

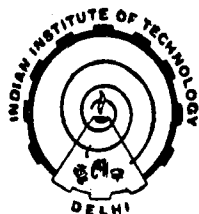
**A STUDY OF THE PROPAGATION
CHARACTERISTICS OF CIRCULAR AND
ELLIPTICAL CORE MONOMODE OPTICAL FIBERS**

by

SOMENATH SARKAR

Thesis Submitted in Partial Fulfilment of the Requirements for the

Award of the Degree of Doctor of Philosophy



DEPARTMENT OF PHYSICS

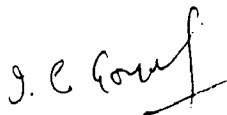
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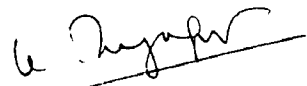
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C E R T I F I C A T E

This is to certify that the thesis entitled, "A STUDY OF THE PROPAGATION CHARACTERISTICS OF CIRCULAR AND ELLIPTICAL CORE MONOMODE OPTICAL FIBERS," being submitted by Mr. Somenath Sarkar 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. Somenath Sarkar 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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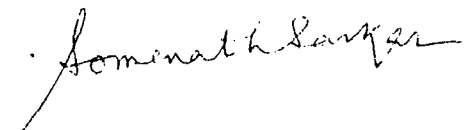
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(SOMENATH SARKAR)

ABSTRACT

Optical fiber transmission systems employing monomode fibers have, of late, attracted worldwide attention because of their large information carrying capacity (due to very low dispersion) and very low attenuation. Presently the commercially used monomode fibers for long-haul high bit rate communication systems are of circular core and nominally step-index profile. In order to utilise the minimum loss window at $1.55 \mu\text{m}$ and make use of Wavelength Division Multiplexing, system engineers have currently focussed their attention on both dispersion-shifted and dispersion-flattened monomode fibers. Such fibers are characterised by a suitable refractive index profile viz. triangular profile, W-profile (both homogeneous core as well as graded core), quadruple clad profile etc. Besides this, single mode elliptic core fibers that can maintain a definite state of polarisation of the incident beam have also attracted a great deal of attention in view of their potential applications in coherent optical communication, fiber-optic sensors and in coupling with polarisation sensitive integrated optical devices. In this thesis we have studied a number of propagation characteristics of circular and elliptical core single mode fibers.

One of the important parameters in single mode fibers is the modal field distribution and it is well known that it is possible to predict various characteristics like splice-loss, microbending loss, mode excitation efficiency, intramodal dispersion etc. if the modal field distribution is known. Since exact solutions for the modal field are available only for step index elliptic core fiber and are also quite involved, we have developed a scalar variational analysis based on Gaussian approximation of the fundamental mode of monomode elliptical core fibers. The variation of the normalised modal spot sizes (along the major and minor axes) of the step and parabolic core fibers with the normalised frequency are studied. The variation of spot size noncircularity with core noncircularity is shown to agree with the recent experimental results. The analysis has been used to calculate various splice losses at a joint between two elliptical fibers and these calculations have been compared, with experiments.

Using the above formulation, we have presented accurate empirical relations describing the spectral dependence of the spot sizes along the semi-major and semi-minor axes in a homogeneous elliptic core fiber. These relations are achieved after large number of computer simulations based on the Gaussian approximation of

the fundamental mode in a monomode elliptic core fiber. Analogous to the method used in the equivalent step index (ESI) determination of graded circular core fiber, these relations can be used to determine the ESI elliptic core fiber of a given fiber by fitting our empirical relations to the experimentally determined variations of the spectral dependence of the spot sizes along x and y directions. We have shown the applicability of the method through calculation of cut-off wavelength of a parabolic index elliptic core fiber and comparison with recent experimental results.

Using the Gaussian approximation, we have also made an in-depth study of the excitation of monomode elliptical core fibers by laser diodes (having elliptical intensity profile) through a ball lens. We have also obtained important characteristics like variation of loss with different misalignments like longitudinal, transverse and azimuthal, which gives the tolerance to these misalignments.

Since the real circular core fibers need not necessarily follow a perfect step-index profile we have developed a theory to study microbending loss in graded-core monomode fibers. We formulated an analytical method to evaluate the spot sizes determining microbending loss in monomode fibers with arbitrary refractive index profiles. Comparison with the exact numerical results shows

that the present method gives very accurate results for spot sizes. The method is simple and requires relatively less computational effort.

It has been reported from experimental observation that some of the CVD fibers exhibit profile fluctuations like ripples across their index profile. We have made a theoretical investigation as to the effect of such profile ripples on total dispersion in single mode graded index fibers. We have computed total dispersion in single mode parabolic-core fibers from the exact numerical solution of the scalar wave equation in the presence and absence of ripples in refractive index profiles. The variation of the zero dispersion wavelengths and optimum core radii with ripple amplitude and spatial frequency are given. It is observed that for larger ripple amplitude, the zero dispersion wavelength and optimum core radius increase. However, we find that if the ripple amplitude is 5% of the core-cladding refractive index difference (this is the value reported in practical fibers) the effect on zero dispersion wavelength and optimum core radius is very small (about 2-3%).

Further, we have compared splice loss sensitivities of dispersion-shifted and dispersion-flattened single mode fibers at $\lambda = 1.55 \mu\text{m}$ with different refractive index

profiles of practical interest. Since splices are highly tolerant for longitudinal separation, transverse offset and angular tilt are considered. It is observed that the trapezoidal profile with aspect ratio $S = 0.25$ and parabolic index profile give the optimum profiles for both types of losses in dispersion-shifted family alongwith the W-fiber in the dispersion-flattened group.

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