# DEPARTMENTS

## BOOK REVIEWS

### Introduction to Photorefractive Nonlinear Optics

Pochi Yeh, 420 pages, illus., references, appendixes, author and subject index. ISBN 0-471-58692-7. John Wiley & Sons, Inc., 605 Third Avenue, New York 10158-0012 (1993) $79.95 hardbound.

**Reviewed by Ragini Saxena,** Rockwell International Science Center, Applied Optics Department, 1049 Camino Dos Rios, Thousand Oaks, CA 91360.

Photorefractive crystals are some of the most sensitive materials to date, with large refractive index changes induced by milliwatt beams over the entire visible spectrum. These crystals have been used to demonstrate a wide range of nonlinear optical applications including optical data storage and dynamic holography, phase conjugation, image amplification, information processing, optical computing, optical resonators, inertial navigation devices, and associative memories. This book lucidly describes the theory and many such applications of nonlinear optics in photorefractive media. Other books on photorefractive materials, effects, and applications are edited volumes that are not suitable as textbooks. An introductory book on photorefractive nonlinear optics is essential for both researchers and students. Yeh's book is the first self-contained comprehensive treatment of the field that can serve as a text for an advanced course in modern optics for electrical engineering and applied physics students and also provide an excellent introduction for new researchers in this field.

In the first chapter, the author introduces wave propagation in anisotropic media and gives examples of the linear electro-optic effect in photorefractive materials like GaAs and $BaTiO_3$, different from those discussed in *Optical Waves in Crystals* by Yariv and Yeh. The second chapter gives a detailed description of wave propagation in periodic media, since many photorefractive phenomena involve the scattering of light from periodic index gratings induced in the medium. Thin and thick gratings are clearly distinguished, followed by a thorough derivation of the coupled-mode theory for diffraction from fixed uniform index gratings (transmission and reflection) with and without phase mismatch. The text is suitably augmented with numerical examples and plots and should be easier to follow than the classic paper on this subject by Kogelnik ["Coupled wave theory for thick hologram gratings," *Bell Syst. Tech. J.* **48,** 2909 (1969)], which the author does not reference. A discussion on transmission and reflection absorptive gratings would also have been appropriate in this chapter. The chapter concludes with an excellent description of Bragg diffraction in anisotropic media and the powerful technique of the grating integral used in solving wave mixing in photorefractive media, with no reference to relevant papers published in the field. The third chapter describes the mechanisms responsible for the photorefractive effect and derives the steady-state space-charge field by means of the band-transport model. Special cases of applied dc electric field, moving grating, transient response, and photovoltaic effect are all derived coherently in this chapter. No attempt is made to relate the different notations in the literature characterizing the photorefractive response in terms of electric fields, response times, or transport lengths, and the Hopping model of the photorefractive effect is not discussed. Chapter 4 describes several aspects of two-wave and four-wave mixing in photorefractive media: transmission and reflection gratings, nondegenerate frequencies, anisotropic coupling, etc. Students will benefit tremendously from the results of various research papers derived simply in the longest chapter of the book. The same field notation throughout the chapter facilitates comparison of the various cases. Numerical plots illustrate the energy exchange involved in the wave-mixing process in photorefractive media, and the equations for four-wave mixing are also solved by means of the grating-integral method. The subsequent chapters describe some of the applications of photorefractive materials in nonlinear optics, a task made easier by the monumental Chaps. 3 and 4. Uni- and bidirectional ring oscillators and linear resonators are discussed in Chap. 5, while self-pumped and mutually pumped phase conjugation are discussed in Chap. 6. The nuances of photorefractive gratings, where a read beam writes a new grating with its diffracted component, are explained in Chap. 7 along with discussions on fixed gratings not subject to erasure during readout. The chapter concludes with an impressive explanation of integration constants in four-wave mixing based on reciprocity. The important issue of k-space degeneracy and storage capacity in photorefractive media is addressed in Chap. 8, while Chap. 9 describes phase-conjugate interferometry. Applications of photorefractive media to optical interconnections and neural networks are discussed in Chap. 10, while some other applications are described in Chap. 11. Since "many of the subjects covered in this book are the result of several years of research and development carried out by my colleagues and myself" at the Rockwell International Science Center, the applications included reflect the author's vast experience, yet a reader with some interest in the field could question the selection of topics.

My overall view is that this book is an invaluable contribution to the field of photorefractive nonlinear optics. The style employed is simple and effective, and the division of the book into chapters is well planned. This book will become a standard as an excellent text for a graduate-level course and also as a comprehensive introductory book for researchers in the field. The lack of complete references was anticipated by the author: "I apologize to any of my colleagues whose work has not been acknowledged or adequately represented in this book," since "this is primarily a textbook!"

## Optical Waveguide Analysis

Masanori Koshiba, x + 160 pages, illus., bibliography. ISBN 0-07-035368-9. McGraw-Hill Advanced Science and Technology Series, McGraw-Hill, Inc., 1221 Avenue of the Americas, New York 10020 (1992). Translated from *Hikari Doharo Kaiseki,* Asakura Shoten, Tokyo, Japan (1990). $45 hardbound.

**Reviewed by Richard P. Kenan,** School of Electrical Engineering, Georgia Institute of Technology, 777 Atlantic Drive, Atlanta, GA 30332-0250.

This very short book is intended to be an "easy to understand introduction to the analysis of optical waveguides" and is intended for use by undergraduate and graduate students as well as beginning researchers in related fields. It is easy to understand if you are already familiar with integrated optics, and most readers of this book should already have had courses or exposure to integrated optics.

There are 10 chapters in all. The first three chapters comprise a review of integrated and fiber optic waveguide technology. The next two chapters are reviews of analytical approximate solutions for optical waveguides, culminating in Chap. 5 with an overview of the equivalent-network method in which the wave equations for transverse confinement are replaced by the equivalent telegrapher's equations, enabling solution by standard transmission-line methods.

Together, these five chapters comprise a concise vade mecum—a compact reference to carry with you—of guided-wave optics that will be useful to many students and researchers who are already familiar with the technology; newcomers will find the going rough.

The final five chapters provide an overview of numerical analysis of optical waveguides. These chapters provide analyses, exclusively by the finite-element method, for planar, channel, and fiber guides, including measures that may be used to avoid the spurious solutions that are the main headache of this method.

It is both remarkable that this book is able to provide so much information in so few pages and a bit disappointing that none of the other numerical methods—finite difference methods, the method of lines, beam propagation, etc.—are discussed at all. Given the intentional brevity of the work, the approach taken is certainly justifiable and the choice of a single illustrative technique is understandable. Furthermore, in the introduction the author expresses the hope that he will be able to discuss other waveguide problems (for example, problems where the effective mode index may vary longitudinally) in the future; I hope that he may also venture into discourse on other numerical techniques.

The book is a translation of the author's Japanese text. The translation is generally very good, with one exception: the use of the word "only" as a substitute for "however" or "but" [on p. 17 just before Eq. (2.31) and on p. 18 just after Eq. (2.32)] is confusing; I recommend just deleting the word "only" in both sentences.

The chapter titles are as follows: Types of Optical Waveguides and Analytical Techniques, Basics of Optical Waveguide Analysis, Optical Waveguide Modes, Analytical Approximation Solutions for 2-D Optical Waveguides, Analytical Approximation Solutions for 3-D Optical Waveguides, Finite-Element Analysis of 2-D Optical Waveguides, Finite-Element Analysis of 3-D Optical Waveguides, Finite-Element Analysis of Axisymmetrical Optical Fibers, Finite-Element Analysis of Non-Axisymmetrical Optical Fibers, and Finite-Element Analysis of Nonlinear Optical Waveguides.

Altogether, the book provides students and researchers alike a convenient summary and guide to the technology and a serious look at how one numerical analysis technique of a rather general nature may be applied.

The bibliography is divided into topical areas but numbered from start to end. This division allows the reader to select directly from the bibliography those references of most interest, which is a nice touch that required extra work on the part of the author.

This is a good piece of work that will provide those who are serious about working on the analysis of optical waveguides a good starting point. It is simultaneously a sales piece for the finite-element method and a handy reference for everyone.

## BOOKS RECEIVED

**Light and Electron Microscopy,** by Elizabeth M. Slayter and Henry S. Slayter. xvi + 312 pp., illus., subject index, author index, references following each chapter, list of abbreviations, appendix. ISBN 0-521-32714-8. Cambridge University Press, 40 West 20th Street, New York, NY 10011-4211 (1992) $64.95 hardbound, $27.95 softbound. Covers light and electrons, wave interactions, interference effects and diffraction patterns, polarized light, lenses, imaging: microscopy and diffraction, contrast, resolution, the light microscope, imaging of phase objects, polarizing microscopy, prospects for biological x-ray microscopy, the conventional transmission electron microscope, scanning microscopes, practical aspects of electron microscopy, the quest for ultimate electron microscopic resolution, innovations in microscope development, and photography.

**Rare Earth Doped Fiber Lasers and Amplifiers,** edited by Michel J. F. Digonnet. From the Optical Engineering Series. xv + 659 pp., illus., index, references following each chapter. ISBN 0-8247-8785-4. Marcel Dekker, Inc., 270 Madison Avenue, New York, NY 10016 (1993) $165 hardbound. Topics include rare earth doped fiber fabrication: techniques and physical properties, optical and electronic properties of rare earth ions in glasses, devices and configurations for fiber laser sources and amplifiers, theory of operation of laser fiber devices, $Nd^{3+}$- and $Er^{3+}$-doped silica fiber lasers, narrow line width and tunable fiber lasers, broadband operation of erbium- and neodymium-doped fiber sources, Q-switched fiber lasers, mode-locked fiber lasers, rare earth doped heavy-metal fluoride glass fibers, erbium-doped fiber amplifiers: basic physics and characteristics, and applications of fiber amplifiers to telecommunications systems.

**Introduction to Photorefractive Nonlinear Optics,** by Pochi Yeh. From the Wiley Series in Pure and Applied Optics. xii + 410 pp., illus., subject index, author index, problems and references following each chapter, four appendixes covering convergence proof of perceptron, storage capacity of associative memory, useful mathematical formulae, and useful integrals. ISBN 0-471-58692-7. John Wiley & Sons, Inc., 605 Third Avenue, New York, NY 10158-0012 (1993) $79.95 hardbound. Covers electromagnetic waves in crystals, electromagnetic propagation in periodic media, photorefractive effects, wave mixing in photorefractive media, photorefractive resonators, photorefractive phase conjugators, diffraction properties of gratings in photorefractive media, volume holograms and planar holograms, phase conjugate interferometry, optical computing, other applications, and higher order photo-induced gratings.

**Particle Field Holography,** by Chandra S. Vikram. xv + 265 pp., illus., subject index, references. Volume 11 of the Cambridge Studies in Modern Optics series. ISBN 0-521-41127-0. Cambridge University Press, 40 West 20th Street, New York, NY 10011-4211. Covers historical background, introduction to holography, general theory of in-line Fraunhofer holography, system design considerations, practical considerations, analysis of reconstruction, aberrations and their control, hologram fringe-contrast and its enhancement, non-image plane analysis, velocimetry and high speed holography, and the off-axis approach.