5-1992

Review: 'Optical Fiber Communications' (2nd edition), by Gerd Keiser

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DEPARTMENTS

BOOK REVIEWS

Optical Fiber Communications

Gerd Keiser, 2nd ed., 464 pages, illus., index, references, and five appendixes. ISBN 0-07-033617-2. McGraw-Hill, Princeton Road, Highstown, NJ 08520 (1991) $59.41 hardbound.

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If first impressions are worth anything (and they usually are), I would have to admit that my first impression of the second edition of Gerd Keiser's now popular text *Optical Fiber Communications* was quite good. My compliments are hereby extended to the publisher for choosing a rather handsome cover and dust jacket. It stands in strong contrast to the text's first edition, which still ranks as probably the ugliest book I own, with color choices ranging from dull cream and "baby" blue to pale pink! I am now happy to say that this older version has been discretely retired to the lower reaches of my furthest office book shelf—down near my few remaining college texts on psychology and chemistry and a long forgotten copy of David Singmaster's classic *Notes on Rubik's Magic Cube.*

Trivial though these initial feelings were, I found myself compelled to open the cover and investigate further. What I found was an expanded and extensive introductory text on fiber optic principles. Most of the topics one could imagine covering in a single-semester introductory course on fiber optics are examined in at least some detail in this book, with lots of relevant homework problems at the end of each chapter. (A solution manual is available.) The figures and tables crucial for visualizing the many transcendental functions encountered in fiber optic modal and dispersion theory are numerous and well presented, and the reference lists following each chapter are extensive. I counted 749 references in all. Because I was already fairly familiar with the overall content of the text, having read the first edition, I rather hurriedly adopted the second edition for use in my first-year graduate course in fiber optics at the University of Dayton. For the most part, I am happy to say, I was not disappointed. To assist in my further evaluation of this edition, though, I asked my fiber optics students this past fall semester (1991) to provide written critiques of appropriates sections as part of each homework assignment. I will attempt to faithfully share their impressions and comments, as appropriate, as part of this review.

Chapter 1, of course, provides a general introduction to fiber optic concepts and terminology as well as an overview of the text as a whole. This chapter has been expanded in the second edition, and my students and I uniformly agreed that it provided a good foundation for the course as well as the rest of the text. Enough said.

Keiser then takes us on an intellectual roller coaster ride through Chap. 2. Sections 2.1 and 2.2 discuss the "Nature of Light" and "Basic Optical Laws and Definitions," respectively. I personally feel these sections are overly simplistic and do not adequately prepare the student for the more detailed modal analyses presented in some of the later sections of Chap. 2—although I recognize that this is not primarily a text on electromagnetic theory. Specifically, because most of my students had not had an advanced course in applied electromagnetics, I felt it necessary to review more fully some rudimentary electromagnetic principles, for instance, the derivation and solution of the wave equation for various coordinate systems in uniform media, boundary condition requirements, and the Poynting vector. In addition, I have found that a detailed ray analysis of the optical fiber is very helpful to the student in initially gaining an intuitive feel for optical wave guidance. Keiser attempted such an analysis, but ultimately left me unsatisfied. In Sec. 2.3.4, Keiser explains that total internal reflection is a necessary condition for guided wave/ray propagation and that light must enter the optical fiber through the numerical aperture (NA), which he derives analytically to satisfy this condition. Keiser then explains in Sec. 2.3.5 that other phase matching conditions exist that must be satisfied for wave guidance, and he attempts to provide an argument as to why only energy entering the fiber at discrete angles within the NA are allowed to propagate.

Although Keiser's intent is clear and his conclusion that only discrete guided ray angles are allowed within the NA is correct, I believe that his "proof" is in error. Specifically, in his derivation of Eq. (2-26) (which in essence represents a guided wave eigenvalue equation derived from a ray analysis approach), Keiser asserts that a single guided ray must encounter a $2n\pi$ phase shift after propagating the maximum distance through the waveguide that yields only two total internal reflection events.

I believe a more appropriate analysis of this problem was presented by Marcuse. In essence, Marcuse's approach begins with the premise that a given guided ray must propagate along a path such that its phase at any given point is within $2n\pi$ of an analogous ray propagating in a uniform medium of index of refraction equal to that of the waveguide core region. The validity of Marcuse's approach is verified by the fact that by his method one can exactly derive the eigenvalue equation for guided modes in symmetric and asymmetric planar waveguides by using ray techniques. This is not the case if one follows Keiser's approach. (To be fair, though, I should mention that Sec. 2.3.5 is only about one page long.) Thus ends Keiser's ray analysis. I, however, generally find it necessary to continue the ray analysis to include discussion of how transverse standing waves and evanescent waves arise in the core and cladding regions, respectively. I end my ray discussions by introducing the concept of effective modal indices and by discussing how they relate to allowed ray propagation angles. Only then do I attempt a more rigorous wave analysis of the optical fiber.

As my primary interest in fiber optics comes from an applied electromagnetics perspective, I spent a great deal of time on Secs. 2.4, 2.5, and 2.6, in which Keiser provides a fairly complete wave analysis of guided mode properties. For the most part I have no complaints about these sections. The progression of topics is logical, and in the equations I specifically checked, I found no errors or typos. Several of my students did express that the increased complexity of these sections was quite abrupt (the big roller coaster hill) and that without a feel for optical wave guidance, it was easy to become lost in the many Bessel function manipulations. The likelihood of this confusion would, of course, have been increased had this course been taught at the undergraduate level. Thus, the progression through these sections was slow, and I found it necessary to provide lots of intermediate steps to Keiser's derivations as well as several pages of my own supplementary notes. In addition, I found it necessary to provide further information on modal degeneracies, the origin and significance of TE and TM modes, and the effects of the weak guidance condition. Again, to be fair, I mention that this is an introductory book on optical fiber communications not optical waveguide theory, and my personal interests do not detract from the fact that Keiser does a fairly good job of covering the more critical wave guidance concepts.

Keiser ends Chap. 2 with a mosaic of "low-impact" sections covering topics such as appropriate optical fiber glasses, fiber fabrication, mechanical properties of optical fibers, and fiber optic cabling. These sections were mercifully short.

Chapter 3 is probably the chapter on which I spent the next largest amount of time. This is the chapter in which the concepts of optical signal attenuation and dispersion are presented. Because these are probably the two optical phenomena that most strongly influence optical fiber communications system design, I am pleased to say that Keiser covers them accurately and in detail. I was especially interested in his expanded discussion of pulse broadening in graded-index optical waveguides (Sec. 3.3). Although one of my students did point out that in Keiser's discussion of Eq. (3-31) in which he describes rms intermodal dispersion, a mysterious parameter $<A>$ is introduced and defined as the average of another mysterious quantity A_{rms} I am afraid these quantities still have us puzzled, because they are neither part of Eq. (3-31) nor any other equation in Sec. 3.3. Keiser finishes Chap. 3 with interesting discussions on the characteristics of design optimized single-mode fibers with alternate refractive index profiles. I chose to cover these topics more qualitatively than quantitatively, specifically deferring a rigorous analysis of dispersion flattened waveguides to a more advanced follow-up course devoted entirely to optical waveguide theory.

I moved through the next couple of chapters fairly quickly. Chapter 4 reviews semiconductor physics and discusses the principles of LED and laser diode operations. The presentation is clear and concise, and I especially appreciated Keiser's discussion on the significance of narrow linewidth single-mode lasers (i.e., the distributed-feedback, distributed-Bragg-reflector, and distributed-reflector lasers). Those students who read Chap. 4 in detail said it was informative and easy to follow, and those with previous laser theory experience said the chapter provided a good review. Chapter 5, on the other hand, though probably necessary for the sake of completeness, would probably find a better home in a laboratory manual. In this chapter, Keiser discusses power launching and coupling, splicing, misalignment losses, etc.,—concepts that have little or no meaning to the student who has no hands-on experience with fiber optics. I skipped Chap. 5 completely.

Keiser picks up the pace again in Chap. 6 with a very nice discussion of photodetectors. Both avalanche photodiodes and positive-intrinsic-negative diodes are discussed as are the primary photodetector noise sources. As with the first edition of this text, I especially liked this chapter. It provides one of the simplest, clearest, and most easy-to-follow treatments of optical signal-to-noise ratio analysis I have found. The text then progresses naturally to the material of Chap. 7 (Optical Receiver Operation) and Chap. 8 (Digital Transmission Systems). Unfortunately, due to an approaching final exam date, I had to severely limit my discussions of this material. Primarily my discussions were limited to the probability of error (Sec. 7.2.1), loss budget (Sec. 8.1.2), and rise-time budget (Sec. 8.1.3) analyses. Again, Keiser covers these topics adequately and at a level that is easily understood. One of my students and I noticed, though, that the material dispersion term in Eq. (8-17) of Sec. 8.1.3 is expressed as an rms quantity. Because Eq. (8-17) is the expression given for the overall optical system rise time, I think that perhaps a conversion from rms material dispersion to an equivalent rise time quantity is needed. This conversion was performed for an assumed Gaussian intermodal dispersion response in Eq. (8-13). Possibly a similar conversion should apply to the intramodal dispersion effects. At a minimum, I feel the rise time degradation due to intramodal effects should be more carefully accounted for and/or discussed.

Thus, came the end of the semester. Due to lack of time, I was unable to cover the last three chapters of the book directly. I did, however, find use of these more advanced chapters (and their associated references) as sources of several term projects for my students. Chapters 9 and 10, for instance, provide very nice introductions to the concepts of analog and coherent fiber optic communications systems, respectively, while Chap. 11 addresses some of the topics of current interest to the fiber optics community, including wavelength division multiplexing, local area networks, and photonic switching.

In all I have found the second edition of *Optical Fiber Communications* to be a well-written, well-rounded, and fairly comprehensive introductory text, with only a few minor flaws. Except for the abrupt transitions between topics in Chap. 2, my students seemed to like the text as well. I think my choice of texts for my fiber optics course was good and I fully intend to use it again.

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[1] Dietrich Marcuse, *Theory of Dielectric Optical Waveguides*, 2nd ed., pp. 3–7 Academic Press, Boston (1991).

Principles of Adaptive Optics

Robert K. Tyson, 300 pages, illus., index, and bibliography. ISBN 0-12-705900-8. Academic Press, Inc, 1250 Sixth Avenue, San Diego, CA 92101 (1991) $49.94 hardbound.

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As an engineer and educator performing research in the area of adaptive and atmospheric optics, I was very excited when I heard about Robert Tyson's book *Principles of Adaptive Optics*. I am often in the position of guiding the research of students in their efforts to learn about adaptive and atmospheric optics. This process usually involves asking the student to read a large number of journal and conference papers that have appeared over the last 20 years. Putting all this information together in a coherent way is difficult even for the best student. A book that brings all of this information together in a clear and understandable fashion is exactly what I've been looking for. Tyson's book largely meets these requirements, but does so in a way that is of most use to those already having extensive knowledge in the area. For the engineer or scientist just beginning to learn about adaptive optics, the book is most useful from a qualitative rather than a quantitative point of view.

In Chap. 1, Tyson outlines the history of adaptive optics and introduces the background information needed in subsequent chapters. This background material includes, most importantly, a discussion of the basic problems that adaptive optics technology addresses: imaging and beam