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OPTICS AT THE APPLIED PHYSICS LABORATORY

Work in optics at the Applied Physics Laboratory has steadily grown over the past decade, and has become a major discipline that rivals the traditional APL specialties in microwaves and acoustics. Optical activities at APL include areas as diverse as research, sensor evaluation, and optical techniques as applied to medical, space, military, and oceanographic tasks.

This issue of the *Johns Hopkins APL Technical Digest* reviews current and recent tasks in optics at APL. Harris begins with an introductory article on optical design that is intended to acquaint the nonspecialist with the optical design process, available tools, and typical APL products.

Several articles look at different facets of optical technology. Thomas and Joseph describe a process for characterizing the optical properties of transparent materials through a combination of theory, models, and measurements. Gearhart and Thomas show the feasibility of a spectroscopic remote-sensing technique for measuring the temperature of gases.

The remaining papers review APL optical instrument development and the resulting data. The article by Rust, O'Byrne, and Harris describes an imaging polarimetric optical instrument that measures the solar magnetic field. Duncan reports on two optical instruments for medical applications: an interferometer to measure inner-ear motion and a laser Doppler velocimeter to determine shear in blood flow. Mayr and Warren recount the design and development of an optical position-measuring system that gathered pointing and tracking data to characterize a precision laser director system. The final theme article of this issue is a description of the APL laser machine tool by Blum and Charles.

The theme of optics will continue in the next issue of the *Digest*. Articles for the next issue will describe the development of new semiconductors as optical sources and detectors, technology allowing improved light-gathering and optical resolution in astronomical telescopes, signal processing, ocean optical properties, and space measurements of ultraviolet and visible backgrounds.

CAPABILITIES AND ACTIVITIES IN OPTICS

Three APL departments, along with the Eisenhower Research Center and the Biomedical Program, conduct a significant number of optical projects. The capabilities, facilities, and typical tasks of these APL divisions are

described in the following paragraphs. References 1 to 24 are articles on optics from previous issues of the *Technical Digest*. Those past articles, along with the articles in this issue, present examples of APL work in optics.

Fleet Systems Department

Optical work in the Fleet Systems Department focuses primarily on performance of detection, tracking,¹ guidance,⁷ and communication⁴ systems for the Navy, as well as basic research in propagation,²³ material properties,²⁴ device characterization, mensuration, and remote sensing. Research activities in the department include optical signal processing, property measurements, remote sensing, and biomedical instrumentation development. The department has a complete optical design and measurement capability that supports instrument development and performance evaluation throughout APL. Optical methods have been applied to many sensor- and instrument-development tasks (Fig. 1), and instruments and systems are used in the field for precise measurements.

The department maintains an optical sensor laboratory for testing visible- and infrared-light sensors, a signal- and image-processing laboratory for superconducting-detector and optical-processing work, and an infrared laboratory for measurements in the ultraviolet to submillimeter spectral regions. Special instrumentation includes a high-resolution Fourier transform spectrometer, cryogenic systems for detectors and laser diodes, high-power argon and carbon dioxide lasers, and a heterodyne laser interferometer.

Space Department

Optical programs of the Space Department concentrate on spacecraft instruments operating at ultraviolet, optical, and near-infrared wavelengths, as well as optical systems for ground-based astronomical observations. Several groups design, build, and use optical instruments.

Work in space optics began with radiative-transfer measurements for thermal control. In 1967, the first APL imager was flown on the DODGE spacecraft. Optical instrumentation was used also in the SAS and Mag-sat² satellites. More recently, APL has built ultraviolet and visible-light imaging and spectrographic instruments for auroral observation from space (HILAT^{12,13} and Polar BEAR^{21,22}) and for Strategic Defense Initiative experiments (Delta 180 and 181).



Figure 1—Roger Lapp inspecting lightweight, 1.8-m-diameter mirror made for the U.S. Navy by REOSC (France). APL assisted the Navy in holding, mounting, and transporting the mirror.

The Space Department has also worked on several astronomical telescopes (the Hopkins Ultraviolet Telescope¹⁶ and the Space Telescope¹⁷) and maintains an active program in solar astronomy. The Center for Applied Solar Physics, funded by a University Research Initiative, is located at APL. Several ground-based instruments have been built for solar astronomy,²⁰ including seismology and magnetic field measurements, and a small observatory is maintained at APL as a test site for their development.

Submarine Technology Department

This department uses optical instruments for oceanographic measurement and remote sensing, including optical measurements of wave structure,^{3,9} radiometry of the ocean surface,⁸ and modeling and measurement of underwater optical propagation, reflection, and scattering at the air/sea interface. The department also develops and tests charged-coupled-device imaging systems for ocean remote-sensing investigations. A facility is maintained for the characterization and calibration of the imaging systems.

Research Center

The center carries out research in optical techniques, materials, and devices. Early optical work included development of chemical lasers, advances in photochemical and photoacoustic techniques, and studies in laser-induced decomposition. Current work includes the use of



Figure 2—Donald Duncan (left) and F. Fausten Mark making laser Doppler velocimeter measurements of simulated blood flow. The crossed laser beams of the velocimeter are seen emerging from the model of a segment of artery. Further information is given in the article by Duncan.

laser deposition methods for making thin-film high- T_c superconductors, development of molecular electronics and nonlinear organic optical devices, thermal wave imaging for nondestructive testing,¹⁹ and the development of optical switches and III-V semiconductors for optical emitters and detectors. Extensive biomedical research is conducted on optical properties of the corona^{10,18} (laser effects and scattering), laser fluorescence, spectroscopy,⁵ and the role of singlet oxygen⁶ in biological systems.

The Research Center makes extensive use of optical systems and techniques in most of its laboratories. Staff members have experience in Raman, coherent anti-Stokes Raman spectroscopy (CARS), and laser Doppler velocimeter techniques. The center has many medium- to high-power laser systems, including excimer, ruby, Nd:YAG, dye, and carbon dioxide systems. Property measurements are made with FTIR and UV/visible spectrometers and an ellipsometer.

Biomedical Programs

The biomedical programs at APL began in 1964 with five projects in ophthalmology; since then, this work has been characterized by a large proportion of optical tasks (Fig. 2). Early work included development of optical methods for evaluation of the retina, optical systems for eye geometry and dye movement measurements, and laser systems for photocoagulation. Biomedical activities are managed by a program office that uses primarily the

capabilities and resources of the departments as described above. The biomedical program has a biodynamics laboratory and an imaging laboratory that support measurements, data analysis, and system development activities. Biomedical work is extensively reported in the *Technical Digest*.^{6,10,18}

Other Departments

The Aeronautics Department has long been a user of sophisticated optical instrumentation¹¹ to support their work in aerodynamics, propulsion, and structures. Its staff makes extensive use of flow-visualization methods such as shadowgraph and Schlieren techniques (Fig. 3), video recording, and laser Doppler velocimetry.

The Technical Services Department maintains a variety of optical equipment and supporting services, including a metallograph, ellipsometer, microscopes, coating-deposition equipment, and laser machining. The capabilities and typical uses of the laser machining facility are described in the article by Blum and Charles.

EDUCATION IN OPTICS

The APL staff participates in education in optics, both as teachers and students. Graduate programs offered at APL by The Johns Hopkins University G. W. C. Whiting School of Engineering include an option in optics as part of the applied physics program. The curriculum includes courses in modern optics, quantum electronics, and applied optics. In addition, many other courses in such diverse areas as astrophysics, ocean physics, optical properties, optical signal processing, and fiber optics offer significant optical content.

APL also offers fellowships and professorships that allow staff members to pursue independent study at The Johns Hopkins University Homewood and Medical campuses. In the 1987-88 academic year, Ralph Cohn and Keith Peacock worked on optical problems under Merle A. Tuve and Lawrence Hafstad fellowships, respectively. Cohn developed a high-speed imaging ellipsometer with

the Department of Materials Science and Engineering; Peacock worked on design problems of the Magellan telescope project at the Center for Astrophysical Sciences. Peacock will report on the status of large-telescope technology in his article in the next issue.

APL also offers employment opportunities for students. Educational assistance is available to staff members through the APL part-time study program. Summer and cooperative appointments are available for undergraduates. Graduate students can conduct thesis and dissertation work under temporary appointments, and post-doctoral research fellowships are also available.

PARTICIPATION IN THE OPTICS COMMUNITY

APL has long been active in scientific societies, technical meetings, and publication. The late Archie I. Mahan was active in the Optical Society of America, serving as a director, treasurer, and journal editor. Staff publications have appeared in many optics journals, such as *Applied Optics*, *Optics Letters*, *Journal of Applied Physics*, *Physica Status Solidi*, *Solar Physics*, *Applied Physics Letters*, and *Journal de Physique*. APL papers appear in major proceedings, such as those of the Conference on Lasers and Electro-Optics (CLEO), the Society of Photo-Optical Instrumentation Engineers (SPIE), the American Institute of Aeronautics and Astronautics (AIAA), the National Aeronautics and Space Administration (NASA), and the International Astronomical Union (IAU) (Fig. 4).

APL is an active participant in the Infrared Information Symposium (IRIS), sponsored by the Office of Naval Research, and in other forums for optics. In recent years APL has hosted a national IRIS meeting and five of seven IRIS specialty group meetings (targets, backgrounds and discrimination; passive sensors (IR imaging); atmospheric physics; infrared materials; and active systems). Four IRIS specialty group meetings were held at APL in 1988. APL also hosts a variety of other

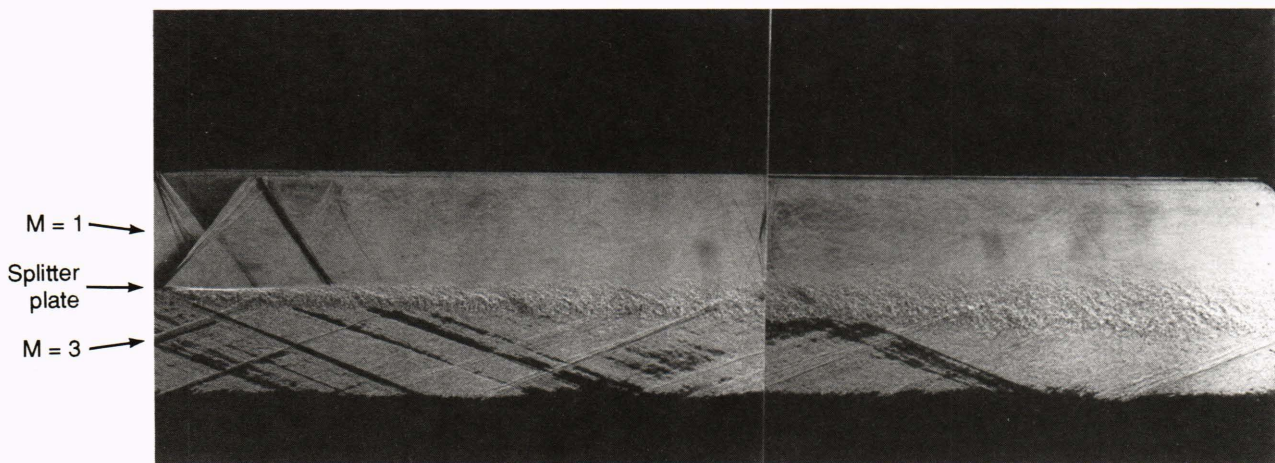


Figure 3—Schlieren photograph used as a method of flow visualization, showing the shear layer formed between air streams of different velocity. The upper flow speed is Mach 1 and the lower is Mach 3. The flows are separated by a splitter plate at the left and move toward the right side of the figure (courtesy of Louis Mattes).

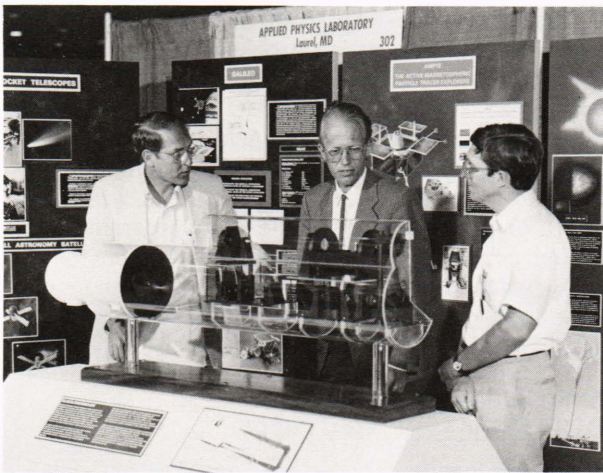


Figure 4—APL astronomy exhibit at the International Astronomical Union's 20th General Assembly, held at the Baltimore Convention Center in 1988. David Rust (left) of APL is explaining the workings of the solar vector magnetograph to J. O. Stenflo (center), Director of the Institute of Astronomy in Zurich, and to Knox S. Long, The Johns Hopkins University project scientist for the Hopkins Ultraviolet Telescope (HUT). The solar vector magnetograph is described in the paper by Rust, O'Byrne, and Harris.

optics meetings, including SMOKE conferences and various tri-service and professional society meetings.

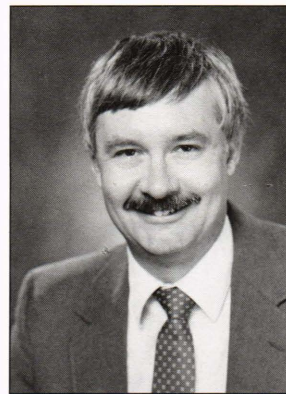
Optics publications have won APL Outstanding Publication awards, including those for outstanding classified paper (1985) and outstanding *Johns Hopkins APL Technical Digest* paper (1986),¹⁸ and a special award for a book chapter (1987).

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