STUDIES ON SINGLE MODE INTEGRATED OPTICAL WAVEGUIDES AND DIRECTIONAL COUPLERS

by

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TO MY PARENTS AND SAVITA

CERTIFICATE

This is to certify that the thesis entitled, "STUDIES ON SINGLE MODE INTEGRATED OPTICAL WAVEGUIDES AND DIRECTIONAL COUPLERS", being submitted by Mr. Ashok Nath Kaul 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. Ashok Nath Kaul 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

Most of the research in the field of integrated optics has been simulated by the use of integrated optical devices in high speed optical - fiber and data - transmission systems. Since, waveguides constitute the basic elements of integrated optical circuits, there have been a lot of fundamental studies on these waveguides resulting in new theoretical models as well as new techniques to describe their properties. In particular, the emphasis is on the propagation characteristics of single mode waveguides, because of their importance in signal processing, switching and other device applications.

We have developed a simple numerical method to obtain the propagation characteristics of single mode inhomogeneous planar optical waveguides with arbitrary refractive index profiles. We have evaluated the propagation constant, the modal field and the cutoff frequencies corresponding to the fundamental TE and TM modes. The method has also been used to compute the cutoff frequency of the first higher order TE_1 mode, which determines the limit of single mode operation.

Metal - clad optical waveguides can be designed to act as efficient polarizers, as the loss suffered by the

TM mode is much greater than the TE mode. It is well established, that for metal - clad planar optical waveguides the attenuation of the TM mode passes through a resonance peak while the TE mode attenuation decreases monotonically. We have also made a study of the attenuation characteristics of the fundamental TM mode of a metal-clad inhomogeneous planar optical waveguide with a dielectric buffer, by making use of the above mentioned numerical method.

Since the propagation characteristics of an optical waveguide depends on its refractive index profile, it is important to have a knowledge of the refractive index profile of the optical waveguide. We have developed a method to estimate the profile of a single mode inhomogeneous planar optical waveguide from its measured propagation constants (corresponding to different wavelengths). It has been shown that even with experimental uncertainties in the measurement of the propagation constants, the profile parameters can be estimated reasonably well.

Channel waveguide directional couplers are being developed for a number of applications including beam splitters, high speed modulators, optical switches and wavelength filters. Thus, in working with such devices

it is important to understand their, coupling characteristics. We have developed an accurate analysis to evaluate the coupling characteristics of a two-channel and a three-channel waveguide directional coupler, by taking the effect of corner regions into account through the first order perturbation theory.

Finally, we have shown the applicability of the commonly used effective - index method to inhomogeneous waveguides and polarization maintaining waveguides. The method is simple and straight forward and can be used to analyse these waveguides with a reasonably good degree of accuracy.

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