions, which kept me going on the right track. My heartfelt thanks also go to Mr. Verghese Paulose for the help he has provided me during the tenure of this work.

I have greatly enjoyed working in the company of Mr.U.K.Das, Mr. Vishnu Priye, Ms. Supriya N. Diggavi, Ms. Swagata Bannerjee, Ms. Jacintha Kompella, Ms. Vrinda Khurana, Ms. Anju Taneja, Ms. Pushpa Bindal, Mr. Saeed Pilevar, Mr. Saeed Gadhiri, Mr. Sukhdev Roy, Mr. Hemant Singh, Mr. Jaspreet, Mr. Ajay Dankar and Mr. M.P. Khare.

My family members contributed a lot for the successful completion of this work. In particular I acknowledge the encouragement provided by my brother, who wanted me to adopt research as a career. I also thank my wife, Neena for her patience and understanding.

Lastly I acknowledge the financial support provided to me by Council of Scientific and Industrial Research (CSIR), India.


(Ravindra Kumar Sinha)

CONTENTS

	Page No.
Abstract	i
Acknowledgements	iv
1 Introduction	1
2 Characterisation of Single Mode Asymmetric Slab Waveguide from far field measurements.	
2.1 Introduction	14
2.2 Theory	15
2.3 Characterisation of Symmetric Planar Waveguides.	20
2.3.1 Characterisation procedure:	22
2.4 Characterisation procedure of an Asymmetric Planar Waveguide.	23
2.5 Conclusions	27
3 Characterisation of Single Mode Rectangular core Waveguides from Far Field Measurements	
3.1 Introduction	28
3.2 Far field pattern of a rectangular core waveguide	31
3.3 Characterisation Procedure	35
3.4 Application to Elliptical Core Fibers	36
3.5 Conclusions	40

4	Scalar Modes and Coupling Characteristics of Eight Port Optical Waveguide Couplers	
4.1	Introduction	41
4.2	Analysis	44
4.3	Modes of Structure 2	46
4.4	Coupling Characteristics	51
4.5	Conclusions	56
5	Coupling Characteristics of Eight Port Coupler Consisting of Circular/Elliptical Core Fiber with Rectangular Arrangements	
5.1	Introduction	58
5.2	Circular core Fibers in a Rectangular Arrangements	59
5.2.1	Results and Discussion	63
5.3	Elliptic core Fibers in a Rectangular Arrangements	65
5.3.1	Vector modes of strucutre 2	68
5.3.2	Results and Discussions	71
5.4	Conclusions	73
6	Analysis of a PSK Homodyne Receiver using 4x4 Waveguide Coupler	
6.1	Introduction	74
6.2	Receiver Analysis	76
6.3	Proposed Signal Processing Scheme	79
6.4	Conclusions	86
	Summary and Future Scope of the Work	87
	Reference	92
	Reprints of Publications	