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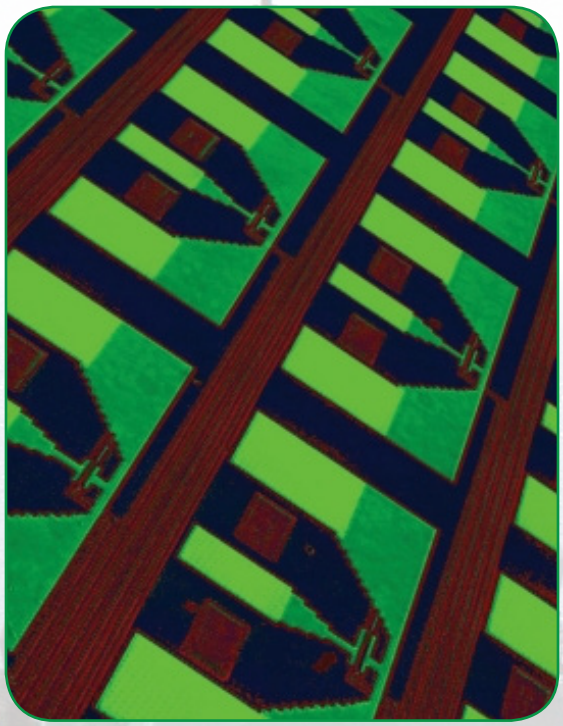


EXECUTIVE BRIEFING

The new frontier of optical computing

This executive briefing discusses the promise of optical computing to supply crucial bandwidth for demanding aerospace and defense signal processing.

Optical computing in military and aerospace applications has the potential to make a quantum leap the speed at which data moves among subsystems, as well as among system components such as processors, solid-state memory, and data storage. In addition to vastly improved data-throughput speeds, optical computing also resists the effects of electromagnetic interference and electronic jamming that can place critical military data in jeopardy. The most promising aerospace and defense uses of optical computing are in the most demanding high-performance embedded computing (HPEC) applications like radar and sonar processing, signals intelligence, and electronic warfare.

Optical technology: at the speed of light

Optical components and systems benefit aerospace and defense applications with high speed, low weight, and increased security.

BY **COURTNEY E. HOWARD**

THE REQUIREMENT FOR compact, lightweight, low-power electronics-exacerbated by the growing demand for greater data throughput and bandwidth-is driving the use of optical technologies in military and aerospace applications. Optical components and systems are increasingly being investigated, as well as adopted, by aerospace and defense engineers for a wealth of land, sea, air, and space applications.

IBM has unveiled CMOS Integrated Silicon Nanophotonics chip technology, which is said to enable a 10X improvement in integration density and produce smaller, faster, and more power-efficient chips than is possible with conventional technologies.

"Customers are definitely requesting more optical solutions in the mil-aero realm, and the interest is typically driven by one of more of optics' advantages over copper," explains Gregory Powers, market development manager at TE Connectivity Ltd. in Seattle (Tyco Electronics was renamed TE Connectivity Ltd. last month). "There are several benefits to optical computing, including: reduction of size, weight, and power (SWaP); electromagnetic interference (EMI) immunity; the fact that fiber optics offers a secure communication line where any tapping can be detected; ease of installation; and data rate over distance.

"Some of these advantages are interdependent," Powers adds. "For instance, because optical fiber is immune to EMI, there is no need for shielding of the cables. Shielding is heavy, adds size, and brings about installation and application problems. In composite aircraft, special provisions have to be made for bonding the shields to assigned grounds and protection of shielding relative to lightning strike. Optical computing can minimize all these issues."

Optical advantages

Optical components and systems are attractive for airborne applications, ranging from a flight-critical databus to a video or sensor link, given the desire for the reduction of SWaP, ease of installation, and EMI immunity, Powers says. In ground-based applications-such as secure bunker-to-bunker communications, electro-optic (EO) sensor mast-to-control station links, or RF over fiber antennae links-the advantage of optics over distance often is the deciding factor, followed by EMI immunity, security, and reduced weight.

"The big thing we're seeing is in a lot of aircraft, they want to reduce weight," observes Kirk Lussier, program and account manager at DiCon Fiberoptics in Richmond, Calif. "Fiber weighs a lot less [than copper]-that's a big advantage of moving to fiber-optic systems.

"In telecom, fiber deployment started with the longest networks, where optical technology proved itself quickly from a cost perspective," says Robert Schleicher, vice president of product development at DiCon Fiberoptics. "Over the years, it has spread out and proven itself in smaller and smaller networks-regional and then local networks, even within office networks-and to some extent, the same trend is now extending itself to the networks within planes, ships, and land vehicles."

Farther and faster

Optical components hold the potential for higher performance, an attractive attribute given the amount of data being acquired and exchanged on the digital battlefield. "Optical interconnects allow faster data transmission and, thus, higher processing speeds," admits Andreas Gerster, worldwide business development manager of optics at Agilent Technologies in Santa Clara, Calif.

"As transceivers that are usable on aircraft become faster and faster, designers want higher data rates," Lussier notes. "It's not a problem for optical technology. Our switches are all-optical; there's no OEO (optical-electrical-optical) conversion, so it can handle any data rate."

Optical technologies provide the ability to transport high volumes of data over significant distances. Copper backplanes and cable assemblies, as are deployed throughout mil-aero environments, are extremely length sensitive. "The greater the distance, the higher the attenuation and the lower the data rate," Powers explains. "Optical fiber has much, much lower attenuation, thereby eliminating distance as a primary design constraint. Computers that need to communicate can be hundreds of meters apart and interact as though they are in the same chassis."

TE Connectivity Ltd. provides rugged optical connectivity solutions for use in various high-reliability applications.

"The transmission speeds in electronics have now reached 10G (10 gigabits) and more per I/O (input/output) pin, which drives all kinds of digital interconnects based on copper to the limit," Gerster says. "This makes optical computing technologies much more attractive for applications in the aerospace and defense sector."

Rugged ebedded computing systems need to have high-data-rate input/output, for which fiber optics are ideal, Powers says. "The I/O could be a relatively short link, connecting two plug-in modules in the same chassis, or it could be a longer run, say from a shipboard sensor mast to a processor and data storage bank. There are numerous data-intensive applications where the advantages of optical computing pay dividends, including radar installations, EO sensor suites, persistent wide area surveillance, signals intelligence, and more."

Design distinction

"Most processing is done in an elec- tronic chip (an ASIC, a semiconduc- tor) and, at some point, you convert to light," Powers explains. After this electro-optic conversion, "the light can be sent through circuit boards in a waveguide, which is typically outside of the circuit board in today's applications. As soon as the light is introduced to a fiber, you can route that fiber anywhere. You can take that very fast data stream and run it from a daughter module through the backplane to an I/O connector, and then it could stay inside the chassis or be sent a kilometer away. The computers really know no difference.

"That whole concept is powerful," Powers continues. "What fiber optics enable is not distance-sensitive, like copper is. If someone is designing a large platform-a 747 or C5 aircraft or a military base perimeter system-they can have these cards virtually anywhere they need them. Let's say it was going in an aircraft, you could put these boxes where it made sense in the aircraft for weight distribution or heat or protection issues; with copper, you need to co-locate the items because of length sensitivity. That's one of the powerful aspects of fiber optics: location-independent architecture. It frees the designer of distance constraints."

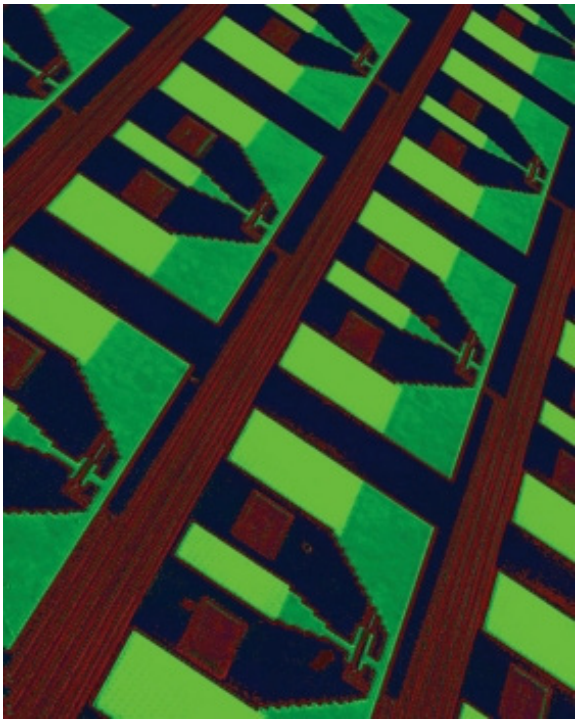
Safe and secure

Higher security is, likewise, a big advantage in mil-aero applications. Optics, by nature, are "immune to electronic countermeasures and reconnaissance, as there are no electromagnetic emissions," Gerster adds.

Optical computing, networking, and communications avoid TEMPEST (Transient Electromagnetic Pulse Standard) issues, increasing security. "TEMPEST relates to emissions from copper cables carrying signals that could be sniffed or detected in some way," Schleicher describes.

"When the information is in a fiber, there's no electromagnetic radiation by which the information can get out and be sniffed by someone you don't want to sniff it. You have to get to the fiber physically to get the information," Lussier explains.

"In defense applications that make use of data communications over copper wire, the barrage of emissions testing used to prove the security of the data path is typically referred to as TEMPEST testing. The use of fiber-optic communication



IBM Research staff unveiled nanophotonic avalanche photodetectors on a silicon chip.

can significantly reduce this sort of data security issue. TEMPEST testing is a big concern for product developers and our customers," Schleicher continues. "You want to make sure the information doesn't get to the wrong people. Improved data security is another key advantage of fiber optics in general, and of all- optical systems in particular."

Optical technology also plays a role in physical security. Fiber-optic intrusion detection technology from Future Fibre Technologies (FFT) in Mountain View, Calif., physically protects highly sensitive communication and data networks at an unnamed U.S. military facility.

The installation, using the FFT Secure Link system as an "alarmed carrier" Protective Distribution System (PDS), protects Secret Internet Protocol Router Network (SIPRNet) data links between facilities against illegal interference, data tapping, and unauthorized physical disturbance. SIPRNet is a system of high-security, interconnected computer networks used by the U.S. Department of Defense (DOD) and the U.S. Department of State to transmit classified information.

"The FFT solution is perfect for military networks that require real- time notification of intrusion attempts," says Emmett McGrath, Secure(it) program manager for Communications Supply Corp., a subsidiary of WESCO Inc., in Carol Stream, Ill. "Secure Link is a cost-effective alternative to conducting periodic visual inspections and provides real-time notification of the precise location of intrusion attempts."

Industry investment

The benefits of optical technologies are many, and organizations are working to deliver capable fiber-optic components, systems, standards, and information to the mil-aero community for myriad applications.

Calumet Electronics Corp. officials have deployed a new optical interconnect research lab at the company's production facility in Calumet, Mich. "Electronic operating systems have had a steadily increasing need for higher digital data-transfer rates within on-board components, circuit boards, and backplanes," a spokesperson says. Current state-of-the-art interconnect systems use "metal interconnects with limited data-transmission capacity. Latencies associated with the speed at which the data can be transferred impose a limit on the overall system performance."

Calumet engineers are working with specialists at Michigan Technological University of Houghton, Mich.; Dow Corning Corp. of Midland, Mich.; and Lockheed Martin of Bethesda, Md., in a joint research-and-development program funded by the Department of Defense to develop manufacturing capability to produce circuit boards with optical interconnections that provide data processing solutions.

The Boeing P-8A Poseidon's test flight incorporated an optical secure switching unit from DiCon Fiberoptics.

"The deployment of this facility will allow us to mature optical interconnect materials and manufacturing processes that will take this critical technology from our lab to our production floor," states Stephen Marshall, national sales manager at Calumet. He anticipates the company will provide a "Made in the USA solution for this quantum shift in interconnection technology."

TE Connectivity, too, specializes in connectivity, including electrical, optic, and electro-optic conversion. "These technologies are all fundamental within optical computing," mentions Powers, who is a member of the VITA 66 Working Group within the VITA Standards Organization in Fountain Hills, Ariz. The VITA 66, Fiber Optic Interconnect draft specifications are in a mature state, following more than two years of work, and are likely to be completed and ratified this year.

"VITA 66, which is the optic connectors, and Vita 67, which are RF connectors, are moving forward rapidly as draft specifications. They will round out the VPX

(VITA 46) ecosystem; you'll have high-speed digital connectors and also a choice of RF and optic modules that are compatible," Powers adds. "VITA 66 will be quite revolutionary."

"Fiber-optic interfaces today are largely through the front panel. In two-level maintenance and conduction-cooled systems, front-panel I/O is generally not desired," says Steve Edwards, chief technology officer, Curtiss-Wright Controls Embedded Computing (CWCEC) in Ashburn, Va. "VITA 66, when approved, will provide options for bringing fiber-optic I/O directly into a module through the backplane side of the card, which will help system integrators who require fiber interfaces."

CWCEC provides Ethernet switches and I/O products with fiber-optic interfaces available through the front panel. The company's VME-682 and VPX6-684 support up to four fiber gigabit Ethernet ports in 6U VME and VPX form factors. Curtiss-Wright Controls Electronics Systems, headquartered in Santa Clarita, Calif., delivers Fibre Channel and Serial Front Panel Data Port mezzanines, also with front-panel fiber interfaces. CWCEC is releasing packaged Ethernet switch products with a mix of 1 GbE and 10 GbE optical ports. Curtiss-Wright Controls Electronics Systems will support VITA 66 backplanes.

VITA is listed as a hosting organization to the new OpComp technical forum, designed to bring together academia, research and development, and application developers to discuss optical computing technologies for critical Embedded Computing systems. The inaugural OpComp is scheduled to take place September 26-27, 2011 in San Jose.

P-8A Poseidon

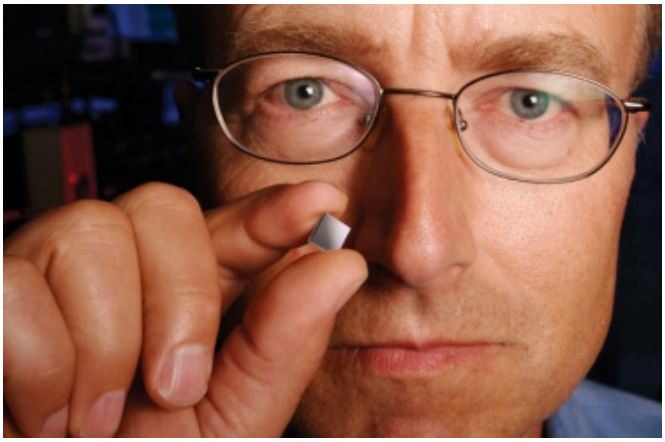
"When DiCon Fiberoptics was founded in 1986, we were making optical switches for the U.S. Navy," Lussier says, noting increased interest from defense programs as time goes on. The DiCon Fiberoptics Secure Switching Unit (SSU)-an optical switching device that enables secure fiber-optic signals to be routed by the company's MEMS (microelectromechanical systems) optical switches-was used in the first mission systems test flight of the Boeing P-8A Poseidon aircraft. U.S. Navy officials plan to replace the existing P-3C fleet with P-8A Poseidon anti-submarine, anti-surface warfare, intelligence, surveillance, and reconnaissance aircraft.

IBM's nanophotonic avalanche photodetector generates an avalanche of electrons.

"We have integrated our COTS (commercial off-the-shelf) fiber-optic switch components into the SSU to provide Boeing a reliable way to route secure fiber-optic signals in the P-8A," Schleicher says. The mil-spec, common criteria-certified, all-optical SSU delivers compact size, low weight, low power consumption, the ability to withstand harsh environments, and a frictionless design that enables operation for billions of switch cycles.

In a FOG

Fiber-optic gyros (FOGs), which span the performance range from tactical to strategic applications in mil-aero, are at the forefront of optical fiber technology, says Jay Napoli, vice president of FOG and OEM sales at KVH Industries Inc. in Middletown, R.I. "FOG technology is unchallenged in terms of performance in demanding environments, including wide operating temperature and high vibration."



Intel researcher Richard Jones holds an optical computing innovation: a Hybrid Silicon Laser chip

The KVH high-performance FOGs are employed in the Javelin Basic Skills Trainer (BST), used by the U.S. Army to train soldiers to operate the Javelin anti-tank missile system. KVH's FOGs precisely measure the shoulder-fired BST's movement, and the system's computer synchronizes that movement with the digital imagery scenario shown on the simulator's viewfinder.

"In the Javelin BST, KVH's solid-state, all-fiber FOGs measure angular rotation precisely and then deliver high-speed data to the simulator's computer, enabling the BST to provide the trainee with a very realistic and accurate user experience," Napoli describes. Precision FOGs are well suited to an expanding number of optical and image stabilization applications, including mobile mapping, dynamic surveying, gimbaled cameras, autonomous vehicles, and underwater remote-controlled vehicles.

FLIR Systems Inc. in Wilsonville, Ore., also provides FOGs, such as its TacFLIR III, for airborne, land, maritime, and unmanned applications.

UAV FOG

Israel-based Rafael Advanced Defense Systems has adopted KVH's dual-axis DSP-4000 FOGs for integration within its Remote Weapon Station (RWS), which provides critical optical and weapon stabilization capabilities to increase RWS accuracy and effectiveness. "Remote weapon stations like those produced by Rafael are playing an increasingly critical role on the battlefield, enabling soldiers to acquire and fire upon targets while remaining protected from hostile fire within the armored hull of the vehicle," Napoli says. KVH delivered to Rafael an enhanced version of its militarized, dual-axis DSP-4000 all-fiber gyro, featuring low noise, high bandwidth, high resolution, and stabilization and tracking capabilities for turret, antenna, optical, and weapon stabilization systems.

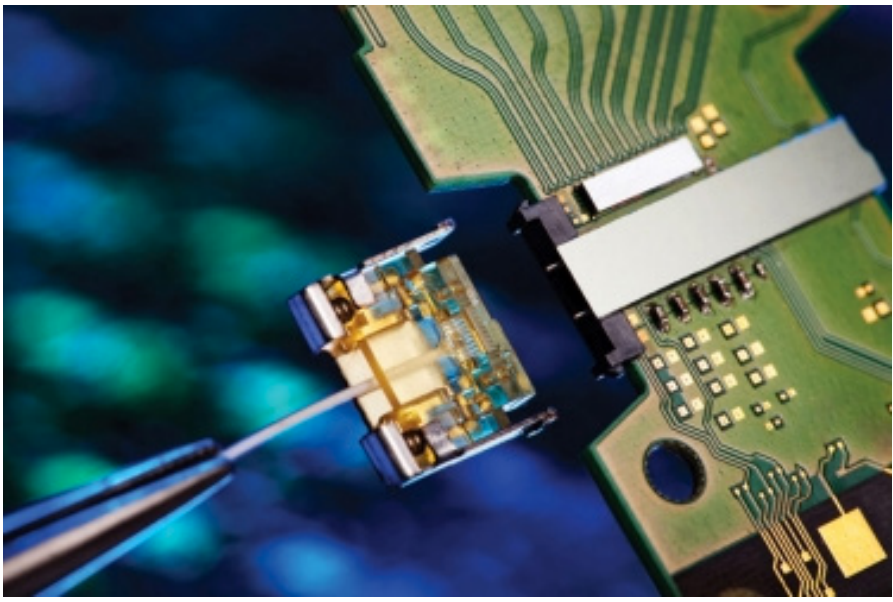
The Tamam Navigation FOG from Israel Aerospace Industries (IAI) in Arlington, Va., is an airborne navigation and attitude heading reference system for unmanned aerial vehicles, target drones, small aircraft, and helicopters, and accurate targeting applications in stabilized electro- optical/infrared systems. The system combines an FOG-based inertial measurement unit from the Tamam Division of IAI's Systems Missiles and Space Group and a GPS receiver.

Tackling testing

Testing is an all-important aspect of the use of optical components and systems in mil-aero environments. In the absence of a test system and protocol, "an operator would be disconnecting and reconnecting a fiber every time they want to test a different line," Lussier explains. "Every time you disconnect and reconnect, you put the connector at risk. You really have to be careful and

clean it. If you get a piece of dust on it and reconnect it without being aware it's there, you can introduce problems in the information flow. It won't get through correctly." DiCon Fiberoptics' test systems, used by defense contractors, automate testing processes via software.

Agilent Technologies provides a portfolio of test and measurement instruments and systems for the design and manufacturing of components for optical computing. "Through Agilent's expertise in military and aerospace electronic test, we provide customers with greater assurance in system readiness, enabling them to focus on fulfilling today's mission and managing the transition to what comes next," Gerster says.



IBM Research scientists working on optical computing developed the nanophotonic avalance photodetector.

Agilent officials helped establish a new chip-scale, micro- and nanophotonic-systems testing facility on the University of California, San Diego campus. The new facility is part of the National Science Foundation Major Research Instrumentation project, and is set up in conjunction with the multi-university Center for Integrated Access Networks, led by The University of Arizona. The facility supports testing and characterization of micro- and nano-scale, ultra high-speed optical components and subsystems.

Fiber's future

Optical technologies and components are likely to enjoy a bright future in mil-aero applications. Technology firms intend to bring rapid optical advancements to myriad applications in aerospace and defense environments.

"Over time, I expect to see more and more appearances of wavelength-division multiplexing (WDM) to get more bandwidth out of the fiber infrastructure,"

Schleicher predicts. "It has been prevalent for years in telecom, which is now migrating from fixed DWDM (dense wavelength-division multiplexing) configurations to ones that are reconfigurable in real time. In mil-aero, perhaps the next step is some form of DWDM, and then reconfigurable optical networks over time, as well." After all, tailoring an infrastructure to changing data patterns, adding and removing service installations, and reconfiguring a network on the fly certainly hold promise for mil-aero applications.

COURTNEY E. HOWARD is chief editor of *Intelligent Aerospace* and executive editor of *Military & Aerospace Electronics*. She can be reached at Courtney@pennwell.com.

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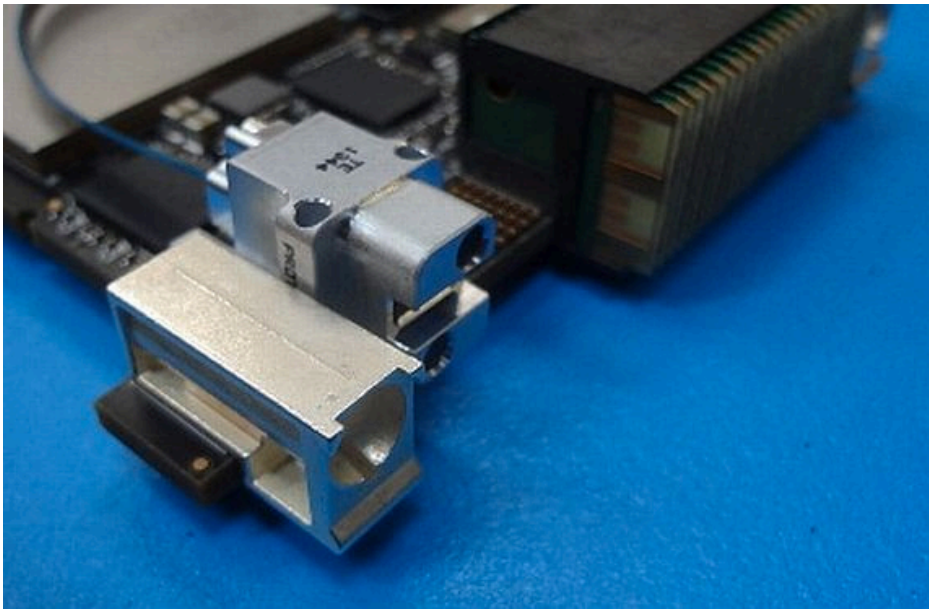
Embedded computing community seeks to push I/O speeds in exploring new frontier of optical interconnects

By **JOHN KELLER**

PHOENIX. DESIGNERS OF high-performance embedded computing (HPEC) systems are exploring the use of optical fiber-based interconnects among circuit cards in electronic enclosures, and among the enclosures themselves, in efforts speed system performance.

Not only does the use of fiber interconnects offer the potential to add speed to system I/O, but it also can help optical embedded computing systems designers increase the distance between computing nodes and reduce size and weight, says Matthew McAlonis, product development engineering manager at interconnect expert TE Connectivity in Middletown, Pa.



A fiber optical backplane even can be layed out on sheets of lightweight Mylar sheets to help save space and reduce weight in HPEC systems with optical interconnects, McAlonis says.

Some of the most promising applications of optical computing include remote radio receivers, which could couple digital signal-processing subsystems near the antenna mast on a ship, and move signals over optical fiber to radio control rooms deep inside the vessel, says Rodger Hosking, vice president at embedded computing specialist Pentek Inc. in Upper Saddle River N.J.

Pentek is one of the first mainstream embedded computing companies to make use of optical interconnects in off-the-shelf products. McAlonis and Hosking made their comments in presentations this week at the Embedded Tech Trends conference in Phoenix.

Optical interconnects have several advantages compared to the copper interconnects they are being designed to replace: they are faster, more lightweight, and are impervious to electronic interference. Still, there are tradeoffs. Copper arguably is more reliable than fiber, is well known, and has a large installed base.

“Fiber optic technology still has its challenges, but steady progress has led to rapidly expanding deployment,” says Greg Powers, market development manager at TE Connectivity.

Another potential problem with optical fiber is it tends to break if pulled too hard or curved too tightly inside systems. Higher costs, reliability concerns, and higher complexity when compared to copper will give systems designers pause.

TE Connectivity engineers are working on an optical interconnect approach for embedded computing that involves magnifying lenses where lengths of optical fiber join. The lens physically separates the fiber ends to help resist the effects of shock and vibration, as well as mitigate the effects of contamination.

Despite fiber’s drawbacks, its potential benefits are great, and the VITA Open Standards and Open Markets embedded systems industry trade group in Fountain Hills, Ariz., is pushing forward with optical interconnect standards. The group’s VITA 66.4 standard defines optical backplane interfaces for VPX cards, and companies like Pentek have implemented optical interconnects in HPEC systems.

While optical connects offer tremendous increases in data throughput speeds, this technology is not for everyone, experts acknowledge. Large, demanding new HPEC systems are the most likely candidates for optical interconnects, while small, inexpensive, and routine applications most likely will stay with copper, experts say.

For more information contact TE Connectivity online at www.te.com, Pentek at www.pentek.com, the Embedded Tech Trends conference at www.embeddedtechtrends.com, or the VITA trade organization at www.vita.com.

JOHN KELLER is Editor-in-Chief of Military & Aerospace Electronics.

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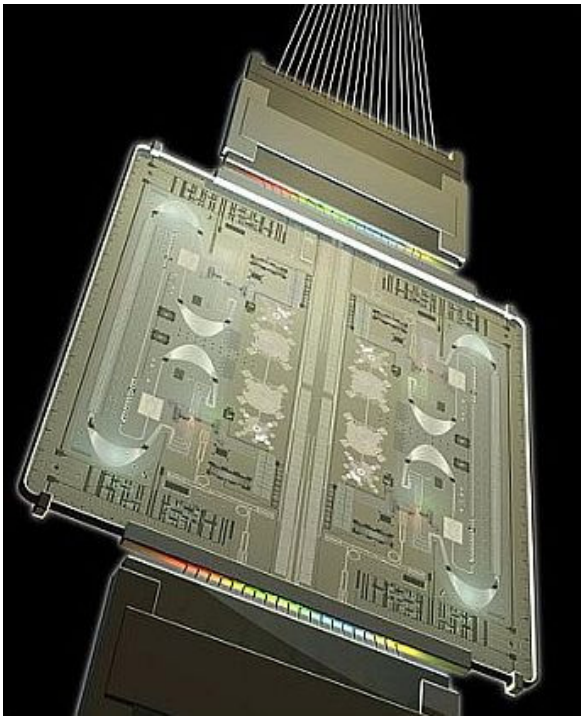
Navy looks to Enablence Technologies to fabricate photonic integrated circuits for high-speed optical communications

By **JOHN KELLER**



SAN DIEGO. OPTICAL communications experts at the U.S. Space and Naval Warfare Systems Command (SPAWAR) Systems Center Pacific in San Diego are looking to optical network specialists at Enablence USA Components in Fremont, Calif., to fabricate photonic integrated circuits for advanced high-speed naval optical communications. Enablence USA Components is part of Enablence Technologies Inc. (TSX VENTURE:ENA) headquartered in Toronto.

SPAWAR officials on Thursday announced a plan to award a sole-source contract to Enablence to fabricate photonic integrated circuits for optical-to-electrical-to-optical conversion in optical networks. The amount of the contract has yet to be negotiated.

Enablence is a specialized developer for access network solutions, such as high-capacity FTTx and multiservice access systems for high-bandwidth networks. The company fabricates optical chip technologies for carrier-grade architectures and vertically integrated subsystems. The company operates foundries dedicated to polymer, silica-on-silicon, and III-V materials (InP/GaAs platforms) for photonic wafer processing.

Enablence specializes in active component design, manufacturing, and fabrication, of products ranging from miniature transceivers to large-scale optical circuits. The waveguide process at Enablence can be customized for performance and yield, from the wafer level to individual bare die handling and testing.

The Enablence integrated Planar Lightwave Circuit (PLC) optical chips, components, and subsystems are for next-generation high-capacity communications systems for access, metro, and long haul networks. The company's custom and off-the-shelf integrated modules and subsystems help provide communications functionality in small sizes at speeds as fast as 100 gigabits per second.

The company provides technologies that can add as many as 88 high-speed communications channels to one optical fiber and manage speeds to 100 gigabits per second on each channel.

SPAWAR delivers high-end Navy information technologies to the fleet and other U.S. Department of Defense warfighters. As the Navy's Information Dominance Systems Command, SPAWAR develops and deploys advanced communications and information capabilities. SPAWAR-developed products and services transform ships, aircraft, and vehicles from individual platforms into integrated battle forces, with advanced information and communications capabilities among naval forces, Marines, joint forces, federal agencies, and international allies.

SPAWAR is the Navy's technical lead for C4ISR, and provides the hardware and software to connect warfighters at sea, on land, and in the air — from the initial research and development, to acquisition and deployment, to operations and logistics support.

For more information contact Enablence Technologies online at www.enablence.com, or SPAWAR at www.spawar.navy.mil.

JOHN KELLER is Editor-in-Chief of Military & Aerospace Electronics

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