

Coupled-mode theory for a plane and a cylindrical wave in optical waveguide Bragg grating lenses

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Received May 19, 1980

The coupling of a plane wave and a cylindrical wave, as expressed by a Hankel function, in optical waveguide Bragg grating lenses is theoretically treated in two dimensions. Analytical solutions of the coupled-mode equations are derived, and numerical examples for lenses with rectangular corrugations are shown for both the TE and the TM modes. The results are also compared with those obtained by treatment in one dimension.

INTRODUCTION

A Bragg grating lens¹ for integrated optics is considered as a volume hologram that has the structure of an interference pattern produced by a plane and a cylindrical guided wave or by two cylindrical guided waves. The properties of volume holograms have been discussed by many authors. Kogelnik first treated the coupled-wave theory for infinite plane waves.² Solymar extended the theory in two dimensions.³⁻⁵ Kenan applied the theory to guided optical waves⁶ and analyzed the operation of crossed-beam gratings made by two finite plane waves.¹⁰

In this paper, expressions for plane and cylindrical guided waves in a dielectric three-layer configuration are given, and the coupling of these waves in a Bragg grating lens, consisting of a rectangular corrugation in the waveguide film, is theoretically treated in two dimensions. Solutions of the coupled-mode equations in integral forms are derived, and their numerical results are shown. A comparison of these results with those obtained in a one-dimensional analysis is also given.

1. WAVEGUIDE STRUCTURE AND GUIDED MODE

Consider a dielectric planar waveguide, as shown in Fig. 1, where d is the thickness of the film and n_1 , n_2 , and n_3 are the refractive indices of the substrate, film, and cover, respectively; that is,

$$n(x) = \begin{cases} n_1 & x \leq 0, \\ n_2 & 0 \leq x \leq d, \\ n_3 & x \geq d, \end{cases} \quad (1)$$

and $n_2 > n_1, n_3$. When time dependence $\exp(i\omega t)$ of the wave field is assumed, Maxwell's equations in these media are written as follows:

$$\nabla \times \mathbf{H} = i\omega\epsilon_0 n^2(x) \mathbf{E}, \quad (2)$$

$$\nabla \times \mathbf{E} = -i\omega\mu_0 \mathbf{H}, \quad (3)$$

$$\nabla \cdot \mathbf{E} = 0, \quad (4)$$

where $\mathbf{E}$, $\mathbf{H}$, ω , ϵ_0 , and μ_0 are the electric vector, the magnetic vector, the angular frequency, the dielectric constant of vacuum, and the magnetic permeability of vacuum, respectively. Here, the relative magnetic permeabilities of these media are assumed to be unity. Equations (2)–(4) lead to the wave equation for the electric field $\mathbf{E}$, given by

$$\nabla^2 \mathbf{E} + k_0^2 n^2(x) \mathbf{E} = 0, \quad (5)$$

where $k_0^2 = \omega^2 \epsilon_0 \mu_0$.

In this section, only the guided wave of the TE mode ($E_z = 0$) is considered. Then, a solution in the form

$$\mathbf{E} = \begin{pmatrix} A_x \\ A_y \\ 0 \end{pmatrix} F(x) \quad (6)$$

is obtained,^{11,12} where A_j ($j = x, y$) must satisfy the equations

$$\left(\frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} \right) A_j + \beta^2 A_j = 0, \quad (7)$$

$$\frac{\partial A_x}{\partial x} + \frac{\partial A_y}{\partial y} = 0, \quad (8)$$

and

$$F(x) = \begin{cases} \cos \Phi_1 \exp(\gamma_1 x) & x \leq 0, \\ \cos(\kappa_2 x - \Phi_1) & 0 \leq x \leq d, \\ (-1)^m \cos \Phi_2 \exp[-\gamma_2(x-d)] & x \geq d, \end{cases} \quad (9)$$

$$k_0^2 n_1^2 + \gamma_1^2 = k_0^2 n_2^2 - \kappa_2^2 = k_0^2 n_3^2 + \gamma_2^2 = \beta^2, \quad (10)$$

$$\kappa_2 d - \Phi_1 - \Phi_2 = m\pi \quad (m, \text{integer}), \quad (11)$$

$$\tan \Phi_1 = \frac{\gamma_1}{\kappa_2}, \quad \tan \Phi_2 = \frac{\gamma_2}{\kappa_2}. \quad (12)$$

For a plane wave propagating in the θ direction from the x axis, the electric and magnetic fields, respectively, are given as

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Coupled Mode Theory, 1984 This book deals with microwave and optical transmission from the unique viewpoint of Maxwell's theory and via the consistent theoretical framework of coupled modes ideal modes local modes and super modes A feature of the book is its particular emphasis on the usefulness of the coupled mode theory The author has carried out to the end the solu

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Technology A. F. Harvey,2012-12-06 Although microwaves and coherent optics being two of the largest and most useful branches of electrical engineering to emerge technologically are usually considered as distinct subjects many of the underlying fundamental principles scientific achievements and practical applications have common features Following the evolvement of the initial principles and techniques during the closing decade of the last century microwave engineering has long matured to a stage of ready availability of components automation and accuracy of measurement economical manufacturing methods and application of sophisticated systems Further this development of electromagnetic phenomena having spatial and temporal coherence has based on several centuries of study and practice of noncoherent light in the last two decades reached the optical region Hence it is now practicable to consider a comprehensive treatment of these two fields division being made by subject matter rather than by the artificial distinctions of frequency and or wavelength ranges However a full text on the combined subjects would be very large and unwieldy and thus this Bibliography is presented in the hope that it will prove useful as a compact reference source to a large body of workers and by putting forward the latest scientific and technical advances stimulate a multi disciplinary approach The material of the book commences with the fundamentals of radiation and matter progressing through components and devices amplification and generation transmission reception and processing of information and methods of measurement to conclude with a wide range of applications *Nanophotonics* Arthur McGurn,2018-04-27 This book gives a readable introduction to the important rapidly developing field of nanophotonics It provides a quick understanding of the basic elements of the field allowing students and newcomers to progress rapidly to the frontiers of their interests Topics include The basic mathematical techniques needed for the study of the materials of nanophotonic technology photonic crystals and their applications as laser resonators waveguides and circuits of waveguides the application of photonic crystals technology in the design of optical diodes and transistors the basic properties needed for the design and understanding of new types of engineered materials known as metamaterials and a consideration of how and why these engineered materials have been formulated in the lab as well as

their applications as negative refractive index materials as perfect lens as cloaking devices and their effects on Cherenkov and other types of radiation Additionally the book introduces the new field of plasmonics and reviews its important features The role of plasmon polaritons in the scattering and transmission of light by rough surfaces and the enhanced transmission of light by plasmon polariton supporting surfaces is addressed The important problems of subwavelength resolution are treated with discussions of applications in a number of scientific fields The basic principles of near field optical microscopy are presented with a number of important applications The basics of atomic cavity physics photonic entanglement and its relation to some of the basic properties of quantum computing and the physics associated with the study of optical lattices are presented

Scientific and Technical Aerospace Reports, 1992 **Technical Abstract Bulletin** Defense Documentation Center (U.S.), 1964 **Twelfth Annual Conference in European Fibre Optic Communications and Networks** Conference on European Fibre Optic Communications and Networks (12, 1994, Heidelberg), 1994 **Theory of Dielectric Optical Waveguides 2e** Paul Liao, 2012-12-02 Theory of Dielectric Optical Waveguides Second Edition focuses on the practical usage of optical waveguides This book explores the rapid growth of integrated optics which is devoted to the development of microscopic optical circuits based on thin film technology Organized into nine chapters this edition starts with an overview of the properties of dielectric slab waveguides This book then examines the theory of directional couplers with and without diffraction gratings Other chapters describe the numerical methods for solving guided mode as well as wave propagation problems This text discusses as well the beam propagation method and the popular effective refractive index method The final chapter deals with the significance of nonlinear phenomena This book is a valuable resource for undergraduate and graduate students of physics and electrical engineering Practicing engineers and scientists in the fields of integrated optics optical communications and fiber sensors will find this book extremely useful

Fano Resonances in Optics and Microwaves Eugene Kamenetskii, Almas Sadreev, Andrey Miroshnichenko, 2018-11-20 This book discusses the development of Fano based techniques and reveals the characteristic properties of various wave processes by studying interference phenomena It explains that the interaction of discrete localized states with a continuum of propagation modes leads to Fano interference effects in transmission and explores novel coherent effects such as bound states in the continuum accompanied by collapse of Fano resonance Originating in atomic physics Fano resonances have become one of the most appealing phenomena of wave scattering in optics microwaves and terahertz techniques The generation of extremely strong and confined fields at a deep subwavelength scale far beyond the diffraction limit plays a central role in modern plasmonics magnonics and in photonic and metamaterial structures Fano resonance effects take advantage of the coupling of these bound states with a continuum of radiative electromagnetic waves With their unique physical properties and unusual combination of classical and quantum structures Fano resonances have an application potential in a wide range of fields from telecommunication to ultrasensitive biosensing medical instrumentation and data storage Including contributions by

international experts and covering the essential aspects of Fano resonance effects including theory modeling and design proven and potential applications in practical devices fabrication characterization and measurement this book enables readers to acquire the multifaceted understanding required for these multidisciplinary challenges *Photonic Crystal Materials and Nanostructures* Richard M. De La Rue, 2004 Proceedings of SPIE present the original research papers presented at SPIE conferences and other high quality conferences in the broad ranging fields of optics and photonics These books provide prompt access to the latest innovations in research and technology in their respective fields Proceedings of SPIE are among the most cited references in patent literature *Proceedings of the 8th International Multidisciplinary Conference on Optofluidics (IMCO 2018)* Lei Xu, Lei Zhou, 2021-02-08 This book is a compilation of selected papers from the 8th International Multidisciplinary Conference on Optofluidics IMCO 2018 held in Shanghai on August 5 8 2018 as well as papers from the IMCO 2019 held in Hong Kong on June 14 17 2019 The work focuses on the current development in the fields of optofluidics microfluidics silicon photonics optical metamaterials and other related areas Readers from both academia and industry will benefit from the experts opinion and the latest development in the multidisciplinary field of optofluidics

Single-Mode Fibers Ernst-Georg Neumann, 2013-04-17 Single mode fibers are the most advanced means of transmitting information since they provide extremely low attenuation and very high bandwidths At present long distance communication by single mode fibers is cheaper than by conventional copper cables and in the future single mode fibers will also be used in the subscriber loop Since single mode fibers have many applications a variety of people need to understand this modern transmission medium However waveguiding in single mode fibers is much more difficult to understand than waveguiding in copper lines A single mode fiber is a dielectric waveguide operated at optical wave lengths Since 1961 I have been involved in experimental and theoretical research on dielectric rod waveguides in the microwave region From the experiments I learned much about the properties of a wave guided by a dielectric rod or a glass fiber especially about its behavior at waveguide discontinuities like bends gaps or the waveguide end Since 1972 my co workers and I have also been investigating dielectric waveguides at optical frequencies and since 1973 I have lectured on Optical Communications These activities have shown that there is a need for a tutorial introduction to the new technical field of single mode fibers In this book the physical fundamentals are emphasized and the mathematics is limited to the absolutely necessary subjects Besides presenting a physical explanation of waveguiding in single mode fibers it is also the aim of this book to give an overview of the knowledge accumulated in this field Optical Fiber Telecommunications VA Ivan Kaminow, Tingye Li, Alan E. Willner, 2010-07-28 Optical Fiber Telecommunications V A B is the fifth in a series that has chronicled the progress in the research and development of lightwave communications since the early 1970s Written by active authorities from academia and industry this edition not only brings a fresh look to many essential topics but also focuses on network management and services Using high bandwidth in a cost effective manner for the development of customer applications is a central theme

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research and development of lightwave communications since the early 1970s Written by active authorities from academia and industry this edition not only brings a fresh look to many essential topics but also focuses on network management and services Using high bandwidth in a cost effective manner for the development of customer applications is a central theme This book is ideal for R D engineers and managers optical systems implementers university researchers and students network operators and the investment community Volume A is devoted to components and subsystems including semiconductor lasers modulators photodetectors integrated photonic circuits photonic crystals specialty fibers polarization mode dispersion electronic signal processing MEMS nonlinear optical signal processing and quantum information technologies Volume B is devoted to systems and networks including advanced modulation formats coherent systems time multiplexed systems performance monitoring reconfigurable add drop multiplexers Ethernet technologies broadband access and services metro networks long haul transmission optical switching microwave photonics computer interconnections and simulation tools

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