MARINE TECHNOLOGY REPORTER

September 2014 www.marinetechnologynews.com

Ocean Observation

Keeping Watch Below the Waves

Fiber Optics
Going Big in Small Packages

ROV Tech
Deepsea Pipeline Repair

Clear to Hear
Advancing Digital Hydrophones

Multi-channel Fiber Optic System Design:

Going Big in Small Packages

By Steve Bell, Optical/Photonics Engineer at BIRNS, Inc.

Abstract

Data channels can be added to fiber optic systems by adding fibers, adding wavelengths, or adding both. Dense wavelength divisional multiplexing (DWDM) allows a single fiber to carry multiple data channels. Passive components, such as optical circulators, double a fiber's capacity by allowing information to flow in both directions. While these technologies are well known in the terrestrial communications industry, subsea designers may be less aware of what tools are available to them. These technologies allow the subsea designer to pass many data channels through small, single or limited fiber count connections.

Designers of terrestrial fiber optic systems have paved the way for today's subsea system designers in that their designs have already improved over the years as new technologies emerged. Subsea designers are seeing these same technologies "emerge" in the sense that they are discovering what's been available to their terrestrial counterparts for some time now. The advantage that the subsea designer has is that someone else has already been through the learning curve for these technologies. With high bandwidth devices such as side-scan sonar and high definition television becoming more commonplace, subsea designers find themselves in need of more efficient ways to add fiber connectivity to their designs.

Many designers tend to approach a project in a basic manner and then scale up as their systems grow in complexity and require more capability. Thus, many subsea systems start with a single optical fiber servicing a single instrument. That instrument talks whenever it needs to while the receiver is set to passively listen. In this simple arrangement, adding instruments is usually done by adding fibers. This is acceptable when only a handful of instruments are being considered, but quickly becomes unworkable when large numbers of fiber optic devices are added to a vehicle or system. This becomes even more apparent when the subsea designer needs to add instrument control, rather than just passive data collection. In the simple view of one fiber for one channel of data, adding control doubles the number of fibers in a system; one for transmitting and one for receiving data.

This duplication of fibers is avoided by using single fiber, bi-directional (BiDi) modules to convert the data from electrical to optical and vise versa. BiDi modules use coarse wavelength divisional multiplexing (WDM). They utilize two widely spaced wavelengths; usually 1310 nm and 1550 nm. They operate in pairs wherein one transmits on one of the two wavelengths while its mate receives on the other. This doubles the capability of a single fiber connector, like the BIRNS Millennium F-series connector, by changing it from a simplex connection to a duplex connection.

However, using BiDi modules still requires one fiber per instrument. Doubling the number of instruments on your vehicle doubles the number of fibers required in both your cables and the connectors or penetrators you use. The optical circulator offers a way around this.

An optical circulator is a non reciprocal, passive optical device. By non reciprocal, we mean that light traversing the device will travel along a path determined by the direction of propagation. Light propagates through the device from one port to the next, but not in the opposite direction. Typically, these are three port de-

Reprinted with Permission from the September 2014 edition of Marine Technology Reporter www.seadiscovery.com

vices. Light that enters through port 1 exits through port 2. Light launched into the circulator through port 2 exits through port 3; not port 1. Any light trying to circulate in the opposite direction is blocked.

The simplest use of optical circulators would be to use a pair of them; one, for example, on an ROV and the other on the support vessel. The umbilical would connect the dry end circulator's port 2 to the wet end circulator's port 2. Light launched into port 1 on the dry end would emerge at port 3 on the wet end. Signal returning from the ROV would launch into port 1 on the wet end and be received at port 3 on the dry end. Thus, we establish two way communication with the ROV over a single fiber link. The difference is that, unlike the BiDi, this is done within a single wavelength band. The importance of this will be discussed in more detail later.

More devices could be added to our system by using multiple circulators. A ring is constructed using circulators connecting port 3 of each to port 1 of the next in a daisy chain configuration. Each port 2 would be routed to port 2 of an additional circulator that would route signals to and from the transceiver module's transmit and receive ports. Each device on the ring would have its own address and would retransmit any signal that was not addressed to it. This configuration also makes it possible for the devices to communicate with one another as well as with the support vessel, all through a single fiber connector or penetrator.

The drawback to this architecture is latency in the network. The maximum data throughput rate is limited to that of the slowest transceiver in the system. This is acceptable if there is no requirement for simultaneous communications over the network. However, if there is such a requirement, or if one or more of the devices cannot cache its data for transmission when the network is available, then dense wavelength divisional multiplexing (DWDM) offers an approach that will allow for simultaneous communications in the network.

BIRNS Millennium 3F single fiber cable plugs (CPs) provide high bandwidth in a single optical fiber and can be expanded from a simplex connection to multi-channel connections using tools such as BiDi modules, optical circulators, or DWDM modules.

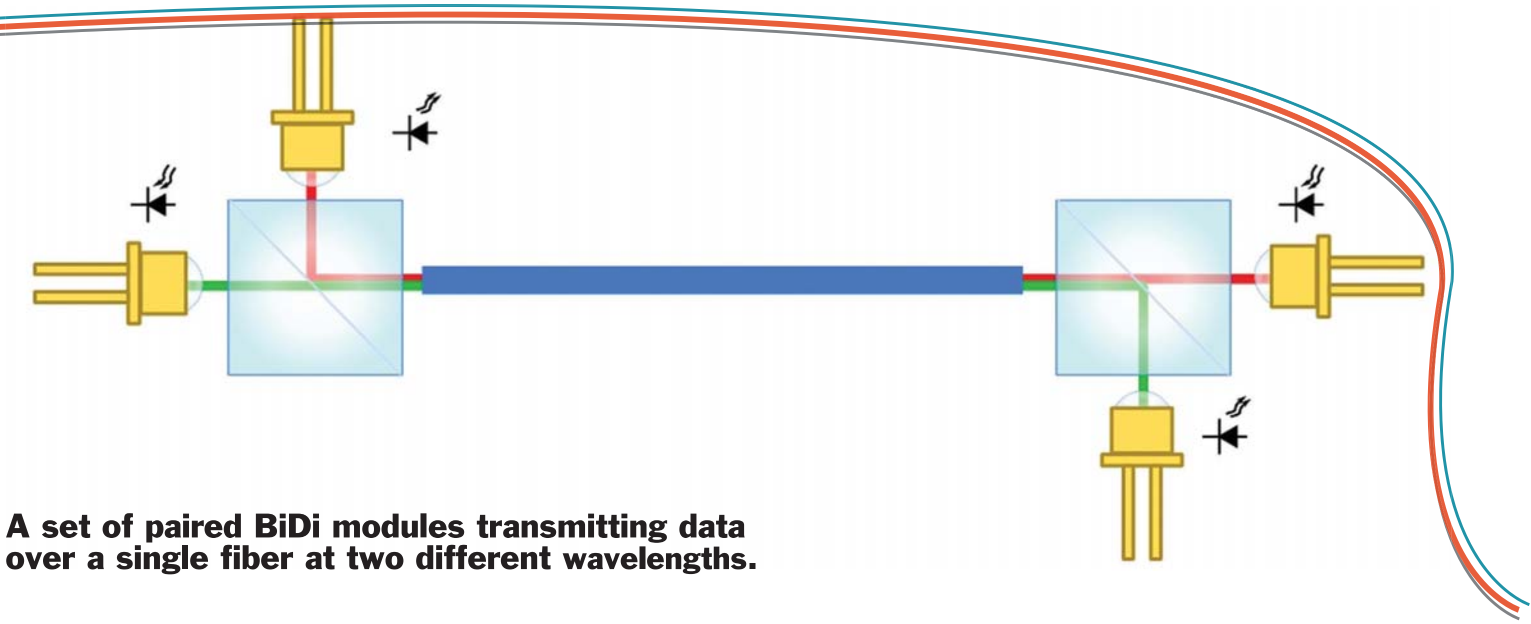
(L-R) BIRNS Millennium 3O Dual O-ring Receptacle (OR) with four optical fibers, 3T flanged receptacle (FR) with two optical fibers and 3O FR with four optical fibers have a small footprint but offer significant versatility in data transference and spare capability for future subsea system upgrades.

With DWDM, multiple wavelengths, or colors, of light are used. Each wavelength is its own data channel. The advantage is that the individual wavelengths do not interfere with one another. DWDM allows two or more devices to transmit data over the network at the same time without crosstalk.

DWDM utilizes another type of passive optical component called an optical add/drop module (OADM). An OADM either removes or adds light at its design wavelength. These are 3 port devices. Port 1 is the common lead, with all wavelengths present. Port 2 is the add/drop lead with only the design wavelength present. On port 3, all wavelengths except the design wavelength are present. When light is launched into port 1, the design wavelength is picked off and redirected to port 2. All other wavelengths continue on to port 3. When light at the design wavelength is launched into port 2, it is redirected back to port 1. When all wavelengths except the design wavelength are launched into port 3, the light is directed to port 1.

The power of dense wavelength divisional multiplexing to increase the capacity of a network is seen when we consider just how many wavelengths can be packed into a single fiber. DWDM channel spacings have been getting progressively tighter and tighter. 200 GHz modules were replaced by 100 GHz modules; then 50 GHz, then 25 GHz. The latest ITU standard is 12.5 GHz. The wavelengths span a spectral range from 184.5 THz to 195.9375 THz, or 1624.89 nm to 1530.04 nm. In this band, the 12.5 GHz is a channel spacing of approximately 0.1 nm, creating

Reprinted with Permission from the September 2014 edition of Marine Technology Reporter www.seadiscovery.com



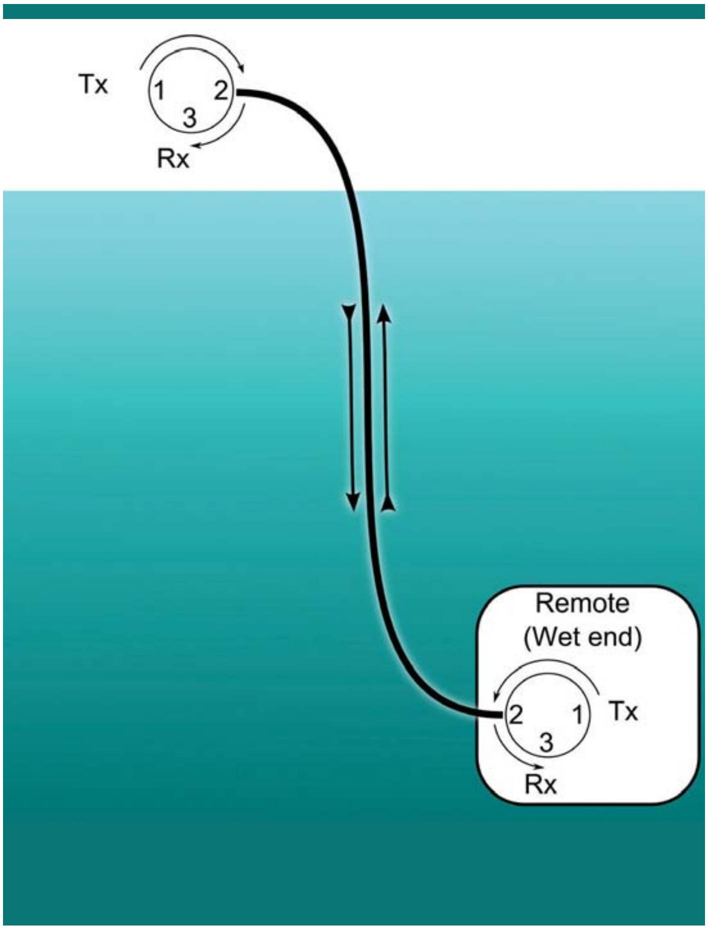
A set of paired BiDi modules transmitting data over a single fiber at two different wavelengths.

over 900 possible channels. The latest technological innovations have lead to fiber optic links capable of transmitting data at a rate of 1Tb/s.

DWDM operates in the C and L bands (1520 nm to 1620 nm). Optical circulators are available that can span this entire spectral range. Optical amplifiers are also available in this spectral band to increase the reach of a fiber optic network. Because of these components cover the same spectral range, we can combine DWDM and optical circulators to construct our network. To connect multiple devices on a single fiber, we would build two identical OADM networks; one for the dry end and one for the wet end. Each add/drop port would have a circulator to route signals to and from each device's transceiver module. Each device, along with its dry end controller, would transmit and receive over the network as though it were the only device present. It would be oblivious to the other devices operating at different wavelengths.

One advantage of this architecture is that we have simultaneous communications on our network. Another is that there is no requirement to construct a fiber ring to complete the network; the network is a single string rather than a closed loop. The network is also easily reconfigured. In ring architectures, removing a device breaks the ring. With a DWDM network, we simply unplug the device and cap the unused connector. Adding a device is easily done by adding another OADM to the end of the network. The disadvantages are that the network is more complex to construct and that the various devices cannot communicate directly with one another. Any device to device communication must be done through a server that's probably aboard the support vessel.

Yet another benefit of DWDM is the ability to reduce cost by leveraging existing connectors, cables, and umbilicals. If we look back at how many designers start adding fiber optic capability to their systems, the average designer would have started by using a small, single fiber connector such as the BIRNS Millennium 3F-1F connector. By adding OADM and circulator networks on either end of an existing fiber link in a case like this, we increase its capacity while maintaining the same ½ inch aperture we started with. In multi-fiber or electro-optical connectors, we add bandwidth with a minimal effect on the other vehicle systems that also use the cable. Another way of looking at DWDM is as a method to "repair" a cable. By using OADM/circulator networks, we can redirect network traffic in a partially damaged cable from



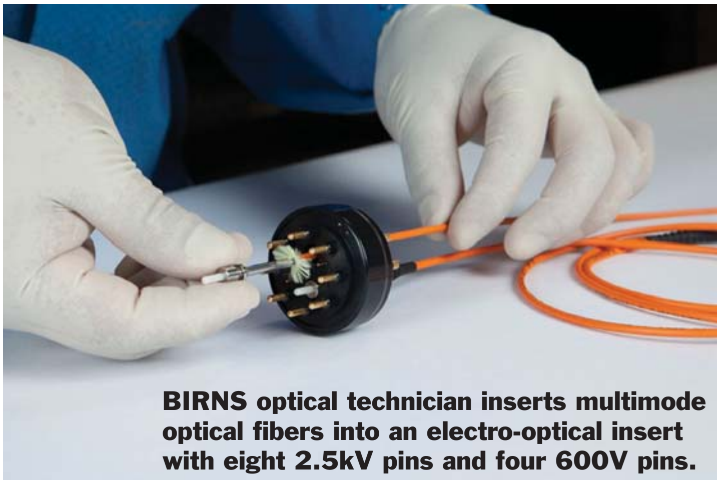
A pair of optical circulators providing a multi-channel data link over a single optical fiber. Multiple data channels, each on a different wavelength, can be transmitted simultaneously through the circulators.

Reprinted with Permission from the September 2014 edition of Marine Technology Reporter www.seadiscovery.com

the damaged fibers to its remaining fibers. This may seem circuitous or cumbersome, but it may be a very reasonable option if a replacement cable has a high price and/or a long lead time.

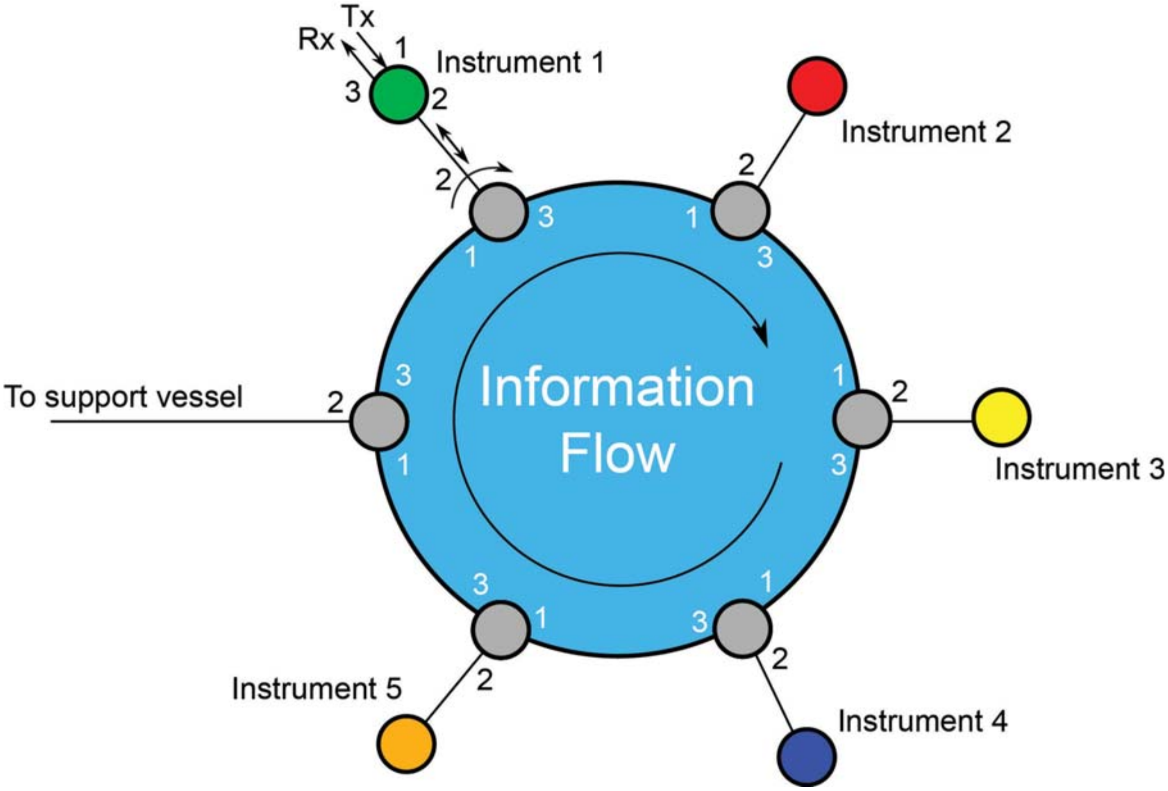
These technologies also allow for much smaller packages. Rather than creating the need for a large, and expensive, multi-fiber cable to service all of a vehicle's data requirement, tremendous amounts of data can be sent through a 1-4 fiber cable. This is especially important for designers of small vehicles that require lightweight umbilical cables. The smaller the optical portion of a cable, the more space is left available for electrical power. As a result, the subsea designer can take advantage of small electro optical connectors such as the BIRNS Millennium O and T-series connectors to combine power and data into a single small hull penetration. As an example, the 3O-2F2 connector family can provide 2 electrical conductors and 2 fibers in an aperture that's only 1 1/8" in diameter. By utilizing passive components such as DWDM and circulators, a designer can route all of a vessel's data through one of the two fibers, reserving the other fiber in the 3O-2F2 as a spare, or as a convenient way to quickly add new instruments for particular missions.

More than ever before subsea designers are faced with limited space and limited budgets. Fiber optics allow the addition of high bandwidth devices without a dramatic increase in the size of a vehicle's tether. Terrestrial designers faced a similar limit to the space available to them. Public utility right-of-ways have only so much space available. These limitations lead them to use technologies such as circulators and DWDM to not only conserve space, but also to reduce their cost per data channel. And now that they've worked the kinks out of these technologies, the subsea designer can benefit and enjoy the same ability to put large amounts of data into a small package.



BIRNS optical technician inserts multimode optical fibers into an electro-optical insert with eight 2.5kV pins and four 600V pins.

An example of a ring architecture to connect multiple instruments to a single optical cable. Each instrument's transceiver retransmits data addressed to the other instruments to the next module in the loop. A server aboard the support vessel manages communications between the instruments.



Reprinted with Permission from the September 2014 edition of
Marine Technology Reporter www.seadiscovery.com

Contents
Volume 57 • Number 7

The Authors in This Edition of MTR


Dennis Bryant


Michael Jones


Steve Bell


Claudio Paschoa


Tom Peters


Jon Wilkins

Bryant
Dennis L. Bryant is with Maritime Regulatory Consulting, and a regular contributor to Maritime Reporter & Engineering News. e: dennis.l.bryant@gmail.com *p. 18*

Jones
Michael B. Jones is President of The Maritime Alliance and The Maritime Alliance Foundation. He can be reached at mbjones@themaritimealliance.org. *p. 20*

Bell
Steve Bell is an Optical/Photonics Engineer at BIRNS, Inc. and has more than 25 years of expertise in designing and testing subsea and terrestrial fiber optic systems. E: sbell@birns.com. *p. 28*

Paschoa
Claudio Paschoa is Marine Technology Reporter's correspondent in Brazil. *p. 36*

Peters
Tom Peters is a freelance writer living in Lower Sackville, Nova Scotia. He is retired from the newspaper business after 41 years with The Halifax Chronicle-Herald. *p. 46*

Wilkins
Jon Wilkins is the US Sales Manager for Silicon Sensing and has been in the inertial field since 2001 with roles in engineering and program management. *p. 62*

Leska
Mark Leska is Senior Marketing Coordinator for Wachs Subsea and E.H. Wachs, A Division of ITW. E: sales@wachssubsea.com. *p. 52*

Reprinted with Permission from the September 2014 edition of Marine Technology Reporter www.seadiscovery.com