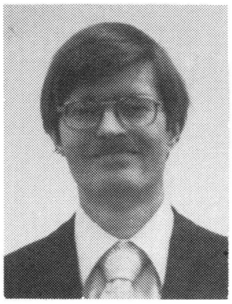

Editorial

H. J. Caulfield, Editor

Tutorial Materials in *Optical Engineering*

With this issue we revive a practice once common in *Optical Engineering*—the inclusion of tutorial material in the SPIE Reports. This offers me a chance to say what I hope these tutorials can accomplish and to seek reader assistance in finding topics and authors for future tutorials.

Optical Engineering is aimed at those people who make optics work. The archival papers are intended to share specific information on what the authors have achieved in very specific areas. The SPIE Reports are intended to provide other forms of usable information. One of the practical problems faced by every optical engineer in the world is the fact that he cannot be an expert in all of the areas which bear directly on his project. Some of those areas are covered well in books. This is why I regard our book reviews as vital. Other areas are not covered in books because they are too new, the audience is too low, or the amount of material is too limited. For these areas, the tutorial is the ideal vehicle for communication.

The tutorial author must combine acknowledged authority with a skill for communication. Clearly this is a very difficult task. Accordingly, I am delighted that the first tutorial under my editorship is by the authoritative and productive team of George O. Reynolds and John B. DeVelis writing on a subject with which they have been concerned for the last fifteen years—coherence effects in instrument design.

Theirs will be a tough act to follow but it needs to be followed. Many tutorial topics occur to me but the motivation must come from you. Please share with me your thoughts and suggestions. *Optical Engineering* will be your journal to the extent that you participate in it.

OPTICAL ENGINEERING EDITORIAL SCHEDULE

JULY/AUGUST 1981

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MAY/JUNE 1982

Coherent Optical Strain Analysis

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JULY/AUGUST 1982

Incoherent Optical Strain Analysis

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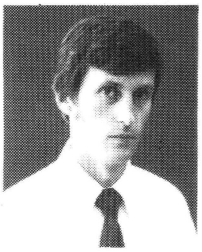
Forum

Laser Velocimetry



W. M. Farmer

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1. INTRODUCTION

Recent reports and publications have indicated renewed interest in applying laser velocimeter (LV) systems, to the measurement of three simultaneous components of velocity. It is of interest, therefore, to briefly describe the technology in this area which has been reported thus far in the literature or which is presently known to the author. It should be pointed out that all three component laser Doppler velocimeter (LDV) systems reported thus far have involved the measurement of nonorthogonal velocity components. These components are then transformed into an orthogonal set by transformation equations of the Euler type.[1] The examples of three component laser velocimeter systems which have been reported thus far in the literature can be divided into either (1) local oscillator systems wherein reference beams are used, or (2) combined local oscillator and differential Doppler systems, or (3) angularly separated differential Doppler systems. These systems are briefly discussed in the following sections.

1.1. Local oscillator systems

The most notable systems of this kind reported thus far or which have been proposed have been those by Huffaker[1]; Jackson, Poslajko, and Harwell[2]; and by Rizzo.[3] The system reported by Jackson et al. is identical to the system originally described by Huffaker.[1] Figure 1 illustrates the optical arrangement which is used in such a system. Basically, a single laser beam is focused into the flow and transmitted into the detector assembly. Scattered light from three different directions which are symmetrically located about the primary beam is folded into the reference beam thereby providing three nonorthogonal velocity components. This system was mounted on a large mill bed and used a very sturdy optical system to maintain alignment. However, it provided considerable data as evidenced by the report by Jackson et al.[2]

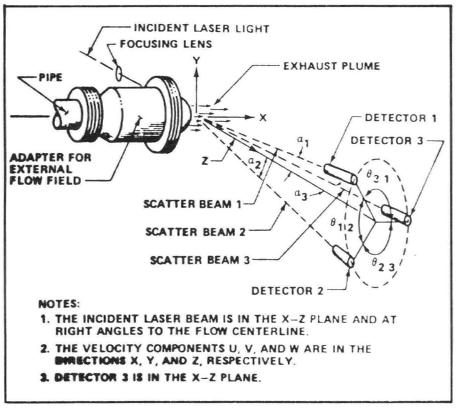

Fig. 1. Schematic of the three-dimensional local oscillator LDV and its alignment relative to the exhaust plume flows.

The system described by Rizzo is apparently not nearly as sensitive to angular alignment with the reference beams since it used a scattering plate arrangement to provide a broad spectrum of potential reference directions for the scattered beam.[3] It also measures nonorthogonal velocity components.

1.2. Combination local oscillator and differential Doppler systems

These systems have been described by Farmer, Hornkohl, and Brayton,[4] Orloff and Logan,[5] and Schwiesow, Cupp, Post, and Calfee.[6] The system described by Farmer et al. was operated over a transmission distance of approximately 30 meters and was originally intended as a system to be operated in atmospheric applications. However, it was not found sufficiently sensitive for ranges much greater than 30 m because of atmospheric scintillation and the need for relatively high data rates which it was unable to provide. It was found, however, that in short term applications, it did work reasonably well, although spatial resolution in the third component which used a local oscillator beam was poor. It should be pointed out that in this type of approach the angles between the measured velocity components were all nearly orthogonal. Two such components are directly orthogonal and the third is not perpendicular to the other two by less than a degree. The system described by Orloff and Logan was capable of directional sensitivity via a Bragg cell frequency shifter and used polarization separation to identify the respective components. Again, it provided two orthogonal velocity components and a third component which was nearly orthogonal to the first two. The system described by Schwiesow et al. was originally designed to measure velocities in atmospheric vortices, such as dust devils, and to be of a sufficient size that it could be flown in a small airplane. It utilized a combination, which to this author's knowledge has not been proposed before, wherein two reference beams were made to cross and focus at point S (see Fig. 2). The local oscillator beams produced two nonorthogonal components. A third component which was perpendicular to the bisector of these two beams was determined through the interference generated between beams 1 and 2. Spatial resolution for this system was found to be quite poor because of the size of the optics and range over which the system operated.

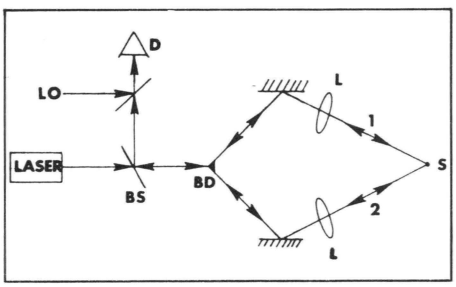

Fig. 2. Three-dimensional LDV by Schwiesow et al.

1.3 Differential Doppler systems

These systems have found prominent use in recent applications. Farmer originally described the transformation equations which were required for applying these types of systems to the measurement of three orthogonal velocity components.[7] Since that time, Heltsley, Crosswy, and Brayton[8] have described such a system which has operated on a 1 ft. transonic tunnel at Arnold Engineering Development Center (AEDC) and Yanta[9] described a system which has been operated on a tunnel at the Naval Surface Weapons Center in Silverspring, MD. Hallermier[10] also described a system which was to be used in the characterization of slow speed gravity waves introduced into tides. It is the work by Heltsley et al. and by Yanta which has brought to the fore some of the major limitations which have been found in trying to use these instruments in the characterization of turbulent flows. Some of these limitations will be discussed in future reports. Here it is of interest to examine most of the major operational limitations which use of these instruments has revealed.

1.4. Major three component LV system limitations

A major concern in applying any of these systems is in the identification and separation of the velocity components. This has been done either through multiple colors, for example, in the use of two or more wavelengths in an argon laser or by frequency shifting by Bragg cells. Polarization separation has also been attempted. However, experience has shown that this approach can often lead to ambiguities.

LV systems which combine differential Doppler and local oscillator types of measurements have conflicting number density requirements. It is generally accepted that differential Doppler systems work best when the average number of particles present in the probe volume is less than one, whereas local oscillator systems work best when there are numerous particles in the sample volume. It is easy to see that striking a happy medium in this case is not easy.

When multiple sample volumes are present, as might be encountered with two angularly separated differential Doppler systems, it has been found that making the sample volumes coincide can be a difficult mechanical problem. This is especially true when large angles are to be used to separate the LV systems. This problem is also encountered in two-component multiple-wavelength systems. Even in this case (when a single transmitting lens is used), if the angle between the beams forming the probe volume is large, or if a chromatic aberration exists, there can be probe volume misalignment. Obviously, if the probe volumes are not coincident then it will be very difficult to obtain simultaneous measurements of the type required for the computation and subsequent transformation of three orthogonal velocity components. It should also be evident that when it is necessary to make two optical systems form a common focus that optical system alignment and vibration sensitivity become significant and much attention must be paid to mechanical design.

Spatial resolution may very well be different for any one of the velocity components which are measured. For example, if local oscillator and differential Doppler measurements of the type described by Farmer et al.[4] or by Logan et al.[5] are obtained, then the local oscillator may have a volume which is significantly larger (or even smaller depending on beam size) than that defined by the differential Doppler system.

Acceptable error in the velocity measurements

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has been shown to depend on the separation angles between the two systems as defined, for example, in the paper by Farmer.[7] Recent experience has indicated that the errors for characterizing turbulent flow may be totally unacceptable for all system orientations less than 90° when three velocity components are to be measured.

The problem which has not received a great deal of attention in the laser velocimeter literature is that of dealing with the effects of velocity component measurement coincidence. It would be desirable to obtain the three velocity components all from the same particle. This, of course, presumes that all the sample volumes are coincident. Even when they are coincident it may arise that the signal processing electronics will not respond at the same time to the particle generating the signal. Hence, multiple component signal processing systems are often arranged such that they do not have to begin simultaneously to acquire valid data. In fact, it has generally been found that if the electronics are configured for simultaneous signals that data rates become unacceptably low. The errors which are attendant to this type of trade-off have not been studied in detail and will require much additional study. Finally, it should be pointed out that multiple component LDV systems are very data intensive and can require large computer memories. For example, each data point might require, (a) velocity component identification, (b) magnitude, (c) orientation, (d) direction, and (e) relative acquisition time. Additionally, a need may exist to impose on these measurements such things as a simultaneity test for when the various components are measured and after the data are obtained to calculate the appropriate coordinate transformations if three nonorthogonal velocity components are, indeed, measured. As might be surmised from the above discussion, the problems encountered as one increases the number of velocity components measured in any given situation is a highly nonlinear function of difficulty. However, it appears we are on the threshold of a new wave of information in this area of laser velocimetry with the development and application of two major systems such as have been described by Heltsley et al.[8] and by Yanta.[9]

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Book Reviews

Chemical and Biochemical Applications of Lasers

C. Bradley Moore, Ed. xii + 281 pp., illus., index, bibliography. ISBN 0-12-505405-X. Academic Press, 111 Fifth Ave., New York 10003 (1980) $23.

Reviewed by Joel Silver, Alan Stanton, Mark Zahniser, Andrew Freeman, Aerodyne Research, Inc., Crosby Drive, Bedford, MA 01730.

This volume, the fifth in a series on the application of lasers, is intended to deal specifically with their use in spectroscopy and photochemistry. In order to be current, the authors of each chapter were added to preview, rather than review, their fields of expertise. This goal is admirably accomplished and results in a book which describes state-of-the-art laser techniques as well as their potential industrial applications. Generally, the articles are well written and detailed enough for the reader to obtain a basic understanding of the techniques, with adequate references provided for those interested in more detail. This is a text not for the expert but more for the scientist interested in learning how lasers have increased the amount of spectroscopic information and improved the detection sensitivity of atoms and small molecules.

"The Laser Selective Detection of Single Atoms" by V. S. Letokhov presents three methods for detecting single atoms. Discussed are resonance fluorescence, photoionization, and atomic deflection. The chapter is well written, with a description of the overall problem and then an easily understood development, mentioning the advantages and disadvantages of each technique. In addition, he shares some ideas for the possible application of single atom detection methods to identify nuclear reaction products, isotopes of cosmic origin, and trace impurities.

The chapter by Eizi Hirota on "Structual Studies of Transient Molecules by Laser Spectroscopy" is a detailed discussion of techniques, primarily using diode lasers, for spectroscopic detection of free radicals, combined with recent results obtained by Hirota and his colleagues. Although the amount of detail is perhaps forbidding for the general reader, the discussion of problems associated with diode laser experiments is valuable for workers in the field. The latter part of the chapter presents new spectroscopic results for a number of molecules. This article should be of interest to spectroscopists or physical chemists involved with detection of free radicals, but probably contains little information of general interest to the less specialized reader.

The chapter entitled "Far Infrared Laser Magnetic Resonance" by K. M. Evenson, R. J. Saykally, D. A. Jennings, R. F. Curl, Jr., and J. M. Brown presents an excellent state-of-the-art review of this field. Laser magnetic resonance is described as both a powerful new method for the spectroscopist and as a unique tool for the kineticist for detecting transient species and free radicals with a sensitivity and specificity unmatched by other detection techniques. The authors present an interesting historical background of its progress from first applications to stable diatomic molecules through recent extensions to metastable and ionic species. Emphasis is placed on the inherent sensitivity of this method and its wide applicability to any paramagnetic species in the gas phase. A thorough treatment of the theory is given including the Zeeman interaction and the interpretation of magnetic resonance spectra. The authors' style is readable enough to hold the interest of those readers seeking an introduction to the field, yet is sufficiently detailed in the finer points of theory to be valuable to the more advanced reader.

The use of laser induced fluorescence to investigate reactions of free radicals is described by Hanna Reisler, Metin Mangir, and Curt Wittig in the chapter "Laser Kinetic Spectroscopy of Elementary Processes." They provide a detailed description of the production, reaction, and product branching for a host of radicals, most notably involving C_i (i = 1,2,3) molecules and various carbene radicals. The chapter is well organized and presents a great deal of detailed information, yet not so much as to bore the nonexpert.

"Infrared Photochemistry in Matrices" by M. Polickoff and J. J. Turner critically examines the successes and failures which have occurred in this field. The goal of inducing single photon mode-selective chemistry has met with qualified and often controversial success. The authors delve into the effects of relaxation, activation energy, and energy transfer processes which affect the course of IR induced reactions, as well as certain effects which are characteristic of matrix chemistry. This chapter provides a balanced review of the field and expresses the feeling of those in the field that despite the many frustrations, the future is still very promising.

Allen Hartford, Jr. and John H. Clark, in "Laser Purification of Materials," give a general discussion of how lasers may be applied to industrial applications, in contrast to the more basic research orientation of the other chapters in this book. Included are discussions of the use of lasers in the semiconductor industry, coal gasification, and solar cell production. Their description of present results in each field and indications for future applications makes for interesting reading.

In contrast to the previous chapters which describe work involving gas phase chemistry, Terence Donahue relates the use of lasers (mostly visible and UV) for "Photochemical Separation of Elements in Solution." Presently this technique applies mostly to metals, and the author describes the two photochemical processes employed: photoredox, where the oxidation state of the metal is changed, and photosubstitution, which involves the breaking of a chemical bond. He explains various separation techniques and gives some recent results demonstrating their usefulness. Finally, a simplified cost analysis is done, showing the potential economic benefits which could result, especially for processing spent nuclear fuels. This chapter is easily read, informative, and demonstrates that the use of lasers in not limited to the gas phase.

Sixth European Conference on Optical Communication

W. A. Gambling, chairman. Univ. of York, U. K., Sep. 16-19, 1980. IEE Conference Publication 190. xxiv + 466 pp.; illus.; author index; references. ISBN 0-85296223-1. Institution of Electrical Engineers, London (1980). Order from IEE, IEEE Service Ctr., 445 Hoes Lane, Piscataway, NJ 08854. $73.20 paper.

Reviewed by Gerald B. Brandt, Manager, Electro-Optics, Westinghouse Electric Corporation, R&D Center, 1310 Beulah Road, Pittsburgh, PA 15235.

In order to qualify for archival status, or at least sufficient status to justify space on a bookshelf already crowded with the fruits of the information explosion, conference proceedings should be timely and representative of the state of the art of the field at the time of the conference. By prompt publication in an attractive format of the 3- to 5-page extended abstracts of the Sixth European Conference on Optical Communication, the Institution of Electrical Engineers has produced a timely summary of international efforts in fiber optics communications systems and the related device technologies. Although the conference was held in England, and in spite of its title, the conference was truly international in scope with the exception that only one paper represented optical communications work from a Communist country. Thirty percent of the papers were contributed by authors with Japanese affiliation, and several other papers included Japanese authors on leave to Europe. This number, compared with the twenty percent each contributed by authors from the United Kingdom and United States, makes clear both the magnitude of the Japanese effort in fiber optics communication and their willingness to talk about their work. For the readers of *Optical Engineering*, this publication offers a good opportunity to sample the international efforts in optical fiber communications with a timely snapshot of a rapidly moving field.

Optical communication for the purposes of this conference is defined exclusively as optical fiber (fibre in the proceedings) communication systems and the components needed to realize them, namely, fibers, sources, detectors, couplers, and switches. Much of the device work involves research aimed at overcoming shortcomings in existing devices. Much of the work on fibers and systems involves evaluation of the properties and performance, with the goal of making incremental improvements. Integrated optics was represented by only seven percent of the papers, consistent with the pragmatism of the conference and its treatment of operational or nearly operational devices and systems. One key area of the conference dealt with characterization of fiber properties, namely the dispersion, mode, and polarization retention properties of fibers. Characterization studies has remained a constant proportion of the offerings at the conferences since 1975, according to Sandbank in the introductory paper; however, as fiber losses have dropped, the type of measurement has changed. Physical measurements on fibers, diameter, index profiles mode, mode noise, and dis persion are important in the manufacturing of fibers with losses as low as 12 dB in 22 km. Sources and detectors remain important areas of research since, unfortunately, perfection has not been achieved in either. Integrated optics represented only a small proportion of the papers, as did the session on coupling methods. These sessions represent nascent efforts to put additional signal processing and switching at the ends of the fiber links. Finally, sessions on fiber optic cables and fiber optic systems completed the conference.

My copy of the conference proceedings is a paperback volume, the standard European size slightly longer than our 8 1/2″×11″ paper. Production was made full scale from original copy so the result is a large, highly legible, easily readable type. In some instances, I suspect that the copy was enlarged to fit the standard format, and only a few papers had been reduced to the largely unreadable size typical of many conference proceeedings. A complete listing of the program and an author index form the initial 24 pages and make finding the papers relatively easy. Only in locating related papers in the poster sessions listed last in the book did I have any difficulty.

In summary, this is a well-produced proceedings which will be of interest to those working in or on the periphery of the optical communication field. It deals generally with fibers, propagation, and other characteristics and with the components which are needed to make systems operable. It also covers systems architecture and performance. It is not tutorial but rather is a time slice of a rapidly moving technology.

Safety with Lasers and Other Optical Sources

David Sliney and Myron Wolbarsht. xxvii + 1035 pp.; illus.; subject and author indexes; references. ISBN 0-306-40434-6. Plenum Press, 227 West 17th St., New York 10011 (1980) $49.50.

Reviewed by Leon Goldman, Laser Laboratory, University of Cincinnati Medical Center, Cincinnati, OH 45267.

As the authors indicate, it has been almost a decade since there was a detailed review article on the hazards of optical radiation. With the increasing developments of lasers and other optical devices in such diverse areas as industry, military, biology, medicine, and surgery, it is well now to review the hazards. The authors have provided, for all concerned with lasers and optical systems, a very detailed and comprehensive reference handbook for current review. The lasers are covered in detail including brief mention of junction diode lasers now so important in the field of communication. The recent interest and concern of the ANSI-Z136 on laser-diode-LED sources with fiber optics has been reviewed, but, as yet, not included in publication. Wolbarsht has been very much interested in whether the data for MPE (Maximum Permissible Exposure) are appropriate for laser transmission through optic fibers.

The important laser systems for current use and abuse are listed in detail. There is also a review of the significant features of the eye and the skin to acquaint people who are not familiar with the anatomy and physiology of these important organs. These data are necessary to evaluate laser hazards. The hazards specifically for these laser systems are listed in detail. The details for classification and permissible exposure make this a valuable reference for any laser safety officer. The need for standard nomenclature is shown also in regard to output measurements. With standard nomenclature it will be easy to compare exposure effects on an international basis. There are even separate sections, such as on the research laboratory, where a great many hazards are found and not considered by physicists who usually disregard the establishment. The medical facility is also considered. Here, often the personnel unfortunately learn laser safety from a laser catalogue or the salesman. There is also information for use in industry and military. Lidar applications are also listed in detail. This comprehensive book explores many other sources of lighting systems, fluorescent lamps, mercury pressure, mercury lamps, carbon arc sources, and welding. For these days of heathen sun worship there is also a large section on the hazards of the sun and even of daylight. For those who have to give people advice about the commercial sun tanning booths and drugs and materials which make the skin more sensitive to light, this book again provides an excellent background. So, the main current concerns about safety hazards of lasers and other types of lamps are present in this handbook. This will remain the standard bible for evaluating the laser hazards for some time. It cannot as yet be said of this book, as it can for many hard cover books on lasers, that it is out of date as soon as it is published. As there will be more research and development of VUV and x-ray lasers and increasing use of combined laser systems, more information may have to be added in the future. But the basic excellent structure of this book will remain.

Short Courses

Univ. of Wisconsin-Extension programs

The University of Wisconsin-Extension, Engineering and Applied Science, offers the following programs in June: **Photogrammetry/#750, June 1–5; Energy Engineering for Buildings-EE2/#777, June 8–12.** University of Wisconsin-Extension, Engineering & Applied Science, 432 North Lake St., Madison WI 53706.

Univ. of Michigan infrared courses

Infrared Technology: Fundamentals and System Applications/#8106, June 15–19, 1981. $495. Reflects advances in the state-of-the-art and changes in approaches to utilizing infrared; presentations cover radiation theory, radiative properties of matter, atmospheric propagation, optics, and detectors; system design and the interpretation of target and background signals are stressed. **Advanced Infrared Technology/#8107, June 22–26, 1981.** $495. Presents the advanced technology need for modern, state-of-the-art infrared and optical systems; presentations cover atmospheric propagation, detectors and focal plane array technology, discrimination characteristics of targets and backgrounds, and system designs; prerequisite is familiarity with fundamentals of infrared. Combined fee for 8106 and 8107 is $790. University of Michigan, Continuing Engineering Education, 300 Chrysler Center, North Campus, Ann Arbor MI 48109. 313/764-8490.

Laser Institute of America summer courses

Modern Optics with Communications Applications for Scientists and Engineers, Washington, D.C., June 15–19, 1981. New development and techniques in optics including matrix methods of analyses, beam propagation, information processing, detection and recording, fiber optics communications and nonlinear phenomena. **Laser Fundamentals and Systems, Washington, D.C., June 22–26, 1981.** Principles and techniques of laser operation, pulse generation, output characteristics and measurements, classes of lasers and applications in materials processing, communications, medicine, holography, and data processing. **Chemical Lasers, Washington, D.C., July 6–10, 1981.** Theory, design, hardware, and techniques of lasers wherein the population inversion is created by chemical reactions. Treatment of theory of chemical reactions, molecular spectroscopy, and first generation devices, as well as recent technological advances, present capabilities and limitations, short and long term probable applications. **Optical Fiber Communications, Princeton, NJ, July 20–24, 1981.** Design, fabrication, test and applications of information transmission systems using optical fibers. Daily problem solving and hardware laboratory sessions. Ideally suited for engineers and technicians. **High Energy Lasers, San Francisco Bay area, July 29–31 and Aug. 3–5, 1981.** Two independent three-day courses either or both of which may be taken, depending upon participants' background or training objectives of management. First course: production, propagation, control, and detection of laser outputs. Second course: treatment of CO_2 laser operation theory including spectral characteristics of molecular lasers, laser spectroscopy and line broadening, high energy laser systems and optical design, atmospheric propagation, and weapons design considerations. **Laser Safety, San Francisco Bay area, Aug. 3–7, 1981.** Hazards evaluation, standards, control measures, and laser safety program management. **Laser Optics, Santa Fe, NM, Aug. 17–21, 1981.** Principles of geometric and wave optics, characteristics of coherent gaussian beams, and operational techniques/selection criteria for laser/optics components. Special sessions on lens aberration corrections and matrix optics. Ideally suited for engineers and technicians.

Institute of Optics short courses

The Institute of Optics at the University of Rochester announces its 20th annual summer course series, 1981: **Contemporary Optics, July 13–24; Image Formation and Detection, July 13–17; Optical System Design, July 13–17; Digital and Optical Image Processing, July 20–24;** and **Color Specification and Measurement, July 20–24.** Tuition: $550 for one week, $950 for two weeks. Series features hands-on evening laboratory sessions and tours of research facilities. For enrollment forms or inquiries about course content, contact Nicholas George, Director, The Institute of Optics, University of Rochester, Rochester NY 14627.

Univ. of California/Santa Barbara courses

University of California Extension, Santa Barbara, Department of Science and Management offers **Fiber Optic Communication Systems, July 13–17, 1981,** a tutorial review of fiber-optic technology as applied to communication systems, and **Detection of Infrared Radiation, July 27–31, 1981,** a review of the basic properties of various infrared detection mechanisms along with the most recent advances in infrared detectors and their systems applications. University of California Extension, Dept. of Science and Management, Santa Barbara CA 93106.

Sira Institute courses and seminars

Microprocessor Familiarization (101), Cudham, Sevenoaks, Kent, England, June 15–16, Sep. 7–8, Nov. 16–17, 1981. Using Microprocessors and Microprocessor-based Equipment (102), Cudham, Sevenoaks, Kent, England, June 17–19, Nov. 18–20, 1981; Microprocessor-based Equipment Design and Development (104), Cudham, Sevenoaks, Kent, England, June 8–12, Nov. 9–13, 1981. Testing Complete Thermal Imaging Systems and Associated Optical Materials and Components, Sira Institute, Chislehurst, Kent, England. Seminars: **Assessment of Imaging Systems: Visible and Infrared, University of Reading, Reading, Berks, England, April 7–9, 1981. Laser Safety, The City University, London, England, Sep. 22–23, 1981. Light Measurement 1981, University of Surrey, Guildford, Surrey, England, Sep. 8–9, 1981.** Conference & Courses Unit, Sira Institute Ltd, South Hill, Chislehurst, Kent BR7 5EH England.