EXCITATION OF A SINGLE SURFACE WAVE MODE IN
BRAGG REFLECTION WAVEGUIDES

BY

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CHAPTER 1
INTRODUCTION

Integrated optics is concerned with the guidance of electromagnetic energy at optical frequencies by thin films or strips in order to perform the necessary processing operations on information signals at optical frequencies. The wavelengths of interest lie mostly between 0.1 and 10.0μm. Its origins have been stimulated and influenced mostly by microwave engineering and thin film optics. A special role has been played by semiconductors at optical frequencies.

Use of the optical frequency spectrum offers advantages of much larger bandwidth and negligible sensitivity to interference by natural or man-made electromagnetic fields of lower frequencies.

Integrated optics has components such as light sources, modulators, and detectors that are the counterparts of those used in integrated electronics. The use of gallium arsenide (GaAs), in conjunction with some of its associated compounds provides all necessary functions for signal processing in integrated optics [1].

Modulation, detection and oscillation (lasing) are possible with GaAs whose role is analogous to that of silicon in integrated electronics. GaAs is now regarded as the basis for integrated optics systems. Lithium niobate (LiNbO₃) is a dielectric medium which is used for waveguidance at optical frequencies.

The potential applications of integrated optics are in the
fields of optical communication and in integrated electronic circuits where the optical components may replace complex electronic circuits, and where optical fibers can replace bulky cables.

One of the most important components of an integrated optics system is the optical waveguide. It is used to confine and guide the waves in a thin film as surface-wave modes so that the signal to be processed can easily be transferred from source, or input transducers, to output points, or output transducers, while at the same time providing a medium for the different signal processing operations. Thus GaAs diodes may be placed within the guiding layer so that modulation can be performed on the optical signal using the nonlinearity of the diode characteristics. The analysis of such processes will be greatly simplified if the field description in the waveguide is as simple as possible. Hence, it is preferable to have a single mode field in the waveguide. In this thesis, we are going to see how a single mode can be excited in a thin-film waveguide.

Yeh and Yariv [2] proposed the possibility of using Bragg reflection to obtain lossless confined propagation in slabs with lower dielectric constant than that of the surrounding media. But they analyzed the source-free problem. The basic idea behind their work is the use of Bragg reflection in a medium of periodically perturbed refraction index instead of the phenomenon of total internal reflection. Total internal reflection occurs when the thin film has a higher refractive index than the surrounding media thus leading to a number of waveguide modes. The
Bragg reflection waveguide uses an inverted index distribution between the thin film and its surrounding media. In other words, the refractive index of the thin film is smaller than that of its surroundings as shown in Fig. 1. Yeh and Yariv [1] applied Floquet's theorem for waves in periodic layers to show that only one mode can propagate for this choice of index distribution. In another paper [3], they extended the theory to the case of an optical fiber with an inverted index distribution, but Floquet's theory was not explicitly applied to show the single-mode behaviour. Instead, they showed that the outward flux is a minimum under the Bragg condition.

In this thesis, we look at the problem of exciting a single surface mode in a two-dimensional Bragg reflection waveguide (shown in Fig. 2) by means of a line source which is representative of any source distribution at the waveguide input (z = 0). Thus we are going to solve for the Green's function by using the bilateral Laplace transform [4]. We will find out one interesting result by considering different source frequencies, i.e. the waveguide transverse dimensions increase with increasing frequency contrary to conventional dielectric slab waveguide whose dimensions decrease with increasing frequency making it hard to obtain uniform thickness for thin film waveguides supporting a single mode. The Green's function approach also sheds the light on the efficiency of mode launching and makes it possible to calculate the field radiated by the source.

In Chapter 2, we formulate the problem for the Green's func-
tion in a two-dimensional Bragg-reflection waveguide. In chapter 3, we consider the solution of the eigenvalue equations for surface modes and leaky modes which give rise to the radiation field of the source. However, the leaky wave modes are not pursued further to calculate the radiation field and is the object of a future research effort. In chapter 4, the results of the calculation of the residues at the surface wave poles are presented for different waveguide parameters.