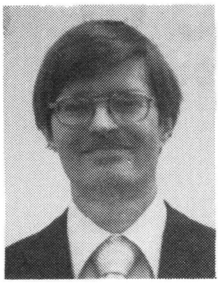

Editorial

H. J. Caulfield, Editor

Science Is Child's Play

In common usage the words "child's play" often indicate something extremely simple. Your Editor has been impressed by his recent readings of the pioneer child psychologist Piaget. Piaget suggests that child's play ceases abruptly when the task is no longer challenging. Our usual connotation therefore slanders the child. Piaget further suggests that what interests the child is the idea of a problem known to be challenging yet suspected of being solvable. Great joy and elation come from the satisfactory solution of such a problem. Clearly, science *is* child's play.

Those of us who are afflicted with the habit of analyzing everything—including the habit of analyzing—may learn much from Piaget's analysis. I know that the joy of my scientific career has two components. First, there is what Thomas Jefferson wisely called "the pursuit of happiness." The joy of working toward a goal, however ill-defined that goal may be, is quite sustainable for long periods of time, as long as that goal seems attainable. This is the reason most scientists welcome new problems. Working toward the solution of real problems is very rewarding. The second type of joy that comes to me is more brief and intense, and almost unpredictable. This is the joy of suddenly seeing the solution to a problem in which I have invested much previous effort. This buildup and release of tension is common in all life, for adult and child alike.

Having now admitted publicly what I have always told my family and friends—that I don't work, I play—I feel another kind of great relief. It is very difficult to take yourself and your work terribly seriously when you realize that in the end it is all child's play. This is not to say that our work does not benefit the world. It simply means that I no longer feel terribly concerned if friends label me a workaholic. Playing a constantly changing, ever-exciting game for the entirety of one's life is a wonderful experience. It should not amaze anyone that the experience is somewhat addictive.

OPTICAL ENGINEERING EDITORIAL SCHEDULE

May/June 1984

Liquid Crystal Applications

Sun Lu
Crystal Vision, Inc.
1313 Geneva Ave.
Sunnyvale, CA 94089 408/745-0833 Ext. 221

Image Scanning & Recording Methods

Philip S. Considine	Robert A. Gonsalves
EIKONIX Corp.	EIKONIX Corp. &
23 Crosby Drive	Northeastern University
Bedford, MA 01730	360 Huntington Ave.
617/275-5070	Boston, MA 02115
	617/437-2165

July/August 1984

Precision Surface Metrology

James C. Wyant
Optical Sciences Center
University of Arizona
Tucson, AZ 85721 602/621-2448

September/October 1984

Particle Sizing and Spray Analysis

Gerald W. Stewart	Norman Chigier
Aerodyne Research, Inc.	Carnegie-Mellon Univ.
45 Manning Road	Dept. of Mechanical Engineering
Billerica, MA 01821	Pittsburgh, PA 15213
617/663-9500	412/578-2498

Robot Vision

David P. Casasent
Carnegie-Mellon University
Department of Electrical & Computer Engineering
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November/December 1984

Laser Spectroscopy

Fred Milanovich	Stanley M. Klainer
Lawrence Livermore National Laboratory	ST&E Technical Services, Inc.
MS L-524	20 Belinda Court
P.O. Box 808	San Ramon, CA 94583
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415/422-6838	

Pattern Recognition

Joseph L. Horner
Rome Air Development Center/ESO
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January 1985

Optical Computing

John Neff
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Arlington, VA 22209 202/694-5800

Optical Information Processing Components

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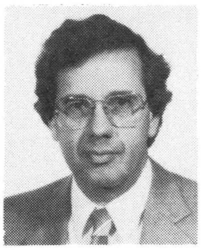
Los Angeles, CA 90089	617/253-6858
213/743-6152	

Forum

The Business Side of Optics



Curt Deckert

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CA 92660

REVITALIZATION OF OUR INDUSTRIES
Some Opinions and Suggestions*

WE ARE FALLING BEHIND OTHER NATIONS

As you know, in recent years the United States has been falling behind other industrialized nations in its rate of growth and in its ratio of exports to imports. This is partly due to the fact that American products are less competitive than they have been in the past because we are using too much uncompetitive equipment.

Another reason for the United States falling behind is the lack of new research and development. The R&D leadership that the U.S. demonstrated in past years has declined. That portion of the gross national product spent for R&D has decreased from approximately 3% in 1964 to approximately 2.4% today. Much of this now goes into military development. Foreign growth rates are at least partially explained by our lack of R&D, if we take into account large foreign investment in R&D, and inefficient technology transfer in the U.S. because of military constraints.

Recently, the United States has made slower advances relative to other industrialized countries in areas such as robotics, electronics, and other technical developments.

OUR COMPETITIVE ENVIRONMENT HAS CHANGED

Since international competition is increasing, the United States must work harder to increase its growth rate in key industries to at least match those of other industrialized nations, such as Japan, Canada, France, West Germany, and the United Kingdom.

Part of the problem involves marketing research in creatively selecting the best areas for focus of long- and short-term R&D. A result of selecting R&D programs in less than optimum areas is that their efficiency and profitability are reduced. This, plus the long-term low R&D investment, has led to our relatively slow rate of growth.

Investment in new plants and equipment needs to increase at a time when much U.S. equipment, especially in the optical industry, is less suited for efficient and competitive high productivity. Although there are many applications that do not require the sophistication of diamond-turning, high speed grinding and polishing, robotics, or automated processing, there are still situations where economies can be derived from simpler new technologies, such as molding of aspheric optics to reduce the total number of elements in a system. Recently, some optical and structural parts have been combined by automatic molding and assembly techniques by a few of the more advanced optical companies. This helps these companies compete in the large potential consumer markets.

OUR NEED FOR MORE R&D

There is significant research activity going on in our universities. Much of this is funded by the government, but this funding is not sufficient to compete with the work of many other industrialized countries. Also, there has been a shift of research workers from the academic to the commercial community because of salary levels. New incentives are needed for university researchers and educators to help prepare new people for R&D to revitalize our industries.

Many competing countries have made considerable advances in education, so that area also needs increased attention. Proportionately, the United States has a problem graduating enough qualified engineers from its universities. More integration of academic and commercial activity could further our national commitment to R&D. SPIE and other technical societies can contribute to this end.

The quality of competitive foreign products has increased, but much new international R&D seems to follow American innovation. For example, a number of foreign companies have taken seriously what the U.S. has been taught, while many American firms do not seem to listen carefully enough to consultants and other business leaders.

Competition reduces the time of technological advantage, which affects marketing methodology and pricing. This is an important issue in defining and justifying new R&D expenditures when one knows a new development may be copied, with improvements, within a short time. In any case, this points out the need for more R&D to stay ahead of the competition.

OUR NEED TO INCREASE PRODUCTIVITY

There is an obvious need for the United States to increase efficiency in productivity because of the higher prices of our products relative to those produced elsewhere. Many large U.S. companies are investing in overseas optical and electronic fabrication and assembly facilities.

New technology needs to be developed to help counter the present U.S. balance of trade and increase productivity. Future survival and growth depend upon having high productivity. The optical industry in this country will be superseded in the future if we do not take more advantage of new technological approaches to higher productivity, such as CAD/CAM, high speed production, molding, and replication. If we do not, our prestige in the world market will decline, and we will find U.S. systems using foreign optical components. The lack of extensive flexible machinery using computer automation is responsible for some of the U.S. national relative productivity decline, but initiative in well-focused, production oriented R&D is a significant part of the problem of declining productivity in the international market. It is now technically feasible to automate from preliminary design to finished product.

Increased productivity provides higher profits, new opportunities for growth into new ventures, and more R&D to create new opportunities. It is good to see the work being carried out by many consulting organizations in the Association for Management Consultants, the Institute of Management Consultants, ACME, Inc., and other organizations to increase productivity. These commitments to excellence and increased productivity should have a positive effect on American business in the near future.

METHODOLOGY TO INCREASE PRODUCTIVITY AND GROWTH

Naturally, increases in R&D could provide a better technology base for increased growth and productivity. In order for that to happen, one needs to seriously review the R&D function and take aggressive action toward more complete market research and planning in support of more effective and economic R&D.

There is an increasing need for a continuous technical audit of the R&D function directed by the CEO of a company and aided by outside consultants. This will probably become more important than financial and operational auditing in the future for high technology business. The technical auditing process should review present and future product markets, potential product changes, new products, production automation including CAD/CAM, quality control instrumentation, and information systems. This review function must coordinate with the marketing function and the CEO so that new R&D projects are objectively evaluated for new or continuing R&D investment.

Another approach to advancing the optical industry is to provide standardization of glass and plastic components, much like the electronics industry has done to provide for multiple sources. Larger economies of scale could be provided by adopting industry standards. Each company could then concentrate its efforts in more specialized areas to reduce prices to internationally competitive levels. This would take considerable cooperation, market research, and work in formulating self-imposed regulations. Existing organizations such as ANSI, SPIE, OSA, etc., may be able to play future roles in this standardization.

Optics companies also need to research and then pursue new market segments and applications where optical components or systems can provide new benefits. New markets for low-cost optics may be found in areas such as office equipment, toys, recreational equipment, communication, instrumentation, data processing, etc. High cost optics markets will continue to be found in fusion, microlithography, military systems, etc. New strategies need to be developed to pursue new market segments and applications. Strategies should concentrate on effective and efficient methodologies to market the new products.

As there is an increase in the standard of living in many countries, new marketing opportunities

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*Ed. note: The purpose of this article in part is to stimulate discussion, and alternative views are encouraged. Readers should send comments to Joseph L. Horner, Editor, SPIE Reports, Rome Air Development Center/ESO, Hanscom AFB, MA 01731.

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in agriculture, military systems, communication, and entertainment will also develop. It is imperative that we maintain a technological lead in order to meet new international needs. For some countries the new markets might be in the military, while for others they might be in agriculture, entertainment, and communications.

Management with hands-on operating experience plus knowledge of new technology and markets will play an important role in revitalization of our optical industry. It takes more than new management personnel with M.B.A. degrees to develop significant new applications and strategy that will work within existing highly technical organizations with broad marketing requirements.

In areas where R&D is done through acquisition of technology, some American companies have had trouble competing in international markets. This is probably true because of the lag in technology transfer.

The book *In Search of Excellence* (by Thomas J. Peters and Robert H. Waterman, Jr.) makes a point about serving people's needs, giving people quality, and giving good customer service. The authors note that new U.S. companies with outstanding management are presently growing at significant rates. The book includes patterns, questioning, perception, and answers to business questions raised by recent problems. It places an emphasis on getting back to old-fashioned values, such as respect for people.

The United States is still the leader in basic scientific research and development. One indication of this is the fact that there are more Nobel prizewinners in the U.S. (over 100 since World War II) than in other countries, but a smaller percentage of new U.S., as compared to foreign, patent applications are being submitted to the U.S. Patent Office. One problem of applied R&D is the lack of capital to transfer new technology from the laboratory to multiple-application international markets. This represents a major economic challenge for many small- to medium-sized companies.

USE OF R&D LIMITED PARTNERSHIPS AS A MEANS OF INCREASING OUR R&D

Funding of basic research by the federal government has been significant. American industry also supports some new research, but since the high cost of capital has placed an excessive emphasis on short-term earnings, long-term R&D has been reduced. Some new technologies require sustained commitments of two to five years before obtaining profit potential, so we must again take new initiative in planning and supporting more major new technological innovations. That initiative will give profitable advantage in international markets or, at least, help us to compete.

The present U.S. policy for long-term economic recovery is to minimize governmental regulations and other similar barriers; to reduce federal spending, including commercial nondefense R&D; to promote new investment incentives as outlined in the Economic Recovery Program; and to establish a stable policy and predictable economic framework in a free market. The Commerce Department is encouraging formation of R&D limited partnerships through its Industrial Technology Partnership program.

There is a need for commercial R&D in new technologies such as high speed electronics, new materials, biotechnology, communications, transportation, and other related industries. Use of an R&D limited partnership is one way to accelerate R&D for new products in these markets.

The research and development limited partnership approach to funding corporate R&D does not significantly impact the balance sheet. Since funds from an R&D partnership are treated as income, the cost of R&D activities is considered an expense against this income. Limited partnership financing guarantees that the receiving corporation will never have an unprofitable R&D program since, in the case of a failure, the R&D limited partnership absorbs the project expenses.

When the R&D partnership project is a success, the corporation shares a portion of the success with the partnership in the form of royalties. Several groups that specialize in these partnerships, as previously outlined, are Daleco in Newport Beach, Calif., Capital Technology Group, Inc. in Newport Beach, Calif., University Group, Inc. in Long Beach, Calif., and others throughout the country.

Other means of new financing have not been emphasized here because the limited partnership appears to be the best way for small- to medium-sized businesses to expand their R&D. If you feel that an SPIE-sponsored seminar, workshop, or additional articles should address this topic in more depth, please let me know about your questions or suggested topics.

Book Reviews

Fiber-Optic Rotation Sensors and Related Technologies

S. Ezekiel and H. J. Arditty, eds., *(Springer Series in Optical Sciences, Vol. 32,* A. L. Schawlow, Series Editor), 440 pp., illus., index, references. ISBN 3-540-11791-1. Springer-Verlag Publishing Co., Inc., 175 Fifth Ave., New York, NY 10010 (1982) $33.

Reviewed by John R. Haavisto, Northrop Corporation, Precision Products Division, 100 Morse Street, Norwood, MA 02062.

This book is the proceedings of the First International Conference on Fiber-Optic Rotation Sensors held at Massachusetts Institute of Technology in November 1981. The aim of the conference was to assemble the key researchers in the field of fiber optic gyroscopes to exchange information about recent developments. The quality of the presentations and the scope of the topics covered made the conference successful; these same characteristics make the proceedings a valuable text for workers in the field.

The first chapter, a tutorial review written by the editors, is an excellent primer on fiber optic gyroscope operation. Key topics covered include a straightforward (and correct) derivation of the Sagnac (rotation-induced) phase shift, the method and configurations used to measure it, its fundamental limits, and the technology employed. Noteworthy for those new to the field are the discussions of open-loop and closed-loop operations and of reciprocity and the minimum configuration. Included in this section is a general bibliography of 195 (titled) references.

Chapter 2 discusses theoretical considerations, the Sagnac effect, polarization problems, and reciprocity considerations. The article on the Sagnac effect by Arditty and Lefèvre presents a relativistic derivation of the rotation-induced phase shift which demonstrates the independence of the phase shift from material properties, a fact often incorrectly presented in more heuristic derivations. Another key article in this chapter is an extremely thorough derivation of polarization effects on fiber optic gyros output by Ulrich. It and subsequent articles in the chapter describe the necessity for polarization control in fiber gyros and indicate some schemes to accomplish this.

The third chapter deals with building blocks for the gyros: integrated optics and fiber optics components, single-mode fibers, and diode lasers. The articles on integrated optics components include an overview by Papuchon, an article on electro-optic modulators by Leonberger, and a description by Ramer of a fiber-coupled modulator chip fabricated at Hughes Research Laboratories. The fiber optics components (actually used in a fiber gyro at Stanford) include single-mode bidirectional couplers, a polarizer, and polarization controllers, and are well described in the lead article. Other articles discuss fiber couplers and phase modulators. The heart of the components section is the discussion of single polarization maintaining fibers. An excellent tutorial by Kaminow is followed by the description of several techniques for fabricating such fibers and for characterizing their properties.

Experimental configurations of both open-loop and closed-loop devices are described in Chap. 4. Results from various universities and industrial laboratories show the magnitude of noise sources in various configurations and some practical noise suppression schemes. Recent results using polarization-preserving fibers and broadband sources, presented since the conferences, make some of these articles dated.

The next chapter discusses some specific gyro performance-limiting sources. One important error observed was the nonreciprocal error arising from the intensity-dependent Kerr effect. Other topics discussed include magnetic field effects and detector noise limitations.

Chapter 6 presents several articles on advanced concepts, specifically, fiber resonators, phase-conjugate systems, and Kerr effect enhancement of the Sagnac effect. The configuration described first, a reentrant fiber optic rotation sensor, is particularly useful since the resonator approach is an interesting alternative to the basic fiber optic interferometer, and recently has been the subject of several interesting laboratory experiments.

Chapter 7 describes several other sensor applications in which fibers have been used, such as

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magnetometers, strain sensors, sensor sensors, and accelerometers. Much work has been done on fiber optic sensors, and this section would have benefited greatly from an overview and descriptive summary of the various categories of sensors.

The volume ends with a summary of the marketing considerations for fiber optic rotation sensors: the potential is very large but the existing mechanical sensors, technologically mature and inexpensive, will be difficult to replace.

In summary, I feel the book is an excellent reference for fiber optic gyros, a necessity for those entering the field and recommended for those currently working in it. While some of the material may become dated (indeed, some already has), the tutorial and overview articles provide a solid basis for understanding fiber optic gyro operation, configurations, and error sources.

Photon Correlation Techniques in Fluid Mechanics

E. O. Schulz-DuBois, ed., *(Springer Series in Optical Sciences, Vol. 38,* A. L. Schawlow, Series Editor), 399 pp., illus., references. ISBN 0-387-11796-2. Springer-Verlag Publishing Co., Inc., 175 Fifth Ave., New York, NY 10010 (1983) $33.

Reviewed by Bahaa E. A. Saleh, Dept. of Elect./Computer Eng., University of Wisconsin, Madison, WI 53706.

Photon correlation is a high resolution spectroscopic technique that is capable of measuring line widths ranging from a few Hz to many MHz. It has also been known as "light beating spectroscopy" and "intensity interferometry." The technique has been associated with laser light scattering. Narrow-linewidth laser light is scattered from a slowly fluctuating medium, and the measured spectral broadening of the scattered light gives information on the target fluctuations. The narrow spectrum is measured by counting photoelectrons and computing their autocorrelation using high speed electronic correlators.

Since its conception in the mid-1960s, interest in the technique has grown rapidly. It attracted considerable attention in the seventies, a decade that witnessed extensive fundamental studies on the nature of the technique and its limitations, as well as a widening of the scope of its applications. It is safe to say that photon correlation spectroscopy has now reached maturity. The issues today involve details arising from new applications (e.g., velocimetry), refinements allowing extraction of finer details of the nature of target fluctuations (e.g., particle polydispersity), and improvements in instrumentation hardware and software that followed the fast improvements in electronic components. This is particularly manifested in this volume, which contains the proceedings of the latest of a series of five important international conferences on this subject that have been held since 1973.

Proceedings of conferences are collections of a large number of independent papers. Typically, one is interested in reading a few papers, which one promptly photocopies without the need to actually own the book. The case of this book is not quite typical. This book was intended to give "an authoritative account of the field, of what has been achieved thus far, and the directions in which current research is heading... an up-to-date synopsis." In my opinion the book succeeds in achieving its goals, given the limitations of a multiauthored undertaking. The book is well-organized; it begins with a well-written introductory survey of the fundamentals of the technique written by the editor and is divided into three parts, each beginning with a comprehensive review article. Such review articles, as well as the collection of papers on "state-of-the-art" research on the subject, are usually a persuading factor for a researcher working in the area to actually have the book on his/her self.

Part 1 (18 papers and 2 abstracts) deals with the application of photon correlation to velocimetry. It begins with an introduction and a survey of applications to velocimetry by J. B. Abbiss. Topics covered in this part include laser Doppler velocimetry, laser transit velocimetry, and new methods for the direct measurement of components of the velocity gradient tensor.

Part 2 (6 papers) is devoted to advances of the techniques of photon correlation, including alternative schemes of signal preprocessing and processing in the correlator and the use of signals other than photoelectron pulses in correlation techniques. The first paper in this part is a review of the subject by K. Schatzel.

Part 3 (13 papers and 3 abstracts) deals with studies of particles under Brownian motion. The problem of extracting information on particle polydispersity by use of inverse techniques is addressed by several papers, beginning with a short review paper by N. Ostrowsky and D. Sornette. Other papers in this part address particle dynamics in several special applications (charged particles, particles in the concentrated regime, aggregating particles, mixed micelles, multiple scattering, fluorescence correlation). This part also includes a tutorial introduction to the dynamics of interacting Brownian motion by P. N. Pusey.

In conclusion, the organizers of the conference, the participants, and the editor of the proceedings have provided an excellent source of information on the latest advances in photon correlation techniques.

Radiometry and the Detection of Optical Radiation

Robert W. Boyd, 254 pp., illus., index, references. ISBN 0-471-86188-X. John Wiley & Sons, Inc., Order Dept., One Wiley Drive, Somerset, NJ 08873 (1983) $34.95.

Reviewed by James M. Palmer, Optical Sciences Center, University of Arizona, Tucson, AZ 85721.

The author states in the preface that this book is directed to first-year graduate students in optics and covers some of the basic aspects of generation, propagation, and detection of radiation at optical frequencies. The book is arranged quite logically into 14 chapters. The first six chapters cover E&M from Maxwell's equations and the wave equation, through blackbody radiation (theory and applications), to classical radiometry (the propagation of radiance) and photometry. The final eight chapters cover the detection of optical radiation, including phenomenological descriptions of detection mechanisms and fundamental limitations imposed by noise. The emphasis is mostly theoretical, with a large number of mathematical derivations of important topics, i.e., blackbody radiation, the radiance theorem, noise power spectrum analysis, photon noise limitations, and detector NEP. Each chapter has a short bibliography and appropriate problems for homework assignments. With the exception of some poor definitions and errors, to be mentioned later, this book provides an adequate basis for a course in radiometry and detectors, assuming the course emphasis to be theoretical.

The dust jacket states that the book is a "comprehensive treatment of the generation, transfer and detection of optical and infrared radiation that is... extremely useful to the working scientist and engineer." It further states, "... the working professional obtains invaluable practical information." Whoever wrote those statements either did not read the book or does not know what constitutes "practical" information in this field. This is not a book that the practicing engineer will use very often. The material covered by Boyd should indeed be studied at one point in one's career to gain a fundamental understanding of the topics covered. Then the book can be put on a high shelf or returned to the library. An inevitable comparison must be made with two recent volumes from the series "Optical Radiation Measurements," edited by F. Grum. The first of these, *Radiometry,* by Grum and R. Becherer, is a fine example of a practical source book. The fourth volume, *Physical Detectors of Optical Radiation* by W. Budde, is the book of choice when the reader wishes to actually do something with a detector.

This book suffers greatly from numerous errors of two types: those missed typos and glitches apparently due to carelessness and haste in meeting publication deadlines, and those errors due to the author's inexperience and unawareness of previously established definitions, conventions, etc. Examples of the first type include misspelling the names Seebeck and Lambertian; the ordinate labeling of Fig. 4.2; interchanging the λc values for CdSe and CdTe in Table 10.1; the equation reference to (8.62) on the bottom of p. 214, which should be (8.63); and the term "transmitted" instead of "reflected" on p. 59. On pp. 173–174, the symbol r(N) is defined as a recombination coefficient, using ρ as some "constant." On the next page, however, r(N) is redefined as a recombination rate with ρ now used as a recombination coefficient. Inconsistencies such as these are particularly confusing in an introductory text. Finally, the first copy that I received had a number of blank pages, ostensibly for note-taking. Unfortunately, these pages should have contained half of the last chapter and the first part of the index. Caveat emptor!

The "errors of the second kind" are potentially more hazardous, particularly for the student who has had little or no prior exposure to this material. The following examples are indicative of definitions and concepts that are either marginal or incorrect. The chief ray is defined as "any ray that passes through the center of the aperture stop," whereas it should be those rays that pass through the aperture stop *and* through the edge of the object (and image). "Photoconductive" is once more used as an adjective for a photovoltaic detector. It would be much less confusing if the term "back-biased photodiode" were used instead. The ambiguous term "sensitivity" is used in several places to imply "detectivity." This term is now considered obsolete and has been replaced with "responsivity," which has a different connotation. Pn is not generally used for noise equivalent power, but NEP is quite acceptable. In addition, ϕ rather than P is the accepted symbol for power. The long-standing discussion distinguishing terms ending in -ance and those ending in -ivity is not at all aided by the definitions presented. The term "radiation temperature" is misdefined as the temperature of a blackbody whose radiance at a given (not specified) wavelength is the same as that from the unknown source, whereas it should be defined as the temperature of a blackbody radiator whose *total* radiant

Continued on Page SR-048

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Continued from Page SR-046

exitance is the same as that of the source in question. The author's definition is properly applied to "brightness temperature." The term "intensity" is given a new set of adjectives, "physical" and "radiometric," to attempt to alleviate the long-standing confusion, but these do not help. The discussion on "excess noise" is a valuable contribution to understanding the role of signal- and background-generated shot noise and photon noise components of the total noise, but the term "excess noise" has prior usage as one of the synonyms for $1/f$ noise. Either the root word "trivial" is misused on pages 20 and 80, or the author really does consider these results to be of little importance. It comes as a surprise that radiant energy detectors are classified into three types: thermal, photon, and coherent. The former two are quite sufficient, since examples of each can be used in coherent detection schemes.

My final comment deals with the method of referencing. Short bibliographies are included at the end of each chapter, although not all of the entries are mentioned within the chapter. Most of the specific references are embedded within the text without further notation, a scheme that makes the process of tracking down references at a later time very difficult. I suspect that this practice results in economies of publishing and fewer errors in the reference list, but it is not in the best interests of the reader.

Should the optical scientist have this book on his or her shelf? Maybe. The derivations are for the most part lucid and need to be studied at least once during one's career. How about the optical engineer? Probably not, inasmuch as the reference material is limited, and the references to other literature are largely inaccessible.

Absorption and Scattering of Light by Small Particles

Craig Bohren and Donald Huffman, 530 pp., illus., index, references. ISBN 0-471-05772-X. John Wiley & Sons, Inc., Order Dept., One Wiley Drive, Somerset, NJ 08873 (1983) $49.95 hard cover.

Reviewed by R. H. Picard, Air Force Geophysics Laboratory, Infrared Technology Division, Hanscom AFB, MA 01731.

Beginning with the basic premise that the absorption and scattering of light by small particles is inseparable from the condensed-matter physics of the material from which the particle is composed, Bohren and Huffman have written a book that should be a marvelous addition to the literature on light scattering. The book is basically an advanced monograph, in the authors' own estimation. However, it is written with real attention to pedagogy and seems stylistically more akin to a textbook without problem sets than to a monograph. At any rate, a book of such combined scope, depth, and insight has probably not been published since van de Hulst's *Light Scattering by Small Particles* appeared in 1957.

The book is written in three parts: one dealing with electromagnetic scattering concepts, one with the optical properties of bulk matter, and the final part merging the two concepts. In Part 1, the electromagnetic theory of scattering by particles of specified complex refractive index is presented. After an introductory chapter, a chapter on electromagnetic waves is included, beginning with Maxwell's equations and ending with propagation through a slab and the analogy between slabs and particles. This is followed by chapters on general scattering concepts, the Mie theory of absorption and scattering by an arbitrary sphere, the Rayleigh scattering limit of small particles, the Rayleigh-Gans theory, and the geometrical optics limit, ending with a discussion of various generalizations and extensions to inhomogeneous particles, anisotropic and optically active particles, and so forth. Part 2, the shortest part, treats the optical properties of bulk condensed matter, starting with presentations of the classical models of Lorentz, Drude, and Debye and ending with a discussion of measured reflectance spectra and the inferred complex refractive indexes. The latter discussion focuses its attention on three typical materials, namely MgO, aluminum, and water, which the authors keep returning to throughout the remainder of the book—a very effective stratagem. Part 3 studies the scattering of light by real particles having realistic optical properties. This part begins with a survey of the Mie theory predictions for extinction by particles composed of the three representative materials of Part 2, followed by general considerations on absorption and extinction by real particles. The presentation continues with a chapter on resonant modes, or so-called surface modes, of particles, a chapter on the theory and practice of measuring the angular dependence of scattering matrix components, and a chapter on a variety of atmospheric, astrophysical, and laboratory applications.

The subject of scattering and absorption by particles is attacked by a varied and multifaceted approach. Heavily mathematical sections are interspersed with more descriptive sections dealing with experimental or computational methods, the results of numerical computations or experiments, experimental apparatus, and applications. There is no attempt to avoid intricate mathematics, and some readers may find the chapter dealing with the Mie theory (Chap. 4) mathematically awesome. The authors, however, attempt in parallel to develop the reader's intuition for the behavior of small particles exposed to light waves, and for the most part they succeed admirably well. The reader is offered numerous useful rules of thumb and aphorisms to salt away for a time of need, such as, "if there is an interesting effect in a thin film, there will be a corresponding effect albeit with possibly a few new twists in small particles" (p. 335). As another case in point, while Rayleigh scattering by small spheres is derived from Mie theory, Rayleigh's original derivation of the λ^{-4} law is also reproduced in its entirety. The latter argument, based on dimensional analysis, is a jewel of economy and elegance and has high intuitive appeal.

Bohren and Huffman clearly stake out the territory of the book to include only single scattering by isolated classical particles and to exclude any discussion of the quantum theory of dispersion, multiple scattering by particles, inelastic (Raman and Brillouin) light scattering, and scattering by thermodynamic fluctuations. The book champions the cause of classical mechanical descriptions of matter, and the reader is correctly urged to give classical models a chance while refraining from invoking quantum size effects at the first hint of any unexpected behavior of light in relation to small particles. Nevertheless, the authors do not hesitate to include a brief section on light scattering by electron hole droplets in germanium, a cooperative quantum system recently in vogue and subject to extensive study.

A novel feature of this book is a series of three programs, written in FORTRAN, to handle Mie scattering calculations for a homogeneous sphere and for a coated sphere, as well as scattering by a normally illuminated infinite cylinder. An extensive set of more than five hundred references is included, and all topics treated in the text are extremely well documented by literature references. In addition, each chapter has a valuable "Notes and Comments" section at the end, which is really an annotated bibliography referring the reader to the literature for extensions and alternate approaches to the subject under discussion.

While some may consider the book to be afflicted with excessive verbiage, others—this reviewer included—will feel instead that it makes judicious use of the time-honored pedagogical tool of repetition. The authors look at many problems in several different ways and intersperse the development with strategically located summaries. In addition, their style is often colloquial, manifesting the book's evolution from lecture notes, and the text is studded with picturesque language, imagery, humor, and even an anecdote (p. 279).

As might be expected, in spite of its many strengths Bohren and Huffman's book has a few minor shortcomings. Athough the text is remarkably free of typographical errors, there are occasional misprints, one of the more interesting being the invention of Planck's quantum of inverse action (p. 240) through the relation $\epsilon_0 = \omega_0/\hbar$. There are also some poor choices of notation, notably the use of k for both the wave vector and the imaginary part of the refractive index, the introduction of two different Greek epsilons, ε and ϵ, having different meanings without so much as a comment, and the overuse of Q to represent one of the Stokes parameters, the scattering matrix, and the extinction (scattering, absorption) efficiency. The authors also tend to ramble from time to time and to drag out the discussion of points that could be made quite concisely.

These relatively minor objections did not diminish my overall favorable impression of the book. I enjoyed reading it and recommend it enthusiastically to anyone who wants a lucid, complete, and up-to-date discussion of scattering and absorption by small particles for self-study or for a variety of classroom applications.

Absorption and Emission by Gases—Physical Processes

Earl J. McCartney, 320 pp., illus., index, references. ISBN 0-471-04817-8. John Wiley & Sons, Inc., One Wiley Drive, Somerset, NJ 08873 (1983) $49.95.

Reviewed by Robert McClatchey, Air Force Geophysical Lab., Hanscom AFB, MA 01731.

This book is an excellent treatise on the subject of absorption and emission by atmospheric gases, both for the experienced worker in the field and for the newcomer. Earl McCartney has a way of providing a *Scientific American* kind of intuitive understanding of many facets of the technical area, but at the same time he backs up this understanding with a detailed physical and mathematical description of the material.

The book contains seven well-organized chapters, starting in Chap. 1 with general comments on the origin of spectral absorption and emission lines and their relationship to atmospheric phenomena, along with a description of the laws of blackbody radiation. The second chapter emphasizes the gas laws, thermodynamic properties of gases, and the kinetic theory of gases so necessary for the discussion of quantized energy states and radiative properties of gases to come in the later chapters.

Chapters 3, 4, and 5 provide an adequate, although condensed, summary of theoretical spectroscopy as it applies to the important constituents of the atmosphere. The author takes us all the way from quantized energy states associated with the Schrödinger equation through a very lucid discussion of statistical mechanics and into a discussion of the transitions that can occur between and within the bound energy states of matter, giving rise to the complicated spectral structure observed in high resolution atmospheric spectra. These three chapters represent a real effort to make a difficult subject comprehensible in terms of the atmospheric molecules of interest. There are many books on theoretical spectroscopy available that go into far more detail, but there is none that provides the clarity of understanding, at the right level of complexity, provided by McCartney.

In Chap. 6 the physical basis for shapes of spectral lines in the atmosphere is provided, and the mathematical formulations are developed. Results are first developed for a single line and then for the models describing the arrays of lines so typical of the spectra of atmospheric molecules, particularly in the infrared. The seventh chapter provides a description and sources of absorption and emission data in the laboratory, in the atmosphere, and available through computational techniques using information on the spectral line structure of the various atmospheric constituents.

This book contains eight appendixes covering material ranging from units and physical constants to blackbody curves, including some typical atmospheric transmittance results. The bibliography is adequate for the reader to find additional important references from which to begin a detailed understanding and analysis of any of the material described in this work, but the bibliography is not exhaustive.

The only other book that comes close to covering the range of material covered here is the 1964 book by R. M. Goody, *Atmospheric Radiation I Theoretical Basis.* Goody's book gives much less attention to the physics of spectroscopy and is harder for the newcomer to understand. Because of its date, the Goody volume does not contain the up-to-date information on data sources contained in McCartney's book.

There are many volumes on theoretical molecular spectroscopy that go into much more detail than McCartney does (notably the Hertzberg volumes *Infrared and Raman Spectra* and *Spectra of Diatomic Molecules,* but they are much more difficult reading than McCartney and provide more detail than most atmospheric physicists require.

Earl McCartney brings a capability to this subject not available in any other single source. He is unique in his ability to extract the essential physical and mathematical details from other more complicated sources and set them down in a manner that is both easy to read and easy to understand. In some instances he uses examples drawn from other walks of life to clarify a point. For example, he provides a particularly good description of entropy and its relation to information theory by describing the order (or lack thereof) in a file full of cards. He provides many simple visual-conceptual explanations for complex physical processes—an example of which is his description of ℓ-type doubling in Chap. 4.

Those of us who work in the area of atmospheric absorption and emission will be delighted to have this book on our shelves, so that we might review some physical or mathematical detail in a clear and concise manner. Those who may be new students to the field owe McCartney much, because their effort to understand the processes of atmospheric absorption and emission will be made much easier due to his effort.

Emission Computed Tomography: Current Trends

Peter D. Esser, ed., 320 pp., illus., references. ISBN 0-932004-16-4. Society of Nuclear Medicine, 475 Park Avenue South, New York, NY 10016 (1983) $20 for society members, $27 for nonmembers, plus $2.50 postage and handling.

Reviewed by William W. Stoner, Science Applications, Inc., 3 Preston Court, Bedford, MA 01730.

Technical people desiring an introduction to the field of emission computed tomography will find this book useful. For the uninitiated, emission computed tomography (ECT) is a nuclear medicine diagnostic imaging technique analogous to x-ray computed tomography. The patient is first dosed with a radioactive tracer (a radiopharmaceutical); then gamma-ray profiles are measured as a function of the emission direction. As in x-ray computed tomography, these "projection" data are inverted to produce cross-sectional images of the radiopharmaceutical concentration within the patient's body.

Although the book is a collection of papers from a symposium, it is reasonably well focused, with 80% of the papers dealing directly with some aspect of emission computed tomography. One of the lead papers, by A. Todd-Pokropek, provides an excellent review of the mathematics and physics of ECT. The emphasis in Todd-Pokropek's paper is on single-photon ECT, as distinguished from the PET technique established by G. L. Brownell that uses coincidence detection of antiparallel annihilation quanta generated by the decay of positronium. The emphasis on single-photon ECT is consistent throughout the book; only one paper specifically addresses PET.

The companion lead paper, contributed by G. T. Gullberg, J. A. Malko, and R. L. Eisner of General Electric Medical Systems Operation, concerns the gamma-ray attenuation corrections that must be made to obtain good images. The standard approach to the problem is to first measure the 3-D location of the patient's skin (or boundary) so that absorption effects can be approximated by assuming that inside the boundary the gamma rays encounter a uniform linear absorption coefficient. Gullberg, Malko, and Eisner discuss techniques for deriving the boundary directly from the ECT data, as well as the absorption correction of ECT images with the boundary information.

There are four other sections to the book. These are "Emission Computed Tomography: System Performance and Quality Assurance" (five papers), "Practical Problems and Clinical Applications" (five papers), "Data Processing" (five papers), and "Other Topics" (four papers). The "Other Topics" are purely tangential: radionuclide angiography, radionuclide measurement of left ventricular function, color display techniques, and an expert or knowledge-based artificial intelligence system for management of hepato-biliary disease.

The overall organization of the book is sensible and helpful for readers who are interested in specific areas. The papers are readable and informative. Although there is no index, this is not a serious problem since appropriate papers are easily accessed via the table of contents.

In summary, I found the book enjoyable and valuable. ECT is rapidly evolving, however, so this book of "current trends" probably has a lifetime of between two and five years.

Books Received

Handbook of Measurement Science, Vol. 2. Peter H. Sydenham, ed., 1413 pp., ISBN 0-471-10493-0. John Wiley & Sons, New York (1983) $97.95. There are 32 chapters, of which one is optical, devoted to basic principles, design, and philosophy of measurement of all kinds. It also includes chapters on various types of transducers.

Energy Conservation in Buildings 1973-1983, a Bibliography of European and American Literature on Government, Commercial, Industrial and Domestic Building Energy Management and Technology. Penny Farmer, viii + 107 pp., ISBN 0-946655-00-6. Technical Communications, Turvey, Bedford, England; U.S. distributor: Scholium International Inc., 265 Great Neck Road, Great Neck, New York 11021 (1983) $39.50.

Clear and Cloud-Free Lines-of-Sight from Aircraft (Addendum). Eugene A. Bertoni, 8 Aug. 1977, Reprinted 6 Sept. 1983. Report #AFGL-TR-77-0141, Metrology Division, Air Force Geophysical Laboratory, Hanscom AFB, MA 01731.

Transmission Electron Microscopy. Ludwig Reimer, 521 pp., ISBN 0-387-11794-6. Springer-Verlag Publishing Co., 175 Fifth Ave., New York, NY 10010 (1983) $46. Monograph on the electron microscope dealing mostly with the physics of electron optics and electron-specimen interactions.

Meetings

APRIL 1984

Apr. 12-13 International Symposium on Optical Communication Technology, Tokyo, Japan. Sponsored by Nippon Telegraph and Telephone (NTT). Contact Kazunori Yoneno, NTT, 200 Park Ave., Room 2905, New York NY 10166. 212/867-1511.

Apr. 16-19 International Symposium on Remote Sensing of Environment, Third Thematic Conference: Remote Sensing for Exploration Geology, Colorado Springs, CO. Sponsored by Environmental Research Institute of Michigan (ERIM). Contact Donald R. Morris-Jones, ERIM, P.O. Box 8618, Ann Arbor MI 48107. 313/994-1200, ext. 344.

Apr. 17-20 1984 Spring Conference on Applied Optics, Monterey, CA. Apr. 17-18, **Science of Polishing;** Apr. 17-19, **Optical Interference Coatings** (presented in cooperation with American Vacuum Society, Society of Vacuum Coaters, and SPIE); Apr. 18-20, **Workshop on Optical Fabrication and Testing;** Apr. 18-20, **Optical Data Storage** (sponsored by OSA and Quantum Electronics and Applications Society of the IEEE; in cooperation with American Vacuum Society and SPIE); Apr. 19-20, **Gradient-Index Optical Imaging Systems.** Optical Society of America, 1816 Jefferson Place, N.W., Washington, D.C. 20036. 202/223-8130.

Apr. 19-20 Fifteenth Annual Pittsburgh Conference on Modeling and Simulation, Pittsburgh, PA. Sponsored by School of Engineering, Univ. of Pittsburgh. Contact William G. Vogt or Marlin H. Mickle, Modeling and Simulation Conference, 348 Benedum Engineering Hall, Univ. of Pittsburgh, Pittsburgh PA 15261.

Apr. 24-26 Seventh Topical Meeting on Integrated and Guided-Wave Optics, Kissimmee, FL. Sponsored by Quantum Electronics and Applications Society of the IEEE and OSA. Optical Society of America, 1816 Jefferson Place, N.W., Washington, D.C. 20036. 202/223-8130.

Apr. 24-26 Smoke/Obscurants Symposium VIII, Harry Diamond Laboratories, Adelphi, MD. Sponsored by the Dept. of Army, Office of the Project Manager Smoke/Obscurants. For more information, contact PM Smoke/Obscurants, ATTN: DRCPM-SMK-T (Mr. Klimek), Aberdeen Proving Ground MD 21005. 301/278-5411 or 5605.

Apr. 24-27 Symposium Optika '84, Budapest, Hungary. Organized by the Section for Optics of the Optical, Acoustical and Filmtechnical Society. Sponsored by Optical Div. of EPS, IMEKO, Eötvös Loránd Physical Society, Hungarian Optical Works, TUNGSRAM, and SPIE. Contact OPAKFI, Budapest, Anker köz 1, H-1061, Hungary. Telex: MTESZ Budapest, 22-5369 for OPAKFI.

Apr. 29-May 2 Fourth International Symposium on the Planning of Radiological Departments (ISPRAD IV), Dorado, Puerto Rico. Contact Harry W. Fischer, University of Rochester Medical Center, P.O. Box 648, Rochester NY 14642. 716/275-2733.

Apr. 29-May 4 SPIE • Technical Symposium East '84 and Exhibit, Arlington, VA. General Chairman: William H. Carter, Naval Research Lab. Program includes related tutorial short courses and the following selection of two-day technical conferences: **Applications of Artificial Intelligence.** Chairman: John F. Gilmore, Georgia Institute of Technology. **Integrated Circuit Metrology II.** Chairman: Diana Nyyssonen, NBS. **Fiber Optic and Laser Sensors II.** Chairmen: Emery L. Moore, Litton Guidance & Control Systems; O. Glenn Ramer, Hughes Research Laboratories. **Infrared Optical Materials and Fibers III.** Chairman: Paul Klocek, Consultant. **Fiber Optic Couplers, Connectors, and Splice Technology.** Chairman: Carl A. Villarruel, Naval Research Lab. **Optical Technology for Microwave Applications.** Chairman: S. K. Yao, TRW Technology Research Center. **Excimer Lasers, Their Applications, and New Frontiers in Lasers.** Chairman: Ronald W. Waynant, Naval Research Laboratory. **Optical Alignment II.** Chairman: Mitchell C. Ruda, Talandic Research Corporation. **Applications of Laser Chemistry and Diagnostics.** Chairman: Albert B. Harvey, Naval Research Lab. **Recent Advances in Civil Space Remote Sensing.** Chairman: Harold W. Yates, National Environmental Satellite, Data, and Information Service, NOAA. **CRITICAL REVIEW OF TECHNOLOGY: Remote Sensing.** Chairman: Philip N. Slater, Optical Sciences Center, Univ. of Arizona. SPIE, P.O. Box 10, Bellingham WA 98227-0010. 206/676-3290.

MAY 1984

May 1-2 1984 Symposium of the IEEE Society on Social Implications of Technology: Electro-Culture 1984, Arlington, VA. Presented in conjunction with SPIE's Technical Symposium East '84. For further information about the technical program contact Prof. Stephen H. Unger, Dept. of Computer Science, Columbia University, New York, NY 10027. Telephone 212/280-8187 (or leave messages at 212/280-2736).

May 1-3 Fibre Optics '84—The International Exhibition and Conference on Applications of Fibre Optics, London, England. Tutorial: April 30. Contact Sira Conference Unit, South Hill, Chislehurst, Kent BR7 5EH, England. 01-467 2636. Telex 896649. Exhibition information: Evan Steadman Ltd., The Hub, Emson Close, Saffron Walden, Essex CB10 1HL, England. 0799 26699.

May 7-11 International Thermography Congress, Lucerne, Switzerland. Cooperating organizations include Swiss Association of Thermography in Buildings (VSEB), Swiss Association of Nondestructive Testing (SVMT), German Association of Thermography (VTD), European Association of Thermography (EAT), and SPIE. Contact Chr. Florin, Florin & Scherler AG, Postfach 108, 6010 Kriens, Switzerland. Telephone 041-41 0137.

May 13-17 Computer Graphics '84 Conference and Exposition, Anaheim, CA. Sponsored by the National Computer Graphics Association. Cooperating organization: SPIE. Related tutorials. Contact National Computer Graphics Association, 8401 Arlington Blvd., Suite 601, Fairfax VA 22031. 703/698-9600.

May 14-17 British Robot Association Seventh Annual Conference, Cambridge, England. Contact The Conference Director—B.R.A. 7, British Robot Association, 28-30 High St., Kempston, Bedford MK42 7AJ, England. Tel: (0234) 854477. Telex: 825489.

May 14-17 International Conference on Communications (ICC-84), Amsterdam, The Netherlands. Cosponsored by IEEE Communications Society and IEEE Benelux Section. Contact Dr. T.A.C.M. Claasen, Secretary ICC-84, Philips Research Laboratories, WY-2, 5600 MD Eindhoven, The Netherlands.

May 15-16 Sixth Advanced Aircrew Display Symposium, Naval Air Test Center, Patuxent River, MD. Contact Frederick C. Hoerner (SY70C), NAVAIRTESTCEN, Patuxent River MD 20670. 301/863-4157. Autovon: 356-4157.