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MDA Update

Linking American Businesses to Missile Defense Technology
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INSIDE

Gimbal System Scores Big for SBIR Company *by Leslie Aitcheson*

Football fans reclining in their SuperBowl sweatshirts may be surprised to learn they received better game coverage last fall due to missile defense technology gone Hollywood. Thanks to MDA SBIR support and cost sharing from commercial industry, Sequoia Technologies, Inc. (Albuquerque, NM), developed a precision motion control and stabilization, or gimbal, system that is now being used by CableCam International as part of its CableCam™ capability for televising sporting events and other programs.

Keith Denoyer, CEO and leader of the gimbal development team of Sequoia Technologies, explained that "size, cost, and precision benefits of the gimbal system made it highly attractive for CableCam's application" and thus resulted in cost sharing for development and the sale of two gimbal systems. CableCam televises events by tethering a high-definition television (HDTV) camera on a ropeway that can be configured in various ways and controlled with a joystick. In doing so, it can quickly (up to 30 miles per hour) move down the football field to capture an image. It thus gives television viewers the sense that they are part of the game, huddling with the quarterback, running with the ball carrier, and celebrating with the team in the end zone, all in a matter of seconds. Sequoia's gimbal enables CableCam's system to precisely capture an image of the event without distortion caused by jitter. The entertainment company's previous option was a helicopter turret, which was too large and intrusive to meet the requirement for a low visual profile design. Sequoia's gimbal addressed this as well as cost issues.

As a result of the collaboration, Sequoia's MDA-funded gimbal system debuted last fall at the NFL Thanksgiving Day game, giving the fans of the Indianapolis Colts a better view of fumbles, recoveries, and sacks that led to a defeat of the Detroit Lions, 41 to 9. The gimbal also played a role in the NFL Playoffs, not to mention other games such as basketball and golf. On a more stellar stage, Sequoia's technology assisted in televising the likes of actors Clint Eastwood, Leonardo DiCaprio, and Julia Roberts at the Academy Awards in Tinseltown this February, enabling the gaffer to reposition the camera anywhere within the Kodak Theater for distortion-free close-up images of award recipients and the glitter-garbed audience.

Entertainment is just a side trip on the road to this technology's success. Sequoia's gimbal system was initially developed for ballistic missile defense under the SBIR program to address precision and vibration control issues related to the Airborne Laser, and with Denoyer's background in the military, that is where much of the focus will remain. "What we developed under the SBIR projects," explained Denoyer, "incorporates numerous different advances including very high-stiffness composite materials, advanced processing and active control techniques, as well as some innovative engineering for the drive design and overall

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Aerial view. *Sequoia's gimbal system is part of CableCam International's capability for televising football and other events, making the viewer feel like they are in the game. Pictured above, the device debuted last fall during the Colts-Lions game on Thanksgiving Day.*

MDA Update

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FROM THE EDITOR

CAN YOU HEAR ME NOW?

You know that geeky guy in glasses in those Verizon TV commercials—the one who pops up all over the place, cell phone stuck to his ear, asking, "Can you hear me now?" While this phrase may be nothing short of annoying, it could also serve to illustrate how important communications technologies are to MDA.

Think of the Ballistic Missile Defense System (BMDS) as an integrated network of systems and components that all work together to provide a superior defense. But what good is this network if its systems and components cannot "talk" with one another? It becomes totally ineffective if, for example, a space-based launch detector transmits an alert that never reaches a terrestrial tracking system.

To avoid this scenario and others like it, MDA has funded the development of myriad communications technologies. Its ultimate goal is to create a more robust and higher speed communications network that meets the evolving needs of the BMDS. What's more, it's interesting to note that many of the communications technologies MDA funded over the years also have applications in the commercial marketplace.

Consider Trex Enterprises and its subsidiary Loea Corporation. As far back as the early 1990s, MDA's predecessor, BMDO, funded Trex to develop critical millimeter-wave components. The original intent was to improve speed and capacity for airborne and satellite communications. Now Trex's subsidiary is selling advanced millimeter-wave transceivers for commercial point-to-point high-speed data transmission.

Then there is TLC Precision Wafer Technology, Inc., supplying the kind of multifunctional mixed-mode chip modules that will be at the heart of millimeter-wave/photonic transceivers and other technologies such as adaptive cruise control systems. Another MDA-funded company, Kigre, Inc., is making specialized glass and laser transmitters that may also one day be incorporated into the photonic part of such hybrid components. On the far horizon, INTRINSIC Semiconductor is pioneering the manufacture of new wide-bandgap materials that will be used for high-power radio frequency transceivers.

It turns out that the Verizon TV commercials do have a basis in fact. There is a team of geeks who each drive 100,000 miles annually in specially outfitted vehicles to test the reliability of Verizon's network. Maybe MDA's crew isn't too far behind.

A New Look

Next issue, things are going to look a bit different for our readers. We've been working on a long-awaited and long-overdue redesign. More graphics and illustrations are being added to improve readability. Layout changes will bring a fresh and more modern appearance. But the design isn't the only thing being changed. We've also been developing new types of content to meet the evolving information needs of technology developers and seekers.

I'm confident that our readers will be pleased with these changes. Your feedback is most certainly welcome.

Patrick Hartary
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WHO SAYS MY BUSINESS STINKS?

Diverse group of business experts dispense sage advice to MDA-funded companies.

Before a panel of seasoned business experts, a scientist presented his ideas on how to turn his MDA-funded technology into a profitable enterprise. What he heard back from the panel was a complete shock.

"Your entire business is built upon false and grossly incorrect assumptions on market needs and interests on the commercial side," said one panelist. "Your market estimates, for example, are at least six years out of date." A second panelist offered his own prediction for the scientist's new venture. "With your current objectives, your business will crash and fail within the next six months."

Who speaks to companies like this? And is it helpful?

The panelists' comments came during the most recent Technology Applications Review (TAR), a free service provided by MDA to technology companies, universities, and even Federal laboratories the agency funds. The TAR helps these organizations focus on issues needed for commercial success. Similar to a board of directors meeting, company representatives present summaries of their MDA-funded research and business plans to a panel of business experts who, in turn, provide advice, perspectives, new contacts, and other strategic assistance.

The strength of a TAR lies in the quality and experience of its panel. Panelists come from relevant areas of the business, education, and government communities. Many are entrepreneurs. Most have both technical and business development experience and hold or have held senior positions in the corporate word.

Consider the caliber of panelists who attended the most recent TAR. Chairing the meeting was a senior executive at a technology and engineering university who also has responsibilities for large Federally funded research centers and experience in setting up and running "turnkey" international technology operations. Other key panelists included:

- an investment principal at a large international investment firm who was previously associated with a large international energy firm;
- a former senior executive at two very large technology companies with significant defense business who is currently a member of several Federal and private advisory boards;
- a president of a strategic consulting firm who was previously vice president for strategy in a worldwide firm in the optoelectronics industry and sits on advisory boards for the Department of Defense in electronic devices;
- a managing partner of a strategic business firm, formerly a general manager of the business unit of a well-known optoelectronics company;
- a practicing intellectual property attorney with an advanced technical degree and previous experience with profit and loss responsibilities who also was the legal officer in a successful technology start-up; and
- a former manager of financial and manufacturing enterprises for one of the biggest of the "Fortune 50" who currently guides a state's investment fund.

Many technology developers cannot afford the cost of hiring a wide range of business experts to provide guidance in everything from finding strategic partnerships to evaluating an intellectual property portfolio.

Tough love. *At the MDA Technology Applications Review, business experts review and critique the commercialization plans of MDA-funded researchers. The researchers benefit by learning about new applications, markets, business opportunities, and customers.*

The comments and contacts these companies receive during the TAR are true blessings. Comments are used to refine business plans, focus on key markets, and evaluate intellectual property positions. New contacts help the companies seek out strategic partners and create technical advisory boards. Although the criticism found in the opening example is somewhat extreme, in most cases the advice and assistance provided by the panel is positive and targeted toward building a successful business. Overall, the vast majority of organizations attending the TAR have found the service to be well worth their investment in time and intellectual engagement.

The TAR is administered by the MDA Technology Applications program. The service has been provided to MDA-funded companies since 1987. The March meeting was the program's 76th TAR.

by Patrick Hartary

COMPOSITE OFFERS FLEXIBILITY OF RUBBER, STRENGTH OF STEEL

Flexible shaft. *A helicopter manufacturer is incorporating Lawrie's composite in tail-rotor drive shafts (pictured above). Because the material offers light weight, high strength, and high flexibility, traditional flex couplings can be eliminated from drive shafts.*

Lawrie's resin injection process practically eliminates voids, improving compression and shear properties of the company's composite material.

A new composite could provide rubber-like flexibility and steel-like strength for aircraft rotors, pumps, and other machinery, improving their performance and extending their lifespan. Additionally, membranes made from this material have been shown to offer artificial muscle-like behavior.

MDA-funded Lawrie Technology, Inc. (Girard, PA), has embedded fibers within an elastomeric matrix, creating a new material whose properties differ wildly from "normal" isotropic materials. "If we made a flexible-matrix composite profile like an I-beam that was long, and we put all of the fibers in the lengthwise direction, it would twist as though it were made of rubber—very soft," said Duncan Lawrie, president of the company. "But it would be stiff in bending in a fashion controlled by the fiber—exactly as if it were an epoxy fiber composite." The company's material, therefore, should offer steel-like performance in bending and tension, but in terms of torsion and shear, it will act more like rubber.

The properties of the material should prove useful in components for high-endurance parts such as aircraft rotor assemblies, and the company already has targeted makers of planes and helicopters as potential customers. In machines such as high-power compressors, blowers, and pumps, the strength and flexibility of the composite eventually could lead to devices that rely on fewer moving parts, reducing wear and tear and improving the lifespan and durability of the devices. Applying the flexible material in large drive shafts also could prevent the breakage that sometimes occurs when rigid steel shafts flex due to misalignment.

Instead of batch processing, one composite-production method used by Lawrie involves pultrusion, a continuous molding process that allows a constant cross-section in composite formation. A big advantage of pultrusion is its lower cost. Lawrie said his process runs from $40 to $80 per pound while competing processes cost as much as $400 per pound.

Lawrie's resin injection process also results in virtually no voids (spaces). The lack of voids improves compression and shear properties. The company has addressed voids by developing methods to control the phase known as wet-out—when voids are likely to occur. Specifically, the company changes the fiber-volume fraction and consolidation pressure to allow wet-out without material leaking from the pultruder entrance and producing possible voids. "That's what everybody else has been stuck with," Lawrie said. "They can wet it through via their means, but they always end up with a large void content and, therefore, very poor structural properties at the end of the day. So we were able to solve that problem completely and get essentially zero voids with a continuous process—no atmospheric moisture curing or contamination."

MDA's predecessor, BMDO, originally funded Lawrie through a Phase II SBIR contract to develop low-weight, low-cost materials with inherent damping for absorbing vibrations that could damage onboard electronics. The company has been concentrating much of its recent commercial efforts, however, on a new business based on its composites design and manufacturing expertise that will focus on making tail-rotor drive shafts for helicopters. It also has been working with the Boeing Company to show the viability of its pultrusion process, which already has met Boeing's specification for airframe stringers—in this case using carbon epoxy.

Bio-inspired composite membranes using the material—in particular architectures—hold great promise for fluid control, pumping, and propulsion devices with no moving parts. By amplifying strain up to two orders of magnitude, the concept is currently being researched for bandwidth and achievable system pressures.

Lawrie continues to look for commercial opportunities that would involve aerospace-standard design principles and a low-cost continuous pultrusion process.

by Scott Tillett

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MICROWAVES COULD MAKE BETTER METAL-CERAMIC COMPOSITES

Putting metal in the microwave usually generates a lot of sparks—and panic—in the kitchen. But M Cubed Technologies, Inc. (MCT; Newark, DE), is using microwaves to make metal-ceramic composites with greater speed and higher quality. A custom-designed cavity rather than a conventional furnace is used to heat reinforcement preforms and infiltrant metal.

Working with Pennsylvania State University researchers, MCT is using its microwave technology to enhance three of its existing composite manufacturing processes: pressureless metal infiltration, directed metal oxidation, and reaction bonding. Company researchers also say the technology is ideal for producing body armor vest inserts, a market for which MCT already manufactures as many as 20,000 vest inserts each month. In addition to the inserts, researchers say other applications—from heat sinks to high-quality mirrors to machinery used in semiconductor manufacturing—may exist.

MCT was funded by MDA through a Phase II SBIR award to improve processes for materials used in military systems such as the Exoatmospheric Kill Vehicle. Prototype materials emerging from the project are being offered to Raytheon for use in missile defense projects, according to Prashant Karandikar, director of research and development for MCT.

MCT's microwave-assisted processes would compete with traditional resistance-heating methods such as those involving furnaces. When a furnace is used, the core of the material preform reaches an infiltration temperature much later than the areas nearer the surface. But MCT's technology simultaneously affects the entire volume of the preform, reducing process time by 50 to 80 percent, according to Karandikar. Moreover, an added benefit of the process is superior microstructural characteristics of the final product, he said.

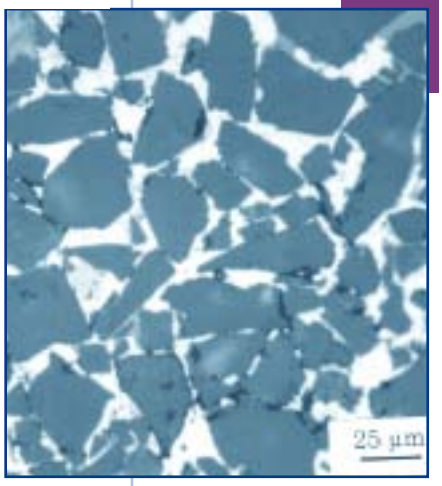
"What happens in a microwave is volumetric heating, so all the molecules in the work piece can couple with the microwaves," Karandikar said. "So the heating is happening everywhere in the part itself, unlike in the conventional process, where you are heating the furnace element, which then radiates to the part surface, and then the heat has to go from surface to inside of the part."

Karandikar said the microwave technology avoids generating the sparks that might occur when subjecting metal sheets or foils to microwaves by using powdered metals or adding susceptors such as silicon-carbide rods. Susceptors heat up and then transfer the heat to the alloy without generating sparks. After the alloy reaches a certain temperature, it starts coupling directly with the microwaves, he said.

Microwave energy has been commonly used for sintering ceramics and powdered metals, but MCT's MDA-funded research for metal-infiltration-based composite manufacturing is a first, according to Karandikar. The company modified a commercial microwave oven for the initial testing, and later built a much larger unit with a 20-inch-diameter cavity, allowing researchers to work with pieces of about 6 x 12 x 14 inches.

The current challenge for MCT is in scaling up the microwave equipment to handle larger pieces. The company also is focused on quantifying benefits of its methods and prototypes, according to Karandikar. "We are building enough experience in terms of making components, so now we can start looking at production rates and energy costs in more detail," he said.

by Scott Tillett



Faster cooking. *MCT's process uses microwaves to speed up the manufacture of high-quality metal-ceramic composites. Pictured above is a micrograph image of an aluminum-based composite created using MCT's process.*

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"The biggest mistake people make in life is not making a living at doing what they most enjoy."

—Malcolm S. Forbes

LASER COMMUNICATIONS WITHOUT THE LASER

Move over free-space optics. There's a new entrant in the field of wireless high-speed broadband telecommunications. It's not just fiber optics without the fiber; it's laser communications without the laser.

The new technology is called advanced millimeter-wave radio, and it may fill an important market niche in-between fiber optics and free-space optics. Trex Enterprises Corporation (San Diego, CA) created Loea Corporation based in Kihei, Maui, to develop, build, and install transmitter-receivers (transceivers) that can exchange 1.25 Gigabits per second (Gbps) at distances of up to 1.75 kilometers. The Loea 2000 Series Radio transmission ignores fog and clouds in a way that laser beams cannot, which makes it potentially ideal for airborne, shipborne, and island-based high-speed data exchange.

Fog buster. *Two radio transceivers share a common tripod that rests on the rooftop of the Price Jonah Kalanianaole Kubio Federal Building in Honolulu, Hawaii. Using millimeter-wave frequency, these devices work under fog conditions. Beams have been added for illustration purposes.*

The missile defense program has fostered advanced millimeter-wave radio communications in many ways. Not only is MDA funding Trex to improve the existing technology to higher data rates of 2.5 Gbps and perhaps even 10 Gbps, but also its predecessor, BMDO, funded research and development on critical components as far back as the early 1990s. The original intent was to improve speed and capacity for airborne and satellite communications.

When the company was known as Thermoelectron Technologies Corporation and later ThermoTrex Corporation, BMDO awarded a series of Innovative Science & Technology contracts to ThermoTrex to develop laser communications systems that could transmit sound and video at data rates of up to 1.2 Gbps over a distance of approximately 50 kilometers. ThermoTrex demonstrated a system in October 1994 at the Jet Propulsion Laboratory's Table Mountain Observatory and subsequently again in September 1995 in a 150-kilometer mountain-to-mountain test between two Hawaiian islands. ThermoTrex created a new division called Trex Communications in the hopes of commercializing the laser communications technology.

Beginning in 1995, the Army Research Laboratory funded ThermoTrex to develop imaging technology using passive millimeter-wave imaging in the 70 to 100 GHz frequency range. Millimeter-wave imaging occupies a middle ground between infrared imaging (at a shorter wavelength) and short-wave radio imaging (at the longer wavelength). The engineering expertise to design, construct, and test low-noise power amplifiers and other componentry was a springboard for work on the radio transceiver. Since 2002, MDA Advanced Systems has funded refinements of millimeter-wave communications devices, improving data rates from 1.25 Gbps to 2.5 Gbps.

Cutting through the clouds

In 2000, employees of the research and development division of ThermoTrex Corporation decided to spin off as an independent company called Trex Enterprises Corporation, headquartered in San Diego. It was also at that point that they decided to concentrate on advanced millimeter-wave communications. Loea Corporation was formed in May 2001.

Advanced millimeter-wave communications works much as free-space optical communications, but with an important difference: radio sends signals through clouds and fog. Lasers are very good for high-speed communications but they have a drawback: laser beams are attenuated (scattered) by dust, atmospheric disturbances, mist, fog, and clouds. There are ways around all of these problems, but at reduced range or decreased availability. Some laser communications systems rely on radio backup.

The advanced millimeter-wave radio technology had advanced to the point that Trex designers thought it could serve admirably as a mainstay and not merely a backup. The added advantage was that millimeter-wave radio signals would not be scattered by clouds or heavy fog. And above frequencies of 60 GHz, the transmissions would not be absorbed by oxygen in the atmosphere.

From a regulatory point of view, this was a new ("unlicensed") spectrum. Nobody had ever tried to transmit such

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Laser . . . from page 6

extremely short-wave radio frequencies commercially. Working with Loea Corporation, the Federal Communications Commission (FCC) initially decided to issue Special Temporary Authority permits so that the company could install and operate equipment. In January 2004, the FCC formalized its rules and today the 71 to 76 and 81 to 86 GHz bands are licensed. Loea has installed more than half a dozen working systems for U.S. government customers such as the Coast Guard as well as with commercial partners such as Electronic Data Systems and customers such as the Hawaii Institute for Marine Biology.

The typical Loea transceiver has an antenna dish measuring anywhere from 2 to 4 feet wide, uses about 40 watts of power requiring only a standard 110-volt AC input power source, and connects with a standard telecommunications network. In fact, the company has completed testing of a standard network management protocol interface, so the equipment is compatible with software tools used for monitoring the status of a network. But the best news of all may be the price, which is far less than the cost of deployed fiber-optic cable and reasonably competitive with free-space optic systems: about $60,000 for a pair of transceivers, with an additional $20,000 to $40,000 installation cost.

Advanced millimeter-wave radios could be used for any broadband communications network requiring rapid deployment, redundancy, or mobility—characteristics typical of free-space optical equipment. This includes point-to-point high-speed data transmission for points that are remote or impractically accessible such as islands, oil-drilling platforms, and ships.

Another intriguing application, one that has significance to homeland security and firefighting, is real-time geospatial airborne surveillance. In fact, the Office of Domestic Preparedness funded Trex, in partnership with Earthdata and Raytheon, to investigate means of providing an airborne wireless link that would relay high-quality infrared images in real time to a ground-based command center for analysis. The feasibility of such a link, with obvious implications for the battlefield, was demonstrated in February 2005.

Trex prices on units, installations, and servicing are published on the GSA schedule. The company recommends interested parties contact it directly for additional information.

by Adam Gruen

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Safe harbor. *Shipping traffic in Honolulu Harbor takes advantage of high-speed broadband wireless communications links between Sand Island (left) and the Federal Building (right) on the Oahu main island. Links have been added for illustration purposes.*

"If you can't explain it to a six year old, you don't understand it yourself."
—Albert Einstein

ELECTRONICS

INDIUM PHOSPHIDE SUBSTRATE TRANSLATES INTO BETTER CHIPS

Chip shot. *Electronic devices based on innovative chip circuitry and substrates provide improved performance in a smaller space.*

TLC estimates the market for its O-chip to be $10 million in 2007 with potential for growth thereafter.

Driving through a mountain pass, unaware of an accident ahead, a trucker finds himself suddenly plunged into an unexpected fog bank where a collision avoidance system equipped with a laser rangefinder would be useless. But thanks to a transceiver that can process millimeter-wave signals as well as optical signals, the warning system kicks in and his vehicle automatically brakes to a safe stop.

TLC Precision Wafer Technology, Inc. (TLC; Minneapolis, MN), is developing chip circuitry on an indium phosphide (InP) substrate that offers mixed-mode capabilities for transceivers. The new O-chip, as the company calls it, can handle both optical signals at the 1.55-micron wavelength as well as radio frequencies in the range of 2 to 100 GHz. MDA has long held an interest in combining these capabilities in one miniature package to save weight and volume in airborne and space-based communications systems, but the technology could be applied to other areas such as adaptive cruise control or commercial communications networks.

In 2000, BMDO awarded TLC a Phase I SBIR contract to develop and demonstrate an epitaxial wafer structure for a radiation-hardened InP-based chip that would provide high-speed signal-processing capability across a wide spectral range (both millimeter-wave and photonic). In 2002, MDA awarded a follow-on Phase II SBIR contract to simulate, fabricate, and test actual multimode devices that would enable communications in X-band to terahertz frequencies.

TLC manufactures its own InP wafers using a proprietary, base-layer doping technique. Proprietary and patented designs are etched on these wafers using 0.15 micron fabrication processing. The company uses a design technique called lattice-engineered, mixed-mode epitaxial wafer structuring. The result? A relatively high yield for circuitry and chips, which TLC claims have superior efficiency and reliability. The InP O-chip provides seven functions for receiving and transmitting frequencies ranging from 2 to 100 GHz. The power output for a typical Ka-band to W-band multiplier transmitter module, of approximately 0.25 inch x 0.5 inch x 0.75 inch dimensions, is 10 to 18 dBm with very low phase noise.

The integration of circuitry that can handle both optical wavelengths and radio frequencies will possibly enable new performance characteristics for miniature transceivers used in automotive design and high-speed broadband communications. In automotive design, vehicles could be equipped with automated laser rangefinder or information transmit modules to enable adaptive cruise control. A similar technology could be used for long-range electronic/photonic security systems, which require more power than current state of the art. In high-speed broadband communications, multifunctional mixed-mode transceivers could enable the creation of hybrid free-space optical and advanced millimeter-wave transceivers to safely and securely transmit and receive 1.2 to 10 GBps of data over distances of more than one kilometer, at low cost, regardless of weather conditions

TLC estimates the realistic market for the O-Chip to be $10 million in 2007 with potential for growth thereafter. The company already has signed contracts with two communications/radar systems providers, but hopes to find additional customers. The current intent is to sell the chips at commercially compatible pricing levels, but to do so the company will need additional funding to expand its production facility. The company welcomes inquiries about performance specifications and reliability of the new InP O-Chip from interested parties as well as interest from firms that might supply investment capital.

by Adam Gruen

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NEW DIELECTRIC FILM PERMITS DENSER CIRCUITS

A new approach to producing circuit boards and printed wiring boards should allow greater circuit density, offering size and weight advantages as well as improved reliability and lower costs. The innovation should result in electronic products that are cheaper, smaller, more powerful, and less prone to failure.

The new method, being commercialized by Oxazogen, Inc. (Midland, MI), involves a film invented by The Dow Chemical Company. Intellectual property for the film was donated by Dow Chemical to Michigan Molecular Institute (MMI), a not-for-profit organization that conducts research in polymer science and technology. And MMI teamed with Oxazogen on an MDA-funded STTR project to develop the film for advanced microelectronics packaging.

The film, a dielectric material called "polyimide benzoxazole" (PIBO), shows promise as a replacement for materials that, in multilayer circuit boards and printed wiring boards, separate copper conductors of information, thereby preventing short circuiting, signal crosstalk, and other circuitry failures. Oxazogen's commercial plan is to metallize the film with copper, making it ready for use in a roll-to-roll process for manufacturing printed circuit boards and wiring boards. The company already has worked with contractor Hoover Technologies, Inc., to produce samples of a metallized film.

David Dalman, development manager at Oxazogen, said that the dielectric properties of the film would allow makers of circuit and wiring boards to put copper conductors closer together when etching the boards. Having the copper lines closer together would mean that manufacturers could increase chip density, packing more circuits into an electronic product. And a more tightly packed design means that product makers can produce smaller, thinner, lighter devices or add functionality within the existing product footprint. Dalman said that, compared with competing ceramic dielectrics that can measure one-quarter of an inch per layer, the metallized PIBO film would measure about one one-thousandth of an inch per layer.

One key to making the PIBO film more reliable than competing materials is its coefficient of thermal expansion (CTE), a measure of the rate at which it expands and contracts when heated and cooled. If the CTEs of a board and an attached silicon chip don't match, cracking or failure may occur as the components expand or contract at different rates due to temperature changes. But the PIBO film boasts a CTE that matches silicon. Competing materials do not match silicon's CTE and often require methods that add thickness to the board. For example, some device makers use a special type of copper or quartz-woven materials to reinforce resins in dielectrics to balance the overall CTE of the chip and board. "The problem with all of these approaches is that they are thick, they are heavy, and they are very expensive," Dalman said.

Compared with other materials that would cost anywhere from $15 to $30 per square foot, metallized PIBO film from Oxazogen is expected to be priced competitively, but with superior properties, in the marketplace, according to Dalman. Oxazogen is focusing on area-array microelectronics packaging such as multilayer printed wiring boards because flexible circuitry would present a difficult competitive market to enter, according to Dalman. He added that Oxazogen's chosen niche would encompass circuitry areas such as flip chips, ball grid arrays, chip-scale packaging, and tape-automated bonding.

Oxazogen continues to work with MMI and other partners to develop a commercially available metallized PIBO film. MMI holds the patents to the film and has granted an exclusive worldwide license to a commercial film producer. In executing a commercial strategy for a PIBO-based product, Oxazogen might seek a second type of license to produce and sell a metallized version of the film. Dalman said Oxazogen continues to consult with the commercial film producer to develop a commercial strategy. Meanwhile, Oxazogen is seeking makers of electronic products who might be interested in using the PIBO film in circuitry.

by Scott Tillett

On a roll. *David Dalman, development manager at Oxazogen, unrolls his company's new dielectric film for multilayer circuit and printed wiring boards. The film allows manufacturers to place copper conductors closer together during the etching process.*

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ELECTRONICS

IMPROVED YIELD FOR SEMI-INSULATING SILICON CARBIDE

Silicon carbide (SiC) and gallium nitride (GaN) are the one-two punch of future high-powered electronics. A relatively new company based in Northern Virginia may have delivered the knockout blow to high prices on high-purity SiC for GaN devices.

Better wafers. *The INTRINSIC process improves quality and yield on high-purity SiC boules. These materials are sliced into wafers, which are used for high-power devices.*

INTRINSIC Semiconductor (Dulles, VA) developed and has filed several patents on a manufacturing technique that improves the quality and yield of SiC boules. Because these boules are sliced into wafers for use as substrates for high-power GaN devices with military applications in X-band radar, MDA took an early interest in research on the new material. SiC/GaN devices also have commercial applications in power amplifiers for wireless base stations.

INTRINSIC SiC boule technology was funded by MDA in multiple ways. Beginning in June 2000, Bandgap Technologies, Inc. (Columbia, SC), received multiple Phase I and Phase II SBIR contract awards related to research on various aspects of bulk growth of SiC boules. When INTRINSIC purchased Bandgap in 2004 and moved many of its employees and much of its equipment to Virginia, the former acquired the manufacturing expertise and capability of the latter company.

INTRINSIC's process satisfies MDA requirements for 4-inch-diameter wafers, which have been difficult to produce in high yields with desired electrical characteristics. In 2003 and 2004, MDA awarded separate Phase I SBIR contracts to INTRINSIC Semiconductor for innovative radar and radio-frequency devices based on semi-insulating high-resistivity SiC ingots. Then, shortly before the acquisition of Bandgap took place, MDA awarded a follow-on Phase II SBIR contract to INTRINSIC to improve the process of bulk growth of SiC.

The INTRINSIC process uses a proprietary high-temperature physical vapor transport (PVT) process at temperatures above 2000°C. In a reaction-controlled chamber (or reactor), 50 to 100 parameters must be controlled during crystal growth to achieve the desired properties of low defect count and exceptionally high purity for 4-inch-diameter wafers. Resisitivity of the material must be uniformly above 105 Ohm-centimeters.

SiC crystals are formed by growing layers of molecules on top of an initial or "seed" layer. The layers have a repeating pattern, for example, repeating every 4 layers ("4H polytype") or every 6 layers ("6H polytype"). Because the polytype affects the electrical characteristics of the substrate, wafers that are not homogeneous in the correct polytype must be discarded. INTRINSIC engineers claim that their PVT process has achieved nearly 100 percent polytype uniformity in the boules, with an overall process yield of approximately 80 percent.

Combining techniques learned from previous work at both Bandgap and INTRINSIC, the new process has reduced micropipe densities from above 100/cm^2 to below 20/cm^2; in fact, it regularly achieves micropipe densities below 10/cm^2. The process results in an improved yield rate, which permits a price reduction of approximately 50 percent.

INTRINSIC supplies materials and device technologies to customers who, in turn, supply assemblies and systems to the U.S. government for a variety of communications and defense-related needs. According to Cengiz Balkas, INTRINSIC's CEO, the company also has over 60 global customers. Balkas believes the primary commercial application for high-purity SiC is its use in power amplifiers for wireless base stations. The company continues to seek customers and welcomes inquiries on prices and quantities for SiC substrates, GaN epitaxy as well as SiC epitaxy.

by Adam Gruen

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DEVICE DISRUPTS ELECTRONIC SYSTEMS—MAYBE CANCER

Directed-energy technology being developed by ARC Technology, Inc. (Whitewater, KS), might prove useful for disrupting electronic systems in everything from speeding cars to roadside bombs. It might even help doctors treat patients with cancer.

ARC was funded through an MDA Phase II SBIR award to develop compact radio-frequency (RF) systems for unmanned aerial vehicle (UAV) payloads. Through this research, the company has built a series of plug-and-play antennas that can directly radiate the output of their compact, high-peak-power electrical pulse generators, effectively using RF signals to disrupt electronics systems. The antennas allow fast reconfiguration between various beam patterns and frequencies for mission-specific radiation profiles. ARC has packaged the antennas into an integrated autonomous, directed-energy system for applications requiring low mass and volume.

ARC's device relies on pulsed energy—very high power for very short periods of time, lasting only tens of nanoseconds. Power levels range from hundreds of megawatts to up to 1 gigawatt. Radiation by the antennas is accomplished using high-dielectric-strength materials and impedance matching to achieve efficient energy conversion without voltage breakdown, according to William Carey, president of ARC.

"The application is to be able to disrupt or destroy communications systems or computer systems, sensors, or even remote triggering devices without being lethal to people around them," said Carey, who explained that the technology could also be used to disrupt electronic systems in vehicles such as cars fleeing from law enforcement. Military applications could include disabling the electronics of enemy vehicles, weapons, or roadside bombs, according to Carey.

The technology produces a very short high-power pulse that damages electronics by producing a voltage transient across a semiconductor chip, for example, or an overvoltage spike that can damage a chip. Signals from the ARC device also could interact with memory circuits and change a 0 to a 1 in binary data effectively altering or destabilizing a system's memory. Competing technologies would require a lot of power for continuous output at high-energy levels, but ARC's approach involves only a short high-energy spike. The device does not operate continuously, so its power source can be relatively small and lightweight, making it ideal for UAVs or portable applications.

ARC has built prototype devices that call to mind images of classic science-fiction weaponry—a sleek cylinder crowned with an array of whip antennas. Once development of the technology is completed, final devices should appeal to the homeland security market, police agencies, the military, and makers of UAVs. The company expects its final device will be usable at longer distances than competing devices. This means police or military, for example, won't have to be very close to vehicles or bombs to disable them.

Cancer treatment is another potential application. ARC is providing pulsed energy systems to the Center for Bioelectrics in Norfolk, VA, and Eastern Virginia Medical School, which are studying the effects of nanosecond-pulsed electric fields on cellular biology. Pulsed electric fields could damage certain cells such as tumors while leaving other healthy cells undamaged.

Zap. *ARC's technology creates a very short, high-power pulse that can damage nearby electronics systems. Law enforcement, border patrol, and homeland security personnel might find this technology useful to stop fleeing vehicles.*

Carey said ARC's technology will be man-portable, meaning troops in the field or police officers on the beat could easily operate an RF pulse device to disable electronic systems. Additionally, the technology will be based on more affordable and accessible commercial off-the-shelf technology. The company is avoiding expensive novel materials or techniques, said Carey, explaining that some competing technology relies too much on custom parts.

ARC is looking for partners who would be interested in the technology, especially major defense contractors. The company also continues to look for new sources for funding.

by Scott Tillett

ARC's technology could help the military to disable electronics inside roadside bombs such as those being used against American forces in Iraq.

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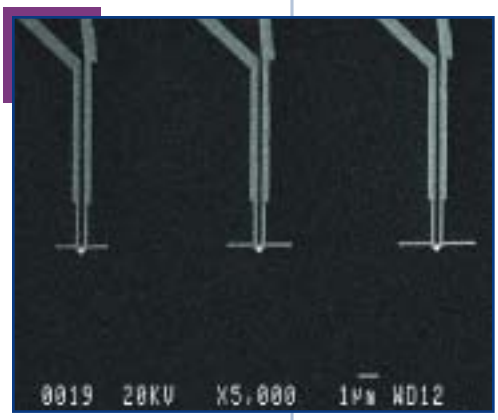
A NEW VISION FOR INFRARED DETECTION



See all. *Pictured above is a single pixel of the IR detector. Each pixel contains a series of MOM sensors whose dipole antennas vary in length, providing the detector with multispectral capability.*

Two MDA-funded research teams are studying a new way to detect infrared (IR) radiation in multiple wavelengths without the need for cryocooling. The new "uncooled" multispectral IR detector, when matured, could bring significant cost and performance benefits to MDA and the IR industry.

In 2004, MDA awarded a Phase I STTR contract to EUTECUS, Inc. (Austin, TX), and the University of Notre Dame. The team's mission was to design and simulate a nanoantenna detector operating in IR that can be integrated in the existing cellular nonlinear neural network (CNN) processor developed by the Office of Naval Research and MDA using standard integrated circuit fabrication techniques. Also in 2004, MDA awarded a Phase I STTR to ITN Energy Systems, Inc. (Littleton, CO), and the University of Central Florida for the same effort.

Fundamentally different

The antenna-coupled IR detector technology is still in early development. However, when matured, it could provide a fundamentally different approach to IR detection.

The unique feature of the technology is that it responds to the resonant frequency of the incident IR radiation rather than to photons. The detector device includes a tiny antenna (e.g., a dipole ranging from 2 to 5 microns in length) with a metal-oxide-metal (MOM) detector element. The MOM is the oxide film layer between two metals (e.g., aluminum and platinum). The oxide layer thickness is 10 to 20 angstroms and MOM junction area is approximately 50 x 50 nanometers.

The antenna couples the incident radiation inducing high frequency current in the antenna to the MOM detector. Taking advantage of the quantum tunneling effect, the MOM rectifies the induced current to produce a proportional DC output voltage.

As proposed in this early-stage development, the antennas could be manufactured in a variety of shapes and sizes for specific purposes to respond to specific wavelengths. The lithographically defined antennas are placed on silicon substrates that act as a quarter-wavelength resonator to improve performance. In addition, the substrate can be modified to change its resonant wavelength in response to a DC bias voltage. This allows the antenna-coupled MOM device to be tuned over a spectrum of wavelengths, replacing mechanical filter wheels used in current sensors.

Conventional high-resolution imaging technology cannot detect multiple IR wavelengths at each pixel, requiring separate sensing and computing functions. This separation creates a bottleneck for image processing throughput. The MOM technology integrated into the CNN chip could potentially eliminate this bottlenecking problem.

Potential benefits

For decades, MDA has invested hundreds of millions of dollars in mercury-cadmium-telluride (MCT) photodetectors, mainly for the detection, tracking, and discrimination of enemy missiles. Applications of these devices, however, have been limited by the need for cryogenic cooling to temperatures usually below 100 degrees K and multiple filters to select wavelengths of interest. When matured, MOM technology could change all that.

MCT photodetectors detect radiation by excitation due to incoming photons. However, thermal background noise also can excite these detectors, causing false readings. Cryogenic cooling is used to reduce this noise problem. Because the physical principle for the MOM technology is different (i.e., it relies on electromagnetic fields rather than photons), thermal noise may not be as dominant an issue. Thus, room temperature operation is possible. Without the need for cryocooling, MOM technology may offer additional benefits including lower cost, lower power consumption, lighter weight, and higher reliability (due to no mechanical parts).

"MOM detector technology, which is still in its infancy and not yet proven, has a number of advantages over conventional photodetectors. These advantages include lower power usage, potential room or near room temperature operation,

Continued on page 13

A New Vision for . . . from page 12

and compatibility for integration with CMOS-based processors," said Dr. Pashang Esfandiari, a program manager with MDA's Advanced Systems directorate.

While MCT device fabrication requires significant precision and the use of exotic semiconductor materials, MOM technology would not. Because of the relative simplicity of the MOM structure, yield and producibility may not be a problem. Because MOM antennas are silicon compatible, the functions of detection and processing could be merged.

Future vision

Compared to state-of-the-art detectors, MOM technology is expected to provide IR imagers with greater bandwidth, increased sensitivity, decreased cost, and the ability to track targets with polarization sensitivity and multispectral imaging. Once the technology has been demonstrated, strong commercial and military interest is expected. Potential applications include vehicle navigation, medical imaging, security/surveillance, firefighting/rescue, preventative maintenance, and nondestructive materials evaluation.

by Patrick Hartary

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ROBOTICS COMPETITION NURTURES STUDENTS' INTEREST IN SCIENCE AND TECHNOLOGY

What if science, math, and engineering could be as cool for kids as sports? The University of Notre Dame is making it so by sponsoring an annual event for young students to build and compete robots made out of LEGO® building blocks.

This year, Notre Dame held its fourth FIRST LEGO League tournament, which introduces science and technology to elementary and middle school students using real-world challenges and hands-on learning. An international program, the FIRST LEGO League is affiliated with a nonprofit organization called FIRST (For Inspiration and Recognition of Science and Technology), which was founded by Dean Kaman, inventor of the Segway people mover.

With the help of LEGO Mindstorms™ robotics kits, the students build autonomous robots using LEGO bricks and other elements such as sensors, motors, and gears. Then, they compete against each other by successfully performing different "missions" designed to test their robots' capabilities. The tournament marks the culmination of 10 weeks of research and robot building for the students, ages 9 to 14, and their adult mentors.

The competition challenges kids to think like scientists and engineers. Alongside their mentors, the youngsters solve technical problems while developing self-confidence, knowledge, and life skills. "When the kids encounter a problem, the coaches teach them not to pull the robot apart and start from scratch," says Carol Osmer, coordinator of Notre Dame's annual FIRST LEGO League tournament. "They instruct them how to break down a problem and approach it step-by-step."

Each tournament has a theme: In 2004, the theme addressed the specific needs of individuals who face physical challenges in today's society. Students and their robots had to complete missions including serving food, opening a gate, reading signs, and climbing stairs. In 2005, the tournament will focus on science and technology to better understand the world's oceans. The importance of enhancing such understanding has been underlined tragically by the terrible loss associated with the recent tsunami in the Indian Ocean.

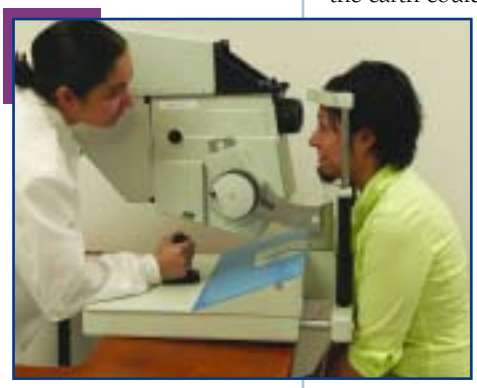
Research engineers at the university volunteer to help organize and run the tournament. Osmer is optimistic that Notre Dame ultimately will benefit as well. "We want to support the local schools and communities. It would be wonderful to get the kids who participate in the program to become involved in Notre Dame's engineering program."

by Patrick Hartary

For more information about Notre Dame's FIRST LEGO League tournament, visit the Web site at http://www.nd.edu/~fll.

Child's play. *Students build and compete autonomous robots in a competition held at the University of Notre Dame. The competition is designed to stimulate the students' interest in science and technology.*

HYPERSPECTRAL IMAGING FOCUSES ON EYE HEALTH



Eye spy. *Hyperspectral imaging technology developed by Kestrel could help doctors make better diganoses of eye health. A medical school is currently testing a prototype.*

Kestrel uses 80 percent of returned light to make an image, besting other methods by a factor of 2 to 10, according to company scientists. In biomedical applications, too much illumination could create eye-safety issues.

A technique commonly used for producing detailed images of the earth could allow doctors to see eye disorders and diseases at their earliest stages.

Hyperspectral imaging allows airborne and satellite sensors to snap images of the earth's surface using hundreds of spectral bands at very narrow bandwidths. Imagery is then analyzed to detect subtle color differences between soil composition or vegetation cover, for example. The technique effectively measures the amount of electromagnetic energy that is reflected, emitted, or absorbed by a surface—and it measures the energy level at hundreds of points on that surface.

Through a Phase II SBIR contract, MDA funded Kestrel Corporation (Albuquerque, NM) to develop its hyperspectral imaging technology for assessing the effectiveness of the Airborne Laser, a plane-mounted laser designed to intercept missiles. The company's innovation also shows promise for analyzing the human eye, giving medical experts more information—and providing it more quickly.

Typically, when examining the retina, a doctor often looks at a basic photographic image of the retina, taken with a digital or film-based camera. To perform an analysis, the doctor essentially qualitatively evaluates the photo to see if the retina appears healthy and if any visible signs of problems exist. Using hyperspectral imaging to take a picture in hundreds of colors, doctors could measure or observe changes in the eye based on very subtle differences in color. The more quantitative hyperspectral mode of examining the retina should increase the accuracy in diagnoses, according to Kestrel. The company already has provided an instrument to the medical school at the University of Iowa, which is looking at spectral signatures in an effort to determine whether people have eye diseases or disorders before signs would become apparent during a normal eye examination. The same approach would work for examining skin or other tissue, according to the company.

Kestrel's technology includes a commercial hyperspectral imager (a camera) and related hardware and software used to conduct a Fourier transform on collected data. The technology then encodes optical signatures from a target (a military target, a retina, or other tissue) to produce an interferogram—a kind of diagram or map of the extracted colors and their location.

The company compares hyperspectral imaging to television. If you were to view, say, the leaves of a tree on a black-and-white television, you might not observe colors that indicate disease. But if you were able to view the leaves on a color television—which displays variations of red, green, and blue—you might easily be able to pick out brown spots or other telltale signs of disease. Taking the analogy one step further, if you were able to view the leaves in hundreds of colors—not just red, green, and blue—you might be able to pick out minute or faint color differences that indicate disease.

The analogy carries over to looking at eyes and other parts of the human body. "You can look at the eye and you can find different colors associated with different types of diseases that might be starting on the eye," said a Kestrel researcher.

Kestrel's use of hyperspectral imaging also promises time savings. The company said that other researchers have attempted, through various means, to produce more detailed images of the retina—but almost always requiring several minutes of observation and therefore many flashes of light onto the retina. Such an approach is not only annoying to the patient but also does not account for saccades, the tiny almost imperceptible movements of the eye that constantly occur. "You don't see them. Your brain takes that out," said the Kestrel researcher. "But they're real important when you try to take a picture. In our case, saccades don't make any difference because we collect all the spectral data in a matter of 40 milliseconds."

Kestrel seeks a manufacturing partner as well as new opportunities that will allow the company to commercialize the technology without deviating from its core business, which is research and development.

by Scott Tillett

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MICROLASER USES NEW GLASS

The MK-88 is about the size of a matchbox and emits a non-blinding laser light at a wavelength of 1.54 microns. Useful for a laser pointer? Well, not exactly. Try a laser rangefinder with improved accuracy and resolution.

Kigre, Inc. (Hilton Head, SC), has developed a diode-pumped laser transmitter that can be used in laser rangefinders that run 3 to 10 times faster, with shorter pulse lengths than existing state-of-the-art. Part of what enables this performance improvement is a new generation of high-gain glass—with that research partly funded by MDA's predecessor, BMDO.

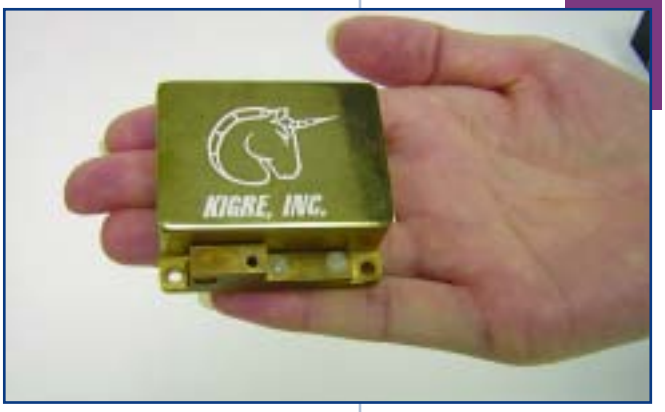
In 1999, BMDO awarded a Phase I STTR contract to Kigre to develop high-performance erbium-ytterbium-codoped phosphate glass for use in 1.54-micron optical communications systems. In 2000, BMDO awarded a follow-on Phase II contract to prototype an integrated optical splitter/amplifier. Kigre had been the first to demonstrate that the new kind of doped phosphate glass could indeed be drawn into high-gain fibers; as a result of the funding the company developed working expertise with the glass and discovered more about its high-gain properties. The composition method of making the glass is proprietary.

Both a special design and Kigre's high-gain glass are necessary to provide improved performance for an "eyesafe" microlaser. The glass enables high-gain amplification of approximately 0.5 dB per millimeter. The laser output pulse width is 7 nanoseconds and the pulse repetition rate ranges up to 10 Hz, which makes the unit 3 to 10 times faster than existing laser transmitters used in state-of-the-art laser rangefinders. The shorter pulse width provides better accuracy and better resolution of target images.

The MK-88 and its packaging measures approximately 0.8" x 1.2" x 1.4", which means it occupies a volume of only about 1/8th of the standard hand-held laser rangefinder called Miniature Eyesafe Laser Infrared Observation Set (MELIOS). The package requires between 18 and 32 volts to drive the diode. The MK-88 uses an estimated 1/80th the energy of the MELIOS per pulse. The laser transmitter has potential applications beyond that of rangefinding. Kigre has prototyped an eyesafe plasma source for laser induced breakdown spectroscopy. A laser beam is focused on a target and creates a microexplosion of plasma on a target, which then gives off an analyzable spectrum revealing what elements are in (or on) the target.

Breakdown spectroscopy could have real use in geological prospecting as well as police work and homeland security. The effective range of a device would be fairly limited—centimeters, not meters—owing to power limitations. Nevertheless, an eyesafe imaging spectrometer at reasonable cost would enable quick and non-invasive inspection of containers, luggage, and personal effects for contraband or hazardous materials.

Kigre already sells complete laser transmitters to both U.S. military and civilian customers. The company has delivered preproduction prototypes of the MK-88 to existing customers who have placed orders for production units. However,



Easier on the eyes. *Kigre's MK-88 "eyesafe" microlaser transmitter uses high-performance glass developed for 1.54-micron optical communications devices.*

Kigre would like to find additional commercial uses for its diode-pumped laser transmitters, and welcomes inquiries from interested parties.

by Adam Gruen

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"A poor idea well written is more likely to be accepted than a good idea poorly written."

—Isaac Asimov

MDA Update
SUMMER 2005

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Entertainment is just a side trip on the road to this technology's success. Sequoia's technology could be used in a variety of ground-, airborne-, or space-based sensor platforms for the defense and aerospace communities.

Gimbal System . . . from page 1

packaging of the system." In addition to the Airborne Laser, the technology can be used for a variety of ground-, airborne-, or space-based sensor platforms for the defense and aerospace communities.

Sequoia has essentially taken a ground-up approach for designing, developing, and packaging the gimbal system to maximize performance at costs below competing systems. It uses high-strength, high-stiffness, and lightweight composites designed by modern design techniques to maximize performance. For the commercial application, the company employed low-cost composites and carefully applied a conventional design architecture that met required stiffness and strength requirements. It also incorporated a control element tailored to both the packaging design and the application. This resulted in a gimbal system architecture with composite packaging that offers greater dynamic performance, lower mass, and better disturbance rejection (jitter) at a lower cost and with better delivery schedules than competing systems. One of the benefits is that Sequoia can easily modify the system for varying customer requirements and produce a gimbal of the correct performance with very short development cycles.

Sequoia's success in making a commercial product at such an early stage of development was a combination of luck and networking. "It's about being at the right place at the right time. Through mutual acquaintances, CableCam heard about our work and gave us a call. We had a very quick meeting and we showed them what we were doing on the SBIR contract," stated Denoyer, who is a first-time business owner. Sequoia was just incorporated in March 2004 and has six full-time employees who hope to commercialize the technology into other areas as well. "We're really hoping that this opens some additional doors in the security area. There's certainly things with mobile platforms that we could do."

Sequoia welcomes inquiries from outside industry with interest in its new technology.

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