

Light propagation in glass-fiber waveguides

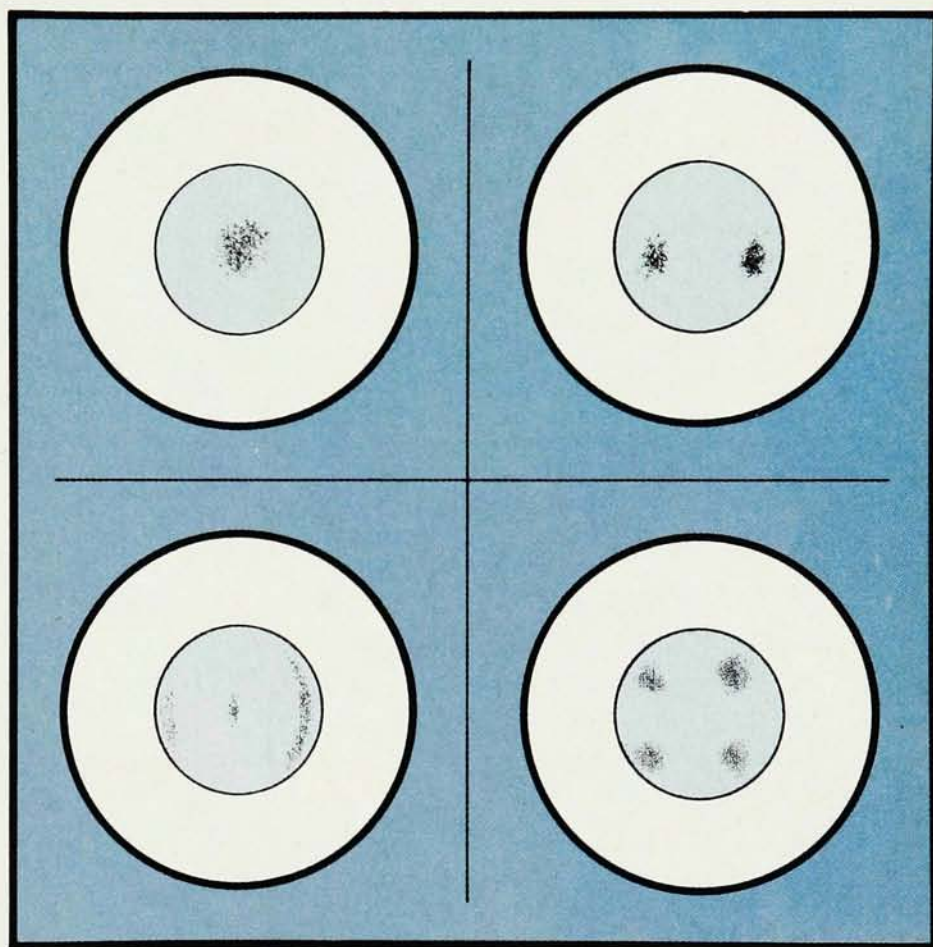
Planar Optical Waveguides and Fibres

H.-G. Unger
751 pp. Oxford U.P., New York, 1977.
\$45.00

Reviewed by Esther Conwell

A significant by-product of the invention of the laser and the advances in electro-optic (or opto-electronic) techniques that followed is the rapid growth of optical communications. Optical-communication systems, although still considered to be at an experimental stage, have been used for cable TV, computer and military systems in many parts of the world. Many telephone companies, including AT&T, are testing experimental systems for introduction in the early 1980's. The essential ingredient of these systems, after the laser, is the glass-fiber waveguide for transmission. Manufacturers can now make these fibers with a thickness of the order of a human hair and in multi-kilometer lengths with the remarkably low attenuation of 2 dB/km, or less, at the wavelength of the semiconductor laser or near infra-red neodymium-based lasers. The rapid development of these fibers owes a good deal to microwave theory and techniques, on the one hand, and to semiconductor technology as well as, of course, usual and unusual glass technology, on the other hand.

H.-G. Unger devotes the major portion of *Planar Optical Waveguides and Fibres* to the theory of light propagation in these fibers, developed with a view to their applications. He also treats planar waveguides, that is, guides with rectangular (rather than cylindrical) geometry, as well as techniques for introducing light into the guides. Although Unger begins the book with a brief historical treatment, he does not attempt to survey the by-now voluminous literature in this field. Rather, the book constitutes a unified and fairly complete exposition of the theory of planar optical waveguides and fibers that starts from first principles, assuming only a knowledge of Maxwell's equations. Unger supplements his exposition of waveguide theory with brief accounts of the design and fabrication of the guides



An optical fiber, provided the core diameter is large, can guide many modes, and the penetration of the electromagnetic field of the light into the cladding is different for each of them. Several modes in a step-index fiber are shown above. The fundamental mode (top left) has most of the power concentrated at the center of the core and is the only mode that can be guided in a single-mode fiber. H.-G. Unger discusses these guided modes in his *Planar Optical Waveguides and Fibres*, reviewed on this page. (Photograph courtesy of the Bell Laboratories Record)

and the technologies that have been developed for and applied to them.

After the historical introduction, the book begins, appropriately, with the discussion of plane-wave absorption, scattering and dispersion in the bulk of optical-waveguide materials, and total reflection at interfaces. The exposition on planar waveguides—films (slabs), strips and strip-derived structures—follows. As the interconnections and the basis for the components of integrated optics, these may one day play an important role in optical communications but that is not yet clear. In any case, the discussion of these

waveguides provides a good background for the treatment of the more complicated fiber guides. As he does frequently for easier physical insight, Unger first derives the guided modes (characteristic electromagnetic-field patterns that can survive propagation over long distances) from the simple geometric-optics concept of rays and total reflection at the guide boundaries. He does this not only for the simple slab guides but for each new type of guide—guides with transverse confinement, graded-index guides (in which the index of refraction changes gradually throughout the guide rather than in steps



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Edited by J. Tran Thanh Van
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Clothbound, FF. 250/US\$ 56, 1978.

The Proceedings of the Lepton Session is published under the title:

GAUGE THEORIES AND LEPTONS

Clothbound, FF. 260/US\$ 58, 1978.

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at the boundaries), the different types of fiber guides—as it is introduced. Unger then derives the modes from Maxwell's equations plus the boundary conditions.

The brief discussion of planar-waveguide technology that concludes the section on these waveguides is the least adequate part of the book. Although the publication date of the book is 1977, the references in this section essentially end in 1974. Great advances have taken place since then, particularly in the technology of integrated optical circuits made entirely of gallium arsenide and its alloys with aluminum and other materials ("monolithic" integration). Unger's statements that "we obtain more efficient optical devices when the best materials for the respective functions are combined" ("hybrid" integration) and "usually only such hybrid integration results in optical circuits with satisfactory performance" stand in contradiction to the current state of affairs in integrated optics.

The chapters on fibers are extensive in their coverage, with attenuation and dispersion both discussed at length. The dispersion analysis takes account of mode, material and index-profile dispersion to arrive at near-optimum profiles for minimizing pulse broadening in transit. Unger devotes a chapter to the effects of fiber imperfections such as bending, deviations from circularly symmetric geometry, and microscopic and macroscopic fluctuations in refractive index. He de-

velops the solutions of coupled-wave and coupled-power equations and a power-diffusion approximation to make possible the specification of fiber tolerances for particular levels of signal degradation. The final chapters on fiber fabrication and cabling, junctions and transitions, provide much more comprehensive coverage than the section on planar-waveguide technology.

Unger, writing well and clearly, has digested and presented in logical fashion material from many diverse sources. Starting from first principles as it does, the book provides a good introduction to waveguide theory and fibers. It should serve well as a text for a course on optical waveguides, including fibers, provided more recent references on the technology supplement it. One suspects that Unger, who is Professor of Electrical Engineering and Director of the Institut für Hochfrequenztechnik, Technische Universität, Braunschweig, developed it through teaching such courses. Additional pluses are numerous references at the end of each chapter and a 9-page "List of Principal Notation."

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Esther Conwell, a principal scientist at the Xerox Webster Research Center, has worked on waveguide theory and other aspects of integrated optics for several years. She has written a number of reviews of integrated optics, including one published in PHYSICS TODAY, May 1976.

Galileo at Work: His Scientific Biography

S. Drake

536 pp. Univ. of Chicago, Chicago, 1978.

\$25.00

Galileo at Work begins with a charming vignette of the famous scientist as an old man tending his garden, dressed as a "clown" rather than in his philosopher's robes. This introduces us to Drake's purpose, which is to show Galileo in his "working clothes" and to give a "fair overall view of Galileo's scientific career." He turns from perennial questions concerning philosophical influences on and implications of Galileo's work and gives instead a careful and detailed chronological account of what Galileo actually did.

As the major translator of Galileo's works into English, Drake has also written many articles about Galileo. His forte is discovery and translation of documents previously unknown in English—sometimes previously unpublished anywhere—and his series of "Galileo Gleanings" (in various history-of-science journals) includes much useful analysis of documents and events pertaining to

Galileo's life and work. (A few of these "Gleanings" were collected together in Drake's *Galileo Studies: Personality Tradition and Revolution* (University of Michigan, 1970).)

Galileo at Work, Drake's first attempt at a book-length treatment of his subject, pulls together into a comprehensive chronological account materials found in his earlier papers as well as other sources. There is also much that is new. Among the most striking bits is, perhaps, the background to Galileo's development of a theory of errors (page 307), the extent and frequency of Galileo's illnesses and the bearing of these on his work, and many details surrounding Galileo's numerous controversies. Most of these and similar nuggets are found in Galileo's correspondence, which Drake has probably read more thoroughly than anyone else since the early years of this century. Also, much important material is here translated into English for the first time, including a number of Galileo's manuscript notes on motion and the so-called "Fifth Day" of the *Discourses and Mathematical Demonstrations Concerning the Two New Sciences Pertaining to Mechanics and Local Motion*.

Galileo at Work contains much that will be of interest to a wide range of