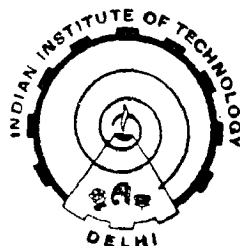


STUDIES ON PROPAGATION EFFECTS IN SINGLE MODE OPTICAL FIBRES AND DIRECTIONAL COUPLERS

by
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Thesis submitted
in partial fulfilment of the requirements of the degree of
DOCTOR OF PHILOSOPHY

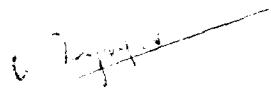



Department of Physics
Indian Institute of Technology, Delhi
January, 1985

To
my
Parents

C E R T I F I C A T E

This is to certify that the thesis entitled, "STUDIES ON PROPAGATION EFFECTS IN SINGLE MODE OPTICAL FIBRES AND DIRECTIONAL COUPLERS", being submitted by Mr. Ramanand Tewari to the Indian Institute of Technology, New Delhi, for the award of the degree of DOCTOR OF Philosophy, is a record of bonafide research work carried out by him. Mr. Ramanand Tewari 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

Single mode fibres are considered to be the most suitable transmission media for high bandwidth (because of very low dispersion) and long distance (because of very low loss) fibre optic communication systems. Most of the work in the studies of the various propagation effects in single mode fibres were restricted to the step index profiled fibres only. However, during the fibre drawing process, the profile of a single mode fibre often deviates from an ideal step index profile and yields a somewhat graded index profile inside the core; thus it is very essential to study the propagation characteristics of such fibres. In this thesis, we have studied various propagation effects in single mode, graded index fibres and also in single mode directional couplers.

The transverse modal field distribution in a single mode fibre is one of the very important parameters which characterises a single mode fibre. We have developed a variational theory by approximating the modal near-field with a Gaussian + exponential (GE) trial field to obtain the modal field distribution of graded profiled single mode fibres from its far-field radiation pattern. We have presented the results in the form of universal curves from which one can deter-

mine the modal field distribution of the fundamental mode, and also the index exponent 'q' which determines the profile shape and the normalised frequency V of a single mode fibre.

We have also made an independent study of the main propagation characteristics of the so called smoothed-out profiled fibres by exploiting the above mentioned GE trial field for the fundamental mode and have shown that for this class of fibres, the GE approximation yields the nodal field, the normalised propagation constant, the normalised group delay and the normalised dispersion parameter to a great accuracy and in particular, to a much better accuracy than the widely used Gaussian approximation, through out the single mode region.

A parameter which is often taken, both for theoretical and experimental purposes, as representing the near-field is the so called "Petermann spot size" of the fundamental mode field. It is well known that the wavelength dependence of this spot size can be used to study the various propagation effects in single mode fibres, such as splice loss, microbanding loss, dispersion and so on. We have evaluated this spot size by fitting a two parameter Gaussian-Hankel (GH) function to the exact near-field of a single mode fibre

simulated by numerical calculations. We have also shown that this GH fit to the near-field yields the spot size to a very high degree of accuracy as compared to the very widely and often used Gaussian function fit to the same near-field. We have also shown that by fitting GH function to the far-field expression of a graded single mode fibre one can obtain the near-field/spot size of the fibre simply by measuring the main lobe of a single mode fibre's far field. The proposed theory has been checked by carrying out actual measurements on a single mode fibre. The measurement of the far-field being relatively simpler than the near-field, our proposed method should be very useful in characterising single mode fibres.

Further, we have provided an accurate theoretical analysis to estimate the fundamental mode excitation efficiency in graded core single mode fibres when excited by lenses which simulates the most common optical system used for exciting and testing single mode fibres. We have shown that the power launched into the fundamental mode is highly tolerant to longitudinal misalignment while lateral misalignment is quite critical.

Finally, we have obtained the coupling characteristics of a fibre directional coupler consisting of two

identical graded profiled single mode fibres. Using the coupled mode theory for weak coupling cases, we have obtained the variation of the normalised coupling length with the fibre-fibre separation. We have formulated an empirical relation between the normalised coupling length and normalised separation. This relation must be useful for analysing directional couplers with variable spacing. We have also presented an analytical study to obtain the propagation characteristics of a directional coupler formed by two channel waveguides with graded index profiles, fabricated on chalcogenide amorphous semiconductor films by the electron beam writing technique. We have approximated the refractive index distribution of the waveguide by a secant hyperbolic profile and obtained their normalised propagation constants as well as the normalised coupling length.

CONTENTS

<u>CHAPTER</u>	<u>PAGE</u>
1 INTRODUCTION	1
2 VARIATIONAL APPROXIMATIONS FOR THE FUNDAMENTAL MODE OF SINGLE MODE GRADED INDEX FIBRES	18
2.1 Introduction	18
2.2 Scalar Variational Analysis	21
2.3 Approximations of the Fundamental Modal Fields	26
2.4 Conclusion	28
3 CHARACTERISATION OF SINGLE MODE FIBRES FROM FAR-FIELD PATTERN	30
3.1 Introduction	31
3.2 Theory	32
3.3 Experiment	35
3.4 Conclusion	37
4 DISPERSION STUDIES IN SINGLE MODE FIBRES WITH SMOOTHED-OUT PROFILES	38
4.1 Introduction	38
4.2 Theory	41
4.3 Numerical Results and Discussion	45
4.4 Conclusion	47
5 ACCURATE ESTIMATION OF FUNDAMENTAL MODE SPOT SIZE FROM NEAR-FIELD AND FAR-FIELD MEASUREMENTS	48

<u>CHAPTER</u>	<u>PAGE</u>
5.1 Introduction	48
5.2 Theory	49
5.3 Determination of $\overline{W}^2 - \lambda$ curve from The Near-Field	53
5.4 Determination of $\overline{W}^2 - \lambda$ curve from The Far-Field	55
5.5 Experimental Determination of Peterrmann Spot Size from Far-Field Pattern	57
5.6 Conclusion	59
6 MODE EXCITATION BY LENSES IN SINGLE MODE OPTICAL FIBRES HAVING GRADED INDEX PROFILES	61
6.1 Introduction	61
6.2 Theory	62
6.3 Results and Discussion	70
6.4 Conclusion	72
7 SINGLE MODE WAVEGUIDE DIRECTIONAL COUPLERS	73
7.1 Introduction	73
7.2.1 Single Mode Fibre Directional Couplers	74
7.2.2 Theory	75
7.2.3 Results and Discussion	82
7.2.4 Conclusion	83
7.3.1 Propagation Characteristics of Single Mode Waveguide Directional Coupler Fabricated by Electron Beam Writing Technique	84

<u>CHAPTER</u>	<u>PAGE</u>
7.3.2 Theory	86
7.3.3 Exact Analysis	91
7.3.4 Results and Discussion	92
7.3.5 Conclusion	94
APPENDIX	95
REFERENCES	97