FEDERAL LAB

LASER TECH BRIEFS

February 1995
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REPORTING THE LATEST FEDERALLY-DEVELOPED PHOTONICS TECHNOLOGY

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Deploying Photonics for Environmental Restoration

CEBAF'S
Free-Electron Laser

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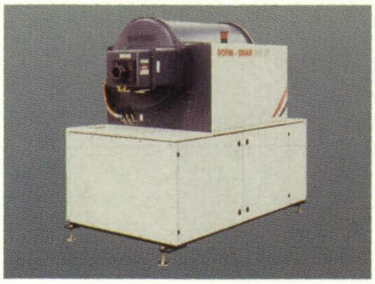
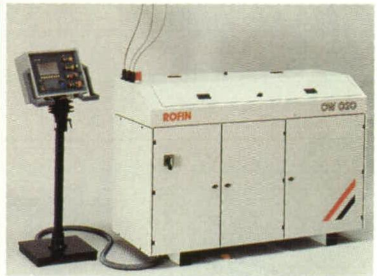


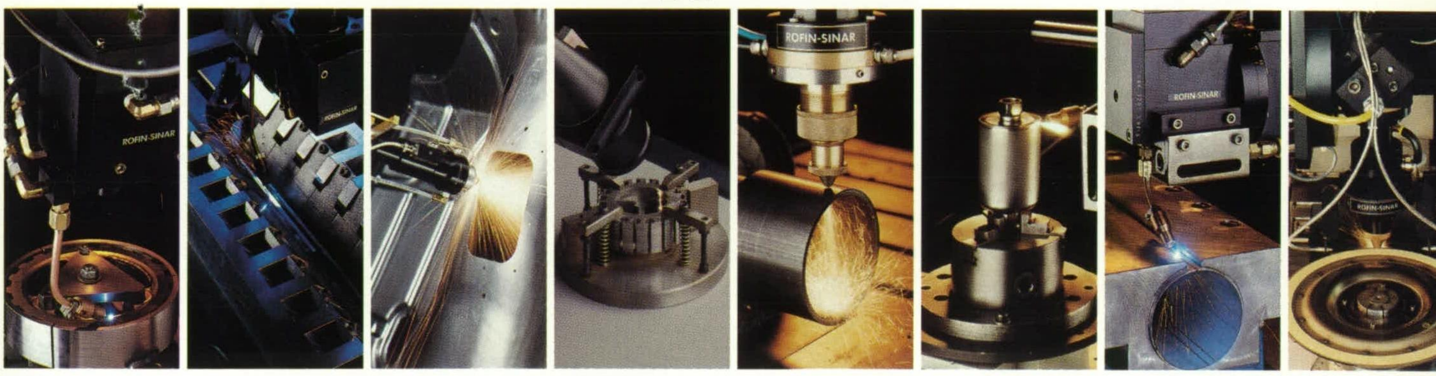
RS 860HF – 6kW CO_2 high frequency laser

DC 020 – 2kW CO_2 diffusion cooled laser



CW 020 – 2kW CW Nd:YAG laser

Applied.



The operative words being *more* and *new*. The key word being *applied*. With the introduction of three new laser systems, Rofin-Sinar continues to lead the way in developing the kinds of laser technologies that can be applied... applied to a variety of cutting, welding and surface treatment tasks.

The three new technologies represent Rofin's willingness to listen to the needs of the industrial marketplace and matching those needs by developing simple, flexible, reliable and easy to use lasers.

RS 860HF – a high frequency powered 6kW CO_2 laser engineered to achieve maximum productivity. High power with more stable discharge and greater control of the beam. Ceramic electrodes have replaced conventional DC anode/cathode to virtually eliminate contamination during operation and reduce maintenance procedures. Compact design minimizes floor space and allows for easy integration into automated processing systems.

DC-020 – a diffusion-cooled 2kW CO_2 laser with correcting optics and waveguide structure to generate high beam quality. The diffusion-cooled design eliminates the need for complex gas circulation and associated cooling systems. The system requires virtually no gas – less than one liter versus 95 liters/hour for units in the same power range. The construction minimizes moving parts, which greatly reduces maintenance schedules.

CW-020 – a 2kW CW Nd:YAG laser for both cutting and welding applications. Simple and compact with high power and high beam quality. Three ways of delivering output for processing flexibility – continuous wave, pulsing or a combination of both. Includes a new fiber optic beam delivery system with sensors to detect heat build up for safety and a newly-designed connector to minimize power loss at the fiber interface.

Rofin-Sinar Laser – where the words *more* and *new* are actually *applied*.

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LASER TECH BRIEFS

FEBRUARY 1995
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In a Savannah River Technology Center laboratory, scientist Pat O'Rourke manipulates spectral data derived from an in situ chemical analysis system. Using a Coherent Innova argon-ion laser, the system identifies chemical molecules by their vibrations. See the story on page 6.

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SAVANNAH RIVER TECHNOLOGY CENTER

The South Carolina nuclear materials facility is embracing a broader mission.

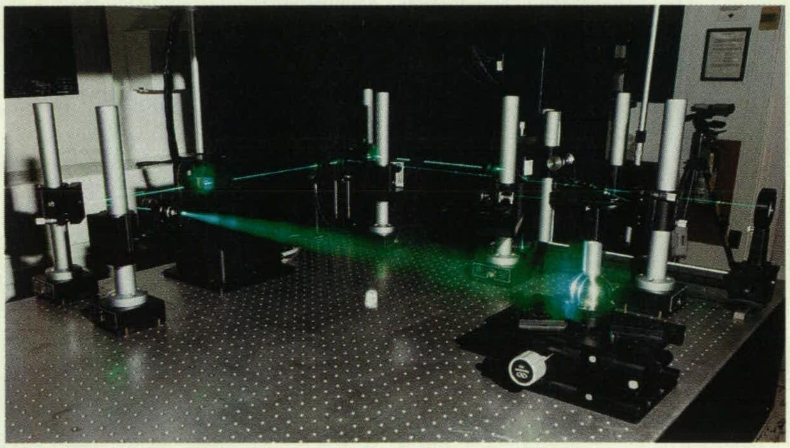
As the new year gets under way, the Department of Energy's Savannah River Technology Center continues to evolve from its former mission of almost singly supporting the manufacture of materials for nuclear weapons to directing its scientific and technical talent toward waste management, environmental restoration, and technology transfer as well as national security.

Dr. Susan Wood, the center's director, describes its new thrust as "the development, deployment, and exchange of high-impact technologies that fulfill the needs of our internal and external customers and significantly enhance the industrial competitiveness of our nation and the economic viability of our region." She adds that "the center's work in fiber optic and laser technology greatly contributes to this mission."

This applied research and development laboratory is located at the Savannah River Site near Aiken, South Carolina. Operated by Westinghouse Savannah River Company for the DOE, the center houses a coherent optical measurements laboratory and laser application laboratory, as well as chemical, robotics, environmental sciences, and instrument development labs. The center's scientists, engineers, and technicians use these resources to support all the major activities and operating facilities at the site.

The Savannah River Laboratory, predecessor to the Technology Center, began using lasers and fiber optic technologies for unique applications nearly two decades ago. The Site's defense mission provided challenges for remote manipulation, measuring, and testing of radioactive materials. One example of a fiber optic application from the eighties is the use of a remote fiber fluorimetry system developed to monitor uranium concentrations directly in the plutonium production facilities as part of process control. In this system an optical fiber carried laser radiation to a remote sampling point; then an optrode (the optical analog of an electrode) coupled the laser light into a sample solution. In turn the optrode collected emissions from the sample and sent them through the same fiber to a detector. Multiplexing made it possible to analyze several different sampling positions with one laser and detector.

Applying laser technology to environmental studies at the Savannah River Site also began in the mid-eighties. A series of laboratory investigations on laser-induced fluorescence emission characteristics of pond water, alga cultures, and terrestrial vegetation was conducted at the Site with the cooperative efforts of NASA. In these studies, a NASA Airborne Oceanographic Lidar equipped with a frequency-doubled Nd:YAG laser with a high pulse repetition rate flew a series of missions over the Site. Studies included surveying an excavated stream basin, mapping the spread of a fluorescent dye tag, and metric studies of wetland vegetation and forestry parameters.



Holographic interferometry is employed at Savannah River Technology Center as part of a solid-state weld development program. A specimen's hologram is stored on a thermoplastic medium; the specimen is then heated and illuminated by laser light, and viewed through the hologram. Fringes formed by thermal expansion show discontinuities or inhomogeneities, indicating weak bonds.

To further the application of laser technology, the Savannah River Technology Center established a coherent optical measurements laboratory. This facility provides Site support in visual nondestructive examination, experimental mechanics including validation of computer stress analysis, vibration and dynamics measurements, and metrology. The emphasis of the lab is on such coherent optical methods as holographic and speckle interferometry, laser Doppler vibrometry, and similar optical interferometric techniques.

One idea being developed in this lab is a laser-based method of measuring residual stresses. This technique is based on heating a small spot with a modestly powered infrared laser and using an electronic speckle-pattern interferometer to measure the subsequent in-plane displacement. The stress prior to heating is computed for the measured displacement near the heated spot. This method is a thermo-optical analog to the blind hole-drilling technique that is commonly used for residual stress measurements. However, this new method is totally nondestructive, since it does not require removing material. Also, although the material is heated in the process, the temperature increase is relatively small.

Demonstration experiments have been performed with tension specimens constructed from austenitic stainless steel. The specimen was mounted in a load frame and placed under a predetermined load that defines the tensile stress. Once the load was established, the ends of the specimen were fixed so that only local displacements were possible. The electronic speckle-pattern interferometer captured an image of the illuminated region, which was then stored in the computer. A small spot in the center of the region was heated for a few seconds and then allowed to return to room temperature. The peak temperature for these experiments was approximately 200 °C.

As the specimen was heated, the yield stress of the heated area declined. When that stress fell to a value below that of the local stress, a minute amount of plastic local deformation occurred. After cooling, a second image was collected and subtracted by the computer from the first image. This subtraction process generates the fringe pattern, which when analyzed provides the resultant strain. As in blind-hole drilling, it was the displacement surrounding the disturbed area that was determined.

Three-dimensional finite element analyses (FEAs) were performed to predict the thermal and mechanical responses for the experimental conditions. These analyses are used to compute the surface displacements near the heated area for a given initial stress state and heat load. The analyses include the effects of thermal expansion as well as the variation of the elastic and plastic properties with temperature. The final displacements as computed by the FEAs were compared with the electronic speckle-pattern interferometer measurements, yielding excellent agreement between theory and experiment.

Lasers Serve Robotics

Engineers at the center are also applying laser technologies in several robotics system- for use in various operations throughout the Site. An example is the Mobile Automated Characterization System (MACS).

MACS is a software navigation system enabling a mobile robot to monitor and control its location. The system uses retroreflective targets placed at designated known fiducial points in the area to be navigated by the robot. The robot is equipped with a rotating device that transmits a Class IIIB laser beam. The laser sweeps the series of retroreflective targets at the fiducial points. MACS interprets the reflected beams to determine the dual-axis location of the robot. The transmitting device rotates at 4 Hz. By monitoring the robot's distance from multiple fiducials four times each second, the system provides an extremely precise, real-time determination of the robot's location.

Previously, K2A robots (such as the Savannah River Site's SIMON and SWAMI) were limited to using sonar technology with building structures to monitor a robot's position. The robots needed to bounce their sonar continually off nearby objects to enable them to find their way. MACS employs the sonar technology in structured areas, but has the added advantage of employing this lidar technology in open, unstructured areas. MACS has been successfully tested and enables a robot at the Savannah River Site to navigate an area independently while monitoring the space for radioactivity.

The scientists and engineers in the center's robotics lab recently tested a Class II laser line projector with a black-and-white camera on glossy black drums to determine the feasibility of detecting drum dents and bulges. Initial indications are that the system will be able to capture usable data while staying within the Class II restriction.

Another example of applying laser technologies to robotics systems has affected a cooperative research and development agreement (CRADA) between Westinghouse Savannah River Company and PaR Systems, Inc. PaR Systems sells complex robotics systems to large industries such as the nuclear industry. Through this CRADA, PaR Systems will provide software and train Westinghouse Savannah River employees to write robot controller applications. The employees will write two such applications and transfer them to PaR Systems.

The applications are force-control saw cutting and standoff-control torch cutting. The second uses a laser sensor that enables a robotics arm to achieve the proper standoff distance while using a plasma-arc cutting torch. This technology can be used for remote cutting of metal containers and other large pieces of metal. It has great potential for reducing the volume of solid wastes, whether hazardous, mixed, or radioactive.

Laser technologies are not the only photonics technologies being developed at the center. Fiber optic systems make possible real-time on-line chemical process control and environmental monitoring.

The Site developed and installed its first fiber optic sensor system more than a decade ago. Among the pioneers in this field, the center has now expanded its capabilities and advanced development to a fourth-generation system. Center scientists have developed quality analytical capabilities in ultraviolet, visible, and near-infrared spectroscopy.

The Site integrates process interfaces and fiber optic probes, spectrophotometers, optical multiplexers, instrument controllers, and software for multivariate calibration and instrument operation into systems for remote, real-time, on-line *in situ* chemical process analysis.

An optical multiplexer is used to select the desired process locations for sample measurement. Fiber optic cables carry light from the lamp from the multiplexer to the process interfaces at the sample sites. The light returns through the multiplexer to a spectrometer, which measures the wavelength and quantity of light that interacted with the samples. These measurements are displayed as spectra. Each is interpreted by the instrument controller and converted to useful process information. The specific chemical compounds and process conditions determine the process interfaces, spectrometer, lamp, and optical fibers.

The site-developed software runs in a DOS environment to perform multivariate calibration and instrument operation. Multivariate analysis software generates models for real-time on-line chemical measurements in a dynamic environment.

The fiber optic multiplexer gives users the capability to measure 20 or more on-line process locations in addition to standard and reference positions. Standard positions make real-time quality-assurance measurements at user-selected intervals. The reference position corrects system changes such as detector sensitivity and lamp drift. It also permits the user to make new reference measurements without the interruptions associated with cleaning and refilling a process interface with reference material.

Process interfaces and probes allow fiber optic spectrometers to examine samples *in situ*. The center developed interfaces to monitor chemicals in tanks, pipes, and wells and to examine materials such as textiles moving through a process. Each interface provides unique features that allow light to interact with particular sample types. For example, the interface for measuring solutions with a high-solid content includes a self-cleaning filter element. Additional process interfaces can measure gases, liquids, and solids.

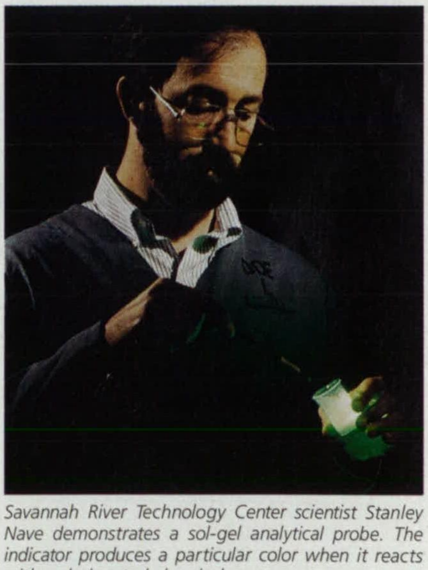
Another area of fiber optic development at the center is flow-injection analysis, a technique to automate the analysis of solution chemistry. A unique flow cell has been designed using sol-gel indicator technology. The acid-based indicator Bromophenol Blue is used as the color reagent in a sol-gel glass matrix to measure the pH of aqueous solutions in a range of 4 to 7. Preliminary results indicate resolution of 0.25 pH units or better.

The sol-gel indicator is completely reversible and reusable, appears to be robust and dependable, and remains intact in the thin layer of sol-gel on the windows of the flow cell for an extended period of time. Development work is underway to examine additional indicators to expand and broaden the pH range and to determine other ions of interest, including heavy metals and priority pollutant organic compounds.

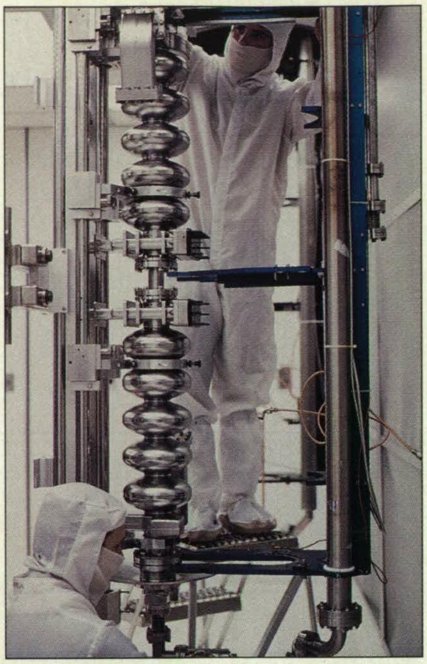
Building Technology Partnerships

The scientists, engineers, and technicians of the Savannah River Site have developed significant applications in laser and fiber optic technologies, as well as many other fields. Patent disclosures from Site scientists and engineers number more than 1700 since 1989. More than 50 licensee applications are pending for use of Site-developed technologies by industry.

Savannah River offers many opportunities and a variety of vehicles for sharing its technology and scientific talent. Partnerships can be formed through the use of CRADAs, user or deployment centers, work for others, personnel exchanges, direct technical assistance, licensing, and integrated demonstrations. Advancements in technology are being made through strong partnerships with industry, educational institutions, local communities, and federal and state agencies. ■



Savannah River Technology Center scientist Stanley Nave demonstrates a sol-gel analytical probe. The indicator produces a particular color when it reacts with a designated chemical.



Scientists examining CEBAF's superconducting niobium cavities, which would drive the planned free-electron laser.

CEBAF'S FREE-ELECTRON LASER

A Unique User Facility Struggles to be Born

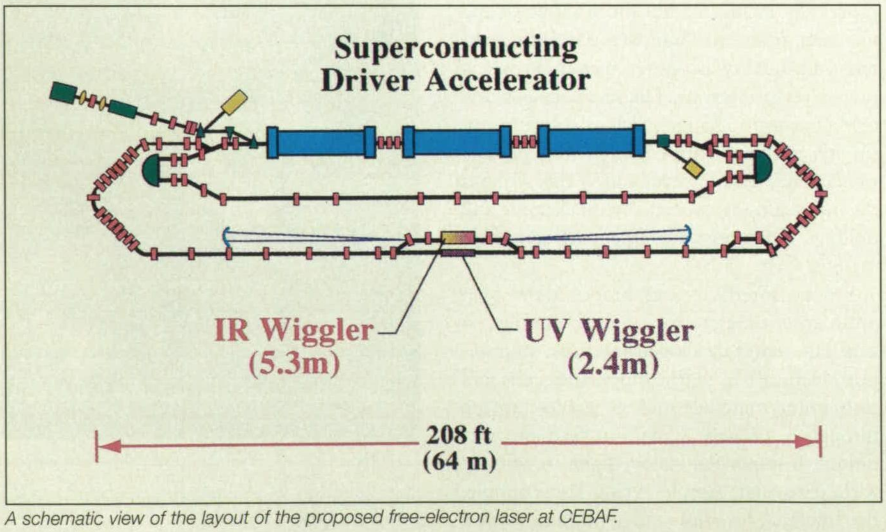
To lay observers, the Continuous Electron Beam Accelerator Facility (CEBAF), located in Newport News, VA, might seem to be a complex laboratory with an obscure pure-science mission likely to bar it from any dual-use role. In fact, it promises to be a unique example of cooperation between government, academia, and industry. But as the budget-cutting noose tightens around the Department of Energy, CEBAF may be forced to go to the mat to secure its technology transfer future despite its merits.

As far back as 1976, physicists first envisioned CEBAF as a basic research laboratory to probe atomic nuclei for an understanding of the quark structure of matter. After development of a preliminary design, the DOE called for proposals. In a competition with the Massachusetts Institute of Technology, University of Illinois, Argonne National Laboratory, and the National Bureau of Standards, the contract went in 1984 to a consortium, the Southeastern Universities Research Association (SURA), now numbering 41 academic partners. Construction began in 1987, and the first experiment took place last year as scheduled.

Currently CEBAF has a scientific and technical staff of 400. Facilities include class 100 clean rooms, wet chemical etching, a thin film deposition laboratory, high-vacuum electron beam welder, and more. Managed and operated under a DOE contract by SURA, the facility represents a $600 million investment by the federal government, the Commonwealth of Virginia, the City of Newport News, several foreign contributors, and the US nuclear physics research community. The 200-acre site includes federal, state, and SURA land.

Beginning in 1990, CEBAF has identified ways its technologies could be exploited for industrial development. An Industrial Advisory Board (IAB) was set up to examine how the facility — its superconducting accelerator cavities, real-time control system software, accelerator-driven light source, cryogenic systems, magnet technology, accelerator diagnostics, particle detectors, and data acquisition systems — could participate in technology transfer initiatives. One area singled out was a free-electron laser (FEL) user facility for materials processing.

The next step was the formation of a Laser Processing Consortium, which brought such leading US firms as DuPont, 3M, IBM, Xerox, AT&T, Newport News Shipbuilding, and Northrop-Grumman into partnership with CEBAF and several SURA universities, including Virginia Polytechnic Institute, Hampton, Old Dominion, the College of William and Mary, and the Universities of Delaware, Virginia, and North Carolina State. Together these entities formulated a proposal that CEBAF's superconducting radio-frequency cavities be employed as a driver for high-power FELs, which could supply tunable, monochromatic laser light for industrial-scale processing. A peer review by a panel sponsored by NASA Administrator Dan Goldin last year confirmed the significant potential of the FEL light for industrial processing, calling the proposal "a model for an industry/national laboratory/university partnership."



A schematic view of the layout of the proposed free-electron laser at CEBAF.

A Wealth of Applications

As currently planned, CEBAF's FEL facility would provide 1-3 kW of laser light broadly tunable over two wavelength ranges: 1-20 µm and 190-350 nm. Consortium industry members point to a number of industrial applications, some already demonstrated in their corporate laboratories using conventional lasers. Among them are:

- Surface modification of polymer film, fiber, and composite products;
- Micromachining and surface finishing of metals, ceramics, semiconductors, and polymers; and
- Materials analysis and process monitoring instrumentation.

But the experience of members often is that in-house lasers are not adequate to making these applications commercially viable — thus their interest in a user facility. According to the CEBAF sources, its FEL facility could provide laser light for process development and testing at high power, lower unit cost, and more tunability than those currently available. In addition, it would further the advance of high-power FELs themselves toward commercialization.

Consortium members who currently use wet chemistry to impart specific surface properties such as adherence and compatible metallization characteristics to polymers have found that deep-UV radiation using excimer lasers is a workable alternative. Patents have been obtained for laser processes, all with high market potential given a powerful industrial laser, to do the following:

- Improve the adhesion of metals on polymers for electronic applications;
- Improve the adhesion of polymer films

in packaging applications; and

- Add microtexturing to fibers and film for better adhesion in composite products, improving their efficiency as a filter material.

Of interest to consortium members who manufacture semiconductor, photonic, and magnetic materials would be the high-average-power infrared laser lines. They would make possible important nonlinear spectroscopic techniques with these applications:

- Basic characterization of complicated materials growth processes;
- Production-quality control monitoring; and
- Nondestructive testing of intermediate or final products.

Commitments from consortium industries, the Commonwealth of Virginia, universities, and the City of Newport News already total $27 million. The state has pledged $5 million and Newport News $12 million for an Applied Research Center building, and industry in-kind contributions total $10 million. A conceptual team is at work to optimize the FEL design; with industry participation, it aims to minimize cost and technical risk, provide reliable cost and scheduling estimates, and prepare the final design report.

Work that will accelerate the project's completion when fully funded has begun at CEBAF and in the laboratories of both industry and university members of the consortium. With Commonwealth funding, CEBAF is constructing a continuous-wave photoemission electron gun, a key component in the FEL driver accelerator. The technology is also used in CEBAF's main accelerator, dedicated to nuclear physics. At the same time DuPont is funding laser applications studies at three consortium universities, the Aerospace Corp. is collaborating with CEBAF on FEL micromachining applications, and several CRADAs for FEL-related design studies this year are being negotiated with consortium industry partners.

But in spite of possessing all the ingredients for apparent success, in particular the crucial cooperation between government, industry, and academia, the project has yet to receive a commitment of federal financing. The Laser Processing Consortium puts the total anticipated federal cost at about $27 million for a three-year construction project for the laser system.

An Uphill Battle

A recent National Academy of Sciences review panel recommended that the DOE fund a user facility operating only at far-infrared (10-1000 micrometer) wavelengths. That group's mandate was confined to the study of facilities for scientific research alone, not industrial applications, but sources at CEBAF fear that the report's impact will reach beyond its mandate, creating further obstacles.

Surely, any new Department of Energy funding initiative faces an uphill battle in the current fiscal climate. On December 20 Energy Secretary Hazel O'Leary announced that the department will cut $10.6 billion from its budget over the next five years. Within the department, it has been the Basic Energy Science (BES) directorate that has funded the development and operation of existing synchrotron light-source user facilities, and BES underwrote the NAS review. But the directorate received $40 million less than requested for its fiscal year 1995 operating budget, and existing BES user facilities want to increase their budgets to meet customer demands. So the outlook for any new DOE money for CEBAF's FEL is at best uncertain.

But for Frederick Dylla, CEBAF's Technology Transfer Manager and also manager of the FEL program, the spirit of collaboration that marks CEBAF's ties with state and local governments and its industrial partners make it a first-class example of the kind of project that enhances US industrial competitiveness and leverages existing national laboratory resources. More important, he says, CEBAF's industrial partners believe this to be true. CEBAF and the consortium partners will continue working with DOE and other federal agencies on a funding plan because, as he puts it, "the project is such a wonderful idea, it is not a question of *if* it will be funded, but only of *when.*" ■

ELECTRONIC COMPONENTS AND CIRCUITS

Gigabit Transparent Optical ATM Packet-Switch Node

An optically transparent packet-switching node operating at 1.3 micrometers yields multigigabit-per-second transmission rates.

Rome Laboratory, Photonics Center, Griffiss Air Force Base, New York

A transparent optical node operating at a wavelength of 1.3 micrometers has been developed for an asynchronous-transmission-mode (ATM) packet switch operating at 1.24416 gigabits-per-second header recognition rates. The node is intended for use in two-connected, slotted networks, is self-clocking, and has drop/add multiplexing, buffering, and routing capabilities. Multigigabit data rates can be realized in transmission by such nodes in space switching transparent optical networks, since these nodes are connected by dedicated fiber links. The limitation in the bit rate is a result of electronic control of the switching nodes, since routing computations must be performed within the duration of an incoming packet. Thus it is very desirable to have extremely simple node structures with low loss and simple control, while still providing good throughput-delay performance.

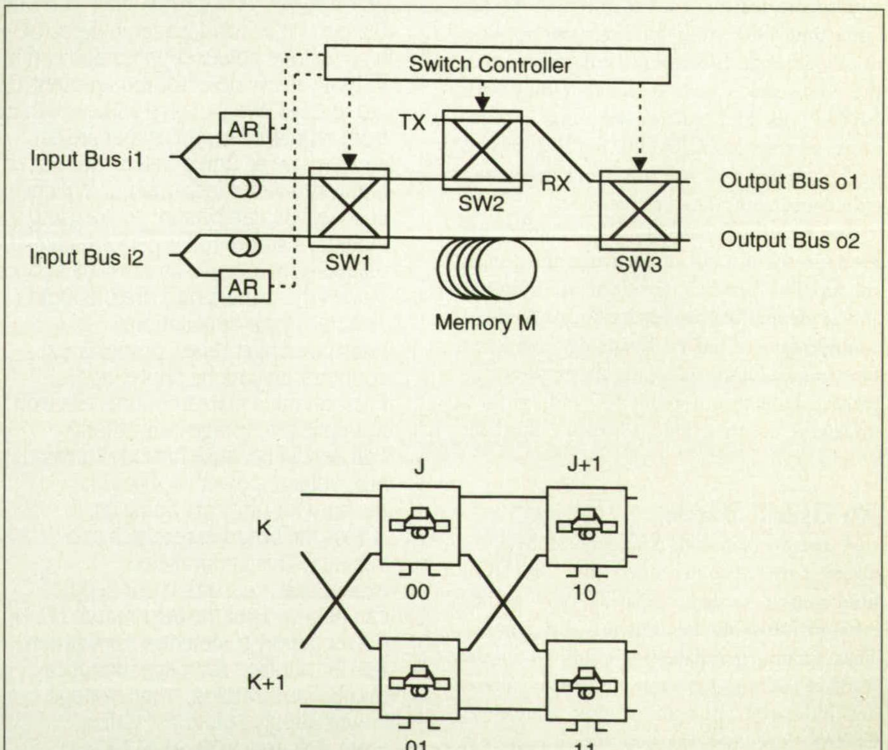
A new node structure (see figure) with a single transmitter TX and receiver RX employing deflection routing is proposed for use in two-connected, slotted networks, *i.e.*, two input and two output bus lines with dedicated time slots for packets to occupy. In this configuration, only three 2 X 2 optical switches are used, the theoretical minimum of all possible single-buffer all-optical-node schemes, for a node capable of transmitting to or receiving from either channel. Without the one-packet fiber delay loop memory M, it would be a 3 X 3 completely nonblocking switch.

Packets entering the node at inputs i1 or i2 are perceived by the controller in one of five possible ways: empty (E), for the node (FN), caring to exit on output o1 (C1), caring to exit on output o2 (C2), or don't care (DC), *i.e.*, both outputs provide equivalent shortest-paths to their destination. Deflections occur when packets at the input of SW3 vie for the same output. When packets at inputs i1 and i2 are FN, one is missed. The objective of the controller is to maximize the node's throughput by minimizing the number of deflections or misses. Switch SW2 is just transmission/reception, and routing switch SW3 is controlled with a simple nonpriority hot-potato routing of its input packets.

The throughput vs. offered load (*i.e.*, the probability of having a packet ready at TX at each clock cycle or packet slot) for a 64-node ShuffleNet in uniform traffic has been theoretically evaluated. A comparison was made between the throughput of this node with one loop memory M, of nodes with no delay loop memory M (*i.e.*, hot-potato routing where the network itself becomes the buffer), and of nodes with infinite-buffers (*i.e.*, store-and-forward S&F such as can be approached by all electronic node structures). The results show that at full offered load, the proposed node structure yields 71% of the maximum S&F throughput, while the node with no delay loop memory yields only 52%. This is a 37% increase in throughput at the cost of building only a slightly more complicated controller.

The transparent optical node was constructed with three lithium niobate ($LiNbO_3$) electro-optic crossbar switches (SW1, SW2, SW3) and an integer packet length of optical fiber for the purposes of routing, buffering, and drop/add multiplexing of incoming packets. The $LiNbO_3$ switches were measured to have average fiber-to-fiber losses of -6.4 dB for an overall loss of -19.2 dB for a packet traversing all three switches. Such a loss can be reduced significantly by improving the fiber splice connections within the node structure; alternatively, power levels can also be restored by an optical amplifier placed at the bus output ports of the node.

For experimental demonstration, a four-node banyan interconnect was assumed for routing purposes. Address recognition of packet structures consisting of a 5-byte header field and 48-byte data field was performed at a 1.24416-



Schematic diagram of **Optically Transparent Packet-Switch Node Structure** and four-node two-connected banyan interconnect topology.

gigabit-per-second nonreturn-to-zero header rate. The address signals of interest were detected by tapping off a portion of the incoming signal power with an optical fiber bidirectional coupler. The power in the address recognition portion of the signal is sent through an optical fiber 1 X 4 divider and delay structure for parallel detection of four bits of information in the header field.

Every incoming packet structure, including empty packets, begins with a two-bit-wide framing pulse in the header field. This pulse is used for self-clocking of packets entering the node and for maintenance of overall network synchronization. Since the framing pulse must be sent with every packet time slot, an address bit in the header field determines whether or not an empty packet has been sent in the slot. The destination address of the packet is then a two-bit binary combination JK signifying each node in the four-node interconnection. Prior to entering the node, the packet is buffered by a length of optical fiber, while the state of the three $LiNbO_3$ switches is set according to the routing algorithm. In this manner, fully functional routing, buffering, and transmission/reception of packets appearing simultaneously at inputs i1, i2, and TX was demonstrated at the 1.24416-gigabit-per-second header recognition rate.

This work was a collaborative research effort between R.K. Boncek, J.L. Stacy, and H.F. Bare of the Air Force Photonics Center, **Rome Laboratory**, *Griffiss Air Force Base, New York, and P.R. Prucnal, A. Bononi, and J.P. Sokoloff of the Department of Electrical Engineering at Princeton University, Princeton, New Jersey. No further information is available.*

Inquiries concerning rights for the commercial use of this work should be addressed to Rome Laboratory, Office of the JA, Griffiss Air Force Base, New York 13441.

95B10086

Growth of δ-Doped Layer on Silicon CCD

Response to ultraviolet light is enhanced.

NASA's Jet Propulsion Laboratory, Pasadena, California

A back-side-illuminated silicon charge-coupled device has been fabricated that exhibits nearly 100% internal quantum efficiency in the near ultraviolet, by using molecular beam epitaxy to grow a thin crystalline-silicon layer that contains a high concentration of boron (p-type dopant). By confining the dopant icon layer is said to be "δ-doped." In the CCD, the δ-doped layer is located at the back surface of a thinned commercial device (EG&G Reticon RA0512J). The δ-doped layer is formed by stripping the native oxide from the CCD and depositing boron atoms on the heated silicon surface, followed by growing a thin layer

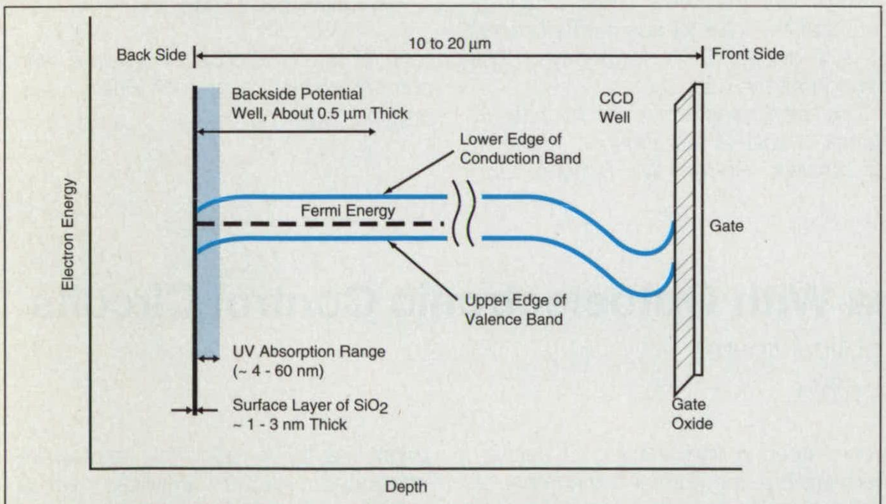


Figure 1. The **Potential Well** on the back side of a non-δ-doped, back-side-illuminated CCD traps charge carriers that are photogenerated near the back side. Because most ultraviolet photons are absorbed near the back side, this effect reduces or eliminates the response of the device to ultraviolet.

atoms to one or a few atomic layers in the silicon lattice, the concentration-vs.-depth profile can be made to resemble the Dirac δ function, and the resulting sil- of crystalline silicon to encapsulate and protect the dopants from oxidation.

Previously, the growth of thin, precise films by molecular-beam epitaxy on the back sides of preprocessed CCD's was not feasible because of the high processing temperatures that were used. Two developments have made it possible to decrease the processing temperatures to such an extent that now the required precise δ-doped layer can be formed. The first of these developments is a substrate-cleaning process in which an atomically clean silicon surface can be prepared at a temperature as low as 200 °C. The previous substrate-cleaning process for molecular-beam epitaxy required a temperature ≥800 °C.

The second development is a commercial high-temperature Knudsen cell for the evaporation of elemental boron. By use of this cell, one can grow a highly p-doped epitaxial layer of silicon at a temperature <450 °C. Previously, p doping of silicon in molecular-beam epitaxy was obtained by evaporation of compounds like HBO_2 and B_2O_3, and it was necessary to heat the device to a temperature of ≥550 °C to prevent incorporation of oxygen into the growing layer of silicon.

An explanation of some of the physical effects that occur in the CCD is prerequisite to an explanation of the improvement afforded by the δ-doped layer. The oxide layer on the back side is nonuniform in thickness, composition, and density of defects, and generally exhibits a substantial fixed positive electric charge. This charge bends the conduction and valence electron-energy bands downward, forming a potential well at the back surface.

The range of absorption depths for ultraviolet photons in silicon is such that photogeneration of electron/hole pairs occurs within 4 to 60 nm of the illuminated (in this case, the back) surface. The potential well at the back surface traps most of these photogenerated charge carriers. The back-surface oxide is full of interface quantum states and localized traps in which most of the charge carriers are annihilated by recombination of electrons and holes. The net result is low quantum efficiency and low sensitivity of the CCD under ultraviolet illumination.

In principle, a δ-doped layer one atomic layer thick would give rise to a dipole layer of charges less than 0.5 nm wide, nearly eliminating the back-surface potential well. Figure 2 shows the measured quantum efficiency of two δ-doped CCD's. The observed quantum efficiency follows closely the silicon transmittance curve, which accounts for losses due to reflection from the silicon surface and absorption in the oxide. These data indicate that the internal quantum efficiency of a δ-doped CCD is nearly 100% throughout the near UV.

This work was done by Michael E. Hoenk, Paula J. Grunthaner, Frank J. Grunthaner, Robert W. Terhune, and Michael H. Hecht of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information,* ***write in 134*** *on the Reader Information Request Card.*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

William T. Callaghan, Manager
Technology Commercialization
JPL-301-350
4800 Oak Grove Drive
Pasadena, CA 91109

Refer to NPO-18688, volume and number of this Laser Tech Briefs issue, and the page number.

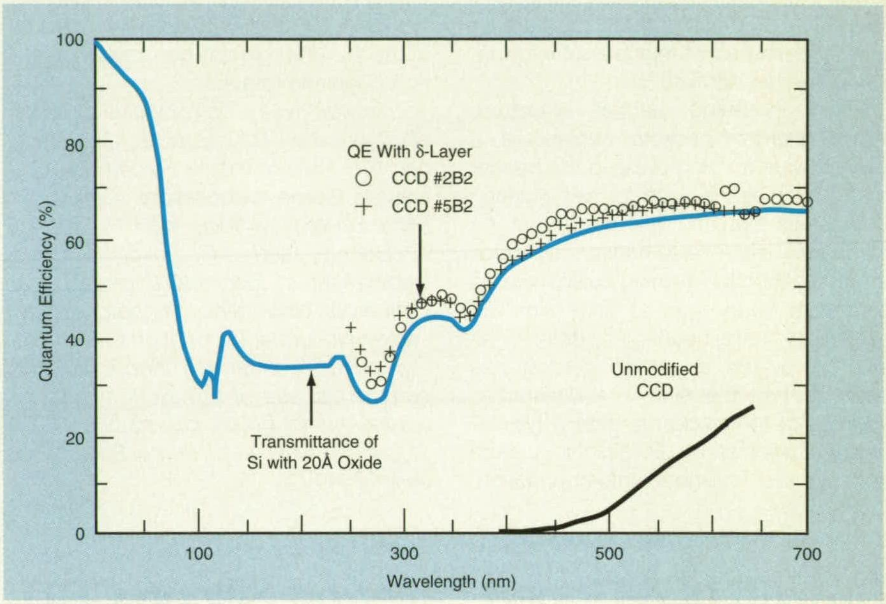


Figure 2. **Measured Quantum Efficiency of Two CCD's** is modified with the growth of a δ-doped silicon layer. The transmittance of silicon, calculated from published optical constants of Si and SiO2, determines the shape of the observed quantum efficiency spectra. For comparison, the quantum efficiency of an unmodified CCD is also shown in the figure.

Phased-Array Antenna With Optoelectronic Control Circuits

Control signals are distributed via optical fibers.

Lewis Research Center, Cleveland, Ohio

Phased-array microwave antennas in which phase- and amplitude-controlling signals are distributed to the radiating elements via optical fibers are undergoing development. A four-element, Ka-band (27 to 40 GHz) prototype was expected to be completed shortly after this article was written.

Phased-array antennas that contain individually controllable elements offer the advantages of flexible, rapid electronic steering and shaping of beams. Furthermore, the greater the number of elements, the less the overall performance of an antenna is degraded by a malfunction in a single element. In an antenna of the type being developed, the Ka-band radio-frequency power is distributed to each element by a power divider (basically a transmission-line network). The phase and amplitude of the signal radiated by each element are controlled by a monolithic microwave integrated circuit (MMIC), which includes a multiple-bit digitally controlled variable-gain amplifier and variable phase shifter.

Ten or more control signals are needed for each element. Optical fibers are well suited to the distribution of the many control signals in the limited space available on a typical array because they are relatively small and invulnerable to crosstalk. They also offer advantages of lightweight and mechanical flexibility.

The prototype four-element antenna is structured in layers (see figure). The topmost layer is a circuit board that distributes dc bias and serves as a structural support. The next lower layer is a circuit board with the radio-frequency power divider on its upper surface and the radio-frequency-ground plane on its lower surface. The digital control signals are transmitted serially on optical fibers to monolithic optoelectronic interface circuits (OEICs), which convert the signals to parallel format compatible with the MMICs. Each OEIC is adhesively bonded to the associated MMIC package and electrically connected via wires to the MMIC and to the dc-bias-distribution circuit board.

The radio-frequency output of each MMIC is coupled electromagnetically, through an aperture in the radio-frequency-ground plane, to an antenna patch (the associated radiating element) on the bottom surface of the structure. Such electromagnetic coupling is very efficient and eliminates the need for direct electrical coupling between the power-divider/MMIC layer and the antenna-patch layer.

This work was done by Richard R. Kunath, Kurt A. Shalkhauser, Konstantinos Martzaklis, Richard Q. Lee, and Alan N. Downey of **Lewis Research Center** *and Rainee N. Simons of Sverdrup Technology, Inc. For further information,* ***write in 186*** *on the Reader Information Request Card.*
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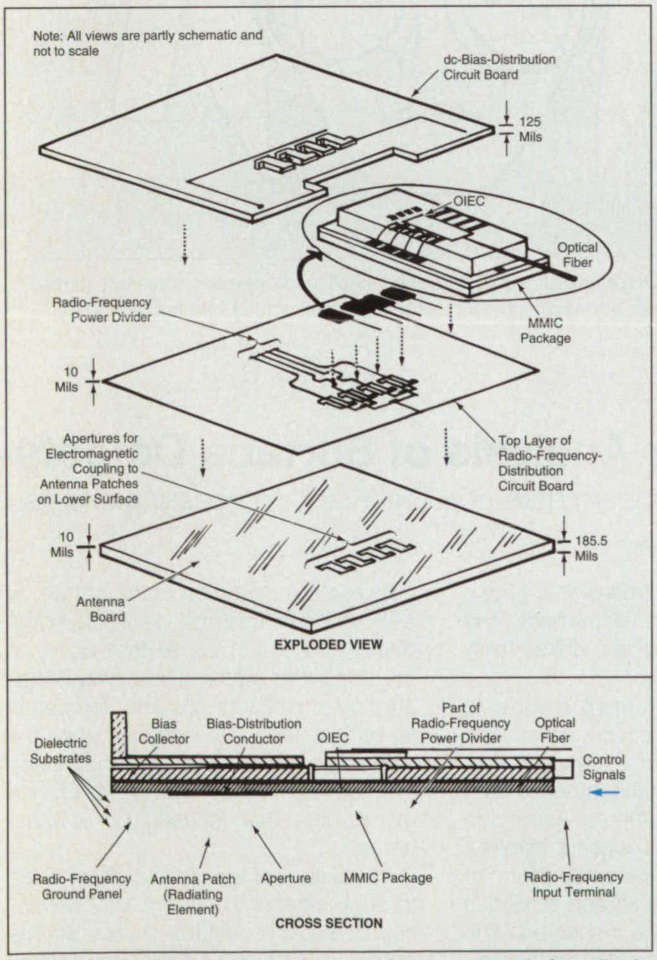

The **Prototype Phased-Array Antenna** features control of amplitude and phase at each radiating element. The amplitude- and phase-control signals are transmitted on an optical fiber to an OEIC, then to an MMIC at each element.

Holographic Helmet-Mounted Display Unit

This unit would be used to develop innovative concepts for display of information to pilots.

Langley Research Center, Hampton, Virginia

The helmet-mounted display unit shown in the figure has been designed for use in testing innovative concepts for the display of information to aircraft pilots. It weighs about 4.8 lb (about 2.3 kg), but its weight is distributed so that the wearer senses no imbalance. It operates in conjunction with computers that generate graphical displays. A magnetic sensory device tracks the orientation of the unit to provide data for variation of displays with the change in orientation of the wearer's head.

The display unit includes two ocular subunits containing miniature cathode-ray tubes and optics that provide a 40° vertical, 50° horizontal field of view to each eye, with or without stereopsis. Each ocular subunit is adjustable to vary the overall horizontal field of view from 50° to 100°, with corresponding variation in the stereoscopic overlap region. The optical components are fully color-corrected, though the miniature cathode-ray tubes are monochrome; this provides for upgrading to color as color display technology matures. In a future color application, each ocular subunit would include a trichromatic holographic combiner tuned to the red, green, and blue wavelengths of the phosphors most likely to be used in the development of miniature color display devices.

This work was done by James R. Burley II of **Langley Research Center** *and Joseph A. LaRussa of Technology Innovation Group. For further information,* ***write in 26*** *on the Request Card.*

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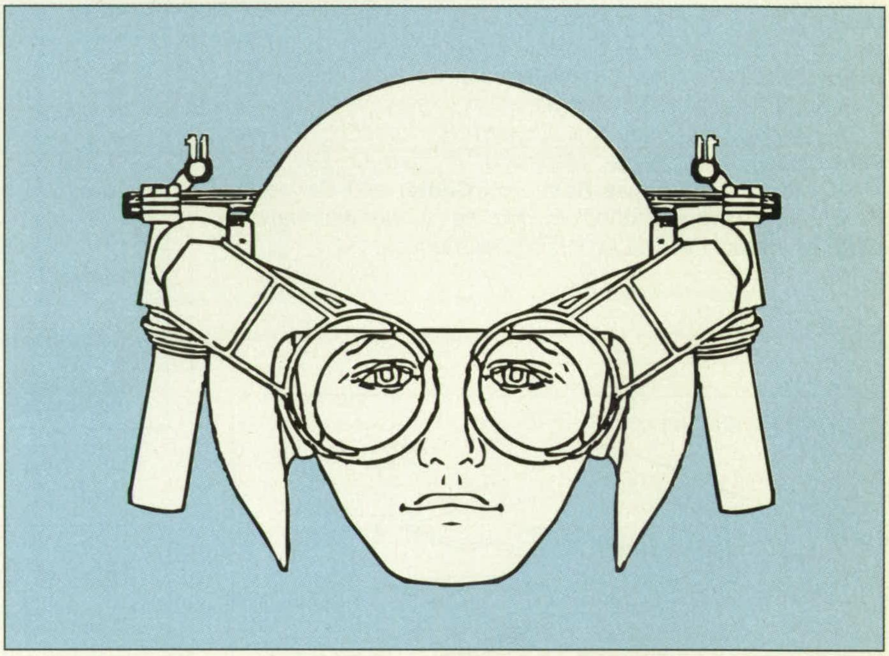


The **Helmet-Mounted Display Unit** would offer the flexibility to operate in a variety of modes for investigation of human and technological factors in the display of information to pilots.

Optoelectronic Instruments for Analysis of Surface Defects

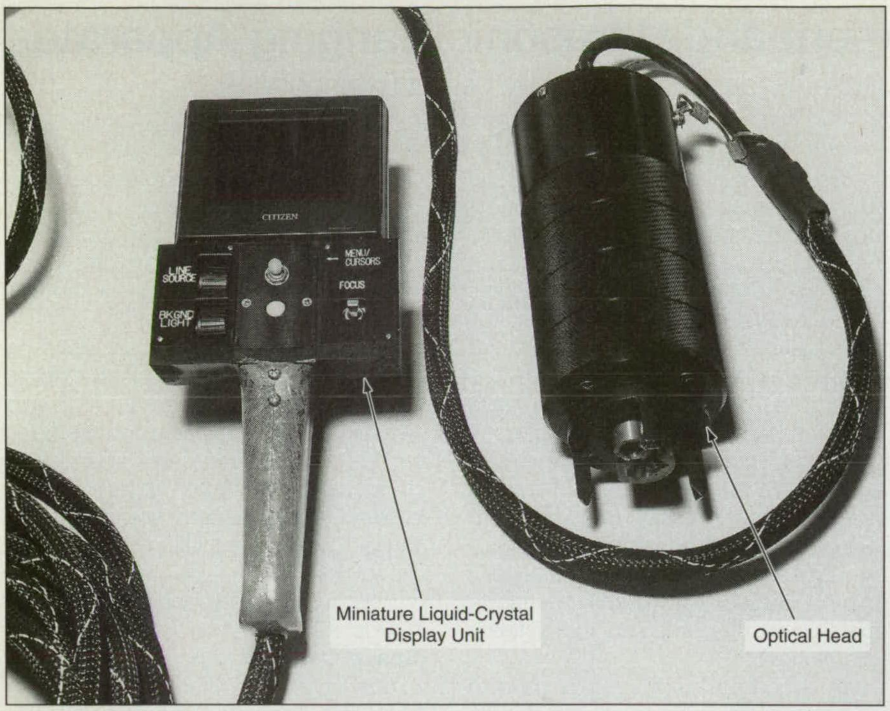
Structured-light microscopes are combined with modern data-acquisition and -processing circuits.

John F. Kennedy Space Center, Florida

A family of portable optoelectronic instruments is being developed to facilitate the inspection of surface flaws like gouges, scratches, raised metal, and dents on large metal workpieces that are subject to surface-finish requirements. Previously, impressions of flaws were taken in a polymeric material, and the hardened polymeric samples were carried to a laboratory, where they were sectioned and examined under an optical comparator to determine dimensions of the flaws: this process was labor-intensive and took hours for each flaw. The present optoelectronic instrument is brought to the workpiece and semiautomatically makes an electronic record of the three-dimensional shape of a flaw. With this instrument, the entire inspection process takes only minutes.

The prototype instrument includes a structured-light microscope, which represents a variation of a concept that has been the basis of a number of optical inspection instruments since the year 1932. The basic concept involves the projection of a known pattern of light [one or more line(s) and/or dot(s)] onto the surface to be inspected. The topography of the surface is then determined from the distortion of the pattern as viewed through the instrument, by use of the known proportionality between the distortion of the pattern at a given point and the deviation in the depth of the surface at that point. In this case, the pattern (laser line) is created by a miniature projector located in an optical head that is placed upon the workpiece at the location of the defect. The optical head also contains the microscope that is used to view the pattern.

The output of the video camera is fed through a cable to a frame-grabber circuit board in a desktop computer. The computer software enables the technician to view the image (whether live or frozen) at high resolution on the cathode-ray-tube display unit of the com-



The **Optical Head** contains a structured-light microscope equipped with a miniature video camera. The liquid-crystal display unit provides a low-resolution image that assists in positioning the optical head over a surface flaw.

puter, or at low resolution on a liquid-crystal display unit, which is mounted on top of the optical head (see figure). The low-resolution image helps the technician to find the defect and center it in the field of view when positioning the optical head on the workpiece.

The computer software provides cursors that the technician can move about in the image for measuring surface flaws. (For this purpose, the instrument must first have been calibrated against known standards.) After an image has been captured and the cursors set, the computer generates a report in the form of an annotated graphical image of the flaw. The image can be printed by use of a miniature high-resolution ink-jet printer and/or stored on a floppy disk.

The prototype instrument has a measurement range of about 0.001 to 0.020 in. (about 25 μm to 0.51 mm) in width and depth, with a resolution of about 0.0002 in. (about 5 μm) and an accuracy of about 0.0005 in. (about 12 μm). However, the range of measurement can be readily changed simply by changing the optics to increase or decrease the magnification.

This work was done by J. David Collins, Robert P. Mueller, and Richard M. Davis of **Kennedy Space Center** *and Stuart M. Gleman, Carl G. Hallberg, Stephen W. Thayer, David L. Thompson, and James E. Thompson of I-NET Space Services. For further information,* ***write in 21*** *on the Request Card.* *KSC-11686*

Optoelectronic Alignment and Ultrasonic Ranging Apparatus

A beam of light guides alignment, then range is measured by use of ultrasound.

John F. Kennedy Space Center, Florida

An optoelectronic/ultrasonic apparatus facilitates the three-dimensional alignment of a spot on one object with respect to a facing (but not touching) spot on another nearby object. The apparatus was designed to help in positioning the external tank of the space shuttle between the two solid rocket boosters, and should be useful in other applications in which one seeks to align large components that are to be locked together in assemblies.

The apparatus includes a sensor head mounted on one of the two objects that are to be aligned with each other. The head contains a bright red light-emitting diode with a focusing lens that projects a spot of light about 3/4 in. (about 19 mm) wide at a distance of about 1 ft (about 30 cm). The light is turned on and off at a rate of 1 Hz to increase its visibility. Alignment in the plane perpendicular to the beam is achieved by moving the objects relative to each other until an alignment mark on the other object becomes centered in the beam.

The sensor head also contains an ultrasonic range sensor that measures the distance between the two objects by the well-known pulse/echo-delay technique. This ultrasonic technique was chosen over optical and microwave techniques because of its lower cost, lower risk, and suitability for rapid development. The ultrasonic sensor used in the prototype of the apparatus is a commercial unit that consists of ultrasonic transducers connected via a cable to a microprocessor-controlled measurement circuit that produces the distance information.

An added microprocessor is used to convert the raw distance to the desired units (inches in the original application), subtract out the length of protrusion of the transducer, and compensate for variations in the speed of sound with changes in temperature of the air. The added microprocessor can also compute the distance through which a crane must move to position one of the objects (the external tank).

The added microprocessor drives a 16 × 4-character liquid-crystal display, indicating distances measured by two sensor heads, temperature, and remaining battery life. Processing and display are powered by a 12-V nickel/cadmium battery. The apparatus measures distances with a resolution of 1/16 in. (about 1.6 mm).

This work was done by J. David Collins and Jorge Rivera of **Kennedy Space Center** *and Robert Youngquist, J. Steven Moerk, William Haskell, Robert Cox, and Kenneth Rose of I-NET. For further information,* ***write in 35*** *on the Request Card.*
KSC-11654

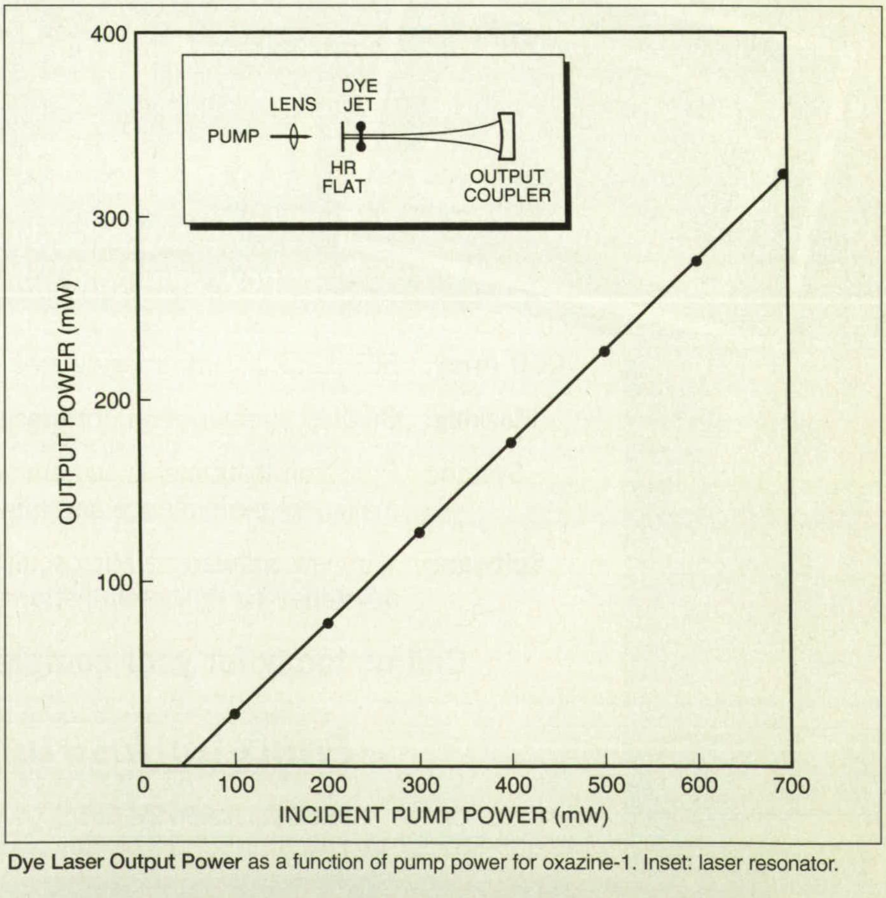
Dye Laser Pumping with Red-Emitting Diode Lasers

An efficient, compact diode-pumped dye laser provides battery-powered operation.

Naval Command, Control and Ocean Surveillance Center, San Diego, California

Continuous-wave dye lasers are versatile devices that are useful for a wide range of applications. However, the ion lasers typically used as pump sources are bulky, expensive and inefficient. Dyes that operate above 700 nm are pumped with a krypton-ion laser whose electrical efficiency is 0.05 percent and that furthermore requires substantial cooling.

The recent introduction of moderate-power red-emitting visible laser diodes has provided the opportunity to demonstrate a diode-pumped dye laser in the 700-800-nm wavelength range. These diodes have AlGaInP active layers and operate between 610 and 690 nm. Visible laser diodes are small, lightweight, and efficient (typically 15 to 25 percent). Individual diodes are currently available at power levels as high as 0.5 W. By polarization combination of two diodes to produce a single pump beam, more pump power can be obtained in the red than is available from small-frame krypton-ion lasers. Furthermore, because of the unique features of the dye jet (100 micrometers thick and high absorption coefficient at the pump wavelength), efficient scaling to high pump-power levels can be achieved by angular multiplexing of



Dye Laser Output Power as a function of pump power for oxazine-1. Inset: laser resonator.

many individual laser diodes.

The dye laser resonator consists of a highly reflective (HR) flat and an output mirror with a 10-cm radius of curvature in a nearly hemispherical configuration. The dye jet was placed as close to the HR flat as was practical, oriented normal to the resonator axis, and located near the resonator waist. Initial experiments used rhodamine 700 (LD 700) dye. The dye concentration was optimized for pumping at 670 nm, the emission wavelength of the two polarization-combined pump laser diodes. The diodes were powered by four AA batteries, and the only additional electrical power consumed was that required to drive the dye-jet pump.

Other dyes demonstrated in the laser were oxazine 750, DOTCI and oxazine 1. The best performance was achieved with rhodamine 700 and oxazine 1. For each of these dyes the minimum incident threshold power was approximately 5 mW and the maximum slope efficiency was more than 50 percent. The untuned output wavelength was approximately 750 nm. The overall electrical efficiency of the diode-pumped lasers is 10 percent. With 700 mW of pump power provided by a DCM-based dye laser, more than 360 mW of output power was produced.

The laser resonator and pump optics represent an important advance in the operation of dye lasers. Although the first diode-pumped dye laser was reported in 1974, the current generation of visible laser diodes has made this technology a practical one. Since visible laser diodes can emit near the peak absorption point of several near-IR-emitting devices, diode pumping can be an effective alternative to krypton-ion laser pumping.

This work was performed by Richard Scheps of the Electro-Optics Branch, Code 754, of the **Naval Command, Control and Ocean Surveillance Center, RDT&E Division (NRaD).** *Inquiries concerning rights for the commercial use of this invention should be addressed to Harvey Fendelman, Legal Counsel for Patents, Code 0012, NRaD, San Diego, CA 92152; (619) 553-3001.*

Ambient-Light Simulator for Testing Cockpit Displays

A computer-controlled apparatus simulates sunlight, darkness, or lightning on demand.

Langley Research Center, Hampton, Virginia

95B10091

An apparatus provides illumination from outside, through the windows and into the interior of a simulated airplane cockpit. The apparatus and cockpit are used to evaluate aircraft-instrumentation display devices under realistic lighting conditions.

The apparatus (see photo) simulates such diverse lighting conditions as direct sunlight shining onto the display surface through a side window or over the pilot's shoulder, sunlight reflecting from a white shirt onto the display surface, the Sun in the pilot's forward field of view at a low elevation angle over a deck of clouds, darkness, and lightning flashes in a dark sky. Illuminance at the pilot's instrument panel can be controlled from darkness to over 10,000 foot-candles; luminance in the forward field of view can be controlled to as high as 18,000 foot-lamberts over a small area.

The Ambient-Lighting Simulator surrounds the forward section of a simulated airplane. The simulator provides control over the intensity, color, and diffuseness of solar illumination and of the position of the Sun relative to the airplane.

The apparatus includes a Sun simulator that comprises several movable sources of light with scrolling color filters and a diffusing cylinder. The apparatus also includes an array of stroboscopic lights of various powers, selectable to obtain multiple flashes of various intensities and durations to simulate a main lightning flash followed by a trailing sequence of flashes. The apparatus is controlled by the same computer that hosts a software model of a modern transport aircraft represented in the simulated cockpit.

This work was done by Vernon M. Batson and Lawrence E. Gupton of **Langley Research Center**. *Further information may be found in AIAA paper 90-3146, "Design, Development, and Testing of an Ambient Lighting Simulator for External Illumination of a Transport Simulator Cockpit."*

Copies may be purchased [prepayment required] from AEROPLUS, Burlingame, California 94010, Telephone No. (800) 662-2376, Fax No. (415) 259-5047.

LAR-14668

A91-16699

Frequency-Resolved Optical Gating for Laser Pulse Measurement

The compact device measures intensity and phase of the ultrashort pulses crucial for quantum-control experiments.

Sandia National Laboratories and Los Alamos National Laboratory

Frequency-resolved optical gating (FROG) is an intuitive, self-contained, and general technique that measures the full time-dependent intensity and phase of an individual ultrashort laser pulse. FROG solves a long-standing problem in optical science, and is now being used by experimenters attempting to attain complete control over chemical reactions.

FROG utilizes the concept of a spectrogram from the field of acoustics, gleaning information from spectra of slices of the pulse created by gating the pulse with itself. It then reduces the mathematics to two-dimensional phase retrieval, a well-known solved problem in image science, to determine the pulse's time-dependent intensity and phase evolution.

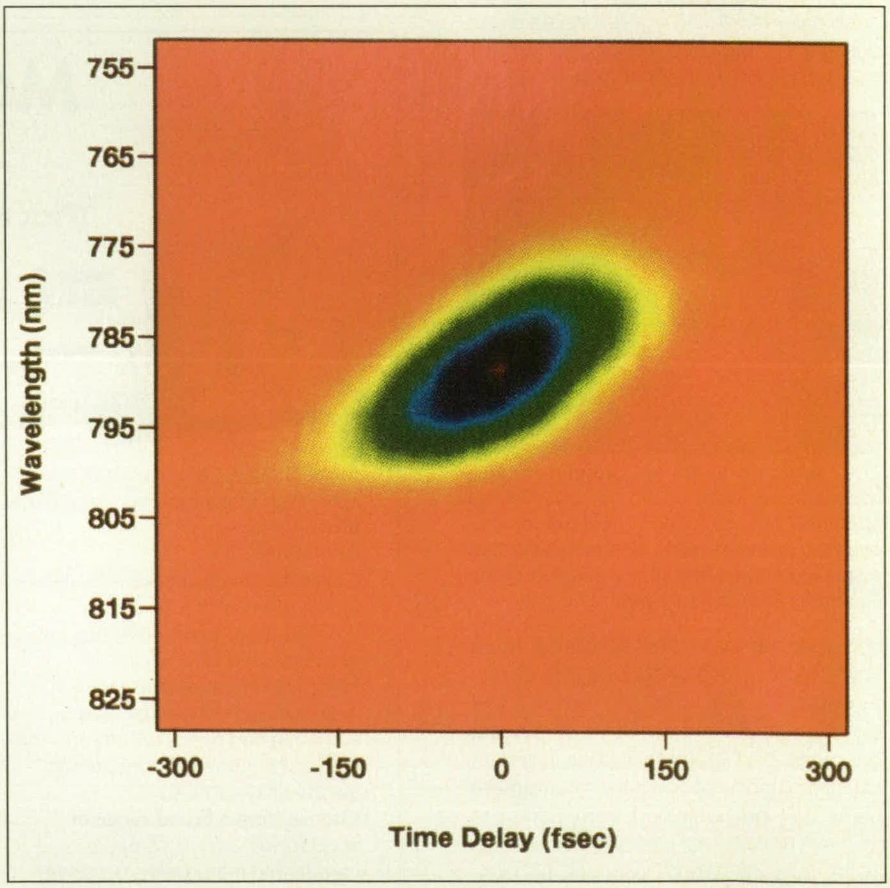
The commercial FROG apparatus, which measures about one foot by two feet by seven inches, consists of mirrors, mounts, polarizers, a prism or grating, a camera, and a computer. It can measure the average over many laser shots or a single ultrashort pulse.

One version of FROG uses a polarization gate arrangement. Specifically, a pulse is split into two replicas, one of which (the gate) has its polarization rotated by propagating along an out-of-plane path. The other (the probe) propagates through crossed polarizers, maintaining its polarization until the second of the polarizers rejects it. The pulses are focused and cross at a small angle in a very rapidly responding nonlinear optical medium, typically quartz, located between the crossed polarizers. The gate pulse induces an excitation in this medium, which rotates the polarization of the probe pulse. A spectrometer then disperses this slice of the probe pulse so that a camera can record its spectrum. The relative delay between the two pulses is scanned; as the gate pulse is scanned, it slices out a different piece of the probe pulse. The spectrum is then measured for each slice. As a result, spectra for all possible slices of the pulse are measured.

In single-shot FROG, a cylindrical lens focuses both pulses to line-shaped beams in the nonlinear optical medium, where they cross at a large angle. This maps the relative delay between the pulses onto position in the medium. On one side, pulse A precedes pulse B, whereas on the other side pulse B precedes pulse A. A spherical lens then images the beams at the nonlinear medium onto the spectrometer's entrance slit. The relative delay between the pulses is thus mapped onto position at the slit, and after spectral dispersion by the spectrometer, the wavelength of light varies in the perpendicular direction.

The spectrometer's optics image the slit onto the camera, at which delay is scanned in one direction and wavelength in the other. As a result, the full experimental trace of intensity vs. wavelength and delay is measured in one laser shot. The measured FROG trace is then run through a two-dimensional phase-retrieval algorithm to yield the pulse intensity and phase vs. time.

Researchers in diverse areas, including physics, biology, and engineering are expected to benefit from this technique. In research projects ranging from electronic component development to DNA research, fundamental events occur on time scales that can be measured only with ultrashort pulses.



A FROG trace (intensity vs. wavelength and delay) for a relatively smooth ultrashort laser pulse. More complex pulses would yield traces with additional structure.

Of perhaps the greatest potential is the device's usefulness to chemists, specifically the coherent control community. Coherent control researchers are already working with FROG, their goal being to control chemical reactions completely using laser beams. Accomplishing this would mean that, for example, a chemist attempting to combine AB + CD to produce ABC + D could consistently do so, rather than producing the various other possible combinations.

Because chemical reactions occur so quickly, controlling them requires ultrashort laser pulses of specific shapes and phases. Logically, a researcher must first know a pulse's phase and amplitude in order to determine the transformations necessary to tailor it for optimal reaction control. FROG, as a measurement and diagnostic tool, can be used to optimize ultrashort pulses for specific reactions. It both helps determine the modulation necessary to transform one pulse into another, and verifies that the desired optical waveform has been produced.

This work was performed by Rick Trebino and Kenneth DeLong of **Sandia National Laboratories** *and Dan Kane of* **Los Alamos National Laboratory.** *The invention has been licensed under an exclusive arrangement; however, inquiries concerning commercialization of variations on it can be directed to T. Michal Dyer, Sandia National Laboratories, California Technology Transfer 8800, P.O. Box 969, Livermore, CA 94551; (800) 294-TEKT; FAX (510) 294-3422; e-mail: tech transfer.info@sandia.gov.*

Improved Microwave Fiber-Optic Link

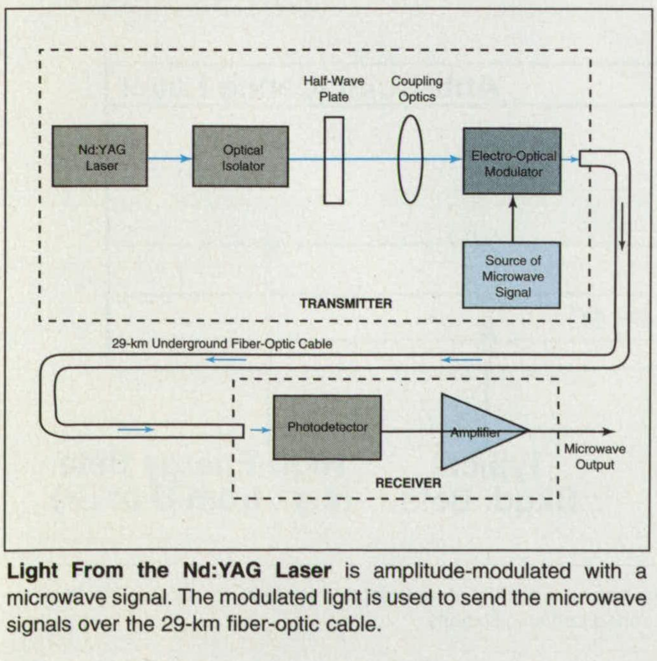
95B10092

Microwave signals can be transmitted long distances with high stability.

NASA's Jet Propulsion Laboratory, Pasadena, California

High-stability transmission of microwave signals along fiber-optic cable has been achieved in experiments by extending previously developed high-stability fiber-optic techniques to microwave frequencies. This system uses an external modulator to amplitude-modulate the intensity of light from a continuous wave (CW) laser at various frequencies from 2 to 12 GHz. The CW laser used in the experiments comprised a neodymium:yttrium aluminum garnet (Nd:YAG) laser pumped by a semiconductor laser diode. The external modulator was a lithium niobate traveling-wave electro-optical Mach-Zehnder interferometer. The phase noise of this system is -110 dBc in a 1 Hz bandwidth, 1 Hz from an 8.4 GHz carrier. The modulated optical signal was transmitted over a 29-km fiber-optic cable connecting two Deep Space Stations in the NASA/JPL Goldstone Deep Space Communications Complex (DSCC). The signal-to-noise ratio of the signal after transmission was > 100 dB•Hz and the Alan deviation was 1×10^{-15} for 1,000 seconds averaging time.

The high power output and narrow linewidth of the Nd:YAG laser and external modulator combination enable higher stability and higher dynamic range fiber-optic transmission of microwave signals over longer distances than is achievable with directly modulated semiconductor-laser based systems. This system is a prototype to test the concept of high fidelity transmission of received microwave signals over fiber-optic cables, without the need to downconvert the microwave signals for transmission as is done now in a DSCC. This type of fiber-optic system should also prove useful in distribution of future, more stable, frequency reference signals, phased array radar systems, and aircraft landing systems using bistatic radar.



Light From the Nd:YAG Laser is amplitude-modulated with a microwave signal. The modulated light is used to send the microwave signals over the 29-km fiber-optic cable.

This work was done by Ronald T. Logan and George F. Lutes of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 272*** *on the Request Card.*
NPO-19007

BetaScint Fiber Optic Sensor for Radionuclide Detection

A new technology rapidly characterizes uranium and strontium in soils.

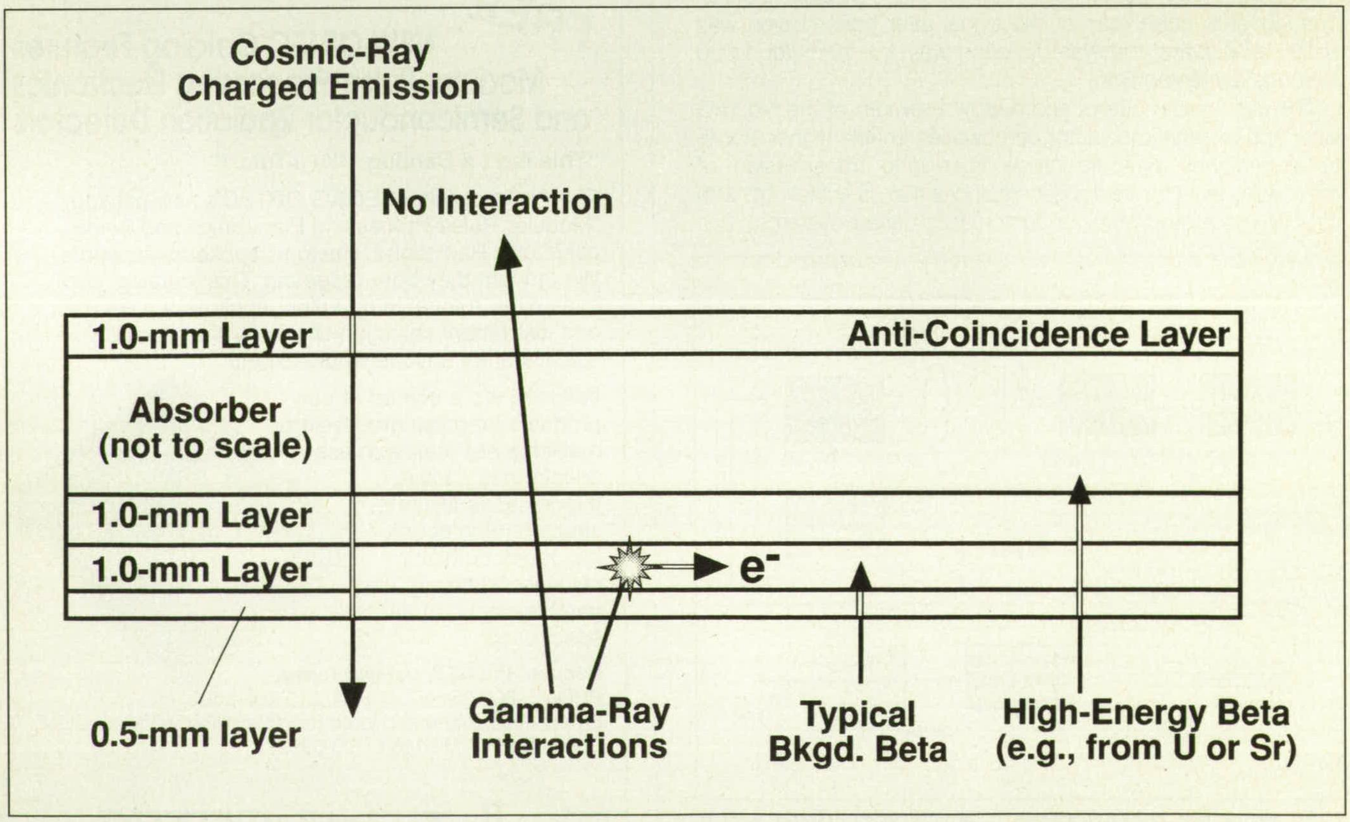
Pacific Northwest Laboratory, Richland, Washington

Recent studies have identified dozens of waste sites at US Department of Energy facilities that exhibit radionuclide contamination exceeding established limits. In many cases the radionuclides include uranium and strontium, two of the most prevalent contaminants that result from nuclear power generation, weapons development, nuclear testing, and atomic catastrophes. Historically there have been no technical methods of rapidly and efficiently characterizing these sites and the potentially contaminated regions that surround them. Existing characterization methodologies have been excessively costly and time-intensive, causing unnecessary delays in identifying and removing these contaminants.

One mechanism for detecting charged species, such as beta particles emitted from the radioactive disintegration of uranium-238 or strontium-90, uses a substance that scintillates, or emits light, upon passage of these particles through such sensitive material. Polystyrene-based plastic fibers can be doped, during the process of casting them, with various fluorescent compounds that are carefully selected to produce the desired scintillation, optical, and radiation-resistant characteristics necessary for the technical requirements. Charged particles passing through these fibers lead to ionization and excitation of the fluorescent dopants, which subsequently de-excite by emitting visible light. The resulting light pulses, partially transmitted down the length of the fiber, can be converted into electrical signals by a light-sensitive device such as a photomultiplier tube or silicon avalanche photodiode.

Researchers at Pacific Northwest Laboratory (PNL) incorporated these fibers into the BetaScint fiber optic sensor, a technology developed at PNL to characterize uranium-238 and strontium-90 in soils rapidly and efficiently. The sensitive volume of the detector is composed of 0.25-mm^2 and 1.0-mm^2 plastic scintillating fibers (obtained from the Bicron-Harshaw Corporation of Newbury, Ohio), which engineers at PNL fashioned into a light-tight stack of flat ribbons. This configuration facilitates the characterization of the relative energies and abundances of incident charged particles. Normally incident particles with energies exceeding 2 MeV, such as those originating from the decay of uranium-238 and strontium-90, will penetrate all three lower layers and generate light pulses within each fiber ribbon. Potentially interfering gamma rays and lower-energy charged particles, however, lead to distinctly different signals and are effectively discriminated against: low-energy particles are unable to traverse all three ribbon layers, and gamma rays are likely to produce scintillations in only a single layer if at all through the generation of low-energy Compton electrons.

Radiation-induced scintillations within the individual ribbon layers are converted to proportionate electrical pulses by the light-sensing device. These current puls-



Schematic representation of the **BetaScint sensor**, showing interactions between scintillant material and incident emissions. Double lines denote particle tracks that lead directly to excitations/ionizations and consequent scintillations.

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es are amplified by a two-stage microwave-amplifier circuit (>2-GHz bandwidth) and converted to high-fidelity voltage pulses. A lower-level discriminator placed at the amplifier output to improve the signal-to-noise ratio allows differentiation between valid signal pulses and noise generated in the light-sensing device or amplification circuitry. A comparator allows for adjustment of the output pulse width that, in turn, controls the time window associated with interlayer and intralayer coincidence overlaps. The end-to-end, or intralayer, coincidence requirement militates against false positives caused by random noise generated in the light-sensing devices. The interlayer coincidences are a direct indication of the charged-particle energies, which are uniquely indicative of their parent radionuclide.

The BetaScint sensor is calibrated against soils spiked with known concentrations of the target radionuclides, then placed above a moving or stationary surface. Within moments, it indicates contaminant activity. The technology has been successfully demonstrated in the field at a number of defunct uranium-processing facilities, where it has characterized radionuclide contamination in support of remediation efforts. The sensor has also been used in a conveyor-belt configuration for monitoring potentially contaminated materials moving at speeds up to 8 centimeters per second.

Scientists and engineers at PNL are currently exploring additional applications for this technology, including a roboticized version for monitoring enclosed or structurally unsound spaces that preclude safe access of personnel in to-be-decommissioned nuclear facilities. Small hand-held designs are also being evaluated for use in monitoring equipment, personnel, structures, etc. Inquiries from national laboratories, universities, and industry regarding collaborative efforts in this field are encouraged.

This work's laboratory and field efforts were managed by Dr. Alan J. Schilk of **Pacific Northwest Laboratory**, *and supported by the US Department of Energy's Office of Technology Development. A US patent has recently been awarded, and negotiations are currently under way with a potential industrial partner for licensing the commercialization of this technology.*

Inquiries may be addressed to Dr. Schilk, PNL, PO Box 999, MSIN P8-01, Richland, WA 99352; (509) 376-9510, FAX (509) 376-3868, e-mail aj_schilk@pnl.gov.

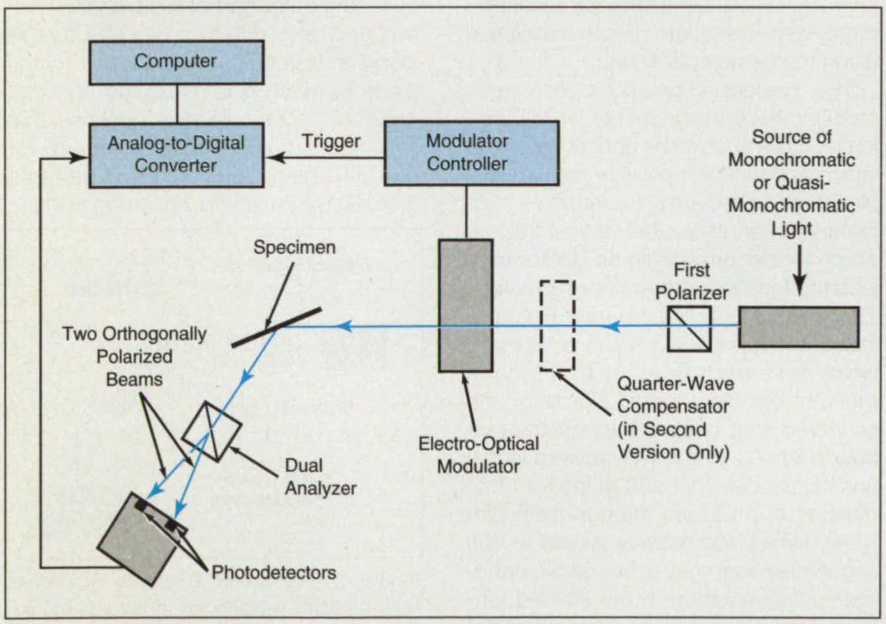
Small-Modulation Ellipsometer

Alignment is simple, and no tedious calibration procedure is needed. 95B10093

Marshall Space Flight Center, Alabama

The small-modulation ellipsometer is an improved ellipsometer that can be made compact and rugged for operation in harsh environments. Older ellipsometers (the null, rotating-polarizer, and large-modulation ellipsometers) are sensitive to small misalignments and must be calibrated. In contrast, the small-modulation ellipsometer contains no rotating or sliding parts and tolerates small misalignments, and both its calibration parameters and misalignments are computed directly from the outputs of its sensors. Thus, it calibrates itself and operates with a minimum of intervention by a technician, in keeping with the trend to eliminate tedious setup procedures in modern scientific instrumentation.

In ellipsometry, one characterizes a specimen of material (usually a thin film) by measuring the change in polarization of polarized light transmitted through the specimen or reflected from the specimen at a glancing angle. Ellipsometry can be used to measure optical constants of specimen materials, thicknesses of layers, roughnesses of surfaces, and anisotropies. Conventionally, the measured reflective polarization



The **Small-Modulation Ellipsometer** contains no moving parts and is insensitive to small misalignments. It provides real-time, simultaneous measurements of both ellipsometric parameters, without need for separate calibration measurement or tedious adjustments.

effects of a specimen are summarized by converting them into a standard form prescribed by the following equation

$$\frac{r_p}{r_s} = e^{i\Delta} \tan(\Psi)$$

where rp and rs denote complex reflection coefficients on two specimen reference planes called "p" and "s," tan (Y) denotes the ratio between the intensity of the p-polarized reflected light and that of the s-polarized light, and Δ denotes the difference between the phases of the p-polarized and s-polarized reflected light. In the case of transmission measurements, each reflection term is replaced by its corresponding transmission term.

The small-modulation ellipsometer provides simultaneous and continuous measurements indicative of tan(Y) and Δ of the specimen. This feature, plus its self-calibration capability and its ruggedness, makes it suitable for real-time monitoring of growth, annealing, treatment, or degradation of specimens.

The small-modulation ellipsometer can be assembled in two slightly different versions (see figure). In the first version a beam of monochromatic or quasi-monochromatic light (from a laser, light-emitting diode, lamp with bandpass filter, and the like) is linearly polarized, then sent through an electro-optical modulator, which alters the state of polarization at a chosen frequency that can be as high as several gigahertz. The second version is similar to the first version except that a compensator is inserted between the first polarizer and the modulator. The compensator is a birefringent quarter-wave plate that converts the linear polarization to elliptical or circular polarization. The amplitude of the modulation is kept low so that the change in polarization remains small.

The modulated beam is reflected from the specimen, then passes into a dual analyzer (a polarizing beam splitter) that separates it into orthogonally polarized components. These components are sensed by photodetectors. The outputs of the photodetectors can be processed by use of any or all of a number of techniques that could include analog-to-digital conversion followed by digital computation, analog or digital filtering, lock-in amplification, and/or Fourier analysis. An essential part of the processing is extraction of the amplitude of the dc components of the photodetector outputs, plus the amplitudes of the components at the modulation frequency and its first few harmonics. By use of a set of approximations that are accurate to second order in the modulation amplitude, M, one can compute tan(Y) and Δ from the amplitudes of the dc, fundamental, and second-harmonic components. To obtain greater accuracy and account for small misalignments, one can compute tan(Y) and Δ by use of another set of approximations that are accurate to fourth order in M and that include the third- and fourth-harmonic components in addition to the lower-frequency components.

This work was done by J. Woollam, B. Johs, S. Ducharme, and H. Machlab of J. A. Woollam Co. for **Marshall Space Flight Center**. *For further information,* ***write in 127*** *on the Request Card.*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

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Refer to MFS-26235, volume and number of this Laser Tech Briefs issue, and the page number.

Improved Optics for Quasi-Elastic Light Scattering

Spatial resolution is enhanced for better intensity and fluctuation measurements

Lewis Research Center, Cleveland, Ohio

An improved optical train has been devised for use in light-scattering measurements like those of quasi-elastic light scattering (QELS) and laser spectroscopy. Measurements of this type are typically performed on solutions, microemulsions, micellular solutions, and colloidal dispersions. In particular, simultaneous measurements of the total intensity and fluctuations in total intensity of light scattered from a sample at various angles (see Figure 1) provide data that can be used, in conjunction with diffusion coefficients, to compute the sizes of particles in the sample.

Accurate determination of the angle of scattering, q, is essential to the measurement of total intensity. Accurate determination of that plane in the sample from which the light was scattered is essential to the measurement of fluctuations in intensity; this is because light scattered spuriously from the sample/wall and wall/air interfaces of the cell that holds the sample can grossly affect the fluctuation measurement. Thus, there is a need for both a measurement with adequate angular resolution about the optical axis at scattering angle q, and a simultaneous measurement with adequate depth resolution along the same optical axis.

The present improved optical train satisfies these requirements by combining features of an older optical train — in which two pinholes provide angular resolution but no depth resolution — with features of another older optical train, in which lenses provide some depth resolution but inadequate angular resolution. The present optical train (see Figure 2) includes two lenses, central portions of which have been bored out to accommodate pinhole masks. Some of the scattered light passes through the pinhole in lens 1, then travels toward lens 2 and its pinhole. That part of the light that reaches and passes through both pinholes (which collectively establish the angular resolution) is detected by a photodetector mounted in the second pinhole. Thus, the output of this photodetector is the desired high-angular-resolution signal proportional to the total intensity of scattered light.

Lens 1 collimates the light that reaches it. The outer part of the pinhole mask at lens 1 also contains two slits that lie along a diameter perpendicular to the plane in which q is measured and that pass only those collimated light rays that lie in strips of width w between radii R1 and R2. The parts of the collimated light that survive the slits pass through lens 2,

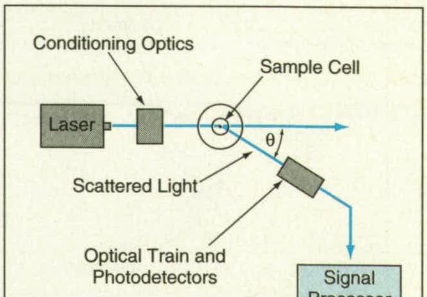

Figure 1. The **Laser Beam Is Scattered** from particles suspended in the sample liquid. The intensity and fluctuations in the intensity of scattered light are measured as functions of *θ*.

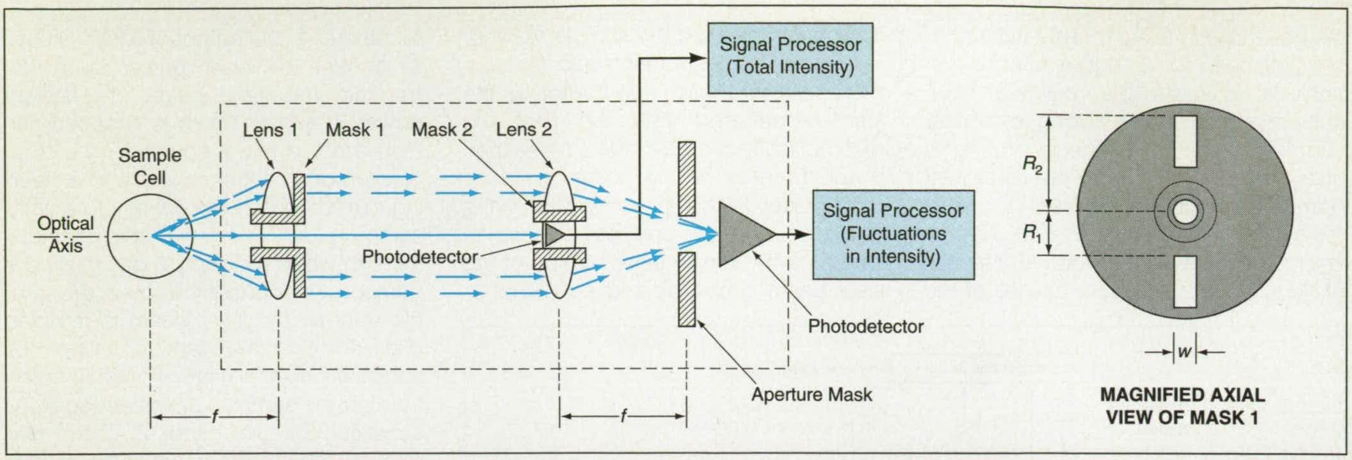

Figure 2. The **Improved Optical Train** enables simultaneous measurements with both depth and angular resolution.

which focuses them onto another photodetector.

By eliminating those rays scattered at angles nearly parallel to the optical axis, the combination of masks and lenses thus selects only those rays that provide depth information. An aperture mask with an aperture of radius RA discriminates further against light scattered from positions other than at the desired depth within the specimen. The minimum resolvable increment of depth is given by $\Delta z = RAf/R1$, (where f = the focal length of each lens) while the minimum resolvable increment of angle is given by $\Delta q = 2\arctan(w/2f)$. Thus, the output of the second photodetector has both some angular resolution and the depth resolution needed for accurate determinations of fluctuations in intensity.

This work was done by Harry Michael Cheung of the University of Akron for **Lewis Research Center***. For further information,* ***write in 9*** *on the Request Card.*

Title to this invention, covered by U.S. Patent Nos. 5,028,135, 5,298,968, and 5,298,969 has been waived under the provisions of the National Aeronautics and Space Act {42 U.S.C. 2457 (f)}. Inquiries concerning licenses for its commercial development should be addressed to

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Refer to LEW-15621, volume and number of this Laser Tech Briefs issue, and the page number.

Improved Raman-Scattering Gas-Species Monitor

High efficiency is achieved by multiple passes of laser beam, fast collection optics.

John F. Kennedy Space Center, Florida

The figure illustrates, schematically, an improved Raman-scattering instrument that provides real-time measurements of the concentration of a gas species of interest mixed with other gases. For example, in the original application, the instrument is used to determine whether there is a flammable or explosive concentration of leaking hydrogen present in an atmosphere that contains varying concentrations of helium, air, and possibly other gases in addition to the hydrogen.

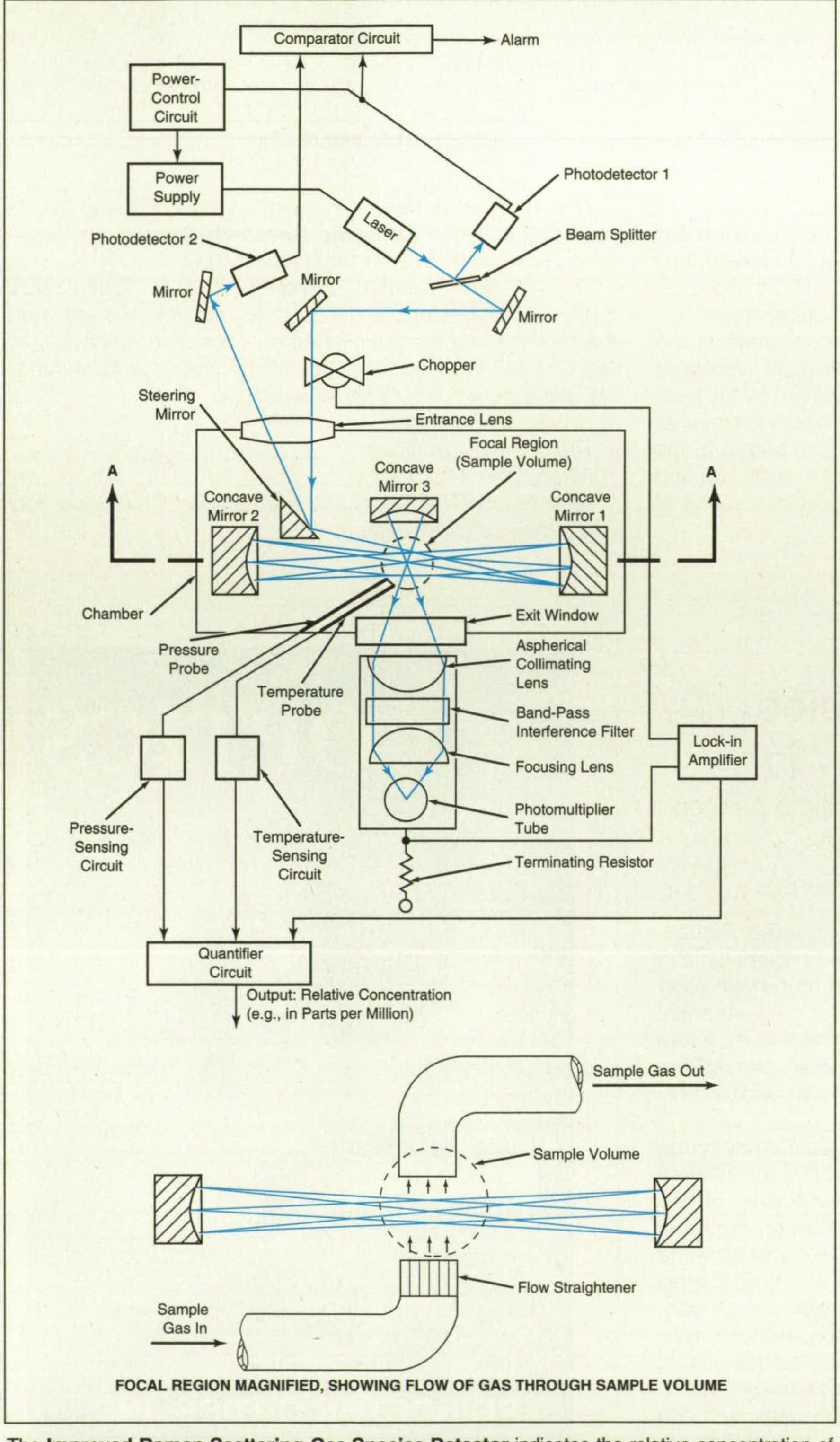
Like other Raman-scattering gas-species-monitoring instruments, this one offers the advantages of (1) the inherent simple proportionality between the concentration of the species of interest and the intensity of the Raman-scattered light, (2) the independence of Raman scattering from the composition, pressure, and temperature of the other gas(es) with which the gas species of interest is mixed, and (3) consequent simplicity and reliability of calibration, with no need for a second sample chamber containing a reference gas. In comparison with other Raman-scattering gas-species-monitoring instruments, this one costs less, weighs less, and can be operated more easily, largely because the intense illumination needed to obtain sufficient Raman scattering is provided by smaller, more rugged means: Instead of passing the sample gas through a laser cavity (with consequent need for an active control system to maintain the delicate laser adjustment) or using strong externally supplied illumination (necessitating a bulky, expensive laser), the improved Raman-scattering instrument incorporates a relatively inexpensive external laser and achieves the needed intensity of illumination by multiple passes of the laser beam through the sample volume. The improved instrument also features more-efficient optics for collecting the Raman-scattered light, so that the external laser can be made smaller than it would otherwise have to be.

The laser in this instrument is of the argon-ion type and operates at a wavelength of 488 nm. A small portion of the laser beam is split off and sent to photodetector 1, the output of which is used to control the laser power supply to maintain the laser beam at constant power. The laser beam is chopped and then directed into a chamber. The combination of an entrance lens and a steering mirror focuses the beam into a small sampling volume, within the chamber, through which the sample gas mixture is pumped. After passing through the sample volume, the laser beam is reflected back through the sample volume by spherical concave mirror 1, then reflected through the sample volume yet again by spherical concave mirror 2. These mirrors are adjusted to focus in the sample volume, so that the laser beam passes through the sample volume many times (typically as many as 40).

The last bounce returns the laser beam to the steering mirror at an angle slightly different (not as shown in the figure) from that at which it entered, so that it is reflected to photodetector 2 for additional measurement of the power in the laser beam. The output of photodetector 2 is a sensitive measure of the cumulative effect of alignments of the optical components. The outputs of photodetectors 1 and 2 are sent to a comparator, which puts out an alarm if they differ by more than a preset amount, signifying fouling or misalignment of the optics.

Light Raman-scattered from hydrogen (at a wavelength of 612 nm) is collected over a large solid angle (about 1 steradian) by an aspherical collimating lens. A third concave mirror catches Raman-scattered light that travels into the opposite solid angle, reflecting it back through the sample volume and into the collimating lens, so that the amount of Raman-scattered light collected is about double what it would otherwise be. On its way out of the chamber, the light passes through an exit window, which is a glass filter colored to pass light at the hydrogen-Raman-scattering wavelength of 612 nm and suppress scattered laser light at the original 488-nm wavelength. The collimated light goes through an interference filter that passes light in a wavelength band 5 to 10 nm wide centered at 612 nm, thus providing further selectivity to separate the 612-nm Raman signal from background fluorescence, scattered laser light, and ambient light. The collimated Raman-scattered light that remains after band-pass filtering is focused onto the photocathode of a photomultiplier tube.

The output of the photomultiplier is processed via a lock-in amplifier that is synchronized with the chopper, to suppress the dc contribution of the photomultiplier dark current. The amplified output is processed further by a quantifier



The **Improved Raman-Scattering Gas-Species Detector** indicates the relative concentration of the gas species of interest (hydrogen in this case) in the sampled gas stream that passes through the sample volume.

circuit. Probes in the sample region measure the pressure and temperature of the sampled gas. A quantifier circuit multiplies the photodetector output by an amount proportional to the absolute temperature of the sampled gas and divides by an amount proportional to the pressure of the sampled gas to obtain a final output in the form of the relative concentration of the gas of interest (hydrogen in this case) in the sampled gas.

This work was done by Steven Adler-Golden, Neil Goldstein, and Fritz Bien of Spectral Sciences, Inc., for **Kennedy Space Center**. *For further information,* ***write in 198*** *on the Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Kennedy Space Center [see page 4]. Refer to KSC-11566.

Real-Time, Holographic, Dynamic Image-Storage Device

Multiple refractive crystals are used for dynamic storage of images.

Langley Research Center, Hampton, Virginia

95B10096

A solid-state device has been developed for high-speed acquisition, dynamic storage, and amplification of three-dimensional holographic images. In previous applications of real-time holography and optical image processing via two- and four-wave mixing in photorefractive crystals, only a single crystal was used in each case. As a result, applications that involved storage of holographic images have been limited to static storage, wherein a holographic image is created in a single photorefractive crystal by mixing two or more coherent beams of light. The source of light is removed after the holographic image is established, and the image remains in the crystal (provided the crystal is isolated from light) for an amount of time that depends upon the charge-migration characteristics of the crystal. The characteristic time (time constant) for retention of an image can range from fractions of a second to years, depending on the crystal. Any exposure to light erases the stored information.

In the present device (see figure), holograms are generated via four-wave mixing in two or more photorefractive crystals (or subelements of a single crystal) to create a single-crystal or multicrystal oscillator. The oscillator acts as a dynamic three-dimensional optical image-storage device (memory), or as the basic unit cell of an optical computer. A hologram is generated within the first crystal (or subelement) by mixing three beams of light that are coherent. One of these beams, denoted the reference or writing beam, is of an intensity much greater than that of the second beam, which is denoted as the object beam. The third beam, denoted the probe or reading beam, is counterpropagating with respect to the reference beam, and is of about the same intensity as that of the reference beam.

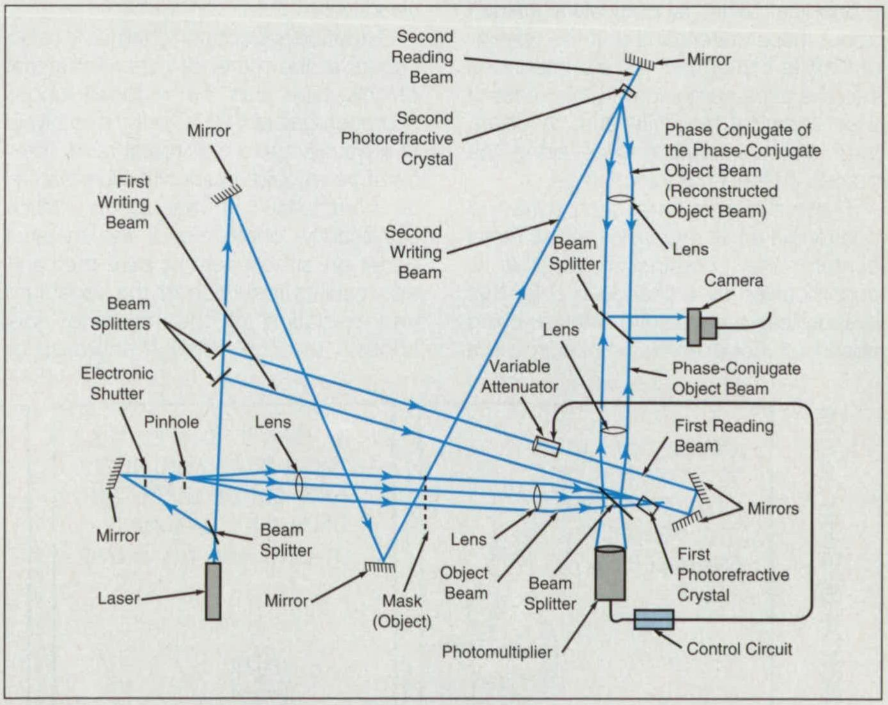
The mixing of these three beams in the first crystal creates a phase grating that diffracts a portion of the reading and writing beams. The diffracted beam leaves the crystal as a fourth beam that is the phase conjugate of the object beam and that counterpropagates with respect to the object beam. This phase-conjugated object beam is directed onto a second photorefractive crystal (or subelement) and is mixed with another coherent reading and writing beam. A phase grating is thus established within the second crystal, and it diffracts a portion of the reading and writing beams into a fourth beam that is the phase conjugate of the phase-conjugated object beam. This beam is directed back to the first crystal to act as the object beam. Thus, the original object beam can be turned off, and the image information is stored in a dynamic way as it oscillates between the two or between more crystals or subelements of a single crystal.

Any material that exhibits photoconductivity or a photovoltaic operation can be used as the photorefractive crystal. Examples include barium titanate and bismuth siliconoxide crystals, which are sensitive to visible light, plus such semiconductor materials as gallium arsenide and silicon, which are sensitive to infrared light.

This device is expected to provide the capability to store, amplify, process, and transmit time-varying, two-dimensional, spatial information. Possible developments include sensors, actuators, and optical computers that would operate at speeds on the order of the speed of light. This device may have potential in any application in which there is a need for high-speed acquisition and storage of three-dimensional holographic images.

This work was done by Raymond C. Montgomery and Sharon S. LaFleur of Langley Research Center. No further documentation is available.

This invention has been patented by NASA (U.S. Patent No. 4,913,534). Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, **Langley Research Center** *[see page 4]. Refer to LAR-13989.*



This **Four-Wave-Mixing** apparatus provides dynamic storage of a holographic image of the object after the electronic shutter is closed to turn off the object beam.

Porous Silica Sol-Gel Glasses Containing Reactive V_2O_5 Groups

These materials may prove useful as sensors, scrubbers, or catalysts.

NASA's Jet Propulsion Laboratory, Pasadena, California

Porous silica sol-gel glasses into which reactive vanadium oxide functional groups have been incorporated exhibit a number of unique characteristics. Because they bind molecules of some species both reversibly and selectively, they may be useful as chemical sensors or indicators or as scrubbers to remove toxic or hazardous contaminants. These materials have also been found to oxidize methane gas photochemically: this suggests that they may be useful as catalysts for conversion of methane to alcohol and for oxidation of hydrocarbons in general. Moreover, by incorporating various amounts of other metals into silica sol-gel glasses, it should be possible to synthesize new materials with a broad range of new characteristics.

In experiments, it was found that glasses of this type can be synthesized by the co-condensation of tris-isopropoxyvanadium oxide with tetraethylorthosilicate. The resulting porous glasses are transparent and can contain up to 0.5 mole percent vanadium oxide. Because they are purely inorganic, these glasses can be stabilized at high temperatures without affecting their bulk properties. What is particularly unique about these materials is that the vanadium oxide centers, which are integrated into the silica framework, retain most of their chemical reactivity and, in effect, form discrete reaction sites along the porous channels of the silica gel.

These materials have been shown to coordinate small molecules at the metal centers; the coordination reaction is accompanied by a change in color that is specific to the type of molecules being absorbed. For example, vanadium-silica gels that have been dried and stabilized at a temperature of 500 °C are completely transparent; however, upon exposure to moist air, they slowly turn orange. The change in color induced by the uptake of water is completely reversible. In addition to water, other molecules also coordinate reversibly to the metal centers in the dried gel and impart colors. Examples of these molecules and colors are shown in the table. Clearly, the striking changes in color that accompany absorption of these molecules suggest that the developmental materials may be useful as chemical indicators.

In addition, the vanadium centers coordinate certain molecules preferentially to others. For example, formic acid displaces water, with a concomitant change in color from orange to green. Similarly, water is absorbed preferentially to hydrogen sulfide. In addition, some materials are not absorbed at all (for example, ethylene, pyridine, and formamide). In short, along with their chemical-indicating capabilities, these materials can be used to remove certain impurities from gases or liquids selectively.

Oxidation/reduction chemistry also occurs at the metal centers. A material of this type can be reduced under hydrogen gas at 420 °C or by photolysis at a wavelength > 350 nm at room temperature to yield a sapphire-blue material characteristic of vanadium(IV). More significantly, photolysis of the material under an atmosphere of pure methane also causes reduction of the vanadium and oxidation of the methane: this appears to occur through activation of the carbon-hydrogen bond in the methane molecule, as methyl radicals can be detected via electron-spin-resonance spectroscopy. Oxidation of methane is difficult, usually requiring high temperatures and pressures and has only rarely been accomplished photochemically. That these materials appear to oxidize methane efficiently and at relatively low energies suggests that they may be catalytic toward the oxidation of hydrocarbons.

This work was done by Albert E. Stiegman of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 232*** *on the Reader Information Request Card.*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

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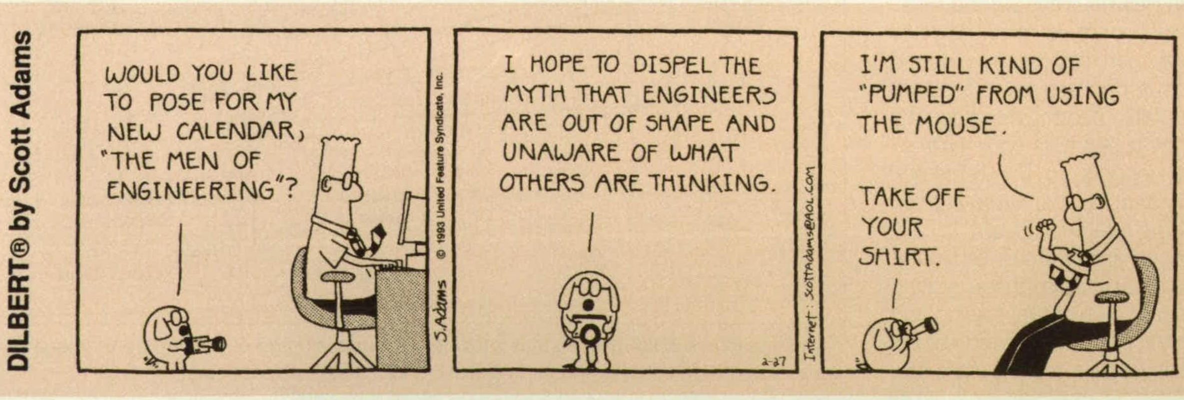
Refer to NPO-19135, volume and number of this Laser Tech Briefs issue, and the page number.

Absorbed Molecule	Color
Water	Orange
Hydrogen Sulfide	Amber
Ammonia	Yellow
Acetonitrile	Yellow
Formic or Acetic Acid	Green

Absorption of These Molecules in silica sol-gel glasses that contain reactive vanadium oxide groups is reversible and gives rise to the noted color in each case.



Video Photometer for Rapid On-Line Analysis

A new color-measurement instrument uses innovative technology for real-time on-line analysis.

US Bureau of Mines, Salt Lake City Research Center, Salt Lake City, Utah

Analyzing industrial process streams is important to enhancing materials recovery, improving efficiency, and reducing costs. As part of its mission to promote innovations in mineral processing, a team at the US Bureau of Mines (USBM) has developed a state-of-the-art color measurement instrument. Currently, most analyses are conducted off-line with expensive analytical equipment on carefully prepared samples. This method is time-consuming and leads to delays in process optimization.

USBM's inexpensive video photometer, a real-time on-line means of analysis and process control, is a PC-based software-driven system using a true red-green-blue (RGB) color video camera and a unique patent-pending peak detector that digitizes the RGB signals for a color resolution exceeding 23 billion hues. Since such hues can indicate chemical concentrations, the system can chemically analyze substances.

The digitized signal from the peak detector is the control variable for process control. Such control is PC-software directed, a major advantage over conventional systems. Not only is this less expensive, but it also allows for integrating innovative control methods such as fuzzy logic, neural networks, adaptive control, and introduction of various color models.

During decopperization of copper in an electrolytic circuit, deadly arsine gas is formed if the copper concentration drops below approximately 1.5 grams per liter. The USBM video photometer was used on site to assess this circuit stream in order to maintain the concentration above the level where arsine gas would be formed. The system analyzed and controlled copper to within ±300 parts per million, an acceptable level for industrial application. The video photometer can analyze any homogeneous color-specific stream, making it especially well adapted to metallurgical processing where many metals, chemicals, and their complexes have distinctive colors whose intensity varies with concentration.

The photometer is a complete system for on-line analysis with automatic standardization and rapid-response process control based on analytical results. This technology provides analysis, representation of RGB values, and calculation of proportional, integral, and differential control all in real time.

This work was done by the **US Bureau of Mines***, Salt Lake City Research Center. USBM is seeking cooperators interested in licensing this technology or in furthering its development. Inquiries and requests for more information should be directed to Donna Harbuck, USBM, Salt Lake City Research Center, 729 Arapeen Drive, Salt Lake City, Utah 84108-1283; (801) 584-4146.*

Self-Directed Control of Pulsed Laser Deposition

A new process produces high-quality thin-film coatings ten times faster.

Wright Laboratory Materials Directorate, Wright-Patterson Air Force Base, Ohio

Research groups have collaborated to develop an intelligent system that automatically controls a laser process for applying high-quality thin-film tribological coatings. Self-directed control of the pulsed laser deposition (PLD) process makes this operation ten times faster than the traditional manual process, while improving the quality and consistency of the coatings. This reduces cost and lowers the frequency of failure for such PLD applications as hard coatings to increase the life of a part, solid lubricants to reduce friction, and thermal coatings to protect a part from excessive temperatures. In addition to improving film quality and processing time, the control system frees the operator for other tasks and decreases possible exposure to scattered ultraviolet laser light.

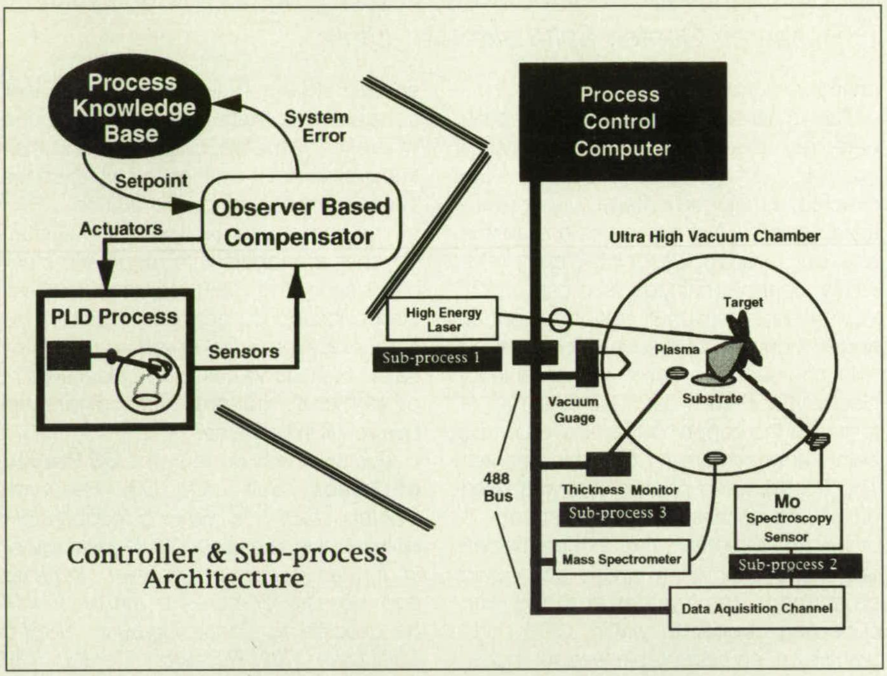
Air Force pursuits in advanced materials for aerospace applications involve the combining of vastly different materials to exploit the best characteristics of each. These new "functionally gradient" materials have become a compelling method for obtaining superior performance. Advanced composites and superlattice semiconductors are well known examples. The advent of these thin-film coatings further exemplifies this powerful concept.

Depositing one material onto another of dissimilar structure can be extremely difficult. Some materials simply do not bond to each other easily. PLD has demonstrated a capacity to bond materials even though the bonds were thought to be technically unachievable or simply not economical for commercial applications. PLD involves depositing a relatively thin layer or coating of a material onto the surface of an object. In this process, an ultraviolet laser is projected through a window into a vacuum chamber and onto the target (e.g., a disk of solid lubricant material). Laser pulses, fired in rapid succession, impinge on the target surface, causing a plume of material to deposit onto a component surface to be coated.

Conventional, i.e. manually controlled, PLD has several limitations. The processing system requires two hours of reinitialization and conditioning for every four hours of operation. The target must be replaced and the laser window cleaned. Ultraviolet light from the laser is hazardous, and human exposure must be avoided. Additionally, the process parameters that must be controlled and the control actions required to produce a range of coating characteristics are dependent on operator experience.

The process was automated by first developing a user-friendly manual control system. This initial system was installed on a PLD research apparatus at the Materials Directorate laboratory. The improved system enables the operator to control and monitor the PLD process from a remote location, avoiding exposure to ultraviolet radiation. Key features of this system currently include automatic data logging, alignment and rastering of the laser on the target, and other options allowing further optimization of film qualities and target life.

The goal of this research has been to improve process repeatability and quality in terms of film morphology and thickness while reducing processing time and cost. To accomplish this goal, the process was studied and plume characteristics were investigated via time-of-flight mass spectroscopy and post-ablation ionization. Although PLD is not yet fully understood, the plume is thought to be the result of thermal expansion, the breaking of valence bonds, or any of several other phenomena. Operating regions where each of these mechanisms dominate can be determined by variation of the laser parameters, including pulse length, pulse frequency, raster scan pattern, etc. Additional nondestructive sensors, which monitor the state of the object to be coated, were added to the system and used to obtain real-time information on film quality and thickness.



Schematic of the process controller and sub-process architecture.

Information concerning patent status of work and availability of rights and licenses is as follows:

1) "Automation of Pulsed Laser Deposition," U.S. Air Force Invention #21469, 16 December 1994.
2) "Hierarchical Feedback Control of Pulsed Laser Deposition," U.S. Air Force Invention #21467, 16 December 1994.

This work was done by Captain Elizabeth F. Stark and Dr. Samuel P. Laube for the **Wright Laboratory Materials Directorate**.

Inquiries concerning rights for the commercial use of this technology should be addressed to the Materials Directorate Technology Transfer Center, WL/MLI-TTC, 2977 P Street, Suite 13, Wright-Patterson AFB, OH 45433-7746; (513) 255-4689.

Electron Cyclotron Resonance Etching of Mirrors for Ridge-Guided Lasers

New electron cyclotron etcher produces semiconductor laser mirrors that approach the performance of cleaved facets.

Rome Laboratory, Photonics Center, Griffiss Air Force Base, New York

Optoelectronic integrated circuits consist of photodetectors, waveguides, lasers, and modulators, fabricated along with conventional electronic circuitry on a III-V wafer heterostructure. Cleaved facets provide consistent high-quality laser mirrors, but cleaves can only be made at the edges of a die. Lasers and waveguides located well within the boundaries of the die pattern must incorporate etched vertical mirrors. Thus, high-quality etched laser mirrors remain a priority for monolithic photonic device integration.

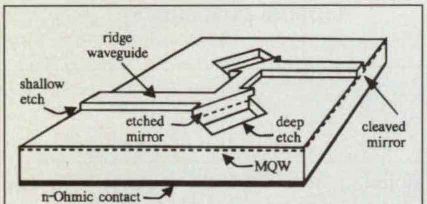


Figure 1. Three-dimensional diagram of a fabricated laser structure.

An electron cyclotron resonance (ECR) etcher was recently used to fabricate ridge-guided lasers in a GaAs/AlGaAs multi-quantum-well heterostructure. The ECR offers several advantages over competing chemically-assisted ion-beam etching (CAIBE), including a higher etch rate and better selectivity between GaAs and the etch masks. The lasers are fabricated by performing a two-level etch in the ECR. The shallow etch (~ 1.5 μm) defines the ridge waveguides, while the deep etch (~ 4 μm) forms the vertical total internal reflection (TIR) mirrors, as shown in Figure 1. The GaAs etch rate, using the reactive gases Cl_2 and BCl_3, is 8600 Å/min, giving a selectivity of 14:1 over nickel and 4:1 over photoresist, the two etch masks.

Reflectivity of the 90° turning mirrors was determined by measuring the laser threshold current as a function of the number of turning mirrors. The overall laser length (700 μm) and width (10 μm) were kept constant for all numbers of turning mirrors, as shown in Figure 2. For the reflectivity tests mentioned in this article, the two end mirrors were cleaved.

Results of threshold current measurements and subsequent calculations indicate a coefficient of reflection of 92% for each 90° turning mirror. For comparison, 90° turning mirrors etched by CAIBE demonstrated a reflection coefficient of only 77%. Because of the higher etch rate and selectivity, and better vertical etch quality, ECR etching is expected to become important in commercial fabrication of optoelectronic integrated circuits.

These devices were designed, fabricated, and tested by J.S. Kimmet, M.A. Parker, and R.J. Michalak of the Air Force Photonics Center, **Rome Laboratory**, *Griffiss Air Force Base, NY, and P.D. Swanson, D.B. Shire, and C.L. Tang of the School of Electrical Engineering,* **Cornell University**. *No further information is available.*

Inquiries concerning rights to the commercial use of this technology may be addressed to the Patent Counsel, RL/JA, Griffiss AFB, NY 13441.

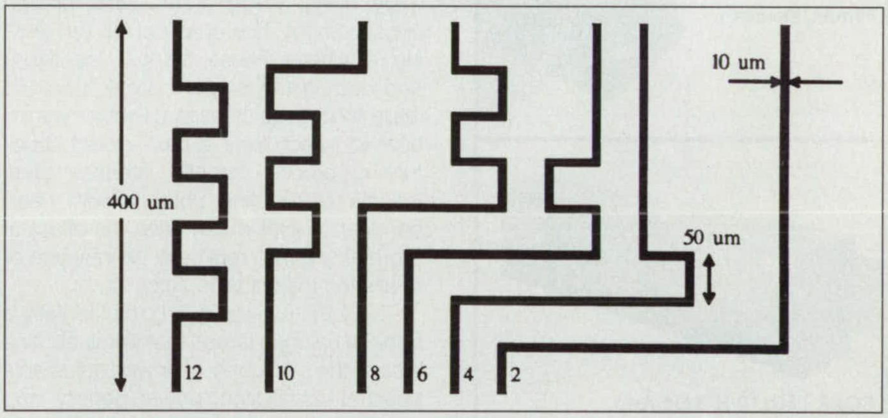


Figure 2. **Example layout** of 700-μm lasers with different numbers of 90* turning mirrors.

Optical Fabrication of Semiconductors

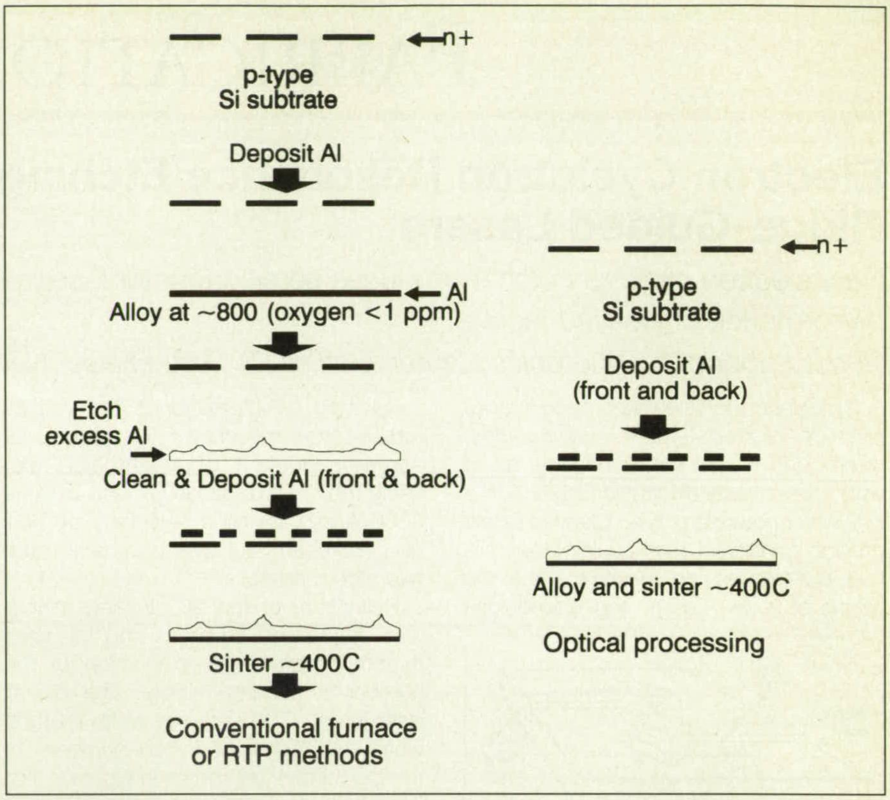
Photon enhancement reduces the number of steps and the expense associated with thermal fabrication.

National Renewable Energy Laboratory (NREL), Colorado

Optical processing is an excellent way of replacing inefficient thermal fabrication of semiconductors with a more selective and less expensive means of alloying back surfaces, sintering front contacts, or texturing interfaces between key layers.

The optical processing furnace (OPF) can be applied to a variety of processing functions in optoelectronics, microelectronics, and photovoltaics. The OPF not only provides direct procedural control of a given task, but also requires less power, lower process temperatures, and fewer process steps than conventional methods. For example, to make low-resistance front and back contacts in solar cells, the standard approaches of rapid thermal processing (RTP) or furnace annealing require seven or eight steps (see figure). The OPF method obtains equivalent results with two steps.

To process a device interface, furnace annealing and RTP must heat the entire device to the process temperature required by that interface. Hence, because different interfaces call for different processing conditions, these conven-



With the **OPF**, alloying back contacts while sintering front contacts requires only two process steps; conventional methods require seven or eight process steps.

tional methods cannot be adjusted to account for such variables.

By using a technique called photon enhancement, however, optical processing eliminates these failings. Identifying and utilizing the proper optical spectrum while filtering out unwanted light allows the user to "reach into" a multilayered structure to process specific interface sites. Selectively directing photons with near-bandgap energies can have the effect of promoting a melt regime at an interface or of altering the diffusion across it.

The OPF uses a quartz muffle with a bank of halogen lamps that illuminate one side of the semiconductor with adjustable spectral distribution, power density, and duration. Optical energy is preferentially delivered onto the interface being processed. This allows control of the melt thickness or the depth of diffusion. Strategic areas are easily masked off from the light to prevent unwanted reactions.

Thus the OPF can be used to create an ohmic contact at the back of a silicon-aluminum interface of a silicon-based semiconductor while simultaneously sintering the front contacts. This is done by selecting light with a proper infrared spectrum and directing it at the device. Light not blocked by the front contacts or by masks travels through the silicon and is preferentially absorbed by the aluminum at the back surface. This melts the metal-semiconductor interface–at the low process temperature of 400 °C–which, upon cooling, forms a uniform epitaxial alloy to create a high-quality low-ohmic contact. At the same time, energy absorbed and reflected from the front contacts provides just enough energy adsorption to produce high-quality ohmic front contacts.

By manipulating exposure time, the OPF may be used to produce a metal-semiconductor alloy at the back surface thin enough to reflect radiation back into the device for absorption and electron-hole generation. Plus, by controlling the power and duration of the radiation incident on the back metal-semiconductor surface, the OPF can be used to texture the interface for total internal reflection.

These are just some of the processing functions the OPF can perform. Currently OPF systems are being employed as post-growth process stations, chemical treatment systems, and materials growth reactors.

This work was done by Chief Researcher Bushon Sopori and his associates in the **National Renewable Energy Laboratory** *optical processing project. A patent application on the OPF process was filed in February 1994. For more information, call the NREL Technical Information Service; (303) 275-4065. For information about cooperative ventures with NREL, call the Technology Transfer Office; (303) 275-3008.*

MATHEMATICS AND INFORMATION SCIENCES

Synthetic-Aperture Coherent Imaging From a Circular Path

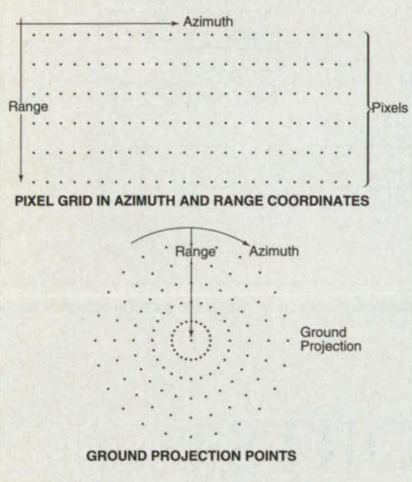
Imaging algorithms are based on exact point-target responses.

NASA's Jet Propulsion Laboratory, Pasadena, California

95B10098

Algorithms have been developed for use in reconstructing the image of a target from data gathered by a radar, sonar, or other transmitting/receiving coherent-signal sensory apparatus that follows a circular observation path around the target. Potential applications include the following:

- Wide-beam synthetic-aperture radar (SAR) from aboard a spacecraft in circular orbit around a target planet;
- SAR from aboard an airplane flying a circular course at constant elevation around a central ground point, toward which a spotlight radar beam is pointed;



This Plot Shows the Mapping between (a) pixels generated from step 2 of the spotlight algorithm and (b) points on the ground.

- Ultrasonic reflection tomography in a medical setting, using one transducer moving in a circle around the patient or else multiple transducers at fixed positions on a circle around the patient ; and
- Sonar imaging of the sea floor to high resolution, without need for a large sensory apparatus.

These algorithms include processing steps similar to those of the chirp-scaling algorithm, which has been limited to process SAR data from straight line paths but with a very narrow radar beam angle in along-track. The present algorithm, however, can be applied to circular paths without limitation of the radar beam angle.

The present algorithms process the return-signal data in the two-dimensional Fourier-transform domain. The processing involves multiplication of fast Fourier transforms (FFTs) of the raw data by a reference function derived from the two-dimensional spectrum of the exact range-and-azimuth response of a point target as a function of time. The reference function is the inverse of this two-dimensional spectrum.

The algorithm for processing data from a wide-beam sensory apparatus comprises the following steps:

1. Compute the raw SAR or other data in the azimuth dimension.
2. Multiply by the phase perturbation for the range curvature (chirp-scaling phase).
3. Compute the FFT in the range dimension.
4. Multiply by the complex (both magnitude and phase) azimuth reference function and by a range-compression-filter function.
5. Compute the inverse FFT in the range dimension.
6. Multiply by the phase correction needed for chirp scaling and for the focusing adjustment made necessary by the variation, along the slant range, of the rate of change of Doppler frequency.
7. Compute the inverse FFT in azimuth dimension.
8. Perform geometric rectification according to a selected projection grid.

The algorithm for processing data acquired with a spotlight beam is similar, except that some of the steps at the beginning and end are modified. The processing steps specific to the spotlight mode are the following:

1. Perform subsampling of echo pulses according to the radius of the spot area. This step is not necessary if the pulse-repetition frequency of the apparatus is tuned to the radius such that there are no redundant data.
2. Perform SAR correlation, using the exact reference function. This step can be repeated over the same data block, each time tuned to a different subset of the range samples. This is necessary when the depth of focus is particularly small.
3. Perform geometric resampling to correct for the geometry and grid spacing (see figure).

This work was done by Michael Y. Jin of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 231*** *on the Reader Information Request Card.*

NPO-19024

Cryptography Would Reveal Alterations in Photographs

A public key would be used to decrypt a hash of the original image data.

NASA's Jet Propulsion Laboratory, Pasadena, California

A public-key decryption method has been proposed to guarantee the authenticity of photographic images represented in the form of digital files. The growing practice of altering digitized images by computer-based techniques has made it virtually impossible to verify the authenticity of the images. In the proposed method, a digital camera would generate the original data from an image in a standard public format; it would also produce a coded signature, which could be used to verify the standard-format image data. The scheme also helps protect against other forms of lying, such as attaching false captions.

The figure illustrates the overall coding/decoding verification scheme. By use of a private encryption key, the camera would generate the signature of an image from a hash of the original image data. The hash in this case would be a reduced set of data constructed by a hashing function, which would map values from a larger domain to a smaller range. (The hashing function could be public.) By using a public decryption key that corresponded to the private encryption key, anyone could decode the signature to recover the hash.

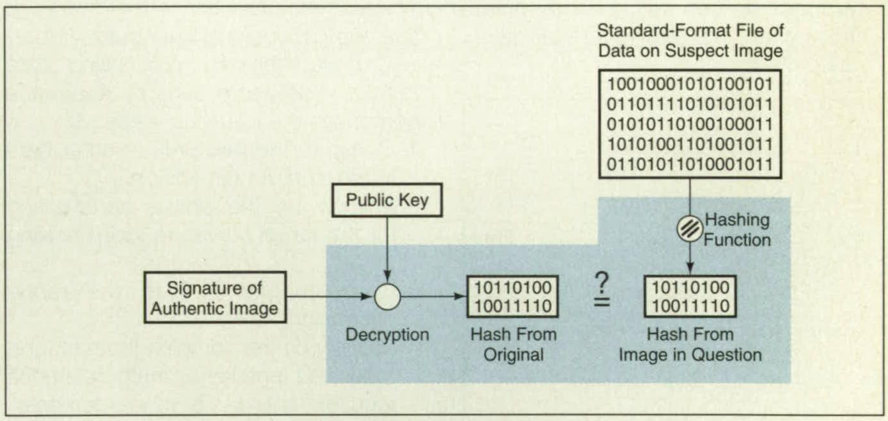
Any examiner could verify the authenticity of a suspected image in the following way: The examiner would generate the hash of the suspected image by use of the hashing function. The examiner would also decode the signature of the original image, by use of the public decryption key, to obtain the hash of the original image. Then, the examiner would compare the two hashes. If the hashes matched, the suspected image would be regarded as authentic. If even a single bit of the suspected image file were to be changed, the hashes would not match even approximately.

Within the border of the image, the camera records textural information that can thwart other time-honored methods of image deception. The camera records the date, time, exposure, light levels, and color balance at the time the picture was made. Additional information such as the direction the camera was pointing and Global Positioning Satellite coordinates help prove where in the world you were when the image was recorded.

The use of a public decryption key would not compromise security: the public key could decode correctly only those data that were encoded by use of the corresponding private key; an attempt at forgery by use of a different private encryption key would cause mismatch between hashes. This system has the additional advantage of being backward-compatible with existing digital imaging systems.

This work was done by Gary L. Friedman of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 260*** *on the Reader Information Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA Resident Office–JPL [see page 4]. Refer to NPO-19108.



The **Image-Verification Process** would involve comparison of a hash (a mapping) of a suspect image with that of the original image.

BOOKS AND REPORTS

Comparison of Infrared Astronomical Observatories

A report presents a comparative study of several proposed astronomical observatories intended to operate in the infrared and submillimeter wavelength range (1 to 1,000 μm). The observatories would be, variously, spaceborne, airborne, and Earth-based. The performances of the observatories for viewing point sources were predicted on the basis of estimated telescope parameters, the celestial background emission, crowding of celestial sources, and performances of detectors. None of the proposed observatories was found to be the optimum general observatory for the entire wavelength range and the full variety of intended observations, though all were found to offer much more sensitivity to weak signals than their predecessors do. For broadband observations, crowding of sources was found to be the factor that exerts the most influence over the lower limit to the detectable signal level. As a result, large apertures are more important than are low optical-system temperatures in detecting the faintest signals in broadband measurements. For moderate spectral resolution at wavelengths greater than 50 μm, the thermal background from noncryogenic telescopes is large and the coldest observatories should be the most sensitive. At wavelengths less than 50 μm, none of the proposed observatories would be subject to significant emission within its optical system, and the most sensitive observatory would be the one with the largest aperture. At high spectral resolution, on the other hand, detectors would be affected very little by thermal background from any source, and for sensitivity at all wavelengths it would be necessary to use large apertures.

This work was done by Donald Rapp of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Estimation and Optimization of Performance of Aerospace Infrared and Submillimeter Observation Systems,"* ***write in 68*** *on the Reader Information Request Card. NPO-19318*

LITERATURE SPOTLIGHT

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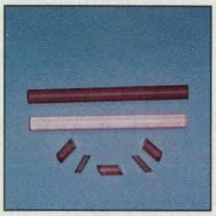

Ti:SAPPHIRE LASER RODS

Literature is available on ATRAMET's Ti:Sapphire Laser Rods. The rods are available with Ti_2O_3 concentrations of 0.03-0.15%, in diameters of 3-8 mm and lengths to 120-130 mm. Rod ends can be cut Plano/Plano (Flat/Flat) or Brewster Angle. Typical FOM values are 220-250. Wavelength-tunable lasers lase over the entire band, 660-1100 nm, λ = 532. Can be used for CW or Pulse systems. Tel: 516-694-9000; Fax: 516-694-9177; email: ATM GRP 717-1325@MCImail.com.

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OPTICAL LIQUIDS

Specialty Optical Liquids catalog features high-transmission, safe-handling laser liquids plus fused silica matching liquids and specific refractive-index liquids (1.300 to 2.11 n_D). Now includes comparative diagrams of glasses and optical liquids. R.P. Cargille Laboratories, Inc., 55 Commerce Rd., Cedar Grove, NJ 07009-1289; Tel: 201-239-6633; Fax: 201-239-6096.

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HIGH-VOLTAGE POWER SUPPLIES

Eight-page selection guide describes Bertan precision high-voltage power supplies with outputs ranging from 500 V to 100 kV at up to 1 kW. Bertan High Voltage, 121 New South Road, Hicksville, NY 11801; Tel: 516-433-3110; 800-966-2776; Fax: 516-935-1766.

Bertan High Voltage

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PRECISION TEST AND MEASUREMENT EQUIPMENT

Stanford Research Systems' 1994-95 Catalog contains complete specifications, technical discussions and application notes on its line of scientific and engineering instruments. This 200-page catalog includes the latest function generators, spectrum analyzers, lock-in amplifiers and delay generators, and is a useful reference for a wide range of test and measurement applications. Address: 1290 D Reamwood Avenue, Sunnyvale, CA, 94089; Tel: 408-744-9040.

Stanford Research Systems

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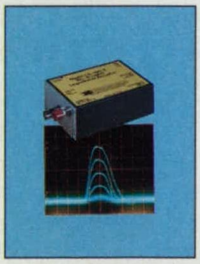

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ElectroSolutions, Inc.

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A 100-plus page, full color HIGH PERFORMANCE CAMERAS catalog from Princeton Instruments, Inc., Trenton, NJ, is now available. Slow scan imaging CCD cameras with spectral response from x-ray to the NIR, and with applications from microscopy to astronomy, are outlined. The catalog also provides the specifications for the more than thirty different CCD chips offered in Princeton Instruments, Inc. cameras and useful application notes to help in the selection of a camera system.

Princeton Instruments, Inc.

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NASA 1995 Calendar

Full-color photos of the space shuttle in action. Includes dates of launches from the 1960's to present. $10.95 plus $5.00 shipping. Mail order and payment to: Associated Business Publications, Dept. F, 41 East 42nd St., #921, New York, NY 10017. Credit card orders call (212) 490-3999.

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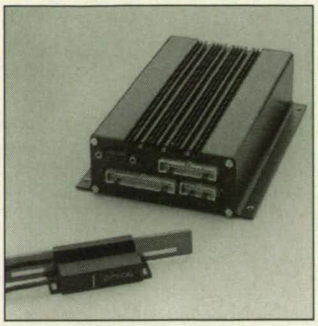
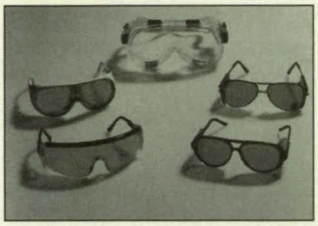


Holographic Linear Encoder

The digital resolution of the ZPE-100 Zero Path Encoder from Opti-Cal, Los Osos, CA, can be user-specified from 3 to 200 nanometers. A patented optical design, the company says, makes possible high stability, accuracy, and economy. Quartz scales are used, and the read head is just half an inch high. Overall repeatability is less than 0.01 micron. The device has quadrature and up-down outputs, and options include infinite-resolution servo outputs, counters, and other features.

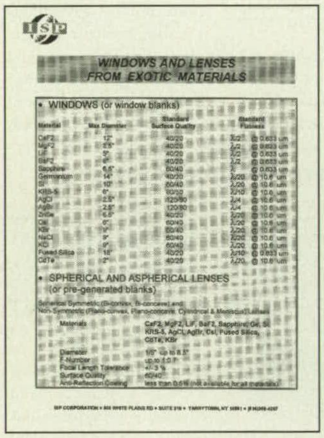
For More Information Write In No. 700



Laser Eyewear Line Expanded

Lase-R Shield Inc., Albuquerque, NM, has added DVO eyewear from Crews Scientific to its line of laser protective eyewear meeting ANSI Z136.1 (1993) standards. The Crews line offers 5 new styles including an Rx option with clear prescriptive snap-in lenses, lightweight wraparounds, and wide-view antifogging goggles. Along with plastic products, Lase-R Shield's on-site optical laboratory features Schott filter-glass prescriptive and nonprescriptive lenses in various frame and goggle styles.

For More Information Write In No. 701

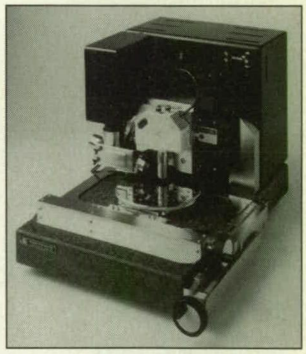


Optics from the "Eastern Bloc"

International Scientific Products, Mt. Kisco, NY, distributes a wide variety of stock and custom precision blanks and polished optics in such materials as calcium fluoride, lithium fluoride, zinc selenide, KRS-5, germanium, fused silica, sapphire, cadmium telluride, and magnesium fluoride. The components, manufactured in Russia and Latvia, are available, the distributor says, for rapid on-time delivery.

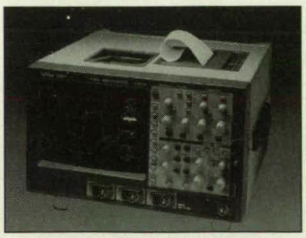
For More Information Write In No. 702

Atomic Force Microscope with Laser Tracking



Digital Instruments is making available the NanoScope® DimensionTM 3000 atomic force microscope (AFM). The company says it supports every available AFM and scanning tunneling microscope scanning technique, and combines many capabilities of the company's Large Sample Stage and MultiMode microscopes. The TrakScanTM tracks the scanning probe to prevent image anomalies.

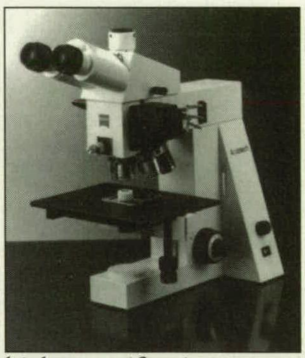
For More Information Write In No. 703



Fast Digital Oscilloscope

LeCroy Corp., Chestnut Ridge, NY, introduces the Model 9362, which it calls the world's fastest digital oscilloscope. It can capture single-shot events at a sampling rate of 10 Gs/sec. In addition, it offers 1.5-GHz bandwidth on repetitive events sampled in random interleaved sampling mode. The company says the 9362 maintains 750-MHz bandwidth when transferred to single-shot data capture. For laser pulse characterization, it can measure rise and fall times, area, amplitude, width, and other parameters and display the latest value, maximum value, minimum value, average value, and standard deviation.

For More Information Write In No. 704

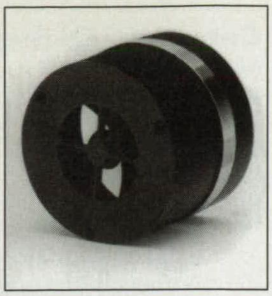


Microscope for Materials Testing

The Axiotech reflected-light microscope from Carl Zeiss, Thornwood, NY, was designed specifically for materials testing. A new line of objectives, called the Epiplan ICS (infinity color-corrected system) series, produce sharp, brilliant, high-contrast images even at high magnifications, according to the company. Axiotech images appear upright and unreversed to the eye. There is a wide variety of options, including the Axiotech vario, a model for viewing large, heavy, or irregularly shaped samples, even an engine cylinder head.

For More Information Write In No. 705

Custom Coated Objectives



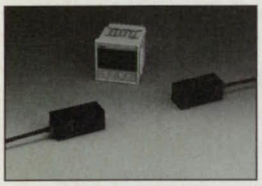
Rolyn Optics, Torrance, CA, is offering all-reflective objectives coated and assembled specifically to customer order. Final assembly is done interferometrically to obviate further adjustment after delivery. Because no refractive elements are used, the company says these objectives are suitable for all applications from 193 nm to far infrared, using different mirror coatings specified at the time of order. The units mount to the standard Royal Microscopal Society threads.

For More Information Write In No. 706

Weld Quality Monitor

Laser Applications Inc., Orlando, FL, has developed a laser weld quality monitoring system for industrial users. The PC-based system monitors the progress of the laser welding process and corrects the weld quality problems in real time. It can be used as a standalone unit or as part of an automation line. Similar monitoring devices are available for drilling, cutting, marking, and soldering.

For More Information Write In No. 708



Laser Beam Sensor

SUNX, West Des Moines, IA, announces the LA511 laser beam sensor system. It has a sensing field of 15 mm X 500 mm and offers repeatability of 10 µm. Minimum sensing target is 0.1 mm in diameter. An optional LA-C1 control provides 3½-digit readout with set points for HI-GO-LO control.

For More Information Write In No. 710

Pulsed Laser Deposition Coatings

Neocera Inc., College Park, MD, specializes in pulsed laser deposition growth of metal oxide thin films on a variety of substrates, from simple binary oxides such as hafnia to complex oxides such as ferroelectric and ferrite films and high-temperature superconductors. The company can provide YBCO and GdBCO on lanthanum aluminate, sapphire, silicon, cubic zirconia, and other substrates up to 2" in diameter, and double-side coated.

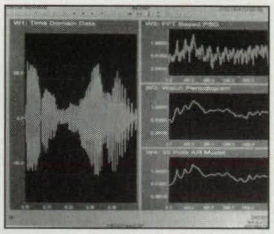
For More Information Write In No. 712

Borosilicate Sheet Glass

Schott Corp., Yonkers, NY, announces its new BOROFLOAT™ borosilicate sheet glass. The company says that the microfloat process used to make it achieves unsurpassed surface quality for flat borosilicate glass. In addition, it is highly resistant to water and to acidic and saline solutions, as well as to chlorine, bromide, iodine, and organic substances. Among applications Schott suggests are precision engineering and industrial lasers.

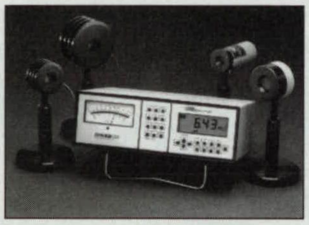
For More Information Write In No. 707

Digital Signal Processing Module



DADiSP/AdvDSP 1.0 from DSP Development Corp., Cambridge, MA, is an add-on digital signal processing module for DADiSP graphical data analysis software, which is designed to collect, analyze, and display technical data. DADiSP/AdvDSP has a wide variety of DSP algorithms, including fast Fourier transform, power spectral density estimation, and digital interpolation. The company says the new package is designed for researchers and engineers working in image processing, among other areas.

For More Information Write In No. 709



Laser Pulse Measurement to 500 pps

The EPM1000 dual-function laser energy/power meter from Molectron Detector, Portland, OR, performs real-time measurements of pulse energy from single pulses to 500 pps, and pJ to J, and power from µW to kW, over the broadest spectrum 0.19-1000 µm. It displays all measurements on both a fast 3½-inch analog mirrored meter and custom alphanumeric 4-digit LCD. User options include absolute units of J, W, or V, and frequency from 0.1-1000 Hz.

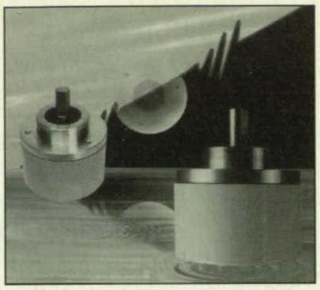
For More Information Write In No. 711

Power Supply with Small Toe-Print

New from Spellman High Voltage Electronics, Plainview, NY, is the integrated surface-mounted MHV series high-voltage power supply. Eight 2-W models come with 0-500 V, 0-1000 V, 0-1500 V, or 0-2000 V. Regulation is 0.03 percent. The supplies have only a 2-in. square PC board toe-print. Price for MHV supplies is $250 each.

For More Information Write In No. 713

Encoder for Harsh Environments



Featuring a rugged die-cast aluminum housing, the Ledex® DG60D incremental encoder from Lucas Control Systems, Vandalia, OH, can operate in temperatures ranging from 0-85 °F. Compact in design (60-mm OD, 47-mm length), the encoder is suited to applications involving water mist, oil mist, coolant, or hose-directed washdowns, the company says. Resolutions are to 5000 pulses per revolution or less off disk, and operating frequency is up to 300 kHz.

For More Information Write In No. 714

Compact Q-Switched Nd:YAGs

New Wave Research, Sunnyvale, CA, is making available two new models in its line of compact pulsed Q-switched Nd:YAG laser systems. They are designated Mini/Lase-10 and Mini/Lase-20, the numbers indicating the pulse repetition rate. At 1064 nm, laser energy is greater than 28 mJ, spatial mode better than 90 percent Gaussian, and peak-to-peak energy stability is less than 6 percent. Optional second, third, and fourth-harmonic crystals can be added.

For More Information Write In No. 715

Haze Measurement Systems

The HMS-1200 series haze measurement systems from Labsphere, North Sutton, NH, are designed for the characterization of brightness, specularity, diffusivity, total reflectance, and directionality of a variety of materials over wavelength ranges from 0.4 to 1.1 μm. Featuring a 12-in.-diameter integrating sphere with an external sample mount, the systems are designed in accordance with ASTM D1003 specifications for haze measurement.

For More Information Write In No. 716

Microscope with Rotatable Head

The new professional compound microscope from Cole-Parmer, Niles, IL, features a fully rotatable 30-degree inclined binocular head and a vertical phototube. It has four color-coded DIN parfocal, parcentered achromatic objectives: 4X, 10X, 40X, and 100X, and paired DIN wide-field 10X eyepieces. Other features are a swing-out filter holder, blue filter, and a 30-W halogen lamp for varying intensities of illumination.

For More Information Write In No. 717

Data Acquisition for Spectroscopy

The SpectraCard™ from Acton Research Corporation, Acton, MA, is a 16-bit digital readout spectrometer capable of spectral data acquisition at up to 1000 data points per second. The system is controlled by Windows spectroscopy software developed at ARC. The company offers more than 25 monochromators (0.15-3.0-m focal lengths) and detectors covering wavelenths from 100-12,000 nm for use with SpectraCard.

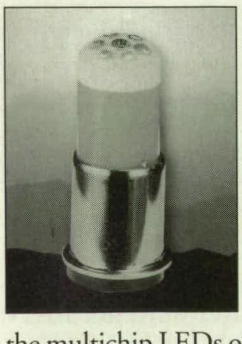
For More Information Write In No. 718

Versatile Photometer/Colorimeter

Photo Research Division of Kollmorgen, Chatsworth, CA, announces the Pritchard® PR-880, a fully automatic filter photometer/colorimeter. Equipped with patented Pritchard optics, the PR-880 can perform complete photometric, colorimetric, and radiometric measurements in seconds, according to the company. The 55-mm f/2.8 (1:1 magnification) lens can be focused from 1.75" to infinity. Applications include aircraft panel luminance and color testing, correlated color temperature determination, automotive lighting measurement, and CRT luminance and contrast measurement.

For More Information Write In No. 719

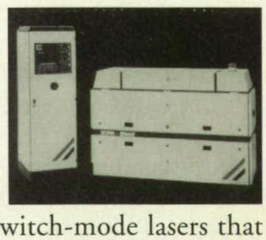
LED Arrays in Yellow and Amber



Available from Lamp Technology Inc., Bohemia, NY, is a new line of ultrabright yellow/amber multi-LED units in 3- and 6-chip models for all popular lamp bases. Using AlInGaP chip technology, the 591-nm units offer 100 mcd and 200 mcd light levels respectively. The company says the multichip LEDs offer 100,000 hours of low-heat, shock-proof life. They are available in voltages ranging from 6-120 V.

For More Information Write In No. 720

New Switch-Mode CO_2 Laser

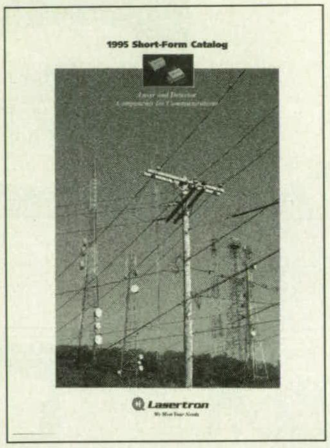


A recent introduction from Rofin-Sinar Inc., Plymouth, MI, is a high-power 2000-W carbon dioxide switch-mode laser. The RS 2000 SM joins the company's line of switch-mode lasers that includes 700, 1200, and 1700-W models. The RS 2000 SM is a fast-axial-flow laser with DC excitation. Because the solid-state power supply can be switched from continuous-wave to pulse-mode operation, it can cut and weld various materials, contours, and thicknesses. Beam divergence is about 1.5 milliradians full angle at distances up to 10 m.

For More Information Write In No. 721

NEW LITERATURE

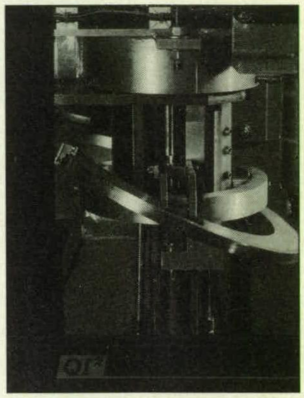
Fiber Optic Components for Communications



Lasertron, Burlington, MA, announces its 1995 Short Form Catalog, containing its entire line of standard fiber optic laser and detector component products for telecommunications, CATV, and cellular communications. New entries include a double pump laser for erbium-doped fiber amplifiers, microcell link products, and an 18-GHz isolated laser source for high-speed communications.

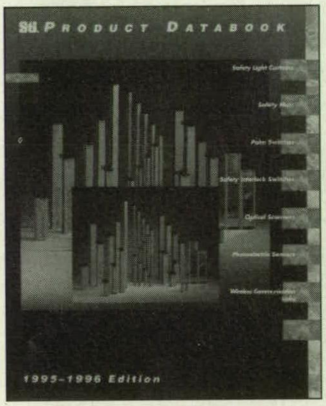
For More Information Write In No. 730

From Research to Products



Among the capabilities described in the 6-page color brochure from Quest Integrated Inc., Kent, WA, is electro-optic technology for automated non-destructive evaluation (NDE) systems and for precision measurements in difficult environments. One example is the laser optic tubing inspection system (LOTIS) used to inspect the interior surface of boiler tubes in ship power plants. QI^2 also has capabilities in ocean science, fluid and solid mechanics, and advanced waterjet technology.

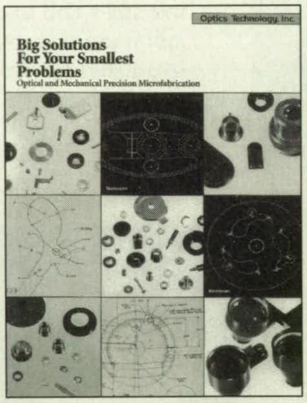
For More Information Write In No. 731



Safety and Sensor Products

The 1995 product catalog from Scientific Technologies Inc., Hayward, CA, contains 368 pages divided into two main sections, safety-related products and sensors for machine and factory automation. In the latter are found optical scanners and photoelectric sensors, as well as wireless communications links.

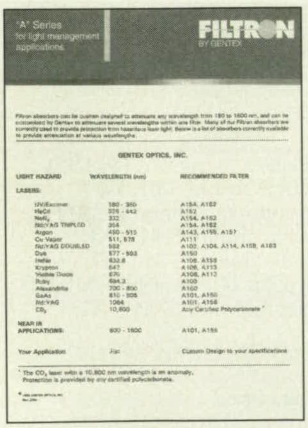
For More Information Write In No. 732



Subminiature Optical/Mechanical Components

A new capabilities brochure from Optics Technology Inc. (OTI), Pittsford, NY, details the company's background and capabilities. OTI specializes in solutions to problems of design and fabrication with close tolerances and involving subminiature optical and mechanical components and assemblies smaller than 1 mm in diameter. OTI has a CIM-controlled CNC fabrication facility for quick turnaround.

For More Information Write In No. 733



"A" Series for light management applications

FILTRON BY GENTEX

Filtron absorbers can be custom designed to attenuate any wavelength from 180 to 1600 nm, and can be customized by Gentex to attenuate several wavelengths within one filter. Many of our Filtron absorbers are currently used to provide protection from hazardous laser light. Below is a list of absorbers currently available to provide attenuation at various wavelengths.

GENTEX OPTICS, INC.

LIGHT HAZARD	WAVELENGTH (nm)	RECOMMENDED FILTER
LASERS:		
UV/Excimer	180 - 350	A154, A162
HeCd	325 - 442	A162
[illegible]	332	A154, A162
Nd:YAG TRIPLED	354	A154, A162
Argon	450 - 515	A143, A155, A157
Cu Vapor	511, 578	A111
Nd:YAG DOUBLED	532	A102, A104, A114, A158, A163
Dye	577 - 593	A150
HeNe	632.8	A106, A155
Krypton	647	A106, A113
Visible Diode	670	A106, A113
Ruby	694.3	A103
Alexandrite	700 - 800	A160
GaAs	810 - 905	A101, A150
Nd:YAG	1064	A101, A156
CO_2	10,600	Any Certified Polycarbonate *
NEAR IR APPLICATIONS:	800 - 1600	A101, A155
Your Application	[illegible]	Custom Design to your specifications

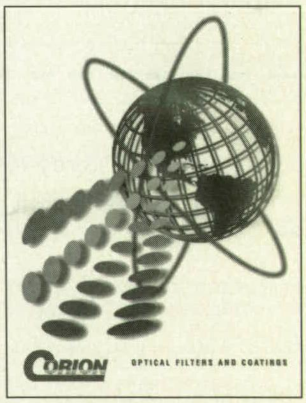
* The CO_2 laser with a 10,600 nm wavelength is an anomaly. Protection is provided by any certified polycarbonate.

Absorbers for Laser Protection

Filtron A Series laser-protective absorbers from Gentex Optics, Carbondale, PA, are the subjects of a series of specification sheets showing transmission/absorption curves for each standard filter. The absorbers can be custom designed to attenuate any wavelength from 180-1600 nm, or to attenuate several wavelengths at once.

For More Information Write In No. 734

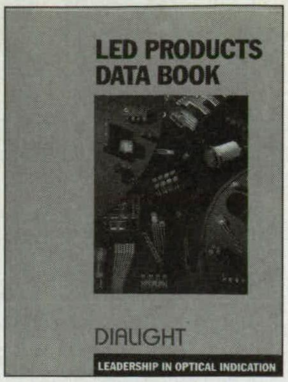
Optical Filters and Coatings



Corion Corp., Holliston, MA, offers a 125-page catalog that contains specifications on more than 1600 optical filters and coatings. Included is a technical supplement with details on coating technology, filter construction, reliability testing, product lifetime, and more, ranging from traditional soft coatings to state-of-the-art hard coatings. Filter sets are described, as well as such new items as Stabilife™ bandpass, fluorescence, laser line, infrared bandpass, and stabilized dichroic filters.

For More Information Write In No. 735

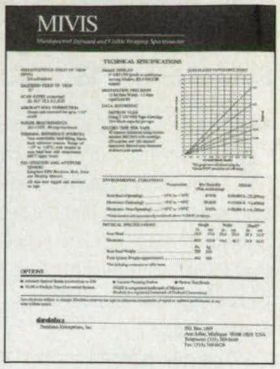
Databook on an LED Family



The 200-page "LED Products Databook" from Dialight Corp., Manasquan, NJ, outlines the specifications on more than 1,000 products from the optical indicator manufacturer. The catalog covers Dialight's discrete LEDs, LED circuit-board indicators, LED panel mount indicators, surface mount indicators, and light pipes. Along with product specifications the book contains a product selector guide, and application notes.

For More Information Write In No. 736

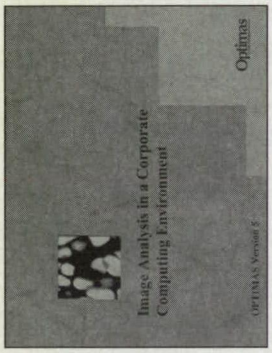
IR/Visible Imaging Spectrometer



Daedalus Enterprises, Inc. is supplying specification sheets on its multispectral infrared and visible imaging spectrometer. Designed to be flown aboard aircraft, the high-performance system can operate in severe environments. A common field stop maintains spatial coregistration of all channels. Optics are temperature-compensated and located in a controlled environment.

For More Information Write In No. 737

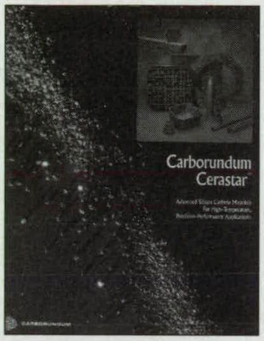
Image Analysis for Corporate Productivity



Optimas Corp., Edmonds, WA, describes its new Optimas Version 5 in a new brochure called "Image Analysis in a Corporate Computing Environment." The company says the new image analysis software has improved data reporting and powerful new application modules. The use of new Microsoft standards such as Object Linking and Embedding (OLE) makes it possible to share data with other programs in Windows.

For More Information Write In No. 738

SiC for Demanding Applications



Cerastar™ silicon carbide from Carborundum Specialty Products, Niagara Falls, NY, is the subject of a new 8-page color brochure. The material is found in products requiring complex shapes and exacting tolerances, as well as those with high elastic modulus, low thermal expansion, and high thermal conductivity. Among them are laser mirror blanks, optical benches, and wafer handling devices.

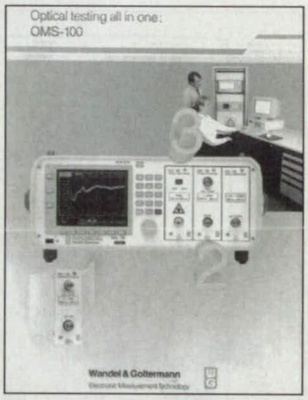
For More Information Write In No. 739

Data Acquisition of Many Kinds

A six-page catalog just released by Monarch Instrument, Amherst, NH, introduces several new products and offers specifications for many more. Included are paperless recorder/data acquisition systems, stroboscopes, tachometers and sensors. Among new products is DataChart™, a one- or two-channel 1/4 DIN paperless recorder, data acqusition system with a high-resolution back-lighted display.

For More Information Write In No. 740

Optical Test Set



A four-page color booklet from Wandel and Goltermann, Morrisville, NC, explains the features, functions, specifications, and applications of the OMS-100, an optical test set used in telecommunications and data communications. Charts and diagrams elucidate the set's functions, including SDH/SONET measurements, PON/PDN tests, LAN tests, as well as calibration and device tests.

For More Information Write In No. 741

Standard and Custom Air-Bearing Products

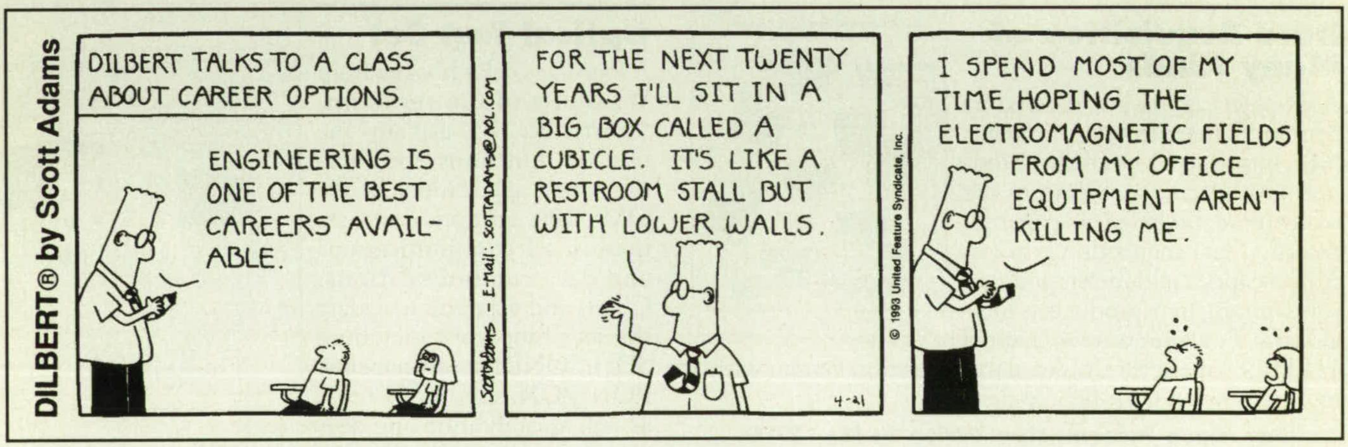
The 12-page brochure from Dover Instruments, Westborough, MA, sets out the company's capabilities in air-bearing system design of products serving a wide variety of industries, including the semiconductor field, magnetic and optical memory manufacturing, optical fabrication, high-resolution imaging and precision metrology. Dover designs and manufactures specialty positioning systems and machine tools, and has a broad range of standard air-bearing linear translation stages, X-Y tables, and multiaxis positioners.

For More Information Write In No. 742

Cryogenic Control Catalog

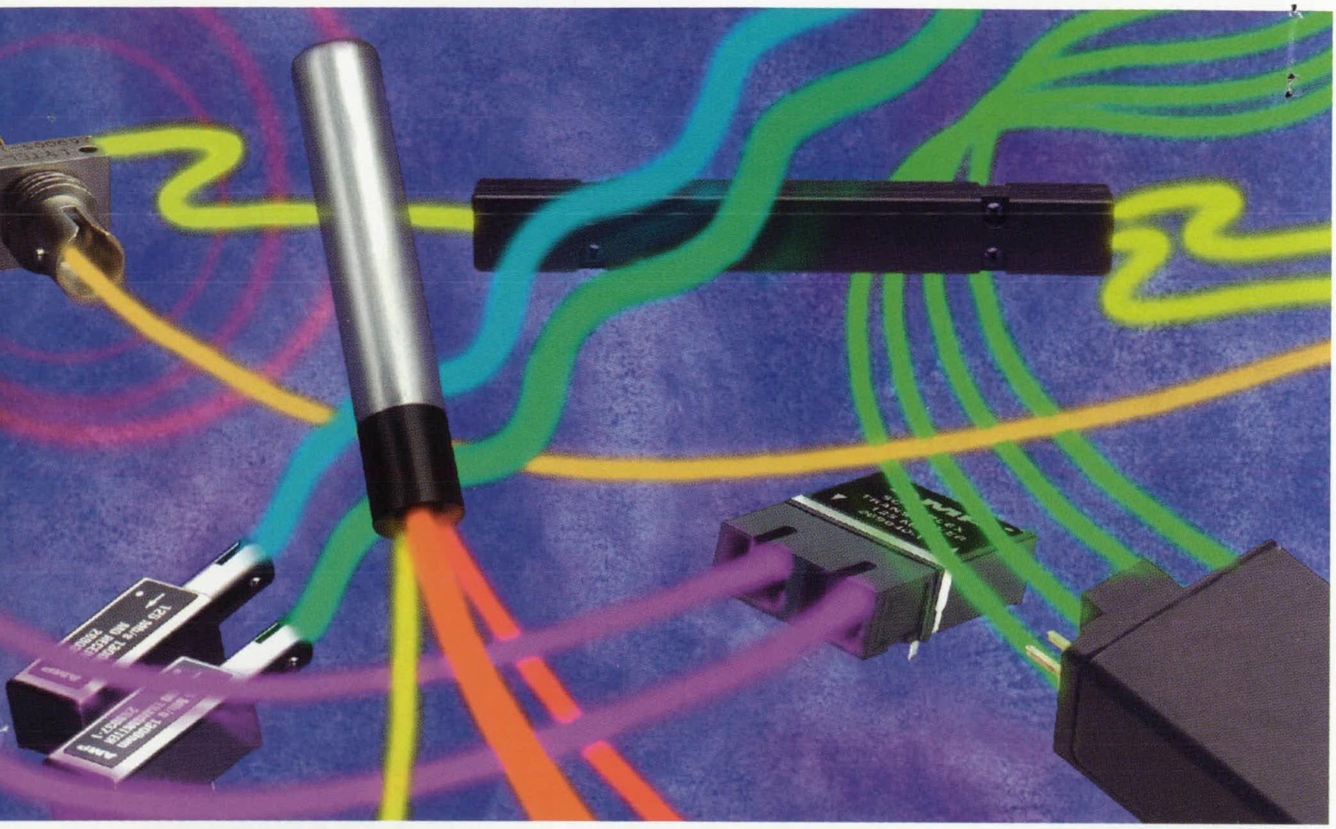
Lake Shore Cryotronics, Westerville, OH, calls its 1995 "Cryogenic Temperature Measurement and Control Product Catalog" a product catalog and reference guide in one volume. Up-to-date information on Lake Shore products includes cryogenic temperature, pressure, and level sensors, temperature and level controllers and monitors, current sources, temperature transmitters, accessories, and more is accompanied by specifications and comparison tables to assist in choosing the correct sensor and control instrumentation.

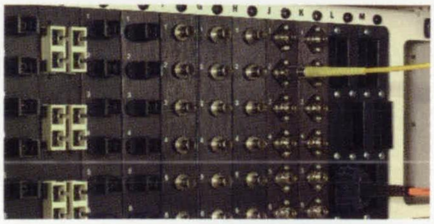
For More Information Write In No. 743



Advertiser Index

Products for the art of fiber design.





Whatever your fiber work of art, we've got the component solutions you're looking for. Active devices. Connectors and assemblies. Couplers, multiplexers, and attenuators. Fiber management hardware, and more. Just the help you need to build, maintain, control, and reconfigure your fiber system. And all our products are designed to simplify and speed the job.

Our data link modules are available in FDDI, ATM, and Fiber Channel versions, with industry-standard footprints and connector interfaces. Our couplers, attenuators, WDMs, and switches offer unique characteristics and a range of performance levels to meet your most demanding transport challenges. We offer a complete selection of fiber connectors – including advanced "crimp" styles that terminate in under two minutes with no epoxy, no risk of improper curing. And our fiber management systems accommodate any need you can imagine – providing simplified access and control of complex network configurations.

AMP is dedicated to the future of fiber – with over 500 people working to develop and produce the industry's best optical interconnection systems. From the circuit board through the network, find out more about what we do, and what we can do to help. Just call.

For more information about AMP optical interconnection systems, call our Product Information Center at 1-800-522-6752 (fax 717-986-7575). AMP, Harrisburg, PA 17105-3608. In Canada, call 905-470-4425.

AMP

D^3. Now CW Blue Output from a Solid-State Laser.

Coherent's New Directly Doubled Diode Laser System Delivers 10mW at 430nm.

For years, inefficient gas lasers with limited lifetimes were the common choice for low power cw output in the blue region. The new D^3 laser's optical efficiency is >20%, resulting in longer operating lifetimes and lower power consumption.

With an $M^2<1.3$ and beam pointing stability of <10μrad/°C, the system provides a focus of exceptional quality and repeatability.

Enhanced detection sensitivity is another benefit of D^3. Optical noise levels of <1% rms are up to 2.5 times lower than helium-cadmium lasers and other technologies.

D^3 runs on standard electrical service, drawing less than 30W. It is conveniently packaged as an integrated head and power supply measuring 490 x 120 x 86 mm. OEM versions as small as 265 x 95 x 84 mm are also available.

To learn more about the new D^3-430, call Advanced Technical Sales today.

1-800-527-3786

COHERENT®

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