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INSIDE

Micromachining Now Faster and More Accurate *—by Patrick Hartary*

Drilling very precise holes is time-consuming. That's a problem for MDA's Airborne Laser (ABL) program, which needs about 24-million holes drilled in the laser's injector heads. On a single workstation at a rate of 1 hole per minute, this task could take up to 46 years to complete!

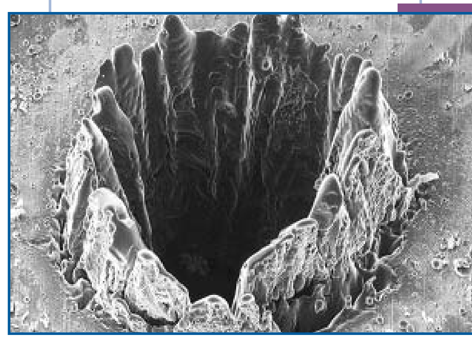
To speed things up, Clark-MXR, Inc. (Ann Arbor, MI), is developing a new tool to produce extremely high-quality holes without post-processing techniques that slow overall processing time, lower yields, and increase costs. The tool will feature a laser source that produces very short pulses of light, which are key to increasing the precision and quality of the micromachining process. Other important features include a high pulse-repetition rate, high average power (which enables a faster rate of material removal), computer-controlled operation (minimal user intervention required), and the ability to create specific patterns in materials from user-defined specifications (input through the computer).

For laser micromachining, short pulses of light are better. Long-pulse micromachining deposits a high amount of heat from the laser to the work piece, causing many undesirable side effects such as microcracks and debris near the hole. Short pulses of directed energy, however, limit the time for potentially damaging thermal conduction to leak away from the micromachined focal spot.

High amounts of energy are deposited in the material so rapidly that the material is forced into a state of matter that physicists call plasma. This plasma then expands away from the material as a highly ionized gas, taking almost all the heat away with it. Essentially, the material goes from a solid to a gas phase without first going through a liquid phase. Consequently, very little heat is left behind to damage the material.

In 2002, MDA awarded Clark-MXR a Phase I SBIR contract to determine whether or not its ultrafast laser micromachining technology was capable of reliable and repeatable operation. Basic concepts were demonstrated using one of the company's laser products. In 2003, MDA awarded the company a Phase II SBIR contract to build a production tool that can produce extremely high-quality holes without post-processing. The agency hopes this technology could eventually replace today's machine tools, which require substantial post-processing and have poorer yields.

Clark-MXR's production tool will open the way for high speed, very fine laser micromachining. In addition to MDA's ABL program, the technology will be useful to commercial companies that manufacture components with holes for fine sprays or nozzles. Inkjet printer manufacturers might consider replacing their excimer lasers with Clark-MXR's production tool because it would be easier to maintain. Clark-MXR believes its technology may also be used by DNA screeners to create tiny wells on the surface of a slide. The wells would



Better holes. *Very fine machining using long-pulse lasers can produce low-quality holes (top). Clark-MXR uses short-pulse laser technology to produce high-quality holes (bottom) without post-processing techniques.*

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MDA *Update*

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FROM THE EDITOR

WHAT INVENTION CHANGED THE WORLD?

In 1999, an online group of scientists gathered to answer the question: What was the most important invention of the past two-thousand years?

While browsing the Internet, I recently came across their list of answers, which made for an enjoyable read.

Nominated inventions ranged from the Hindu-Arabic number system to the printing press to the Internet. Other interesting entries included the horse collar, the atomic bomb, and the birth control pill.

One of my favorites listed was the simple lens. This “mother of all inventions” was the key to not only the creation of the telescope, but also the microscope.

Looking back, the lens and other optical discoveries played an important role in mankind’s development. Looking forward, I imagine they will make far greater contributions in such areas as imaging, computing, communications, and data storage.

MDA has a similar vision. It is tapping the power of new optical innovations to build stronger ballistic missile defenses. In this issue, several are featured. Will they change the world like the battery or the computer? Perhaps not. But, pushing forward the boundaries of modern optical science, they are significant technical achievements nonetheless.

Featured optical innovations include:

- a process to make cheap lenses that could substantially lower the cost of bringing fiber-optic cables into homes and businesses,
- silicon carbide technology that reduces the weight of mirrors for satellites and semiconductor processing,
- optoelectronic signal processing technology that improves the accuracy of commercial and military aviation radar as well as weather forecasting, and
- a technique to polish optics faster and more precisely that reduces the cost of optical component processing.

—Patrick Hartary
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BIG WIN

In February 2003, the *MDA 2003 Technology Applications Report* won a Distinguished Technical Communication award from the Washington, D.C., Chapter of the Society for Technical Communication (STC). The award is part of STC’s annual technical communication competitions program, which highlights the best examples of the art and science of technical communication. Distinguished award winners move on to the international level of competition.

The award-winning report was developed by the National Technology Transfer Center-Washington Operations, which supports the MDA’s Technology Applications program. This is the second time the yearly publication has been recognized at this highest level of excellence in technical communication. In the 2000 STC competition, it received both Distinguished Technical Communication and Best of Show awards.

MARKETING MISCONCEPTIONS JEOPARDIZE COMMERCIAL SUCCESS

—by Tim Bennett, Joel Price, and Patrick Hartary

Rodney Dangerfield gets no respect. Neither does marketing.

High-tech researchers have long been more interested in developing their technology than in developing their technology's path to market. Unfortunately, this unbalanced approach significantly handicaps their beloved technology from attaining successful commercialization.

Marketing misconceptions are to blame. Through its business assistance programs for MDA-funded researchers, the National Technology Transfer Center-Washington Operations (NTTC-WO) has identified many common misconceptions that researchers continue to have while commercializing MDA-funded technologies. Here are four monstrous ones and how researchers can avoid them.

Misconception #1: If We Build It, They Will Come

Researchers are proud of their creations and rightly so. But others, especially customers, will not necessarily see their creations through the same technical glasses.

Researchers need to address the specific needs of the user, and resist the urge to create additional features that they envision customers may find interesting, cool, or occasionally useful in the future. Building a better mousetrap must simply translate into developing a product that increases sales within the marketplace. Taking the approach "if we build it, they will come" worked for Kevin Kostner in the movie *Field of Dreams*, but it will surely lead to failure for researchers.

To make a great-selling product, researchers need to talk with potential customers and distributors early in the technology development cycle to better understand their needs, desired features, price points, and anticipated margins. The money they invest in market research today can save them hundreds of thousands—if not millions—of dollars in the future. Taking the approach "if we go to them, and then build it," researchers are more likely to succeed. "Market pull" is always more effective than "technology push."

Misconception #2: My Technology Will Create an Entirely New Market

Frequently, researchers believe their technology will create an entirely new market. However, such thinking is flawed. Just because a new technology—no matter how advanced—is available, there's no guarantee that customers will buy it. All new technologies initially compete for the potential customers' limited resources, which are being spent on traditional market alternatives.

Consider, for example, Dean Kamen, who developed the Segway human transporter. His company's first transporter product was launched in 2001 with international press release claims of "stealing a slice of the $300-billion-plus transportation industry" and "being the fastest outfit in history to reach $1 billion in sales." As of January 2003, the company's annual sales were $17.2 million, with a development cost of over $100 million dollars. Although he believed the Segway would create a new market within the transportation industry, he failed to adequately account for the customers' traditional alternatives—bicycles, scooters, electric vehicles, and even walking.

Misconception #3: Market Timing Is Not Critical

Does it matter when a product is introduced? Not many researchers think so. Unfortunately, early or late product launches will turn a potential market hit into a failure. The Sharp Wizard® is a good example of a product that was launched before the public was ready. It was the first personal digital assistant device to hit the market in the late '80s, and it had all the bells and whistles. But users did not see the need for the product and sales were minimal. Ten years later, when people were looking for something to help organize their life, the Palm® was introduced, and it became a huge success.

Researchers need to first determine whether the market is ready and truly needs their solution. Once market need is established, they need to develop and follow a structured product development plan that balances the marketing, business, and technical aspects of commercialization. In addition, they need to allocate resources to the project. If they are not familiar with the product development process, they should contact organizations such as the NTTC-WO for business assistance. There is always a brief window of opportunity in

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The NTTC-WO discovered that reseachers possess business and technology misconceptions that could hinder their commercialization efforts. These misconceptions will be covered in future issues of this newsletter.

CORROSION DETECTION IS A FINE MESH

Pass the salt. *DACCO SCI engineers test the mesh-in-appliqué in a salt fog chamber.*

Salt spray, especially under high heat and humidity conditions, is a deadly enemy of even the most advanced materials.

Old U.S. Navy joke: if it doesn't move, paint it. New version: if it doesn't move, appliqué it.

DACCO SCI, Inc. (Columbia, MD), and Integument Technologies, Inc. (Tonawanda, NY), working as partners under a recently awarded MDA Phase II SBIR contract, have fused two known technologies into a unique product that not only provides a surface with corrosion protection superior to paint but also enables inspectors to detect the earliest hints of corrosion or breach upon that surface. An appliqué with an embedded sensor provides a "smart wallpaper" function that is ideal for continuously monitoring inaccessible or remote surfaces.

The interest of the MDA in this technology is likely to be relatively straightforward: missile defense batteries might be deployed under high humidity salt-spray conditions but would need to be ready to fire at any time. Corrosion would be unacceptable and detecting it would be important. MDA awarded a Phase I SBIR contract to DACCO SCI in January 2003 to prove the basic concept of embedding an electrochemical impedance spectroscopic (EIS) thin foil mesh in an appliqué. In the Phase II SBIR contract, DACCO SCI engineers intend to subject the product to rigorous testing in a salt fog chamber as well as to test what frequencies they need to monitor for operational efficiency.

Appliqué is a thin fluoropolymer film with pressure-sensitive adhesive backing that is applied as a roll or patch directly to a flat surface. Fluoropolymer is inert plastic, a non-stick material such as DuPont's Teflon®. Such material is hydrophobic, impervious to many corrosive chemicals, and provides superior corrosion protection. However, it has one major drawback: an adhesive backing won't easily stick to it.

Engineers at Integument figured out how to plasma treat a commercially available fluoropolymer so that it could stick to its adhesive backing without losing the thermal and chemical resistance that made it valuable in the first place. The appliqué material, called FluoroGrip®, is versatile enough to adopt colors or prints, and even a thin layer of sputtered metal. Integument first experimented with this for the V-22 Osprey program as an affordable method to protect against lightning strikes. The company subsequently patented several sensor-based appliqués.

When DACCO SCI engineers became aware of what Integument could do with FluoroGrip, they proposed the idea of a thin-mesh electrode, on the order of 5-mils thick, that could be inserted between the adhesive and the fluoropolymer film. By applying a small AC voltage (about 30 millivolts) to the electrode, engineers measure the induced current and sweep over a range of frequencies. With the calculated impedance, they know exactly what kind of response to expect. If the result measures 10^8 Ohms or above, the surface is good. If the result measures below 10^6 Ohms, however, they know corrosion is taking place.

The commercial prospects for an EIS-sensor-based appliqué are intriguing despite the fact that it is never likely to be cost-competitive against simple paint and visual inspection. The current price of $3 to $5 per square foot of appliqué assumes no multifunctional additions such as sensors or plating. However, there are many instances where relatively inaccessible, mission-critical equipment and architecture with a high penalty for failure need to be protected from corrosion for a decade or more. Such cases include deep-sea oil-drilling platforms, sensor buoys, telecommunications towers, underground pipelines, or roadway bridges. In industrial settings, toxic chemical storage tanks or batch mixing tanks requiring extraordinarily high levels of purity would demand continuous monitoring.

Inquiries about the technique of EIS should be addressed to DACCO SCI.

—A . Gruen

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SILICON CARBIDE OFFERS BERYLLIUM ALTERNATIVE FOR OPTICS

An MDA-funded company is using a simple silicon carbide (SiC) fabrication process to make lightweight satellite mirrors that are less toxic and more thermally stable than beryllium, a commonly used material in space applications. The new technology also is being developed for use in the semiconductor lithography industry.

The company, SSG Precision Optronics, Inc. (Wilmington, MA), is testing and demonstrating its SiC technology with government users including MDA. With Phase I and Phase II SBIR awards, MDA predecessor BMDO originally funded the company's technology for demonstration in telescopes for the Ground-Based Interceptor program, now MDA's Exoatmospheric Kill Vehicle program.

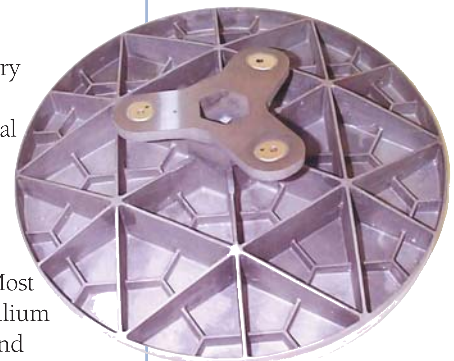
SSG's technology includes techniques for producing optical substrates and mirror cladding that can be used in a wide range of spaceborne and tactical applications. The company has successfully flown SiC-based telescopes on two space experimental programs and is currently developing SiC telescopes for several additional space programs and for a Global Hawk Unmanned Aerial Vehicle.

Key among the benefits of SiC optics is the material's nontoxicity. Beryllium, a naturally occurring metal, can damage the lungs of people working with it. SiC, meanwhile, is about as toxic as sand—which is to say harmless. And SiC is easily acquired, while beryllium must be mined and carefully processed. SSG uses a simple casting approach instead of intensive machining to produce SiC lightweight mirrors.

The SiC approach also boasts time savings. In a production scenario, the SiC castable process will support substrate fabrication in a matter of weeks, compared with six months or more with competing materials such as beryllium or glass, according to Michael Anapol, vice president of advanced development for SSG. Moreover, SiC in optics has thermal stability that is six- to seven-times better than beryllium, which is even more thermally stable than aluminum. SiC optics will operate at or below 50 Kelvin and can withstand heat generated by space-based sun exposure. And SiC optical telescopes have demonstrated visible optical quality performance, which is important in lidar applications.

"When we look at the matrix of where the world's going—which is lighter, better, faster, and cheaper—SiC is applicable to a larger fraction of that world than beryllium or glass-based materials," Anapol said. "And that is why we were so excited about the technology and then pursued it."

SSG's technology includes both SiC substrates and cladding techniques as well as telescope metering structures. Conventionally, manufacturers make precision lightweight mirrors by coating nickel on beryllium optics. In SSG's process, however, the company takes the SiC substrate (analogous to a piece of pottery or a dish that is very lightweight) and applies a silicon cladding. The company then follows its standard finishing steps, including diamond turning and computer-controlled optical surfacing at its Tinsley Laboratory Division.



Harmless. *SSG's optics made from silicon carbide offer a safer alternative to optics made with beryllium, which can damage the lungs of people working with it.*

SSG officials' goal is to manufacture both government-related telescope systems and commercial products. Most items that use beryllium to reduce weight and improve optical performance are a potential application, according to Anapol. Wire bonding for computer chips, for example, are one potential application. The company has examined building structures with ultraprecise mirrors integral to the assembly for lithography stages, used to move microchips during fabrication. Also, SSG is examining SiC mirrors with ultralow scatter performance for extreme ultraviolet laser source assemblies.

Challenges for the company's technology include scaling it up for larger products, improving precision for lithography applications, and making the technology less expensive and more production-oriented at both the component and subassembly level. SSG continues to seek funds to help commercialize the work it has done in lithography.

—S. Tillett

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LIP READING IMPROVES ID VERIFICATION ACCURACY

What did you say? *IC Tech's software combines lip reading and speech recognition technology to boost the accuracy of voice-activated user identity authentication.*

According to the Federal Trade Commission, approximately 27 million American adults have been victims of identity theft in the past five years. Were you one of them? Could you be next?

IC Tech, Inc. (Okemos, MI), is developing software that combines lip reading technology with commercially available speech recognition and authentication engines. Audio-visual speech recognition (AVSR) software will significantly improve the accuracy of existing speech recognition engines for applications such as noise-immune voice command and control, whisper-level commands for enhanced privacy in public places, automotive telematics, and user identity authentication.

IC Tech is focusing on user identity authentication. Identity is currently verified through personal information, smart cards, or biometrics. Unfortunately, all of these types of user identification can be stolen. IC Tech is taking a different approach so that if a user's smart card, or personal or biometric information is stolen, a thief still can not breach security.

Using AVSR, the user is authenticated dynamically in several steps. First, the user's interaction with the secure system is recorded by a microphone and a camera during the attempted access. This type of live user verification ensures a real person willing to be recorded is trying to gain access to the secure system. Second, users are prompted to speak a new random phrase each time they attempt access. Neither the user nor potential identity thieves can anticipate what this phrase will be. The random phrase is in fact the element of surprise. The user has to utter the prompted phrase within seconds. The user's face is captured by a camera while uttering the prompted phrase at the rate of about 10 frames per second. At the same time, the user's voice is recorded.

The captured audio signal is analyzed to verify that it matches the prompted phrase and that it is consistent with the user's voiceprint. The captured video is analyzed for consistency with the spoken phrase. The lip shapes are matched with the visemes expected. Visemes are the atoms of visual speech (i.e., visual lip shapes when saying words) much like phonemes are the atoms of audio speech (sound bytes that form words). Making sure that the spoken phrase matches the prompted one in both the audio and the video domains forms the spoken phrase verification. Matching of the voiceprint is the biometric verification element. AVSR-based user verification requires previously saved speech segments from the user. These are used to construct the user's voiceprint.

Audio speech recognition is based on the most likely model fit for the sequence of phonemes observed. Likewise, visual speech recognition is based on the most likely model fit for the sequence of visemes observed. Since voice and face are natural means of human-to-human identity verification, AVSR is less intrusive than certain security procedures. However, other identifiers, such as fingerprints and retinal or iris scans, can also be used in tandem with the AVSR-based user authentication.

BMDO, now MDA, funded IC Tech with a Phase II SBIR to develop AVSR using hidden Markov models (HMM), which are methods for recognizing sequences of information, whether that be missile trajectory data or lip shapes. Currently, IC Tech is using discrete HMM methods, which quantizes or matches the incoming information with the most similar template available. However, the company expects to develop AVSR with continuous HMM before entering the commercial market. Most commercially available speech recognition engines use continuous HMM methods, which are more advanced and compute based on continuous values.

In addition to MDA, Clarity Technologies is funding 50 percent of the AVSR in exchange for transfer of the technology. IC Tech will license the technology to additional companies once it is fully developed. It is also interested in partnering with a company that develops speech recognition engines.

—T. Spitzer

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AMTI SHATTERS COLD REALITY OF CRYOCOOLER EFFICIENCY

All cryocoolers lose efficiency as they approach absolute zero, but a cryocooler that gets increasingly more efficient (compared to existing technology) as the kelvins drop is in the works.

With MDA funding, Advanced Mechanical Technology, Inc. (AMTI; Watertown, MA), is developing a prototype cryocooler that could be three- to five-times more efficient than other cryocoolers when operating at temperatures below 30K. The company also expects this device to cost less than conventional technology due to innovative design features.

The two key elements of AMTI's design are floating piston expanders and smart valves. Conventional cryocoolers employ mechanically linked pistons with valve trains and crankshafts. AMTI's nonresonant floating piston expanders are sliding displacers in a cylinder that respond to small gas pressure differences. The smart valves, which control the piston motion, are actuated with electronic signals. This further reduces system complexity, improves reliability, and eliminates thermal leakage paths.

Many current and future applications need thousands of compact cryocoolers capable of a few milliwatts (mW) to several watts of 4K- to 10K-cooling power. The largest ground-based application for AMTI's cryocooler is cooling magnets for magnetic resonance imaging (MRI) systems. These systems are currently cooled by Gifford-McMahon-type 4K cryocoolers, but AMTI will address the same application at a much higher efficiency and at comparable or less cost. AMTI intends to meet MRI manufacturers in 2004, but the company is still several years away from delivering a working cryocooler for MRI applications.

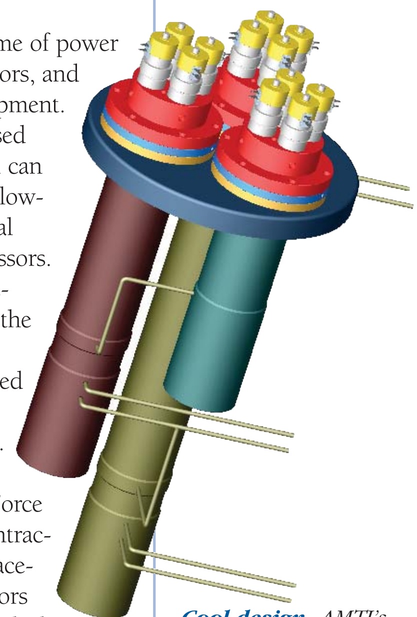
In the emerging field of super-fast computing, cooling superconducting digital electronics will require greater cooling capacity at lower temperatures than is currently available. This is another possible application for AMTI's cryocooler. The semiconductor cooling market is estimated to reach $37 billion by 2010. Almost half of this market is attributed to cryoelectronics. Future digital circuits are projected to achieve processing speeds of 100 gigahertz. However, the circuits will depend on cryocooling at 4K to achieve these performance levels.[1]

AMTI also has its sights set on the stars with U.S. Air Force and DOD applications such as very long-wavelength infrared (VLWIR) focal plane array (FPA) cooling on satellites. MDA has funded AMTI since 2000 with four SBIR contracts, of which two were directed by the Air Force, to develop a cryocooler for FPA cooling on satellites. FPAs typically require approximately 100 mW of cooling at 10K and high reliability with operational lifetimes of 5 to 10 years. High efficiency is critical in reducing the mass and volume of power supplies, compressors, and heat rejection equipment.

For ground-based applications, AMTI can use existing small, low-power, conventional cryocooler compressors. However, for space-based applications the company needs a small, non-lubricated compressor with a high-pressure ratio. AMTI will work with Kirtland Air Force Base to identify contractors developing space-qualified compressors that can be used with the cryocooler.

Currently, AMTI is preparing to demonstrate the three-stage cryogenic proof-of-concept machine for the space military market, which it intends to enter first. This market may require custom designs that the company will fabricate. To enter the commercial market, AMTI needs strategic partnerships with funding for the development of the cryocoolers. Several companies are awaiting the demonstration of AMTI's cryocooler technology.

—T. Spitzer



Cool design. *AMTI's cryocooler design features smart valves actuated with electronic signals and floating piston expanders that respond to small gas pressure differences. These key elements reduce system complexity, improve reliability, and eliminate thermal leakage.*

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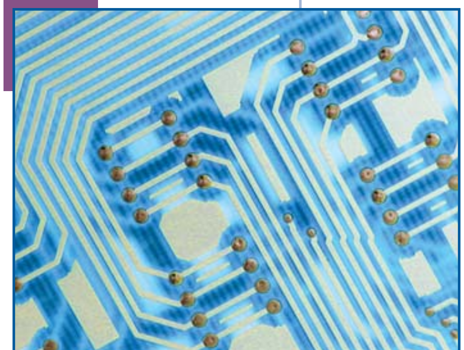
SOI PROCESS MAKES CHEAPER CHIPS



Chips ahoy. *American Semiconductor's Flexfet™ technology makes silicon-on-insulator chip processing more cost-effective.*

Designers have a love-hate relationship with silicon-on-insulator (SOI) technology. They love the way SOI allows electronic devices like wireless phones to use less power. But they hate the premiums charged to obtain better performance.

One new solution for cheaper chips is now in the works. American Semiconductor, Inc. (ASI; Boise, ID), is developing a process that makes chip processing far less expensive than traditional techniques. Called Flexfet™, the technology could help accelerate SOI's transition from niche to mainstream markets.

"For many years, the two main disadvantages of using SOI have been its cost and complexity," said Doug Hackler, ASI's president. "Our proprietary Flexfet process, which is based on scalable, near-fully depleted technology, will pave the way for more cost-effective SOI chip processing."

Key to Flexfet technology is its patent-pending transistor architecture. Flexfet devices will incorporate double-gated transistors within a compact, 4-terminal, dynamic threshold, metal-oxide semiconductor layout. Each transistor's voltage threshold is dynamically selected to enhance device performance. The double-gate characteristics create a unique circuit architecture that is inherently radiation hardened (rad-hard). Competing processes require additional circuitry to meet rad-hard requirements, making chips larger and more difficult and costly to manufacture.

Other Flexfet benefits include very low mask costs and operating voltages. Unlike today's SOI processes, Flexfet requires fewer and less costly masks to make low-power, rad-hard devices. This reduces the overall SOI manufacturing cost by up to 70 percent. Additionally, Flexfet devices can operate at less than one volt, whereas other devices operate in the 2.5- to 3.3-volt range.

MDA funded ASI to develop its SOI process through an SBIR Phase I contract in 2002. Flexfet's inherent rad-hard capability is ideal for electronics used in or near space. The MDA-funded research also supports ASI's plans to build a wafer fabrication foundry in the United States. Currently, there is only one domestic source for rad-hard SOI electronics.

Through its SBIR Phase I research, ASI has conducted successful simulations in silicon of its Flexfet technology. A preprototype short loop fabrication test, which shows complete complementary metal-oxide semiconductor functionality, is currently running at the University of California at Berkeley. Prototypes are tentatively scheduled for 2004. The first version will offer a feature size of 180 nanometers. Overall, the process provides sublithographic capability that generally can reduce features in half on any equipment set.

Eventually, ASI will scale-up the process to reach volume markets. Cheaper chips could find their way into a variety of low-voltage commercial uses such as mixed signal, analog, logic, and memory applications. Examples include keyboards, cell phones, hearing aids, laptop computers, and wireless Internet devices. The rad-hard capability should prove attractive to the military for high-altitude planes and missiles, as well as to the space industry for satellites and space vehicles.

ASI envisions its technology's unique performance capability increasing the overall market growth for SOI. The company believes its work will be synergistic—rather than competitive—for current SOI providers such as Honeywell, Motorola, IBM, and X-Fab Semiconductor Foundries AG.

ASI has received substantial interest in Flexfet. Although the company's primary marketing efforts will not begin until after the completion of the production prototype, it currently has four customers that are designing projects in Flexfet using the preliminary process models, and these customers have already requested prototype quotations. ASI seeks additional requests for prototype quotations from the fabless design community.

—P. Hartary

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SMART CHIPS PROCESS IMAGES FASTER

Digital imaging technology that can process approximately 1,000 frames per second (fps) is considered state-of-the-art. However, smart chips that can capture and process images up to 10-times faster will soon be on the market.

An international group of companies developed the chips using cellular visual microprocessor (CVM) technology, which mimics human visual sensing and thinking to increase processing speed. The group—EUTECUS, Inc. (Austin, TX), AnaLogic Computers Ltd. (Budapest, Hungary), and AnaFocus Ltd. (Seville, Spain)—is using the chips to create new high-speed analog and digital imaging products.

One CVM chip, called Ace16K, is a 128 x 128 array with 70 x 70 micron pixels. Ace16K was adapted to two products: Aladdin, which is a high-speed processor that requires image input, and the Bi-i System, which incorporates stereovision with both image acquisition and processing. Bi-i won the Product of the Year award at the Vision 2003 Conference, a notable machine vision exhibition in Europe. AnaLogic and EUTECUS are developing Bi-i to inspect narrow textile labels. It has been used with a label-manufacturing machine to inspect the finished labels for weaving errors, dirt, and oil spots. The companies plan to sell the Bi-i to original equipment manufacturers (OEMs) and system integrators. They also will be selling the chip and its packaging, as a module, to other companies for inspection devices.

In commercial applications, the Ace16K chip can be used in the quality control processes for manufacturing plants. For instance, in the pharmaceutical industry Ace16K can inspect and identify small pills for imperfections. Currently, it is able to inspect up to 2,000 pills per second. AnaLogic Computers and EUTECUS are seeking industrial partners to assist with this application.

Recently, AnaLogic and EUTECUS have also developed Xenon, which is a 128 x 96 CVM array with 30 x 30 micron pixels. At 30 giga-operations per second, it can perform more complex operations faster and with more stability than its predecessors. It will also have a locally adaptive optical sensor, meaning it can record images at a very high dynamic range.

The Xenon chip is used for high-speed applications requiring complex analysis. In addition to gathering intelligence and helping identify and destroy targets, important to MDA's missile-defense mission, the Xenon chip can also provide visual terrain recognition for unmanned aerial vehicles (UAVs) such as the Predator drone that flew missions in Iraq. The chip can learn and recognize certain landmarks or geographic structures (i.e., mountains, riverbeds, etc.) and follow them, effectively guiding the UAV using visual information. Such visual terrain recognition is considered part of the $12 billion machine vision market.

EUTECUS is the United States development and distribution arm of AnaLogic Computers. EUTECUS received MDA SBIR funding to develop the CVM technology and apply it as a smart sensor for fast missile and decoy target discrimination in Earth's atmosphere or in space. NASA's Jet Propulsion Laboratory, the Hungarian government, and revenue from commercial products, such as Bi-i, are also funding the development efforts. EUTECUS and AnaLogic seek additional funding to further develop products.

—T. Spitzer

Fast inspector. *EUTECUS and AnaLogic Computers developed the Bi-i system to capture and process digital images at high speeds. The technology has been used with a label manufacturing machine to detect weaving errors in textile labels.*

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NEW TECHNIQUE COOLS HIGH-POWER SOLID-STATE LASERS

Keeping it cool. *RTI's vapor-atomizer design uses compressed refrigerant vapor to spray-cool a solid-state laser.*

Solid-state lasers may one day operate at average power levels of 100 kilowatts or more, but only if engineers figure out how to cool them. That problem might already have been solved by a simple idea: spray-cool them with refrigerants.

With MDA SBIR funding, Rini Technologies, Inc. (RTI; Orlando, FL), developed and patented a unique way of spray-cooling solid-state laser components without the traditional bulk and weight associated with current water-based laser cooling systems. By using refrigerants instead of water, the RTI method combines spray-cooling and refrigeration into a single cooling loop and reduces liquid flow rate. Company engineers estimate that this reduces the overall size and weight by a factor of three or more compared to existing micro-channel cooling systems.

Mobile lasers with sufficient power to burn through metal or composite material at long range are an obvious MDA interest, so it comes as no surprise that the agency awarded RTI a Phase I SBIR contract in 2000 and followed up with a Phase II SBIR contract in 2001. Until now, high-powered lasers in the 100-kilowatt range have all been chemical lasers. Solid-state laser technology is rapidly improving, however, and it has the potential to reach up to the higher 100-kilowatt level.

Cooling lasers is a technical challenge. The heat generated within a laser can be 10-times greater than the laser light output power. In short, a 100-kilowatt laser might produce 1 megawatt of waste heat. Water is an inexpensive and ubiquitous coolant, but it does have inherent drawbacks that sometimes make it unsuitable for use with high-power solid-state lasers. What engineers really need to effectively spray-cool solid-state lasers are liquids that have both a lower freezing and boiling point than water, but still retain a high latent heat of vaporization. Ammonia is one such liquid.

RTI's technology uses a unique spray nozzle to impinge liquid droplets onto the heated surfaces of laser components, removing the heat as the liquid vaporizes. By taking advantage of the phase change of the liquid coolant, the spray-cooling system requires 12-times less coolant flow rate than a state-of-the-art micro-channel cooling system. RTI's technology has demonstrated heat removal rates as high as 700 W/cm^2 using ammonia as the coolant.

The key is in the design of the nozzle, not the materials used to manufacture it. RTI's unique vapor-atomizer design uses compressed ammonia vapor to atomize the liquid supplied to the nozzle array, unlike commercially available pressure-atomizer nozzle designs. RTI's spray-cooling loop combines their vapor-atomizer with an integral vapor-compression refrigeration cycle—similar to that used in a car or home—into one simple cooling loop.

The ability to cost-effectively cool 100-kilowatt solid-state lasers under the harsh environmental conditions encountered in a tactical mobile platform, while meeting the strict size and weight metrics associated with these platforms, is an important technology area for the military. This same spray-cooling technology also has potential commercial applications for high-power industrial lasers used for metal cutting, drilling and welding, as well as the next generation of high-power medical, telecommunications, and microwave devices.

RTI has developed a practical and effective cooling solution for a problem that needs to be solved for the continued evolution of solid-state laser technology. The company is seeking to secure ongoing development contracts to further develop this spray-cooling technology to withstand the rigors of real-world conditions. RTI also invites inquiries from interested parties who may need a compact and lightweight laser cooling solution.

—A . Gruen

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HOLOGRAMS OPEN WINDOWS TO RUGGED, LOW-COST OPTICS FOR LASERS

Holograms that have narrow spectral selectivity and absolute diffraction efficiency—greater than 95 percent—at all wavelengths from visible to near infrared (IR) will be available in about 18 months.

Light Processing & Technologies, Inc. (LPTI; Orlando, FL), is producing robust holographic optical elements based on Bragg gratings in photo-thermo-refractive (PTR) glass. The holograms can serve as mirrors, mode selectors, deflectors, samplers, filters with adjustable transmittance, and other components in high-energy lasers. In 2000, MDA funded LPTI to develop holographic mirrors for its optical systems. Since then, LPTI has demonstrated the ability to use its holograms in a variety of high-energy laser components, opening the way to a new class of rugged, low-cost optics.

The company is using its holograms for a technique called incoherent or spectral beam combining, which joins two or more laser beams of slightly different wavelengths to generate high-power laser radiation. An incoherent laser beam can be used to create a portable anti-missile system for MDA. Commercial applications may include cutting, welding, and drilling processes in the automotive, aerospace, and ship industries. Currently, LPTI is participating in the commercialization of two research projects at the University of Central Florida (UCF), which were sponsored by the Defense Advanced Research Projects Agency (DARPA).

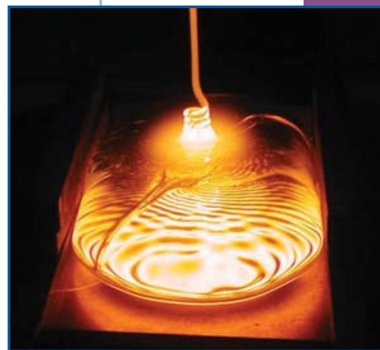
The Steering of Agile Beams (STAB) project is creating devices for very fast, precise steering of laser beams used in target recognition systems. According to the Microsystems Technology Office (MTO) at DARPA, "the goal of the STAB program is to eliminate the slow, heavy gimbals and replace them with compact, electronically controlled laser beam steering components." LPTI is part of a research group—headed by Raytheon—that is working on the STAB project. Raytheon, which is also a business partner of LPTI, plans to use LPTI's holograms in its future production process.

LPTI is also participating in the Terahertz for Operational Reachback (THOR) project intends to bring optical communication to the battlefield by establishing theater-level, free-space, optical communications between ground-based and airborne platforms. THOR's goal is to affordably link military platforms using technology that provides an order of magnitude reduction in size, weight, and power over today's technologies, according to DARPA.

One of the founders of LPTI, Dr. L. Glebov, began the preliminary research for the holographic technology 16 years ago in Russia. Upon arrival in the United States, he created the research team and began developing the technology at the UCF with MDA funding. They created a two-step process involving exposure to ultraviolet (UV) radiation followed by thermal development to form a Bragg grating in PTR glass. The Bragg grating is formed on the interior of the glass, making it highly robust. It cannot be removed by exposure to light at other wavelengths and can withstand temperatures up to 400°C. The glass can be several millimeters thick in size and store many independent holograms with an absolute diffraction efficiency up to 98 percent. The size of the plate and the number of holograms depends on the application. LPTI's holograms have different diffraction angles for different wavelengths. For the particular angle and wavelength of interest the hologram is a diffractive element, but for any other wavelength it is only a transparent piece of glass.

In 1999, the UCF assisted with the creation of LPTI as a spinoff. Currently, the company is housed at UCF, but it is exploring the possibility of moving into a research park that is a member of the university's incubator. LPTI is also in the initial stages of discussions and negotiations to develop partnerships with other companies such as United Defense. Several hologram prototypes have been fabricated and delivered to potential customers for evaluation. The company seeks funding to develop commercial products.

—*T. Spitzer*



Liquid glass. *LPTI researchers mold photo-thermo-refractive glass into holographic filters with adjustable transmittance. Pictured above is the casting of a large-aperture diffractive optic.*

The photo-thermo-refractive technology developed at UCF is protected by two issued patents and two pending patents, and exclusively licensed to LPTI.

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OPTICAL PROCESSOR PURSUES WIDEBAND APPLICATIONS

Digital dandy. *Essex' advanced optical processor can create images for radar systems in greater detail using less processing power than other technologies.*

What a radar sees as one object might actually be two, creating confusion and uncertainty for radar operators. But new signal-processing technology from an MDA-funded company could help solve that problem, providing a solution for radar users in the military, in commercial aviation, and in weather monitoring.

With radar systems, the issue of target discrimination becomes especially real as radar systems move from the narrowband realm into the wideband realm, generating images with finer resolution but more data that needs processing. Moreover, emerging radar systems for wideband must deal with unwanted signals or "noise" in sidelobes, the areas other than a target's main return in range.

Optoelectronic signal processing technology developed by MDA-funded Essex Corporation (Columbia, MD) will provide higher-fidelity wideband radar imagery with greater resolution and diminished noise in sidelobes. The improved imagery will increase the success of the discrimination task for determining warhead threats.

Typically, a signal processor converts analog radar signals into digital ones that are handled by digital signal-processing computer hardware to generate radar images. But according to Essex officials, suitable analog-to-digital converters (ADCs) have yet to surface for wideband applications, which cover approximately 1-gigahertz (GHz) bandwidth and greater. Moreover, Essex' technology would require less processing power (fewer lines of software code) than the all-digital processors being proposed for wideband radar applications that support lower integrated range sidelobes, according to the company.

MDA, through contracts from its Manufacturing and Producibility program, funded Essex' development of a 1-GHz bandwidth, real-time processor in 2002, as well as further development and testing work in 2003. The processor will perform real-time imaging in an upcoming demonstration for MDA. Contracts with the Ballistic Missile Defense Organization, MDA's predecessor, also have fueled development of the processor.

With the Essex advanced optical processor (AOP), analog signals go directly into an optical channelized receiver that converts wideband waveforms into 2,000 smaller channels. Those channels are then digitized by much lower-bandwidth ADCs. This waveform conversion is followed by modest digital signal processing to compute the images for the radar systems. The AOP consists of a 200-milliwatt near-infrared, single-mode laser diode on the front end, coupled with a wideband acousto-optic modulator. It has a coherent architecture, using one path for the radar reference signal and a second path for the radar return signal. For its output, the AOP produces the product of the Fourier transform of the two signals and then images the results onto a custom photodetector, a charge-coupled device.

The result is a signal processor that produces great detail with less processing power than an all-digital processor using a wideband ADC. Since the Essex approach channelizes waveforms before digitization, it also diminishes the effects of electromagnetic interference. Essex officials say that compared to other proposed signal processors for wideband, their optical technology requires from 4- to 20-times less power, depending on the amount of processing required.

The Essex processor could be applied to distributed array radar architectures, synthetic aperture radar architectures, and commercial aviation or weather monitoring. And since the optical-processing technology serves as a wideband correlator, it could be used to help filter data in large databases. Moreover, the wideband modulator that the company is using for the laser could find application in architectures for tele-communications and other defense-related signal analysis.

Essex officials continue to seek additional military projects suited to their technology.

—*S. Tillett*

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PERIODIC POLING KEEPS LIGHTWAVES IN PHASE

Periodic poling sounds more like a strategy for a Venetian gondolier than an opto-electronic switch matrix designer, but it may be the key to the future of high-speed optical networks.

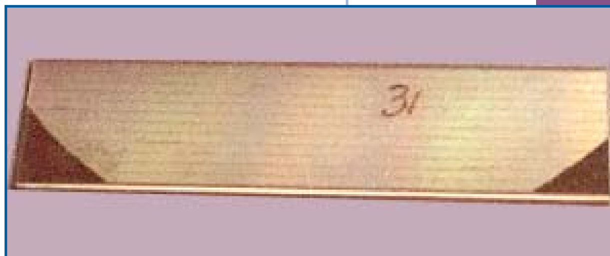
Lightwaves can be transmitted regardless of their polarity over standard fiber-optic cable. However, at very high rates of speed in the 40 Gb/s range where frequencies are packed closely together, the transmission of lightwaves suffers from a phenomenon called polarization dispersion. In an opto-electronic switch, where light traveling down one waveguide path needs to be precisely and quickly transferred to a different path, polarity mismatches can cause significant signal degradation.

In theory, the waveguide substrate in a switch could be designed to slow down and speed up waves of light so that they remain exactly in phase and are not lost. That is precisely what Srico, Inc. (Columbus, OH), achieved with SBIR funding from the MDA as well as the U.S. Air Force, National Science Foundation, and NASA. The company developed a proprietary method of modifying opto-electronic waveguide substrates to provide an optical switch that is polarization insensitive and has negligible polarization dependent loss.

In 2002, MDA awarded a Phase I SBIR contract to Srico to prove the feasibility of a high-speed switch matrix in a new periodically poled lithium tantalate (PPLT) optical waveguide substrate. Periodic poling is a modification technique that can be applied to a variety of substrates, but lithium tantalate was chosen for investigation because of its unique properties and in the hope that it might overcome some of the limitations of lithium niobate for switching voltage and speed. Srico successfully designed a high-speed switch using the new technique and PPLT material. Most recently, in 2003, MDA funded Srico to extend the periodic poling technique to a new class of lithium niobate wafers called stoichiometric lithium niobate.

What exactly is periodic poling? In a lithium tantalate crystal, lithium, tantalum, and oxygen atoms repeat in the same sequence, and as a result the crystal has a uniform property everywhere. With periodic poling, however, alternate sections of the crystal have the opposite structure for these atoms, which reverses the properties of the crystal for that section. The alternating sections of poled regions serve the purpose of slowing down and speeding up lightwaves so that they remain in phase.

The use of affordable opto-electronic switches and add/drop multiplexers operating reliably at processing speeds above 100 GHz would abet the deployment of 40 Gb/s networks and ease deployment of fiber links directly to residences. However, telecommunications is not the only broadband use for periodically poled waveguide substrates. Any application requiring high processing speeds, such as computing and sensors, might benefit from the availability of high-speed opto-electronic switches.



PPLT. *Srico's optical waveguide substrate made of periodically poled lithium tantalate forms the basis for a high-speed opto-electronic switch.*

Srico provides technology development and integrated optic circuit design services for clients and to the U.S. government, and currently manufactures opto-electronic switches in prototype quantities. The company seeks either to license its existing patents or to find one or more strategic partners to fund and further investigate the characteristics and reliability of devices that use periodically poled substrates for volume manufacturing.

—A. Gruen

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> *"Success usually comes to those who are too busy to be looking for it."*
>
> —Henry David Thoreau

CHEAP GRIN LENSES TO CUT COST OF LAST MILE

Glass act. *BeamTek thermally fuses together a glass rod and tube (pictured above) to create a preform, which is then drawn into a rod and sliced into lenses.*

A high-yield process that reduces the cost of gradient-index (GRIN) lenses by 80 percent has been developed. The cheaper lenses could substantially lower the cost of bringing fiber-optic cables into homes and businesses, often referred to as the "last mile."

The process, developed by BeamTek, Inc. (Tucson, AZ), can produce more than 10,000 radial GRIN lenses in a few hours from one preform with a diameter of 5 centimeters (cm) and a length of 150 cm. While current GRIN lens technologies contain such toxic materials as cesium or thallium ions, BeamTek's GRIN lens is created using non-toxic materials. The GRIN lenses can be fabricated from numerous glass materials to offer a wide range of refractive indices from 1.48 to 1.70.

MDA funded BeamTek to develop a process to fabricate GRIN rods for optical communications and data networks. The company plans to use these rods to fabricate GRIN lenses for telecommunications applications such as fiber-to-the-home (FTTH).

To make GRIN lenses, BeamTek thermally fuses together a glass rod and tube to create a preform, which is then diffused to make a gradient index profile. Similar to optical fiber, the preform is drawn into a radial GRIN rod. The GRIN rod is then sliced into numerous sections and polished to form individual GRIN lenses. BeamTek also can produce large-diameter GRIN glass tubes, which enable the size of the GRIN lenses to be virtually unlimited.

Similar to optical waveguides, BeamTek's GRIN lenses focus photon energy transmission for optical communications devices; they are the building blocks for connecting fiber-optic components. The technology will help provide low-cost optical components with reduced insertion loss. The GRIN lens can be used where fiber-optic components must be coupled without transmission loss.

BeamTek will have prototypes of its fiber-optic components available in 2004 and needs additional funding to further commercialize the technology. FTTH will become a big market in 2004, according to Bob Whitman, manager of global broadband market development at Corning and co-founder and member of the FTTH Council board of directors.

FTTH is the telecommunications industry's answer to customer demand for broadband and two-way, interactive video-based services in their homes. In Japanese cities, 630,000 houses currently receive information through FTTH and an additional 80,000 Japanese subscribers per month sign up for the service.[1]

Unlike Japan, the United States FTTH services have mainly been limited to small rural areas. So far, 94 communities have FTTH services, according to Whitman,[1] but interest is growing. The most recent evidence of a spurred interest in fiber-to-the-premises (FTTP), which encompasses FTTH, was the release of a joint request for proposal from BellSouth, SBC Communications, and Verizon, which are in the process of selecting companies to be FTTP suppliers.

Based in Tucson, Arizona, BeamTek was founded in 2000 by a group of professionals active in the area of glass material and optical engineering. The company focuses on developing passive optical components for the optical communications market and other military and commercial applications. BeamTek has over 3,000 square feet of manufacturing and laboratory facilities equipped with a full optical fabrication line of machinery and various instruments for assembly and testing. The company seeks inquiries from those interested in its GRIN lens and other optical technologies.

—*T. Spitzer*

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[1]Peach, Matthew. "Fibre's Coming Home," Lightwave Europe. November 2003.

LIQUID-TO-SOLID APPROACH SPEEDS OPTICS POLISHING

Polishing large, lightweight optics faster and more precisely should save the planners of space missions valuable time and money. One MDA-funded company has developed technology to do just that and expects it to find use in other industries with precision polishing needs.

The company, QED Technologies, Inc. (Rochester, NY), has developed a system that uses a liquid that quickly alters its physical state to solid and back to a liquid depending on exposure to an electromagnetic field. QED boasts that its technique will provide benefits in the areas of time and precision, offering cost advantages in the optics-polishing process. Also, QED's focus on producing lightweight optics should offer savings for users of large optics in satellites and other spaceborne applications, where each added pound can amount to thousands of additional dollars in launch costs. MDA funded QED's technology for its potential in large, lightweight optics for space-based and ground-based missile defense.

The high-precision technique that QED is developing will enable large optics such as mirrors for space-based telescopes to be made thinner and lighter. Lightweight optics are inherently weak or fragile, making them difficult to polish without deformation or damage. And conventional polishing of large, lightweight optics is often done manually, taking months to complete. But QED's approach, which uses interferometry and customized software to analyze optics before polishing and to guide the polishing instrument, promises to reduce the process time to only days or weeks. A QED spokesman said that other companies have developed proprietary, automated polishing techniques but that QED's technique, called magnetorheological finishing (MRF), still promises greater speed.

The instrument that QED has developed circulates a special liquid known as a magnetorheological fluid in a closed-loop filtered system. This fluid, with about the viscosity of mineral oil, travels from a nozzle toward a motion-controlled arm that holds the optic and that rests above a strong electromagnetic field. As the fluid enters the field, it almost instantly transforms into a solid state, polishing the optic. The slurry-like solid maintains a clay-like viscosity while exposed to the field. After leaving the field, it returns to a liquid state.

Since the system polishes on a tangent to the optic rather than by a normal direct force, the system is less likely to create defects in the mirror surface. The automated approach also offers the ability to measure and correct for print-through effect—the quilted or ridged pattern that sometimes bleeds through from the back of an optic when making it lightweight.

Large optics under 50 kilograms (kg) per square meter are considered lightweight. QED expects to process optics that will weigh less than 10 kg per square meter. The company's techniques also can be used to craft aspherical optics, which do not produce the aberrations of spherical optics.

Company officials also see application of their technology in the production of silicon or compound semiconductor wafers, which must be flat with as few defects as possible. According to QED, its MRF technique also could ensure uniformity of thin films applied to such wafers.

Phased approach. *QED's technique for polishing optics relies on a liquid that changes to a solid when exposed to an electromagnetic field.*

QED officials say they can produce optics with a quality exceeding $\lambda/10$ or $\lambda/20$ (peak to valley)—that is, 10- or 20-times smaller than the wavelength of light at which the optic will be used. By comparison, $\lambda/6$ is typical for high-quality camera optics.

The company, which was awarded an MDA Phase I SBIR contract in 2003, was founded in 1996 and already sells polishing machines that can handle optics up to 400 millimeters in diameter. As they build on their MDA-funded work for larger, lightweight optics, QED officials hope to develop and sell a new line of machines or to offer polishing services for a fee. Company researchers are now building a machine that will process large lightweight optics up to 1 meter in diameter.

—S. Tillett

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MDA *Update*
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Polymer manufacturers also may use Clark-MXR's production tool to make spinarettes, nozzles that have a specific shape through which polymers are forced to make fibers.

Micromachining . . . from page 1

confine and localize DNA probe segments, which tend to run together, making it easier to distinguish between them.

Automobile and heavy truck manufacturers might use the production tool to place a discontinuity or sharp edge inside the contour of the fuel injector's bore, which would break large fuel droplets into smaller ones. Better fuel atomization may lead to more efficient and lower emission engines.

The production tool has two other interesting applications. First, it can be used to create sub-micron features. In a demonstration using 500-nanometer light, features were created in the surface of a material down to the range of 20 nanometers. Second, the technology can machine features inside transparent materials. For example, it can be used to write gratings in planar waveguides and optical fibers or even to directly write waveguides in bulk glasses. In a recent test, Clark-MXR created a waveguide amplifier in neodymium-doped silicate glass.

Although Clark-MXR doesn't expect to complete the ABL production tool before 2005, the company seeks new applications for its micromachining technology.

—P. Hartary

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Up Front . . . from page 3

the marketplace before other technologies make their predecessors obsolete. The goal should be to understand the state of the market to avoid entering too early or too late.

Misconception #4: We Have No Competitors

Many researchers say they have no competitors. This just isn't true.

Every technology and product competes for a limited source of funds within the market, and therefore has competition. It is imperative for researchers to understand the advantages and disadvantages of the competitors' products and, if possible, to surpass them in both cost and performance. Realizing that human nature is resistant to change, it is crucial to offer a compelling reason to adopt a new technology or product.