DEPARTMENTS

BOOK REVIEWS

Optical Shop Testing

Edited by Daniel Malacara, 2nd ed., xviii + 773 pp., illus., index, references following each chapter. ISBN 0-471-52232-5. John Wiley & Sons, Inc., 1 Wiley Dr., Somerset, NJ 08875 (1992) $79.95 hardbound.

Reviewed by John S. Loomis, University of Dayton, 300 College Park, Dayton, Ohio 45469-0001.

The first edition of *Optical Shop Testing*, published in 1978, was a comprehensive, authoritative information source on optical test procedures used in the fabrication of optical components. With the publication of the second edition, many of the original chapters were revised, others were extensively rewritten, and a few were added.

For those unfamiliar with the first edition, *Optical Shop Testing* emphasizes tests that provide information primarily about the shape (figure) of an optical surface or lens. Such tests can generally be classified as interferometric tests, that measure wave front directly, or geometric tests, which measure wave front slope (rays). Specifically excluded from consideration are tests that measure the optical transfer function (although such measurements are discussed briefly at the end of Chap. 3).

Eighteen chapters are included in the second edition: (1) Newton, Fizeau, and Haidinger interferometers; (2) Twyman-Green interferometer; (3) common-path interferometers; (4) lateral shearing interferometers; (5) radial, rotational, and reversal shear interferometers; (6) multiple-beam interferometers; (7) multiple-pass interferometers; (8) Foucault, wire, and phase modulation tests; (9) Ronchi test; (10) Hartmann and other screen tests; (11) star tests; (12) null tests using compensators; (13) interferogram evaluation and wave front fitting; (14) phase-shifting interferometers; (15) holographic and speckle tests; (16) moiré and fringe projection tests; (17) contact and noncontact profilers; and (18) angle, distance, curvature, and focal length. The two appendices cover (1) an optical surface and it characteristics and (2) some useful null testing configurations.

The first 12 chapters are very similar to their counterparts in the first edition. The pattern of revision was to add a few paragraphs of new text, as appropriate, and update the references. Generally, the revisions added approximately 10% to the length of each chapter. For example, the chapter on star tests contains additional material on Gaussian beams and beams with very small convergence angles (low Fresnel numbers). The page count increased from 29 to 30, and the number of references increased from 20 to 22. As another example, the chapter on Foucalt, wire, and phase modulation tests included only minor changes to the original book, such as the addition of another figure, but the number of references increased substantially, from 77 to 147, and the page count increased from 51 to 56.

Chapter 13, on interferogram evaluation and wave-front fitting, includes the material originally in appendices 2 and 3 in the first edition (on Zernike polynomials, wave-front representation, and fitting) that consisted of 23 pages. The author added an additional 22 pages of information about data analysis, fringe digitization, and Fourier analysis of interferograms. There are 80 references at the end of the chapter. This new chapter is very well done. Anyone studying this chapter, however, should also read the material in Sec. 2.7 on typical interferograms and their analysis, which I believe should have been included in Chap. 13.

Chapter 14, on phase-shifting interferometers, is completely rewritten from the original in the first edition entitled fringe-scanning interferometers and is the longest chapter in the book (98 pages). The chapter starts by introducing basic concepts of interferometer configuration, phase modulation techniques, data collection, and phase recovery and unwrapping. This introduction is followed by a detailed discussion of algorithms and data collection strategies. Next is a discussion of calibration requirements and sources of error. Then comes a discussion of detectors, spatial sampling, and phase unwrapping techniques. Following that is a review of other algorithms and techniques, some general comments on computer processing and output, and finally a section on implementation and applications. This last section, in my opinion, would have been better split into two independent sections. The mixture of topics does not flow smoothly as presently arranged.

Chapters 13 and 14 show strongly the influence of computers on the practice of optical testing, especially during the time between the publication of the first and second editions.

Chapters 15 (holography and speckle) and 16 (moiré) were originally combined into one chapter. The separation is a logical consequence of the additional work done in these areas. Both chapters are well written. It is interesting to note how the outside world is creeping into optical testing. The first applications discussed in Chap. 15 are concerned with optical components. The next examples show the use of holography in nondestructive testing. Chapter 16 contains no direct discussion of applications to optical surfaces (other than a passing reference in the introduction), but instead covers more popular applications in contouring irregular objects.

Chapter 17 (profilers) is a completely new chapter. Profilers are instruments used to measure surface finish (roughness) and the geometry of small features on an object. These instruments may be either contact (stylus) or noncontact (optical). Also discussed are noncontact scanning probe microscopes.

Finally, Chap. 18 has been rewritten from the first edition. This chapter covers parametric measurements such as wedge, curvature, distance, and focal length.

Optical Shop Testing is a superb book on practical methods for optical testing, and the second edition is a welcome sequel to the first.

I especially like the extensive lists of references found at the end of each chapter. No book review should fail to mention errors, and this book has its share of typos and inconsistencies. The ones I found were obvious or unimportant. For example, the first entry for coma in Table 13.1 is wrong (n=3, l=1), but the corresponding entry in Table 13.2 is correct.

I expect that most readers of *Optical Engineering* are familiar with the first edition of *Optical Shop Testing,* and I have tried to emphasize the differences between the two editions. If you like the first edition, you will certainly want to upgrade to the second.

Optical Signal Processing

Anthony VanderLugt, 625 pages, illus., index, references, bibliography, and two appendixes. Wiley Series in Pure and Applied Optics, J. W. Goodman, Ed. ISBN 0-471-54682-8. John Wiley & Sons, 605 Third Avenue, New York, NY 10158 (1992) $90 hardbound.

Reviewed by John N. Lee, Naval Research Laboratory, Optical Information Processing Section, Code 6523, Washington, DC 20375.

During the last three decades optical processing has with regularity been looked on as a wave of the future. None of this interest has led to a permanent introduction of optical processors for applications such as signal processing. One of the problems is that development of a useful product invariably requires multifaceted and multidisciplinary expertise. Research and development in optical signal processing requires expertise not only in the obvious areas of classical optics and traditional signal processing, but also in materials for various devices such as spatial light modulators and photodetectors; characterization and design of such devices; design of robust and extremely high-performance optical subsystems; and, most importantly, integration of optics with electronic and digital systems. This book has captured some of the needed multidisciplinary flavor.

The timing of this book could not be better, as researchers are presently attempting to put together real processing systems. The book is in the form of a textbook with exercises; this is in contrast to most of the past books on optical processing that are edited works consisting of contributions by a collection of specialists often geared toward other specialists in various subfields of optical processing. While this book is geared toward a studentlike audience, I expect such "students" to also include new (and perhaps not-so-new) researchers in this field, since their work should employ the material covered by this book as necessary foundation and tool. A student should gain from this book an understanding of a broad spectrum of optics and signal processing concepts, with further insights provided by the coverage of important examples of realizations of optical signal processing concepts.

The main problem that the nonspecialist may encounter is that while the book title seems to promise "signal processing," in actuality the maturity of developments is sufficient only to produce specific signal processing operations rather than full signal processing system functionality. In particular, a true system requires control and memory functions, neither of which can be performed optically yet. (I note that digital signal processing books often do not cover system issues either.) If the readership is, in fact, the nonspecialist electrical engineer, a major question sure to arise is the relationship of this material to the enormous progress that has occurred in digital technology for signal processing. The statement found in Chap. 1, "it is difficult to process wideband signals in real time without using the power of optics," can only confuse the issue. Perhaps the audience can be alerted that some answers will be in the forthcoming chapters.

The book is accurately advertised as two books in one. The first part of the book (Chaps. 1 through 6) could really be called Optics *for* Signal Processing. In the first half of the book, the author does an admirable job in what I consider almost a no-win situation, i.e., should the material be geared toward the optical scientist who needs to learn something about signal processing, or should it be geared toward the electrical engineer with little background in optics? The level of treatment, I think, is most appropriate for the latter, because the book gives a good summary of traditional topics in optics such as optical diffraction, Fresnel and Fourier transforms (Chap. 3), selected topics in geometrical optics needed in subsequent discussions of components (Chap. 2), and designs and components for optically performing spectrum analysis and spatial filtering (Chap. 4). The optical scientist probably will not get a good grounding in signal processing from this book, although all the necessary fundamentals are provided (Chaps. 1 and 5). However, I believe an electrical engineer who is typically trained to perform spectral analysis with time-domain electrical filters and FFTs will get a satisfying, comprehensible answer to how a piece of glass can perform spectral analysis. Critical implementation issues such as dynamic range are discussed in commendable detail—almost to the point that an audience might need a reminder of the rationales for the optical implementation. The first half of the book concludes with more than 80 pages devoted to spatial filtering and spatial filtering systems, including correlation and filter construction. Particularly noteworthy is discussion of issues involving information extraction from optical processors; these issues have not received much recent attention, but involve substantive topics covered in this book, including on-chip processing approaches and adaptive filtering techniques such as constant-false-alarm thresholding (Chap. 6).

A small problem I had with the first half of the book is that the background material is somewhat thin for those who would want to dig deeper into the details. The choice and depth of discussion of topics is necessarily limited by length limitations. I would have liked to have seen more referral to any of a number of good in-depth references for physical optics and geometrical optics. Otherwise, the references are good and reasonably complete, and the author usually provides an appropriate amount of introductory material whenever needed; an example is Sec. 5.2 entitled "Some Fundamentals of Signal Processing." I have only a few suggestions for additional references. Further background on interferometric techniques, especially the optical chirp transform, might include reference to an old work that I like very much—*Transformations in Optics* by Larry Mertz (1965). The discussion on weighting functions could be supplemented by referencing complete works such as one by F. Harris [*Proc. of IEEE* **66**(1), 51–83 (1978)]. It is apparent that whenever the number of topics in these background chapters needed to be limited, the choices were determined by the topics that appear in subsequent chapters. For example, in Chap. 2 on geometrical optics, an early introduction to prisms is given, which can be puzzling unless one knows that use of prisms is popular in optical processing systems to be discussed in later chapters. The discussion of lenses is fairly comprehensive, and I have only one suggestion for addition. The Fourier transforming properties of lenses is discussed in Chap. 3, but the description is appropriate for thin lenses in the paraxial approximation. Extension of the material in Chap. 2 to real Fourier transform lens systems with large apertures would be desirable.

An attractive feature of the presentation is the frequent use of mathematical correspondences between optical processing and electrical engineering concepts. However, in several places more explicit discussion of the differences between the optical and electrical implementations would have been nice. One reason I feel this is necessary is because such understanding helps determine ultimate limits to optical performance. One case is in the important discussion of third-order intermodulation (IMD) signals that I found somewhat vague. Spurious IMD signals occur when several simultaneous signals are present in a device, and hence they must be carefully considered in broadband optical devices. Of course, IMD signals also occur in electrical devices, but the nonlinear physics in optical devices such as acousto-optic cells is quite different than in, say, an electrial amplifier. In acousto-optic cells, both intrinsic and material-related origins exist. The origins of the intrinsic effect—multiple optical diffractions from the acoustic signals—was not very clear from the discussion. As a result, the context of the subsequent discussion of elastic nonlinearity in materials as a second mechanism for IMD is somewhat confused. Another instance where the difference between optical and electrical should be emphasized is in the discussions of optical scatter and the use of Gaussian laser beam profiles. These discussions should relate strongly to spectral band shape for the channels in a high dynamic range spectrum analyzer. However, discussion of optical scatter occurs after the discussion of channel band shape and seems to concentrate on scatter from the undiffracted light beam, even though Fig. 8.6 would indicate the importance to channel band shape. Optical scatter is just one contributor to degraded band shape. Laser beams cannot always be assumed to have a Gaussian cross section; this is especially true for semiconductor laser diodes that are now very popular in optical processing systems. The Gaussian approximation is good for pedagogical purposes, making the mathematics very tractable, but again does not provide a sufficiently accurate representation needed for high dynamic range systems. I would emphasize that these are not criticisms, but rather points of caution for the uninitiated reader relating to whether and how optical processors might be improved.

The second part (Chaps. 7 through 15) covers acousto-optic techniques and demonstrations that have validated many of the concepts for optical processing. I believe acousto-optics is the most appropriate choice for exemplifying the concepts from the first part of the book. With this emphasis on acousto-optics, the reader may be in danger of assuming that the subject matter is rather narrow. Such an assumption would be a serious mistake. Through this approach the author provides a means for broad understanding of optical signal processing concepts and of issues in their implementation. Use of acousto-optic Bragg cells is an already existing means for implementing ideas/concepts that would otherwise be just so much pie-in-the-sky. The range of topics covered is excellent. Even so, some topics were not covered, particularly the system integration issues.

Chapter 7 covers acousto-optic interactions and devices. I suspect that because this work is intended to be more of a textbook than a design manual, only the briefest description of acousto-optic device performance and construction is given. There is some possibility that the student may come away with unrealistic expectations. For example in Figs. 13.11 and 14.6 two Bragg cells are shown built on a single crystal. Such a device configuration is good only for low resolution, since it relies on shadow-casting imaging of one cell onto the other. Since diffraction spreading of the acoustic wave means the two waves must be well separated, significant Fresnel diffraction spreading will occur with shadow casting.

Chapter 8 on acousto-optic spectrum analyzers discusses design concepts for such systems. For the nonspecialist who would like to fully understand these processors, this is one of the best and most complete descriptions I have seen. This chapter also serves as the introduction to processors that use only the optical intensity. Much more effort is subsequently spent covering processing concepts that employ both the amplitude and phase of the light, using heterodyne techniques (Chaps. 9 through 12). Background on the heterodyne process is provided (Chap. 9), followed by application of heterodyne techniques to spectrum analysis (Chaps. 10 and 11). The heterodyne techniques are then shown to allow more general signal filtering operations (compared with intensity-only techniques) to be performed on the temporal wave forms, such as excision of undesired signals (Chap. 12). Chapters 13 and 14 cover optical correlation of temporal wave forms. Both the space- and time-integrating techniques are discussed. Finally, Chapter 15 discusses 2-D processing concepts that are a natural advancement of the 1-D systems of the previous chapters. Concepts including production of time-frequency transforms such as the ambiguity function, the bispectrum, and the Wigner-Ville distribution are covered. The ambiguity function processing concepts illustrate how 2-D optics can be used to perform a combination of the spectral analysis and correlation techniques covered earlier. I only wish that the treatment had not stopped after covering only the narrowband ambiguity function. Additional 2-D processing concepts for signal filtering and for phased array processing for combined spectrum analysis and direction-of-arrival determination are then described. The book ends abruptly at this point; I am sure that this was because of a limit on the allowable number of pages for the text. I would have liked to have seen a connection back to the 2-D Fourier processing concepts discussed in Chap. 6. Such a connection would have indicated a major future direction for uniting the sucesses in acousto-optic techniques and the need to employ 2-D techniques to fully exploit the capabilities of optics.

This is a very well-written book. The intended use is as a textbook, and consequently a large amount of mathematical description is given. However, I generally found the math very easy to follow, and, more importantly, it provides the mathematical foundations for specialists working to advance the field. Problem sets are included at the end of each chapter, and a booklet is available that provides complete descriptions of the solutions. (I am under the impression the booklet is obtained separately from the textbook.) The author states that the goal of the problems is to provide further insights and understanding of the subject matter, rather than a "plug-and-chug" verification of formulas. This goal has been achieved admirably in most cases; I would therefore recommend that the nonstudent specialist also examine the problems. My only question would be whether an instructor should intersperse the problems with the lecture material, rather than wait until the end of a chapter to introduce them. In summary, both the student and the specialist should consider this book. The textbook approach that is employed should not hinder the fact that many practical design concepts are considered and some critical implementation issues are addressed. I highly recommend this book especially to anyone who wants to know how the high potential of optics can be applied within the large area of signal processing.

BOOKS RECEIVED

From Instrumentation to Nanotechnology, edited by J.W. Gardner and Harry T. Hingle. 348 pp., illus., index, ref., ISBN 2-88124-794-6. Gordon and Breach Science Publishers, 5301 Tacony Street, Drawer 330, Philadelphia, PA 19137 (1991) $48.00 hardbound. Based on a series of lectures presented at the Advanced Science and Engineering Research Council Vacation School on Instrumentation and Nanotechnology held at the University of Warwick, 16-21 September, 1990. Covers trends in instrumentation and nanotechnology, signal processing, correlation methods applied to instrumentation, mathematical modelling of instruments—application and design, algorithms for computer aided precision metrology, ultrasonic sensors, recent advances in solid-state microsensors, nanotechnology, optical metrology, optical diffraction for surface roughness measurement, and calibration of linear transducers by x-ray interferometry.

Laser Pioneers, by Jeff Hecht. Revised edition, 308 pp., illus., index, ref. ISBN 0-12-336030-7. Academic Press, Inc., 1250 Sixth Avenue, San Diego, CA 92101 (1991) $39.95 hardbound. Covers laser history, infrared and optical masers, origins of the laser, masers and nonlinear optics, laser development, the helium-neon laser, the semiconductor laser, the carbon-dioxide laser, the ion laser, metal-vapor lasers, excimer lasers, the free-electron laser, and the x-ray laser.