STUDIES ON OPTICAL WAVEGUIDES USED IN FIBER AND INTEGRATED OPTIC DEVICES

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by

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to my mother and father

C E R T I F I C A T E

This is to certify that this thesis entitled STUDIES ON OPTICAL WAVEGUIDES USED IN FIBER AND INTEGRATED OPTIC DEVICES, being submitted by M. Rajaram Shenoy, to the Indian Institute of Technology, Delhi, is a record of bonafide research work carried out by him. He 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

Recent advances in material fabrication and characterisation techniques, analytic tools and computational power have greatly enhanced the scope of fiber and integrated optics. Rapid progress in low loss high bandwidth optical fiber communication, as well as the increasing interest in fiber and integrated optical devices for use in non-communication applications such as signal processing and fiber sensors, has been the impetus for the design and development of a wide variety of fiber and integrated optical waveguides. The present thesis is devoted to the study of some of the waveguides and waveguiding configurations that occur in various fiber and integrated optical devices; a major portion of the thesis deals with the most important theoretical aspects of these waveguides relevant to the design of devices.

In the first part, a general and efficient matrix technique for planar waveguides with a few modes and arbitrary index profiles is established. The method involves straightforward multiplication of 2x2 matrices and does not require the solution of any transcendental/differential equation. In particular, the applicability and usefulness of the method to determine the propagation constant, field profile, and leakage/absorption losses have been demonstrated. Next, we have presented an analysis, under the

weakly guiding approximation, describing the propagation and loss in bent waveguides characterised by a separable profile, which may be graded in the transverse direction. We have then shown how the matrix method can be used to calculate accurately the bending loss in such waveguides. We have also suggested a novel refractive index profile for which the bending losses can be made extremely small. Further, the applicability of the matrix technique to one dimensional Schrodinger equation, and hence to quantum well structures, has been demonstrated. The method allows straightforward estimation of bound-state and quasi-bound state energy eigenvalues (and lifetimes of the latter) for arbitrary one dimensional potentials. Lastly, the matrix method has been extended to the analysis of optical fibres characterised by cylindrically symmetric refractive index profiles. As specific examples, three different fibres, namely, a single-clad fiber, a coaxial fiber, and a double-clad fiber are considered. Attempt in all the above examples has been to show the applicability of the matrix approach and that it is capable of yielding very accurate results. Apart from its simplicity and versatility, the most important advantage of the method is its ability to calculate the loss coefficient of a given mode in a leaky or absorbing waveguide, without involving any additional complexities unlike other numerical techniques.

In the second part of the thesis, a study on some of the birefringent waveguides has been presented. In particular, we have applied a perturbation method to determine the propagation characteristics of a rectangular-core anisotropic waveguide characterised by a diagonal dielectric constant tensor. The method has been then extended to determine the polarization characteristics of elliptic-core fibres with stress induced anisotropy; the method simultaneously takes into account both geometrical and stress birefringence. We have shown that neglecting the geometrical birefringence, even under the weakly guiding approximation, can lead to significant errors in the calculation of polarization-mode-dispersion (PMD) and the wavelength of zero PMD. Finally, we have presented an experimental technique for the measurement of propagation constant, and hence modal birefringence of highly birefringent single-mode fibers using prism (output) coupling. Experimental details and results of birefringence measurements on an elliptic-core fiber has been presented.

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