
Comment

**Comment on the paper
“Theory and applications of a surface
inspection technique using double-pass
retroreflection”**

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I am moved to comment in support of your invitation to authors, published as an editorial in the September 1993 issue, to submit their proceedings papers suitably extended to *Optical Engineering*. Perhaps if this policy had been observed in the middle of the last decade, your author Reynolds et al.,¹ appearing in the same issue, would have seen the paper by Biddles and Baker² describing the use of retroreflective material for inspecting transmitting and reflecting surfaces, published apparently some eight years before their discovery.

References

1. R. L. Reynolds, F. Karpala, D. A. Clarke, and O. L. Hageniers, “Theory and applications of a surface inspection technique using double-pass retroreflection,” *Opt. Eng.* **32**(9), 2122–2129 (1993).
2. B. J. Biddles and L. R. Baker, “Surface inspection of optical and semiconductor materials,” *Proc. SPIE* **60**, 34–38 (1975).

Response

**Response to “Comment on the paper
‘Theory and applications of a surface
inspection technique using double-pass
retroreflection’ ”**

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While we agree wholeheartedly with making selected material from proceedings more accessible, we are not convinced that it has any bearing on our paper. The authors are aware of Biddles and Baker’s device (as well as similar retroreflective-based inventions), having discovered them during our patent search. It is clear to us that our use of non-scanned full-field illumination with a non-coincident light source makes the hardware configuration unique and significantly different from those devices, postulated by others, that have made use of retroreflection.

DEPARTMENTS

BOOK REVIEWS

High Sensitivity Moiré

Daniel Post, Bongtae Han, and Peter Ifju, 444 pp., 245 illus., 161 fringe patterns/contour maps, index, references, three appendices. ISBN 0-387-94149-5. Springer-Verlag New York, Inc., 175 Fifth Avenue, New York, NY 10010 (1994) \$69 hardbound.

Reviewed by James W. Dally, University of Maryland, Mechanical Engineering Department, College Park, MD 20742.

The authors of this book are world-class authorities in the field of moiré and moiré interferometry, and the extremely complete and detailed treatment of the subject reflects this fact. The senior author has been a principal contributor to advances in geometric moiré for several decades and was the primary contributor to the development of moiré interferometry, beginning with his pioneering work in the early 1980s. Han and Ifju have worked closely with Post during the past decade and have contributed significantly to advances in the method of moiré interferometry and to several interesting applications of the method to problems of commercial significance.

After introducing the subject and briefly describing references that cite the history of moiré methods, the authors divide the book into two parts. Part I covers the fundamentals and will serve as an excellent text on moiré in graduate courses on this topic. Part II is devoted to applications of moiré interferometry to a number of challenging contemporary problems.

The principles of optics are covered in Chap. 2. This treatment is extensive and provides a suitable foundation for all experimental methods of mechanics that employ optics. In addition to the standard treatment on lenses, mirrors, and light sources, the chapter includes an excellent section on coherent superposition that provides the theory necessary for a clear understanding of interference. Another important section covers

diffraction, which is vital to the development of high-sensitivity moiré.

The third chapter covers geometric moiré and is important because it couples the older developments in moiré (the period from 1950 to 1960) with the more modern developments of moiré interferometry. The fourth chapter is the heart of Part I because it covers many important aspects of moiré interferometry. This chapter begins with a rigorous mathematical treatment of the interference patterns, introduces the theoretical limit of the resolution, describes the schematics of the optical systems employed, introduces the methods for producing specimen gratings, and covers a variety of additional topics of considerable importance to the investigator working in the laboratory.

The fifth chapter covers microscopic moiré where a small region of a specimen is examined. The small viewing area implies that the in-plane displacements will be small even though the strains are not small. Accordingly, enhanced sensitivity of the method is necessary. The improved sensitivity is achieved by employing immersion interferometry and optical/digital fringe multiplication. In the treatment of immersion interferometry, detailed descriptions are given of the ingenious optical arrangements that are employed with optical microscopes to yield extremely high-sensitivity (4800 lines/mm) interferometers. A description of fringe multiplication using digital techniques and precision fringe shifting is an important contribution to this chapter.

The final chapter in Part I covers limits on moiré interferometry. Very well-written discussions on spatial resolution, displacement resolution, and strain resolution are included. It is interesting to note that the authors state that the absolute accuracy of the controlling factor (the reference grating) was 1 part in 10^5 .

Part II of the book deals with applications of the method. These applications are largely drawn from the work conducted by Post and

his students in the laboratories at Virginia Tech. Chapter 7 deals with laminated composites subjected to compression. Several interesting experiments are described where the abrupt ply-to-ply variations in the displacement fields are measured. The significant free edge effects for cross-ply materials are investigated in considerable detail. Interfacial strains are examined in bimaterial joints subjected to temperature changes in Chap. 8. Again abrupt variations in the stress fields occur at the interface. The local nature of the fields is accommodated in the experimental approach by employing high magnification immersion moiré.

An interesting and difficult application of moiré interferometry to textile composites is covered in Chap. 9. The experimental techniques are described, results are presented, and new optical instruments required for this study are illustrated. A very important series of experiments is described in Chap. 10, where moiré interferometry is applied in the study of thermal deformations produced in microelectronic devices. The fringe patterns illustrate the displacements that occur between chip carriers and printed circuit boards when the assembly is subject to temperature changes. The patterns shown for the solder ball connections are particularly interesting. This work demonstrates the potential of moiré interferometry to aid in the visualization of the thermal stresses developed in electronic systems.

Chapter 11 covers applications to advanced composites and includes studies with ceramic composites, metal matrix composites, residual stresses, and the effects of wavy plies. Applications to metallurgy, fracture, and dynamic loading are treated in Chap. 12. This chapter is somewhat terse in that a number of different problems are introduced and the details and results are sparse when compared to the much more thorough treatments in the other chapters. This approach is compensated by a complete list of references that cover the omitted details.

The final chapter is devoted to an application where moiré interferometry is used to calibrate the calibration fixture employed by strain gauge manufacturers to establish gauge factor and cross-sensitivity factors for electrical resistance strain gauges. This application is of major importance to those firms worldwide that produce this popular transducer. It is also important in showing the precision that can be achieved by a careful and artful experimenter.

Appendices are included to extend the treatment. Appendix A shows the use of the optical/digital fringe multiplication method with shadow moiré and with the in-plane geometric moiré. Appendices B and C give very important information describing the production of master and submaster gratings and the adhesives used to replicate the gratings that are subsequently applied to the specimens.

It is important to note that exercises are provided at the end of each chapter. These exercises are well written and provide a valuable resource if the book is used as a text in a graduate course dealing with high-sensitivity moiré.

In summary the book is excellent. The writing is well organized, clear, and easy to understand. The illustrations are abundant and of the very highest quality. The coverage is extensive and in sufficient detail to satisfy the most meticulous researcher. Part I, in covering the fundamentals, represents an excellent text that can be employed in the classroom at the graduate level. The topic is probably too specialized to be included in an undergraduate curriculum. Part II is important in that it covers many applications in areas at the forefront of research in mechanics and materials today. The results presented should be of significant interest to a large community of researchers.

Optical Characterization of Semiconductors: Infrared, Raman, and Photoluminescence Spectroscopy

Signey Perkowitz, 220 + x pp., illus., subject index, references. ISBN 0-12-550770-4. Academic Press, Inc., 1250 Sixth Avenue, San Diego, CA 92101-4311 (1993) \$69 hardbound.

Reviewed by Mohammad S. Alam, Indiana University/Purdue University, Engineering and Technology Building, #327A, 2101 Coliseum Boulevard East, Fort Wayne, IN 46805-1499.

This book deserves a special place in the library of engineers and scientists interested in using photoluminescent emission, infrared absorption, and Raman scattering for the optical characterization of semiconductors in rapid and nondestructive ways. To the best of my knowledge, this is the first book entirely devoted to the use of optical methods for

semiconductor characterization.

The book consists of eight chapters. The first chapter provides a brief overview of the main topics covered. Chapter 2 briefly introduces electromagnetic theory, whereas Chap. 3 includes the optical physics of semiconductors. These two chapters are intended for individuals with little background in semiconductor physics. The author skillfully explains the 79 equations included in these chapters so that they can be understood without additional reference material. Chapter 4 covers different measurement techniques, sources of equipment, and sample considerations. The main strength of the book lies in Chaps. 5, 6, and 7, where the author presents the book's primary components: case studies on photoluminescence, infrared, and Raman characterization with actual characterization applications adapted from the available literature (involving mainly GaAs and $\text{Al}_x\text{Ga}_{1-x}\text{As}$). In Chap. 8, the final chapter, the author summarizes and compares the three techniques, which may help users in choosing a particular method. The book concludes with an excellent discussion on the future of optical characterization.

I enjoyed reading this book. It is very well written and understandable, and the eight chapters are arranged in an organized and logical fashion. The book is clearly illustrated with ample data plots, tables, and figures and is easy to follow. An exhaustive list of references given at the end provides an opportunity for interested readers to access most treasures from the past. There are no problem sets at the end of the chapters, which makes this book difficult to use as a textbook. However, it can be used as a supplemental textbook for graduate and advanced undergraduate courses.

The editorial quality of the book is also excellent. The index is adequate but limited, and an initial reading did not reveal any typographical mistakes. I strongly recommend this book to anyone interested in its subject area. In conclusion, the book is an invaluable contribution to the field of optical characterization employing Raman, infrared, and/or photoluminescence spectroscopy.

BOOKS RECEIVED

Electro-Optics Handbook, edited by Ronald W. Waynant and Marwood N. Ediger. xxiii + 975 pp., illus., subject index, list of acronyms and contributors, references following each chapter. From the Optical and Electro-Optical Engineering Series. ISBN 0-07-068663-7. McGraw Hill, Inc., 11 West 19th Street, New York, NY 10011 (1993) \$89.50 hardbound. From materials and design to the practical application of electro-optical systems and devices in science and industry—this all-in-one handbook offers detailed coverage of the entire field of electro-optics. With contribu-

tions by more than 30 renowned experts, the book offers up-to-date information on the wide array of gas, solid state, semiconductor, dye, chemical and free electron lasers that operate over parts of the spectrum from the x-ray/VUV region through the far infrared.

Progress in Optics—Volume XXXII, edited by Emil Wolf. xviii + 385 pp., illus., subject and author indexes, bibliographical references following each chapter, acknowledgments following some chapters. From the Progress in Optics Series, contains cumulative index for volumes I-XXXI, contents of previous volumes. ISBN 0-444-81592-9. Elsevier Science Publishers B.V., Sara Burgerhartstraat 25, P.O. Box 211, 1000 AE Amsterdam, The Netherlands (1993) \$131.50 hardbound. Covers guided-wave optics on silicon: physics, technology and status; optical neural networks: architecture, design and models; the theory of optimal methods for localization of objects in pictures; wave propagation theories in random media based on the path-integral approach; radiation by uniformly moving sources; and nonlinear optical processes in atoms and in weakly relativistic plasmas.

Acoustical Imaging, Volume 20, edited by Yu Wei and Benli Gu. xvii + 791 pp., illus., subject index, references following each paper, list of participants. Volume 20 from the Acoustical Imaging Series. From the Proceedings of the 20th International Symposium on Acoustical Imaging held at Southeast University, Nanjing, China, Sep. 12–14, 1992. ISBN 0-306-44585-9. Plenum Publishing Corporation, 233 Spring Street, New York, NY 10013 (1993) \$149.50 hardbound. Covers mathematics and physics of acoustical imaging; components and industry application; applications in medicine and biology; applications in geophysics; and underwater acoustical imaging.

Stellar Photometry—Current Techniques and Future Developments, edited by C. J. Butler and I. Elliot. xxiv + 369 pp., illus., references and "Discussion" following each paper, list of participants. Proceedings of the International Astronomical Union Colloquium No. 136 held in Dublin, Ireland, 4–7 Aug. 1992. ISBN 0-521-41866-6. Cambridge University Press, 40 West 20th Street, New York, NY 10011-4211 (1993) \$54.95 hardbound. In this survey, professionals discuss state-of-the-art and future technology including photometry with millimagnitude accuracy, multichannel arrays used in the optical and IR, a global network of automatic photometric telescopes, and time-series photometry of faint sources using CCDs and photometry from space. These articles provide an up-to-date account of all aspects of photometry and a guide to future developments—an essential survey for professionals involved in the design and use of such instruments.