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INSIDE

Tiny Wireless Computers Create Sprawling Networks —*by S. Tillett*

Combining sensors and miniature software promises to bring hidden data to users in real time.

Computers seem to be practically everywhere these days, but they soon could be found in even more places and in much smaller form. Tiny devices running miniature (ultracompact) software could be coupled with sensors and attached to almost anything—from soldiers in the field to sides of beef to industrial machinery—giving users a more comprehensive information picture by generating more data and by generating it in real time.

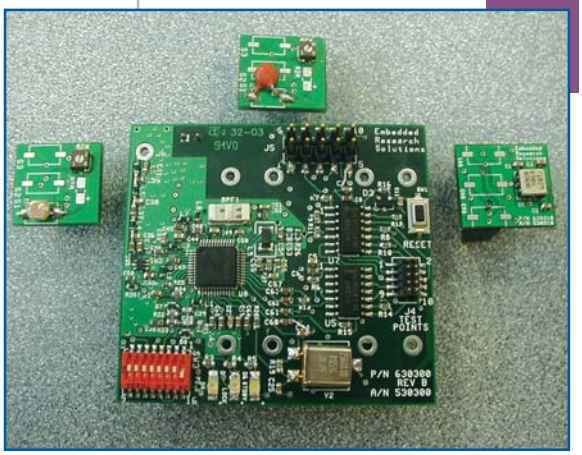
A number of companies and laboratories across the nation are developing such devices, and one MDA-funded company recently has released a commercial product that could whet users' appetites for such technology.

Embedded Research Solutions, LLC (Annapolis, MD), has developed matchbook-size wireless computers that can be attached to sensors and distributed widely, allowing users to create real-time networks that can automatically gather data at many locations. Compared with other data-collection methods such as large satellite-linked data transmitters, the small devices promise size and cost benefits. They also can be reconfigured to work with many types of instruments to perform multiple functions or to share data with sister devices. The software for the Embedded technology was funded through MDA SBIR Phase I and Phase II contracts for pervasive computing applications.

Embedded's TinyNode™ technology is commercially available as an evaluation kit for researchers, scientists, and other users. It includes three tiny devices, or nodes, that communicate wirelessly with a PC. Users can distribute the radio frequency (RF)-based nodes, attached with their own desired sensor (for light, temperature, humidity, etc.), and the battery-operated nodes will form a network by themselves and gather information at a rate that can be configured by the user—with collected data being dumped in real time into a database of the user's choosing. Essentially, the kit serves as a reconfigurable subnetwork of a larger network, bringing real-time data and miniature software to the larger network.

The Remote Monitoring Evaluation Kit offers users a taste of how basic everyday information collection might occur in the future. Today, the gatherers of information might collect data in dozens of ways. Environmental managers, weather watchers, and researchers, for example, might rely on a handful of sensor-equipped buoys and satellite communication to monitor conditions in a bay or other large body of water. Other researchers might trek into the field with instruments to gather information such as data on soil conditions, keying

Continued on page 11



Smaller net. *Embedded's TinyNode™ is surrounded by removable plug-and-play sensors. The board can support the variety of sensor types (e.g., light, temperature, and acceleration).*

MDA Update

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FROM THE EDITOR

WHEN LESS IS MORE

Digital signal processing. Wavelength multiplexing. Phased-array radar. Millimeter wave transmission. These are just a few of the complex technologies we've recently covered in this newsletter.

I don't doubt for a minute that MDA needs technology with a high level of sophisication. Shooting down an enemy missile with a missile or laser requires new tools that twist and turn the science of physics inside out. You really can't buy these tools off the shelf.

But technology doesn't always have to be complicated. Sometimes, less is more.

Our technology cover story is a good example of simplicity that works. Embedded Research developed wireless technology that lets users deliver real-time data over a network of tiny sensors. Unlike competing software that might be as large as 4 megabytes, Embedded's technology runs on only 4,000 bytes of code.

Embedded has even made it simple for researchers, scientists, and other potential users to test its MDA-funded technology. The company is selling a remote monitoring evaluation kit consisting of three nodes that wirelessly communicate with a PC.

Simplicity is also evident in the MDA-funded lithium battery research discussed on page 8. Boundless Corporation is working on technology to create multifunctional components for aircraft and space vehicles that not only provide structural support, but also energy storage.

In this example, simplicity works again. Once separate, batteries and structure become one. For example, a structural battery panel could form the substrate for mounting solar cells and integrating charge control electronics.

Although simplicity isn't easy to obtain, it is important. Some of the most successful technologies are simple. Now if only commercial success was, too.

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GET YOUR FREE COPY

During the past year, the MDA Technology Applications program developed several free reports that highlight many commercial applications of MDA-funded technologies. These reports include:

- *MDA Tools to Counter Terrorism* (Code: COUNTER)
- *2003 Technology Applications Report* (Code: TAR)
- *Sensors: Making the Unknown Known* (Code: SENSOR)
- *Tools for Responding to Emergencies* (Code: EMERG)

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WHERE ARE THEY NOW?

In August 2003, the MDA Technology Application program exhibited at the August 2003 Space and Missile Defense Conference and Exhibition in Hunstville, Alabama. During the conference, we interviewed dozens of MDA-funded SBIR/STTR companies, many of which have already been featured in the *MDA Update*. Several companies told us about their recent commercial progress, which is documented below.

Avanza Technologies

Avanza Technologies, Inc. (Spring 2003), recently moved its offices to the Los Alamos Research Park (New Mexico), which is owned by the Los Alamos Commerce and Development Corporation. There, Avanza has started the Information Systems Validation Center to perform network testing on a secure, large-scale configurable network for corporate clients. Avanza's secure peer-to-peer network environment technology, funded by MDA's SBIR program, will be incorporated into the test network.

InfoValley

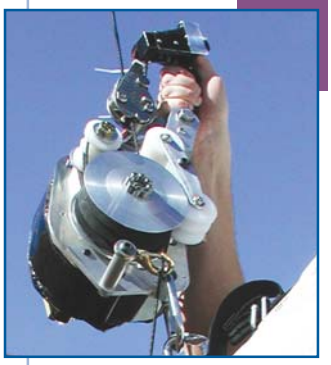
InfoValley Corporation (Spring 2003) has established a new company to sell Interactive InfoWall systems that use computer-interface technology funded by the MDA. The new company, LaserDraw, Inc., will focus on sales and marketing, while InfoValley will continue to specialize in display R&D. InfoValley's newest creation, Annotate, works with a single projector display and is targeted at multimedia projector users. A project is now underway to integrate Interactive InfoWall technology into an off-the-shelf product, the 3M Digital WallDisplay.

Quoin International

Quoin International, Inc. (Spring 2002), will begin commercial sales of its new PowerQuick® personal lifting device in the first quarter of 2004. Quoin officials say their next step is to enhance the military version of the product for use by U.S. Special Forces or in homeland security. The PowerQuick product emerged from BMDO-funded research on kinetic-energy kill vehicles and components. Through a meeting at Huntsville, Quoin reached an agreement with Aerojet to team on further development of flywheel attitude-control systems for future kill vehicles.

Surface Treatment Technologies

Surface Treatment Technologies, Inc. (Summer 2000), has found yet another interesting commercial application for its laser-induced surface modification (LISI[SM]) technology: fifth wheels used in heavy duty trucking. In collaboration with manufacturer The Holland Group, Inc., and the University of Tennessee Space Research Institute, Surface Treatment Technologies has treated over 5,000 fifth wheels, improving wear resistance and reducing the need for environmentally damaging lubricants. The company was funded through BMDO's SBIR program to develop and commercialize the University of Tennessee's patented LISI process.



Power lift. *Quoin's PowerQuick lifting device can propel an individual up to 5 meters per second. A faster unit has been developed for the military and law enforcement.*

CHECK OUT OUR REDESIGNED WEB SITE!

The MDA Technology Applications program has recently redesigned its Web site, **MDATechnology.net**, to make it easier for you to navigate and find MDA technology with commercial potential. New site features include:

- A main navigation bar that appears consistently at the top of every page, allowing you to move around the site more easily and logically.
- Quick Search: It's now possible to type in and search for any word or phrase that appears in our extensive database of technology articles.
- Suggested Search: Now you can search our database using the most popular words and phrases found in the database.
- Print and e-mail capabilities for all *MDA Update* and technology articles.

The site also features two new interactive multimedia components. A short flash presentation that explains what the program is and does has been added. A screen-saver program with 10 high-tech images of commercially successful MDA-funded technology also can be downloaded.

We want MDATechnology.net to work for you. Your feedback is appreciated. Send all comments to techapps@nttc.edu.

ADVANCED MATERIALS

FOUR-INCH GaN WAFERS TO DEBUT IN 2004

For Sale. *Kyma Technologies is selling two-inch GaN wafers for optoelectronic applications. By the end of 2004, the company plans to branch into additional industries by scaling up to four-inch GaN wafers—the next wafer size of interest in the microelectronics industry.*

Kyma Technologies, Inc. (Raleigh, NC), plans to produce four-inch gallium nitride (GaN) wafers by the end of 2004. These wafers are needed for next-generation optoelectronic and microelectronic technology applications. BMDO, now MDA, awarded the company a 2001 SBIR Phase II contract to develop GaN substrates for X-band radar.

To fabricate its GaN wafers, Kyma is using a fast-growth vapor-phase process. The technology combines a chemical vapor-phase process to grow the bulk GaN material and a physical vapor-phase process, licensed from North Carolina State University, to provide a starting template that ensures excellent uniformity and very high crystal quality.

According to Kyma, the process technology has a growth rate up to 10-times faster than any other commercialized deposition process for nitride-based materials, and it's scalable to the larger four-inch diameter wafer size, which is the next wafer size of interest. The process provides a very high material quality at one-tenth the cost of other manufacturing processes. And, Kyma's process can grow multiple wafers simultaneously out of large crystals. Moving to wafers larger than two inches will create lower cost opportunities through process scaling.

GaN substrates are matched in lattice constant and thermal expansion properties for epitaxial growth of doped GaN layers needed for fabrication of GaN-based devices. This eliminates stress and defects induced by growing GaN epi-layers on non-nitride substrates such as sapphire or silicon carbide, which increase device fabrication complexity and cost and compromise device performance. Kyma's high-purity GaN substrates allow GaN-based device manufacturers to eliminate processing steps and improve device quality compared with those grown on other substrates.

According to forecast data obtained from Strategies Unlimited's *Gallium Nitride-2003: Technology Status, Applications, and Market Forecasts*, projected sales for GaN-based LEDs, lasers, and electronic devices in 2007 will be approximately $4 billion, $402 million, and $129 million, respectively. Kyma's customers are in the optoelectronics industry, which is currently only capable of using two-inch GaN wafers. GaN wafers are applicable to short-wavelength optical applications such as green, blue, and ultra-violet (UV) light-emitting diodes and lasers, and visible and solar-blind UV detectors. The most prominent application of Kyma's GaN wafers is developing laser diodes for optical data storage where the short wavelengths provide higher performance.

Government users, however, require larger GaN wafers. In particular, MDA and DOD are interested in four-inch semi-insulating wafers for microelectronic applications such as the X-band radar, which is a ground-based radar used for threat tracking, target discrimination, and kill assessment. The X-band radar works in conjunction with other sensor and detection systems used by MDA. GaN wafers are needed for amplifiers in the radar systems and transmit and receive modules that form the components of the active phase of the radar. Similar to MDA's needs, the Navy is also interested in four-inch GaN wafers for radar applications.

Kyma is currently partnered with RF Micro Devices on an MDA SBIR Phase I, and the company is also working with several universities, including North Carolina State, on SBIR projects.

The company seeks additional investor funding and contacts for large defense-related programs involving optoelectronic and microelectronic technologies.

—T. Spitzer

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COOLED NIOBIUM CHIPS ARE HOT TECHNOLOGY

Powered flight didn't take off until the invention of the lightweight engine. Similarly, with the advent of compact cryogenic coolers, superconducting microelectronics (SME) is about to soar.

HYPRES, Inc. (Elmsford, NY), is developing an all-digital receiver deploying superconducting pure niobium-based multichip modules for potential use in the Joint Tactical Radio System (JTRS). In July 2003, the Department of Defense Small and Disadvantaged Business Utilization Unit, working in unison with MDA and the Office of Naval Research, awarded the company an $8 million Phase III SBIR contract to perform this work.

This Phase III award represents the culmination of a decade of funding for research and development into digital superconducting devices with real world payoff. Since 1990, the MDA and its predecessors have awarded a plethora of SBIR and STTR contracts to HYPRES in pursuit of various niobium-based superconducting computing and communications technologies. As a return on the funding, HYPRES intends to prove that producing and using SME in radar and communications systems can be done reliably, efficiently, and cost-effectively.

HYPRES engineers have already demonstrated the performance potential of pure niobium circuitry cooled to 4 kelvin at 20 GHz processor clock speeds—current contracts call for at least 40 GHz. HYPRES designers intend to achieve at least 160 GHz speeds. The main obstacle to making a product out of SME has been the size and weight of cryogenic coolers; commercial models that cool chips to 4 kelvin exceed the dimensions of many military electronic enclosures. However, working with suppliers in the cryogenic cooler industry, HYPRES scientists believe the company can acquire a steady supply of reliable compact and lightweight coolers capable of cooling their multichip modules (MCMs).

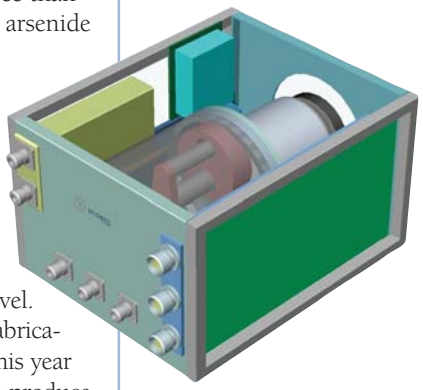
A major application for digital superconducting devices is in the realm of wireless communications. Analog superconducting devices are commonly used today in filters and frequency converters for the commercial cell phone business. The state-of-the-art in analog-to-digital (A-D) conversion has restricted the amount and quality of bandwidth that can be received and transmitted. Faster digitizing speeds translate directly into wider digital bandwidth. HYPRES A-D converters using SME will be programmable devices that digitize a wide range of frequencies directly off an antenna under software control.

Some companies are trying to develop digital superconducting systems using niobium alloys instead of pure niobium because niobium alloys work at slightly higher temperatures. HYPRES focuses on pure niobium because the material enables designers to build better circuitry. The real expense to chip production is in the design phase. Once a circuit is designed, a niobium thin-film chip is actually easier and cheaper to produce than one based on gallium arsenide or indium phosphide.

HYPRES fabricates more than half the world's niobium-based superconducting digital circuits but to date has not been equipped to build devices at the MCM level. The addition of new fabrication equipment later this year will enable HYPRES to produce its own MCMs. A portion of the Phase III funding is targeted to upgrade the facility and equipment necessary for fabrication in-house and on-site. Previously, such work was subcontracted. The Department of Defense assures itself of a robust production capability should digital superconducting prove useful for JTRS and other military programs.

Within one year, HYPRES will deliver a functioning prototype all-digital receiver, cooled by a commercial cryogenic cooler, to a government laboratory for testing. Company management is confident that the technology developed for the all-digital receiver, once proven to be reliable, will attract customers not only in the defense and homeland security communities but also in the commercial wireless industry.

—A. Gruen



Keeping it cool. *HYPRES intends to use cryogenically cooled circuitry to power its all-digital receivers.*

"There is so much cost-savings and performance-improvement potential with our all-digital receiver technology that if we had it [available today] . . . . they'd be buying tons of them."

—Richard Hitt, HYPRES

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PHOTONICS

BEAM-SHAPING OPTICS ENABLE HIGH-POWER, HIGH-BRIGHTNESS LASER DIODES

Bright delight. *Apollo's advanced fiber-coupled devices use beam-shaping optics to maintain laser diode array brightness while increasing power output. Pictured above is a device that can provide 30 to 40 watts of continuous-wave power from a fiber having a 0.1 mm core.*

Until recently, laser diode arrays (LDAs) have been limited in power output and brightness due to optical design and focusing issues. With the help of MDA SBIR funding, Apollo Instruments, Inc. (Irvine, CA), has developed novel beam-shaping optics that address these issues, making it possible to build high-power, high-brightness, high-optical quality LDAs.

To increase the power output of a standard LDA, more emitters are commonly added to a laser diode bar. Between the emitters are spaces of about 500 microns. This area is often referred to as "dead space" because it does not generate any light. The presence of the dead space decreases the brightness of LDA devices. In addition, the raw output beam from an LDA is highly divergent and suffers from two asymmetries—astigmatism and an elliptical beam profile. When the noncircular, astigmatic, incoherent beam from the LDA is focused, the beam spot is greatly elongated, which is undesirable for most applications.

Apollo's beam-shaping technology substantially maintains LDA brightness while increasing power output through beam combination. It uses various configurations of specialized optical elements that shape and re-arrange the beams so that high-efficiency and high-power coupling into an optical fiber can be achieved. In one configuration, two groups of prisms are used to divide and rearrange the beams from the LDA. In another configuration, mirrors are used. Apollo has received several patents covering these unique configurations.

MDA awarded Apollo an SBIR Phase I contract in 2000 to determine whether a high-brightness fiber coupled diode laser using its beam-shaping technology was feasible. Test results showed that the technology was capable of making devices with very high brightness. In a subsequent contract, the technology was also demonstrated to inject kilowatt or even multikilowatt pumping power into a small laser fiber aperture. During the Phase II program, a series of fiber-coupled laser diode devices with various power levels were developed and released for commercial evaluation. Under a separate SBIR Phase II contract, Apollo is developing a kilowatt-class fiber laser that could significantly improve laser-based communication systems for ballistic missile defense applications.

High power and high brightness are critical for many applications such as those requring solid-state lasers. With high-brightness diode lasers, the beam will be more intense at the focal point. It is expected that the availability of high-brightness and high-power collimated and fiber-coupled laser diodes and systems will enable many applications and technologies. For example, at power densities above 10^6 W/cm^2, metal marking or drilling becomes possible with direct use of high-power laser diodes. Other potential applications include medical, industrial graphics and other direct thermal and illumination applications, and monitoring and measurement applications. High-brightness and high-power laser diodes could also become standard building blocks for construction of highly efficient and high-power fiber and other solid-state lasers.

Apollo offers a catalog of 17 standardized laser devices that incorporate its beam-shaping technology. Fiber-coupled laser devices range from a 30 W output via 0.1 mm fiber core diameter to a 500 W output via 0.6 mm fiber core diameter. Collimated laser diodes range from 32 W output with 3 x 3 mrad divergence and 8 x 7 mm beam size to 150 W output with 10 x 20 mrad divergence and 14 x 28 mm beam size. Many of these high-power devices have already been sold for industrial and academic applications.

Using its beam-shaping technology, Apollo expects to facilitate the development of kilowatt-level fiber lasers with high beam quality (M^2 <1). The current devices can generate pumping power of 500 W. The company says that 1 kW output should be attained by mid-2004. Once completed, this laser device will be marketed for industrial processing and solid-state laser pumping applications.

—P. Hartary

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PHOTONICS

BEAM-STEERING SYSTEM TRACKS MULTIPLE OBJECTS IN REAL TIME

The age of tracking and designating multiple targets with slow, single-spot beam-steering devices could soon end. Boulder Nonlinear Systems, Inc. (BNS; Lafayette, CO), and the University of Louisville (UofL; Louisville, KY) have teamed to create the first multispot laser beam-steering system (RAMS-LBS) that operates in real time and can adapt to unexpected changing conditions.

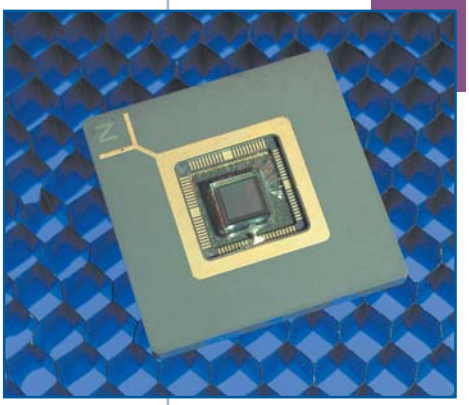
The RAMS-LBS features a 512 x 512 liquid-crystal spatial light modulator (SLM) and a fast diffractive optics design program (DODP) that automatically generates complex and rapidly changing laser illumination patterns. The SLM is constructed by placing a layer of liquid crystal on top of a reflective pixelated silicon backplane. The liquid crystal has a voltage variable index of refraction, thereby producing a programmable phase shift on the incident light at each pixel. The SLM backplane has an 83 percent pixel fill factor and greater than 90 percent reflectance, which provides high on-axis diffraction efficiency, a large number of resolvable steering locations, and high-intensity laser spots.

The DODP will operate in real time under computer-based, event-driven supervision. It accepts design requirements in real time and outputs phase modulation patterns that diffract the incident laser beam into approximately correct intensity patterns. The patterns are improved on or adapted into new patterns based on available computation time and scene environment considerations. The result is a truly autonomous and flexible program. Typical diffractive optics design algorithms produce designs in response to inputs provided by a human designer.

A key component is the supervisor software, which automatically coordinates the DODP with the multiobject tracking algorithms. The software will coordinate the tracking and positioning of the multiple laser beams with the ability of the DODP to design a beam pattern in a given time. It also can greatly simplify the ability of the RAMS-LBS to be configured for evaluation by potential customers.

In the early 1990s, BNS began investigating one-dimensional liquid-crystal beam-steering devices through SBIR Phase I and Phase II contracts from MDA. Interested in active sensing and target designation, MDA awarded BNS an STTR Phase I contract in 1999 and an STTR Phase II contract in 2002. One of the advantages of multispot laser beam steering is that rather than firing a laser at multiple targets sequentially, it is possible to split the beam and track the targets simultaneously. This has the potential to increase the speed of data collection and eliminate target reacquisition problems.

In addition to target designation and tracking, the RAMS-LBS could be used as a enabling component in optical interconnects, line-of-sight optical links, holographic optical memories, laser visual displays, ranging systems, marking systems, and even laser micro-particle manipulators (i.e., laser tweezers). In the latter example, BNS and UofL are working with a manufacturer of laser tweezer/laser scissors microscope workstations to evalaute the new functionality made possible by RAMS-LBS for multispot beam steering, as well as considering other potential functions of SLM's in microscopes.



Fast modulator. *Boulder Nonlinear's 512 x 512 spatial light modulator uses liquid crystal technology to generate complex and rapidly changing laser illumination patterns.*

The RAMS-LBS will serve to expedite evaluation by interested parties. It will also help identify many new applications for parallel and independently steered laser beams. BNL and UofL seek inquiries from those interested in evaluating their beam-steering technology.

—P. Hartary

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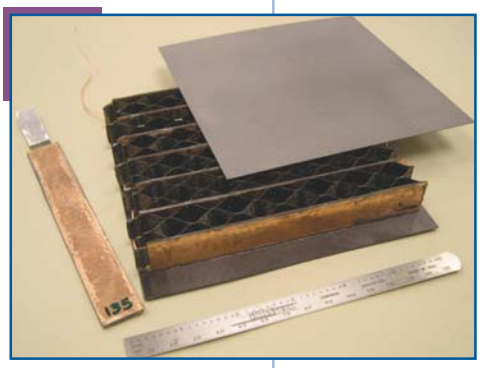
"Opportunity is missed by most people because it is dressed in overalls and looks like work."

—Thomas A. Edison

POWER

ENERGIZED STRUCTURES SAVE SPACE, WEIGHT



Double-duty. *Boundless' multifunctional structural battery bicells (left) supply power and reinforce the solar array substrate (right) for a small satellite. The battery bicells form the rib in the honeycomb core of the sandwich panel.*

Boundless Corporation (Boulder, CO) has developed technology that makes batteries more than just bulky sources of power. The company has incorporated batteries into the physical design of a vehicle or device, creating an energized structure that not only saves weight and space but also boosts battery performance. MDA's SBIR program funded Boundless' structural batteries for their potential in onboard power systems.

Competing ideas involve designing a battery that piggybacks onto the contours of a structure or that can be dropped into a hollow space within a structure itself, adding very little additional strength or stiffness. But with Boundless' approach, the material that makes up a structure becomes an actual element of the battery. In other words, the battery is the structure itself. And conversely, the structure acts as the battery—with the combination forming what might best be described as a multifunctional structural battery. Boundless researchers believe theirs is the only company building such a battery at the component level, designed from the ground up to both store energy and provide structural functionality.

Boundless' structural batteries should prove useful in spacecraft, unmanned aerial vehicles, automobiles, and other large machines that require batteries. However, company officials do not expect their technology to be practical for smaller devices with less structure, such as laptops and cell phones.

The Boundless technology uses partially saturated carbon composites to build lithium-ion battery components. Most carbon composites are fully saturated, meaning resin soaks completely through the reinforcing materials. Boundless, however, has developed composites in which only one face of the single-layer composite is fully saturated for strength and stiffness. The other face is bare carbon fiber, providing its entire surface area for ion intercalation, or insertion. The approach uses fibers that run continuously in and out of the resin, allowing the battery technology to maintain full conductivity even through the saturated portion of the composite. The battery chemistry behind Boundless' technique is standard battery chemistry, according to the company.

When it comes to battery capacity, the company is targeting effective specific energies of 200 watt-hours per kilogram, compared with 120 watt-hours per kilogram typical of current lithium-ion cells. In other words, a user would need an almost 2 kg battery to get the 200 watt-hours of energy that Boundless hopes to provide in a 1 kg battery. Besides boosting battery capacity (or storage), the company also is targeting high battery power—the speed with which the battery can deliver its stored energy. Boundless seeks to deliver battery power performance up to 5 kilowatts per kilogram.

The high-powered, high-capacity batteries should mean makers of satellites, spacecraft, and aircraft can power their instruments with smaller, lighter batteries, saving space and weight. And for space applications, lighter launches mean cheaper launches, since each pound of payload can cost thousands of dollars to put into orbit.

Boundless' structural batteries also promise longevity over conventional batteries. By distributing batteries throughout a structure, and closer to the devices that use them, the Boundless approach seeks to avoid heat build-up that can occur with large centralized batteries. And less thermal fatigue means structural batteries should last longer. The distributed approach also avoids energy loss that can occur when long wires are used to deliver battery power.

Boundless continues to focus on product development and already has shipped functional batteries to the NASA Goddard Space Flight Center for use in a project to measure radiation in the Van Allen belt in Earth's magnetosphere. The project involves several dozen birthday-cake-size satellites. Boundless officials also continue to look for potential partners and users.

—S. Tillett

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NEW RF INJECTOR ADVANCES FEL FOR MAINSTREAM USE

A new superconducting radio frequency (RF) injector is being designed that can bring free-electron lasers (FELs) out of the laboratory and into the mainstream by meeting commercial and military power requirements.

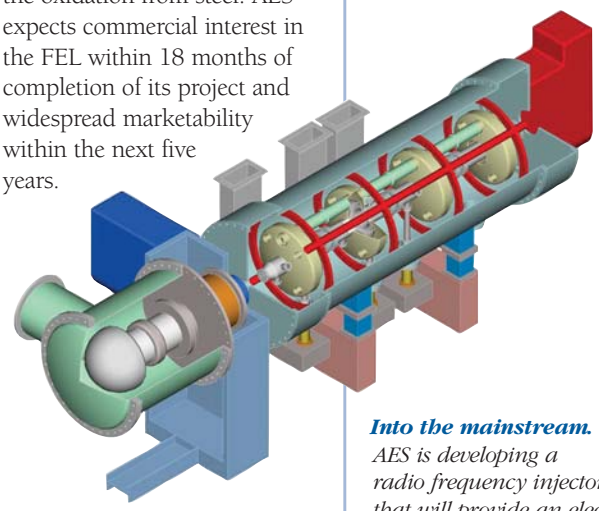
Lack of a suitable high-power, high-beam-quality electron source presently restricts FEL use to primarily research applications. For mainstream commercial use, an FEL that can produce an infrared (IR) output of 100 kW or more is much needed. Answering this need, Advanced Energy Systems, Inc. (AES; Medford, NY), is developing an RF injector that will provide an electron beam of approximately seven million electron volts at about 100 milliamps of continuous current, resulting in an FEL with an IR output of 100 kW.

MDA funded AES with an SBIR Phase I to design and develop the new RF injector. MDA and Naval Sea Systems Command, which also provided funding to AES, are interested in using high-power FELs for directed energy weapons. AES is developing a RF injector capable of going beyond the 100 kW FEL output needs of the commercial world to the requirements of the military. Currently, the FEL's size limits its applications to weapon systems with large platforms.

To get more radiated power from FELs, more current is needed from the injector. To do this AES is developing a new design for the superconducting RF (SRF) injector. In a standard SRF accelerator, the electron accelerating cells are usually joined together and fed power as a unit. Because of power limitations through each RF feedthrough, AES developed the accelerator to be a sequence of single cells that are individually powered.

The second component to AES' RF injector is the direct current (DC) gun. The company has a CRADA with the Department of Energy Thomas Jefferson National Accelerator Facility (JLab) to modify an existing DC gun for the prototype RF injector. The DC gun is driven by a green drive laser that is flashed on a gallium arsenide cathode causing the photoemission of electrons that are accelerated up to 500 kV between the cathode and the anode of the DC gun. The electrons are photoemitted precisely when and where they are needed and deposited as separate bunches in the SRF acceleration stream. The DC gun and the superconducting accelerator fit together to create an RF injector capable of enabling a continuous 100 kW IR FEL.

Commercial industries that may have the ability to support an FEL are pharmaceutical and steel. The pharmaceutical industry could use the FEL for time-released coatings of pharmaceuticals with a polymer coating using a process called pulse laser deposition. Other lasers have been used to perform this application, however the polymer coating is significantly degraded, whereas by tuning the wavelength, the FEL can retain the polymer's properties. The FEL also offers the steel industry an environmentally friendly way of removing the oxidation from steel. AES expects commercial interest in the FEL within 18 months of completion of its project and widespread marketability within the next five years.



Into the mainstream. *AES is developing a radio frequency injector that will provide an electron beam of approximately seven million electron volts at about 100 milliamps of continuous current. This beam will feed an FEL with an IR output of 100 kW, which should meet industry needs.*

AES and JLab plan to complete modifications to the DC gun and the accelerator within a year, and JLab will prepare a test stand for the injector. However, Navy funding is still needed for this development. Specifically, JLab needs funding for a megawatt of continuous RF power to fully test the device to the specified performance.

—T. Spitzer

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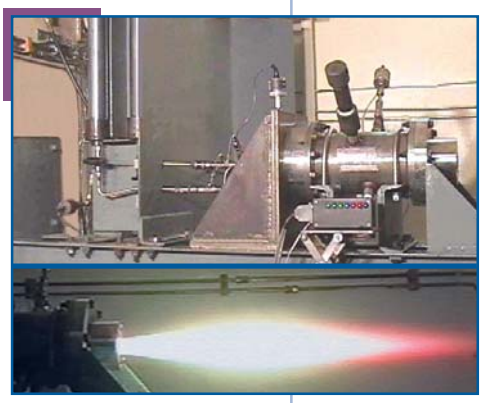
"Few things are harder to put up with than a good example."

—Mark Twain

PROPULSION

GEL PROPELLANT SYSTEM SAFER AND EASIER TO CONTROL



Clean burn. *CPBT is testing its new propulsion system using the rocket engine test setup (top). The system burns a steady plume jet produced from the combustion of bipropellants with nano-sized boron particles (below).*

A new gel bipropellant system that offers safety and controllability and enables the use of environmentally friendly propellants is being tested for military and commercial applications.

Combustion Propulsion Ballistic Technology Corporation (CPBT; State College, PA) is developing a propulsion system that consists of a fuel-rich gel propellant and a separate oxidizer-rich liquid propellant that mix on command and are combusted by a pyrogen igniter. This bipropellant system was funded by MDA with an SBIR Phase I for use in the kinetic energy (KE) interceptor and divert and attitude control systems.

Current solid propellants are typically premixed combinations of fuel and oxidizer. Reactant materials stored individually are more stable and less likely to ignite by accident. By keeping the fuel-rich and oxidizer-rich propellants separate, CPBT envisions a much safer system.

Safety is just one feature offered by this technology. The bipropellant system also enables energy management—via computer feedback, the flow rate and energy release rate of the propellants are controlled as they enter the rocket engine to burn. The tanks are pressurized to force the propellants through the valve openings. In addition, the fuel-rich propellant is in the form of a gel and is atomized—changed from a continuous liquid-like phase to a discrete droplet phase—making it easier to ignite and burn. In contrast, a solid-propellant system, being premixed, has a burn rate that cannot be effectively controlled, unless the chamber pressure is altered.

MDA is interested in higher specific impulse and energy management capability. If it is determined that existing energy will carry the missile toward the target, the bipropellant can be shut off until needed again, extending the range of flight for the missile. Likewise, the flow rate can be increased to speed up, or change the orientation or direction of the missile.

Furthermore, the nature of CPBT's "digital propulsion" system allows for more environmentally friendly propellant materials. For example, hydrogen peroxide can be used in a bipropellant system because the fuel remains in liquid form, unlike solid propellant materials. Plus, solid propellants need a fuel binder to cure and link the oxidizer material, which usually comes in the form of toxic crystalline particles. The gel-based bipropellant system can be selected to operate in the temperature range between -60 and 70ºC.

CPBT is also adding metallized, nano-size powders of boron or aluminum to the fuel-rich propellant. The powders generate a substantial amount of heat when they oxidize, in turn heating the propellant products to high temperatures. The company uses nanopowders as a gellant, making the propellant easier to handle. Another way the nanopowders increase the performance of the propellant is through "damping," an effect where the particles reduce combustion instability by absorbing pressure fluctuations and allowing more predictable missile performance.

Under a subcontract with Pennsylvania State University, the performance of newly formulated bipropellant combinations is being characterized by the research staff of Penn State's High Pressure Combustion Laboratory. Via the continued support of MDA, CPBT will collaborate with several commercial companies to design and develop a large-scale bipropellant rocket engine for application to MDA's KE interceptor. CPBT has been invited to write a proposal for a Phase II SBIR from MDA, which will be used to finish the development and testing of the bipropellant system, finally demonstrating thrust profile variability.

Besides the missile defense applications, CPBT has discussed next-generation space payload insertion and on-orbit propulsion system applications for satellites with several large commercial companies. The company needs additional funding for more rocket engine tests and to hire more employees.

—T. Spitzer

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FEATURE

Tiny Wireless . . . from page 1

the information manually into a computer. Meanwhile, the stereotype of the clipboard-carrying industrial equipment inspector, reading temperature gauges and jotting down information, still lives on in certain corners of industry—although the clipboard in many cases has been replaced with a handheld digital device.

The fact of the matter is that the world—the natural world as well as the manmade one—encompasses an infinite number of data points just waiting to be monitored. So why monitor weather conditions such as temperatures at only a few dozen weather stations across a region? Why not monitor the temperature in hundreds of spots in a metropolitan area? Such live, pervasive data might give weather forecasters and historians better insights into the nuances of active weather patterns as well as perspectives on long-term weather trends.

And why wait until an equipment inspector can get around to reading the gauges on industrial machinery? Why not have gauge data sent wirelessly in real time to a company's network? Similarly, why should inspectors of food such as beef wait to discover evidence of contamination or improper storage temperatures? Why not let sensors coupled with tiny wireless computers send RF warnings to inspectors in real time once the instruments detect a problem?

Size and cost factors

Embedded has developed miniature software that can run on relatively inexpensive 8-bit processors, as well as processors as powerful as 64 bits. Embedded's miniature software consumes less than 1,000 bytes of RAM. In comparison, collecting data at network nodes using conventional software and hardware might require processors requiring hundreds of thousands of bytes of RAM.

The smaller software, running on simpler processors, means that Embedded can produce physically smaller devices—nodes that measure roughly 2 inches by 2 inches in the company's current demonstration models. Having smaller nodes means users can deploy more of them practically.

Embedded now uses two CR123 batteries, commonly used in digital cameras, to power the nodes. Embedded's TinyNode technology also will work with external power sources. Company researchers are working to create a node that will run on one battery, resulting in smaller devices in the future. Embedded also hopes to find new ways to make the devices smaller and to add features in coming years.

While Embedded's small nodes do address the cost issue by operating with simpler, more affordable processors, the nodes aren't exactly cheap yet, although company officials expect the nodes to come down in price as business grows. Embedded now offers it's evaluation kit for less than $1,500.

Features

Another noteworthy benefit of the node-network concept that Embedded seeks to commercialize is the notion of a "self-healing" network. For example, one device in a pervasive computing network might serve initially as a backup device. That device—a thermometer-equipped node, for example, might simply receive and transmit information collected by another node, serving as merely a relay point in the flow of data to a central computer. But if the stream of information from the other node suddenly stops, the first node can kick in to full operation to make sure important data still gets collected. Moreover, a node could pass along information gathered by another node if that other node's RF signal is too weak to reach the interface for the main network.

The technology that Embedded has created is based on standards for port-based, object-oriented computing. Ports are programming interfaces for connecting sensors with the miniature computing devices. Objects meanwhile are essentially bits of software, with each having a particular function. An object could manage an instrument such as a biological sensor, for example. But a user could easily reconfigure the object or map it to another object, allowing a device that had been managing the biological sensor to work with other sensors such as magnetometers, gyroscopes, and so on.

Drew Sweetak, president and chief executive officer of Embedded, believes that the reconfigurable approach, plus the real-time nature and small size of Embedded's technology, sets the company's offerings apart from other emerging technologies. While similar

Continued on page 12

Health monitor. *Embedded's wireless technology could be used to monitor the body temperatures of soldiers in the field (pictured above) or the heart rates of athletes during a competition. Company officials estimate the health monitoring market to be at least $70 billion.*

Monitoring water conditions in the Chesapeake Bay would require hundreds of data-collecting buoys, many as tall as 10 feet. Using Embedded's technology, the buoys could be reduced to matchbook size and be placed in more locations to generate a more thorough picture of water conditions.

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Embedded could create a wireless sensor network that connects company vehicles with a fleet service manager. If a vehicle experiences an engine or exhaust malfunction on the road, the data could reach the manager before the vehicle returns.

Tiny Wireless . . . from page 11

technologies might operate on processors only as small as 32 bits, Embedded's software can run on processors as small as 8 bits. Meanwhile, competing software might be as large as 4 MB, versus Embedded's compact 4,000 bytes of code.

Seeing promise

Users are already beginning to see promise in the pervasive computing vision Embedded is laying out. Lockheed Martin plans to use a scaled-up version of Embedded's technology to monitor temperatures for electronics racks in airplanes, according to Embedded officials. The technology will become flight-qualified later this year.

Embedded is actively seeking additional commercial opportunities, as well as capital. Sweetak said the company is currently searching for fresh funding. MDA funded Embedded's miniature software for pervasive computing because the technology could prove useful in missile defense applications that call for multiple sensors working together on a network.

Embedded's current business strategy is to build products and solutions for a handful of specific industries, first targeting the machine health/diagnostics market, an estimated $150 billion industry that involves managing factory and utility plant equipment. Environmental monitoring is another market, but the company has not developed an estimate on the size of that market. Two other markets include battle-theater intelligence, an estimated $3 billion market, and asset management for locating and tracking, which could bloom into a several-billion-dollar industry in coming years as retailers and other companies embark on using RF identification tags, not just bar codes, to manage inventories.

Current challenges for the company include refining the technology beyond its recently released evaluation kit, to develop products that move beyond the research realm and enter the commercial realm with full force, according to Sweetak.

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