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C4ISR Technical briefing

Inside the black box

For intelligence to be relevant, it must be shared quickly with a complex network of users. Engineer **Kelvin Chau** explains how the latest switching devices use mirrors, lenses and light to direct video, imagery and data where it needs to go.

Traditional optical communications equipment is widely deployed by the world's most elite intelligence agencies, but the critical need for rapid and flexible data dissemination is creating a more central role for purely optical "photonic" switching systems.

To better understand the breakthroughs driving this trend, it is important to put them in context with the industry's evolution and challenges. The great majority of voice, video and data traffic flows over fiber-optic networks. Undersea communications fibers are used to connect continents; signals at satellite terminals are converted into optical streams for ground transmission; sensor signals are carried over optical paths; and fiber-optic cables carry critical information for telecommunications service providers and intelligence agencies.

The systemic deployment of fiber infrastructure has delivered profound benefits, but also major challenges.

Before photonic switches, the main method for directing optical traffic at the intelligence community's communications hubs was to convert it to electrical signals inside optical-electrical-optical (O-E-O) switches. The electrical signals would be redirected, or switched, in a new direction, and converted back to optical signals for transmission through fiber-optic cables.

Managing these optical links is an increasing problem as network operators expand capacity and migrate to Internet Protocol/Ethernet. With an ever-increasing number of fibers, multiple wavelengths per fiber, and ever-increasing data rates, the process of optical-electrical conversion required hundreds of electronic chips, and these chips required a commensurate amount of space, cooling and power. Given these increasing burdens, the idea of sidestepping the conversion process where possible sparked the development of photonic switching technology.

A Three-Dimensional Micro-Electro-Mechanical Systems (3D-MEMS) architecture for putting mirrors on silicon has emerged as the most economically viable approach for building reconfigurable, transparent and scalable photonic switches. 3D-MEMS components are used today in car navigation systems and inkjet heads and many other applications. My company, Glimmerglass, has pioneered their use for photonic switching.

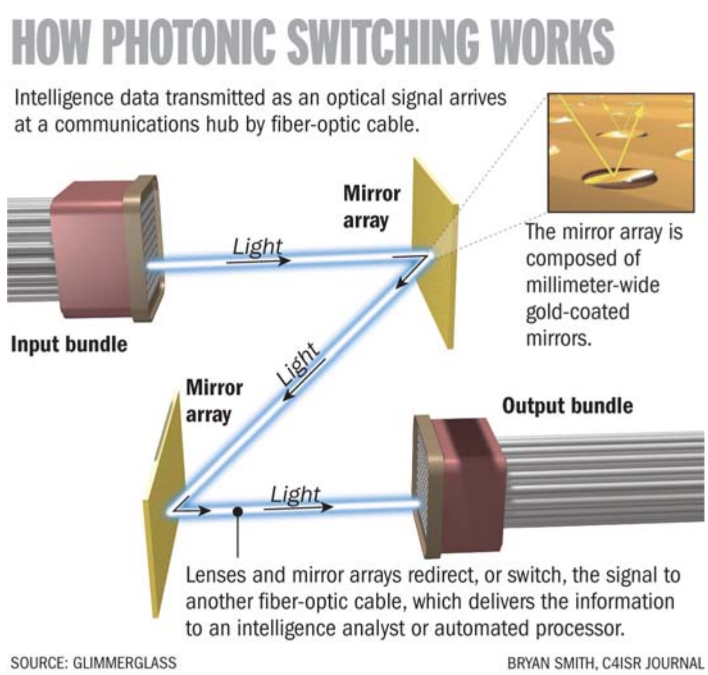
The 3D-MEMS afford a scale needed to support a global communications network node with multiple fibers, each carrying hundreds of wavelengths. Similar tools and techniques to those used to manufacture integrated circuits also enable 3D-MEMS fabrication. This technology has quickly found its way into a variety of commercial, defense and medical applications.

The real power of 3D-MEMS technology is enabling many small but complex elements to be precisely built on a wafer through lithography, etching and masking processes. Through batch fabrication and minimization of materials, 3D-MEMS -based products are now manufacturable and cost-effective across many industries. They are lightweight and require very low power while providing high performance.

After years of testing and design, five major challenges facing the intelligence community have been addressed by advances in photonic optical signal management.

1. FAST SWITCHING, LESS OPTICAL LOSS

Glimmerglass harnessed 3D-MEMS technology to create and control beam steering mirrors, enabling millisecond reconfiguration of optical signal paths for the dissemination of intelligence. The company's 3D-MEMS switch uses control mechanisms to tilt mirrors, allowing many optical channels to be switched



in a very small space. A proprietary algorithm facilitates precision optical, closed-loop beam control to establish low-loss, input-to-output connections and maintain connections under changing environmental conditions.

At the heart of the Glimmerglass photonic switch, is a proprietary 3D-MEMS mirror array. A doublegimbal actuator structure allows a wide range of tilt in all directions. The array, composed of 14 x 15 gold-coated mirrors, is etched out of single-crystal silicon. The individual mirrors are one millimeter in diameter, and manufactured to a uniform and exact degree of flatness and reflectivity to achieve the best optical performance.

Hinges provide the mirrors a full range of movement with no friction and virtually no material stress. With this design, a mirror can be adjusted to a new, stable position within 25 milliseconds. Furthermore, stress testing of this design ran the mirror through 1 billion adjustment cycles and found no hinge fatigue or degradation in switching response. This 3D-MEMS photonic switching architecture offers enormous flexibility and efficiency relative to cost and size. With many systems in the field serving mission critical intelligence applications and many years of reliable data, the products have built a reputation for their dependability.

3D-MEMS have the best performance in terms of optical loss among the purely optical switch technologies. Excessive loss in an optical network could lead to the need for higher-power lasers, increasing the cost of surrounding equipment. Minimizing such loss improves the overall network economics.

Glimmerglass has developed a proprietary process to actively align and attach microlens arrays to a precision-aligned fiber array, creating collimator arrays, providing excellent beam positioning and pointing accuracy. Each collimated beam is parallel to all other beams within the array, and all emanate from the microlens array at a perpendicular angle to MEMS array. These fiber-lens arrays have outstanding alignment and low lens aberrations resulting in optical insertion loss of less than 2 decibels when configured in a 3D-MEMS beam steering mirror engine.

2. MORE CAPACITY

There is a significant increase in port capacity, which equates to increases in the amount of information that can be disseminated and the number of users who can receive actionable intelligence. The modular architecture of Glimmerglass design allows a basic configuration to be extended into a larger port count switch. Instead of a fold mirror, the system can be "unfolded" into two optical subsystems, each comprising a fiber, lens and mirror array. When the two mirror arrays' optical axes are aligned, light can be relayed from one optical subsystem's fiber to the other optical subsystem's fiber. This unfolded configuration can support up to an unprecedented 192 x192 ports.

The photonic switching approach provides great flexibility in intelligence monitoring and resources sharing, reduces network churn and lowers costs. These attributes become more important when data rates and volume climb.

3. FEWER UPGRADES NEEDED

Photonic switching produces bit rate and protocol transparent platforms with minimal system optical loss by redirecting the actual photons instead of processing the information into an electrical signal. Photonic switching devices can accept and manage evolving formats and data rates and manage higher capacity signals without the need for upgrades, thus "future proofing" the network and protecting investments.

4. SMALLER IS BETTER

The switches provide a dramatic reduction in power, size and heat. The 3D-MEMS architecture requires only the micro movement of mirrors to direct optical signal paths, which is highly compact and energy-efficient. Prior to this innovative architecture, the option was huge, expensive and power hungry O-E-O switches typically requiring well over 1,000 watts.

The 192x192 photonic optical switch from Glimmerglass in a compact four rack unit chassis requires less than 85 watts (that of a light bulb), producing minimal heat. This translates into a reduced footprint and cost savings by eliminating power-generating, air-conditioning and distribution equipment such as batteries, rectifiers, diesel generators and monthly maintenance.

5. HANDS-FREE DISTRIBUTION

Photonic optical solutions are transforming intelligence collection and dissemination by enabling the flexibility of nonintrusive, remote monitoring and rapid reconfiguration of optical signal paths through software control, eliminating the need for costly manual equipment adjustments and precluding human errors. Leaps forward in software and hardware integration make it possible for network operators at remote locations, particularly headquarter control sites, to use Web-based graphical interfaces or command language to control photonic switches. Operators are able to form large networks of multiple switches capable of being monitored and controlled from a single remote server.

In addition to adding major flexibility in the management of optical signal paths, remote capabilities provide significant reductions in operating expenses and capital expenditures. Because network operations can make changes through graphical interfaces, there is no need to send a technician in a truck to manually adjust fiber or reconfigure the network when there are problems. Glimmerglass systems enable agencies to flexibly split, amplify and distribute optical signals directly to a large number of recipients, and simultaneously provide protection and restoration functions for any fiber path. If the system detects a loss of light, it automatically switches to the protection port. When the system detects light restoration, it automatically switches back. Since network reconfiguration can be managed from any workstation connected to the network, remote nodes can be reconfigured without the need for expensive and error-prone onsite intervention.

Consider a military operations center, which requires constant feeds of critical data and where automatic switching from a failed fiber could preclude loss of actionable intelligence. One such example is a knowledge wall displaying high-definition information feeds from many sources requiring complex management.

Many intelligence community applications require remote sensor management. Manning these sensor sites is challenging due to both geographic location and staffing requirements. Several intelligence programs have already realized the flexibility of the remotely managed photonic optical systems. Sensing locations have been set up and, because of the remote management capability, network managers and intelligence analysts can make fiber switching decisions from headquarters. Much has been debated about the ability of various intelligence parties to collaborate. Significant work has been done to improve intelligence sharing, such as across the Department of Defense's Distributed Common Ground/Surface System, the National Geospatial-Intelligence Agency's e-GEOINT Web services and the National Security Agency's Real Time Regional Gateway.

Thanks to major technology advances, photonic switching solutions today offer significant potential for enhancing real-time information exchange among all the relevant intelligence community partners. ■

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