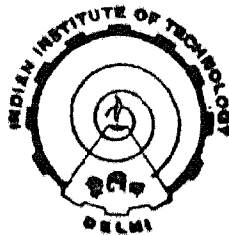


**MODELING AND ANALYSIS  
OF  
OPTICAL FIBERS AND FIBER DEVICES**

by  
**JACINTHA KOMPELLA**

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

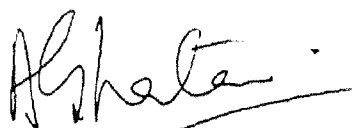


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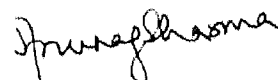
To my parents and Vach,  
who have made it possible

## CERTIFICATE

This is to certify that this thesis entitled *MODELING AND ANALYSIS OF OPTICAL FIBERS AND FIBERS DEVICES*, being submitted by **Jacintha Kompella**, to the Indian Institute of Technology, Delhi, is a record of bonafide research work carried out by her. She 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.



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## ABSTRACT

The increasing applications of optical fibers and fiber devices in optical communication, optical signal processing and optical sensing have provided an impetus for the design and development of a wide variety of fiber profiles. It is imperative then, to understand in depth, the propagation characteristics of optical fibers. Hence, there has been considerable research interest to develop models that can analyse fibers with a variety of profiles. Efforts are on to study fiber devices, which do not maintain the cylindrical symmetry of the original fiber. We have developed a few models that are suitable for obtaining relevant characteristics of fibers and devices based on them.

The first model is based on the Equivalent Step Index (ESI) approximation which has been proposed on the knowledge that, the modal field distribution of a single mode fiber is, to a large extent, insensitive to the details of its index profile. We have shown that a proper choice of fiber characteristics is necessary to obtain an appropriate ESI model. On the basis of this, a new ESI model has been developed. In the new model, there are three adjustable parameters, which are determined by matching the bendloss data and Petermann II spotsize data at one convenient wavelength in the range of 1300-1600 nm. We have carried out numerical simulation studies for fibers with parabolic and triangular index profiles having zero total dispersion at

1300 or 1550 nm. The results show that our model is both very stable, with respect to the wavelength of matching, in the range 1300-1600 nm, and very accurate for predicting fiber characteristics over this range of wavelength. The maximum errors of prediction are less than 5-6%.

Directional couplers and coupler half blocks with an overlay are in-line fiber optic devices that form an integral part of fiber links. We have developed a model for single mode fibers suitable for analysing such fiber devices. The model is based on obtaining an equivalent step index planar guiding structure for the fiber used in making the device. The resulting equivalent planar device structure can be studied analytically. This model simplifies the analysis of polished fiber directional couplers, with a buffer layer, and coupler half blocks, with dielectric and metallic superstates. We have illustrated the use of this model with some numerical examples.

Considerable research efforts have been made to reduce a 2-D index profile to an equivalent 1-D profile. The model described above is an example of one such effort. However the above model is based on two assumptions (i) the field of the fiber is separable in the cartesian coordinates  $x$  and  $y$  (ii) the fields in the  $x$  and  $y$  directions are assumed to be a two parameter cosine exponential function. While the first assumption is necessary and is dictated by the aim of separating the two dimensions so that a 1-D

equivalent waveguide can be obtained, the second assumption is open to other choices of the form of the field. We have developed a method for obtaining equivalent planar structures for circular and elliptical core fibers, without an a priori assumption for the form of the trial field. It is an iterative method based on the variational principle which leads to an optimum equivalent graded planar structure.

Finally we have developed a method of analysis for multimode graded index media. Such media have found wide applications in the field of optical imaging, optical sensing and local area networks. The rays in multimode waveguides exhibit radiation losses when, they encounter bends. Hence a knowledge of the exact ray paths and exact positions of ray caustics is necessary to calculate the power attenuation. We have developed a Lagrangian formulation for studying the ray paths in cylindrically symmetric media. We have illustrated its use for bent slabs as well as fibers with separable profiles.

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To my brother my affection and love.

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A handwritten signature in cursive script, reading 'J. Kompella'. The signature is written in black ink and is positioned above the printed name.

(Jacintha Kompella)

# CONTENTS

CHAPTER	PAGE
1. INTRODUCTION	1
2. EQUIVALENT STEP INDEX MODEL (ESI): A CRITICAL STUDY OF THE EXISTING METHODS AND A NEW MODEL WITH IMPROVED PERFORMANCE	17
2.1 Introduction	17
2.2 The ESI Methods	21
2.3 Bend Loss and the ESI Model	29
2.4 The Number and Choice of ESI Parameters	33
2.5 Choice of Fiber Characteristics to Determine ESI Parameters.	35
2.6 Extraction of ESI Parameters from Bend Loss and Spot Size at One Wavelength.	36
2.7 Performance of the New ESI Model: Simulation Studies.	37
2.8 Summary.	52
3. A MODEL FOR SINGLE MODE FIBERS TO ANALYSE FIBER DIRECTIONAL COUPLERS AND COUPLER HALF BLOCKS.	54
3.1 Introduction.	54
3.2 Existing Methods.	57
3.3.1 Basis of Equivalence of Slab with Fiber.	62
3.3.2 Equivalent Slab Structure.	68
3.3.3 Empirical Formulae to Obtain the Equivalent Slab.	69
3.4 A Simple Directional Coupler.	71
3.5 Directional Coupler with a Buffer Layer.	73
3.6 Polished Coupler Half Blocks.	79

3.6.1	Dielectric External Medium.	81
3.6.2	Metallic External Medium	85
3.6.3	Numerical Examples.	85
3.7	Summary	87
4.	A METHOD TO OBTAIN AN OPTIMUM EQUIVALENT 1-D INDEX PROFILES FOR CIRCULAR AND ELLIPTICAL CORE FIBERS	90
4.1	Introduction	90
4.2	Principle of the Method.	92
4.3	Implementation Procedure.	97
4.4	Performance of the Method.	99
4.5	Summary.	103
5.	A LAGRANGIAN FORMULATION TO TRACE RAY PATHS IN BENT WAVEGUIDES	106
5.1	Introduction	106
5.2	The Optical Lagrangian in Cylindrical Co-ordinates.	107
5.3	Ray Paths in Cylindrically Symmetric (Z-Independent) Refractive Index Profiles.	109
5.4	Ray Invariants and Equations for Profiles of the Form $n_1^2(r,z) = n_1^2(r) + n_2^2(z)$ .	110
5.5	Ray Paths in a Bent Slab Waveguide.	113
5.6	Ray Paths in a Bent Fiber.	121
5.7	Power Attenuation in a Bent Waveguide.	122
5.8	Summary.	125
	REFERENCES	128
	BIO-DATA	145