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Review: 'Theory of Dielectric Optical Waveguides,' 2nd edition, by Dietrich Marcuse

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DEPARTMENTS

BOOK REVIEWS

Fiber Optic Communications Handbook

Edited by Federico Tosco, 2nd ed., 1178 pages, illus., index, references, list of abbreviations. ISBN 0-8306-3201-8. TAB Professional and Reference Books, Blue Ridge Summit, PA 17294-0850 (1990) $89.50 hardbound.

Reviewed by Bernd D. Zimmermann, FIMOD Corporation, P. O. Box 11192, Blacksburg, VA 24062.

The *Fiber Optic Communications Handbook,* compiled by the Technical Staff of Centro Studi e Laboratori Telecommunicazioni (CSELT), Torino, Italy, presents an overview of optical fiber telecommunications technology. In addition to providing a detailed reference document, the book allows the reader to obtain a general impression of the status of fiber optic technology in Europe. Eighty pages of international references support the technical sections of the book and numerous illustrations throughout the book complement them. Different disciplines associated with optical fiber signal transmission are covered in great (but not excessive) detail. Because the different disciplines are covered by various contributing writers, some aspects are repeated as introduction/background information to new chapters. This makes some chapters "stand-alone" sections that could have been linked together more smoothly with allusion and reference to previously mentioned information. Nonetheless, this approach is common in many reference books. A few typographical errors can be found throughout the book and will hopefully be corrected in later editions. Some semantics and technical symbols seem to follow the European/Italian style of writing, but are not excessively difficult to follow once encountered a few times.

The book is divided into six parts: The Transmission Medium (optical fiber), Sources and Dectors, Optical Cables and Passive Devices, Systems, Integrated Optics, and Advanced Topics in Optical Communications. The first part includes a discussion on optical fiber types and their properties, fiber materials and fabrication techniques, theoretical principles of optical fibers, and fiber characterization techniques. A highlight in this part is the in-depth treatment of optical fiber propagation theory. The second part covers electro-optical sources (LEDs and laser diodes), photodetectors (mainly silicon and germanium photodiodes), and materials/fabrication techniques used to achieve heterojunction structures. The resolution with which microphotographs of various electro-optic devices have been reproduced in the latter part of Chap. 7 is impressive. The third part on cables and passive devices lacks detail, particularly in the theoretical analysis of cable design, splices/connectors, and couplers/splitters. Because these devices form an integral part of fiber optic telecommunication systems and have direct impact on system performance, a more precise treatment is required. Basic stress/strain relationships for optical fiber cables, as well as simple fiber misalignment loss expressions, for example, should have been included in Chaps. 8 and 9. The fourth part discusses intensity modulated-direct detection (IM-DD) system design considerations (Chap. 10), applications for such systems (Chap. 11), and a variety of circuit design aspects related to these applications (Chap. 12). These three chapters are examples of earlier mentioned "stand-alone" chapters that seem to have been written without regard to previous chapters. Chapter 10, for instance, discusses in part optical fiber characteristics without ever referring to the first chapter of the book. The fifth part (Chaps. 13 through 18) discusses integrated optics technology at great detail, again with numerous illustrations and excellent device photomicrograph reproductions. The book concludes with Chaps. 19 and 20, which address advanced optical communication topics such as nonlinear fiber optics and all-optical amplifiers. These two chapters need updating, because significant advances in the area of nonlinear optics and all-optical amplifiers have occurred in the last few years. The most recent reference regarding optical fiber amplifiers listed in this edition of the book, for example, dates back to 1989. The developments since then have made this part of the book obsolete.

In summary, this book is another tool for engineers and scientists to use as a reference in the design of fiber optic communication systems. The reader, however, should not expect the latest fiber optic developments to be included in this edition and may opt to look for a more recent source that covers these developments in greater depth.

Theory of Dielectric Optical Waveguides: 2nd Edition

Dietrich Marcuse, 380 pages, illus., index, references, ISBN 0-12-470951-6; Academic Press, 465 South Lincoln Drive, Troy, MO 63379 (1991) $59.95 hardbound.

Reviewed by Bradley D. Duncan, University of Dayton, Center for Electro-Optics, 300 College Park, Dayton, OH 45469-0226.

I suppose I ought to say up front that while preparing this review I often found myself feeling very much like a student evaluating his teacher. After all, it was, in part, the first edition of Dietrich Marcuse's *Theory of Dielectric Optical Waveguides* (among a handful of other similar texts) from which I first studied the principles of optical waveguide theory under the demanding, yet patient and graceful guidance of Dr. Ahmad Safaai-Jazi (presently associate professor of electrical engineering at Virginia Tech). Thus with the utmost respect for a teacher whom I have never met, I shall try to faithfully share my thoughts and feelings regarding the second edition of the *Theory of Dielectric Optical Waveguides.*

A few years have passed since I was first immersed in the study of optical waveguides. Last semester, though, I once again found myself spending more than an occasional late night studying Marcuse's book. This time, however, in preparation for my own graduate-level course in optical waveguide theory, which I teach at the University of Dayton. I chose the second edition of *Theory of Dielectric Optical Waveguides* as the text for my course for several reasons. First, I was already familiar with the first edition. Second, the book is well organized into only nine succinct and fairly "digestible" chapters, each of which follows in a logical order from the one preceding. Clearly, Marcuse makes no attempt to provide an encyclopedia of all topics relevant to the study of optical waveguide theory, yet he succeeds in detailing the more fundamental concepts and provides a nice springboard from which further study may begin. This was very important to me since the primary text for my first course in optical waveguide theory as a graduate student was an unpleasant and absolutely overwhelming "RAGU" style ("It's in there!") text that I still consider to be somewhat intimidating. (Marcuse's book was one of the suggested references I often consulted.) And third, the book is written at a level appropriate for upper-level graduate study. (My students for this course tend to be second-year master's or doctoral-level students.) I should mention that Marcuse claims in the preface to the second edition that he feels this text is appropriate for a broader academic audience consisting of undergraduate students in physics and electrical engineering as well. I have to disagree. This is a fairly advanced book, and I doubt many undergraduate students in physics or electrical engineering would be adequately prepared to wade through Marcuse's math (I doubt I would have been), much less be able to appreciate the wealth of knowledge and concepts he presents. I think a course or two in graduate electromagnetics is a necessity before tackling this book. This is not to say that undergraduates should not be exposed to optical waveguide theory, I just would not use Marcuse's book.

As for the content of the book itself, Marcuse wastes no time in getting directly to the point. Right on the first page of Chap. 1 Marcuse begins his discussion of the asymmetric slab waveguide. By the second paragraph, he is already discussing guided modes, even- and odd-field distributions, and cutoff frequencies. The chapter provides little introductory material other than saying that dielectric slabs are among the simplest optical waveguides. Clearly, Marcuse assumes the reader has some previous exposure to basic optic principles and/or electromagnetic modal analysis. Nevertheless, I like Chap. 1. Both the geometric and wave optics analyses of the asymmetric slab waveguide are clear and easy to follow. In fact, in a graduate fiber optics course I also teach. I use Marcuse's ray optics analysis of the slab waveguide to introduce/review the concepts of wave guidance. Furthermore, in addition to his detailed discussions of guided modes, Marcuse introduces the concepts of radiation modes and leaky waves as part of his treatment of the asymmetric slab waveguide. I attempted a detailed discussion of these topics in class, but after noticing one too many yawning students, I decided that a more qualitative than quantitative analysis of radiation modes and leaky waves would have to suffice. Fortunately, Marcuse provides adequate qualitative material to help out here, especially in the early pages of Secs. 1.4 (Radiation Modes of the Asymmetric Slab Waveguide) and 1.5 (Leaky Waves). Unfortunately, though, due to my truncated discussion of radiation modes and leaky waves I was forced to skip Sec. 1.6 (Hollow Dielectric Waveguides) altogether, and I, frankly, have still not read that section in detail. To end Chap. 1, Marcuse provides an analysis of the rectangular dielectric waveguide. This section is also for the most part clear and easy to follow, and my students seemed to wake up since the analysis is primarily based on guided wave principles. In fact, one of my students found this section interesting enough that he based his term project on numerical simulations of the field distributions and propagation constants of guided modes in rectangular dielectric waveguides. The project proved to be a challenging one, for which he, in part, earned an "A" in the course.

Chapter 2 (Weakly Guiding Optical Fibers) is probably the one on which I spent the most amount of class time. My feelings about Chap. 2 are, however, mixed. On the one hand, I have found no errors in Marcuse's analysis of the weakly guiding optical fiber, and the derivation of the linearly polarized mode fields and the corresponding eigenvalue equation are mostly straightforward and easy to follow. On the other hand, however, I feel the overall presentation of the material is cumbersome and could be made more clear. For instance, Marcuse presents the eigenvalue equation for the weakly guiding fiber on page 68 but waits for 10 pages until he discusses the standard normalization of this equation in terms of the normalized propagation constant b and the normalized frequency V. I personally feel this discussion and the associated b versus V curves of Fig. 2.3.1 should follow immediately after the introduction of the eigenvalue equation. Furthermore, Marcuse waits until after his discussion of the radiation modes of the optical fiber before discussing what happens to guided modes at cutoff! I feel this discussion should be moved up to follow closely after the introduction of the eigenvalue equation as well.

My final comment on Chap. 2 is that Marcuse obviously assumes the reader is already familiar with the true mode solutions of nonweakly guiding optical fibers. This assumption is clear because of his many references to hybrid mode field solutions and his corresponding comparisons of the true mode results to the approximate results he derives for the weakly guiding fiber. (Fortunately, my students had been previously exposed to the true mode solutions of the optical fiber, so for them Marcuse's comments were mostly beneficial.) By contrast, Marcuse spends almost no time discussing the LP_{lm} (linearly polarized) mode field designation. This is unfortunate since a great deal of physical insight into the spatial distributions of linearly polarized modes can be obtained when one realizes that the mode numbers l and m are very closely related to the number of azimuthal and radial zeros, respectively, present in a given linearly polarized mode.

I used the material of Chaps. 3 (Coupled Mode Theory), 4 (Applications of the Coupled Mode Theory), 6 (Theory of the Directional Coupler), and 7 (Grating-Assisted Directional Couplers) to round out the last few weeks of the semester. I got to this material late not because the first two chapters are overly difficult or long, but because (as professors do) I covered a lot of additional material not contained in Marcuse's book. Nevertheless, a tremendous amount of information is covered in Chaps. 3, 4, 6, and 7; with Chaps. 6 and 7 being new to the second edition of the *Theory of Dielectric Optical Waveguides*. It was thus necessary to limit my discussion of any one topic to give some attention to all. In essence I spent quite a bit of time developing the coupled wave equations for perturbed waveguides after which I provided a handful of application examples of the results. Largely my treatment of these topics closely followed Marcuse's more detailed development. As for the material of Chaps. 6 and 7, I chose to describe the action of directional and grating-assisted directional couplers based on an approximation to the coupled mode theory of Chap. 3, which assumes a weak interaction of the constituent coupled waveguides from which the coupler is constructed. Whereas Marcuse presents a more exact analysis based on the interaction of the even and odd compound modes of the composite waveguide structure. I think maybe the next time I'll cover Chaps. 6 and 7 more closely, as the analysis Marcuse presents is quite interesting and leads, I believe, to more exact and robust results.

My study of the remaining chapters has been less formal than that of the earlier chapters and, quite frankly, I have spent very little time studying the finer details of Chaps. 5 (Coupled Power Theory), 8 (Approximate and Numerical Methods), and 9 (Nonlinear Effects). My gut impression of Chap. 5 is that this is a chapter well suited for the dedicated waveguide theorist interested in studying mode coupling in multimode waveguides. Being a bit more practically oriented in my personal study of optical waveguides, I have yet to find sufficient reason to wade through all the math. Chapter 8 (also a new chapter in the second edition), on the other hand, is a relatively short chapter (only 29 pages), which I do intend to study in detail for possible inclusion in my course next year. In that chapter, Marcuse presents the beam propagation and effective index methods, both of which provide powerful techniques for obtaining numerical solutions to wave guidance problems in complex structures. And finally, Chap. 9 (the fourth new chapter in the second edition) is devoted to the more rudimentary concepts of nonlinear optical phenomena with specific emphasis given to the solution.

My bottom line impression of the second edition of the *Theory of Dielectric Optical Waveguides* is for the most part very good. Every time I pick this book up, I learn something new. This text has been, and will continue to be, one of my primary and most recommended reference books on optical waveguide theory. But this book is not for the uninitiated. In the words of one of my top students, "the book is definitely technically rigorous enough,...but for the uninitiated student, it can be a very tedious and unexciting experience." I tend to agree. I think the primary problem is that Marcuse often presents very rigorous math to the exclusion of providing physical insight. For instance, the same student mentioned that "it's possible to go through more than 20 pages of text and equations before running across [an illustrative] figure." Though the section to which he was referring was an extreme example, his comment embodies my overall frustration with this book as a course text. Nevertheless, a part of me still loves this book! I think it's destined to be a classic.