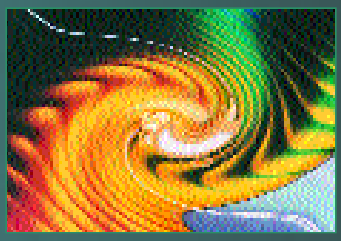
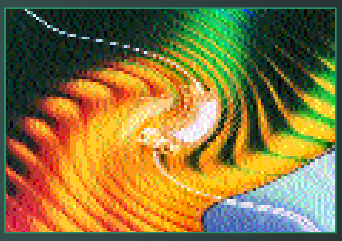
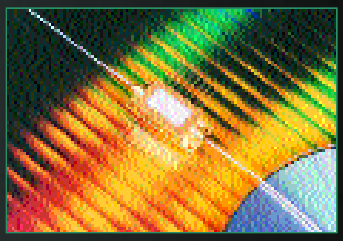
COMMUNICATIONS AND DISPLAYS

With the rapid growth of fiber optics and the introduction of smaller displays, people are communicating faster and more efficiently. Fiber-optic cables and networks are rapidly encircling our Nation, increasing the bandwidth to handle a dizzying array of new interactive communications services. Miniature displays are enabling smaller personal communications devices—such as beepers, cellular phones, and personal digital assistants—allowing Americans to stay in touch while on the move.

Advanced technology offers much in these areas, allowing, for example, the elimination of unwanted light reflections in fiber-optic cables to improve signal quality. It can also enable displays that are lighter, smaller, more colorful, and more energy-efficient than previously available. These displays will find homes in such diverse markets as advertising, laptop computers, medical devices, video games, and even sport fishing.

Today's Market

The United States is the world leader in fiber-optic cable installations, accounting for one-third of the total worldwide market. As the number of fiber-optic cable installations rises, so does the demand for fiber-optic interconnect products. The North American market for these products was about $200 million in 1994 and could climb to $440 million by 2001.[1] The United States is a major player in the worldwide flat-panel display market, which is expected to climb from $8.6 billion in 1995 to about $15.8 billion by the year 2000.[2]

Tomorrow's Opportunity

BMDO has funded numerous photonics, electronics, computer-related, and even power technologies for tracking and destroying ballistic missiles that lend themselves to the communications and display industries. The following section highlights six of these technologies and the companies that are commercializing them.

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[1]Kotelly, George. 1996. The communications future is fiber. Lightwave, December, 4.

[2]Electronic Trend Publications. 1996. Worldwide flat panel display markets and trends. March. World Wide Web at http://www.electronictrendpubs.com/fpd.htm.

Can You Imagine . . .

. . . a user-configurable transceiver that brings gigabit-per-second data transmission to computing applications.

VIXEL MEETS DEMAND FOR HIGH-CAPACITY INTERCONNECT DEVICES

As the global network grows in size and complexity, user-friendliness and flexibility will become the key criteria. Data transmission between older copper wire and new optical networks can link communication nodes without retooling the entire information infrastructure. This capability is crucial when extending new communication methods to traditionally underserved areas, such as developing countries and the rural United States.

To help interweave the various threads of the communications network, Vixel Corporation (Broomfield, CO) acquired a leading information management company, Western Digital (Lynwood, WA). The move cements an alliance that brings gigabit-per-second data transmission to computing applications. Through this alliance, Vixel introduced a new product, the IntraLink 1000™ Fibre Channel hub.

USING BMDO-FUNDED LASER TECHNOLOGY, VIXEL HAS MOVED AGGRESSIVELY INTO THE HIGH-SPEED COMMUNICATIONS MARKET.

The device, a user-configurable transceiver that allows communication between optical and copper wire topologies, offers gigabit-per-second data rate performance and can be reconfigured for different media, including fiber optics and copper. Server and storage array manufacturers intend to deploy this product for distributed database applications. EMF Associates, a technology and marketing group, estimates that Fibre Channel Arbitrary Loop hub sales will top $500 million by the year 2000.

The agencies that funded Vixel's research in optical data transmission and storage included BMDO; the U.S. Army, Air Force, and Navy; NASA; the National Institutes of Health; and the National Science Foundation. This research led to the development of vertical cavity surface-emitting lasers (VCSELs). VCSELs are small, high-powered lasers that operate at high efficiency and are the foundation of Vixel's LASE-ARRAY™ products. LASE-ARRAYs are responsible for the fast optical switching and high-bandwidth characteristics of its new Intralink product.

■ Vixel has supplied samples of its IntraLink 1000™ Fibre Channel hub to Sun MicroSystems and Compaq Systems Division.

To expand LASE-ARRAY manufacturing, Vixel acquired the assets and technology of Bandgap Technology Corporation. This acquisition includes a 5,000-square-foot cleanroom, with machines tailored for producing the semiconductor material for VCSELs. This move allows Vixel to consider new application areas, such as optical interconnects for computers and workstations, detector arrays, multifiber optical ribbon, and machine vision components. Other possibilities include optical data storage and medical instrumentation.

ABOUT THE TECHNOLOGY

VCSELs facilitate optical data transmission. Unlike other diode lasers, which emit light from their edges, VCSELs emit laser beams perpendicular to their surface. This design creates the ideal geometry for stacking VCSELs side-by-side in 1- and 2-D arrays. It also allows VCSELs to be 20 to 50 times smaller than edge-emitting diode lasers. Edge-emitting lasers produce elliptical beams whose high divergence makes focusing difficult; VCSELs produce nearly circular beams that diverge considerably less than the elliptical beams and thus require less sophisticated optics to focus the beam.

Compared with traditional lasers, VCSELs have been relatively inefficient. However, Vixel modified the VCSEL design to approach the efficiency of edge-emitting lasers. Wall-plug efficiencies of its VCSELs are now measured at about 10 percent, resulting in smaller, higher power lasers with extremely fast switching speeds. Also, Vixel's LASE-ARRAYs can operate in wavelengths ranging from 750 to 1,050 nanometers.

OPTICAL ISOLATOR REDUCES NOISE IN FIBER OPTICS

Can You Imagine . . .

. . . an isolator that improves the way optical amplifiers manipulate light to enhance signal quality in fiber optics.

The booming telecommunications market heavily supports fiber-optic technologies, leading to increased development of optical switching, multiplexing, and long-line transmission of the optical signals. Contributing to this technological advancement, E-TEK Dynamics, Inc. (San Jose, CA), developed a new fiber-optic device that reduces the electronic-to-optics transitions in the network.

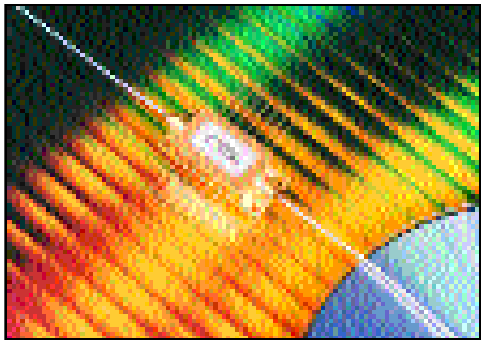
E-TEK's device, called the polarization insensitive fiber isolator (PIFI), eliminates unwanted light reflections in fiber-optic cables. These reflections cause noise, which greatly reduces signal quality. The BMDO SBIR program funded the development of the PIFI for a fiber-optic sensor system to track ballistic missiles. The technology is now finding a role in new fiber-optic systems.

For example, the PIFI is an essential component in advanced fiber-optic communications components, such as the erbium-doped fiber amplifier (EDFA). EDFAs are increasingly replacing repeaters to amplify lightwave signals in long-distance fiber-optic telecommunications (including transoceanic), cable television distribution, and long-distance soliton (isolated wave) transmission. Unlike repeaters, EDFAs do not convert an optical signal into an electric signal to boost it, resulting in lower operating costs, better transmission quality, and more compact systems.

E-TEK'S FIBER-OPTIC TECHNOLOGY IS BEING USED BY SUCH TELECOMMUNICATIONS GIANTS AS AT&T, SPRINT, AND MCI.

E-TEK supplies PIFIs to all of the major EDFA manufacturers that provide optical amplifiers to such telecommunications giants as AT&T, Sprint, MCI, and British Telecommunications. One of E-TEK's main product lines, the PIFI accounts for nearly 50 percent of the company's revenue. According to J.J. Pan, E-TEK's chairman and chief scientist, the company employed about 40 people and had an annual revenue of $1 million when it began the transition to volume production of the isolators in 1990. Today, the company employs 250 people and has annual sales of over $40 million.

The hermetically sealed semiconductor optical amplifier, another E-TEK product, also stems from BMDO-funded research. This device uses a diode laser and a temperature stabilizer to provide low-power optical amplification. Sold primarily for laboratory research, it may also be useful for small fiber-optic networks because of its compact packaging and lower cost than EDFAs.



■ E-TEK's optical amplifier, pictured above, may be ideal for small fiber-optic networks because of its compact packaging and low cost.

ABOUT THE TECHNOLOGY

Fiber isolators prevent one system from disturbing another while transmitting signals between them. E-TEK's PIFI minimizes back-scattering and back-reflection of optical signals, thus maintaining a high signal-to-noise ratio. Mismatching polarization in fiber-optic components causes high insertion loss, so polarization-insensitive fiber isolators are key to amplifier performance. The highly reliable PIFI Classic features 40 decibel (dB) of isolation, with a 0.3 dB insertion loss and 0.2 picosecond polarization mode dispersion. The multistage PIFI Ultimate has 70 dB of isolation, with 0.7 dB insertion loss and 0.5 picosecond polarization mode dispersion.

Can You Imagine . . .

. . . a drive mechanism that precisely aims and holds in position antennas used for satellite transmissions.

ROTARY DRIVE POSITIONS ANTENNAS FOR SATELLITE NEWS GATHERING

SAGEBRUSH'S COMMERCIALIZATION OF ROTO-LOK® DRIVES HAS SPREAD INTO SATELLITE NEWS GATHERING, VIDEO CONFERENCING, AND MEDICAL MARKETS.

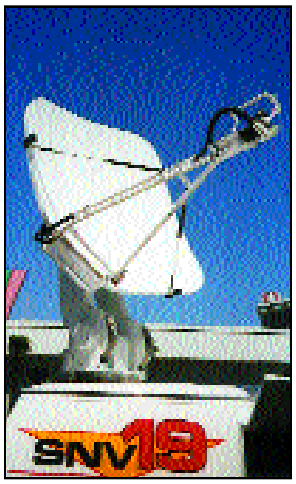
The booming business of satellite news gathering (SNG) uses mobile trucks equipped with portable satellite antennas. Many antenna systems, however, use a linear actuator (motorized rod-and-screw design) that makes it harder to point antennas in the right direction. This design also makes it difficult for the antenna to hold its position in windy conditions and to accommodate truck and satellite movements. Such problems interfere with transmission of sound and image data to television stations or other reception sites.

Responding to this problem, Sagebrush Technology, Inc. (Albuquerque, NM), now sells its Roto-Lok® rotary drive to designers of SNG antenna systems. Using an innovative motorized cable-drive system, Roto-Lok precisely positions and holds these antennas, even in windy conditions. The drive's zero-backlash, virtually perfect smoothness, and high torsional stiffness make it possible to position satellite antennas with greater reliability and accuracy than previous technology provided.

One of Sagebrush's newest customers—Andrew Corporation, a global supplier of communications systems equipment and services—recently introduced a compact, lightweight antenna for SNG trucks. Instead of the typical rod-and-screw design, a Roto-Lok drive precisely points the antenna. "Andrew selected the Roto-Lok drive because it is a very precise pointing system and is virtually maintenance free," says Bob Fitzgerald, Andrew's manager of earth-station antennas.

Electrospace Systems, Inc., also a supplier of communications systems and a Sagebrush customer, recently purchased many Roto-Lok drives to install on mobile satellite antenna systems for military vehicles. Roto-Lok's ruggedness and reliability allow operation in harsh environments, impressing the military. U.S. troops on a peacekeeping mission in Bosnia-Herzegovina used eight drives connected to satellite antennas. According to Don Carson, Sagebrush's vice president of marketing and sales, "These drives survived the coldest winter in European history and didn't lose a minute in downtime."

Sagebrush is supplying 250 Roto-Lok drives to a company that sells videoconferencing equipment to schools and colleges. In addition, the company is using Roto-Lok drives for precision positioning in medical and military equipment. The BMDO Laser Communications program provided key support to develop the Roto-Lok drive into a high-visibility product. In this program, the drive controlled the precision angular alignment of laser beam transmitters and receivers in a communications network.



■ This antenna system uses a Sagebrush Roto-Lok® rotary drive for precise positioning in satellite news gathering.

ABOUT THE TECHNOLOGY

In the Roto-Lok drive, tensioned cables wrap a figure-eight pattern around two closely spaced wheels. Friction carries torque from a powered wheel (capstan) to a driven wheel (drum). The drive maintains precision by employing many cables working in parallel. Sharing the load, the cables average the rotation rate so that any imperfections, dirt, or other slight irregularities on the drum or cables do not affect the drive rate. Because the cables do not slide on the drum or capstan, there is virtually no wear.

The Roto-Lok drive also maintains much higher stiffness than drives that use chains and drive belts because it has springs at the end of each cable, which provide tension throughout the cable. Spring-loaded cables also reduce backlash, a design problem that affects pointing accuracy and transmission efficiency. Roto-Lok positions the drum and the cylinder connected to the drum to within 50 millionths of one degree. It also transmits rotation at efficiency rates greater than 98 percent and runs quietly.

SOLID-STATE AMPLIFIER MAY COMPETE WITH MICROWAVE VACUUM TUBES

Can You Imagine . . .

. . . a solid-state alternative to vacuum tubes for generating and amplifying radio frequency and microwave power.

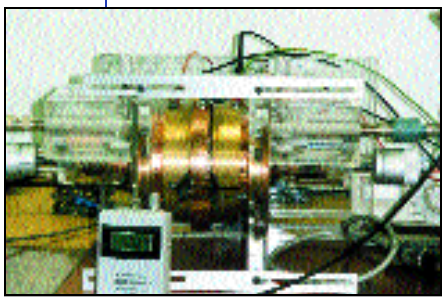
Solid-state devices, such as transistors and integrated circuits, have replaced most vacuum tubes. However, microwave vacuum tubes are an important exception and are still used in such diverse applications as radar, space communications, and television broadcasting equipment. Because solid-state devices cannot handle high-power loads at microwave radio frequencies, microwave vacuum tubes remain the chosen technology to amplify high power.

Aria Microwave Systems, Inc. (AMS; Englewood, NJ), developed a new active radio frequency (RF) cavity concept and prototype that can replace vacuum tubes with solid-state technology. This concept integrates low-power solid-state transmitters into the walls of a resonant cavity, forming a single, high-power structure called the active RF cavity amplifier (ARFCA). With this design, the amplifier handles high-power loads at radio and microwave frequencies with efficiencies approaching those of intrinsic solid-state devices.

With this unique capability, the ARFCA provides an alternative to vacuum tubes for generating and amplifying RF and microwave power. With voltage requirements 1,000 times less than conventional vacuum electron tubes and a cheaper power supply, the amplifier will use smaller, less expensive power conditioning equipment. This rugged and repairable device requires no vacuum, magnets, or complex electrodes, and it can be easily fabricated.

ARIA MICROWAVE IS NOW BUILDING PROTOTYPES FOR EXISTING AND EMERGING COMMERCIAL APPLICATIONS.

Under BMDO SBIR funding, AMS has proved the concept with a device that combines the output of six RF transistors at 1.8 gigahertz. The company is currently building two more prototypes for existing and emerging commercial applications. One will use 60 transistors to achieve an output of 1.8 kilowatts (kW) of ultrahigh frequency (UHF) power at 915 megahertz (mHz). This technology could eventually be used in commercial transmitters such as television, radar, satellite, and cellular communications, all of which are currently dominated by vacuum tubes.



■ Pictured above is Aria Microwave's active radio frequency cavity prototype. It requires no vacuum, magnets, or complex electrodes, and can be easily fabricated.

The second prototype, designed to serve the industrial heating market, contains 20 transistors to produce 1 kW of UHF power at 915 mHz. This ARFCA could replace magnetrons, which produce heat via microwaves for pharmaceutical and petroleum processing. Its reduced power consumption, longer lifetime, and gradual failure rate would make the amplifier cost-competitive with magnetrons. Furthermore, the amplifier would be safer than its high-voltage competitor; for example, magnetrons usually fail catastrophically, which could spark an explosion in chemical plants. The ARFCA's gradual failure mechanism would protect such volatile environments.

ABOUT THE TECHNOLOGY

The ARFCA combines the output from many low-power, solid-state devices into a single high-power device or structure. In the ARFCA, the cavity simultaneously acts as the power combiner, matching transformer, and heat sink. A waveguide or coaxial cable guides the RF and microwave power out of the ARFCA. Dr. Bernard Cheo, inventor of the ARFCA, states that only the number of transistors that can physically fit around the cavity limits the maximum output power. The first prototype produced a combining efficiency exceeding 90 percent.

Can You Imagine . . .

. . . a miniature display, the size of a quarter, that matches the viewing performance of a 21-inch color computer monitor.

BMDO-FUNDED R&D ENABLES SMALLER DISPLAYS, BIGGER IMAGES

From switchable color filters to miniature displays, devices developed by Displaytech, Inc. (Boulder, CO), use ferroelectric liquid crystal (FLC) technology funded through the BMDO SBIR program. Displaytech's innovative research and promising display products led to the company's successful initial public offering in 1996, which raised $2.2 million. Today, Displaytech is commercializing BMDO-funded technology in two areas.

IN 1996, DISPLAYTECH'S INITIAL PUBLIC OFFERING RAISED $2.2 MILLION.

First, Displaytech found a way to shrink color displays based on cathode ray tube (CRT) technology. Applying its patented FLC technology, the company used BMDO funding to develop an electrically switchable red-green-blue (RGB) color filter. The company's FLC-based RGB FASTFilter™, which won *Photonics Spectra*'s Circle of Excellence award in 1995, turns the black-and-white images on a miniature television tube into full-color pictures. Current technology cannot manufacture miniature color television tubes.

Used with a CRT or a charge-coupled device display, the RGB FASTFilter could help produce new head-mounted color displays. In addition, the same filter may help develop color, palm-held computers and 3-D displays for flight simulation and entertainment.

■ Displaytech's ChronoColor™ Miniature Display, pictured above, measures less than one inch diagonally.

In the second area, Displaytech applied BMDO-funded FLC technology to produce a color, high-resolution, video-capable electronic miniature display. The FLC-based ChronoColor™ Miniature Display demonstrates an image that, when magnified, compares favorably with the highest resolution 21-inch color monitors. The miniature display quality is also comparable to that of active-matrix liquid crystal displays used in laptops, but the smaller product features lower production costs and greater compatibility with standard integrated circuit components.

Measuring less than one inch diagonally, the miniature display can be used in a wide range of products, including laptop and notebook computers, wireless communications devices, medical devices, and video games. Displaytech has already built a 1,280 x 1,024 pixel miniature display for demonstration purposes and expects to offer a display with 256 x 256 pixel resolution to selected end-product manufacturers in early 1997.

ABOUT THE TECHNOLOGY

Developed for BMDO optical computing and space-based applications, Displaytech's FLCs switch 100 times faster than conventional liquid crystal displays. Thinly layered on a silicon chip, they construct dense arrays of very small pixels. Standard fabrication technology for complimentary metal oxide semiconductor memory allows cost-effective production of FLCs. The Department of Commerce awarded Displaytech a $1.7 million Advanced Technology Program contract in 1994 to develop low-cost volume manufacturing technology.

NEW DIFFUSERS HOOK DISPLAY MARKETS

Can You Imagine . . .

. . . a light-shaping diffuser that brightens the display of a depth finder used in sport fishing.

Marketing its novel Light Shaping Diffusers™ (LSDs), Physical Optics Corporation (POC; Torrance, CA) hooked several new display markets. Based on holographic technology, POC's LSDs offer unusually efficient light-shaping and transmission capabilities that make displays brighter and easier to see. These devices homogenize the light, smoothing out such irregularities as glare and hot spots.

POC's LSDs are used in many unusual display applications, such as the Humminbird® Jimmy Houston Pro Flasher™ depth finder. Techsonic Industries manufactures the depth finder that helps anglers "see" underwater to find fish, grass, brush, and drop-offs in a stream or lake. An LSD provides uniform illumination on the device's display, which uses a spinning disk to present a visual representation of the water depth. Adding the LSD to the depth finder results in a brighter and easier-to-read high-resolution display than previous light-emitting diode (LED) designs.

Originally developed for BMDO space-based sensor applications, the LSD allows designers to shape light, putting it precisely where they need it most. This capability opens up new commercial applications for the optical elements, for example, brightening and giving high contrast to movie screens, flat-panel displays, and high-definition television screens. In addition, the LSDs allow the reading of documents and can improve the illumination capability of spectroscopy, robotic vision, endoscopy, and LED displays. For beam-enhancing applications related to displays, LSDs come as metal-back reflectors, molded lenses, or thin sheets.

AMONG OTHER APPLICATIONS, POC'S TECHNOLOGY HAS FOUND USES IN MACHINE VISION SYSTEMS AND AIRCRAFT INSPECTION TOOLS.

Manufactured as a display screen, a POC LSD widens the angle of overhead slides. This ability allows nearly everyone, no matter where they sit, to see the information projected on the screen. POC developed two LSD products for this area: the front-projection Lights-On Reflection Screen™ and the rear-projection Light Shaper Viewing Screen™.

■ Pictured above is the Humminbird® Jimmy Houston Pro Flasher™ depth finder. POC's technology provides uniform illumination in the finder's display, making it brighter and easier to read.

In addition to display applications, POC's LSDs have appeared in machine vision and aircraft inspection. Kulicke & Soffa Industries, a producer of semiconductor manufacturing equipment, incorporated an LSD assembly in the machine vision system of a wire bonder. Improving brightness and light uniformity, the LSD helps the bonder locate reference points on the die pad during semiconductor manufacture. In aircraft inspection, POC's LSDs offer a simple, low-cost improvement adaptable to most commercial flashlights. Providing even illumination with more than 90 percent of the light transmitted to the subject, this technology improves inspection efficiency and accuracy.

ABOUT THE TECHNOLOGY

LSDs are surface-relief holograms that can be mass-produced inexpensively. An LSD is like a refractive negative lens in that it bends light, but its surface acts as various-sized, randomly distributed microlenses to produce the desired refraction angle.

LSDs shape light in two ways. First, they homogenize the light beam, eliminating variations in brightness caused by the structure of the light source. Second, they control light energy distribution along both the horizontal and vertical axes to match the light source with the area requiring illumination. An LSD produces a diffusion effect based on refraction rather than scattering, allowing more than 90 percent of the light striking the LSD to be transmitted to the target. The inherently antireflective nature of the holographic microstructure results in the high transmission efficiency.