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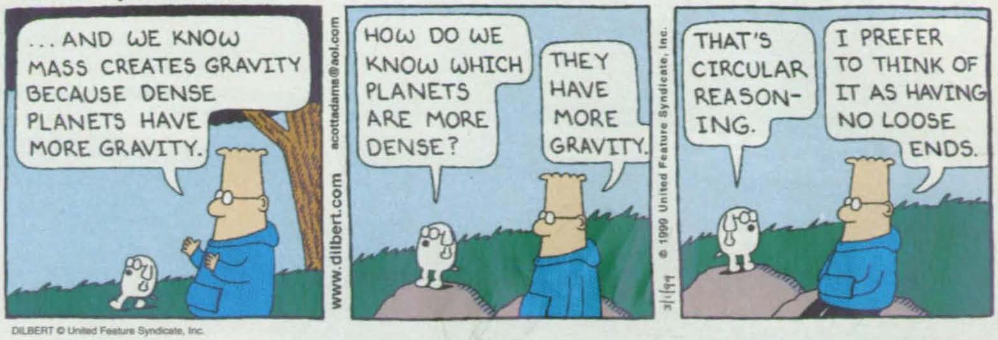

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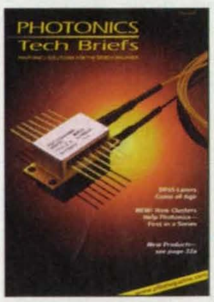

Follows page 16 in selected editions only.

Contents *continued*

PRODUCT OF THE MONTH

FEMLAB® multiphysics modeling and analysis software from COMSOL, Burlington, MA, models virtually any physical phenomena.

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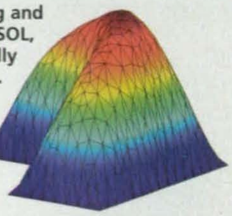

ON THE COVER

The E3G-L1 photoelectric sensors from Omron Electronics, Schaumburg, IL, use a pinpoint beam to detect the presence or absence of minute targets without the use of a laser beam. The beam helps the sensors detect objects regardless of their glossiness, color, material, surface irregularities, or inclination. For more information on this and other new sensing innovations, see the Special Coverage on Sensors beginning on page 34.

(Photo courtesy of Omron Electronics)

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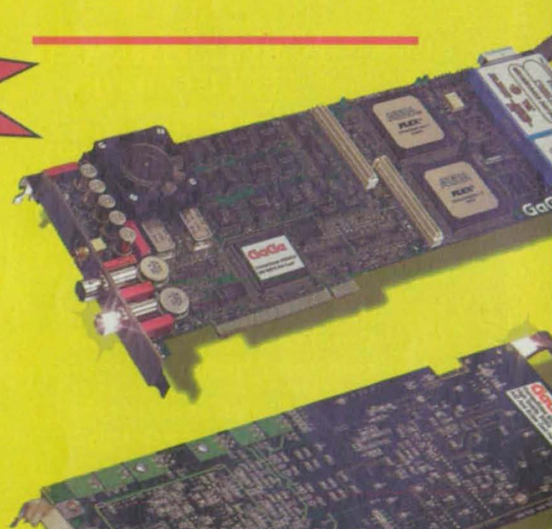

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NASA Commercial Technology Team

NASA's R&D efforts produce a robust supply of promising technologies with applications in many industries. A key mechanism in identifying commercial applications for this technology is NASA's national network of commercial technology organizations. The network includes ten NASA field centers, six Regional Technology Transfer Centers (RTTCs), the National Technology Transfer Center (NTTC), business support organizations, and a full tie-in with the Federal Laboratory Consortium (FLC) for Technology Transfer. Call (609) 667-7737 for the FLC coordinator in your area.

NASA's Technology Sources

If you need further information about new technologies presented in *NASA Tech Briefs*, request the Technical Support Package (TSP) indicated at the end of the brief. If a TSP is not available, the Commercial Technology Office at the NASA field center that sponsored the research can provide you with additional information and, if applicable, refer you to the innovator(s). These centers are the source of all NASA-developed technology.

Ames Research Center
Selected technological strengths: Fluid Dynamics; Life Sciences; Earth and Atmospheric Sciences; Information, Communications, and Intelligent Systems; Human Factors.
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Dryden Flight Research Center
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lee.duke@dfrc.nasa.gov

Goddard Space Flight Center
Selected technological strengths: Earth and Planetary Science Missions; LIDAR; Cryogenic Systems; Tracking; Telemetry; Remote Sensing; Command.
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galcorn@gsfc.nasa.gov

Jet Propulsion Laboratory
Selected technological strengths: Near/Deep-Space Mission Engineering; Microspacecraft; Space Communications; Information Systems; Remote Sensing; Robotics.
Merle McKenzie
(818) 354-2577
merle.mckenzie@jpl.nasa.gov

Johnson Space Center
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(281) 483-0474
henry.l.davis1@jsc.nasa.gov

Kennedy Space Center
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Gale Allen
(407) 867-6226
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Langley Research Center
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Sam Morello
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John H. Glenn Research Center at Lewis Field
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Larry Viterna
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Marshall Space Flight Center
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Sally Little
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Stennis Space Center
Selected technological strengths: Propulsion Systems; Test/Monitoring; Remote Sensing; Nonintrusive Instrumentation.
Kirk Sharp
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technology@ssc.nasa.gov

NASA-Sponsored Commercial Technology Organizations

These organizations were established to provide rapid access to NASA and other federal R&D and foster collaboration between public and private sector organizations. They also can direct you to the appropriate point of contact within the Federal Laboratory Consortium. To reach the Regional Technology Transfer Center nearest you, call (800) 472-6785.

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(440) 734-0094

NASA ON-LINE: Go to NASA's Commercial Technology Network (CTN) on the World Wide Web at **http://nctn.hq.nasa.gov** to search NASA technology resources, find commercialization opportunities, and learn about NASA's national network of programs, organizations, and services dedicated to technology transfer and commercialization.

NASA Program Offices

At NASA Headquarters there are seven major program offices that develop and oversee technology projects of potential interest to industry. The street address for these strategic business units is: NASA Headquarters, 300 E St. SW, Washington, DC 20546.

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Office of Mission to Planet Earth (Code Y)
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gpaules@mtpe.hq.nasa.gov

NASA's Business Facilitators

NASA has established several organizations whose objectives are to establish joint sponsored research agreements and incubate small start-up companies with significant business promise.

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Lewis Incubator for Technology
Cleveland, OH
(216) 586-3888

B. Greg Hinkebein
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Stennis Space Center, MS
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San Jose, CA
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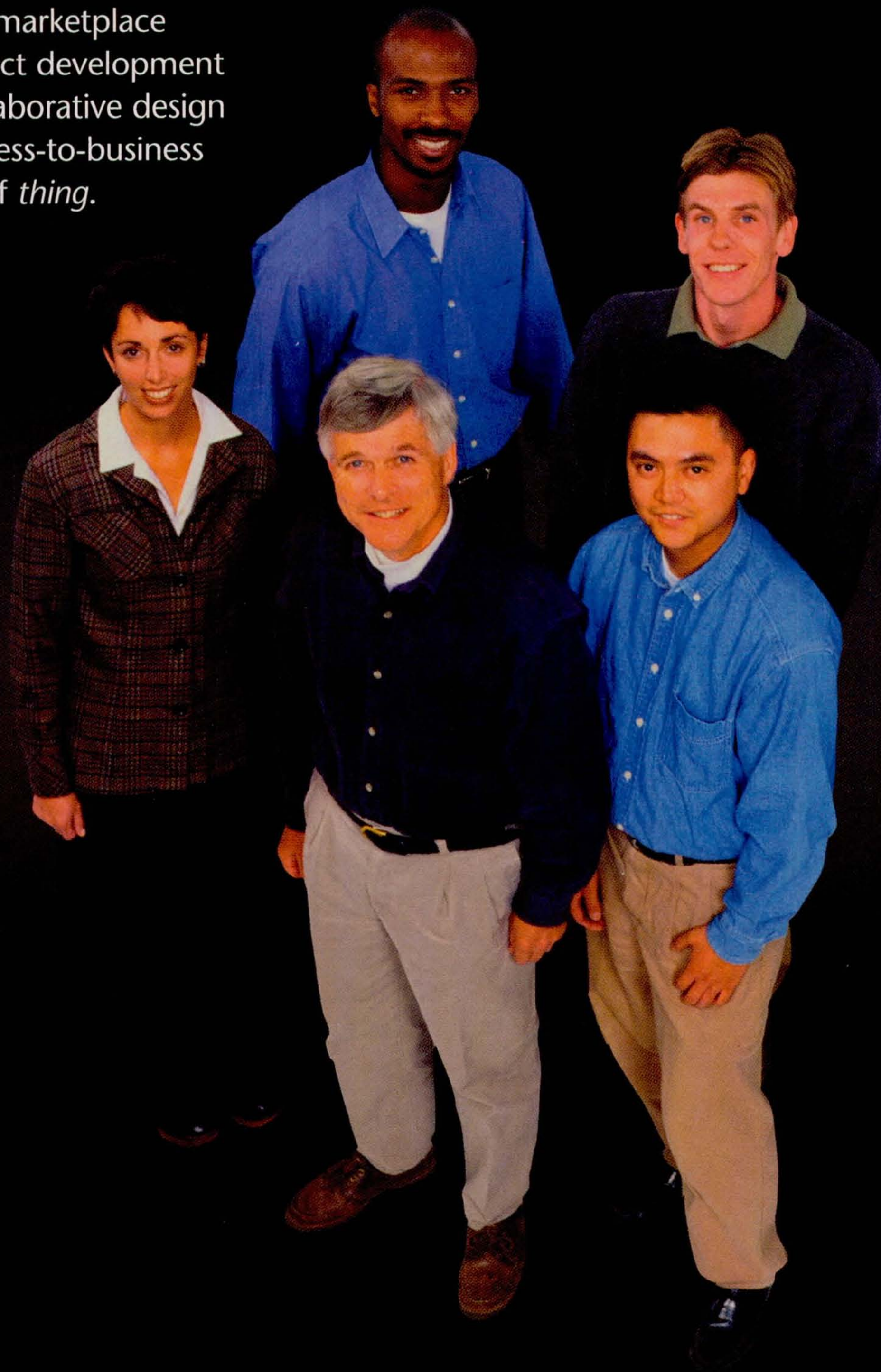
If you are interested in information, applications, and services relating to satellite and aerial data for Earth resources, contact: Dr. Stan Morain, **Earth Analysis Center,** (505) 277-3622.



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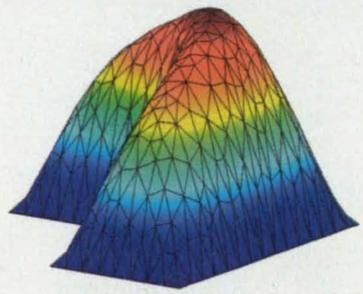
PRODUCT OF THE MONTH



COMSOL, Burlington, MA, has introduced FEMLAB® multiphysics modeling and analysis software that automates methods of parametric analysis and design optimization. The software runs on top of MATLAB® technical computing software from The MathWorks (Natick, MA), and can model virtually any physical phenomena with partial differential equations including heat transfer, fluid flow, electromagnetics, and structural mechanics. Available for most operating systems, including UNIX and Windows, the software can model phenomena that involve several disciplines at the same time. It can import DXF drawing files from CAD software, and includes a Model Library of more than 80 models that shows ready-to-run examples for common situations in multiple application areas. The program features automatic code generation for converting a graphically derived physics model to a sequence of MATLAB commands.

For More Information Circle No. 756

What's New in NTB

Beginning with last month's issue, we introduced a new, regular briefs section devoted exclusively to all aspects of Test and Measurement. Check out this section each month for the latest NASA innovations in test, measurement, and monitoring (see page 48 in this issue).

You may have been surprised to receive an added bonus with your March issue of *NASA Tech Briefs* — the inaugural issue of *AFRL Technology Horizons*, the new quarterly magazine from the publishers of NTB. The magazine serves as a vehicle through which the Air Force Research Laboratory (AFRL) lets the US scientific community know about its research, facilities, and technology milestones.

For more information, or if you'd like a free subscription to *Technology Horizons*, visit www.afrlhorizons.com.

A Revolutionary "IMAGE"

As we come to rely more and more on satellites and cell phones, forecasting solar and geomagnetic storms may be just as important as knowing the chances of rain. Unfortunately, space weather forecasting is about 40 or 50 years behind everyday weather prediction. But a new NASA mission to explore Earth's magnetic space environment may change that.

Launched on March 25, the Imager for Magnetopause-to-Aurora Global Exploration (IMAGE) is a spacecraft designed to study the global response of the Earth's magnetosphere to changes in solar wind. The magnetosphere is an area of space around our planet that is controlled by the Earth's magnetic field. During periods of gusty solar wind, magnetic storms cause vivid auroras, radio and TV static, power blackouts, and navigation problems for ships and planes with magnetic compasses.

Predicting these storms can be tricky, since scientists don't have a global view of how the magnetosphere works. "It's a little like looking at a thermometer in Alaska, checking the barometric pressure in Florida, and then trying to predict the weather in Europe," said Dennis Gallagher of NASA's Marshall Space Flight Center in Huntsville, AL, an IMAGE co-investigator. The instruments on IMAGE, he explained, "provide unique and wholly new ways of looking at the magnetosphere."

The data from IMAGE will be posted to the Web in near-real-time for public viewing. Anyone with an Internet connection can watch the magnetosphere in action. Access the IMAGE home page, managed by NASA's Goddard Space Flight Center, at http://image.gsfc.nasa.gov.

Reader Forum

Reader Forum is devoted to the thoughts, concerns, questions, and comments of our readers. If you have a comment, a question regarding a specific technical problem, or an answer to a question that appeared in a recent issue, send your letter to the address below.

*(**Editor's Note:** The editors of NASA Tech Briefs would like to thank the thousands of you who submitted votes in our 1999 Readers' Choice Product of the Year Awards. Because they are chosen by our readers, the awards hold special significance to the winners. For detailed information on the presentation of the fifth annual awards — and for the names of the lucky readers who were winners in our random drawing — see page 28.)*

I need to locate dielectric data for ceramics with relative permittivities greater than 50,000. Some ceramic compounds have relative permittivities greater than 100,000 — I'd especially like to know more about these. Thanks for any assistance.

Julian Kalmar
jkalmar@earthlink.net

I am developing cold-water-soluble tapioca starch as a lamination adhesive for the corrugated paper box industry. After hydrolysis by HCl acid, I've added caustic soda and borax to get better results, but I want to increase the tack adhesion property, reduce the drying period, and increase the bursting strength of the box. Can anyone suggest some suitable additives? Thank you.

Raja Ranade
fantagum@pn2.vsnl.net.in

*(**Editor's Note:** Fellow reader Lucien Agniel suggests contacting the US Department of Agriculture's laboratory in Peoria, IL, for suitable additives. The Peoria lab has developed most of the modified starch additive technology in the US, according to Lucien. Visit the web site at www.usda.gov for more information.)*

I am currently in need of a supplier of Invar (preferably Invar-36) tubing. The tubing would have approximate dimensions of 1.125" ID x 1.375" OD. Thank you for your assistance.

P. Palumbo
ppalumbo@hach.com

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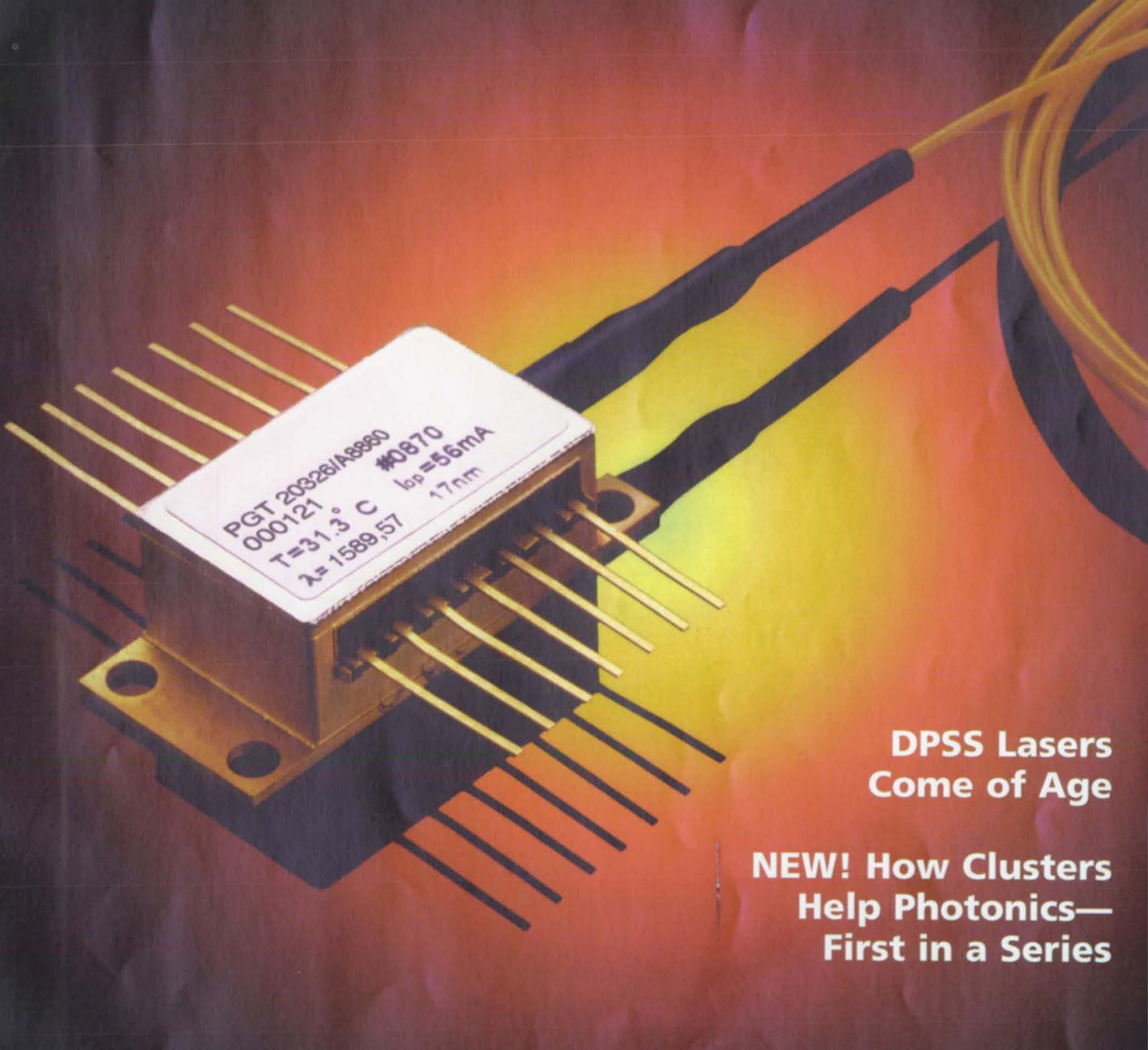

DPSS Lasers Come of Age

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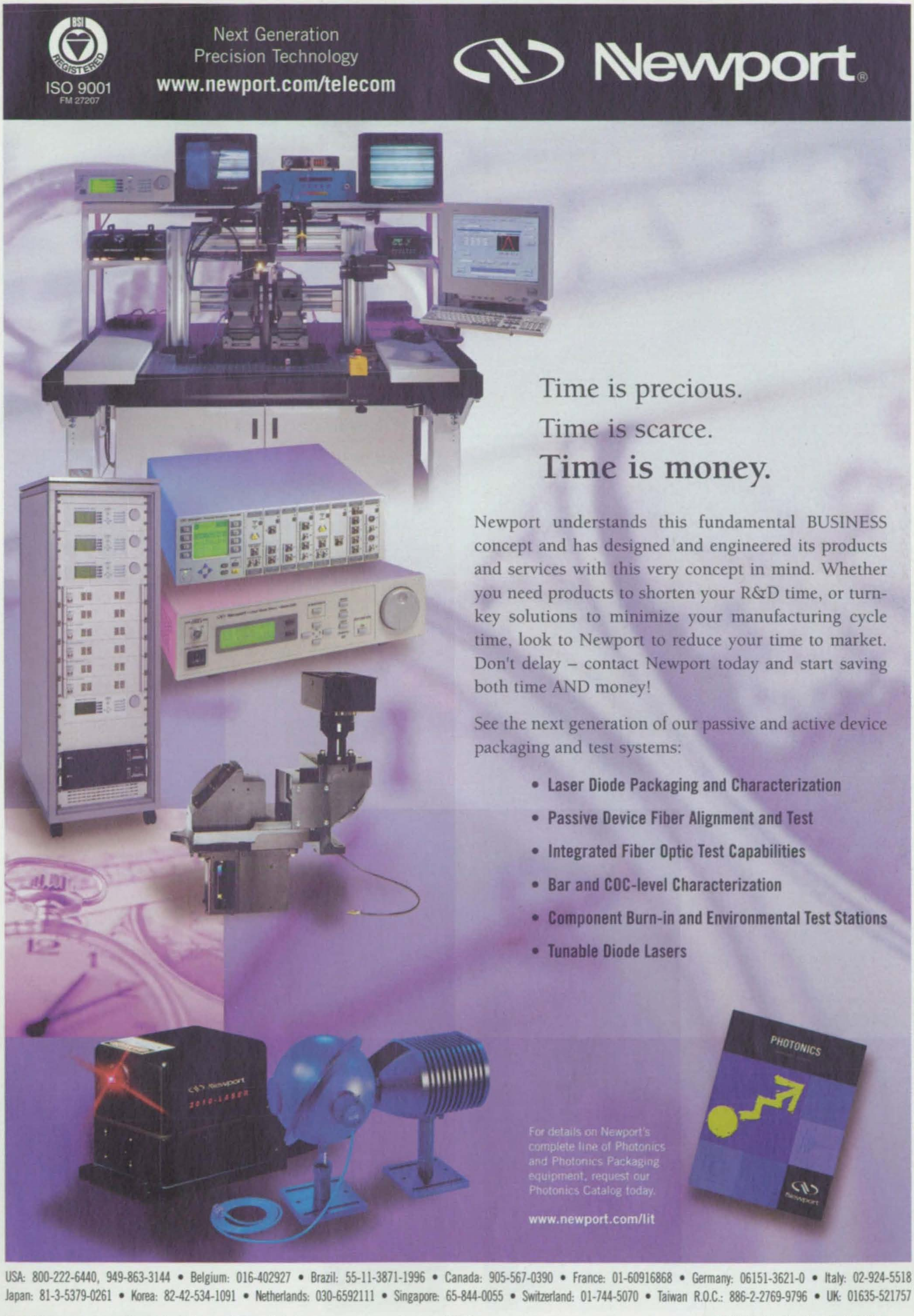
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Tech Briefs

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Cover photo courtesy of Ericsson Inc.

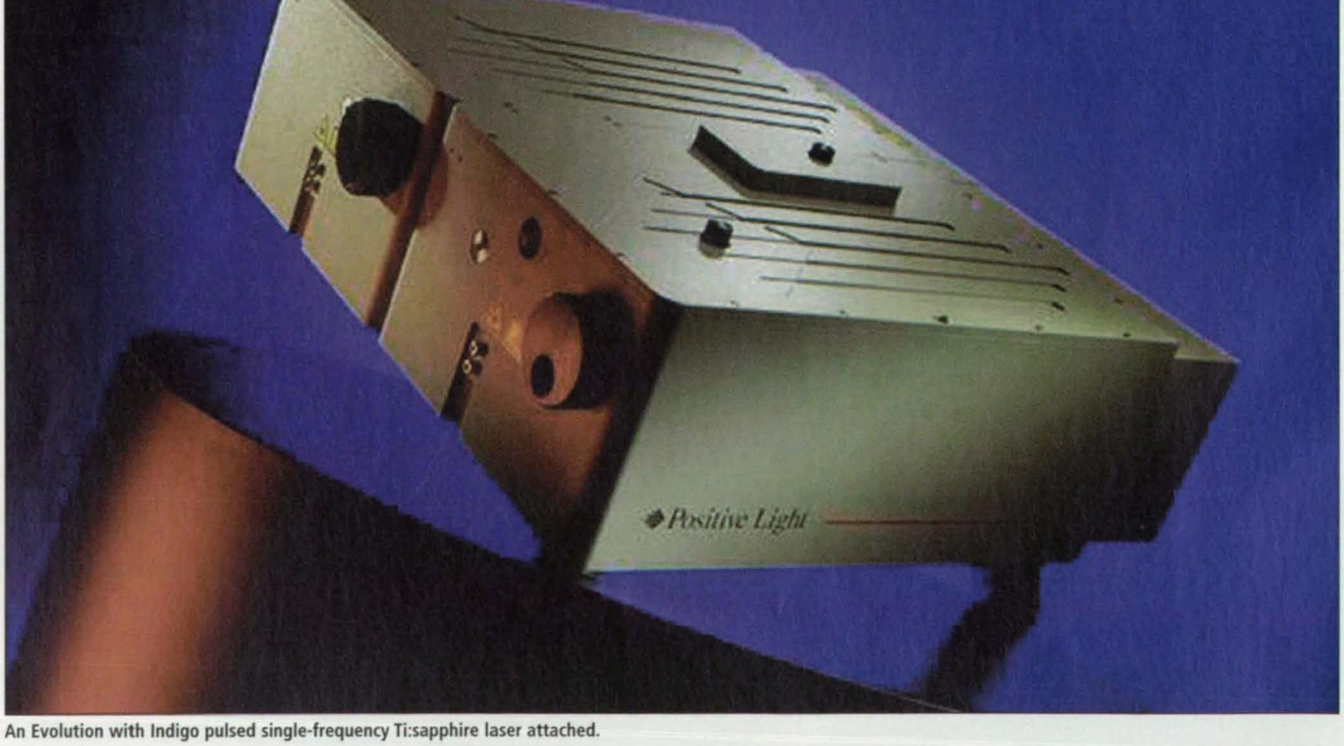
DPSS Lasers Come of Age

Diode-pumped solid-state lasers enter the tunable field.

As little as five years ago, if you wanted a laser producing watts of green light, you could choose from the following:

- An argon laser requiring as much as 10-20 kW of prime power, gallons-per-minute cooling and approximately 20-30 ft.[3] of space;
- An arc-lamp-pumped Nd:YLF or Nd:YAG laser with roughly the same appetite for utilities and real estate;
- A flashlamp-pumped Nd:YAG laser, less gluttonous but somewhat more finicky, and providing only 100 pulses per second at best; and
- A copper vapor laser with a live-in technician to house and feed.

Then along came diode-pumped solid-state (DPSS) lasers, and suddenly 10 watts of green light could be packaged in about 4 ft.[3] of real estate, consuming a couple of kilowatts, including cooling. Of equal importance, the DPSS laser promised vastly improved reliability and much more stable performance than the technologies it was displacing. There was unanimous approval from the scientific laser community. The response from researchers attempting to take the earlier lasers out of the laboratory and into industrial, mobile, and airborne envi-



An Evolution with Indigo pulsed single-frequency Ti:sapphire laser attached.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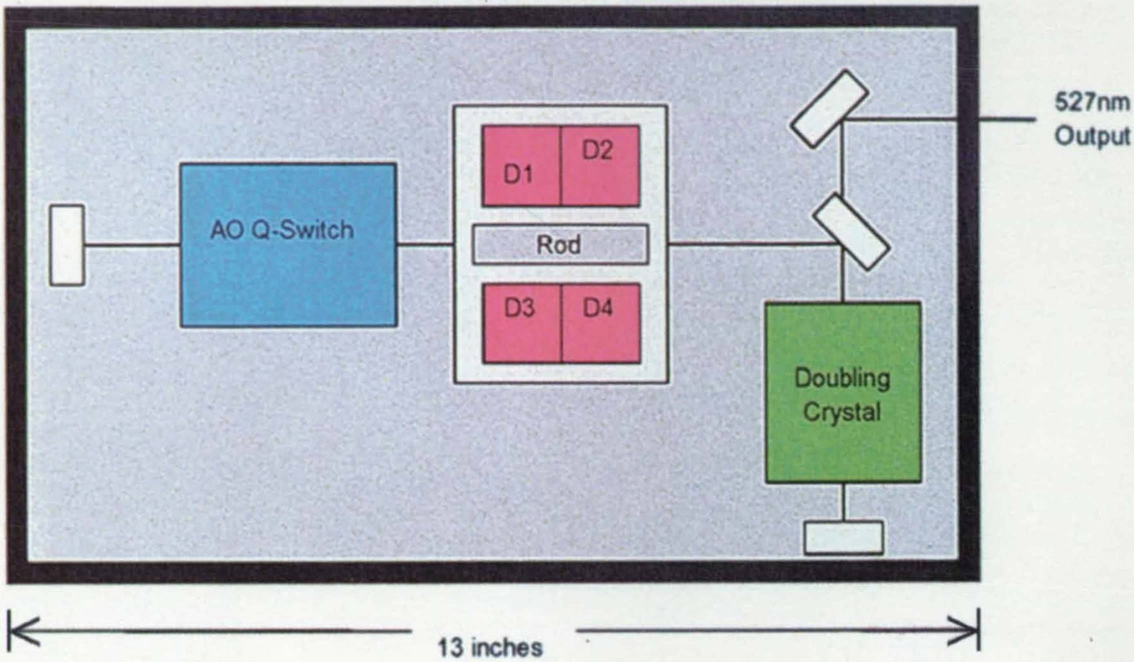


Figure 1. Schematic of the Evolution diode-pumped laser cavity.

ronments was similar: a collective sigh of relief could be heard from JPL to Goddard.

In the five or so years since their widespread introduction commercially, DPSS lasers have more than lived up to their hype, and now stand ready to make significant contributions in research areas that include LIDAR, spectroscopy, and laser remote sensing. A close look at evolving DPSS technology yields even more reason for optimism, as costs, lifetimes, and performance all continue in directions favoring consumers.

An example is Positive Light's Evolution. The Evolution-X is an Nd:YLF laser producing 10 W at 527 nm. The single Nd:YLF rod is transversely pumped by 4 40-W diode bars arranged around the water-cooled rod (see Figure 1). The pump diodes operate continuous-wave, with the slightly lower gain compared to pulsed operation compensated for by the improved diode lifetime. The resonator design produces a multimode output with a flat beam profile. An acousto-optic modulator serves as the Q-switch, and the intracavity LBO frequency-doubling crystal features noncritical phase-matching. By using the LBO crystal at 90° with respect to the optical axis, the angular acceptance is greatly increased, thus promoting long-term stability without the need for continuous tweaking. The result of this design is that a strip-chart recording (see Figure 2) shows the Evolution's output stability is 0.2 percent RMS over a 24-hour period.

Because Nd:YLF exhibits negligible thermal lensing, the Evolution's repetition rate can be easily changed from 1 kHz to 5 kHz without affecting beam quality. Once again addressing the need for long-term reliability and performance stability, the Evolution is mounted onto a monolithic platform that shares water-to-air cooling with the Nd:YLF rod. *(Continued)*

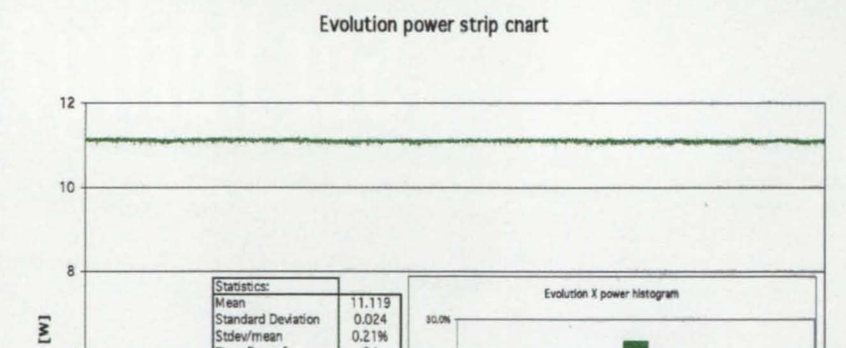
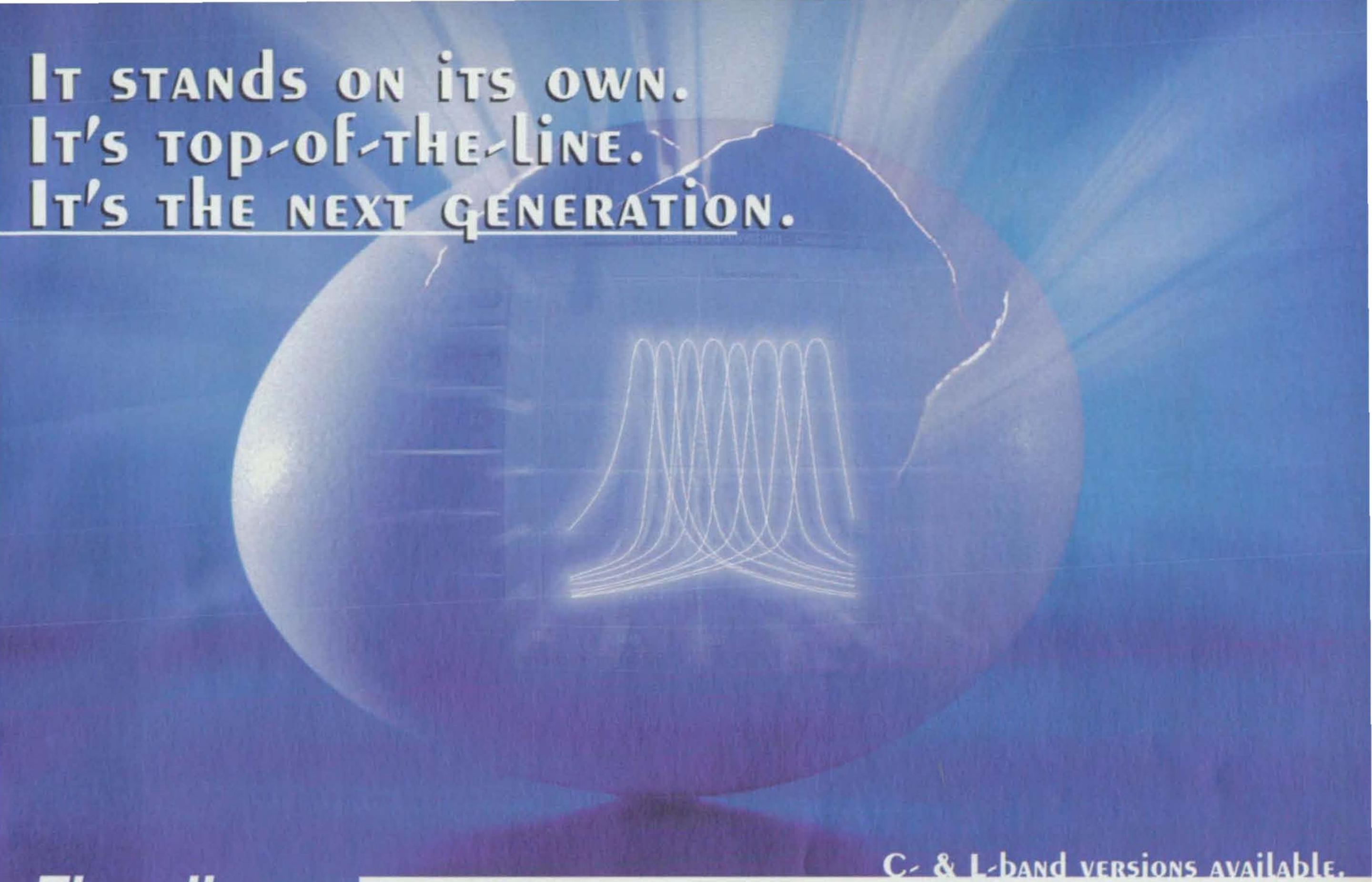


Figure 2. Recording over a 24-hour period of the Evolution's output power, showing excellent power stability of 0.2 percent RMS.



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A Sharp Drop in Price

It is worth noting that while DPSS lasers have been around for more than a decade, the cost associated with diode pumping precluded them from high-power commercial laser viability until quite recently. Within the last two years, diode bar arrays producing in excess of 40 W at about 0.8 µm, a neodymium pump line, have fallen in price dramatically. Somewhat more gradually, the lifetimes for diodes have risen, and Positive Light now guarantees the Evolution's performance for 5000 hours of operation.

Though much can be accomplished using green light at a fixed wavelength (i.e., measurements of aerosol scattering, laser ranging), the market potential for tunable lasers has considerably more appeal. Since the late 70s, argon and frequency-doubled Nd:YAG lasers were put to work as the pump sources for tunable dye lasers. Just as these older pump lasers gave way to DPSS lasers, the dye laser is inexorably being replaced by solid-state alternatives, most notably titanium-doped sapphire (Ti:sapphire).

Last year, under a licensing agreement with Stanford University, Positive Light introduced Indigo, the first all-solid-state pulsed laser combining narrowband (single-longitudinal-mode) performance with wide tunability from the UV to the IR. When paired with Evolution-X, the Indigo produces a 1-kHz output of more than 800 microjoules at 800 nm. The transform-limited pulses are about 10 ns in duration, and pulse-to-pulse energy stability is better than 2 percent over the fundamental tuning range from 690 to 920 nm. The Stanford/Positive Light design features a unique cavity configuration, shown in Figure 3, dubbed "MDW" for mode-discrimination walk-off.

A Ti:sapphire rod 3 mm in diameter and 15 mm in length is longitudinally pumped with an Evolution at 527 nm. The lasing output is gain-switched—the 150-ns pump pulses from the Evolution assure a low peak-power level in the Ti:sapphire, and a comfortable safety cushion against damage on all the optical surfaces.

Three of the main areas of commercial interest in the Indigo system are light detection and ranging (LIDAR), resonant ion mass spectroscopy (RIMS), and ozone detection. Because the stability of the system means it is well suited to harmonic generation, the Indigo can be specified with an output as short as 193 nm, where its ≈5-mW output complements excimer lasers in low-power applications, including metrology and optical system alignment. The entire Indigo-193-nm system consumes less than 2 kW of power, and the system footprint is a paltry 24-×-31-×-6 in. for the laser heads, and 20-×-17-×-13 in. for the power supply.

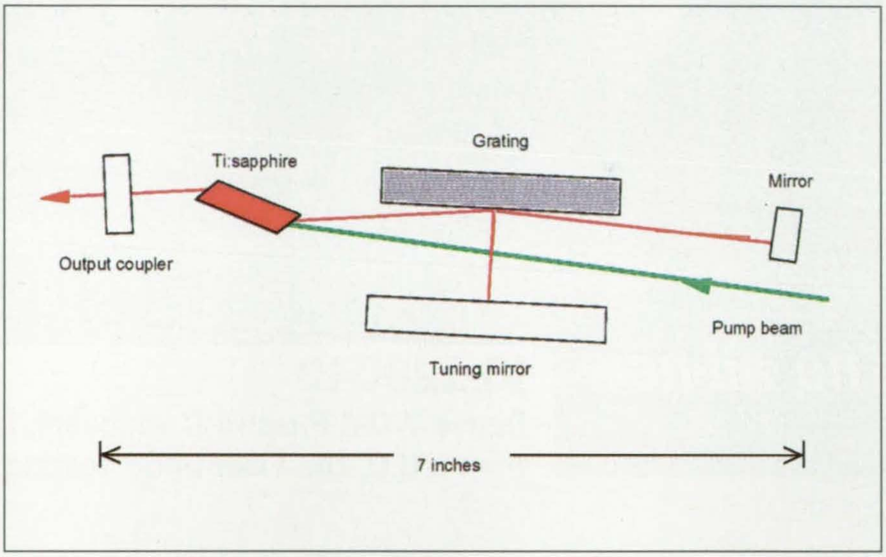

Figure 3. Schematic of the Indigo Ti:sapphire single-frequency laser cavity.

In offering a complete turnkey system for tunable narrowband laser radiation, Positive Light hopes to extend the operating platform for laser systems that have been somewhat notorious in their attendant needs. Higher-power versions of the Evolution are already under development; >20 W output at 527 nm is expected before the end of the year.

For more information contact Leigh Bromley, R&D manager at Positive Light, 103 Cooper Court, Los Gatos, CA 95030; (408) 399-7744; fax: (408) 354-4695; poslight@aol.com.

The Evolution of Structured Clusters

First in a series on a singular economic initiative.

by Robert Breault

This is the first in a series of articles on the topic of structured clusters, in some regions of the world called economic development regions. I hope to present here insights into the evolution and purpose of clusters and some thought-provoking concepts and challenges to leaders in the global optics community.

The successful cluster concept is based on a community's role in evolving a network of efforts beneficial to the industries in the cluster, and thus to the region's economic growth. Cluster building rests on more than the efforts of an industry association, or a public-sector organization. To a large extent, cluster building owes most to an unpaid, voluntary partnership of a few hundred public- and private-sector organizations that focus on the economic and social health and welfare or a region, its industries, and its people.

What is a cluster? At a conference of the Barcelona-based International Competitive Institute last year, a large subgroup debated the better part of a morning on the definition of a cluster. My well-circulated definition that follows represents the type of cluster that I refer to in this and future articles: "A cluster is a concentration of firms across several industries that creates quality jobs, exports goods and services, shares common economic foundational needs, and unites the public sectors of economic development, legislatures at all levels, universities, community colleges, the K-12 educational community, workforce development, support foundations, and all community economic stakeholders."

Clusters may work in conjunction with local, state, and federal offices, and universities and community colleges. The clusters need not be focused only on technical industries: for instance, of the clusters in Arizona, three serve the tourism, food and fiber, and senior living industries.

I want to make it clear that a cluster is more than just an association of similar companies. A cluster and an association are not even close in their functionality. An economic cluster is both a concentration of firms across related industries and a concentration of the public- and private-sector organizations that are stakeholders in local economic development. The successful partnering of these willing groups defines a cluster.

The Arizona Story

Just like natural resources, economic clusters in general have to be found and developed. Though it is possible to build clusters from the ground up, the Arizona Strategic Planning for Economic Development (ASPED) office took on the task of identifying the significant clusters that already existed within the state. Thereafter the

Governor's Strategic Partnership for Economic Development (GSPED) was formed to implement the ASPED plan.

Since that time, the concept has been ported in the United States to Florida, Connecticut, Colorado, New Mexico, Massachusetts, Pennsylvania, and New York; in Canada to Quebec, Toronto, Ottawa, and Vancouver; and abroad to Scotland, Singapore, and Japan. In many regions around the world, clusters that were formed ad hoc are renowned for their success—for example, Silicon Valley, Route 128 in Boston, the fashion industry in Paris, and the retail and leather industries in Italy. Though I will discuss clusters that came about organically, I will place the emphasis on structured clusters, which are created by a known and intentional process.

Arizona's story is about a thousand people who were motivated both by self-interest and the common good. The attitude of many people in Arizona can be summed up as, "If we can run our companies properly and profitably and provide a reasonable return for our shareholders, we can, and must, get involved in the community and have an impact on its direction." This is a challenge to the international optics industry's leaders and regional and national economic developers to step forward and contribute their ideas. This is not a story about old-time associations.

Government and public-sector forces are also changing dramatically. The responsibility for a healthy economy has shifted from the federal government to local regions, paradoxically while markets are more global than ever before. I believe clusters can be created in many regions of the world if they can inspire their community leaders.

Regional efforts are now more important than ever, as the economy and the competition are truly global. One strong business in a region, a Hewlett-Packard, Nortel, or Microsoft, can create a whole economy around it, and account for many spinoffs. In the case of Tucson, the Optical Sciences Center at the University of Arizona has been cited (*Arizona's Economy Is Everyone's Business*, by Alan Korwin et al., Governor's Strategic Partnership for Economic Development, 1992) as an instance in which the regional economic health flows from the strength of the Center. Fourteen local optics companies have been spun off from research work at the Center. Massachusetts Institute of Technology can claim an even bigger impact in the Boston region.

(Continued)

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The cluster process is being replicated at the local level around the world, but Arizona is arguably one of the first to implement a statewide program. Arizona has eleven interactive industry clusters, and a structured set of seven foundations to support the clusters. The state has already received multiple national awards because of its cluster formation and activities. At least one recently published book—*Building Economic Communities: How Civic Entrepreneurs are Transforming America*, by Doug Henton, John Melville, and Kim Walesh (San Francisco: Jossey-Bass, 1997)—cites Arizona, along with six cities and Florida, as exemplary of good cluster development.

Economic development regions have occurred naturally for centuries. Some examples are the first agricultural villages, naval powers, manufacturing industries of all sorts, and now in our time, the telecom regions. In studying the processes that made them successful, it is clear that the social groups that had the better knowledge and organizational skills played a dominant role. Historians have also often attributed the growth of successful societies to geographical location and proximity to transportation; to short-term economic factors such as gold, copper, oil, or other raw and natural materials; or finally to the availability of capital. The cluster concept, however, is provoking new research that challenges these long-held concepts, including the significance of capital formation as being dominant.

Broad Knowledge, Economic Skills

A growing number look on the success of more advanced societies as due to how they developed and incorporated broader knowledge and sounder economic skills than their rivals. Examples would be the Romans' development of wine and weapons, silversmith guilds, dominant shipping centers, and finally Silicon Valley and its associated high-tech industries.

While initially the social entities may have been unstructured, the successful societies evolved more and more structural roles for various sectors of the group. In today's terms we would call the subgroups the public sector (government's civic and economic sectors, and its legislative and judicial branches), the private sector (support industries included), mixtures of both, and educational institutions.

It should be easy to see that this is not a period of economic transition. This is confirmed by the almost simultaneous events such as the demise of the Cold War, downsizing of governments around the world, rapid development of technologies, and the rapid spread of this knowledge. Add to these factors the rapid mobility of capital, global market competition, and access to the information highways.

But this is a period of discontinuity in the evolution of society. No one has yet shown that they know the new rules of the game, but some hold that clusters will be a significant part of the twenty-first century's social and economic structure.

Today's cluster can be viewed as incorporating in a premeditated structure some of the processes of those formed in a more or less ad hoc manner. The principles are a plan, organizational skills, cooperation of the community stakeholders, the educational system, workforce development at all levels, transportation of the products more efficiently than others, competition in the local region, and the integration and modification of multiple foreign technologies.

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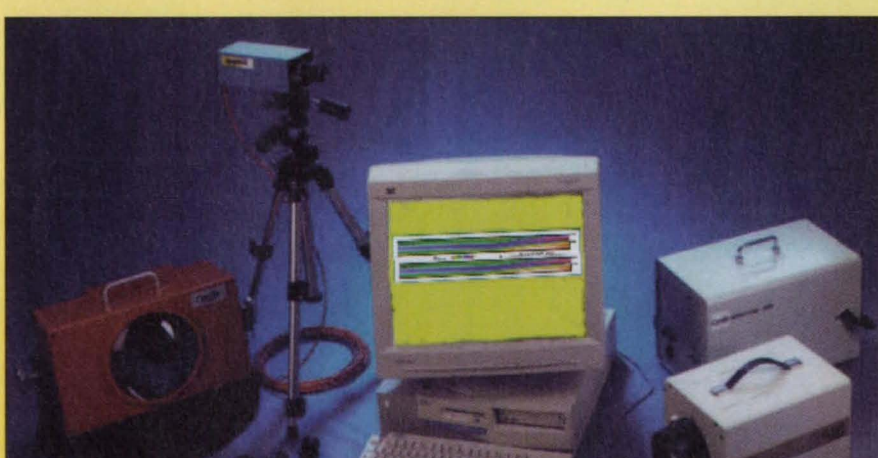
Getting Better **Flow-Structure** Information

The Cooke Corporation's digital CCD camera increases the efficiency of an improved technique called digital particle image velocimetry (DPIV).

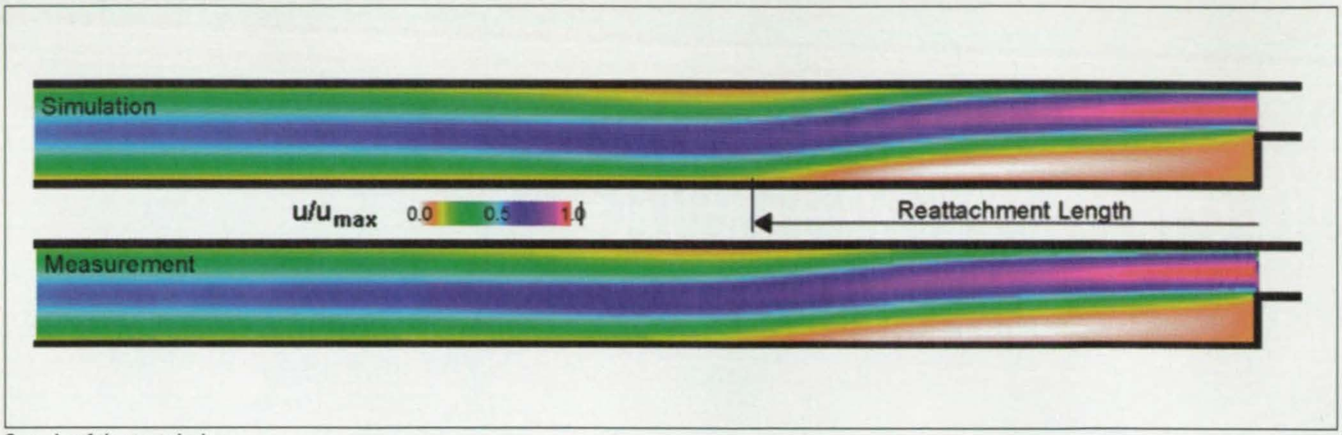
Experimental studies of flow-velocity fields have been greatly advanced by the development of optical techniques that do not interfere with or disturb the flow. One of these, the laser Doppler velocimetry (LDV) technique, has been widely used in velocity measurements. But since the technique provides time-resolved information about a single point of the flow domain, its capacity to provide spatial flow-structure information is limited. For investigation of flow fields with pronounced spatial structures and/or rapid spatial changes, new experimental techniques are necessary.

It is well known that multipoint measurements can be achieved by recording the motion of particles that have been added to the fluid as tracers. A broader group of whole-field velocimetry techniques, called pulsed light velocimetry (PLV), enables the capture of the quantitative flow velocity field instantaneously. The different PLV methods have been developed during the last decades based on various principles. In particular, the PLV method that uses a statistical analysis of the recordings defines the state of the art and can provide a high spatial resolution with reliable accuracy.



SensiCam system shown with lenses, trigger system, flash source, mounting hardware, computer and image processing/analysis software.

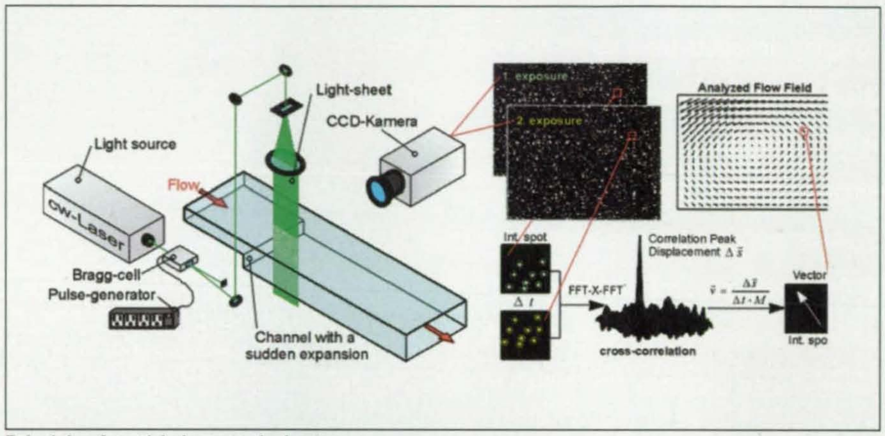
The targeted flow is seeded with small tracer particles with specific characteristics (spherical, identical density for water), which therefore follow the fluid. The investigated observation area can be illuminated with a thin light sheet designed by a lens system. During a measurement, two short laser pulses fired



Sample of the test device.

with a known time separation illuminate the flow. The images of the pulses represent the particle distribution respectively by their displacement in the observation area.

The displacement between the two scattered light images can be analyzed with correlation methods in small segments (interrogation spots) of the recorded image, where a uniform velocity is assumed. The analyzed image displacement, combined with the magnification factor of the optical setup, leads to the particle movement in the flow. This distance, divided by the given time interval, yields a velocity vector for each



Principle of particle image velocimetry.

interrogation spot. The analysis of all interrogation spots in the whole recorded image yields an instantaneous two-dimensional vector velocity field of the flow in the observation area.

Here a digital particle image velocimetry (DPIV) technique was implemented to study the so-called backward-facing step flow (BSF). As one of the fundamental problems in fluid mechanics, flow separation has received a lot of attention during the last few decades. The BSF flow (channel with a sudden expansion) has received most of the attention given to recent configurations. Despite the relatively simple geometrical configuration of the backward-facing step, the flow physics is quite complicated, and comprises the shear layer separating at the step corner, the separation region at the channel expansion, which is characterized by recirculating flow, and far downstream the fully developed channel flow. The availability of data of good quality combined with the feature that the primary reattachment length varies with Reynolds number makes the BSF flow an excellent test case for the accuracy of numerical and experimental methods.

The highly time-consuming image analysis of photographic recordings creates interest in an implementation of digital image processing. The Cooke Corporation's digital CCD camera system, the SensiCam, has been installed, with its ultrafast sequence capturing (200 ns) of two separate image for PIV, 12-bit digitization, and 1280 × 1024 pixels. The SensiCam offers the advantages of on-line observation, calibration of setup parameters, very fast image recording and processing, and accurate measurements. The advantage of digital PIV as compared to classical photographic PIV lies in fast and convenient interrogation of the images, as well as in the possibility of recording the scattered-light images of the two pulses in separated frames. This advantage creates the opportunity to obtain directionally resolved analysis by interrogating the images with cross-correlation techniques, which results in a precise determination of the flow direction and in a higher dynamic velocity range. Furthermore, series of double-pulsed image pairs are recordable, so that for low Reynolds numbers a certain time resolution can also be achieved.

For further information, contact Murad Karmali, the Cooke Corporation, 1091 Centre Road, Ste. 100, Auburn Hills, MI 48326-2670; (248) 276-8820; fax: (248) 276-8825; e-mail: sales@cookecorp.com; www.cookecorp.com.

CLEO®/QELS 2000: AT THE CUTTING EDGE

San Francisco's Moscone Center plays host to the paired conferences.

The 2000 Conference on Lasers and Electro-Optics and its companion Quantum Electronics and Laser Science Conference (CLEO®/QELS) will be held May 7-12 at the Moscone Convention Center in San Francisco, CA, with a technical exhibit from May 9 to 11. Quoting the Advance Program, "CLEO/QELS showcases groundbreaking peer-reviewed research, product and system design solutions, and an exhibit featuring the latest components and imaging subsystems displayed by more than 300 companies." CLEO is sponsored by IEEE/Lasers and Electro-Optics Society and the Optical Society of America (OSA) in cooperation with the Quantum Electronics and Optics Division of the European Physical Society and the Japanese Quantum Electronics Joint Group. QELS is sponsored by APS/Division of Laser Science, IEEE/Lasers and Electro-Optics Society, and OSA.

This year's technical program is divided into ten parallel sessions during the five days of the conference. The technical sessions, tutorial sessions, and two of the photonics-basics short courses will be held at the Moscone Center; the remaining 39 short courses will be held at the San Francisco Marriott Hotel. Together, CLEO and QELS have a total of 1554 presentations scheduled over the conferences' duration. These include three plenary papers and 13 tutorials. CLEO has 43 invited papers and 788 contributed papers, of which 215 will be presented in three poster sessions in the Moscone Exhibit Hall May 9-11. QELS has 59 invited papers and 351 contributed papers, of which 92 will be presented in the three poster sessions.

The plenary and awards session will take place in the Moscone Gateway Ballroom beginning at 8 a.m. Tuesday, May 9. After presentation of OSA's Charles Hard Townes Award, the 2000 Quantum Electronics Award of IEEE/Lasers and Electro-Optics Society, and the sponsors' fellow certificates, three plenary talks follow. Dr. Daniel Kleppner, Associate Director of the Research Laboratory of Electronics at the Massachusetts Institute of Technology, will describe, in "Ultracold Hydrogen—from BEC to QED," his current research on the physics of hydrogen at extremely low temperatures, Bose-Einstein condensation, and ultra-precise spectroscopy. Next, Linn F. Mollenauer, a member of the Photonics Systems Research Department at Lucent Technologies' Bell Labs, will discuss "Dispersion Maps for Ultralong-Distance, Terabit Capacity WDM." Finally, Steve Joiner, manager of the Network Architecture and Technology Department of the Communication and Optical Research Laboratory of Agilent Labs, will examine "Communications Links: Where Will VCSELs Contribute?"

A Tribute to Schawlow

Preceding the conference's formal opening, on Monday, May 8, at 6 p.m., there will be a memorial symposium honoring the late Arthur Schawlow, coinventor of the laser. Steven Chu of Stanford University will preside over special presentations by Charles Hard Townes of the University of California at Berkeley, the laser's other coinventor, Boris Stoicheff of the University of Toronto, Linn Mollenauer, and Theodore Hänsch of the University of Munich, who with Schawlow developed the theory of the laser cooling of atoms, opening up new physics research vistas. Also on Monday, beginning at 8 a.m., is a memorial symposium honoring Dan Walls, the theoretical quantum optics pioneer who also contributed to the theory of atomic Bose-Einstein condensation. Other special symposia include "High Order Correlation Effects in Condensed Matter," "Quantum Interference and Slow Light," and "Quantum Entanglement."

Poster sessions will be held Tuesday through Thursday from 1-2:30 p.m. The program committee will also accept a limited number of postdeadline papers for presentation at the meeting.

CLEO will feature three "Photonics Basics for Engineers and Technicians" (PBET) short courses, taught by educators who have worked in the field as well as in the classroom. On Sunday, May 7, from noon to 8 p.m., Shaoul Ezekiel of MIT will present "Understanding lasers and fiber optics and their applications," and Robert A. Fisher of Fisher Associates will offer "A practical introduction to polarized light." On Monday, Nick M. Massa of Springfield Technical Community College will lead "Fiber optic technology and applications."

On the business side, this year's Lasers and Electro-Optics Applications Program (LEAP) provides sessions on key issues related to high-tech business and intellectual property. They begin Wednesday, May 10, in the Convention Center. CLEO/QELS technical registrants, exhibitors, and exhibit hall visitors may attend these sessions at no cost.

Organic Light-Emitting Diodes (OLED) Have Many Potential Uses

The organic materials used may include "small" molecules or "macro" polymers.

Eastman Kodak Company, Rochester, New York

Organic light-emitting diodes (OLEDs) are grounded in a self-luminous display technology based on thin organic films as the light emitter. Like conventional inorganic light-emitting diodes (LEDs), OLEDs require a low drive voltage to produce bright visible light. But unlike discrete LEDs, which have crystalline origins, film-based OLEDs are an area emitter than can easily be patterned to produce flat-panel displays. Because OLEDs are self-luminous, they do not require a backlight as in LCDs. They have very low power requirements and are thin, bright, and efficient. As a result, many see them as the display technology of the future.

The benefits of OLED technology include the following:

- High brightness and contrast, making displays very bright and easy to read;
- Wide viewing angles, up to 160 degrees;
- Full color, to communicate the most information in the most engaging way;
- Fast response and wide temperature range of operation, for quick-response displays in a variety of environments;
- Low power consumption and operating voltage, maximizing battery life and minimizing heat and electrical interference in electronic devices;
- Light weight, compact, and thin, reducing the size and weight of devices that use displays;
- Robust, tough enough to use in portable devices such as cellular phones and personal digital assistants (PDAs); and
- Low cost.

OLED technology is already at work in car audio units produced by Pioneer Electronics. It will soon be found in cellular phones, PDAs, digital cameras, video cameras, head-wearable displays, and car instrumentation. As the technology is refined, it holds possibilities in computer monitors, video displays, ultrathin lighting panels, and even flexible displays that could be rolled and unrolled.

Eastman Kodak Company scientists discovered OLED more than a decade ago. Since then, Kodak researchers have made a number of breakthroughs that led to patents on basic OLED materials, device structure, doping techniques to improve efficiency and control color, thin-film deposition methods, patterning methods, and design and fabrication methods for both passive- and active-matrix OLED panels.

Kodak's OLED technology grew initially from research on organic electronic devices used in solar cells and electrophotography. Now the company holds more than 40 U.S. patents, has many pending applications, and has patents and applications overseas on the basic structure of OLED devices, several unique classes of OLED materials, and fabrication methods and drive schemes.

The development of OLED technology supports one of Kodak's strategic initiatives in digital imaging technology: a revolutionary electronic image display. A new active-matrix full-color OLED display, demonstrated in October by Kodak and Sanyo Electric Co., will soon be used in digital cameras and many other portable electronics. Because of their superior viewing qualities, the full-color OLED displays will replace many conventional LCD screens.

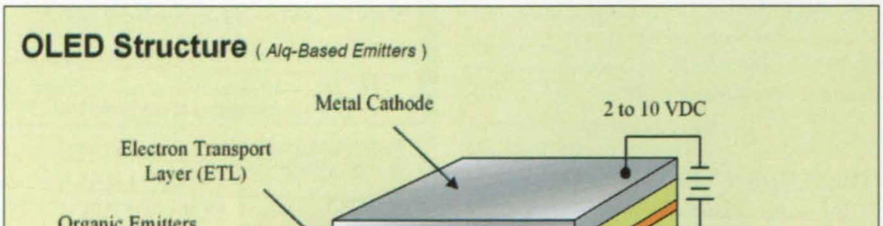


Figure 1. **The basic OLED** structure comprises several thin-film layers of organic materials (ETL, emitters, and HIL) covered over with an evaporated metal cathode. Total thickness of the deposited structure is less than the wavelength of green light.

The basic OLED cell structure (Figure 1) consists of a stack of thin organic layers sandwiched between a transparent anode and a metallic cathode. The organic layers comprise a hole-injection layer, an emissive layer, and an electron-transport layer. When an appropriate voltage (typically a few volts) is applied to the cell, the injected positive and negative charges recombine in the emissive layer to produce light (electroluminescence, or EL). The structure of the organic layers and the choice of anode and cathode are designed to maximize the recombination process in the emissive layer, thus maximizing the light output from the device. Figure 2 shows an active-matrix OLED as contrasted with a conventional LED display.

Remarkable enhancement of the electroluminescent efficiency and control of color output have been achieved by doping the emissive layer with a small amount of highly fluorescent molecules. This doping technique, patented by Kodak, is critical for producing color OLED displays.

There are two types of OLED displays, passive-matrix and active-matrix. The passive-matrix OLED display has a simple structure and is well suited for low-cost and low-information-content applications such as alphanumeric displays. The active-matrix OLED has an integrated electronic backplane as its substrate and lends itself to high-resolution, high-information-content applications, including video and graphics.

A passive display is formed by providing an array of OLED pixels connected by intersecting anode and cathode conductors. Kodak developed a relatively simple but unique method for its fabrication. Here a rib structure is preformed on patterned indium tin oxide (ITO) anode lines. As the organic materials and cathode metal are deposited, the rib structure automatically produces an OLED display panel with the desired electrical isolation for the cathode lines. To drive a passive-matrix OLED display, electrical current is passed through selected pixels by applying a voltage to the corresponding rows and columns from drivers attached to each row and column.

In contrast to the passive-matrix OLED display, an active-matrix display

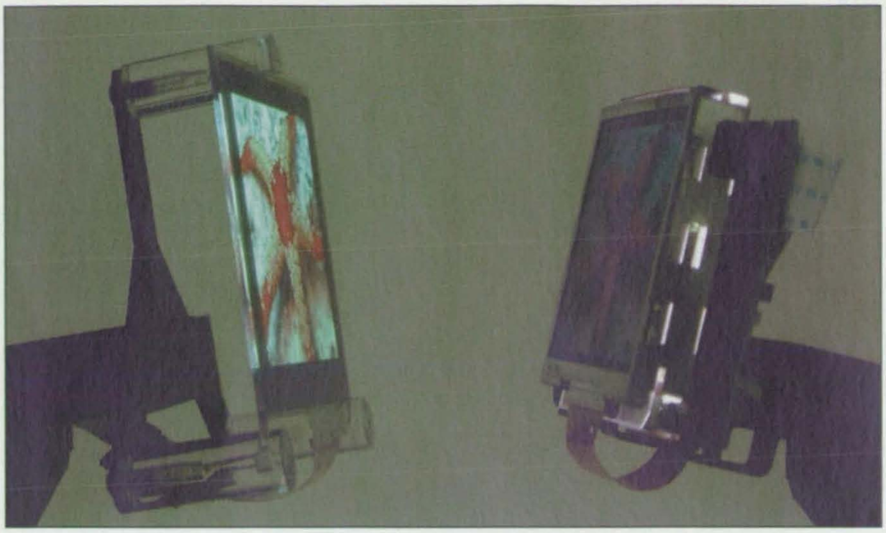


Figure 2. **The active-matrix OLED display** (left) as contrasted with a conventional LED display.

includes an electronic backplane in the display panel. This type is made possible by the development of polysilicon technology (PolySi), which because of its high carrier mobility provides thin-film transistors (TFT) with high current-carrying capability and high switching speed. There are several key advantages in active-matrix displays: low voltage and power consumption, high resolution, large area, robust pixel design, and integrated drivers.

In an active-matrix OLED display, each individual pixel can be addressed independently via the associated TFTs and capacitors in the electronic backplane. In principle, each pixel element can be selected to stay "on" during the entire frame time. Since OLED is an emissive device, the display aperture factor is not critical, unlike LCD displays, where light must pass through an aperture. Therefore, there are no intrinsic limitations to the pixel count, resolution, or size of an active-matrix OLED display. Also, thanks to the TFTs, a defective pixel produces only a dark defect, considered much less objectionable than either a bright-point defect, such as in LCD panels, or a line defect. Furthermore, constant-current drivers for OLED and the necessary scanning circuitry based on PolySci can be built directly on the substrate, thus eliminating the need for high-density (and expensive) interconnects and peripheral drivers.

Kodak engineers expect that OLED technology will have an important impact on the display industry. Low-cost manufacturing methods are already in use for passive-matrix OLED displays, and the advance of the complementary low-temperature PolySci technology has enabled fabrication of high-resolution, full-color active-matrix OLED displays. Although OLED has just entered the display marketplace, Kodak believes it will continue to expand, and the race to manufacture active-matrix OLEDs will accelerate.

For more information on Kodak Professional Products, contact Dr. David J. Williams, **Eastman Kodak Co.**, *1999 Lake Ave., Rochester, NY 14650; (716) 477-7575; or visit the web site at www.kodak.com/go/oel.*

Simplified Radiometer for Quantifying Aircraft Icing Hazard

A single radiometer would supplant a more complex system that includes two radiometers.

NASA's Jet Propulsion Laboratory, Pasadena, California

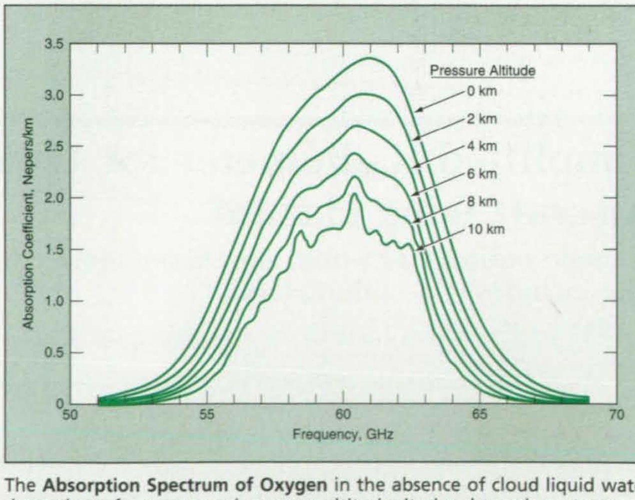
A simplified microwave radiometric apparatus has been proposed for use in quantifying the potential danger of accretion of ice onto an aircraft flying through a cloud. The quantity of interest, called the "icing hazard potential" (IHP), is the product of (1) the liquid-water content (LWC) of the cloud at a given altitude and (2) some function of the degree of supercooling of the liquid water at that altitude.

In 1983, it was demonstrated that reliable values of IHP could be calculated from readings of a ground-based instrumentation system that comprised (1) a water-vapor radiometer (for measuring LWC), (2) a microwave temperature profiler (MTP) (to measure the vertical temperature profile), (3) a hand-held infrared radiometer (to measure the cloud-base temperature and thus, in conjunction with the MTP, the cloud-base altitude), and (4) a surface meteorological subsystem (to measure surface values of temperature, barometric pressure, and humidity). The proposed system would share some features in common with the 1983 system, but would not include a water-vapor radiometer. Inasmuch as the radiometers embodied most of the cost the 1983 system, eliminating one radiometer would reduce the cost significantly.

To be able to determine the IHP, one needs to know the temperature and the LWC as a function of altitude. For the purpose of measuring these quantities, the proposed system would exploit the radiometric characteristics of oxygen and liquid water in the frequency range from about 50 to about 70 GHz. The absorption spectrum of oxygen molecules in this frequency range (see figure) depends on temperature, pressure, and water-vapor density. The brightness temperature observed by an MTP is an exponentially weighted average of all oxygen emission along its line of sight and closely approximates the air temperature at an effective distance from the radiometer equal to the reciprocal of the absorption coefficient.

Consider two observation frequencies — one on the high-frequency and one on the low-frequency side of the peak in the oxygen absorption spectrum — for which the absorption coefficient is equal. In the absence of cloud liquid water along the line of sight within the effective distance, the brightness temperatures observed at both frequencies would be the same, but in the presence of cloud liquid water, the brightness temperatures observed at the higher frequency would exceed that observed at the lower frequency, because cloud liquid water contributes to brightness temperature by an amount approximately proportional to the square of frequency. Thus, in principle, one could infer both the air temperature and the LWC from the brightness temperatures at the two frequencies.

The main radiometer in the proposed apparatus would be an extended version of an airborne MTP now in use. As such, it would include a scanning mirror used to scan the line of sight in elevation angle while measurements were taken at several pairs of frequencies (and thus several effective distances), the net effect being to acquire data from different effective altitudes. The apparatus would also include an infrared gun operating in the wavelength range of 8 to 14 μm to determine the cloud-base altitude, plus simple sensors to measure the ambient temperature, pressure, and relative humidity.



The **Absorption Spectrum of Oxygen** in the absence of cloud liquid water depends on frequency and pressure altitude; it also depends on temperature and water-vapor density, nominal values of which were assumed in computing these curves.

The proposed apparatus would cost less than airport and aircraft radar systems do. Eventually, taking advantage of monolithic microwave integrated circuitry, it should be possible to mass-produce the apparatus and install it in aircraft at relatively low cost. Because icing is of particular concern during long, slow descents and approaches, prior to miniaturization and mass production, it could be desirable to install copies of the apparatus on the approach paths of major airports to warn approaching aircraft of potential icing hazards.

This work was done by Michael J. Mahoney of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category.*
NPO-20291

Bleaching by Laser for Marking Black Anodized Aluminum

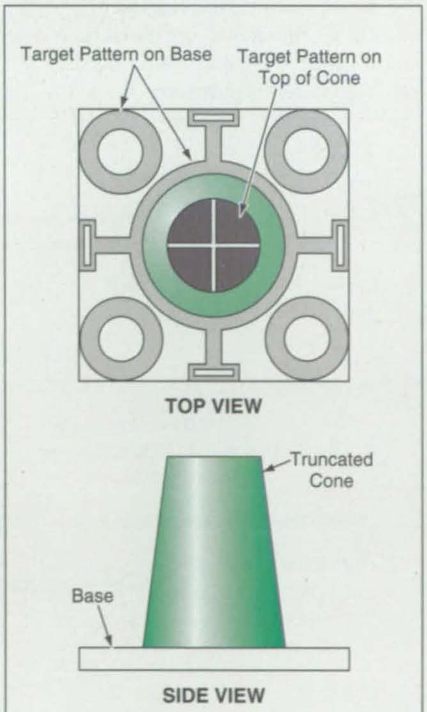
Precise, intricate patterns can be formed at relatively low cost.

Lyndon B. Johnson Space Center, Houston, Texas

Irradiation by the beam from a CO_2 laser has been found to be an effective means of marking a black anodized aluminum surface. In general, this process works on any dark anodized surface. The beam is scanned over the surface to form a desired pattern. Depending on the circumstances, this technique could be an attractive alternative to painting, machine engraving, and etching; in particular, if there is a need to create a precise and/or intricate pattern, then this technique can satisfy that need in less time and at less cost while yielding better results. For this purpose, one uses a laser that is not powerful enough to cut the aluminum workpiece but is powerful enough to bleach the anodized surface to a nearly white appearance. The precise nature and degree of the bleaching depends on the specific aluminum-alloy/anodized-coating combination and on the parameters of the laser beam and scan. Tests at different laser power levels, scanning speeds, and numbers of pulses per unit length of scan must be performed on a sample of the particular anodized aluminum to find the combination of parameters that yields the best results.

The laser-scanning mechanism is driven by the output of a graphics program running under any Windows operating system. From the perspective of the program, the laser-scanning mechanism is merely a Windows printer. The pattern to be applied is drawn by use of the program, making allowances for the width of the laser beam (analogous to the diameter of a cutting or engraving tool). The drawing is then used to perform a test on a specimen of the anodized material to be marked. The resulting pattern is measured and any necessary corrections are made in the drawing data file. The revised drawing file is then tested as before, measured, and corrected as necessary. The cycle of test, measurement, and correction is repeated until the test and measurement indicate success.

The technique has been used to mark anodized aluminum docking targets shaped as truncated cones on square bases (see figure). In this application, there is a need for some additional process steps (beyond the basic steps described above): It is necessary to measure the anodized aluminum workpiece to determine the heights of the target pattern surfaces for proper adjustment of the laser. The corrected target-pattern



Target Patterns can be formed on the upper surface of the base and the top of the truncated cone by laser scanning.

drawing file generated as described above is used to generate three additional files: one for the perimeter of the base, one for the target pattern on the base, and one for the target pattern on top of the truncated cone. The base-perimeter file is used to laser cut a hole in a sheet of poly(methyl methacrylate) or other suitable material on the laser work table; this hole is used to position the workpiece. The other two files are used to control the laser on the base and top surfaces, respectively.

This work was done by Roger Megason, Herbert Mitchell, and Marvin Williams of **Johnson Space Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Manufacturing and Fabrication category.*
MSC-22848

Three-Color Focal-Plane Array of Infrared QWIPs

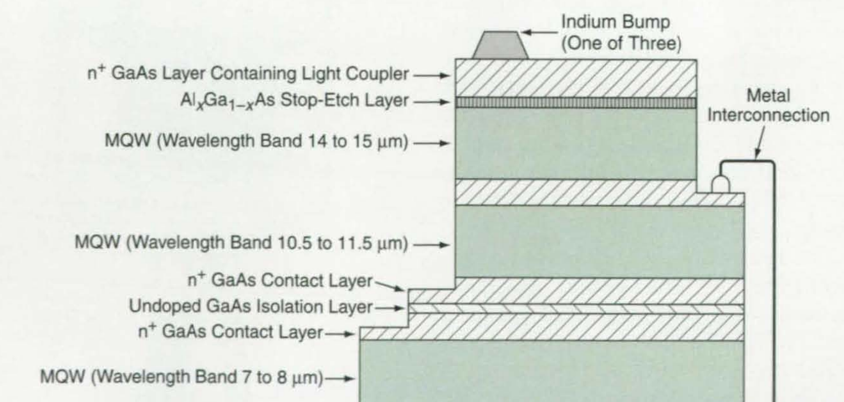
Three-wavelength imaging would provide enhanced temperature-measurement capability.

NASA's Jet Propulsion Laboratory, Pasadena, California

A proposed focal-plane array (FPA) of quantum-well infrared photodetectors (QWIPs) would sense images in three different infrared wavelength bands simultaneously. These and other QWIP infrared image sensors are undergoing development for use in measuring temperature distributions in images; potential applications include scientific (e.g., remote sensing of the Earth and other planets) and military (e.g., discriminating between targets and other objects in terms of temperature).

A one-color QWIP FPA can produce data for an absolute-temperature map of the scene only if the emissivities of the objects in the scene are known. A two-color QWIP FPA can produce data for an absolute-temperature map of the scene even when the emissivities are unknown, provided that the sensed radiation consists solely of thermal radiation from the objects in the scene. The proposed three-color QWIP FPA could produce data for a temperature map of the scene even when the sensed radiation from the object included an unknown component of infrared light, reflected from objects in the scene, that originated at an external source.

The proposed device would be fabricated from a wafer that would comprise multiple layers of $Al_xGa_{1-x}As$ formed by molecular-beam epitaxy on a semi-insulating GaAs substrate. Each pixel of the device would contain a stack of three multiple-quantum-well (MQW) $Al_xGa_{1-x}As$ structures. Each MQW structure would be



The **Device Structure** is shown here for only one of many pixels, for the sake of simplicity. Each MQW structure within a pixel would be photosensitive in one of three infrared wavelength bands; thus, the device would sense a three-color infrared image.

designed for peak photosensitivity in one of the three wavelength bands (see figure): The top MQW structure would be designed for bound-to-bound photoexcitation of electrons in the wavelength band of 14 to 15 µm; the middle MQW structure would be designed for bound-to-quasi-bound excitation in the wavelength band of 10.5 to 11.5 µm; and the bottom MQW structure would be designed for bound-to-continuum excitation in the wavelength band of 7 to 8 µm.

Each MQW structure would consist of approximately 30 periods, each period comprising (1) an $Al_xGa_{1-x}As$ barrier layer 500 Å thick and (2) a GaAs well layer. The mole fraction of aluminum (x) in the barrier layers and the geometric depth of the wells would be chosen to obtain the required spectral response; and the foregoing parameters would be chosen, along with the doping densities and the precise number of periods, to optimize the device for a specific application. The top and middle MQW structures would be separated by a 0.5-µm-thick n^+-doped GaAs contact layer. The middle and bottom MQW structures would be separated by a 0.5-µm-thick undoped (and therefore highly electrically resistive) GaAs isolation layer. Two n^+-doped GaAs contact layers would be grown on both sides of the isolation layer to serve as independent electrical contacts for the middle and bottom MQW stacks.

The three-color QWIP structure as described thus far would be grown on top of a 0.5-µm-thick n^+-doped GaAs bottom contact layer on top of an $Al_xGa_{1-x}As$ etch-stop layer on the GaAs substrate. A 300-Å-thick $Al_{0.3}Ga_{0.7}As$ stop-etch layer would be grown on top of the topmost n+-doped GaAs contact layer. On top of the stop-etch layer, a 1.3-µm-thick n^+-doped GaAs contact and cap layer would be grown, and a light coupler would be fabricated in this layer as described subsequently. The contact layer between the top and middle MQW structures would be short-circuited to the contact layer between the bottom MQW and the substrate, to establish a common (ground) bus. Only three indium bumps per pixel would be needed for bonding the device to a silicon readout integrated circuit that would provide independent readout for each wavelength in each pixel.

As explained in more detail in several prior *NASA Tech Briefs* articles, in order to make photoexcitation possible, a light coupler is needed to alter the polarization of normally incident light so that the light propagating within the device is polarized at least partly along the through-the-thickness direction. In the proposed device, the light coupler would be an achromatic array of reflectors comprising a square pattern of cells, each cell comprising a three-by-three array of subcells. Within each cell, the depths of eight subcells would be chosen to obtain destructive interference at the middle wavelengths of all three wavelength bands; the depth of the ninth subcell would be chosen at random. The cell surfaces would be coated with Au/Ge and Au for ohmic contact and reflection.

This work was done by Sumith Bandara, Sarath Gunapala, John K. Liu, Daniel Wilson, and William Parrish of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category.*

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Refer to NPO-20683, volume and number of this NASA Tech Briefs *issue, and the page number.*

Optical Filters Based on Dense Arrays of Microscopic Pillars

Structures found in moth eyes would be adapted to a variety of uses.

NASA's Jet Propulsion Laboratory, Pasadena, California

A proposal for development of a class of high-transmission and antireflection optical filters is derived from the observation that the eyes of moths reflect almost no light, regardless of the wavelength or the angle of incidence of illumination. The low-reflection property of moth eyes is attributable to dense arrays of microscopic pillars that exhibit little or no diffraction or scattering. This is because (1) the dimensions and pitches of the pillars are smaller than the shortest wavelength of incident light in the wavelength range of interest and (2) a dense array of pillars provides a gradual transition in density from open space to a bulk solid material, so that an abrupt density change, which would generate reflections, is not present.

Long-wavelength-pass filters based on this principle could be used in spectrometers and possibly other optical instruments. For example, one could build a matrix of arrays of microscopic pillars over a matrix of miniature thermoelectric devices, thermopiles, or other detectors. The pillars in each array would have a size and pitch corresponding to a specific cutoff wavelength. Each array would transmit (almost totally) only light at wavelengths greater than its cutoff wavelength to the underlying detectors. The multiplicity of cutoff wavelengths associated with the arrays in the matrix would define increments of a spectrum; thus, in effect, one would have a filter/sensor spectrometer unit with no moving parts.

Large surfaces textured with moth-eye textures have been fabricated by use of holography. To fabricate arrays of microscopic pillars with specific sizes and shapes (or to fabricate matrices of such arrays with different pitches for different cutoff wavelengths), it would be necessary to use x-ray lithography. For example, one would expose a negative x-ray resist to x-rays through a density mask containing nanometer-scale features created by electron-beam milling. The pillars would then be formed as the material left after etching of the exposed resist.

It has also been proposed to make variable-cutoff long-wavelength-pass filters. Such a filter would consist of an array of suitably shaped, sized, and pitched micropillars on a transparent piezoelectric substrate. The cutoff wavelength would be varied by applying a voltage to expand or contract the substrate.

This work was done by Frank Hartley of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category.*

NPO-20448

Tridirectional Gratings as Improved Couplers for QWIPs

Degrees of coupling should exceed those of bidirectional gratings.

NASA's Jet Propulsion Laboratory, Pasadena, California

Tridirectional diffraction gratings have been proposed to provide optical coupling to quantum-well infrared photodetectors (QWIPs) in focal-plane arrays. The tridirectional gratings would be improved versions of the bidirectional (rectangular-pattern) gratings described in "Cross-Grating Coupling for Focal-Plane Arrays of QWIPS" (NPO-19657), *NASA Tech Briefs*, Vol. 22, No. 1 (January 1998), page 6a. The tridirectional gratings would comprise metal patches or holes arranged in a pattern of closely packed regular hexagonal cells (see figure), with dimensions chosen to optimize diffraction patterns to maximize coupling within narrow spectral bands of interest.

A brief review of the problem of coupling light into a QWIP is prerequisite to an explanation of the improvement expected to accrue from the use of the tridirectional gratings. The QWIP light-coupling problem results from three considerations: (1) the direction through the thicknesses of the quantum wells is perpendicular to the focal plane; (2) quantum selection rules allow the detection of only that part of the incident light that is electrically polarized along the direction through the thicknesses of the quantum wells and thus perpendicular to the focal plane; and (3) the light to be detected is incident along directions approximately perpendicular to the focal plane, and thus only a small fraction of it is electrically polarized along the thicknesses of the quantum wells.

By diffracting light so that at least some of it propagates within the quantum wells at angles other than perpendicular to the focal plane, one changes the plane of polarization so that the through-the-thickness component of polarization is increased. Thus, coupling is increased. The problem in designing a grating (whether linear, bidirectional, or tridirectional) for coupling is to choose the dimensions of the grating to maximize the first-order diffraction of optical power to suitable angles away from the perpendicular. Because a tridirectional grating would exhibit the same periodicity along three directions in the focal plane (instead of only two directions for a corresponding rectangular-pattern cross grating or one direction for a corresponding linear grating), the tridirectional grating would diffract more light to higher angles and thus give rise to increased coupling.

One might be tempted to extend the tridirectional-grating concept to gratings with octagonal or even more complex unit cells in the hope of exploiting periodicity along a greater number of directions. However, this approach would be unlikely to yield any improvement because of a fundamental geometric limitation: Any packing of regular octagons or regular higher polygons in a regular pattern would necessarily create empty interstitial areas.

This work was done by Sumith V. Bandara, Sarath Gunapala, Daniel Wilson, and John K. Liu of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category.*

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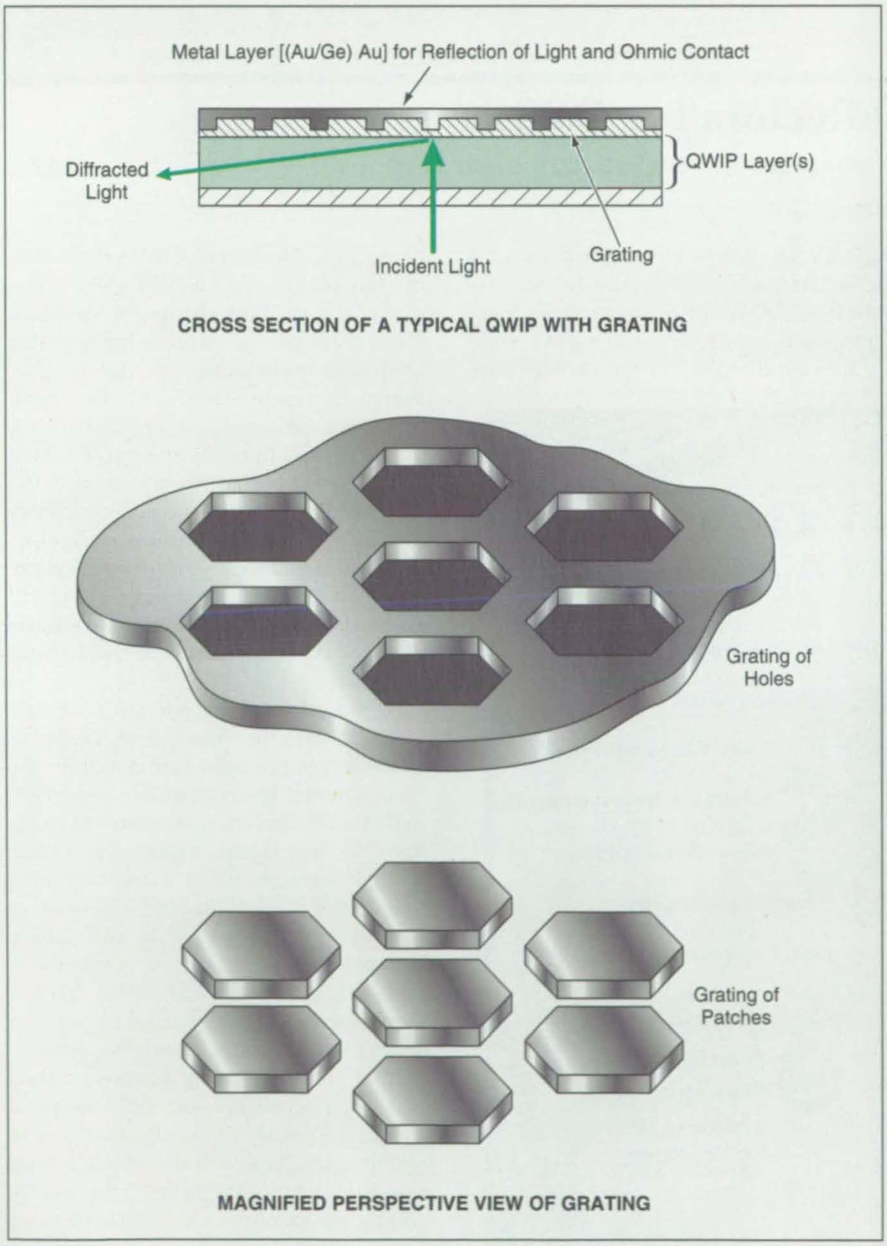

A **Hexagonal Pattern** of either patches of metal film or holes in an otherwise continuous metal film would constitute a tridirectional grating for coupling of light into the quantum-well layer(s) of a QWIP. The grating would be formed in the cap layer of the QWIP.

Update on Fuzzy-Logic-Enhanced Digital-PIV Software

John H. Glenn Research Center, Cleveland, Ohio

Two reports present additional information on the subject matter of "Software for Processing Data in Particle-Image Velocimetry" (LEW-16857), *NASA Tech Briefs*, Vol. 24, No. 1 (January 2000), page 26a. Like the cited prior article, both reports discuss the principles and the practical aspects of particle-image velocimetry (PIV), which is a method of determining a flow velocity field from images of small seed particles that are entrained in the flow and that are illuminated by laser pulses at known intervals of time. Also like the cited prior article, the reports describe PIVPROC — a user-friendly computer program that creates an interactive computing environment for displaying and processing PIV image data and that employs fuzzy logic to maximize the amount and quality of velocity information extracted from the raw data. The cited prior article mentioned in passing that PIVPROC supports the combined use of cross-correlation and particle-tracking image-data-processing techniques to obtain high-quality velocity data over a wide range of particle-seeding densities; the two reports discuss this aspect of PIVPROC in more detail, with some emphasis on the fact that this combination of techniques yields velocities with the highest possible spatial resolution.

This work was done by Mark Wernet of **Glenn Research Center**. *To obtain copies of the reports, "Fuzzy Logic Enhanced Digital PIV Software" and "Particle Image Velocimetry Processing: PIVPROC," access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Mechanics category.*

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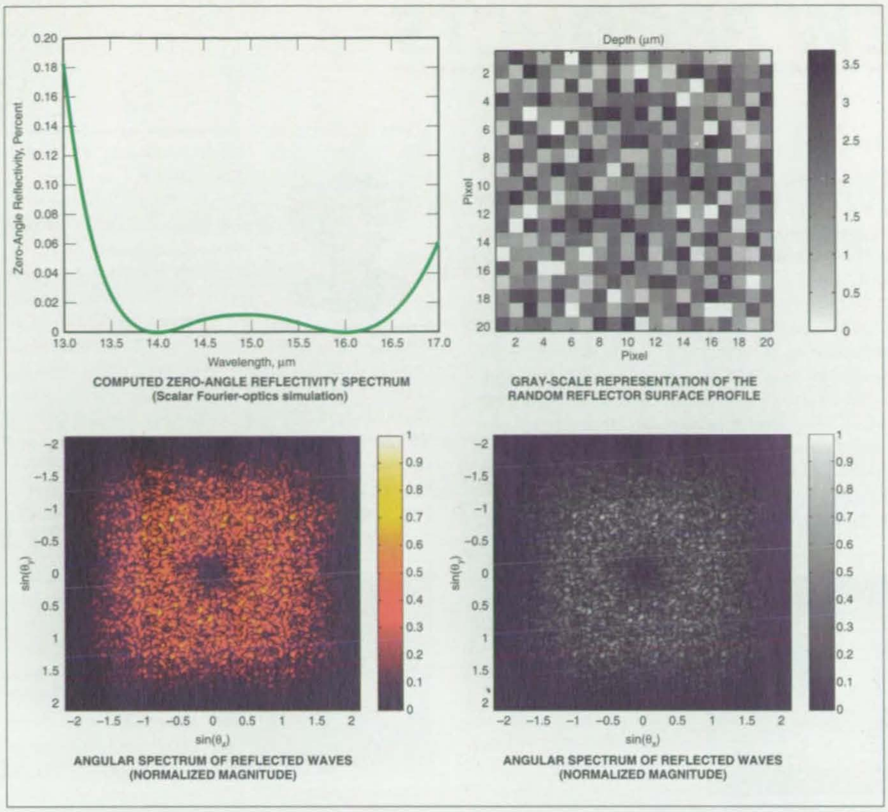
Two-Color Random Reflectors for QWIPs

Reflectors could be designed for two-band or single-broad-band response.

NASA's Jet Propulsion Laboratory, Pasadena, California

Random reflectors of a proposed type would be fabricated on the back surfaces of quantum-well infrared photodetectors (QWIPs) to increase the coupling efficiency of infrared light into the QWIPs in two wavelength bands. A reflective surface according to this proposal would comprise an array of square cells, each cell divided into a 2-by-2 array of subcells that would lie at various, partly random depths relative to the nominal flat back surface of the QWIP. The subcells at the various depths would be formed by one of several lithographic processes, depending on the specific design. In comparison with the light-scattering efficiency of crossed-diffraction-grating QWIP light couplers that have been reported previously in *NASA Tech Briefs*, the light-scattering efficiency of the proposed random reflectors would be less dependent on wavelength; this would be an advantage in QWIP applications in which there are requirements for broad-band or multiband response.

As discussed in more detail in several prior articles in *NASA Tech Briefs*, in order to couple light into a QWIP, the quantum-well layers of which lie parallel to its focal plane, it is necessary to cause light to propagate within the QWIP along a direction other than perpendicular to the focal plane; the efficiency of coupling increases with the angle between the direction of propagation and the perpendicular. Most of the incoming light is concentrated within a small angular range about the perpendicular. Therefore, the purpose served by the proposed random reflectors and by the previously reported cross-grating QWIP light couplers is to exploit diffraction to divert the incoming light, as efficiently as possible, to propagation at large angles from the perpendicular. Additionally, light that is not absorbed will get reflected and encounter a differ-



The **Zero-Angle Reflectivity Spectrum and the Diffraction Pattern** were computed for the reflector pattern shown at the top. (The actual relfectivity would likely be greater but similar in shape.) The computations were based on free-space wavelengths of 14 and 16 µm, a subcell (reflector-grid) interval of 2.5 µm, and an index of refraction of QWIP material of 3.1. A free-space wavelength of 15 µm was used in calculating the diffraction pattern.

ent structure on each bounce. This improves the ability of the QWIP to trap the light and absorb a larger fraction of photons.

For maximum diffraction at high angles, the subcells would be given dimensions of the order of the wavelengths of interest. It would also be necessary to minimize low-angle diffraction in order to minimize waste of light. Therefore, the depths of the subcells would be chosen so that at the middle wavelengths of both wavelength bands of interest, any light propagating along the perpendicular direction would interfere destructively. Specifically, the depths of the four subcells (d_i, $i = 1$ to 4) of a given cell would be as follows:

d_1 = a random value between 0 and $\lambda_1/4$,

$d_2 = d_1 + \lambda_1/4$,

$d_3 = d_1 + \lambda_2/4$, and

$d_4 = d_1 + \lambda_1/4 + \lambda_2/4$,

where λ_1 and λ_2 are the two wavelengths of interest inside the QWIP material.

This choice of depths would cause the subcells to act in pairs to produce destructive interference: At λ_1, destructive interference would occur between subcells 1 and 2 and between subcells 3 and 4; at λ_2, destructive interference would occur between subcells 1 and 3 and between subcells 2 and 4.

The figure shows a gray-scale representation of a reflector pattern of this type, a plot of the computed zero-angle (perpendicular) reflectivity, and a gray-scale representation of the computed diffraction magnitude as a function of the sine of the angular deviation (θ) from the perpendicular. All waves inside the circle of radius $\sin(\theta) = 1$ are propagating, and those outside the circle are evanescent. As needed for efficient coupling, the computed zero-angle reflectivity goes to zero at the two design wavelengths and the computed diffraction magnitude at high angles is strong.

This work was done by Daniel Wilson, Sumith Bandara, Sarath Gunapala, and John K. Liu of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category.*

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NEW PRODUCTS

PRODUCT OF THE MONTH

Fiber-Coupled Laser Diode System

Coherent Semiconductor Group, Santa Clara, CA, introduces the F-Package System, which it describes as a standalone microprocessor-controlled fiber-coupled laser diode system in wavelengths from 650 to 980 nm. Delivering its power through a 0.5-m-long large-core optical fiber, the module consists of a single-stripe laser diode, rated from 0.2 to 2.5 W depending on the configuration, mounted on an active air-cooled heat sink with an optional thermoelectric cooler capable of regulating case temperature from 10-40 °C, along with all necessary laser and TEC drive and control electronics. The F-Package system allows users to swap-out laser diodes at different wavelengths to support a wide variety of applications, including soldering, epoxy curing, medical therapeutics, graphic arts and pumping solid-state laser media.

For More Information Circle No. 736

2.5-Gb/s Oxide VCSEL

The MODE Division of Emcore Corp., Albuquerque, NM, makes available what it terms the industry's first commercial 850-nm 2.5-Gb/s oxide vertical-cavity surface-emitting laser (VCSEL). The company designed Gigalase® with OxideGuide® sources to be the critical high-speed optical link for next-generation serial and parallel optical transceivers for OC-192 and similar uses. Emcore says the VCSEL provides lower current thresholds and smoother slope efficiencies to meet performance requirements of existing and future Gigabit Ethernet standards. The VCSELs are available as bare die or in TO-cans or optical assemblies.

For More Information Circle No. 737

Surface-Mount Bias Tee

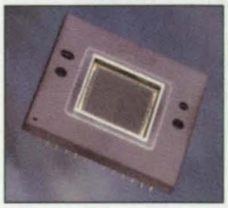
Designed for 10-Gb/s fiber optic telecommunications and data communications applications, the SM 100 surface-mount bias tee from Picosecond Pulse Labs, Inc., Boulder, CO, provides a broadband pulse response for delivering bias and signal to laser diodes or modulators. Features of the tee are 14-kHz-to-13-GHz bandwidth, 21-ps rise time, and maximum DC current of 500 mA. The SM 100's footprint is 0.64 × 1.02 in., and its height 0.252 in. The company says the device will enable engineers to achieve better bit-error-rate performance in systems, and its small size and low cost are additional benefits.

For More Information Circle No. 738

DWDM Comb Source

ILX Lightwave, Bozeman, MT, introduces the FTS-9200 high-density DWDM Advanced Comb Source for optical amplifier and component test and measurement. With up to 48 distributed feedback sources, it features 10- and 20-mW output power, wavelengths across the C- and L-bands from 1528-1610 nm, integrated coherence control, internal and external modulation capabilities, and source shutters. The device also has an integrated multiplexer and variable optical attenuator. According to the company, the FTS-9200's laser diode calibration and control technology have been improved.

For More Information Circle No. 739



Four-Million-Pixel Image Sensor

Eastman Kodak Co., Rochester, NY, is offering the Digital Science™ KAI-4000M four-megapixel solid-state image sensor. The charge-coupled device, with 2048-×-2048-pixel resolution, was designed specifically for medical applications such as fluoroscopy and digital x-ray. Kodak cites the electronic shutter, exposure control, antiblooming protection, low smear, and high dynamic range (60 dB) as contributing to the sensor's high performance. At a 20-MHz clock rate, the quad output architecture allows 15 full frames per second (in the progressive scan option) readout.

For More Information Circle No. 740

Optical Channel Analyzer

Burleigh Instruments, Fishers, NY, announces the availability of the WA-7000 multi-line Wavemeter™ optical channel analyzer, which it says provides the full optical spectrum for precise DWDM channel analysis. The instrument combines Burleigh's scanning Michelson interferometer-based technology with digital processing to measure and differentiate the absolute wavelengths of up to 200 discrete optical channels. The company says accuracy of the measurements is ±1.5 pm, with a spectral resolution as high as 50 pm. The WA-7000 also can calculate parameters such as channel spacing, drift, and signal-to-noise ratios.

For More Information Circle No. 741

1310-nm Optical Amplifier

IPG Photonics, Sturbridge, MA, is offering Fluoroamp 1310, an optical amplifier for that wavelength available in three configurations. As a CATV amplifier its input power is +2-8 dBm, output power up to +18 dBm, and noise <5.5 dB; as a single-stage telecom amplifier, its input power is -20-+8 dBm, output power up to +18 dBm, and noise <6.5 dB; as a dual-stage telecom amplifier, its input power is -25–10 dBm, output power up to +18 dBm, and noise <7.5 dB. Wavelength range is 1290-1320 nm (telecom) and 1295-1314 nm (CATV).

For More Information Circle No. 742

Industrial Gauging Sensors

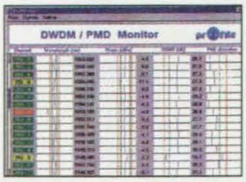
The Industrial Sensors Division of Laser Measurement International (LMI), Heerlen, the Netherlands, says its LMI Selcom SLS 7000 non-contact laser-based specular reflective sensor measures with a 10-nanometer accuracy. It has a 16-kHz sample rate and a 10- to 20-micron visible laser spot that enables profiling of intricate target structures such as minuscule cracks and grooves. LMI says the sensor was designed to measure perfect mirrors, silicon wafers, stainless steel, and other reflective materials.

For More Information Circle No. 743

High-Resolution Enlarging Lenses

Rodenstock Precision Optics, Rockford, IL, has added to its line of high-resolution enlarging lenses. The Apo-Rodagon-N lenses are available in 45 mm, 75 mm, and 90 mm. They are apochromatically corrected lenses that ensure elimination of visible color fringes on high-contrast borders, and are a preferred lens for b&w imaging, according to the company. Rodenstock recommends the lenses for scanners, inspection equipment, duplication work, macro photography, and high-frequency cameras.

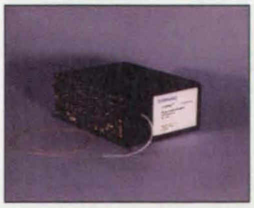
For More Information Circle No. 744



DWDM/PMD Monitor

Profile Inc., Rockaway, NJ, says its DWDM/PMD monitor is an all-optical solution to detect polarization-mode-dispersion (PMD) distortions, give a feedback signal for PMD compensation, and supervise wavelengths, optical power, and optical S/N ratio of each channel of a DWDM network. The company says the device is suited for 10-Gb/s and 40-Gb/s transmission systems. Compared to conventional channel monitoring devices, the system is faster and could be used for PMD compensation independent of the operating bit rate. Minimum detectable PMD change is 0.5 ps.

For More Information Circle No. 745



Dynamic Spectral Equalizer

The Optical Networking Devices division of Corning Inc., Corning, NY, introduces the PurePath dynamic spectral equalizer, a liquid-crystal-based instrument that extends the reach of long-haul communication and DWDM networks by correcting spectral nonuniformities caused by passband narrowing. The company says the equalizer's features include high resolution, fast response time, high isolation, and low insertion loss. It can individually attenuate 40 channels at 100-GHz spacing, and is extendable to 80 channels at 50 GHz.

For More Information Circle No. 746

Vol. 24, No. 5 May 2000 This form expires: October 31, 2000

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FREE NEWSLETTER

IDL 5.3.1 — Great for Interactive Analysis

Steven S. Ross

Does your organization have piles of data that need to be crunched? If the data set is static, there are some great purely statistical packages to do the job — Statistica, SAS, and SPSS among them. If you don't need the stats, but do need nice graphics, Excel or a similar spreadsheet might fill the bill — especially if augmented by an add-on program such as Harvard Chart XL.

But what if your data set is constantly updated, or you want to send data out to many project team members to play with? What if you need to do the stats and the graphics as well? Then IDL (Interactive Data Language) from Research Systems, Boulder, CO, might be just the thing for you. There's an added bonus. The basic package comes with everything you need to create standalone modules for exploring data, even within other applications such as Word or Excel. IDL is an OLE/COM server and comes with an interface builder's kit. The latest version, 5.3.1, even has ActiveX controls for viewing IDL-generated analyses over a network.

The wavelet transform is an orthogonal transform that can be used to reduce the size of a data set. The compression percentage can be adjusted by moving the slider or by clicking and dragging in the plot window.

This is programming, though. Is the learning curve worth it? Many will think it is. It is fairly easy to come up to speed with IDL, at least for straightforward tasks. But the extra niceties do take some getting used to. For example, to process really huge data sets — upwards of a million cells — faster, you can go to wavelet processing or you might consider tweaking the system, perhaps to do everything in integer math instead of 64-bit floating point.

Like MATLAB from The MathWorks, IDL is particularly good at processing arrays — tables and tables of data. The language is compact (a few lines of IDL code can replace hundreds of lines of C++ or FORTRAN). Users of these languages tend to rely on huge subroutine libraries, but even when such libraries are available, the writing and debugging process can be painful. With IDL, signal processing and image processing can be done almost painlessly, once you learn the basic syntax.

Here's an example: Applying a lowpass filter to the noisy data allows low-frequency components to remain unchanged while high-frequencies are smoothed or attenuated. You can construct a filter function by entering step-by-step commands.

To filter data in the frequency domain, we multiply the Fourier transform of the data by the frequency response of a filter and then apply an inverse Fourier transform to return the data to the spatial domain.

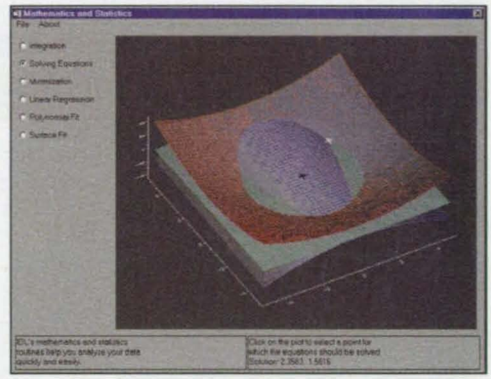
The results can be output graphically, either as static images or as animations. There's good OpenGL graphics support, assuring portability of the programs you write in IDL among various OpenGL platforms.

Existing FORTRAN and C routines can be linked into dynamically. Alternatively, you can write C and FORTRAN programs to call IDL routines as a subroutine library or display "engine."

IDL has been an evolutionary product, with frequent upgrades. Version 5.3 offers faster operation and many enhanced features, including some new commands. Some of the biggest improvements came in speed and in 3D visualization. Often, this has come about because Research Systems has been rewriting subroutines that were written in other languages, into IDL itself as new commands become available.

IDL can read CDF (Common Data Format), HDF (Hierarchical Data Format), HDF-EOS (Earth Observing System extensions to HDF) and netCDF (Network Common Data Format). It can also handle numerous graphics formats including BMP, PNG, GEO TIFF, PPM, SRF, Interfile, JPEG, GIF, and PICT. It can even read DXF (a CAD format) and WAV audio files.

There are versions for Windows, UNIX, VMS, and Macintosh. We reviewed in the Windows NT 4.0 version. The trick to producing portable IDL applications — ones that run on all platforms — is to avoid platform-specific features. Research Systems lists all the trouble spots. If you have, say, the Windows 95/98 version, you can move files across to a Macintosh and use the Mac version to compile the program. Pricing ranges from $1,895 for a single-user PC or PowerMac license, to $3,895 for a single-user, floating network workstation license.



IDL's mathematics and statistics routines help you analyze your data quickly and easily. You can click on the plot to select a point for which the equations should be solved.

A full install requires roughly 140 MB of hard drive space in Windows. The software ran well on a 200-MHz Pentium Pro with 64 MB of RAM. You can download a trial version (it won't save or print files, and it runs for only seven minutes at a time) from www.researchsystems.com. The download is about 80 MB. If you lack a fast connection to the Internet, ask for a demo CD.

Steven S. Ross teaches journalism at Columbia University in New York City. He has authored three commercial software packages, including a units conversion program and an engineering calculations program.

Bruce Spiering, Instrumentation Engineer Stennis Space Center

Bruce Spiering is an Instrumentation Engineer in the Earth System Science Office (ESSO) at NASA's Stennis Space Center (SSC) in Mississippi. He uses optical techniques in remote sensing to conduct research in plant physiology and ocean primary productivity. Spiering developed the Portable Multispectral Imaging Device (PMID), which produces multiple video images of the same scene at spectral bands ranging from the ultraviolet through the infrared.

***NASA Tech Briefs:* What was the original NASA application for the PMID?**

Bruce Spiering: The original idea was to develop a low-cost, reconfigurable optical system that would allow any images in any spectral bands to be acquired so that they were co-registered to each other. That is, each point in a given image aligns with the corresponding point in the other images. This allows processing to be done on the images as they are being acquired, without having to co-register them in some other way. Acquiring multispectral images for analysis is generally referred to as remote sensing. Since there is a broad spectrum of research and application areas that require or can benefit from such processing, the objective was to develop a system that could potentially address many NASA applications, such as hydrogen-fire detection or finding ice on the Space Shuttle's external tank prior to launch.

NTB: Why was PMID technology selected for measuring chlorophyll levels in plants?

Spiering: Dr. Greg Carter, who is also located at Stennis, had been investigating the use of remote sensing to estimate chlorophyll levels in plants for several years. He had identified the appropriate spectral bands, the algorithm for processing the data, and the lab and field methods for acquiring the data. He had been primarily using non-imaging instruments to conduct the research, but had also used individual cameras with the appropriate spectral filters to acquire images of plants. Since the cameras each had independent optical systems (lenses), it was necessary to co-register the images before any of the algorithms could be applied to them. This can require a significant amount of labor, particularly if there are many images acquired. It also requires some relatively expensive software. The use of the PMID eliminates that process.

NTB: How does the PMID work?

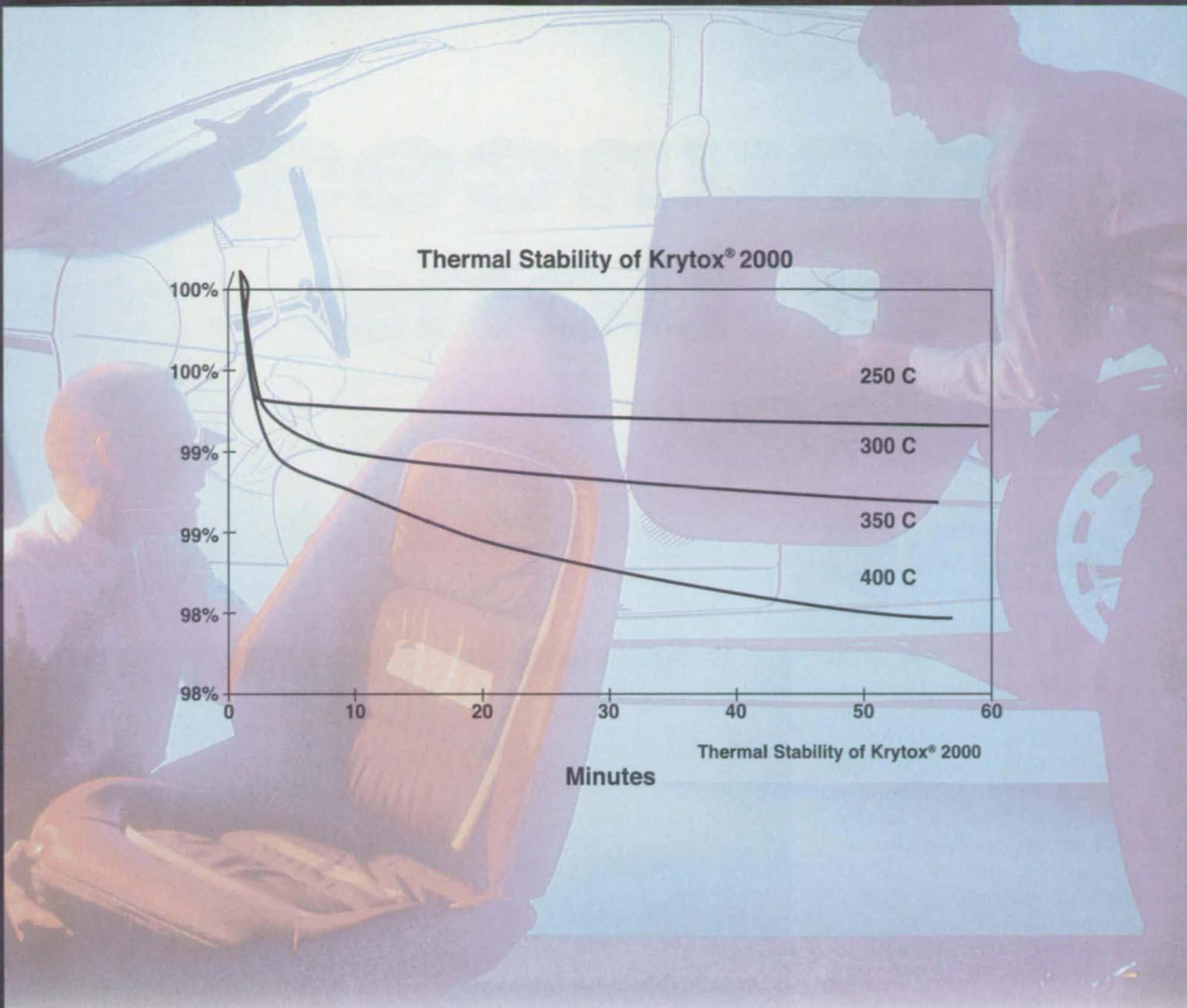
Spiering: A primary objective lens focuses on an image at a field stop. This image is then collimated by a second lens. This produces a collimated beam that is projected through beam splitters, allowing the light to be divided and directed through a spectral filter to one or more image-acquisition systems, such as CCD cameras or even film cameras. Each of the cameras is focused back through the collimating lens onto the same field stop as the primary lens. This allows each camera to be focused, aligned, and given the appropriate magnification so that each image is the same size and is co-registered to the others.

NTB: What features make this device readily adaptable to other applications?

Spiering: The PMID is adaptable due to the fact that the filters can be changed, the primary lens can be changed, and different types of cameras or imaging devices can be used.

As the potential for using multispectral imaging to solve problems becomes more widely known, there is no limit to the number and variety of applications that might develop from industrial, to agricultural, to medical. The main emphasis right now is on agriculture. A farmer would use the data to get a current assessment of crops, as to whether fertilizer is needed and so on. The technology has been licensed for evaluating agricultural crops such as corn, soybeans, cotton, and many others. This type of system could also be used by the horticulture industry and in golf-course management. Other applications could include industrial machine vision for such things as product evaluation, where a few spectral bands could provide a better detection probability than a broad-spectrum camera.

A full transcript of this interview is available at www.nasatech.com. Mr. Spiering can be reached at bruce.spiering@ssc.nasa.gov.



Thermal Stability of Krytox® 2000
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100%
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350 C
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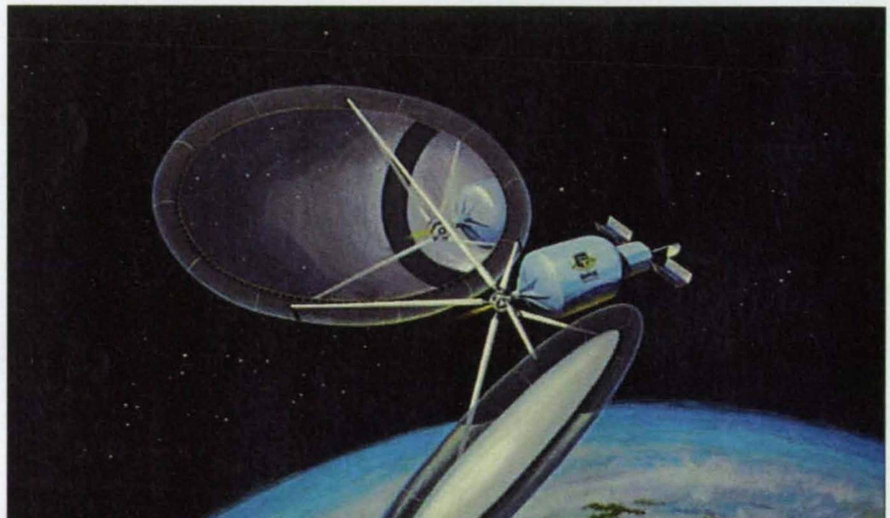
Thermal Stability of Krytox® 2000
Minutes

NASA Announces Inventions of the Year

NASA has selected a high-performance optical encoder and a new class of polyimides as the agency's top inventions for 1999. Douglas B. Leviton of Goddard Space Flight Center has been named winner of the NASA Government Invention of the Year Award for developing the Method and Apparatus for Ultra-High-Sensitivity, Incremental and Absolute Optical Encoding. NASA's Commercial Invention of the Year is the Colorless and Low Dielectric Polyimide Thin Film Technology developed at Langley Research Center. While these inventions originally were designed for spaceborne operations, each has significant terrestrial potential.



SRS Technologies' large concentrators used to collect solar energy for the Solar Thermal Propulsion orbital transfer vehicle (SOTV) are made almost entirely of the advanced polyimide materials developed at Langley Research Center. (Photo courtesy of SRS Technologies)

Revolutionary Polyimides

The Colorless and Low Dielectric Polyimide Thin Film Technology — NASA's Commercial Invention of the Year — has resulted in a class of revolutionary polyimides exhibiting remarkable qualities in the areas of transparency, ultraviolet resistance, and operating temperatures. These materials, known as LARC™-CP1 and LARC™-CP2, are the subject of four U.S. patents, a European patent, and a Canadian patent. The technology was developed at NASA's Langley Research Center in Hampton, VA, by Anne K. St. Clair, Dr. Terry L. St. Clair, and Dr. William P. Winfree.

When cast in a thin-film format, the patented invention is optically clear, highly resistant to the ultraviolet-radiation environment of space, moisture resistant, and has excellent thermal stability at high temperatures. Films may be obtained by hand-brushing, casting, or spraying a layer of solution onto a surface and thermally converting the applied layer to the patented polyimide. An alternative method is to chemically convert the solution to the polyimide, dissolve the polyimide in an organic solvent, apply a film layer of dissolved polyimide onto a surface, and thermally remove the solvent.

This invention has been licensed to SRS Technologies of Huntsville, AL, and to Triton Systems of Chelmsford, MA. The polyimides are being used in the manufacture of solar sails, thin-film solar concentrators, large antennae, solar thermal propulsion systems, and other space applications. SRS is using the material to produce flat film panels for Hughes, which is integrating 16 of the panels into a solar power system to be launched on a satellite later this year. The low-cost, lightweight panels produced with this film are expected to increase power production of photovoltaic arrays by 70 percent.

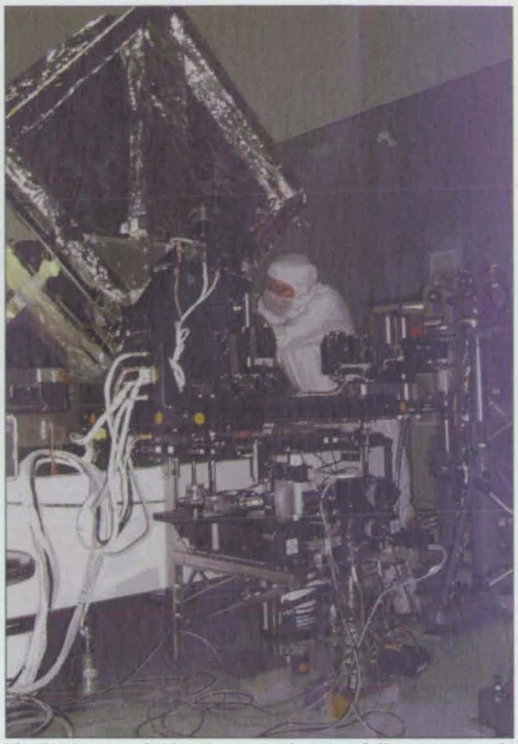
Future applications for the polyimides include optics for use in space applications, thermal-control coatings, solar shielding, high-temperature wire and cable wrapping, coatings for integrated circuits, and insulation for electric motors and generators. Additional applications include flexible printed circuit boards, liquid crystal displays, multi-chip module interlayer dielectrics, solar cells and arrays, UV-resistant protective coatings for art and outdoor statues, and UV-resistant additives for cosmetics and commercial exterior paints.

The Colorless and Low Dielectric Polyimide Thin Film Technology is also NASA's nominee for the National Inventor of the Year Award, sponsored by the Intellectual Property Owners, Inc. (IPO), in cooperation with the U.S. Patent and Trademark Office. For more information on the technology, visit www.stg.srs.com/Aerospace/advpolymers.htm.

High-Performance Absolute Optical Encoder

The Method and Apparatus for Ultra-High-Sensitivity, Incremental and Absolute Optical Encoding was invented by Douglas B. Leviton of the NASA/GSFC Optics Branch at Goddard Space Flight Center, Greenbelt, MD. In its simplest form, the encoder measures the position of a moving object by observing a set of marks, each unique, passing the encoder's imaging detector. Its innovative design offers the advantages of increased reliability, compact form, low-cost production, and higher sensitivity over what is commercially available.

This patented encoder employs several mature technologies, including microlithography, optical projection, electronic imaging, and high-speed image processing. The pattern used on the encoder's glass scale is very coarse compared with those of existing encoders, and the position information obtained is derived by digital processing of scale images. These features result in a considerable immunity to damage-induced loss of position information and about an order of magnitude higher sensitivity over commercially available encoders. The NASA encoder, which has 0.02 arcseconds sensitivity, is under 150 mm in diameter and costs under $5,000 to produce. A commercial absolute encoder with the same resolution is more than 1,000 mm in diameter and costs approximately $200,000. The linear version of the encoder has sensitivity down to 10 nm.



The NASA encoder has been used successfully to accurately position the Reflective Aberration Simulating Calibrator in front of the Hubble Space Telescope (HST) Advanced Camera for Surveys (ACS), and for calibrating ultraviolet spectral dispersion of flight prisms within ACS.

This high-performance optical encoder promises to substantially improve the pointing accuracy of future orbiting telescopes, perhaps even the Next Generation Space Telescope (NGST), scheduled for launch in 2008. It already has been successfully used for calibrating ultraviolet spectral dispersion for flight prisms for the Hubble Space Telescope (HST) Advanced Camera for Surveys (ACS) and will be used in the ultra-precise calibration stimulus for HST Wide Field Camera 3 (WFC3). When there was an apparent problem with the accuracy of an encoder used in the High-Resolution Doppler Limb Sounder (HIRDLS) instrument for the Earth Observing System's Chemistry spacecraft (EOS/CHEM), the NASA encoder was used to verify the HIRDLS encoder's performance, saving the agency considerable costs associated with commercial calibration or replacement. The encoder also has been used in a variety of mission-critical NASA metrology operations which were otherwise technically unachievable or impossible from a cost standpoint.

According to NASA, various commercial enterprises have shown interest in the NASA encoder for applications including high accuracy gimbals, linear positioning platforms for microlithography steppers, inspection equipment, computer-aided machining, and high-accuracy rotary air bearing spindles for the disk-drive manufacturing industry, where higher angular accuracy can mean higher possible information-storage density and reliability.

For more information, visit http://opticsnts.gsfc.nasa.gov/technology/encoders/invention_1999.htm

The Year's Best

NASA's top inventors were honored during a ceremony at NASA Headquarters. Here are the remaining 1999 Invention of the Year nominees:

Glenn Research Center

- Producing Fiber Reinforced Composites Having Dense Ceramic Matrices. Inventors: Donald R. Behrendt and Mrityunjay Singh. NASA Case # LEW 15449-1.
- Self-Lubricating Composite Chromium Oxide. Inventors: Christopher Dellacorte and Brian J. Edmonds. NASA Case # LEW 16183-1.

Johnson Space Flight Center

- Active Synthetic Soil. Inventors: Douglas W. Ming, Donald L. Henninger, Earl R. Allen, and Dadigamuwage C. Golden. NASA Case # MSC 21953 and MSC 21954.

Kennedy Space Center

- Detector for Particle Surface Contamination. Inventors: Paul A. Mogan, Christen J. Schwindt, and Carl B. Mattson. Software Contributor: Steven Kinkle. NASA Case # KSC 11809-1.

Marshall Space Flight Center

- Closed-Loop Autonomous Docking System. Inventors: Richard W. Dabney and Richard T. Howard. NASA Case # MFS 28421.

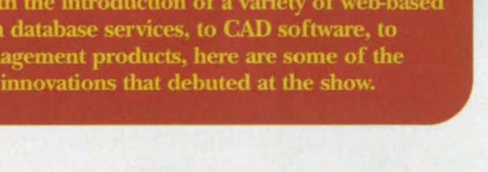
For more information on NASA's Invention of the Year program, visit www.hq.nasa.gov/office/codei/invention.html.

National Design Engineering Show 2000: A New Century of Innovation

The National Design Engineering Show (NDES), part of National Manufacturing Week, was held March 13-16 at Chicago's McCormick Place. NDES featured more than 1,200 exhibitors in three miles of aisles, filled with the hot technologies and winning ideas for tomorrow's successful design engineers. Products and services in CAD/CAM/CAE, materials, motion control, electronics, rapid prototyping, and other areas were displayed.

e-Innovations Take Center Stage

NDES exhibitors illustrated the booming proliferation of the Internet with the introduction of a variety of web-based products. From database services, to CAD software, to enterprise management products, here are some of the Internet-based innovations that debuted at the show.



● MechSoft.com, Austin, TX, announced MechSoft-PROFI, which handles design revisions and "what-if" scenarios on entire assemblies in seconds. By tracking the functional requirements of individual parts and their relationships throughout the assembly, it captures the "why" of a design, intelligently safeguarding the engineer's specified design intent. It also includes MechSoft.com's Standard Part Library, calculations, and the on-line Engineers' Handbook. The Group Manager acts as a map, graphically representing both a design's components and its functions. The Part Library features 1 million standard parts with a set of international standards. Visit www.mechsoft.com.

● PlanetCAD, a web portal for the digital manufacturing supply chain, was previewed by Spatial, Boulder, CO. The first Engineering Service Provider (ESP), the site allows engineers and manufacturers to access a one-stop-shop for CAD/CAM/CAE, interoperability, rapid manufacturing, analysis, and reverse engineering, as well as incorporating educational resources, industry service guides, employment opportunities, communities, links and reference libraries, and industry news. Services include 3Dshare.com, which enables the repair and translation of CAD/CAM/CAE file formats; Bits2Parts.com, which will enable the rapid delivery of stereolithography files to rapid prototyping suppliers; Secure Route, which will enable the secure model routing, management, transmission, tracking, and delivery of product data via the Internet; and 3Dpublish.com that enables users to take "snapshots" of 3D models for archival, demonstration, and marketing purposes. Visit www.planetCAD.com.

● Alibre Design™ Public Preview from Alibre Design, Richardson, TX, leverages the Internet as a platform to provide an integrated team environment for collaborative mechanical design and data management. Operating as an ASP that develops, markets, and distributes its own application services, the service is subscription-based. Its three-tier architecture includes a Web browser-based client, an application Design Server, and a design-data Repository Server. It provides a 3D parametric, feature-based solid modeler that supports design of parts and assemblies, as well as automated and associative generation of 2D engineering drawings. The service also supports Spatial's 3Dshare.com interoperability service described above. Visit www.alibre.com.

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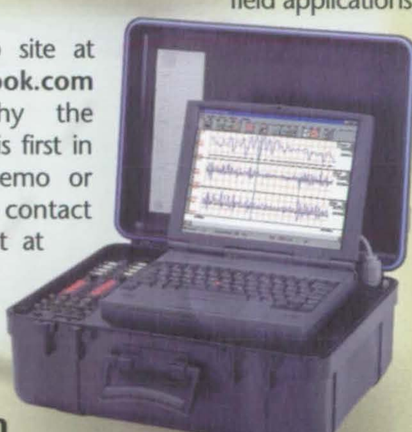

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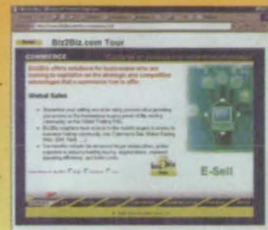
● Supplybase, San Francisco, CA, launched Supplybase.source, an online manufacturing marketplace that matches buyers and suppliers of custom parts and assemblies in the automotive, medical, and electronics markets. Information on more than 80,000 supplier companies is standardized by commodity, and is centrally hosted. Users can parametrically search the database by specific criteria such as technology, capital equipment, agency certification, design services, and industry. Buyers can request that their existing approved suppliers be added to the Supplybase database. Users can initiate contact or follow up with one or more suppliers by e-mail, including standard request-for-quote and e-mail forms. Visit www.supplybasesource.com.

● Primavera Systems, Bala Cynwyd, PA, announced Primavera Enterprise®, a scalable, Web-based project-planning and scheduling software application that allows companies to plan and manage resources, budgets, and costs at an enterprise-wide level. The software is designed to improve time-to-market while neutralizing the risks of new-product development. It enables users to work on projects in midstream and obtain historical and real-time data to help decide the future of projects. It provides easy Web access for all participants, and allows each project to be evaluated individually and in relationship to other projects and strategic initiatives. Visit www.primavera.com.

● Manufacturing Quote.com LLC of Smyrna, GA, previewed MfgQuote.com, a web-based marketplace that connects job shops with companies purchasing custom manufacturing services. The secure service enables companies buying manufacturing services to post a Request for Quotation (RFQ) by completing an online form and attaching a drawing, scanned drawing, or CAD file. Job shops that are members of MfgQuote.com can search for RFQs that meet their expertise and capacity, and can bid on the job by filling out an online quote submission form, which is sent directly to the buyer. The site's Webstore features a collection of software tools for mechanical designers and manufacturers. Visit www.MfgQuote.com.



● Biz2Biz.com, Irvine, CA, is a horizontal collaborative and trading portal for manufacturers, designed to help companies build their businesses online. It provides manufacturers with a centralized location for all search, support, collaboration, and transactions. The vertical portal features commerce sites for buying and selling; global auctions; global requests for quotes (RFQs); design showcases for developing, prototyping, and analyzing; supply chain center; virtual trade shows, advertising, newsletter, and other marketing capabilities; and financial services and career opportunities. Visit www.biz2biz.com.

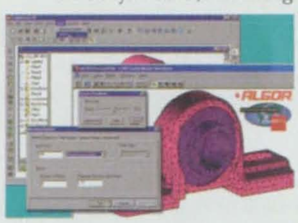
More From the Floor

Here are more innovations from the NDES exhibit floor.

● think3™, Santa Clara, CA, rolled out thinkdesign™ 5.0, the newest version of its flagship 3D design product. The software includes advanced surface modeling functionality along with new, engineering-oriented features for parametric solid modeling and integrated project management. More than 60 new features and enhancements have been added to improve designer productivity. Key areas include profiles and sketches, curves and surfaces, production mold development functionality, solids and features, drafting and layout, product data management, and photo-realistic rendering. Visit www.think3.com.

● MSC.Software, Costa Mesa, CA, demonstrated MSC.Patran running on the Linux operating system. MSC.Patran provides a complete environment for companies performing simulation of mechanical products. The Linux version will be available later this year, taking advantage of Pentium III and Pentium III Xeon processors. MSC.Patran supports all leading CAD and analysis software programs, including MSC.Nastran. Visit www.mscsoftware.com.

● Demonstrations of the latest engineering tools from Algor, Inc., Pittsburgh, PA, included FEA-based Accupak/VE Mechanical Event Simulation software, as well as the InCAD family of products. InCAD provides seamless CAD/CAE interoperability to capture exact part or assembly geometry without file translation. It works with the leading Windows-based CAD solid modelers, and links to Algor's entire line of analysis tools, including Mechanical Event Simulation. Also demonstrated was the Inertial Load Transfer Extender that lets engineers simulate dynamic behavior, calculate inertial loads at each node, and perform a linear or nonlinear static stress analysis using just one finite element model to determine stresses. Visit www.algor.com.



● Hewlett-Packard, Palo Alto, CA, gave attendees the opportunity to experience an HP VISUALIZE Center, a fully immersive visualization system powered by three synchronized HP VISUALIZE workstations with VISUALIZE-fx6 Pro graphics. A large-scale 3D stereographic display screen from Panoram, and CrystalEyes Wired eyewear from StereoGraphics, helped bring startling 3D reality to HP's 10-minute presentation. Viewers instinctively dodged tires and axles as a life-size model of a racing car spun out toward the audience. The Center is designed to allow entire project teams, locally or globally, to immerse themselves in their data for optimal product development and scientific visualization. With the system, design teams can walk through life-size virtual vehicles, airplanes, and buildings; interact with the data; and resolve design problems in real time before physical prototypes are built. Visit www.hp.com/visualize/products.

● Hirschmann Automated Network Solutions Group, Pine Brook, NJ, has added Ethernet automation networking products to its industrial line with a series of Fast Ethernet 100-Mb/s switches, rail hubs, and rail transceivers. Able to be assembled on DIN rails, the products incorporate redundancy mechanisms that prevent failures. The devices are impervious to EMI, dirt, temperature fluctuations of as much as 60 °C, and mechanical loads. Visit www.hirschmann-usa.com.

(more→)

● DuPont Performance Lubricants, Deepwater, NJ, displayed Fluoroguard™, a colorless, odorless, and chemically inert polymer additive based on fluorinated synthetic oil. It is designed for use in gears, bushings, weather stripping, o-rings, seals, and polymer films. It internally lubricates to improve flow properties, uniform mixing of ingredients, and product gloss. The multifunctional polymer additive is a perfluoropolyether (PFPE) available in one-gallon bottles and five-gallon pails. Visit www.dupont.com/fluoroguard.

● Solid Edge Version 8 3D mechanical CAD software from Unigraphics Solutions, Huntsville, AL, features new large-assembly design tools, modeling functions, and drafting capabilities. It facilitates 2D-to-3D migration with improved tools for importing legacy 2D data, and new 2D drafting functions that mimic similar functions in popular 2D CAD systems. The release marks the debut of Cognitive Assembly Design technologies, which enhance assembly design by embedding higher levels of assembly intelligence within models, and by providing detailed feedback to guide the design process. Visit www.solid-edge.com.

● The new Linear Ball Transfer Bearing™ from Thomson Industries, Port Washington, NY, utilizes the company's patented segment bearing technology. Usable as a rack support bearing for either a power or a manual steering gear, the self-aligning bearing supports the steering rack against pressure from the pinion and eliminates stick-slip. It has roll, pitch, and yaw capabilities, and a profile as low as 0.5 in., providing space savings over traditional rolling contact bearings. Its load capacity exceeds 500 lbf for 2 million inches of travel, and its reduction of friction by as much as 100 times compared to conventional technology translates into reduced power requirements. Visit www.thomsonindustries.com.

● Lucent Technologies, Avon, CT, demonstrated its new FiberWire, a rugged industrial optical fiber communications cable system designed to supplant copper wire and coaxial cable on the factory floor. It can operate in the industrial temperature range of -40 to +85 °C, and is immune to EMI and RFI. Its "crimp and cleave" kit permits termination and connection in the plant or field in three minutes, without adhesives, polishing disks, or solvents. Visit www.fiberwire.com.

● Penn Engineering & Manufacturing Corp., Danboro, PA, introduced four new fasteners. The PEM® Type PFT™ panel fastener thumbscrews are metal-and-plastic HYBRID™ panel fasteners that feature stainless-steel threads with internal six-lobe drive molded into a black ABS plastic cap. PEM® Type SMPS™ stainless steel self-clinching nuts can be mounted in extremely thin sheets of 0.025". PEM® Type SL™ TRI-DENT® self-clinching threaded steel locknuts provide permanent load-bearing threads in aluminum or steel sheets as thin as 0.040". PEM® Type HFED™ self-clinching dog point studs enable attachment of steel or aluminum sheets as thin as 0.040". Visit www.pemnet.com.

● SolidWorks Corp., Concord, MA, demonstrated SolidWorks 2000, the latest release of the Windows-native, 3D mechanical design software. This version offers more than 150 customer-driven enhancements, including improved file management, large-drawing performance, large-assembly development, ease-of-use, modeling, surfacing, and drawing productivity. Each license of SolidWorks 2000 includes SolidWorks Explorer, a free file-management tool that automates operations such as copying, renaming, and managing custom properties for SolidWorks files. New assembly-design features include Dynamic Clearance, which displays in real time the distance between two moving components. As the parts move, a dimension automatically appears indicating the minimum distance between two components. Visit www.solidworks.com.

● Parker Pneutronics Division, Cleveland, OH, displayed the X-Valve, which it calls the world's smallest valve. Measuring 8 mm in width, the two-position, three-way digital valve reduces system size, increases reliability, and has short response time. Its body incorporates all of the functional features in a single glass-reinforced PBT-molded body, a design Parker says allows it to handle flow rates far in excess of other miniature solenoid valves in its class, at pressures from 0-30 psig. Visit www.parker.com.

● CADKEY Corp., Marlborough, MA, previewed Parametrics for CADKEY 99, which integrates parametric definition and editing of dimension-driven solid models into CADKEY. The product provides yet another tool within CADKEY's line of solids, surfacing, and 2D/3D wireframe. The next major release of the flagship product, CADKEY 20, was previewed to the company's current users, and is scheduled for release by the end of this summer. According to the company, it involves a complete re-write of the part file format, as well as re-architecting the application's database. Visit www.cadkey.com.

This year's show also featured the Rapid Prototyping Pavilion, which included products ranging from CAM and reverse engineering software, to the latest in desktop parts "printers" and molding equipment. For detailed coverage of this special pavilion, visit Rapid Product Development Online, *NASA Tech Briefs'* digital publication that covers tools and techniques for creating better products faster, at www.rapidproducts.net.

For More Information Circle No. 527

Fifth Annual Product of the Year Awards

The top of the John Hancock Center in Chicago was the setting for the presentation of the 1999 *NASA Tech Briefs* Readers' Choice Product of the Year Awards. The fifth annual awards were voted on by *NASA Tech Briefs* readers, who cast their votes for the Gold, Silver, and Bronze award winners. Nine other Product of the Year Finalists were presented with awards. All 12 nominees had received Product of the Month honors during 1999.

Each month, *NASA Tech Briefs* editors choose a Product of the Month — the one product they feel exhibits exceptional technical merit and practical value. In the December issue, readers are invited to vote for the one product of those highlighted during the year that represents the most innovative product introduced to the engineering community. The product receiving the most votes wins the Gold award, and is named Product of the Year.

The 1999 Readers' Choice Product of the Year Gold winner was CoBrain semantic knowledge processing software from Invention Machine Corp. of Boston, MA. The award was accepted by Phil George, Invention Machine's vice president of worldwide marketing. CoBrain allows users to semantically process large numbers of electronic documents from internal and external sources, including research reports, patents, conference proceedings, and technical journals. It extracts and presents an index of technical documents displayed in a problem-solution format. (www.invention-machine.com)

The Silver Award went to Spatial of Boulder, CO, for its 3Dmodelserver.com web-based model repair and translation service. The service has since be renamed 3Dshare.com, part of the company's PlanetCAD service (see "e-Innovations Take Center Stage" on page 24). Michael Hansen, VP of PlanetCAD site production, accepted the award. (www.spatial.com)

CrystalEyes Wired 3D stereoscopic eyewear was the Bronze Award-winning product from StereoGraphics Corp. of San Rafael, CA. Ian Matthew, product marketing manager, accepted the award for the eyewear, which is designed for CAD, mechanical design, and scientific professionals who work with complex 3D images. (www.stereographics.com)

The following companies were honored as Product of the Year Finalists:

- SGI (Mountain View, CA) for the 320/540 Windows NT visual workstations (www.sgi.com);
- Visionary Design Systems (Santa Clara, CA) for IronCAD Version 2 mechanical engineering software (www.ironcad.com);
- Hewlett-Packard (Palo Alto, CA) for the HP16600A/16700A web-enabled logic analyzers (www.hp.com);
- ESDU International (Englewood, CO) for the ESDU engineering database (www.esdu.com);
- Parker Hannifin (Minneapolis, MN) for the Spectrum Series plastic couplings (www.parker.com);
- Endevco Corp. (San Juan Capistrano, CA) for the OASIS 2000 sensor interface system (www.endevco.com);
- Wolfram Research (Champaign, IL) for *Mathematica* 4 technical computing software (www.wolfram.com);
- Gage Applied Sciences (South Burlington, VT) for the CompuScope 1602 PCI scope card (www.gage-applied.com); and
- Compaq Computer Corp. (Houston, TX) for the Deskpro AP240 workstations (www.compaq.com)

NASA Tech Briefs **Publisher Joe Pramberger (far left) and Chief Editor Linda L. Bell (far right) present the 1999 Readers' Choice Awards. Accepting the awards are (left to right): Michael Hansen of Spatial, the Silver Winner; Phil George of Invention Machine, the Gold Winner and Product of the Year; and Ian Matthew of StereoGraphics, the Bronze Winner. (Photo by Michael Kardas)**

All readers who submitted ballots in the Product of the Year contest were placed in a random drawing to win valuable prizes donated by last year's winners and nominees. Congratulations to these *NASA Tech Briefs* readers:

- Anthony Pizzirusso of MPD Technologies in Hauppauge, NY, winner of InCADPlus Mech/MVE, Mechanical Event Simulation and multiphysics software that works inside CAD, from Algor, Inc., Pittsburgh, PA (www.algor.com). The InCAD technology seamlessly captures solid parts and assemblies from CAD solid modelers for analysis using Algor's FEA and Mechanical Event Simulation software.
- Andy Pandian of Daimler Chrysler Corp. in Detroit, MI, winner of LabVIEW graphical instrumentation software from National Instruments, Austin, TX (www.ni.com). LabVIEW, 1998 Product of the Year, allows users to create programs using block diagrams instead of standard text code, and to use the programs to control instruments and acquire electrical signals to measure temperature, pressure, and other phenomena.

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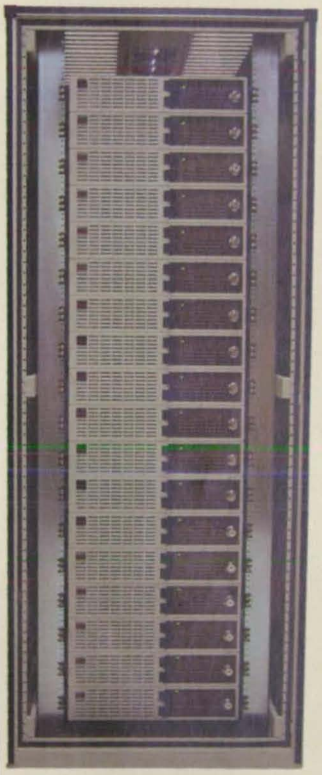

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> — Bruce Faust, founder of DigitalScape and Carrera Computers

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For More Information Circle No. 568

New Spacesuit Concept Designed With Solid Imaging

SLA 500™ stereolithography system
3D Systems
Valencia, CA
805-295-5600
www.3dsystems.com

Hamilton Sundstrand Space Systems International in Windsor Locks, CT, recently built for NASA a wearable mockup of a new spacesuit concept for Mars astronauts. The Mars space suit design is an extension of Hamilton Sundstrand's primary business, which is producing life-support equipment for spacecraft and submarines. The company currently supplies life-support equipment for the International Space Station, and is the prime contractor for the EMU (Extravehicular Mobility Unit) space suit used whenever astronauts go outside the shuttle.

3D Systems' solid imaging technology literally builds a physical prototype — layer by ultra-thin layer — using a liquid epoxy plastic that is hardened by a laser to precise CAD-generated specifications. In many cases, 3D parts are fabricated full size. If a part is too large for the machine, a scale model can be made, or a large part can be made from several smaller parts that are then fit together.

Using the SLA 500 system, Hamilton Sundstrand was able to produce a wearable "hard upper torso" — essentially a torso without limbs and head. Their new geometry absolutely had to

have a 3D working model to prove that the design would work. A full-size model was built from four sections that were glued together. Standard arms, legs, and a helmet bubble were put on it, an air supply was attached, and one of the firm's engineers was put inside to walk around in a closed-loop life support system.

Only two iterations were required to get an acceptable upper torso. The suit was produced in only a matter of months, rather than years. The solid imaging system allowed Hamilton Sundstrand — and NASA — to save money and improve quality as well.

For More Information Circle No. 750

Software Simulates NASA's Hypersonic Flight Systems

ADAMS mechanical system simulation software
Mechanical Dynamics
Ann Arbor, MI
313-994-3800
www.adams.com

NASA's Hyper-X hypersonic flight and ground test program seeks to demonstrate key enabling technologies, including an airframe-integrated, air-breathing engine. Analytical Mechanics Associates (AMA) of Hampton, VA, is a NASA Hyper-X partner that provides expertise in problem-solving with mathematical modeling and immersive engineering tool development. AMA used ADAMS to simulate problems associated with stage separation of the Hyper-X vehicle from the Pegasus rocket booster.

An ADAMS model of the separation mechanisms, including the ejector pistons, Pegasus booster, adapter, and Hyper-X test vehicle was created by AMA. Aerodynamic force data were applied as a multi-dimensional spline, which was generated from wind tunnel data taken over various positions and orientations of the test vehicle.

The ADAMS model was parameterized to allow quick turnaround of changes. More than 50 parameters were set up as ADAMS variables, allowing the model to be mechanized to

support batch simulation. Monte Carlo analysis was performed with ADAMS using random variable values for the parameters. An SGI R10000 12-processor machine was used, running eight copies of ADAMS. Each case was checked for proper clearance during separation and acceptable recovery from the separation upset. The separation of the Hyper-X and the Pegasus booster takes about 400 milliseconds — the approximate time it takes to blink an eye.

Experimental hypersonic flyers currently are under development at NASA's Dryden Flight Research Center in Edwards, CA, and at NASA's Langley Research Center in Hampton, VA. The Hyper-X vehicle is 12 feet long, 5 feet wide, and weighs 3,000 pounds. The combined Pegasus rocket and Hyper-X are launched from under the wing of a NASA Dryden B-52 jet.

For More Information Circle No. 751

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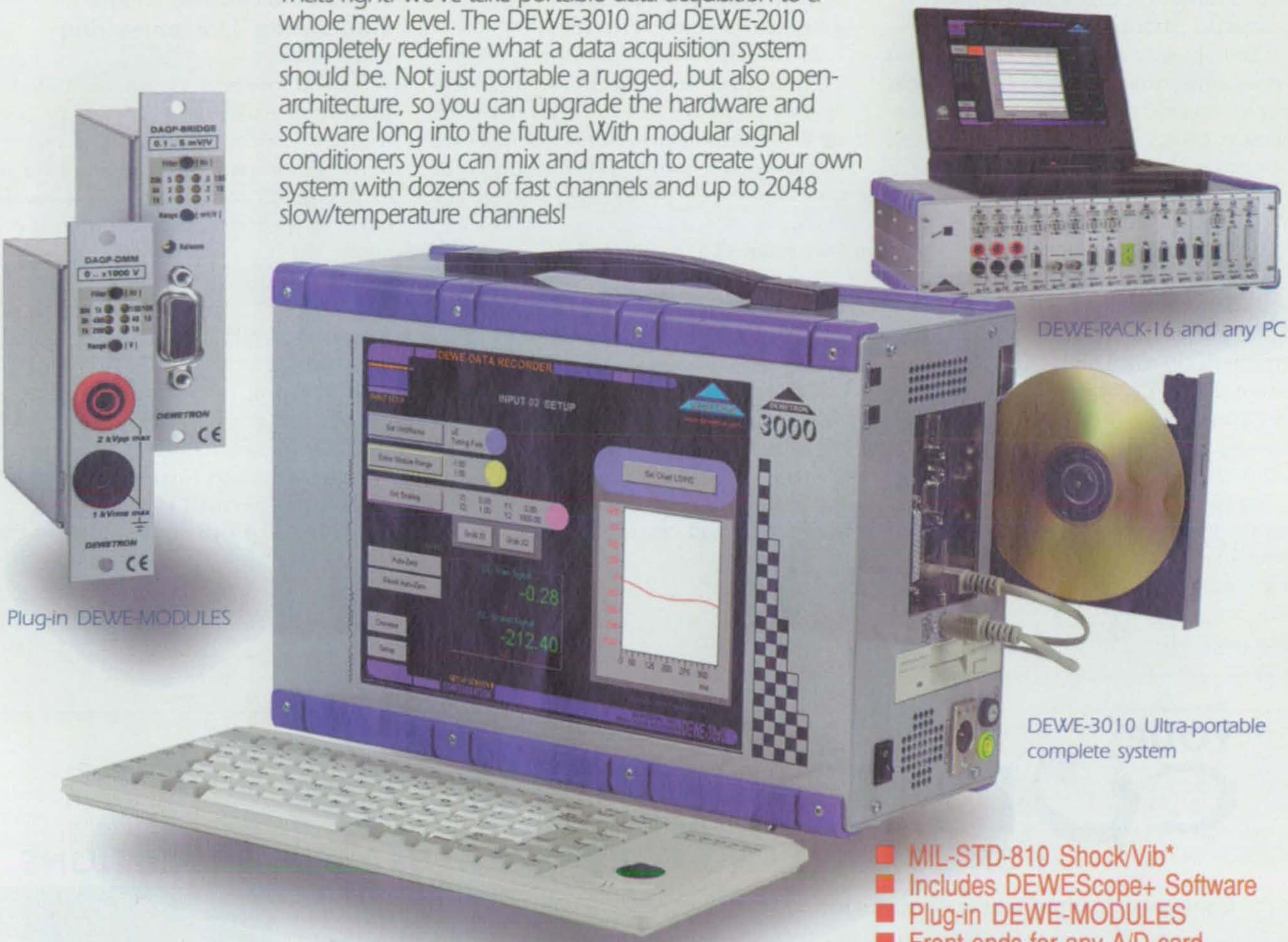

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For More Information Circle No. 533

Self-Temperature-Compensated Ceramic Strain Gauges

These gauges are intended for use at temperatures from room to 1,200 °C and require no external temperature-compensation circuits.
(See page 39.)

"Set and Hold With Power Off" Cryogenic Actuators

These actuators would hold their position when power is not applied, by virtue of the persistent current flowing cirumferentially in the high-temperature-superconductor cylinder.
(See page 39.)

Electrobiotic Toxic-Agent Sensors

Sensors have been proposed for detecting toxic substances in a variety of environments; e.g., mining, battlefield, heavy industry, and other potentially toxic areas.
(See page 41.)

Submillimeter-Sized $Bi_{2-x}Sb_x$ Thermoelectric Devices

Electrochemical deposition is the key to mass-producibility here. This approach promises to fulfill the need for small thermoelectric devices to provide active spot cooling for circuits with ever-increasing packaging and power densities.
(See page 44.)

Instrument Measures Fluorescence From Chlorophyll in Plants

This instrument, a remote passive monitor, can provide early warning on plants under stress. Horticulturists and farmers can then apply fertilizers, water, and/or pesticides to rescue valuable plants and crops.
(See page 48.)

RTM-Processable Resin Containing Thermosetting Plasticizers

Several plasticizers are identified as promising candidates for use in resin-transfer molding of composite material parts. These parts are intended for aircraft engines and other structures that have to withstand temperatures up to about 300 °C.
(See page 56.)

Aerogels With Gradients of Density

Depending on the intended application, the gradient of density can be tailored to obtain the desired optical or acoustical attenuation or index of refraction, permittivity, thermal conductivity, and other properties of interest.
(See page 59.)

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For More Information Circle No. 541

On-Chip Correction for Defective Pixels in an Image Sensor

Readouts from nearest neighbors could be substituted for defective pixels.

Lyndon B. Johnson Space Center, Houston, Texas

A method of correcting for defective pixels in an integrated-circuit image sensor of the active-pixel sensor (APS) type has been proposed. The corrections would be made by additional readout circuitry on the image-sensor chips. By making it unnecessary to discard sensor chips that contain limited numbers of scattered defects, the method would increase effective production yields and thereby lower the costs of individual image sensors.

Two issues arise in trying to correct for defective pixels: how to store information on the locations of these pixels and how to process pixel outputs in the readout process. Because most of the area of an image-sensor chip is occupied by the array of pixels, there is little room for circuitry for storing addresses of defective pixels. Accordingly, the coordinates of any defective pixels and of any defective entire rows or columns of pixels would be stored in several registers (see figure), the number of registers being based on a practical upper bound on the number of pixels, rows, or columns likely to be defective. In the initial proposed design, there would be four such registers, and they would be embedded in the on-chip timing and control circuitry.

The set of registers would function in the manner of a content-addressable memory. During readout, the current row and/or column address would be applied to this memory and a flag would be generated if the current address matched the stored address, signifying that the current pixel, row, or column is defective.

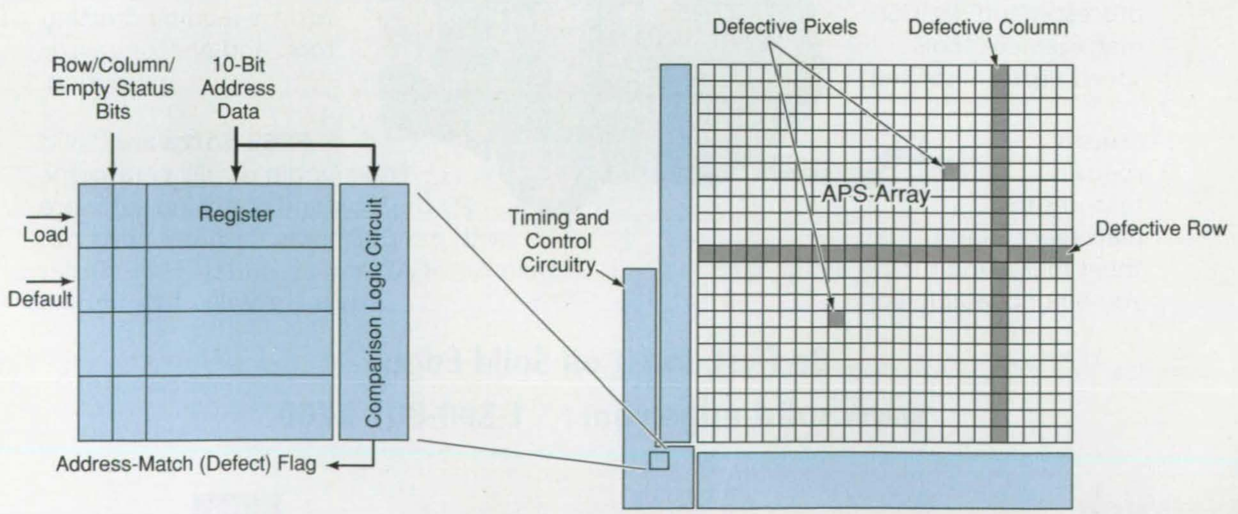
The method admits of alternative designs corresponding to alternative ways to respond to a "defect" flag. The simplest approach is to design the readout control logic circuit to simply skip an entire row that contains even one bad pixel, skip an entire bad column, and increment to the next row or column. In this approach, it would suffice to store only the row address of a single bad pixel.

Another approach would involve substituting, for each defective pixel, the average of readouts from the eight surrounding pixels. This approach would be less practical or attractive for on-chip implementation because it would necessitate more circuitry occupying more chip area. The additional circuitry would be necessary for storing information from three rows at a time (the previous row, the current row, and the next row to be read out) plus processing of information from three rows and columns at a time.

A more practical approach would involve replacing the output from a dead pixel with a copy of the output from a neighboring pixel that was read out previously. The copy could be obtained by use of a simple single-pixel delay line.

An essential step in this method would be a procedure for testing to locate defective pixels, rows, and columns and for writing the addresses of these pixels, rows, and columns in the registers. In the first generation of image sensors designed according to this method, the testing and the programming of registers would probably be performed manually. Eventually, it should be possible to add automatic testing and programming circuitry to the chips.

This work was done by Nick Doudoumopoulos, Roger Panicacci, and Eric H. Fossum of Photobit for **Johnson Space Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Components and Systems category. MSC-22827*



Registers Functioning as Content-Addressable Memories would store the row and column coordinates of defective pixels. As many as four addresses, each 10 bits wide, could be stored for identifying defective individual pixels or defective entire rows or columns of pixels.

Surface Micromachined Silicon Carbide Accelerometers

These accelerometers could be valuable for diagnosis of engines.

John H. Glenn Research Center, Cleveland, Ohio

Surface micromachined silicon carbide accelerometers are undergoing development for eventual use in high-temperature environments like those inside turbines, internal-combustion engines, and other machines. These accelerometers would be used to measure vibrations indicative of deterioration of mechanical components; as such, they would be valuable diagnostic tools that could give advance warnings of failures or for the need to perform maintenance. They would even be small enough to fit into turbine blades.

Like similar accelerometers micromachined out of silicon, surface micromachined silicon carbide accelerometers are based on the concept of displacements of proof masses suspended on springs and they include electrodes for (1) capacitive sensing of displacements of proof masses and (2) electrostatic feedback for centering and for nulling displacements caused by relatively steady forces like those caused by gravitation and centripetal acceleration. The figure depicts an experimental surface micromachined silicon carbide accelerometer in which the proof mass (also called the "shuttle") is suspended at opposite ends by springs in the form of folded beams (pairs of beams joined at trusses). At each end, the outer two beams are attached to a substrate at four anchor locations.

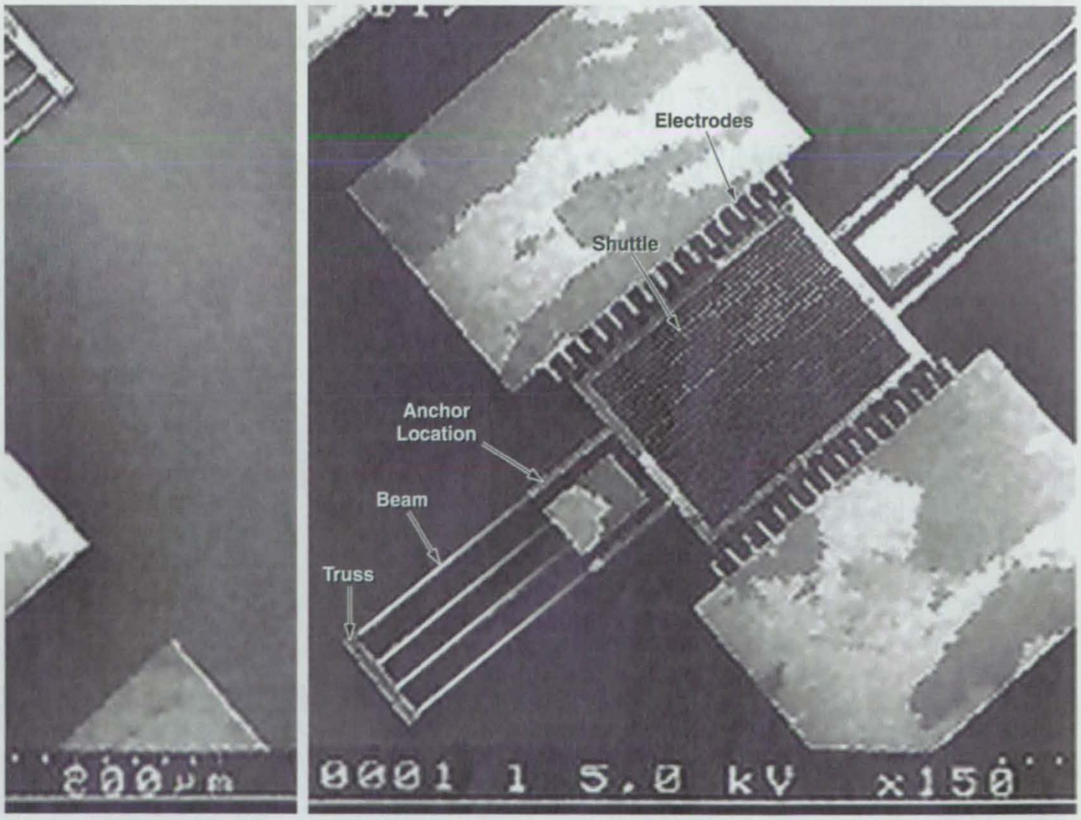
The particular folded-beam structure offers low stiffness (and thus high sensitivity to acceleration) along both directions perpendicular to the nominal longitudinal axes of the beams and high stiffness (and thus low sensitivity to acceleration) parallel to the nominal longitudinal axes of the beams. If an accelerometer of this or a similar configuration were to be used to measure turbine-blade vibrations, then it would be mounted with the nominal longitudinal axis oriented in the radial direction to minimize the undesired response to centripetal acceleration. The folded-beam structure also helps to minimize the undesired differential thermal expansion between the substrate and the shuttle.

Electrodes for capacitive sensing of displacement and electrostatic actuation of the shuttle are located along the sides of the shuttle; two sets of these electrodes are on the shuttle and are interdigitated with adjacent sets of electrodes on the substrate. The gaps between the shuttle and the proximate substrate electrodes are typically 1 µm wide, and the electrode fingers are typically between 10 and 50 µm long. Inasmuch as capacitance between the substrate end shuttle is inversely proportional to the gap for small displacements, maximum sensitivity requires minimum gap. On the other hand, the gap must be made large enough to prevent touching of the substrate and shuttle electrodes at extreme excursions of the shuttle.

The main advantage of the silicon carbide accelerometers over silicon ones is the ability of any corresponding electronics (e.g., capacitance sensing circuits) to function at higher temperatures: Whereas silicon devices must generally be maintained at temperatures below 250 °C, silicon carbide devices can function at temperatures as high as 600 °C. Like silicon devices, silicon carbide devices can be fabricated inexpensively in batches with a high degree of repeatability.

This work was done by Russell G. DeAnna of the U. S. Army Research Laboratory for **Glenn Research Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Mechanics category.*

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Commercial Technology Office, Attn: Steve Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-17002.



This **Scanning Electron Micrograph** shows the main stationary and moving components of an experimental surface micromachined silicon carbide accelerometer.

Software for Predicting Behavior of a Pyrotechnic Actuator

This software has remedied conceptual errors in some prior design models.

John H. Glenn Research Center, Cleveland, Ohio

A theoretical model that predicts the time-dependent behavior of a pyrotechnically actuated mechanism and a computer program that implements the model have been developed. The model and program are especially applicable to a pyrotechnic device known as the NASA Standard Initiator (NSI). Before this model and program were developed, the only principles that guided the design of pyrotechnically actuated mechanisms were those derived through empiricism.

The theoretical model includes (1) equations of conservation of mass, momentum, and energy, (2) equations of state, (3) equations of reaction kinetics, and (4) the assumption that there are no spatial variations in the relevant physical and chemical quantities (the "well stirred reactor" assumption). The computer program that solves the model equations is written in FORTRAN 77. This program requires the use of two other programs, known as "CET88" and "Chemkin," that are standard for calculations of the type in question.

The program has been found to predict accurately (as determined by comparison with experimental observations) the pressure history of an NSI firing into a pin-puller device, a closed vessel that has a volume of 10 cm^3, and an apparatus called the "Dynamic Test Device." The program has also remedied several conceptual errors in prior design models.

This work was done by Joseph M. Powers and Keith A. Gonthier of the University of Notre Dame for **Glenn Research Center.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category.*

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Commercial Technology Office, Attn: Steve Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-16869.

Dither Sensing for Controlling a Segmented-Mirror Telescope

Images of distant point sources are processed to obtain wavefront-correction control signals.

Marshall Space Flight Center, Alabama

Image-plane multidither sensing has been found to be suitable for adaptive wavefront correction in a large telescope in which the main optic is a precise reflector divided into lightweight, controllably actuated segments. In image-plane multidither sensing, the telescope is aimed at a star or other distant point source and image data are

recorded as each segment in turn is dithered slightly about a nominal position and orientation. The image data are processed into actuator-control signals for adjusting the nominal segment positions and orientations to obtain the desired wavefront correction.

For this method to be effective, the telescope system must be quasi-static in the sense that any mechanical and optical disturbances in the system must be characterized by times appreciably longer than the time needed to complete the corrective cycle of dithers and measurements, processing of measurement data, and controlled actuation. The position and orientation errors of each segment, and the corresponding translational and rotational displacements needed to effect correction, are called "piston" (simple translation along the line of sight) and "tilt" (angular displacements about two axes perpendicular to the line of sight). The tilt-correction procedure is based on geometric optics and can be performed at any time. However, the piston-correction procedure is based partly on phase coherence; therefore, in practice, the tilt correction must be made first to provide the coherence needed for the piston correction.

In the tilt-correction procedure, a segment is dithered in tilt and initial and final images are recorded. Although the image plane can be cluttered with subimages from multiple segments, the subimages of all other segments can be suppressed and the displacement of the segment in question tracked by subtracting the initial image from the final image and finding the centroid of the difference image. Subtraction and centroiding are common operations in image processing, and circuit boards that perform these operations are commercially available.

The angular displacement of the dither should be at least twice the diffractive size (wavelength ÷ aperture width) of a segment to enable clear differentiation of the initial and final images. Once the centroid has been located, the segment of interest is tilted to move the subimage cast by that segment to the desired location, which is ordinarily the center of the image plane. This procedure is repeated for each segment in turn, until all have been thus corrected in tilt.

In comparison with tilt corrections, piston corrections are more difficult. The piston measurement for each segment is a measurement of the response of the speckle pattern to a small dither of that segment. There are several alternative piston-correction procedures, each based on a different combination of (1) a quantitative measure of the speckle pattern and (2) determining the signs and magnitudes of piston displacements needed to correct the speckle pattern according to the quantitative measure.

To the extent to which the piston-correction procedures are based on phase coherence, they are subject to the integer-multiple-of-2π-radians phase ambiguity at a given wavelength. Measurements can be performed at multiple wavelengths to resolve this ambiguity; alternatively, one could use broadband light from a stellar source, although this can entail complications at large displacements. The use of less-accurate electronic or mechanical edge sensors might be a more-practical solution.

This work was done by Glenn W. Zeiders of The Sirius Group for **Marshall Space Flight Center.** *For further information, contact the Sirius Group at gzeiders@prodigy.net.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center; (256) 544-0021. Refer to MFS-31352.

Self-Temperature-Compensated Ceramic Strain Gauges

External temperature-compensation circuits are not needed.

John H. Glenn Research Center, Cleveland, Ohio

Ceramic static-strain gauges capable of generating mechanical-strain signals much larger than spurious thermal signals have been invented. These gauges are intended for use at temperatures from room temperature to 1,250 °C. Heretofore, external circuits have been used to provide temperature compensation for (that is, to correct for or suppress the spurious signals of) strain gauges. No such external temperature-compensation circuits are needed for temperature compensation of the present developmental strain gauges.

There are numerous potential uses for self-temperature-compensated strain gauges as the transducers of strain and pressure sensors in automotive and aerospace applications that involve temperatures >200 °C. At the present stage of development, it is not yet possible to construct a single gauge of this type that can operate over the entire temperature range from room temperature to 1,250 °C; instead, one can construct one gauge that functions from 100 to 800 °C and another gauge that functions from 900 to 1,250 °C. Development efforts continue and are expected to lead to publication in a journal.

This work was done by Otto J. Gregory of the University of Rhode Island for **Glenn Research Center.**

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Commercial Technology Office, Attn: Steve Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-16704.

"Set and Hold With Power Off" Cryogenic Actuators

Magnetic fields would be applied to magnetostrictive rods by high-temperature-superconductor electromagnets.

Langley Research Center, Hampton, Virginia

Magnetostrictive actuators that would hold their displacements with power turned off have been proposed for use at temperatures from about 10 to about 77 K. Such "set and hold with power off" actuators are attractive for effecting fine position adjustments in cryogenic scientific instruments, wherein significant amounts of heat would be released and could disturb instrument operation if it were necessary to apply power continually to maintain actuator displacements.

The essential components of a magnetostrictive actuator are a rod of magnetostrictive material and an electromagnet coil to control the magnetic field applied to the rod. In an actuator of the proposed type, the magnetostrictive material would be single-crystal $Tb_{0.6}Dy_{0.4}Zn$, which exhibits a saturation magnetostrictive strain of as much as 0.5 percent at a preload stress of only 13.8 MPa and an applied magnetic field of about 500 Oersted ($\approx 4 \times 10^4$ A/m). The magnetostrictive rod would be surrounded by an electromagnet coil in the form of a monolithic cylinder made of a high-temperature superconductor (see Figure 1), which could be either $YBa_2Cu_3O_{7-x}$ or $Bi_2Sr_2CaCu_2O_{8+\delta}$ (aka BSCCO 2212). The persistent magnetic field needed to maintain a constant magnetostrictive stain (in order to hold a constant displacement with power off) would be generated by an electrical current flowing circumferentially in the superconductive cylinder.

The superconductive cylinder would be charged with the desired current by applying a suitable pulsed current to a normally conductive (e.g., copper-wire) solenoidal electromagnet coil surrounding the superconductive cylinder. The pulse would be tailored so that, at first, the superconductor would first be brought to its critical state (which occurs at the maximum superconducting current), and then additional magnetic field would be applied, all at nearly constant temperature. In the critical state, magnetic flux could be made to move freely into or out of the cylinder (flux could be pumped) with some attendant dissipation that would cause a momentary small increase in temperature. The increase in temperature would be too small to disrupt the superconductivity.

A circuit to implement this charging scheme is depicted in Figure 2, wherein the normally conductive charging coil is represented by inductor L1, the superconductive cylinder is represented by inductor L2. The momentarily dissipative nature of the superconductive cylinder is represented by resistor R, which limits the current in L2 to no more than the critical current, and which is zero when the current in L2 is smaller than the critical current.

In preparation for generating a pulse of charging current, switch S1 would be closed to charge the capacitor from the power supply. Once the capacitor was charged, switch S1 would be opened and switch S2 would be closed. Assuming a high coefficient of coupling between L1 and L2, the current in L1 would rise rapidly immediately following closure of S2 because, at that time, the combination of L1 and L2 would constitute a transformer with a short-circuited secondary winding. The increase in current in L1 would be balanced by an opposite change in the current in L2. Once the current in L2 reached the critical value, it would remain steady at that value and the load presented to the capacitor would suddenly

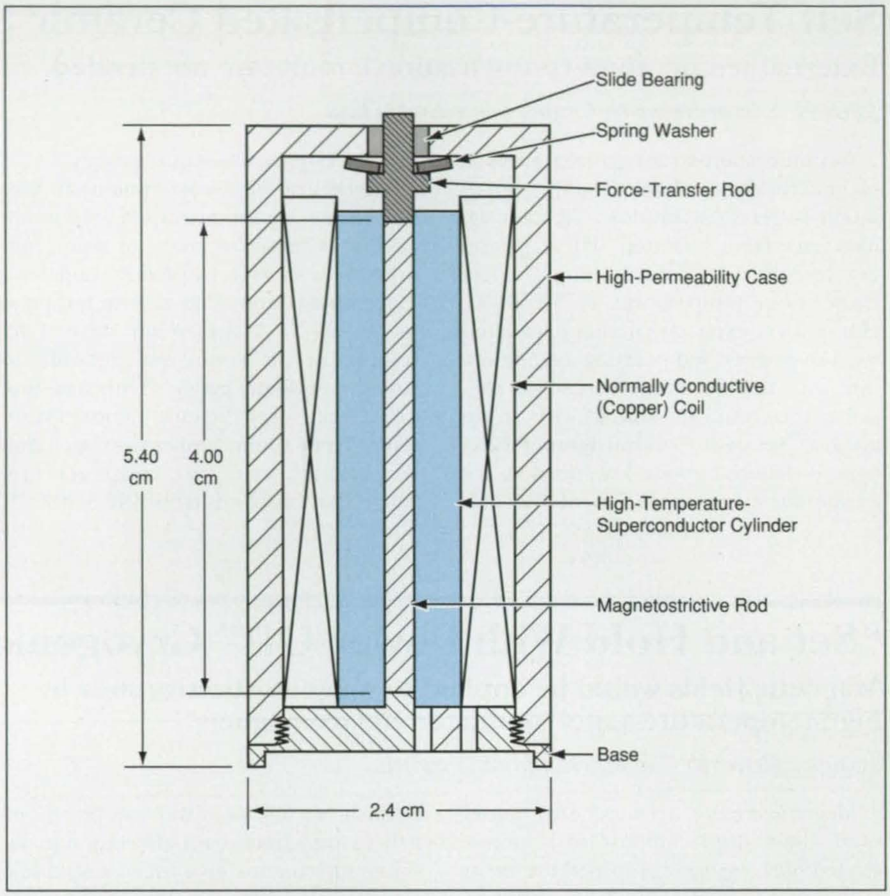


Figure 1. This **Cryogenic Magnetostrictive Actuator** would hold its position when power was not applied, by virtue of the persistent current flowing circumferentially in the high-temperature-superconductor cylinder.

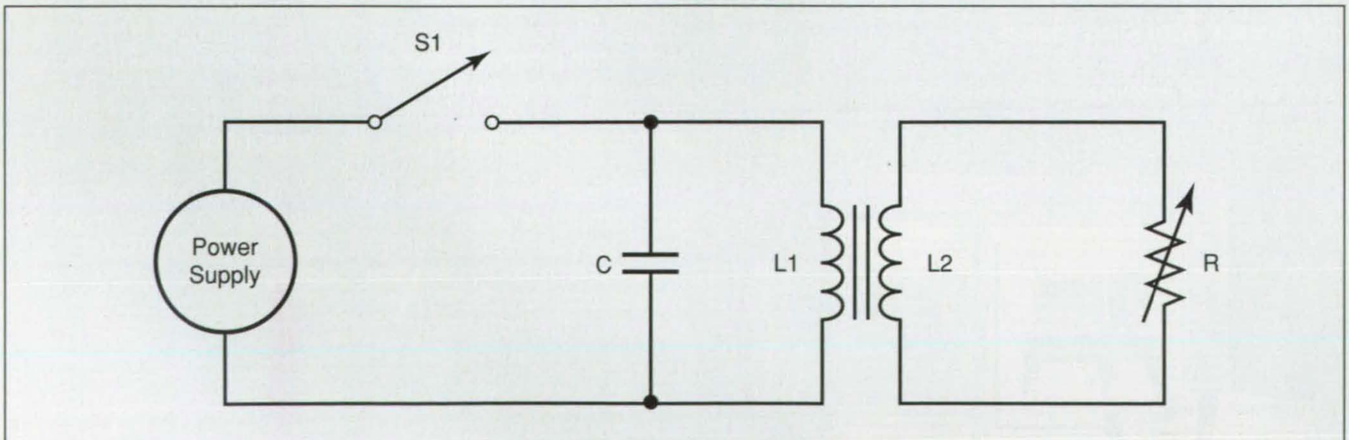


Figure 2. This **Pulse/Transformer Circuit** would charge the superconductive cylinder to the current needed to maintain the desired actuator displacement.

become inductive, slowing down the rate of increase of current in L1. The circuit would then behave like an ordinary capacitor-and-inductor system with a characteristic oscillation period.

Once the current in L1 reached its maximum value and started to decay, the state of the superconductor would depart from criticality; therefore, the inductive load would suddenly disappear and the circuit would once again become a short circuit, with no voltage but large current. With no driving voltage, the current in L1 would decay very rapidly, without oscillations. The final result would be that the energy in the capacitor, minus the energy dissipated in L1, would be transferred to the superconductor.

The charging process as described thus far could be repeated until the current in the superconductive cylinder had increased to the desired value (but not more than the critical value). The current in the superconductive cylinder could also be made to decrease in a discharging process, which would be the identical to the charging process except that the capacitor would be charged in opposite polarity.

This work was done by Garnett C. Horner of **Langley Research Center**, *Leslie Bromberg of Massachusetts Institute of Technology, and J. P. Teter of the Naval Surface Warfare Center. For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category.*
L-17837

Electrobiotic Toxic-Agent Sensors

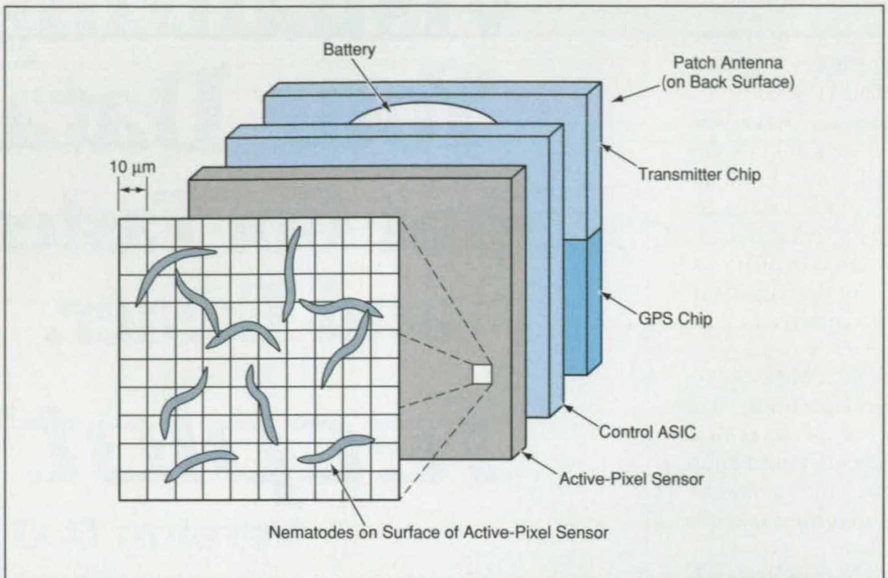
Inexpensive, compact, reliable sensors would be easy to use.

NASA's Jet Propulsion Laboratory, Pasadena, California

Electrobiotic sensors have been proposed for detecting toxic substances in a variety of environments. Electrobiotic sensors would be inexpensive, compact units that would be easy to use and could be deployed either singly or in large numbers, depending on the size of an environment to be monitored and/or the need to locate a toxic source within a larger area. For example, multiple electrobiotic sensors might be deployed on a battlefield or at a large-scale mining operation, whereas a single electrobiotic sensor might be used to monitor the air in a laboratory or at an assembly bench where toxic chemicals are used.

The term "electrobiotic" was chosen for these sensors because the front line of sensitivity would be biological entities and the responses of these entities to toxic substances would be sensed and processed by electronic circuitry. More specifically, a typical electrobiotic sensor (see figure) would include very small live nematodes in a suitable medium deposited on an active-pixel sensor (APS) [a state-of-the art single-chip integrated-circuit array of photodetectors and active readout circuitry]. The movements of the nematodes, which are mutatable to be agent-specific, would be detected through differencing between prompt and delayed pixel readout signals.

A control application-specific integrated circuit (ASIC) on a single chip would monitor the pixel-differencing output of the APS chip to detect movement. If movement were detected, no further action would be taken. If movement were not detected, the control ASIC would activate a microfluidic injection of nicotine to stimulate activity of the nematodes. If activity were still not detected, the nematodes would be assumed to be dead, implicating a toxic environment. The ASIC would then activate



An **Electrobiotic Toxic-Agent Sensor** would contain and monitor a population of small nematodes. Electronic circuitry would detect motion or lack of motion of the nematodes. Upon detecting cessation of the motion (presumably a result of environmental toxicity), the circuitry would transmit a signal. The total volume of the sensor would be about 1 in.^{3} (≈16 cm^3).

the radio transmission of a simple binary signal containing encrypted data on the location of the sensor as determined by a Global Positioning System (GPS) receiver that would also be part of the sensor. If multiple electrobiotic sensors were dispersed over a large area, then they could communicate with each other to relay their status and location data to a central receiver/repeater unit, which would be placed in the area during dispersal of the sensors.

The radio transmitter in an electrobiotic sensor could be very simple and short-lived and its range could be limited [e.g., of the order of a mile (≈1.6 km)]. Therefore, the power demand of the sensor could be satisfied with a very small battery like that used in a hearing aid.

The life cycles of nematodes are typically of the order of 4 days. However, nematodes can be sustained in a dormant state for a few weeks to a few months. Furthermore, they can be frozen for very long periods. Hence, electrobiotic sensors could be stored at low temperatures for future use.

This work was done by Philip Moynihan, Robert Stirbl, and Roger Kern of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Components and Systems category.* *NPO-20721*

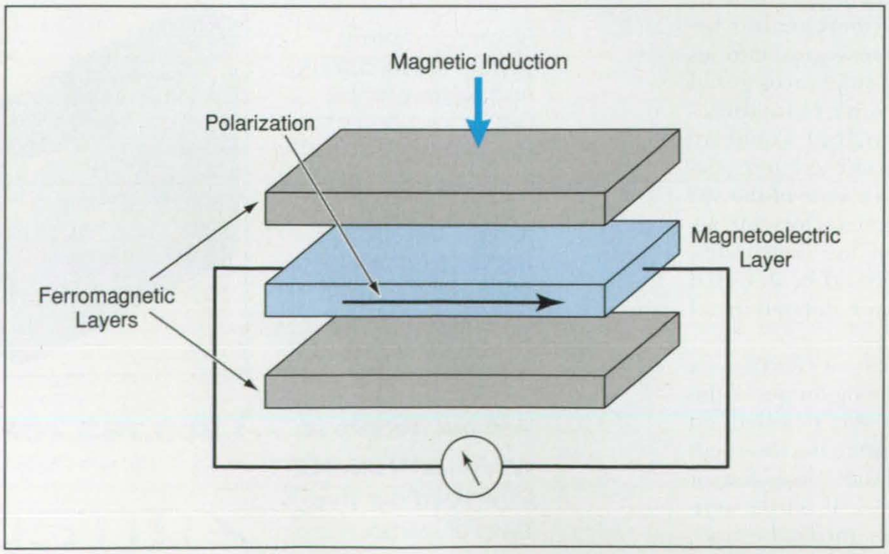
Magnetoelectric Sensors and Electric Generators

Novel applications of the magnetoelectric effect are proposed.

NASA's Jet Propulsion Laboratory, Pasadena, California

Electric generators and magnetic-field sensors of a proposed type would be based on the magnetoelectric effect. A simple device of this type (see figure) would consist mainly of an inner layer of a magnetoelectric material sandwiched between two outer layers of a ferromagnetic material. Electrical contacts would be placed at opposite ends of the magnetoelectric material.

As its name suggests, a magnetoelectric material is one that exhibits the magnetoelectric effect, which is a linear coupling between magnetization and electric polarization. The polarization electric field is perpendicular to the magnetic induction vector and its magnitude is proportional to the strength of the magnetic induction vector.



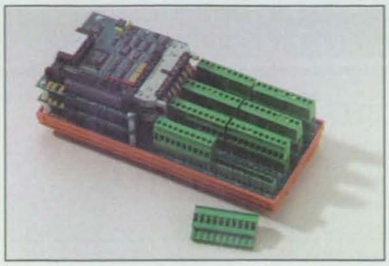
The **Sandwichlike Device** could be used to sense or to extract power from a varying magnetic field.

The electrical contacts could be used to connect the ends of the magnetoelectric layer to a voltmeter or other suitable instrument for measuring changes in the polarization electric charge. The voltage reading would be proportional to the change in the charge and thus to the change in the polarization electric field and thus, further, to change in the magnetic induction. Operated in this way, the device could be used as a magnetic-field sensor.

If the ends of the magnetoelectric layer were connected to suitable external circuitry and the magnetic field varied, then a sustained electrical current would flow. Operated in this way, the device could be used to sense or to extract power from a strongly varying magnetic field.

This work was done by Julian Blosiu and Mary Boghosian of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Components and Systems category. NPO-20523*

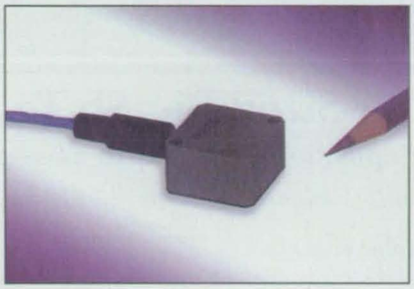
Special Coverage: Sensors



The Model 2518/19 **Ethernet sensor interface** from Sensoray, Tigard, OR, combines Smart A/D for sensors with a 10-base-T interface. The combination allows data acquisition of eight or 16 channels of thermocouple, RTD, strain gauge, thermistor, voltage, 4-20 mA, or resistance data via an Ethernet connection. Each channel is software programmable for a different sensor type. Screw terminations on the Model 2518/19 allow direct sensor connections.

Smart A/Ds attached to the Ethernet board provide sensor excitation, linearization, software filtering, auto standardization, and alarm monitoring. The unit accepts input power from 12 to 24 VDC. A temperature sensor for each group of eight channels serves as a cold reference for thermocouples.

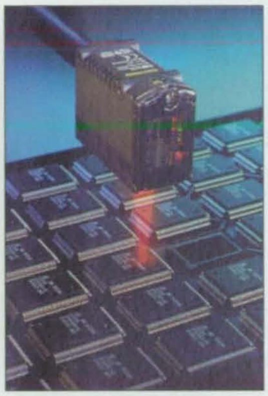
For More Information Circle No. 721



The Series 3700 **capacitive accelerometers** from the DC Sensors Division of PCB Piezotronics, Depew, NY, are available in versions with integral cables. The units can be submerged in water and withstand exposure to oils and other contaminants. Models are available in single-axis and triaxial sensing configurations with versions capable of DC or static acceleration measurements from 20 micro g up to 200 g.

The units utilize on-board voltage regulators to insure constant sensitivity values, regardless of supply voltage. They are protected against shock overloads of up to 3000 g. Lightweight, hermetically sealed titanium housings reduce mass loading to insure accurate measurement results.

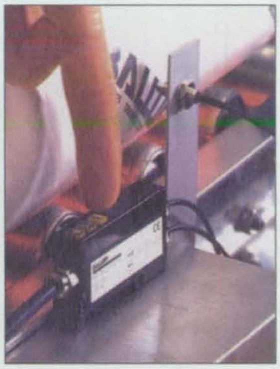
For More Information Circle No. 722



Omron Electronics, Schaumburg, IL, offers the E3G-L1 **photoelectric sensor** that provides a pinpoint beam of 1-mm diameter with a range of 5-50 mm. The beam can detect the presence or absence of minute targets without the use of a laser. The sensor also incorporates one-touch threshold sensitivity teaching adjustment with distance-setting capabilities.

The optical system achieves stable detection of objects regardless of glossiness, color, material, surface irregularities, or inclination. The series offers NPN or PNP models, red or infrared light sources, and cable or connector versions. Features include switch-selectable Light-ON or Dark-ON operation and a NEMA 4 enclosure.

For More Information Circle No. 723



Balluff, Florence, KY, offers the BOS 20K **fiber-optic sensor** with teach-in capability for quick setup. Once the part to be detected is brought into position, sensor setting is locked with a single push of the "set" button. Sensitivity can be fine-tuned manually with +/- buttons, then locked with a disable function to prevent tampering and accidental adjustment. Four display elements indicate sensor output, time delay, stability, and key lockout condition.

The sensor measures 60 x 30 x 13 mm and is powered by 10-30VDC. It is programmable for PNP or NPN operation and includes short-circuit and reverse-polarity protection. It is available with a 2-meter cable or a four-pin M8 connector, and is DIN-rail or screw-mountable.

For More Information Circle No. 726

The Q45UR Flat-Pak **remote ultrasonic sensor** from Banner Engineering Corp., Minneapolis, MN, features an ultra-compact, rectangular remote-sensing head for limited-space applications and difficult environments. The sensor measures 27.5 mm (1.08") square and is 12 mm (0.47") high. It includes integral thermistors that compensate for temperature variations, and is housed in rugged plastic.

The sensor operates in temperatures from -25° to +70° C, and is available in both switched-output (discrete) and analog models. Three LEDs provide continuous indication of programming and operating status. A red, moving dot target indicator simplifies set-up and provides a constant display of performance.

For More Information Circle No. 725

Baumer Electric, Southington, CT, has introduced the UDDK 30 **ultrasonic sensor**, designed for applications involving interfering objects and confined spaces. The sensor includes a teach-in feature that can "learn" to fade out obstacles, facilitating installation and operation on the factory floor.

The sensor features an elliptical measuring area with an opening angle of 8° and one-touch setup. It also can be taught to ignore interfering objects between the sensor and the target, which allows users to detect objects through a grid or narrow opening.

For More Information Circle No. 724

Electronic Components and Systems

Submillimeter-Sized $Bi_{2-x}Sb_xTe_3$ Thermoelectric Devices

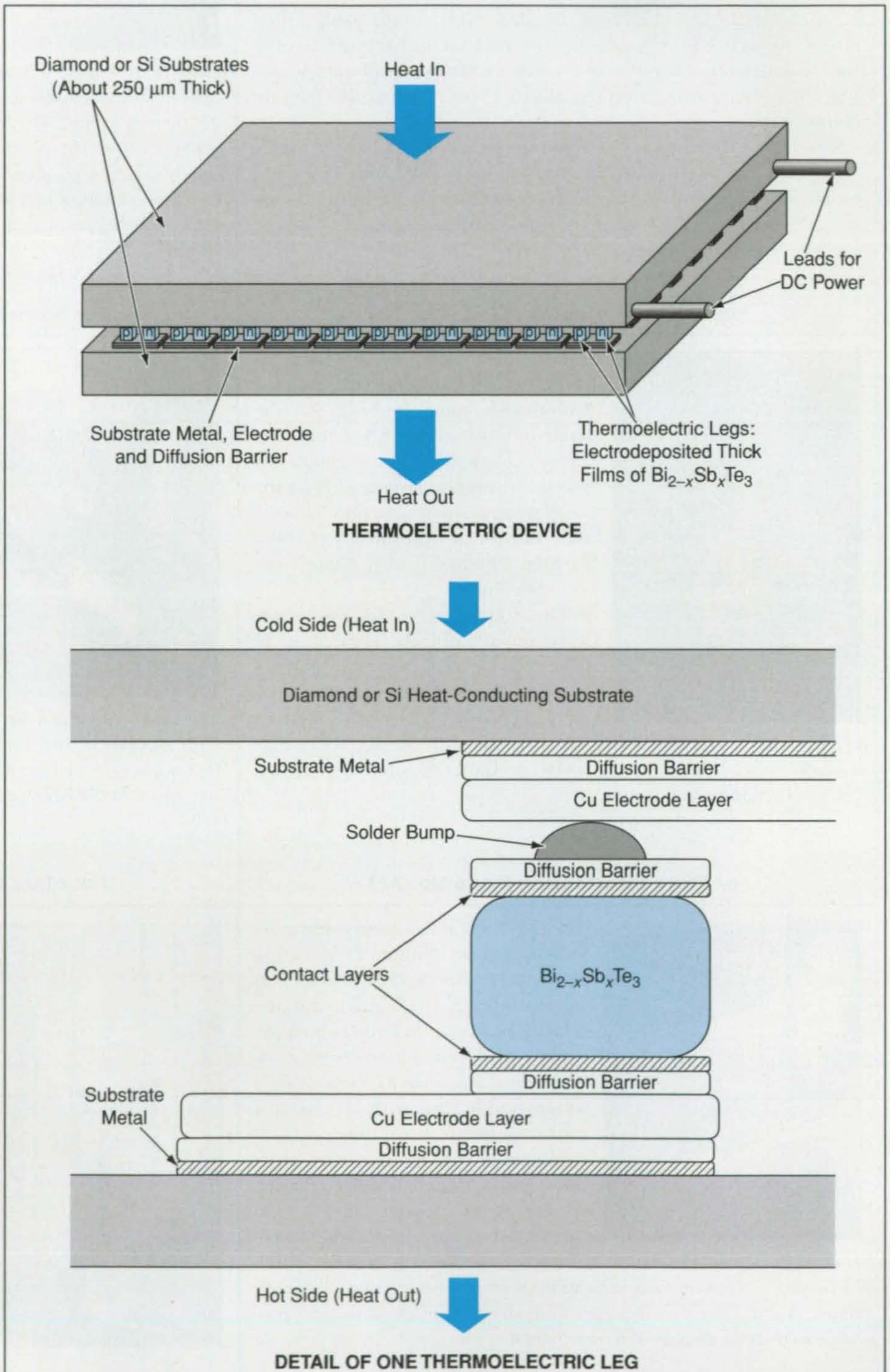
Electrochemical deposition is the key to mass-producibility.

NASA's Jet Propulsion Laboratory, Pasadena, California

Submillimeter-sized thermoelectric devices based on thick films of $Bi_{2-x}Sb_xTe_3$ are undergoing development. As electronic circuits are designed with ever greater packaging densities and power densities, there is an increasing need for small thermoelectric devices to provide active spot cooling for power amplifiers and other heat-generating electronic components. $Bi_{2-x}Sb_xTe_3$ is the preferred thermoelectric material for the operational temperature range (<200 °C) of typical advanced microelectronic components. $Bi_{2-x}Sb_xTe_3$ thermoelectric devices could also be used as electric-power generators; moreover, because of the smallness of the thermoelectric legs in these devices, the numbers of legs can be of the order of 100 times those of conventional bulk thermoelectric devices, making it possible to generate higher potentials (of the order of 100 V), that are more compatible with other electronic components.

The figure depicts a representative device of this type, wherein the $Bi_{2-x}Sb_xTe_3$ thermoelectric legs have lengths, widths, and thicknesses of the order of tens of microns. The thermoelectric legs are integrated with contact, diffusion-barrier, and electrode layers, all sandwiched between two thermally conductive, electrically insulating outer layers (made of AlN or synthetic diamond substrates) that are placed in contact with the heat source and heat sink, respectively. The $Bi_{2-x}Sb_xTe_3$ legs are made by electrochemical deposition from an aqueous solution; the other parts of the device are fabricated by various conventional integrated-circuit-fabrication techniques, including photolithography and vacuum deposition.

In comparison with such conventional semiconductor-fabrication techniques as sputter deposition, vacuum evaporation, and chemical



A **Thermoelectric Module** would contain thermoelectric legs made from thick films of n- and p-doped $Bi_{2-x}Sb_xTe_3$, plus multiple metal layers and outer layers made from high-thermal-conductivity materials. The thermoelectric legs would be connected electrically in series and thermally in parallel.

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For More Information Circle No. 507

chemical deposition offers several advantages for fabrication of the $Bi_{2-x}Sb_xTe_3$ thermoelectric legs. Growth rates achievable by electrochemical deposition are in the range of tens of microns per hour — fast enough for mass production of devices in the desired size range — whereas lower growth rates achievable by the conventional techniques are better suited to fabrication of submicron-sized devices. The conventional techniques are poorly suited to fabrication of $Bi_{2-x}Sb_xTe_3$ devices because the vapor pressures of Bi, Sb, and Te are very different; on the other hand, the compositions of films grown by electrochemical deposition can be controlled via the concentrations of the constituents of the aqueous deposition solutions.

Substrates can be coated with metal interconnection busses and contact pads and then masked, all by conventional integrated-circuit-fabrication techniques. Then $Bi_{2-x}Sb_xTe_3$ thermoelectric legs can be electrodeposited onto the contact pads through the holes in the masks. Thus, conventional integrated-circuit-fabrication techniques can readily be combined with electrochemical deposition for mass production of submillimeter $Bi_{2-x}Sb_xTe_3$ thermoelectric devices.

A significant part of the development effort thus far has been devoted to the electrochemical deposition process. The general approach is to dissolve Bi, Sb, and Te in nitric acid, then put the resulting solution in an electrochemical cell, wherein $Bi_{2-x}Sb_xTe_3$ (which is insoluble in HNO_3) is deposited on a cathode. Process parameters that must be optimized include the pH of the solution; the concentrations of Bi, Sb, and Te in the solution; the temperature of the solution; stirring of the solution; the deposition voltage and current density; the surface finish of the cathode; and post-deposition annealing. One of the findings of experiments conducted thus far is that the limited solubility of Sb in the solution can be enhanced by use of tartaric acid as a buffer.

This work was done by Jean-Pierre Fleurial, Margaret A. Ryan, Alex Borshchevsky, Wayne Phillips, Elizabeth Kolawa, G. Jeffrey Snyder, and Thierry Caillat of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Components and Systems category.*
NPO-20472

High-Speed Complex-Amplitude Liquid-Crystal SLMs

Frame rates of the order of several kilohertz are achievable.

Lyndon B. Johnson Space Center, Houston, Texas

High-speed complex-amplitude spatial light modulators (SLMs) containing liquid crystals with pixel electronic circuitry on single-crystal-silicon backplanes are undergoing development. The basic approach taken in this project is to use fast-switching liquid-crystal materials and modulation-enhancing device geometries that have not been used in prior display systems.

The modulator materials selected for this project are chiral smectic liquid-crystal (CSLC) materials of the high-tilt type. These materials are capable of modulating light with switching times <100 μs; however, they have traditionally been dismissed with respect to use in analog complex-amplitude SLMs because they give rise to the following disadvantageous device characteristics:

- Rotative switching (rather than variable retardance) occurs and results in bipolar amplitude modulation in the typical crossed-polarizer arrangement. A variable-birefringence device produces coupled phase and amplitude modulation when operated in the same fashion.
- Depths of modulation are inadequate; CSLC materials act to produce either continuous operation over small ranges or else two-state (binary) switching.
- Relatively strong electric fields and thus high drive voltages are needed for full switching in analog CSLCs.

These device characteristics as well as other pertinent issues have been addressed during the project. Accomplishments have included the following:

- Alignment techniques and drive schemes for high-tilt materials to obtain true gray-scale modulation were developed. These CSLC materials directly provide bipolar amplitude modulation (real-axis coverage) and are essential for nondispersive phase modulation.
- A polymer cholesteric liquid crystal has been verified to function as a handedness-preserving mirror, which enhances the modulation depth of a resonated or a two-pass non-resonated phase-only CSLC modulator.
- A nonresonated 2π-radian analog phase modulator containing a cholesteric-liquid-crystal (CLC) mirror and a high-tilt analog half-wave element has been demonstrated.
- A thin-film CLC has been investigated for use as a low-stress planarization layer for a very-large-scale integrated (VLSI)-circuit backplane. The CLC film acts as a phase-flat mirror inasmuch as the top surface is formed against an optical flat. The top surface is reflective and masks the underlying VLSI structures.
- A mathematical-modeling program that utilizes a 4 ¥ 4-matrix technique was developed for use in analyzing the geometries of modulators that exploit rotative switching in CSLCs or variable retardance in nematic liquid crystals.
- Closed-form solutions were derived for the modulators for general input polarizations, giving a variety of available operating curves not obtainable when using nematic liquid crystals. This analysis pertains to the arrangement of a reflection-mode SLM with a polarizing beam splitter as an analyzer and beam-routing device.
- The use of a high-voltage backplane was found to improve optical-correlation performance.
- A high-performance 128 ¥ 128 analog SLM with a VLSI backplane was demonstrated (at the time of reporting the information for this article, there were plans to develop subsequent devices with higher pixel densities). This VLSI backplane operates at a potential of 12 volts and at a load rate of 10,000 frames/second, with full analog signal storage at each pixel and a pixel pitch of 40 μm. This VLSI backplane supports a variety of liquid-crystal modulators in addition to those based on high-tilt CSLCs.
- SLM drive circuitry and control software were developed and tested. The SLM drive system is controlled by a personal computer.
- A postprocessing technique for planarizing a VLSI backplane was investigated. The technique involves deposition of a thick oxide layer on the VLSI silicon wafer, followed by chemical-mechanical polishing. After polishing, optical-quality pixels are deposited and connected to the underlying VLSI circuits.

Overall, the project has been instrumental in increasing understanding of the principles of operation and of manufacturing liquid-crystal-on-silicon SLM products.

This work was done by Gary Sharp and Steve Serati of Boulder Nonlinear Systems, Inc., for **Johnson Space Center.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Components and Systems category.*
MSC-22840

Instrument Measures Fluorescence From Chlorophyll in Plants

Effective discrimination against solar background radiation is achieved without critical optical and mechanical parts.

Stennis Space Center, Mississippi

An optoelectronic instrument, known as a plant fluorescence sensor, is being developed for use as a working tool in agricultural settings. This instrument is a remote, passive monitor that provides a means of discerning plant stress at very early stages. With sufficient warning, the user could provide timely applications of fertilizer, water, and/or pesticide to achieve maximum crop yield at minimum cost. Figure 1 presents two views of the plant fluorescence sensor. The instrument is the subject of U. S. Patent 5,567,947.

Measurement of steady-state plant fluorescence offers the possibility of determining the physiological status of a green plant. The magnitude of plant fluorescence and its spectral (color) distribution is sensitive to a number of factors which are related to the ability of a plant to perform photosynthesis (the process by which green plants convert atmospheric water vapor and carbon dioxide into sugars and oxygen, using sunlight as fuel). For instance, the light capture efficiency of the plant is dependent on the type and amount of pigment molecules (such as chlorophyll) which in turn is dependent on adequate fertilization. Plants stressed from a lack of fertilizer will limit chlorophyll production and exhibit both lower overall level of fluorescence and shift in spectral distribution compared to healthy plants. Another factor, such as lack of adequate water, can serve to limit the rate of photosynthesis by causing the plant to close its stomata (the openings which allow the leaf to draw in carbon dioxide and water vapor); when this happens, the level of plant fluorescence will generally increase. Thus, measurements taken with this sensor can guide growers in the allocation of resources such as irrigation water, fertilizer, and pesticides.

Under sunlight, the chlorophyll in plants fluoresces at wavelengths from about 660 to 800 nm. The major problem in measuring this fluorescence is to discriminate against scattered sunlight, which can contribute a spurious component to the measurement. The present sensor is of the class of apparatuses known as Fraunhofer-line or spectral-line discriminators, but this sensor differs from others of its class by virtue of a unique design that exploits the spectral absorption lines of oxygen in such a way as to obtain enhanced spectral discrimination at lower cost. The desired spectral resolution and discrimination are achieved without need for the highly precise, expensive optical components with critical mechanical adjustments (e.g., Fabry-Perot cavities) that are used in other spectral-line discriminators.

Atmospheric oxygen strongly attenuates incident sunlight in spectral lines in two groups known as A band (wavelength ≈760 nm) and B band (wavelength ≈688 nm). Each of these bands includes about 40 spectral lines with such strong absorption that the atmosphere can be considered opaque at the middle wavelengths of these lines. Chlorophyll fluoresces strongly at these wavelengths. Thus, if light from plants at these wavelengths is measured, one can be assured that the measurement represents only fluorescence from chlorophyll, without contribution from

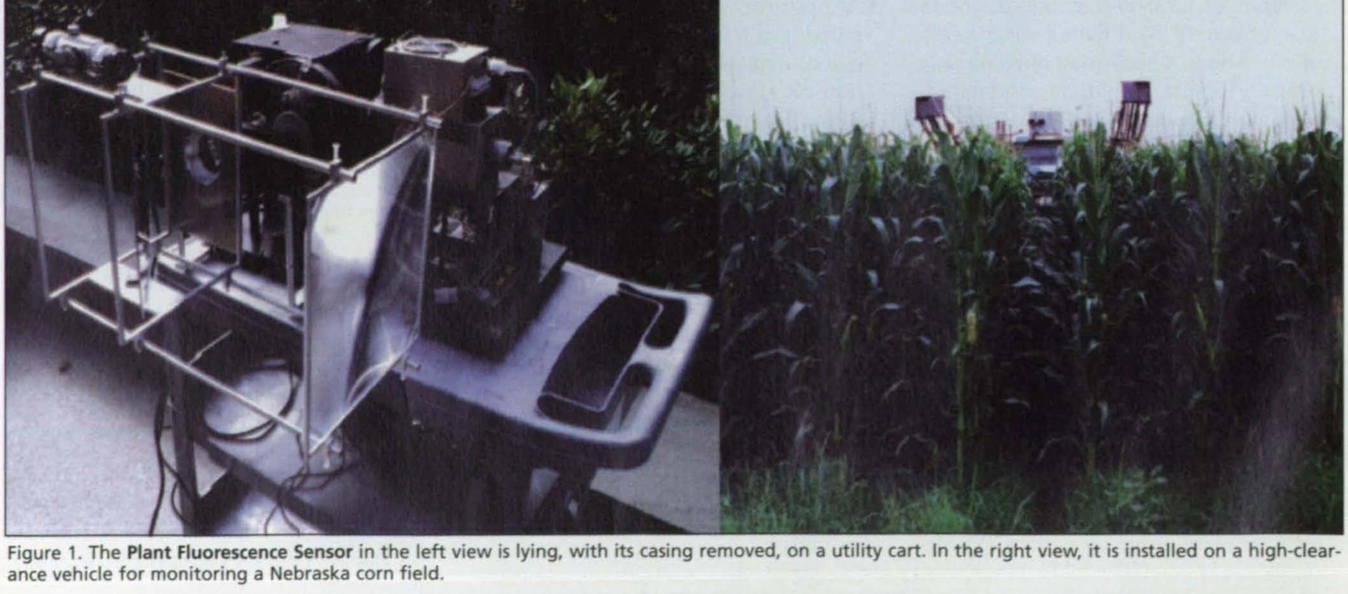
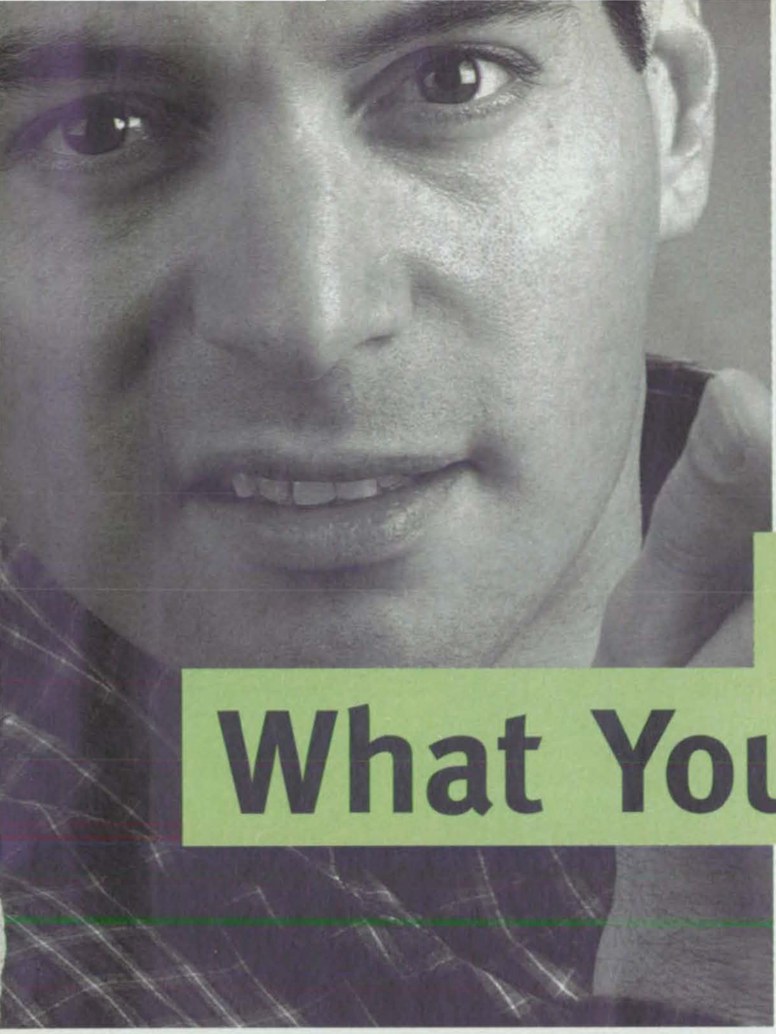


Figure 1. The **Plant Fluorescence Sensor** in the left view is lying, with its casing removed, on a utility cart. In the right view, it is installed on a high-clearance vehicle for monitoring a Nebraska corn field.



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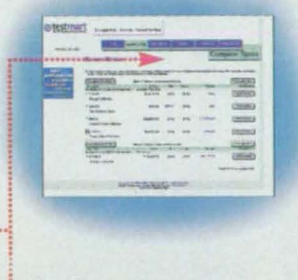

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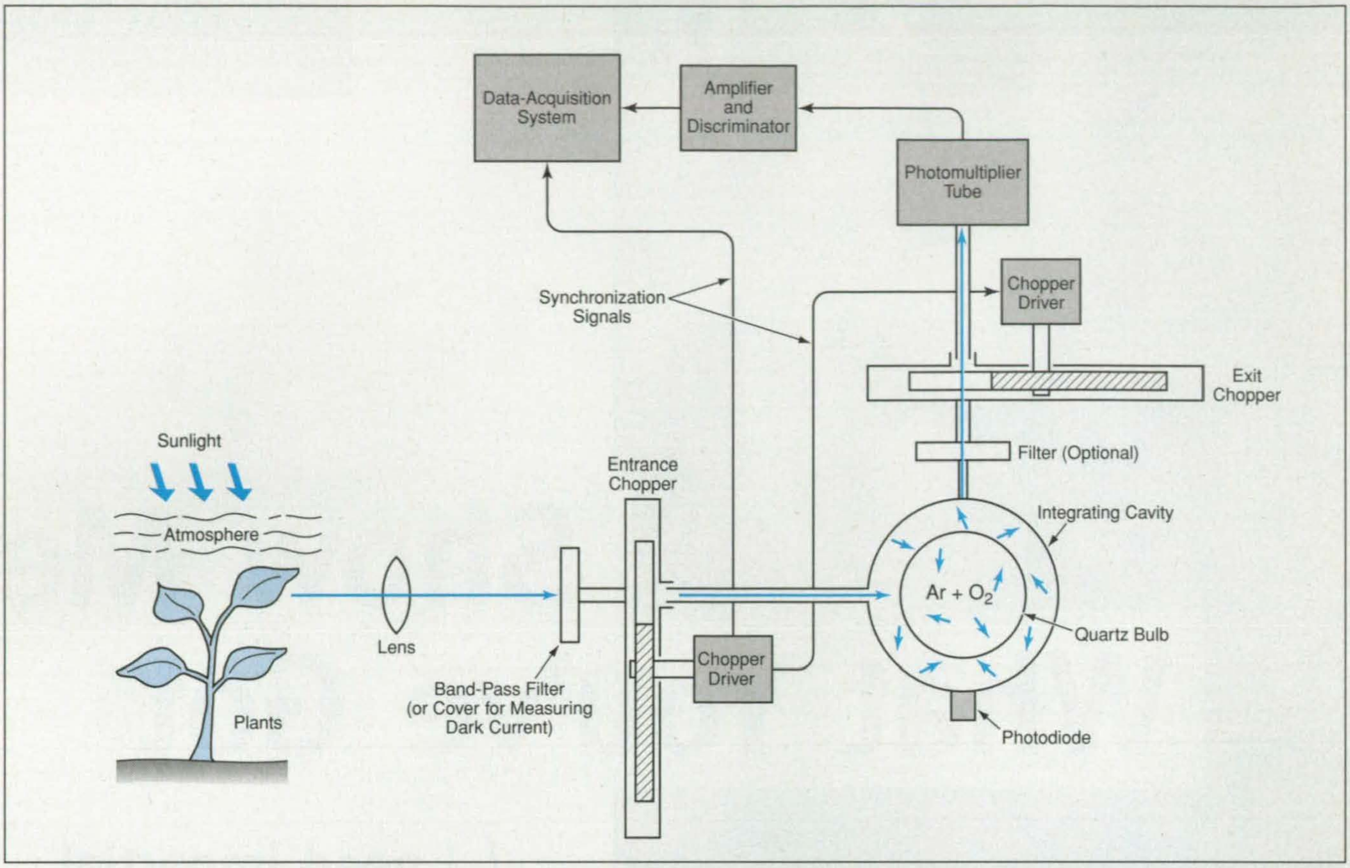


Figure 2. This **Spectral-Line Discriminator** measures fluorescence from sunlit plants. Discrimination against scattered sunlight is achieved by a design that utilizes the absorption spectrum of atmospheric oxygen in combination with absorption and fluorescence in a bulb that contains oxygen.

scattered sunlight. Of course, the measuring instrument must be close enough to the plants in question that atmospheric oxygen does not also appreciably absorb the fluorescence from the chlorophyll, along with sunlight at the affected wavelengths; the resulting practical limit on the range of the present instrument or any similar instrument is 100 to 200 meters.

The present sensor (see Figure 2) is based on this spectral-discrimination principle. Light from sunlit plants is focused by a lens, then made to pass through a filter that passes wavelengths in a chosen 10-nm-wide subband of A or B band. The band-pass-filtered light passes through an entrance chopper, then along a light pipe to a spherical integrating cavity. Centered in the cavity is a quartz bulb that contains a gaseous mixture of oxygen and argon at a total pressure of about 100 torr (about 13 kPa).

When the entrance-chopper aperture is open, the oxygen in the bulb is illuminated by plant fluorescence plus scattered sunlight in the chosen subband of A or B band, but the oxygen absorbs only the light at its characteristic absorption wavelength in this subband. Because the atmosphere has already filtered out sunlight at these wavelengths, the light absorbed by the oxygen consists almost entirely of fluorescence emitted by the plants. While the entrance-chopper aperture remains open, a silicon photodiode measures the total A- or B-band radiation received by the cavity.

When the entrance-chopper aperture is closed, the oxygen in the bulb emits the absorbed light energy as fluorescence in A band (regardless of whether the illumination is in A band or B band). Because the entrance-chopper aperture is closed, the remaining light in the cavity consists entirely of this secondary fluorescence, proportional to the fluorescence from the plants. An exit chopper synchronized in opposite phase with the entrance chopper opens to allow this light to pass to a photomultiplier tube cooled to a temperature 40 K below ambient. The output of the photomultiplier tube is processed and fed to a data-acquisition system.

This work was completed by Paul L. Kebabian, Herman E. Scott, and Andrew Freedman of Aerodyne Research, Inc., for **Stennis Space Center** *under 1996 SBIR Phase II: NAS #NAS13-707. For further information, contact Herman Scott of Aerodyne Research, Inc., at (978) 663-9500 extension 267).*

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

Laurie S. Dean,
Commercialization Manager
Aerodyne Research, Inc.
45 Manning Road
Billerica, MA 01821-3976

Refer to SSC-00037, volume and number of this NASA Tech Briefs *issue, and the page number.*

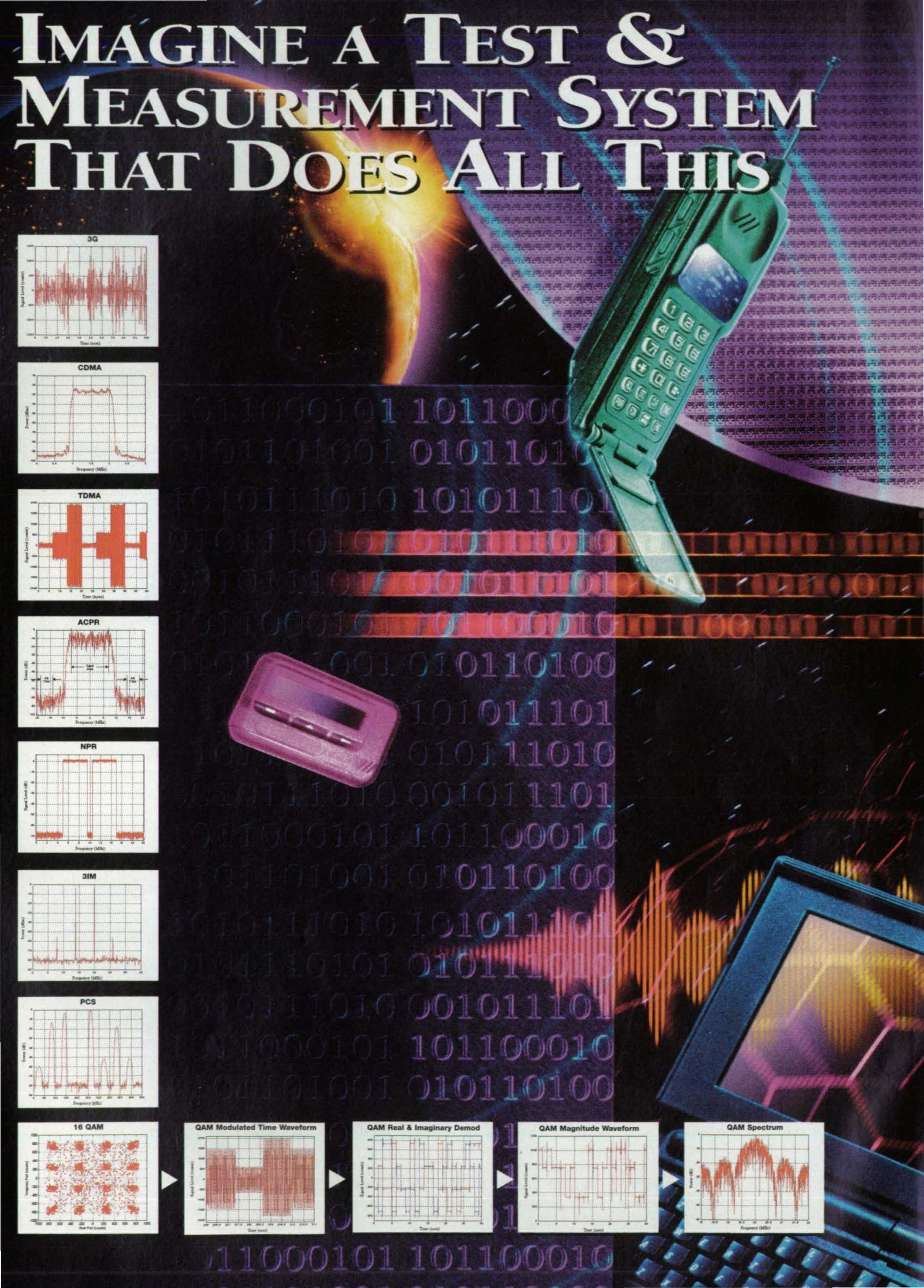
Laser Heating for Testing Rocket-Engine Insulating Phenolic

Marshall Space Flight Center, Alabama

A continuous-wave CO_2 laser has been selected as a source of heat for testing the thermal response of carbon-cloth phenolic like that used as insulating material in a reusable solid-fuel rocket motor (RSRM). The particular thermal response of interest, observed during operation of an RSRM, is pocketing. By suitable adjustment of the size and power of the laser beam, the rate of heating can be made nearly identical to that in the RSRM nozzle during operation.

The use of the laser as the source of heat in such testing is accompanied by the use of optical means to measure the surface temperatures of specimens. The surface-temperature measurements make it possible to construct better mathematical models and develop better understanding of the thermal response of the material under test. Moreover, unlike the environment in a test motor during operation, the environment in the vicinity of a laser-heated specimen is not dominated by hot chemicals in high concentrations; as a result, additional instrumentation that cannot be used in tests in an operating rocket engine can be used in laser-heating tests.

This work was done by Timothy N. Johnson and Edward C. Mathias of Thiokol Corp. for **Marshall Space Flight Center.** *MFS-31272*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QAM Magnitude Waveform
QAM Spectrum

Software

SIMON – School Internet Manager Over Networks

This program is designed for managing access to the Internet for teachers and students.

Lyndon B. Johnson Space Center, Houston, Texas

School Internet Manager Over Networks (SIMON) is a software tool, exclusively for use on Macintosh computers, that is designed to provide access to, and management of, Internet information for teachers and students in kindergarten through twelfth grade. By eliminating the requirement for advanced system services typically provided by proxy seravers (the computer tools of choice for access to the Internet), SIMON, which is available free on a NASA web site, has eliminated the related need for costly hardware servicing and system administration. Indeed, after installation, SIMON can maximize the overall utility of a user's local-area network (LAN), retrieve Internet information, and organize and present information to students. SIMON is not unique in the industry: several programs now commercially available perform a subset of functions that SIMON also performs. However, inasmuch as SIMON is uniquely tailored to the public-school milieu, it uses equipment commonly available to public schools, thereby reducing costs and serving as a more user-friendly product, relative to the other programs.

In these days of restricted funding, it is hardly surprising that public school systems are often short of money. Unfortunately, proxy servers, which are typically used as Internet-access tools, are available only on computers that are capable of hosting advanced system services (e.g., UNIX™ or Windows NT™). These systems are usually not financially viable for public school systems. Moreover, because proxy servers also demand a high degree of hardware support and system administration, the public school environment is not suited to these either.

SIMON overcomes these obstacles to access to the Internet. It does this by enabling the users for which it is uniquely tailored — public school systems — to use their own computers to retrieve Internet information, even when their computers are not directly connected to the Internet. More specifically, SIMON enables the users' system browsers to interact with mini-servers running on the users' own computers. Information requests are thus sent from a user's mini-server to the SIMON master server running on the computer connected to the Internet. By using the SIMON master server in this fashion, to funnel requests and distribute data across a LAN, teachers can control the content of the information and use stored library information to retrieve information even when the information is requested numerous times. Moreover SIMON is able to discriminate among users, recognizing two groups: teachers, who have special system privileges, and students. Teachers submit queries, which are answered with existing library documents and/or directly from Internet sources, and create the presentation documents, which are on file in the library. Students have access only to documents filed in the library. This arrangement enables teachers to manage materials used in the classroom and enables students to perform research and analyze information by use of Internet-based techniques.

As an Internet-access software tool, SIMON has few peers. Although it runs only on Macintosh computers, this one restriction is far outweighed by its benefits. SIMON features numerous search and retrieval functions (off-line searching, off-line browsing of search results, and downloading of web sites), lesson-building functions (off-line browsing of web sites, a lesson builder with web-page selector, and a lesson editor), and lesson-library-management functions (an off-line lesson library, automatic or manual lesson addition, and lesson-sharing utilities). By virtue of these advantages, as well as ease of installation and use, SIMON will surely serve as a tool of the future — one that can satisfy a primary need in grades kindergarten through 12. Already used by the Department of Education, the user-friendly SIMON can be used in the development of curricula as well as to restrict access to the Internet.

This work was done by Robert O. Shelton of **Johnson Space Center**, *Stephanie Smith of Lincom Corp., and Dat Truong and Terry Hodgson of Space Applications International Corp. For further information, access* ***http://prime.jsc.nasa.gov.***
MSC-22898

Special Coverage: Composites and Plastics

RTM-Processable Resins Containing Thermosetting Plasticizers

These plasticizers lower viscosities without giving rise to volatiles.

John H. Glenn Research Center, Cleveland, Ohio

A number of matrix resins that contain thermosetting plasticizers have been developed for use in the resin-transfer molding (RTM) of composite-material (fiber/matrix) parts. These resins and composites are candidates for use in manufacturing lightweight components of aircraft engines and other structures that must withstand temperatures up to and perhaps somewhat above 300 °C.

RTM is attractive for this purpose because it is a relatively inexpensive process for producing medium quantities (typically, thousands) of complexly shaped parts. In RTM, a fiber preform is infiltrated with a molten resin that, typically, has been partially pre-cured ("staged"). For making high-quality parts, a resin to be used in RTM must have the following characteristics:

- Its viscosity must be low enough to allow it to flow through the preform without distorting the preform;
- It must wet the fibers adequately;
- Its pot life at the RTM processing temperature and viscosity must be at least 30 minutes; and
- It must outgas as little as possible during filling of the mold and subsequent curing of the resin.

The present resins are based on the AMB-21 resin system — a less-toxic system recently developed as an alternative to the PMR-15 polyimide system. [The industry standard polyimide matrix resin, PMR-15 was developed at Lewis Research Center (since named Glenn Research Center) in 1971. The PMR-15 monomer mixture includes methylenedianiline (MDA), a suspected carcinogen.] The basic AMB-21 prepolymer solu-

Resin	Weight Percent of AME-21	Weight Percent of DEDPM	Weight Percent of PEDPM	Thermal History (Staging)	Viscosity @ 120 °C (cPs)	Solvent
1	50	50	-	Rotary Evaporation 100 °C, 30 min	300 to 1,000 (Scattered)	THF
2	60	40	-	"	~100	THF
3	70	30	-	"	~100	THF
4	80	20	-	"	>1,000	THF
5	70	30	-	Vacuum Evaporation 70 °C, 1 hr 90 °C, 1 hr	2,900	Acetone
6	70	15	15	"	2,100	Acetone
7	70	15	15	"	6,000	Toluene
8	70	15	15	Vacuum Evaporation 70 °C, 1 hr	15,000	Acetone
9	70	15	15	"	2,000	Toluene
10	100	-	-	Rotary Evaporation 70 °C, 1 hr	-	Acetone
11	70	30	-	"	2,400	Acetone
12	60	26.6	13.4	"	480	Acetone
13	60	31.6	8.4	"	480	Acetone
14	60	40	-	"	400	Acetone
15	60	35.8	4.2	"	550	Acetone
16	60	26.6	13.4	"	355	Acetone
17	60	26.6	13.4	Rotary Evaporation 70 °C, 1 hr 90 °C, 1 hr	355	Acetone
18	60	26.6	13.4	Rotary Evaporation 70 °C, 1 hr 90 °C, 1 hr 110 °C, 0.5 hr	-	Acetone
19	60	26.6	13.4	Rotary Evaporation 70 °C, 1 hr 90 °C, 1 hr 110 °C, 1 hr	384	Acetone
20	60	26.6	13.4	Rotary Evaporation 70 °C, 0.5 hr 110 °C, 1 hr	-	Acetone

These **Formulations of AMB-21** with the plasticizers DEDPM and PEDPM include some that could be suitable for RTM and a few that are unsuitable for RTM because their viscosities are too high.

tion is a made by combining three monomeric solutions:

- 3,3',4,4'-benzophenonetetra-carboxylic ester (BTDE) in methanol;
- the monomethyl ester of norbornene-2,3-dicarboxylic acid (NE) in methanol; and
- bis(aminophenoxy) propane (BAPP) in tetrahydrofuran (THF), acetone, or toluene.

The basic AMB-21 prepolymer does not have the correct rheological properties for RTM; in particular, its viscosity is too high. The approach taken in the development of the present resins involved the reduction of viscosity through the addition of thermosetting plasticizers (more specifically, low-viscosity reactive diluents that are chemically compatible with AMB-21). Plasticizers that have shown promise include diethynyldiphenyl methane (DEDPM), phenylethynyldiphenyl methane (PEDPM), and mixtures thereof.

During RTM, the plasticizer molecules lower the viscosity of a resin. During the cure that follows RTM, when the plasticizing effect is no longer needed, the plasticizer molecules disappear via addition reactions, without evolution of volatiles. This is advantageous in that volatiles can give rise to undesired voids in the finished part. The cured resin has relatively high thermal stability. The glass-transition temperatures (T_gs) of polymerized matrix resins formulated and processed following this approach equal or exceed the T_g (≈300 °C) of AMB-21.

One potential drawback of this approach is that the high degree of cross-linking in these resins can suppress ductility and induce a brittle failure under single-cycle or fatigue loading, or can cause microcracking during cure. Therefore, the development effort has included tradeoff studies to identify the formulations of RTM-processable resins with the best high-temperature stability and ductility. The table depicts some of the formulations investigated thus far. Composite specimens made from some of these resins have exhibited promising thermal and mechanical properties. These studies were continuing at the time of reporting the information for this article.

This work was done by Robert Kovar, Nelson Landrau, Margaret Roylance, and Thomas Tiano of Foster-Miller, Inc., for **Glenn Research Center**.

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Commercial Technology Office, Attn: Steve Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-16926.

Molded Plastic Simulated Landscapes

Lyndon B. Johnson Space Center, Houston, Texas

Simulated landscapes of Mars have been made of thermoplastic sheets molded to shapes derived from images of the Martian terrain. These simulated landscapes can be used to advantage in scientific experiments, simulations, educational displays, and other applications, in which unitary molded plastic sheets can be handled more easily and pose less risk of contamination than do simulated landscapes made of loose rocks. Fabrication begins with the selection of terrestrial rocks with a distribution of sizes and textures representative of the terrain of interest. The rocks are arranged on the vacuum table of a thermoforming apparatus. A sheet of thermoplastic material (e.g., polycarbonate 1.58 mm thick) is heated to drive off moisture, then is heated further to its softening temperature. When at the softening temperature, the sheet is placed over the rocks, then vacuum is applied via the table to pull the sheet down over the rocks. Once thus formed to the shape of the rocks, the sheet is allowed to cool, then is taken off the table. Any rocks inadvertently captured in the molded sheet are removed.

This work was done by Joseph J. Kosmo of **Johnson Space Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Materials category.*
MSC-22885

Burn-Resistant, Strong Nickel Alloys

Precise control of alloy composition affords both burn resistance and strength.

Lyndon B. Johnson Space Center, Houston, Texas

Investigators at the Johnson Space Center White Sands Test Facility (WSTF) have developed specifications of the amounts of alloying elements needed to increase the specific strengths of nickel alloys while consistently maintaining their burn resistance. The issue of burn resistance versus strength arises because pure nickel resists burning in pure oxygen at pressures up to $>10^4$ psia (>69 MPa), but does not have enough specific strength to satisfy the requirements for use in engineered structures.

The high burn resistances of nickel and of some nickel alloys make them attractive for some structural applications. These alloys can be used in such oxygen-enriched structures as hyperbaric chambers and spacecraft, where fires could have catastrophic results. Because the specific strength of pure nickel falls short of structural needs, elements with high specific strength and low burn resistance — such as aluminum and titanium — are alloyed with nickel. Unfortunately, prior to this investigation, large variations in burn resistance among batches of nominally identical commercial nickel alloys had been observed. For example, while one batch of a commercial nickel alloy was found to burn in pure oxygen at a pressure $> 10^4$ psia (≈69 MPa), another batch was found to burn at a pressure $<5 \times 10^3$ psia (≈34 MPa). This inconsistency renders the use of commercial nickel alloys in oxygen-enriched structures problematic at best, disastrous at worst. The WSTF investigators sought to discover why this inconsistency occurs.

The investigators identified an inherent looseness in the composition ranges of commercially produced, high-temperature, high-strength nickel alloys, which makes the alloys more likely to burn in oxygen-rich atmospheres. Combustion occurs because the alloying elements that are not burn-resistant — aluminum, silicon, manganese, titanium, chromium, and iron — are used in varying quantities to form primary solid solutions with nickel. The investigators found that even small variations in alloying content can significantly affect burn resistance. For example, in preliminary tests on two batches of the nickel alloy Haynes 214, one batch burned at a pressure above $>10^4$ psia (>69 MPa) while the other batch burned at only 3×10^3 psia (≈21 MPa), yet both batches were within manufacturer's specifications. Further study led to the conclusion that the difference between the burn resistances of the two batches was attributable to looseness in the proportions of the alloying elements aluminum and chromium.

If the proportions of the alloying elements in nickel alloys were better regulated, the primary solid solution phases could retain both the burn resistance of

Alloy	Alloying Element	Proportion of Alloying Element, Weight Percent	Pressure for Onset of Burning in Pure Oxygen	
			MPa	psia
Ni-Al	Al	1.0	>69	>10,000
		3.0	>69	>10,000
		5.1	>69	>10,000
		10.3	2.1	294
Ni-Fe	Fe	5.0	>69	>10,000
		10.0	>69	>10,000
		20.0	>69	>10,000
		30.0	>2.68	375
Ni-Cr	Cr	9.77	>69	>10,000
		19.9	>69	>10,000
		37.12	2.1	294
		50.1	3.4	476
Ni-Mn	Mn	1.98	>69	>10,000
		6.0	>69	>10,000
		9.9	>69	>10,000
		52.1	0.34	47.6
Ni-Si	Si	5.0	>69	>10,000
		10.7	>69	>10,000
Ni-Ti	Ti	1.04	>69	>10,000
		3.15	>69	>10,000
		5.01	>69	>10,000
		8.3	31	4,340
		25.9	0.14	19.6
		43.9	0.14	19.6

The **Compositions of Nickel Alloys** affect their ability to resist burning.

pure nickel and the strength of the alloying elements. The investigators found that if elements are added in the quantities shown in the table, the specific strengths of nickel alloys can be increased without reducing resistance to burning. The findings of this investigation are expected to ensure that differences among the burn resistances of manufactured nickel alloys can be reduced, without adversely affecting the safety of individuals who live and work in oxygen-rich atmospheres.

This work was done by Joel M. Stoltzfus of White Sands Test Facility and Moti J. Tayal of Rockwell International for **Johnson Space Center.**
MSC-22698

Aerogels With Gradients of Density

Density gradients could be tailored to obtain desired properties.

NASA's Jet Propulsion Laboratory, Pasadena, California

Aerogels with gradients in density have been produced in experiments, as part of an effort to develop materials that will be used in outer space to capture particles traveling at high speeds for the STARDUST mission.

On Earth, aerogels with gradients of density could be used as lightweight materials with tailorable optical, acoustical, thermal, catalyst-support, or microelectronic-packaging properties. In addition to extremely low (and now optionally spatially varying) densities, aerogels have unique combinations of properties that make them economically competitive with other materials that would otherwise be used in the same applications.

One experimental aerogel exhibited a gradient of density from 5 to 50 mg/cm^3. Depending on the intended application, the gradient of density in an aerogel component could be tailored to obtain the desired corresponding gradient in the optical or acoustical index of refraction, optical or acoustical attenuation, permittivity, thermal conductivity, or other property or properties of interest.

This work was done by Steven Jones and Peter Tsou of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Materials category.*
NPO-20485

New on the MARKET

Pressure Transducers

OMEGA Engineering, Stamford, CT, offers the PX624 Series pressure transducers that combine a photo-optical sensor with SMD electronic circuits. The devices provide accuracies of ±0.05% of span. A getter material in the evacuated reference chamber acts as a sponge to absorb stray gas molecules as they are released from the surface of the reference chamber. Each unit is furnished with a 20-point certificate of calibration traceable to NIST. **Circle No. 708**

GPS for Data Logger

IOtech, Cleveland, OH, offers Global Positioning System (GPS) support for its LogBook/360™ stand-alone, PC-based data acquisition system. The 16-bit, 100-kHz system measures hundreds of channels without requiring a PC at the test site. The LogBook/GPS™ software option uses the worldwide GPS satellite network to record geographic location during remote and mobile applications. The system also can correlate latitude, longitude, and altitude coordinates with acquired transducer data, allowing the user to correlate geographic position with the physical and electrical parameters measured by the data logger. **Circle No. 709**

Portable Computer

Dolch Computer Systems, Fremont, CA, offers the TransPAC™ II ruggedized portable computer designed to withstand severe shock and vibration. It is quick-release mounted and features an all-metal enclosure sealed from contamination. The unit includes a 233-MHz Pentium® MMX processor, and can be configured with up to two removable HDDs, FDD, CD-ROM, PCMCIA slots, and an expansion module with a combination of four PC/104 and PC/104+ add-in slots. Other options include a resistive touchscreen, a GPS receiver, and interface modules for RS-232, -422, -485, or SCSI II. **Circle No. 711**

Locking Cotter Pin

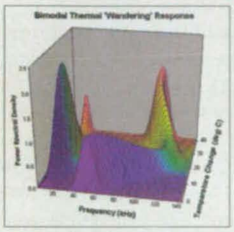
The Bow-Tie™ locking cotter pin from Pivot Point, Hustisford, WI, works like a hairpin cotter but locks itself on. The cotter snaps into a locked position by either pushing or pulling it through the hole. A definite action releases the cotter, yet it cannot be accidentally knocked or vibrated off. The pin can be used regardless of hole position and replaces conventional cotter pins in a variety of applications. The curved cotter leg provides three contact points with the hole, keeping the cotter snug. The reusable pin is available in sizes to fit 3/16" through 1" shafts, and is made of MB spring wire with a zinc-plated finish. **Circle No. 714**

New on DISK

Data Visualization for Linux

Advanced Visual Systems, Waltham, MA, has released Linux versions of its AVS/Express® and OpenViz™ data visualization technologies. AVS/Express is designed for building applications that provide interactive, multidimensional visualization and graphics. It is also suitable for scientists, researchers, and others who need advanced visualization and analysis software. AVS/Express 5.0 for Linux is a complete version of the AVS/Express product built and certified on Linux. OpenViz 1.3, available in 100-percent Java, provides portability across Linux operating systems enabled with a Java Virtual Machine (JVM). **Circle No. 715**

Technical Graphing



SPSS Science, Chicago, IL, has announced SigmaPlot 2000 technical graphing software that includes more graph types, data analysis capabilities, and presentation tools. Users can compute and graph a range of errors, including graphs with asymmetric error bars, range plots, quartile plots, and high-low-close plots. The Quick Transforms feature allows mathematical data transformations without programming. Built-in templates provide the ability to instantly arrange multiple graphs on a page, disseminate work on the Web, or create presentations with a Create PowerPoint Slide built-in macro. The program is compatible with Windows 95/98/NT/2000. **Circle No. 718**

Graphing for Mathematica

Microcal Software, Northampton, MA, has introduced Origin Link for Mathematica, an interface between Origin® scientific graphing and data analysis software, and Mathematica® integrated technical computing software from Wolfram Research. The add-on is designed to simplify the plotting, customization, and export of publication-quality graphs for Mathematica users. It provides access to a large number of plot types, along with a point-and-click interface for editing graphs. Final graphs can be exported in a variety of file formats, including EPS, JPG, and TIF. Origin also acts as an OLE2 graphics server for Windows applications. **Circle No. 716**

CFD and FEA

Gridgen Version 13.3 CFD and FEA pre-processing software from Pointwise, Bedford, TX, features new automatic geometry cleanup that automatically merges adjacent mesh surfaces within a user-specified tolerance, effectively meshing over gaps in any CAD model. Mesh merging also can be performed interactively to account for gaps varying in size across the model. The software also includes new prism and pyramid elements, which enable generation of high-quality grids for complex shapes. The program uses OpenGL® graphics, operates on Windows and UNIX platforms, and offers IGES import. **Circle No. 717**

Collaborative Development

The PIVOTAL family of collaborative virtual product development applications from Centric Software, San Jose, CA, is a scalable, modular suite designed to optimize the product innovation cycle. The unifying environment is based on Internet and Windows NT technology. PIVOTAL Studio is the base platform from which team members can define, visualize, manipulate, and simulate behaviors, and organize all relevant aspects of their program. Add-ins and solutions include synchronous and asynchronous collaboration, real-time visualization, information publish/subscribe, process management, behavioral modeling, and connectors to all major CAD/CAM/CAE and PDM applications. **Circle No. 719**

New LITERATURE

Industrial Computers

A 96-page color catalog from QSI Corp., Salt Lake City, UT, offers a range of industrial computers and accessories. Products include hand-held and panel-mount operator terminals, touch screens, vehicle computers, and custom keypads. Accessories include cases, gaskets, rings, connectors, and cables. **Circle No. 700**

Measurement Solutions

National Instruments, Austin, TX, offers the DAQ Designer 2000 CD that helps engineers and scientists interactively configure custom measurement solutions. It can recommend real-time data acquisition and motion control hardware and software, signal conditioning, computer-based instruments and instrument controllers, and image acquisition hardware and software. Other features include video product descriptions, tutorials, data sheets, and application notes. **Circle No. 701**

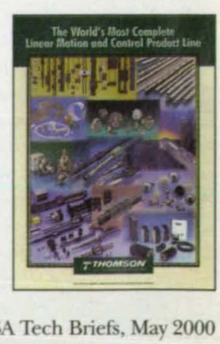
Aluminum Enclosures

A 12-page brochure from Buckeye ShapeForm, Columbus, OH, describes heavy-duty extruded aluminum enclosures in panel-mounted, standalone, and portable models. Products include the "E" Series of aluminum cases in standard 1/16, 1/8, 1/4, and 1/2 DIN sizes with integral card slots on 0.200 centers. Accessories include rear panel and tilt stands, carrying handles, mounts, and customized acrylic front panels. **Circle No. 702**

Electronics Equipment

Specialized Products, Southlake, TX, has released a 400-page catalog offering more than 5,000 off-the-shelf products targeted to telecom, computer, and electronics technicians, engineers, managers, and buyers. Products include tools, cases, and test equipment designed for service-related applications. **Circle No. 703**

Motion Control



A brochure from Thomson Industries, Port Washington, NY, features a variety of motion control products, including linear guides and roller bearings, true planetary gearheads, permanent magnet stepper motors, motor control packages, ball screws and splines, precision balls, polymer bearings, and programmable limit switches. Also offered are software and accessories. **Circle No. 733**

Advertisers Index

Advertisers listed in bold-face type also have banner ads on the *NASA Tech Briefs* web site this month. Visit **www.nasatech.com**

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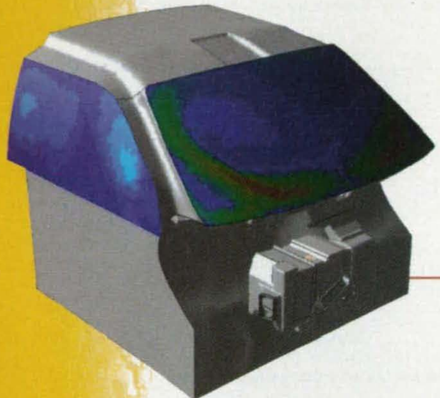
This Month in

Rapid Product Development online

Tools & Techniques To Create Better Products Faster

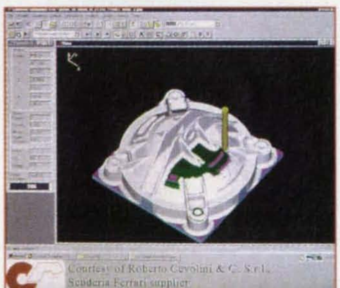
The web publication for *NASA Tech Briefs* readers



NASA Tech Briefs' totally digital publication, Rapid Product Development Online (www.rapidproducts.net), helps engineers develop better products faster by giving them immediate, 24-hour access to the latest information on CAD, FEA, modeling, reverse engineering, and rapid prototyping tools and techniques.

RPD Online includes feature stories, industry and product news, product reviews, show coverage, demos, links, and a keyword-searchable supplier guide.

This month's RPD Online includes:



- **Conceptual Aircraft Engine Design Time Reduced from One Week to One Hour** — Computerized optimization has helped NASA dramatically reduce the time for concurrent engine and aircraft design.
- **New CFD Code Cuts Design Lead Time for Automotive HVAC Systems by 75 Percent** — The latest generation of unstructured mesh computational fluid dynamics (CFD) software makes it possible for engineers to model complex HVAC components in a single day.
- **Show Update** — News from the Rapid Prototyping & Manufacturing Conference and Exposition held last month in Rosemont, IL.
- **New Products** — This month's featured products include integrated software modules for plastic injection molding; a flame-retardant nylon; and software for facilitating the mold, tool, and die machining process.

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Solid Edge is Unigraphics Solutions' mid-range CAD software package.

Spatial

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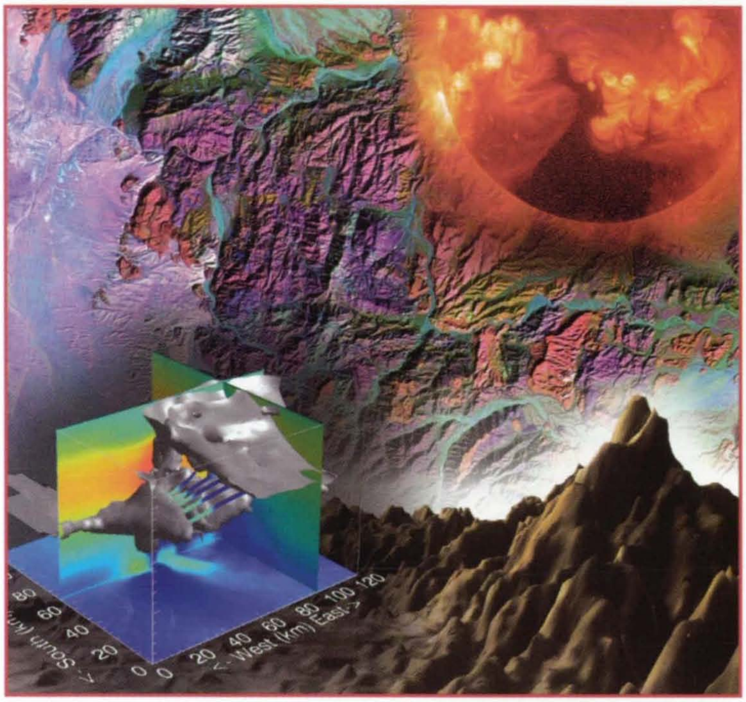

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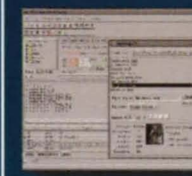

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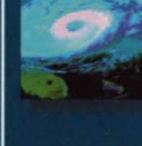

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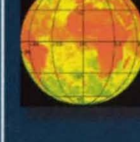

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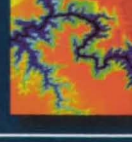

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