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EDITORIAL GUIDE

Improving Optical Network Testing

New user requirements and a steady demand for more capacity have created new test challenges across the optical network spectrum. These articles explore some of the more salient challenges as well as solutions, including the benefits of the right monitoring system, strategies for successful multi-fiber connectorization, and evolving data center test requirements.

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In-Service OTDR Monitoring and Mitigating the Effects of Raman Scattering

by **MICHAEL GRINSTEIN** and **MIKE VENTER**, VeEX Inc.

TODAY'S HIGH-CAPACITY COMMUNICATION networks depend on optical fiber to transport huge amounts of internet, data, and video traffic. Damaged or broken fibers not only disrupt thousands of users, but can threaten the operation of critical infrastructures. It is therefore essential to have a fiber network that is highly available and reliable.

Furthermore, a single fiber link can generate significant revenue for a service provider, so any failure demands immediate response to restore service. Instead of traditional, time-consuming field test practices to isolate and identify faults, integrated network monitoring with targeted action ensures the fastest restoration and highest service availability.

Remote fiber test or monitoring systems

Fiber monitoring solutions have proven to be the fastest, most efficient tool to identify and locate link outages. The ability to proactively detect fiber degradation at an early stage and pinpoint fiber faults precisely from a central location helps service providers meet customer expectations for fiber-optic network availability and maintaining quality of service (QoS) and service-level agreements (SLAs).

Since individual fibers can be prone to damage or degradation, it is becoming more common practice to monitor all the fibers in a cable, whether dark or live (lit). Live fiber or in-service monitoring, which by design does not disrupt network traffic or adversely affect customer experience, is gaining popularity since this provides a dynamic evaluation of network performance. Such monitoring also can be tied to other system alarms or network probes that provide additional triggering capabilities.

Out-of-service testing versus in-service fiber monitoring

During installation and commissioning, optical fibers are usually tested with a field-portable optical time-domain reflectometer (OTDR) operating at the same wavelength(s) as the traffic signals the fiber will transport. This industry-accepted practice verifies the fibers propagate signals according to known attenuation characteristics and that fusion splices and connections are within accepted limits. Since the fibers are not in service or are “dark,” there are no traffic signals to consider or interfere with. Similarly, dark fiber monitoring can also be referred to or classified as out-of-service testing.

In-service or live fiber testing by definition uses an out-of-band wavelength and requires a filtered wave-division multiplexer (FWDM) to combine the OTDR test signal and traffic signal into a single fiber. The FWDM not only combines the OTDR’s signal into the fiber under test, but it also filters and directs the backscattered signal back to the OTDR for processing. Likewise, the FWDM also prevents the OTDR signal from reaching the transmission equipment.

In May 2000, the ITU-T L.41 recommendation identified both 1625-nm and 1650-nm wavelengths for in-service maintenance of transmission networks operating at 1310-nm or 1550-nm spectrum. This recommendation was renumbered to L.301 in February 2016 without modification and remains in force today. With the advent of DWDM technology, the ITU-T in parallel created the G.697 recommendation in June 2004 to focus on the optical monitoring aspects for optical signals implementing bit rates up to 10 Gbps using non-return to zero (NRZ) or return to zero (RZ) line coding, as well as bit rates up to 40 and 100 Gbps using advanced modulation formats.

Generally speaking, 1625 nm is the preferred wavelength for monitoring legacy 1310/1550-nm systems, largely due to laser cost. The 1650-nm wavelength is recommended for CWDM, DWDM, XGS-PON, and TWDM-PON systems where the traffic wavelengths extend into the L-Band.

Nonlinear effects in optical fibers

In-service testing on C-Band transmission systems employing OTDR technology at 1625-nm or 1650-nm wavelengths requires an understanding of nonlinearity effects in fibers. Nonlinear effects are caused when the incident optical power

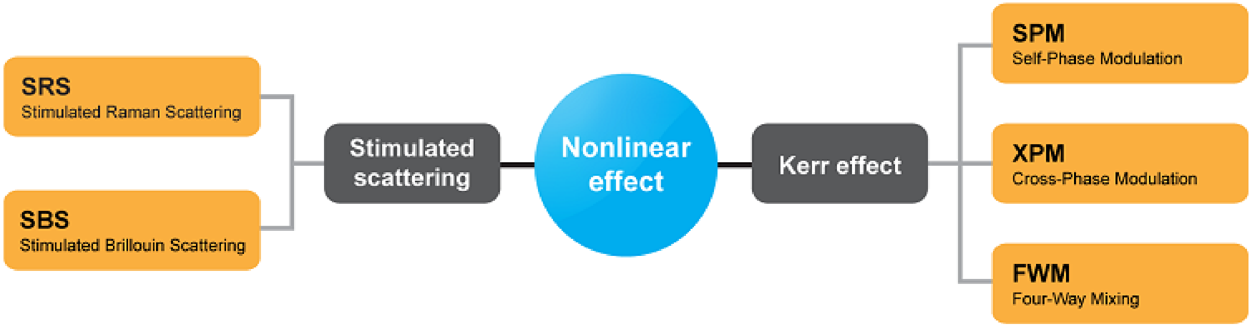

FIGURE 1 *illustrates the major nonlinearities in optical fibers.*

of a fiber exceeds a certain value, triggering the nonlinear polarization of fiber materials. This nonlinear effect is proportional to the optical power density of the signals, so in a DWDM system where a single fiber transports multiple optical channels, this composite high power level produces the nonlinearity effect in the fiber. Nonlinearity becomes a key factor that limits transmission performance if not managed properly.

Raman effects and in-service fiber monitoring

Of all the nonlinear effects identified in Figure 1, stimulated Raman scattering (SRS) is of biggest concern for in-service monitoring applications. In brief terms, SRS is an interaction between the incident wave (also known as the pump wave) and of the new frequency-shifted wave (also known as the Stokes wave). SRS causes depletion of the shorter (pump) wavelength and amplification of the longer (Stokes) wavelength. The Raman gain peak occurs when the Stokes frequency is about 13 THz (~100 nm) away from the pump's frequency, and this falls directly within the OTDR test wavelength spectrum (see Figure 2). If the power of the shorter wavelength signal is less than the SRS threshold then spontaneous Raman scattering (SpRS) occurs with the same spectral properties.

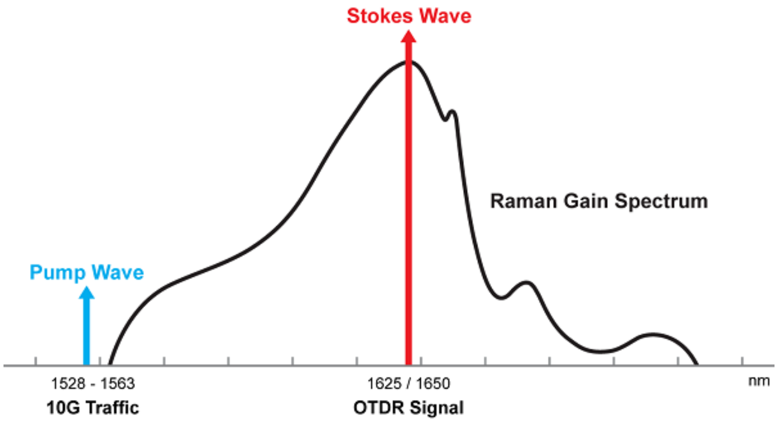

FIGURE 2. *Raman gain spectrum.*

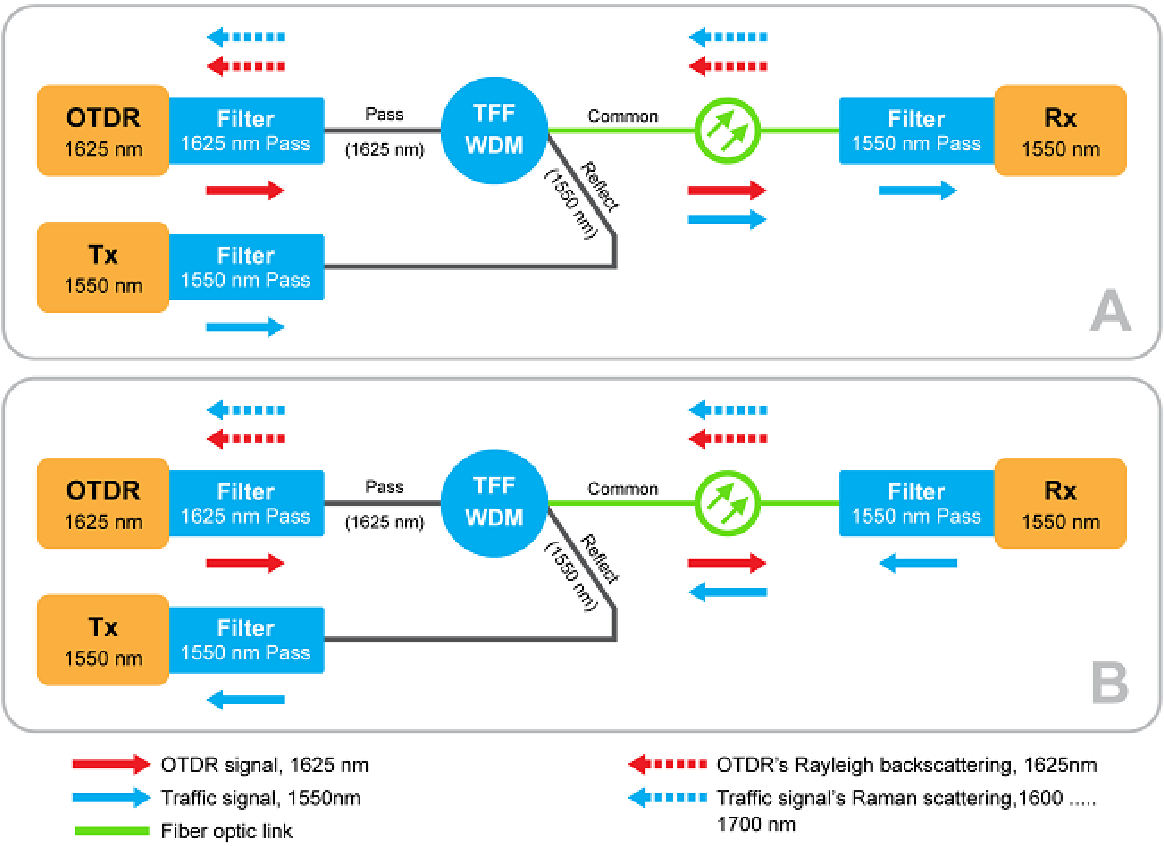

FIGURE 3. *OTDR and communication equipment locations. In A) the OTDR and Tx are at the same end of the fiber link; in B) the OTDR and Tx are at the opposite ends of the fiber link.*

In other words, when the 1550-nm C-band traffic signal propagates along the fiber, the backscattered signal related to the Stokes component coincides with the OTDR's 1625/1650-nm test signal and passes through the OTDR's filtered test port almost without loss. Despite the Raman scattering power level being quite small, the OTDR's sensitivity is very high, and this scattering can significantly reduce the OTDR's dynamic range.

The locations of the OTDR, including the transmitter (Tx) and receiver (Rx) of the communication equipment, are shown in Figure 3. In this example, the OTDR signal at 1625 nm and the traffic signal at 1550 nm can propagate in the same or opposite direction; the backscatter from the Stokes wave or scattered Raman radiation returns to the OTDR.

What is the optimal OTDR location for in-service monitoring?

The question of where the best place to install the in-service monitoring OTDR for optimal performance often arises. To answer this question, the Raman scattering

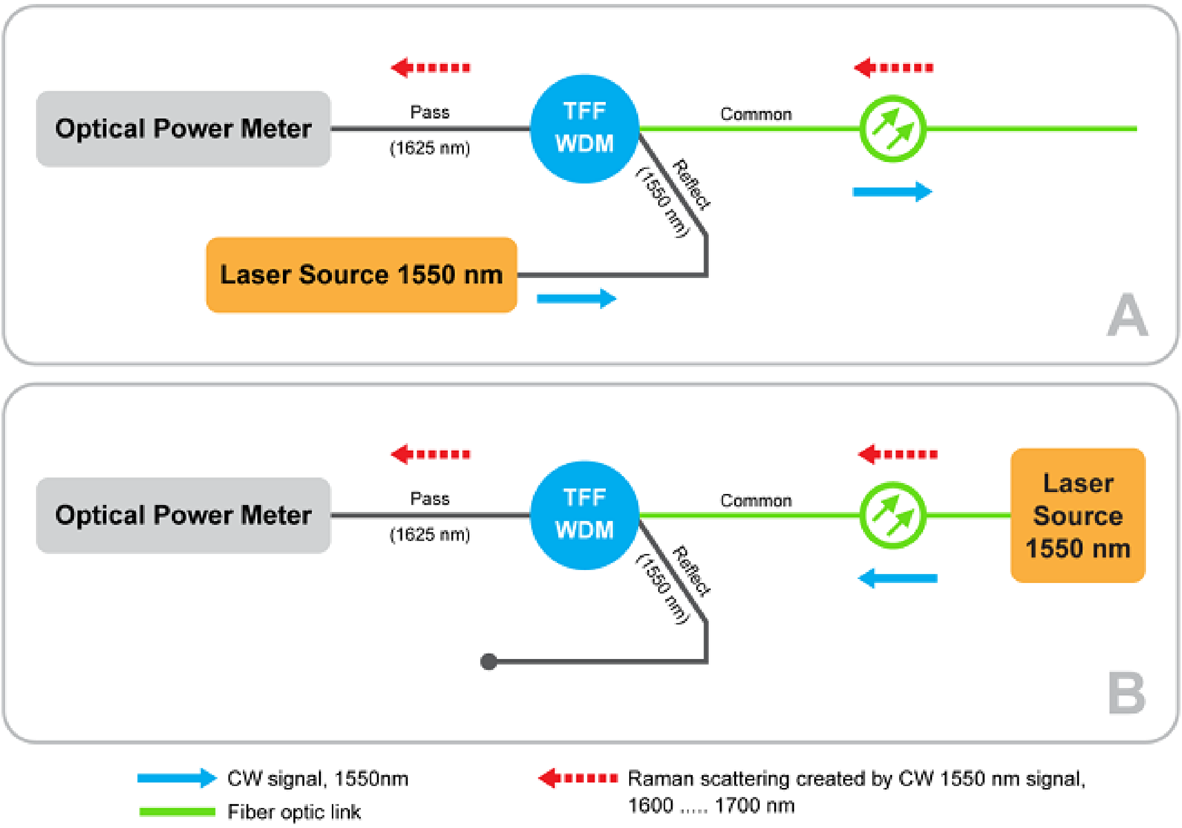

FIGURE 4. *Measurement of the back (a) and forward (b) Raman scattering.*

power from the Stokes wave was measured in an example system. It should be noted that measurements were conducted with a CW laser source, but traffic signals with modulation will deliver slightly different results. The measurement schemes are depicted in Figure 4.

Test procedure

A thin-film filter (TFF) WDM was used to filter out the Raman scattering from the total radiation propagating in the fiber link. The insertion loss and isolation of the WDM were measured with CWDM and 1625- and 1650-nm lasers (see Figure 5). For more precise isolation measurements, the laser spectrum was previously cut with CWDM and appropriate TFF multiplexers.

The 1550-nm laser source with a power level of 0 dBm simulated the traffic communication signal. The broadband optical power meter measured the optical power received by the OTDR port of the WDM filter. The difference between the back and forward Raman scattering power was calculated based on the fiber length.

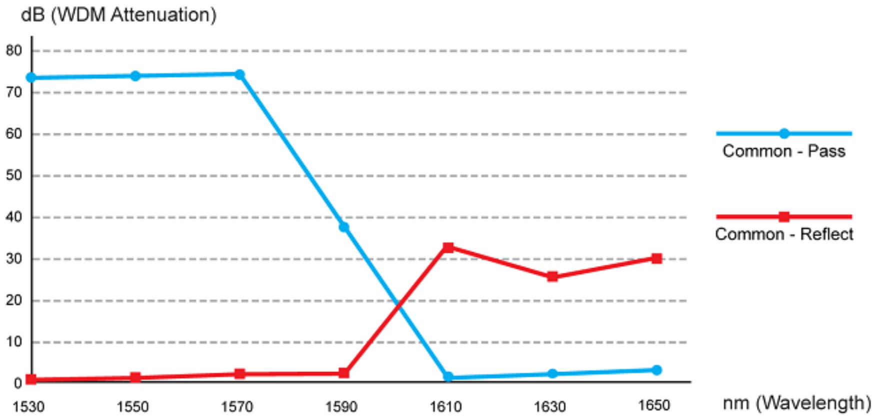

FIGURE 5. *Raman scattering through TFF WDM.*

Figure 6 plots the ratio of spontaneous Raman scattering versus fiber length, where fiber attenuation was assumed to be 0.19 dB/km. The results of the different length measurements for 25, 50, and 100 km are indicated.

Conclusion

Based on these results, it can be concluded that at the OTDR input, the Raman backscattered power is higher than the forward scattered power. Therefore, to minimize Raman interference, the OTDR and the transmitter of the communication equipment should ideally be located at opposite ends of the fiber link.

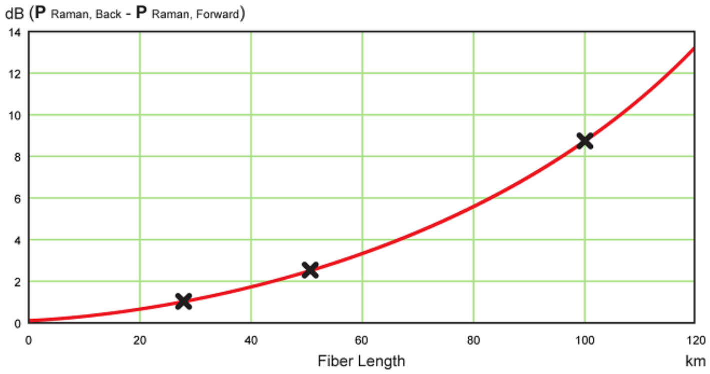

FIGURE 6. *Ratio of Raman power (back and forward) and fiber length.*

However, there are a few caveats:

- This case study excludes situations where Raman amplifiers and EDFAs may be deployed together on the same fiber link.
- Traffic signal was simulated at 1550 nm, but it should be noted that multiple DWDM signals across the entire C-Band, for example, will produce slightly different results.
- Fiber length is not only the criterion for the generation of SpRS. The intensity of the optical signal, the effective area of the fiber, and other parameters will influence the measurement.

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MIKE VENTER is vice president, product development, fiber optics at VeEX Inc. He has been with VeEX since its inception in 2006 and is currently responsible for the company's fiber-optic product and business development worldwide. He led the company's sales and marketing activities in EMEA for over a decade, a territory he also managed at Sunrise Telecom prior to joining VeEX. Before joining Sunrise, he worked at Alcatel and Tektronix in several RF, microwave, and optical product engineering and management roles. Mike has been involved in the telecom market for over 35 years and fiber test and measurement since 1989.

Meerkats and Fiber Networks Agree

Proactive Monitoring Keeps You Alive!

As customers depend more on fiber optic systems for high speed communication, network operators try to protect fiber optic cables as best they can. Unfortunately, fiber breakages do occur followed inevitably by some type of service disruption or network outage. At this point, every second of downtime results in a loss of revenue so fast restoration is key.

By installing a Remote Fiber Test System (RFTS), operators can monitor their fibers around the clock, receiving near immediate alerts of breaks, degraded connections, including intrusion attempts. Fast notification coupled with precise geographic mapping speeds up fault location, so service crews know exactly where to go and what to fix.

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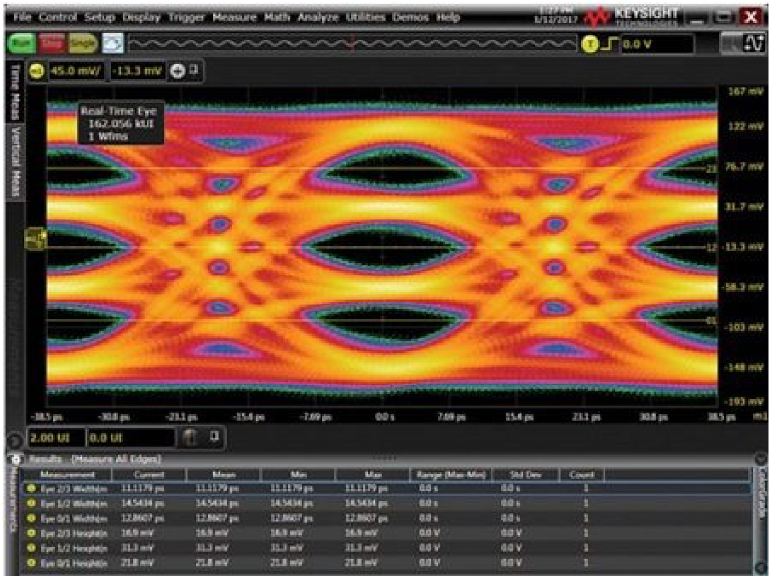
The New Datacom Imperative:

Next-Generation Optical Ethernet and Multi-Fiber Connector Inspection

By **MAURY WOOD,** AFL

WHILE STRUCTURED CABLING using multi-fiber connectors such as MPO/MTP® have been in use in enterprise data centers for many years, the prevalence of this connector type continues to steeply increase. This is due to the confluence of commercial dynamics (including the apparently insatiable consumer demand for broadband data services) and technical dynamics (including the need for parallel full-duplex lanes of transceiver optics for performance purposes). Concurrently, the relentless drive for high optical network operating efficiency, and minimal lost productivity, is leading to an expanding desire, particularly by hyperscale network operators, for 100% microscopic inspection of their infrastructure connectivity.



Measurement	Current	Mean	Min	Max	Range (Max-Min)	Std Dev	Count
Eye 2/3 Width(n	11.1179 ps	11.1179 ps	11.1179 ps	11.1179 ps	0.0 s	0.0 s	1
Eye 1/2 Width(n	14.5434 ps	14.5434 ps	14.5434 ps	14.5434 ps	0.0 s	0.0 s	1
Eye 0/1 Width(n	12.8607 ps	12.8607 ps	12.8607 ps	12.8607 ps	0.0 s	0.0 s	1
Eye 2/3 Height(n	16.9 mV	16.9 mV	16.9 mV	16.9 mV	0.0 V	0.0 V	1
Eye 1/2 Height(n	31.3 mV	31.3 mV	31.3 mV	31.3 mV	0.0 V	0.0 V	1
Eye 0/1 Height(n	21.8 mV	21.8 mV	21.8 mV	21.8 mV	0.0 V	0.0 V	1

FIGURE 1. *Example PAM4 eye diagram showing the four encoding states. (Photo courtesy of Keysight Technologies)*

AFL estimates there are more than 10 million MPO/MTP connectors in use across the world today, with more than 1 million forecasted to be fielded in 2019. An MPO connector market compound annual growth rate (CAGR) of at least 10% is expected to sustain for the next five years.

As all communications engineers and technicians are aware, nearly all link failures occur at points of connection, and very rarely across unbroken network spans. At the same time, the signal modulation technology that underlies the new short-reach 200G/400G optical Ethernet standard reduces the available link budget in high-bandwidth datacom applications – making the operational need for immaculate connector endfaces all the more imperative.

Next-Generation Optical Ethernet Transport Standards (200G/400G) in the Data Center

Data centers typically rapidly adopt the latest networking technologies as their operators seek a competitive performance edge. The new IEEE 802.3bs 200G/400G Ethernet standard specifies the use of PAM4 modulation, a departure from the older non-return to zero (NRZ) modulation method. PAM4 provides higher spectral efficiency, but because it encodes two bits (four states) into the same carrier signal dynamic range as NRZ (which encodes one bit or two states), PAM4 requires about 9.6 dB more link optical signal-to-noise ratio than NRZ to maintain the same symbol error rate statistics (see Figure 1).

While this physical layer transmission technology change may initially seem unrelated to optical connector cleanliness, there is a distinct and important link. In 10G, 40G, and 100G systems using NRZ modulation, a contaminated connector endface may cause optical losses that can be largely ignored on the short-reach cabling common in data centers. However, in 200G and 400G systems using PAM4 modulation, the same level of endface contamination will erode a greatly reduced link budget margin, driving optical network technologists to demand pristine connector endfaces. Best-practice connector cleaning and inspection procedures will become essential to maintain the highest levels of performance and reliability.

A simple real-world analogy might paint a picture here. To a family car driving along at 30 miles per hour, road debris is a mere annoyance. To a sports car racing along at 120 miles per hour, the same road debris is a big risk that may even cause a fatal crash.

The light-carrying core of a single-mode MPO fiber has a diameter of 9 microns or an endface surface area (πr2) of about 64 square microns. A 2-micron-diameter speck of dust has a surface area of about 3 square microns, or about 5% of the endface surface area. A 5% reduction in laser power is about -0.2 dB. In an environment in which link budgets are narrowing and transmit laser power is a significant contributor to overall data center power consumption (there are tens of thousands of semiconductor lasers in a typical modern data center), it is quite easy to understand the opex-driven desire of network technologists for completely clean transport optics.

Moving into 2020, hyperscale data centers are expected to become even larger, leading to structured MPO cabling that is naturally longer in some spans. Unlike the signal losses (attenuation) due to cable-reach physics (about 0.4 dB per kilometer at 1550 nm on single-mode fiber), connector contamination losses can be identified using proper microscopic inspection techniques and fully mitigated using proper endface cleaning methods.

Data Center Cable Infrastructure – An Increasingly Valuable Asset

It is possible to quickly model the asset value of a 400G link for a hypothetical broadband internet service provider. The major players in this global market are chasing the goal of providing the majority of their residential and business subscribers with 1-Gbps downstream service by 2020. Today in the United States, a typical consumer pays about $100 per month or $1200 per year for fiber-to-the-home internet service. With no statistical oversubscription, a 400G link serves 400 customers, and thus places the asset value of each 400G MPO terminated cable (eight fibers at 100 Gbps per fiber full duplex) at $480,000 per year. With a conservative 2:1 oversubscription ratio, this rises to nearly $1 million per year. These rough economics underscore the importance of proper maintenance to avoid network downtime, including multi-fiber connector inspection and cleaning as needed.

In 2002, NTT-AT published a finding that up to 80% of failures in optical networks are caused by contaminated connector endfaces (https://sticklers.microcare.com/resources/faqs/why-clean-fiber-optic-connectors/). And in 2016, the Ponemon Institute/Emerson Network Power reported that the average cost of a data center outage is about $740,000 (https://www.emerson.com/en-us/news/corporate/network-power-study). These numbers provide strong quantitative motivation for data center operators to routinely inspect and clean their multi-fiber connectors.

The Rise of Fast MPO Inspection Tools

Endface inspection of multi-fiber connectors at turnup and during normal maintenance operations can easily identify connector contamination. But until recently, the standard method of MPO connector inspection involved the use of awkward and expensive mechanical scanning stages attached to the front-end snout of an inspection microscope probe. This labor-intensive method yields good results, but might take up to a minute to collect IEC 61300-3-35 auto-analysis pass/fail results for each fiber. The high opex associated with mechanically scanning tens of thousands of MPO connectors in hyperscale data centers has until recently made the goal of 100% endface inspection unrealistic.

FIGURE 2. *A fast MPO inspection microscope showing two rows of 12 fibers with pass/fail results (Photo courtesy of AFL)*

Serendipitously, the availability of high-resolution image sensors, microcontrollers, flash memories, and field programmable gate array (FPGA) semiconductors, all cost-driven by the high-volume mobile device market, has enabled the development of wide field of view inspection probes that slash multi-fiber auto-analysis connector inspection time by an order of magnitude (see Figure 2). With fast MPO inspection tools costing $5,000 or so, the required capital investment is not challenging in the context of billion-dollar data center build-outs. The economics of multi-fiber connector inspection have changed dramatically and favorably over the past 12 months.

Hyperscale and other scale-out optical network operators must now drive their operations to 100% "inspection before connection," particularly given the increased sensitivity to endface contamination in 200G/400G transmission systems, the high cost of data center service interruptions, and the increasing enterprise asset value of multi-fiber cabling. Forward-looking internet content providers are now insisting that their infrastructure equipment suppliers conduct 100% pluggable transceiver connector inspection as well, to avoid initial network turnup problems.

Adding to the appeal of fast multi-fiber inspection tools is the trend toward cloud-based workflow management tools that make integrated Tier 1 (loss test)/Tier 2 (OTDR test) plus inspection reports a breeze. Multi-fiber connector inspection reporting and cloud-based workflow management platforms are a natural fit moving into 2020 and beyond.

Conclusion

Just as rising consumer and industrial demand for internet cloud services and changes to physical layer transport technology have made 100% optical connector inspection an operational imperative, fast MPO inspection tools have appeared on the market to meet this critical need. Both the capex and the opex economics associated with fast multi-fiber endface inspection are now favorable and very compelling.

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Data Center Evolution and the Need for Testing

By **KEITH COLE,** VeEX

DATA CENTERS NEED to continually evolve to support increasing bandwidth demands and reduce operational and management costs. Modernizing the network architecture is required to achieve higher data rates, increase port counts, and lower cost per bit.

Of course, this growth can be a complicated process in an era of rapid technological change. Data center operators need to understand the technology and tools they can utilize to design, install, and maintain new networking products. Let's take a closer look at some of the new technologies available to the data center and the network testing requirements that will play an integral part of successful evolution and operation.

Availability of New Ethernet Port Speeds

The IEEE took 35 years to develop and ratify six Ethernet standards (10 Mbps through 100 Gbps). Currently, an additional six Ethernet standards have either recently completed development or are in their final stages (see Figure 1). These new standardized port speeds range from 400/200G optical Ethernet for high-speed router and switch interconnects to 5G/2.5G rates for increased capacity reusing existing Cat 5e/6 copper cabling.

Within the context of creating modules for these transmission rates, the physics of semiconductor materials limits the achievable clock rates. To build equipment capable of realizing the new high-speed communication rates and standards, network equipment manufacturers apply a variety of techniques, including multiple modulation formats.

For many years, the primary modulation format has been non-return-to-zero (NRZ) modulation. An example of this is 100G Ethernet ports supported with the common QSFP28 pluggable optical module that supports 4x25G NRZ high-speed data lanes.

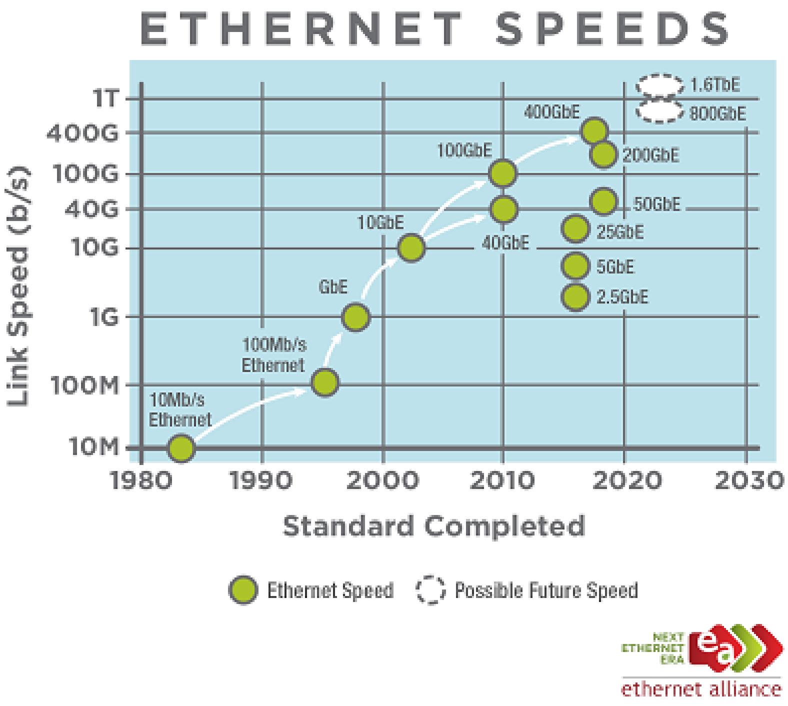
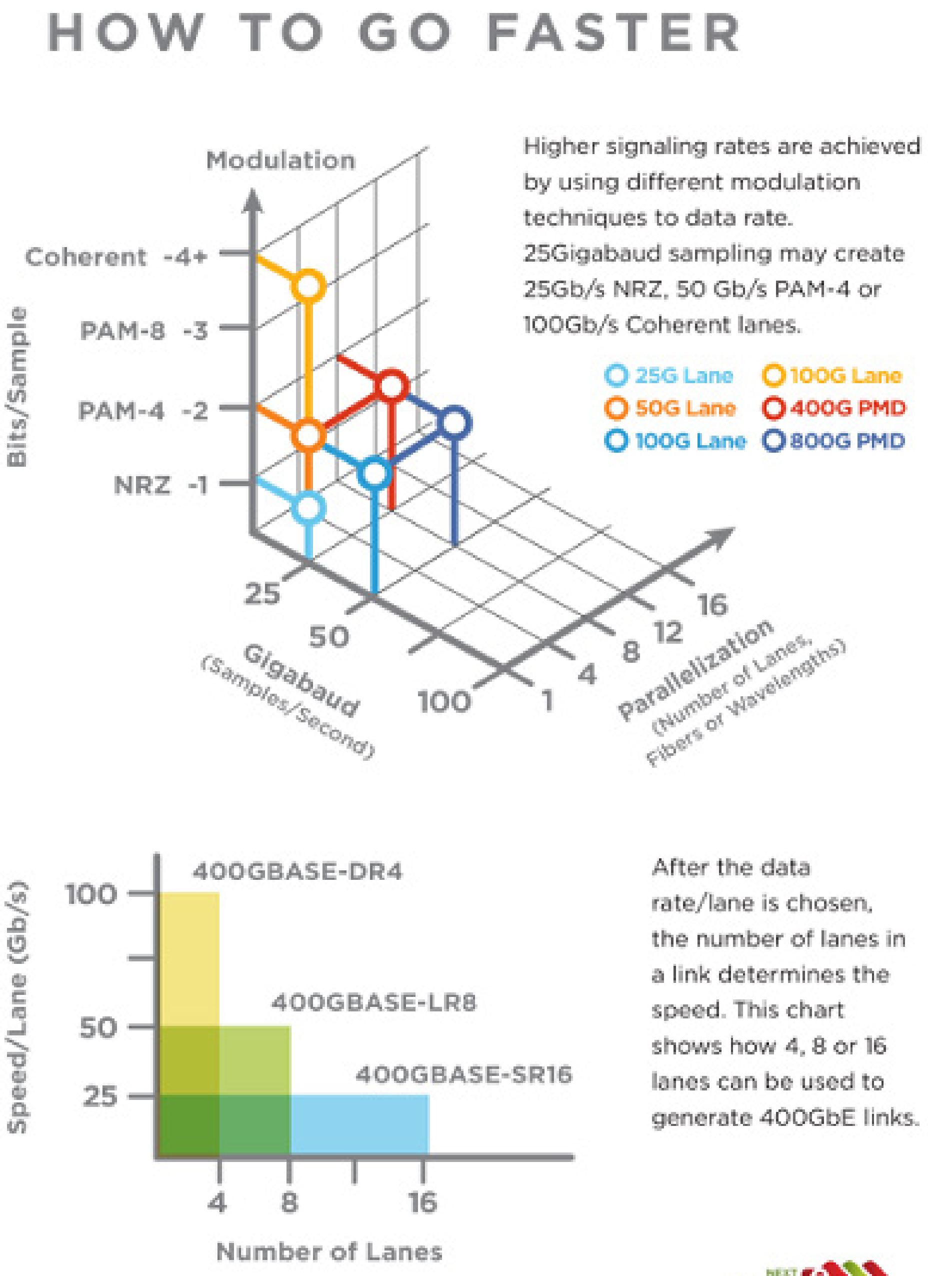


FIGURE 1. *Although some time is likely to pass before some of these standards see broad deployment, data center designers need to prepare now to keep up with bandwidth demand and technology upgrades that will enable them to remain competitive.*

In an attempt to increase bit rates without resorting to the complexities of coherent modulation, the industry has moved toward four-level pulse-amplitude modulation (PAM4; see Figure 2). The approach delivers twice the bit rate compared to NRZ modulation. On the downside, doubling the number of amplitude levels decreases signal-to-noise ratio, making accurate detection and demodulation more difficult. This factor increases the importance of compensation techniques, making forward-error correction (FEC) mandatory for new Ethernet interfaces supporting PAM4.

While the new 400/200/100/50G Ethernet standards utilize PAM4 50G capable high-speed data lanes to support the port rates, there are still variants that may still use 25G NRZ or even 100G. For example, a 400-Gbps Ethernet interface can be realized using eight lanes at 50 Gbps using PAM4 modulation or four lanes at 100 Gbps (see Figure 2).

Maximizing faceplate density is essential, particularly in the data center. An industry goal is to support thirty-six 400-Gbps ports in a 1U Ethernet switch. This has led to the development of a number of new form factors for optical transceiver modules (see Figure 3). Although the classic small form-factor pluggable (SFP) and the quad small form-factor pluggable (QSFP) modules remain the workhorses of the industry, emerging form factors include a quad small



Higher signaling rates are achieved by using different modulation techniques to data rate. 25Gigabaud sampling may create 25Gb/s NRZ, 50 Gb/s PAM-4 or 100Gb/s Coherent lanes.

After the data rate/lane is chosen, the number of lanes in a link determines the speed. This chart shows how 4, 8 or 16 lanes can be used to generate 400GbE links.

FIGURE 2. *Higher signaling rates and more parallel data lanes.*

ethernet alliance

form factor pluggable – double density version (QSFP-DD) that delivers 400 Gbps. The QSFP-DD port has dimensions similar to those of a QSFP28 and is backward compatible with 100G QSFP28 and 40G QSFP+ form factors and data rates.

Flex Ethernet Standardization

Flex Ethernet (FlexE), standardized by the Optical Internetworking Forum (OIF), is a new link aggregation method designed to decouple the Ethernet MAC client interface rates (10G, 40G, and the new Nx25G client) from the physical interface or PHY rate,

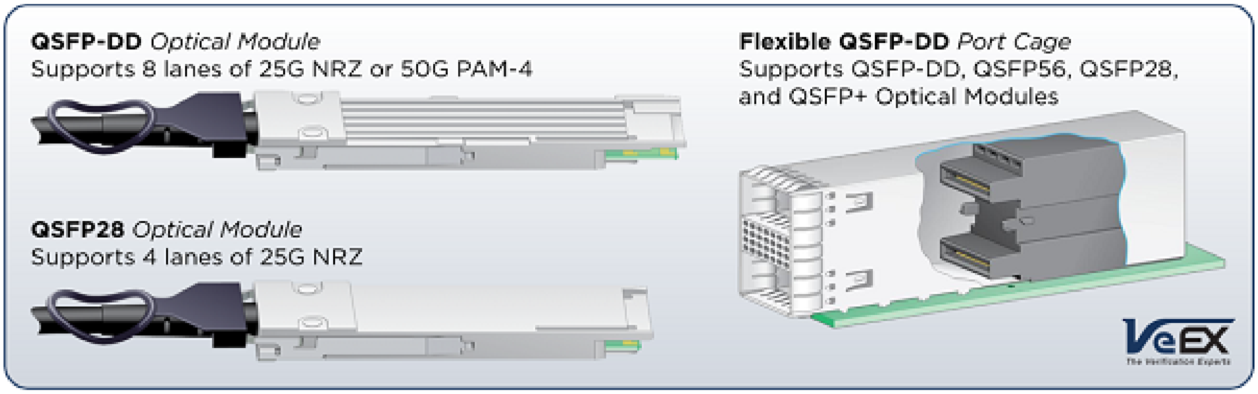


FIGURE 3. *Emerging pluggable optical transceiver developments support new port rates and flexibility.*

which connects routers and transport boxes (see Figure 4). This mechanism enables Ethernet connectivity between high-speed devices such as routers and optical transport equipment in a manner independent of the physical interface between the equipment (the MAC client rate may not match the physical port rate).

The benefits of FlexE are improved end-to-end management and network efficiency, with the flexibility of adjusting the service bandwidth as required. OIF released the first FlexE implementation agreement, IA OIF-FlexE-01.0, in 2016; the 2.0 agreement is expected by the end of 2018.

What Do We Need to Test?

Amid this ever-evolving technology landscape, data centers have to design and build infrastructure and keep it running. Data center operators require specialized test and measurement equipment to qualify the design, installation, and monitoring of these new technologies as port rates and optical modules change.

Traffic Simulation and Measurement for the New Port Rates

Test equipment must be capable of supporting effective traffic simulation and measurement at the new port rates and standards. Remember, the IEEE already has six Ethernet standards in place. The 400G Ethernet standard, one of the six new standards, was ratified in December 2017; in fact, only IEEE 802.3cd (for 50 Gigabit Ethernet, multimode 200 Gigabit Ethernet, and a new “cost effective” version of 100 Gigabit Ethernet) remains to be completed of the new six. Effective testing of connections based on new and “original six” Ethernet requires accurate and consistent traffic simulation at the data rate of interest and accurate, high-

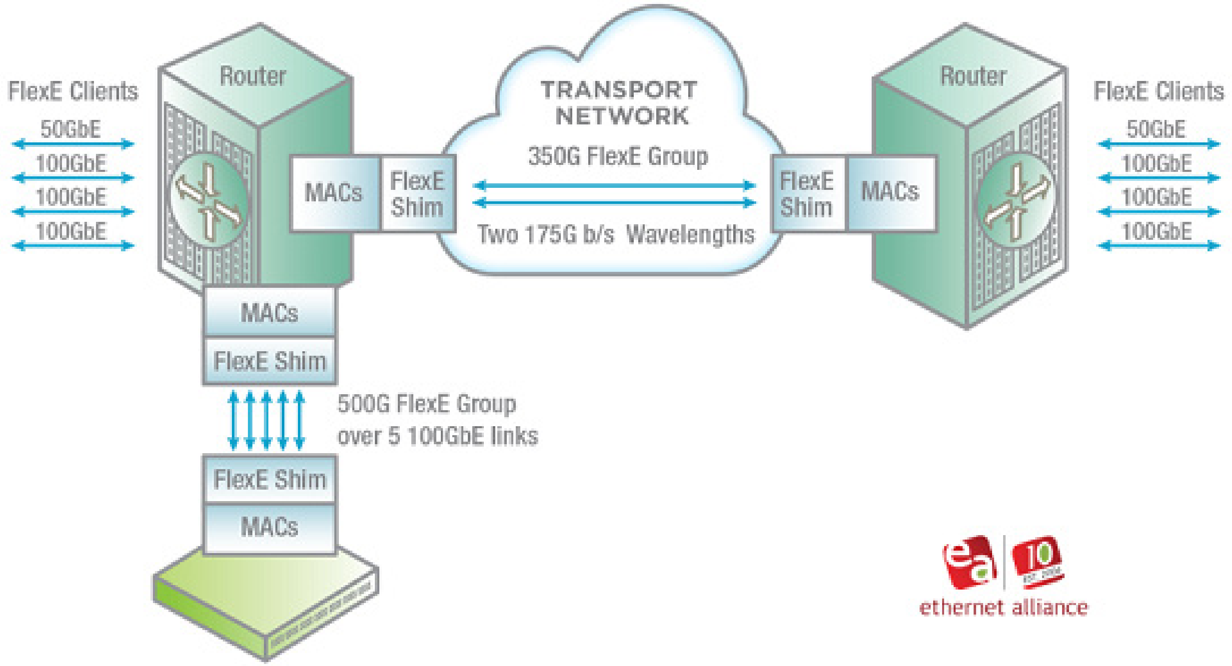


FIGURE 4. *FlexE aggregation of various Ethernet MAC client rates.*

resolution measurement of the results. This is particularly important given that most networks use a mixture of data rates, depending on the specific bandwidth requirement of the interconnect (see Figure 5).

Interoperability and Standards Compliance

Before rolling out new switches and routers that take advantage of faster port rates and new technologies, the equipment must be tested for interoperability in the network and verified for standards compliance.

Network Traffic Verification

We can split Ethernet/IP traffic verification into multiple parts: validating the physical coding sublayer (PCS), the FEC layer for PAM4 and evaluating data exchange in the Ethernet/IP layer.

The PCS is the top level of the PHY layer. It repackages the raw data of the PHY layer to interface with the media-independent interface. Verifying the PCS includes checking lane skew/latency, lane misalignment, and lane swapping.

The process of validating the Ethernet/IP layer includes checking key performance indicators like throughput, frame loss, latency, and jitter, as well

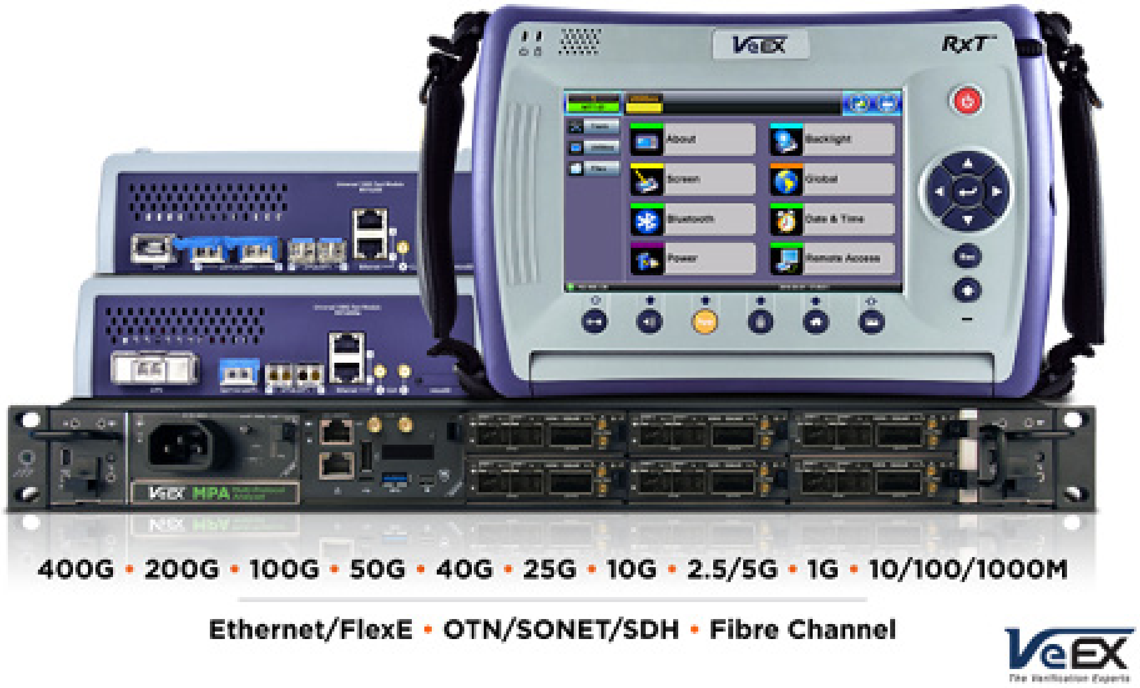


FIGURE 5. *Data center operators require flexible traffic generators and analyzers to test multiple port rates and interfaces.*

as frame-size (MTU) performance. The RFC 2544 and Y.1564 industry standards specify the parameters subject to test and the protocols for evaluating them.

FEC BER Performance

It is mandatory for the new Ethernet standards using PAM4 to support FEC. PAM4 implementations typically use the KP-FEC, which follows the Reed Solomon RS-FEC (544) algorithm. This FEC supports the correction of up to 15 single bit errors or up to 150 bit burst errors. It is critical to characterize the FEC and signal quality performance of switches, routers, optical transceivers, and interconnect cables. It is also beneficial for test equipment to manually inject errors to verify the FEC layer performs the proper bit error correction to maintain performance objectives.

Optical Modules and Interconnect Verification

Pluggable transceivers, especially first-generation products, may be a source of failure in the network as modules are getting smaller and more complex to accommodate the higher bit rates. These modules need to be evaluated prior to deployment to ensure that they meet specifications. Key characteristics include proper thermal cooling, BER performance, and optical power level, both in terms of output and received power. The programming and read-write operation of the MDIO and I2C registers should be verified. It is also important to check input power tolerance and the overall power consumption of the module. Finally, the line clock thresholds of the high-speed lanes need to be evaluated.

All cabling interconnecting the new port rates, whether optical fiber or direct attached copper (DAC) cabling, needs to be tested to guarantee proper operation.

Flex Ethernet Layer Verification

New FlexE deployments will require comprehensive testing to ensure proper equipment performance and service delivery. Test equipment must be capable of simulating and monitoring the various FlexE client types, including the new variable Nx25G option, over various FlexE PHY port rates such as 100 Gigabit Ethernet (GbE).

Testing must include verification of the new FlexE layers such as the TDM shim layer, which aggregates and distributes the Ethernet clients over multiple PHYs. A 100GbE PHY is capable of supporting up to 20 independent 5G channels of data.

The management overhead layer will also need to be verified to ensure proper response to network conditions including proper identification and response to network alarm and failure events. There are also management communication channels defined in the overhead layer, which may be used for end-to-end communication between FlexE equipment and must be verified before placed in operation.

The new FlexE layers must be properly configured and proven to ensure the proposed management and bandwidth efficiency gains are obtained.

Additional Test Equipment Requirements

The new network paradigm, coupled with rapidly changing hardware and protocols, puts special demands on data center operators and the test equipment they use. Engineering and operating the systems are difficult enough - test equipment should be able to meet the technical challenges and simplify the process.

For starters, equipment must be capable of testing components and systems at the new port rates. Optical networking is not a “one-speed-fits-all” proposition. The optimal data rate differs depending on the function, budget, and even age of the network. As it’s financially impractical to buy separate test gear for each speed, equipment must be multifunctional so that it can be used throughout the network as required.

Similarly, the equipment needs to be able to accommodate multiple pluggable form factors. The ideal platform is built around pluggable modules that enable new features and ports to be added when required. This “pay-as-you-go” approach enables test equipment to adapt to the evolving technology.

Traffic generators and analyzers should be designed to provide flexible, high-density traffic generation. It is also useful to have equipment capable of multi-port traffic generation and analysis for high-density and aggregation applications.

Finally, ease-of-use should not be underestimated. Easy configuration speeds set up. Automated test increases repeatability and reliability of results. Installing and maintaining the network may be challenging but the test aspect of it does not have to be.

Conclusion

From software to hardware, port rates to optical modules, the data communications industry is in a radical state of flux. New business models are forcing data centers to become more efficient and expandable. The new hardware and software trends demand the availability of flexible instrumentation to support new product development and network operation. Existing test equipment toolboxes need to be refreshed to be able to support the new technologies that are being deployed. Although some new high-speed network technology may not see broad adoption immediately, data centers need to prepare for the future. The right test equipment will help them do just that.

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