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ECOC LOOKS TO THE FUTURE

Welcome to the Autumn 2024 edition of Optical Connections. ECOC is upon us once again offering a wide range of new products and presentations ranging from FTTx rollout to photonics. Most of all, it provides a glimpse of the future of this exciting industry. In this issue, we aim to echo some of the developments taking the industry going forward, with thought leadership features by industry experts and leading journalists in the field.

Ultra high-speed chip-to-chip optical communication is becoming a critical area of development to meet the demands of AI and ML, and in this issue, we look at two different approaches to these challenges by Intel's **Christian Uricarriet** and Avicena's **Dr Jess Brown**. Pluggables are also a rapidly developing sector, and we talk to **Laurent Hendrichs** and **Pete Del Vecchio** at Broadcom, about the rise of Linear Pluggable Optic transceivers. In addition, Infinera's **Fady Masoud** takes a deep dive into the rise of intelligent pluggables. However, the onset on AI and ML means greater demands on physical space in access points and data centres, and R&M's **Thomas Ritz** and **Andreas Rüsseler** look at high-density infrastructure as a possible solution.

In addition, long-time telecoms writer **Antony Savvas** takes a look at how companies are leveraging AI to solve new test and measurement challenges, and veteran journalist **John Williamson** talks to **Ian Alderdice** and **Gary Nicholl** at the OIF, about the development of the Common Management Interface Specification (CMIS), so crucial for commonality in managing pluggable modules. Another challenge facing the industry is the speed with which fibre can be rolled out to homes and premises across the world, and Nokia's **Filip D Greve** explains how Software Defined Access Networks (SDAN) can meet this and many other challenges. Of course, with the literally millions of connections and splices involved in next-gen fibre networks, cleanliness is of vital importance and MicroCare's **Liam Taylor** debunks some of the most common fibre optic end face cleaning myths, and provides insights into best practices. All this, along with the usual features is a great curtain-raiser for what will be on display at ECOC 2024. Have a great show!

Peter Dykes

Contributing Editor

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Optical Connections is published by
NEXUS MEDIA EVENTS LTD
Suite 3, Building 30, Churchill Square, Kings Hill,
West Malling, Kent ME19 4YU
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Cloud operators drive adoption of converged architecture

Cloud Operator Datacentre Interconnect (DCI) is propelling high volume adoption of coherent pluggable optics, according to the latest Active Insight report, IP-over-DWDM Pluggables Forecast, from research firm Cignal AI. The analyst says IP-over-DWDM, which is the practice of using coherent optics directly within routers and switches, has transformed how Cloud Operators connect their data centres over short distances. The standardization, development, and maturation of 400G pluggable coherent optics (400ZR) has fortuitously coincided with the ongoing AI spending boom, with

volumes increasing faster than any previous DWDM technology.

The report also finds that Cloud Operators, predominantly the big four hyperscalers, will continue to be the driving force behind the technology and volume of pluggable coherent transceivers, and that 400G purchases by Cloud Operators will peak in 2026 once the adoption of 800G and 1600G begins. In addition, it finds that the performance gap between embedded and pluggable optics will further shrink with 1600G, making IP-over-DWDM even more attractive from a network design perspective. However, the

rate of adoption for IP-over-DWDM will be slow and steady. Despite the operational hurdles, the technology's space, power, and cost benefits will justify the change in architecture for many operators.

"The market for router-hosted pluggables is already sizeable, but it will continue to further grow as operational issues are solved and new generations of optics evolve," said Kyle Hollasch, lead analyst at Cignal AI. "The uptake of IP-over-DWDM will vary significantly between Cloud Operators and traditional Service Providers, as will the preferences for the speed and module type."

IP-over DWDM Pluggables

Forecast is part of Cignal AI's Active Insight research service and leverages data from the Optical Components and Transport Hardware reports. This Active Insight report provides forecasts for IP-over-DWDM module deployment by operator type (Cloud, Traditional Service Provider, Enterprise and Government) and coherent module speed (400G, 800G, 1600G).

Active Insight reports provide real-time reporting on important developments in the optical market, including detailed analysis of key product trends, show reports, summaries of quarterly earnings calls, and vendor reports.

PCIe Consortium Releases 2.0 Specification

The Universal Chiplet Interconnect Express™ (PCIe™) consortium has announced the release of its 2.0 Specification. The PCIe 2.0 Specification adds support for a standardised system architecture for manageability and holistically addresses the design challenges for testability, manageability, and debug (DFx) for the SiP lifecycle across multiple chiplets – from sort to management in the field. The introduction of optional manageability features and a PCIe DFx Architecture (UDA), which includes a management fabric within each chiplet for testing, telemetry, and debug functions, allows vendor agnostic chiplet interoperability across a flexible and a unified approach to SiP management and DFx operations.

The PCIe 2.0 Specification includes holistic support for manageability, debug, and testing for any System-in-Package (SiP) construction

with multiple chiplets; improved system-level solutions with manageability defined as part of the chiplet stack; and fully backward compatibility with PCIe 1.1 and PCIe 1.0. Additionally, the 2.0 Specification supports 3D packaging – offering higher bandwidth density and improved power efficiency compared to 2D and 2.5D architectures. PCIe-3D is optimised for hybrid bonding with a bump pitch functional for bump pitches as big as 10-25 microns to as small as 1 micron or less to provide flexibility and scalability. Another feature is optimised package designs for interoperability and compliance testing. The goal of compliance testing is to validate the main-band supported features of a Device Under Test (DUT) against a known- good reference PCIe implementation. PCIe 2.0 establishes an initial framework for physical, adapter, and protocol compliance testing.

Nokia first to self-certify fibre products for use in BEAD

Nokia says it has become the first technology vendor to self-certify its fibre products manufactured in the U.S., ensuring each meets the requirements outlined in the recently announced BABA compliance and self-certification guidelines for the BEAD program. BEAD Applicants can now obtain a Certification Letter from Nokia to prove BABA compliance. The products include Nokia's FX and MF OLT modular product lines, the SF-8M sealed OLT, and the XS-220X-A ONT.

Operators and infrastructure players seeking to participate in BEAD and the US\$42.45bn of available funding will need to ensure – under federal penalty – that certain fibre broadband equipment used in their network buildouts are manufactured in the U.S. To help, the NTIA created a self-certification and compliance framework for manufacturers, allowing each to show its products meet these requirements.

Manufacturers that complete the self-certification process are added to a list managed by the Department of Commerce. Focused on reducing the number of fraudulent claims of BABA compliance, the list requires manufacturers to have an officer of the company certify – under fine or imprisonment – that its products are Buy America-compliant. Manufacturers must also be able to provide a BABA certification letter to subgrantees for audit purposes.

Sandy Motley, President of Fixed Networks at Nokia, said, "We are excited to announce yet another milestone in our BEAD journey. As a certified vendor, we can now provide BEAD applicants with a certification letter that's become essential for applications and BABA reporting requirements. It also provides the confidence and assurance several need to submit product orders today without fear of being out of compliance."



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LINEAR PLUGGABLE OPTICS: A REVOLUTION IN THE MAKING?

Linear Pluggable Optics (LPO)s is revolutionising the way data centres, telecommunication networks, and enterprise IT infrastructures manage and transmit data. This cutting-edge technology leverages modular optical transceivers, which have a number of advantages including lower power consumption and greater reliability than those currently in use. *Optical Connections* editor **Peter Dykes** spoke with **Laurent Hendrichs**, senior product line manager of high-speed Ethernet adapters and **Pete Del Vecchio**, Data Centre Switch Product Line Manager at Broadcom, to find out more about this emerging technology.

PD What factors are driving the development of LPO?

LH It depends on who you ask. Hyperscalers view it as a way to improve AI compute density by reducing the power consumed in the network, thereby leaving more power available for GPUs. Network reliability is a second driver. Simpler modules with fewer active components are inherently more reliable than conventional designs. However, more importantly, the lower power of LPO transceivers enables them to run at lower temperatures, which considerably improves reliability. Broadcom estimates a 3x improvement in MTTF (Mean time to failure) for LPO vs conventional optics. Server vendors like LPOs for their low power consumption. This is especially important for network adapters deployed in hot-aisle configurations, where the optics are cooled by hot exhaust air coming from inside the server. In such configurations, it is particularly challenging to cool conventional optical transceivers. LPO transceivers, in contrast, require much less cooling airflow due to their lower power. Broadcom estimates that LPOs offer up to 40-60% power reduction over conventional equivalents. Finally, cost-sensitive users appreciate the lower cost of LPOs made possible by the elimination of the DSP inside the module.

PD What are the main technical differences between LPO and pluggables in common use today (e.g. ZR, ZR+ etc)?

LH The essential difference is the elimination of the DSP from the optical module made possible by the advanced capabilities of the SerDes in the latest generation of Ethernet NIC and switch ASICs. As an example, Broadcom has included in their recent SerDes design features that were previously only found in optical DSPs. With LPO transceivers, equalisation or reconditioning of the signal is therefore done inside the NIC or switch ASIC.

PD Is it possible to mix LPO and existing pluggables?

LH Yes. Broadcom and multiple other equipment vendors have demonstrated the feasibility of deploying LPO transceivers on one side of the link and conventional transceivers on the other side. This is the focus of Optical Internetworking Forum (OIF). An OIF-compliant LPO module will be fully compatible with the existing optics ecosystem.

By contrast, the LPO MSA focuses on LPO-to-LPO links, allowing for lower power, lower cost, and better end-to-end link performance by removing the constraint of compatibility with retimed optics.

PD What sort of throughput speeds can LPOs achieve currently and in the future?

LH 800G and 400G LPO transceivers are available today. The current target of OIF and the LPO MSA is 100G serial links. Work is already in progress, however, for 200G serial.

PD Where does LPO fit into the future marketplace for pluggables?

LH We expect to see multiple technologies coexist in the market. There will be use cases for LPO, Linear Receive Optics (LRO), Co-packaged optics (CPO), and retimed optics. Adoption of a particular technology will result from a trade-off between performance and the imperative need to reduce connectivity power as SerDes speeds increase and AI servers pack ever more compute density.

Module vendors such as Eoptolink are already offering commercially available LPO transceivers. A selection of LPO transceivers will feature on the module compatibility list of server vendors. Hyperscalers who typically prefer to use cables will likely adopt Active Optical Cables (AOC), in which one or both transceivers will use the LPO technology.

PD Will DSPs still have a role in optical transmission if LPO becomes widely used?

LH Yes. DSPs will continue to offer more advanced signal processing capabilities than those available in Switch and NIC ASICs. Cables exceeding a certain length will continue to require DSPs to achieve an acceptable Bit Error Rate.

PD How is the MSA group progressing LPO and what is the future roadmap?

PDV The LPO MSA work is under NDA and only limited information is made available to the public. The MSA focuses on optimising LPO-LPO links. Free from the compatibility constraints with non-LPO transceivers, the MSA's aim is to offer the lowest cost and power for a given performance level. Future work in the MSA will include standards for LRO. (Linear Receive Optics = half-retimed optics).

Is Broadcom working on a particular aspect of the MSA? Broadcom is a founder and active contributor working on all aspects of the MSA. Peter Del Vecchio, who manages the Tomahawk product line, is co-chair. Karl Muth, a senior engineer in Broadcom's switch business units, is editor for the specification.

PD Do you think LPO is a small step or a quantum leap in pluggable transceiver technology?

LH What we see is a spectrum of connectivity technologies, with different power, performance and cost merits. The LPO technology fills a gap between passive copper cables and retimed optics. Other technologies such as co-packaged optics (CPO) offer even lower power and cost than LPO. Power, reliability and cost are three major technical challenges impacting the deployment of AI networks. Passive copper cables offer by far the best technology over short distances, as they draw almost no power, are several orders of magnitude more reliable than active cables and are unbeatable from a cost point of view. But passive copper cables

only go so far, as their length is limited to 2 meters in the IEEE standard. However, the latest generation of Broadcom Ethernet ASICs supports passive cables up to 5 meters. Beyond that, optical cables are required. LPOs represent a mid-way technology, as they are not as good as passive copper cables, but significantly better than conventional optics in terms of power, reliability and cost. Given their sizable benefits and absence of any major shortcomings, we expect to see widespread adoption of LPOs over the coming years.

PD Thank you. ☺



Laurent Hendrichs
Senior Product Line Manager of high-speed Ethernet adapters



Pete Del Vecchio
Data Centre Switch Product Line Manager at Broadcom

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UNLOCKING AI'S POTENTIAL: THE IMPACT OF OPTICAL CONNECTIVITY ON LARGE LANGUAGE MODELS

Christian Urricariet, Senior Director of Product Marketing for Integrated Photonics Solutions at Intel, looks at how Generative AI and large language models are driving unprecedented requirements on AI infrastructure and its ability to keep up with model sizes. New interconnect technologies are necessary to enable massive scaling of bandwidth as well as clusters and fabric. Connectivity in the form of a new class of optical interfaces offers a solution that provides high-bandwidth, low-latency GPU links at a cost and power efficiency that is scalable. As an example of this emerging segment, Intel's Optical Compute Interconnect (OCI) chiplet recently demonstrated shows us a glimpse of the future – Compact, power-efficient co-packaged optical I/O with performance to enable scaling of AI resources.

In the field of artificial intelligence, the development of large language models (LLMs) has been a game-changer, enabling a range of complex applications that can understand and generate human-like text. However, the computational demands of these models, which can have tens of billions of parameters or more, are immense. Training and running such models require distributing tasks across many GPUs, which often leads to inefficient utilization due to the memory-intensive nature of the workloads. To address this, larger batch sizes are used, but this solution introduces latency and requires even more GPUs to maintain parallel processing efficiency.

The traditional approach of simply scaling up the number of GPUs is not without challenges. High-density GPU configurations consume significant power and necessitate specialized cooling solutions and infrastructure. Even less dense systems are limited by the performance constraints of copper interconnects and require additional

switching levels for larger deployments.

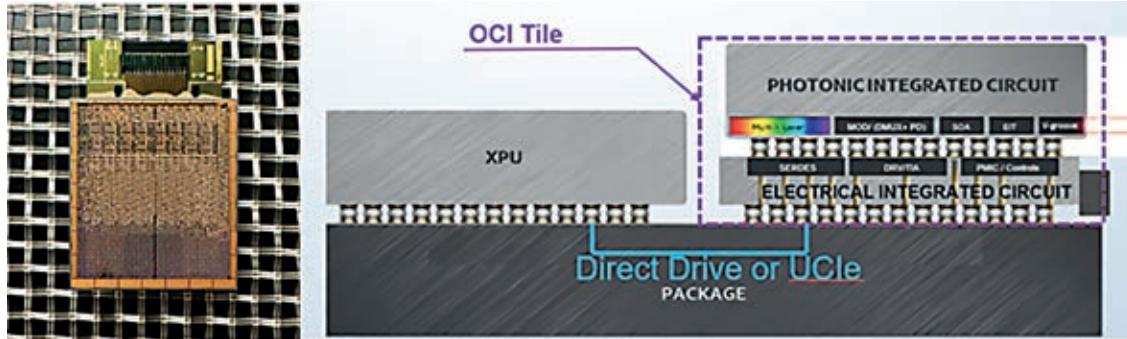
Optical connectivity has emerged as a promising solution to these limitations. It provides high-bandwidth, low-latency connections between GPUs, which not only lowers power consumption but also facilitates better cooling and more efficient data transfer. This advancement is poised to accelerate the training and inference of LLMs by enhancing latency, throughput, and GPU utilization. Moreover, it allows for more flexible GPU placement, which is essential for reducing power and thermal loads, thereby improving the total cost of ownership.

Kernel parallelism, which distributes computations across multiple GPUs, greatly benefits from optical connectivity. The reduced latency in communication between GPUs leads to improved performance and efficiency, making it possible to train larger and more complex AI models.

Despite the potential of optical connectivity, the current generation of pluggable optical transceiver modules used in data centers and early

AI clusters cannot meet the scaling requirements for emerging AI workloads due to their size, cost, and power consumption. New integrated optical connectivity solutions co-packaged with GPUs are required, which can provide the higher bandwidth density, energy efficiency, low latency, lower cost, and extended reach needed for scaling AI infrastructure.

These so-called Optical Compute Interconnect (OCI) applications can be enabled by aggressive integration along three different vectors. Firstly, increased integration at the PIC level, including on-chip DWDM lasers and SOAs to efficiently support scaling through increases in the number of wavelengths, larger number of fibers, and optionally on-chip laser sparing. The use of silicon photonics process technology for the PIC leverages the existing high-yielding and scalable manufacturing and testing infrastructure from CMOS processes, and the hybrid integration of the laser on chip allows the delivery of fully tested, Known-Good-Die (KGD), for



Intel Optical Compute Interconnect (OCI)

Intel OCI Chiplet

maximum yield. Integrating the laser and SOA at wafer-scale results in minimal coupling losses for improved performance, lower cost due to the lack of laser back-end, and greatly improved reliability compared to discrete lasers.

An alternative approach to on-chip integrated lasers is to use an External Laser Source (ELS) where the lasers are independently packaged and connected to the PIC via multiple optical connectors and fiber assembly. This adds significant cost and complexity to the design, greatly increasing the transmitter output power needed, and typically requiring the use of specialized Polarization Maintaining Fiber (PMF). Although this approach may provide some heat management benefits in some implementations, we believe these will be more than offset by its disadvantages as well as by the improvements in fully integrated device performance and manufacturing process described later in this article.

The second vector is the heterogeneous integration of the PIC with the EIC, using advanced packaging to create the die stack or chiplet. Heterogeneous integration decouples improvements implemented on the EIC from the PIC, and it allows leveraging Moore's Law to use the best CMOS IC node suited for each application.

Thirdly, tighter integration with the host CPU/GPU through system-level packaging co-designs that maximize yield by using known good components, which are themselves fully integrated and tested. The transition from direct attachment of a fiber pigtail to a pluggable, reusable optical connector will result in reflow-compatible assemblies and simplify system-level fiber management and handling. It enables the realization of the photonics-chiplet equivalent of the CMOS KGD concept: A complete optical I/O subassembly including laser sources and optical termination, which is tested and characterized before it flows downstream for integration with

high-value GPU packages.

Intel Corporation has made a significant breakthrough in this space with the demonstration of a fully integrated OCI chiplet at OFC 2024. This first chiplet was shown co-packaged with an Intel CPU, running an error-free PCIe Gen5 link over fiber. It is designed to support 64 channels of 32 Gbps data transmission in each direction (4Tbps aggregate) over fiber optics up to 100 meters. The current chiplet's energy efficiency of 5pJ/bit is significantly lower than current pluggable optical transceiver modules.

Looking ahead, Intel has an aggressive development roadmap to scale the performance of future OCI chiplets, with the potential to reach 32 Tbps bandwidth and a shoreline density greater than 1.5Tbps/mm in the next few years by increasing line rate per channel, wavelengths per fiber, number of fibers, and polarization modes. The technical challenges that need to be solved include thermal management, advanced package design, and power delivery. Intel is addressing these challenges by considering standardized die-to-die (D2D) electrical interfaces that facilitate integration with a variety of hosts. The company is also working on improving the performance and reducing the device size (which directly impacts the economics significantly) and power consumption in future OCI chiplets through more advanced designs and the implementation of next-generation manufacturing process nodes for both the PIC and the EIC.

Intel's leadership in silicon photonics is well established, with over 25 years of research and development leading to the shipping of many millions of silicon photonics-based connectivity products into the hyperscale cloud data centers with proven high reliability (<0.1 laser FIT). Our mature platform has demonstrated the ability to increase functionality on-chip through increased component integration, from less than 100 devices/PIC in 2016 to about 2,000

devices/PIC today. The company's integration approach of using hybrid laser-on-wafer technology results in higher reliability and lower costs, setting Intel apart from the capabilities of most competitors.

The path to fully implementing integrated optical connectivity solutions in AI clusters is not without challenges. Reducing the cost of optical components and efficiently integrating these solutions into existing data center infrastructure requires ongoing investment and effort. However, the current technology path promises to revolutionize the training and inference of LLMs by overcoming the limitations of current hardware and infrastructure, leading to unprecedented advancements in AI. ☺



Christian Urricarriet is Senior Director of Product Marketing for Integrated Photonics Solutions at Intel. For more information, visit www.intel.com/siliconphotonics

MULTI-TERABIT µLED BASED INTERCONNECTS: UNLEASHING THE POTENTIAL OF HPC AND AI.

The demand for processing power in HPC (High Performance Computing), AI (Artificial Intelligence) and ML (Machine Learning) is increasing at an unprecedented rate and although Moore's law isn't happening anymore, by its strictest definition, it is still delivering steady improvements in processor performance, albeit at a slower pace. However, the same improvements are not being seen for the chip-to-chip and chip-to-memory interconnect technology, where there is an ever-widening gap between the needs and the reality, writes **Dr Jess Brown**, Business Development, Avicena.

The growth in Large Language Models (LLMs) has completely outpaced the increase in memory bandwidth for in-package high-bandwidth memory (HBM) stacks, as shown in Figure 1. In fact, over the last 5 years LLM parameter count has grown by several orders of magnitude, whereas HBM memory bandwidth has only grown by one order of magnitude.

Electrical interconnects have fundamental limits in terms of reach, size and power efficiency, especially at higher data rates, which is causing this disparity. Therefore, there is a need for low power, compact, short-reach, fast link technologies at a reasonable price point. This article delves into the revolutionary realm of optical links based on GaN µLEDs, offering a transformative approach to chip-to-chip interconnects that promise unparalleled levels of ultra-low power consumption, exceptional bandwidth density, and minimal latency, which is in stark contrast to existing SerDes-based solutions.

INTERCONNECTS: THE OPTIONS

There are two types of interconnect base technologies available: electrical and optical. The diagram below (Figure 2) shows a Figure-of-Merit (FoM) for these two types of technology in different configurations. The FoM plots the product of bandwidth density and energy efficiency against link reach, from 0.1mm to 1,000m. For short reach communications (<10cm) electrical links still currently offer the best performance, whereas for long distance communications (>10m), conventional optical technologies offer the best



Figure 1: LLM Parameter Count Outpacing Memory Bandwidth.

performance, but for the middle range of 1cm to 10m neither offers optimum performance.

Existing multi-mode Vertical-Cavity Surface-Emitting Laser (VCSEL) based links, although well suited for distances up to 100m, are not ideal for shorter optical interconnects, primarily because high-density processors run at elevated temperatures and VCSELs have a limited tolerance for high temperature operation.

Silicon Photonics (SiPh) represent another optical link technology under development and evaluation. However, these were originally developed for medium to long-haul applications, which translates to SiPh interconnects having poor efficiency performance (>5pJ/bit) for short reach interconnects. Moreover, both VCSEL and SiPh based links typically use Serialisers/De-serialisers (SerDes), discussed in the next section, to achieve the high link bandwidth of > 100Gbps per

lane, which adds a significant overhead in terms of power.

Therefore, there is currently a gap between electrical and existing optical solutions, since these technologies cannot provide an optimum solution for on-board data transfer, typically in the 1cm to 10m distance, which is the range for most chip-to-chip interconnects. Avicena's technology can fill this void and provide advantages with an optical µLED based interconnect chiplet, offering ultra-fast, low-power interconnects that bridge the gap between internal processing performance and chip-to-chip communications, for interconnects that reach up to 10m.

TO SERDES OR NOT TO SERDES

Distributed data processing needs high speed data transfer between ICs, whether that is between the processors, between the processors and memory, or both.

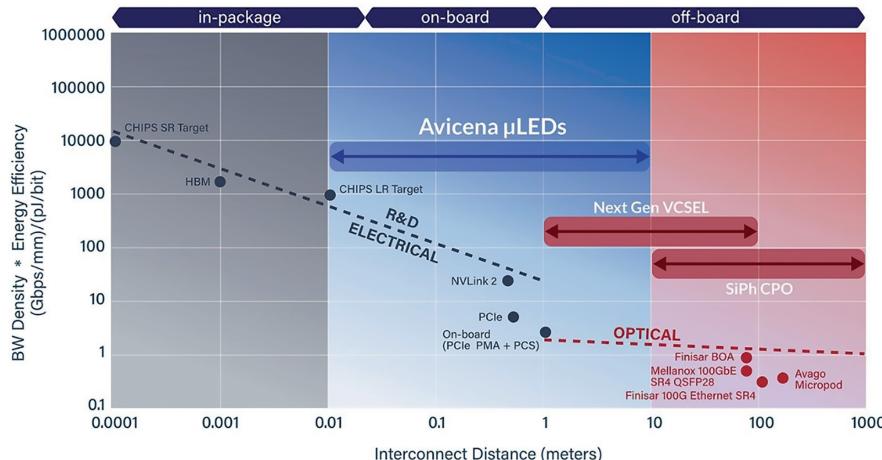


Figure 2: The merit for bandwidth density and energy efficiency vs reach.

Parallel and serial communications are the two options to transfer data between these chips. Parallel data transfer requires multiple connections between ICs, whereas serial data transfer only needs one pair of connections. On-chip communications is typically completed in a parallel format, so to enable serial interconnects a Serialiser-Deserialiser (SerDes) function block providing parallel to serial and serial-to-parallel conversion is required to enable serial communication between the two blocks. The transmitter section is a parallel to serial converter and the receiver section is a serial to parallel converter and most devices offer full-duplex operation, i.e. data in both directions at the same time.

The reason for SerDes is to reduce the number of data paths needed to transmit data (and the associated number of connecting pins or wires) while achieving high link bandwidth. It additionally addresses other issues that come with transmitting parallel data electrically, such as susceptibility to electromagnetic interference and the likelihood of clock timing skew. A SerDes chip might also include an encoder, clock multiplier unit, physical coding sub-block, clock and data recovery unit, input and output staging areas, Forward Error Correction (FEC) blocks and other components.

For long distance optical links there are clear advantages for using SerDes based interconnects because they minimise the number of costly, laser-based transmitters. However, when connecting ICs over distances of up to a few meters, there are clear advantages of using parallel links because ICs feature wide and relatively slow buses with clock speeds of a few Gbps internally.

Avicena have developed an optical solution, using μLEDs, that overcome the disadvantages of SerDes, but still employ optical technology to gain all the associated benefits. Removing the need for SerDes, Avicena's LightBundle™ consists of an array of GaN μLEDs and Si PDs bonded to a transceiver ASIC. The μLEDs are connected via a fibre

bundle to the matching array of PDs on the corresponding receiver transceiver ASIC and vice versa. A typical LightBundle link has a few hundred channels each operating at a few Gbps, providing aggregate throughputs of > 1Tbps per link. The modest per-channel speeds are well-matched to typical IC clock speeds and obviate the need for SerDes and enable the most efficient optical links at <1pJ/bit. GaN μLEDs are already used in free-space Visible Light Communications (VLC), but at limited data rates. Avicena have managed to develop μLEDs that can operate at data rates of over 10Gbps. With this patented technology it has been demonstrated that not only can these μLEDs be modulated at high data rates, but they can also achieve bandwidth densities of > 2Tbps/mm with a power efficiency of < 1pJ/bit. The LightBundle transceiver chiplet can be either co-packaged with the processor using a silicon interposer or an organic substrate or it can be placed on the board and connected to the processor IC package via PCB traces. The only thing that changes in the different applications is the electrical interface between the LightBundle IC and the processor IC.

Fundamentally, any electrical interface can be supported by the LightBundle interconnect. The LightBundle transceiver ASIC will convert the electrical data format to match the optical μLED transmission format. Parallel electrical interfaces are best suited to work in combination with the parallel optical μLED array interface of the LightBundle chiplet since no power hungry SerDes will be needed.

The IC will either match the electrical lane rate to the data rate of each

individual μLED link or provide a simple muxing/demuxing function to keep latency and energy consumption to a minimum. A prime candidate for the electrical interface is the Universal Chiplet Interface Express (UCIE) which is gaining broad industry support, but other protocols like BoW or the emerging UALink are possible as well.

Table 1 compares the advantages and disadvantages of parallel versus SerDes as well as the option of Avicena's μLED optical solution and it can be seen here that Avicena's LightBundle solution offers the best solution for chip-to-chip communications and interconnects.

	Parallel Electrical Interconnects	Serial Electrical Interconnects	Serial Optical Interconnects	Parallel Optical Interconnects using μLED
Power Consumption	High power when reaching outside of package	High power for longer reach	Medium power for longer reach	Low power for medium reach
	Typ. >10pJ/bit <30cm	Typ. 10pJ/bit <2.5m	Typ. 5pJ/bit for SiPh <500m	Typ. <1pJ/bit <10m
Bandwidth Density	• 1Tbps/mm in package • 250Gbps/mm	250Gbps/mm	1Tbps/mm	>2Tbps/mm
EMI Performance	Susceptible to EMI when reaching beyond 1cm	Can be susceptible to EMI	Robust to EMI	Robust to EMI
Skew Requirements	Skew balancing difficult	Skew balancing adds complexity and power consumption	Skew balancing adds complexity and power consumption	Low skew and balancing achieved with low power consumption
Latency	Very low latency	SerDes adds latency	SerDes adds latency	Very low latency
Cost	Low cost	Medium cost	High cost	Low cost

Table 1 Comparison of Parallel, Serial and μLED Optical Interconnect Solutions.

CONCLUSION

Due to the limitations of traditional SerDes based optical interconnects the HPC, AI and IC industry is constantly evaluating innovative solutions to enable high bandwidth density, high energy efficiency and low latency interconnects for short to intermediate reach of up to a few meters. μLED technology, renowned for its application in high-resolution displays and lighting systems, has demonstrated the potential to redefine the landscape of data communication at the chip level. By combining the intrinsic advantages of light as a medium for data transmission with the 2D layout of LED arrays, μLED based optical links present a ground-breaking avenue for achieving previously unattainable levels of performance in interconnect architectures. ☺



Dr Jess Brown, Business Development, Avicena.

OIF: CMIS OVERVIEW AND ROADMAP



Work by OIF on expanding the already substantial remit and utility of the Common Management Interface Specification (CMIS) is gathering speed. Optical Connections' **John Williamson** interviewed OIF to discuss the origins, necessity and future plans of this crucial optical interface standardisation effort. **Ian Alderdice**, OIF Physical and Link Layer Working Group – Management Co-Vice Chair and Ciena and **Gary Nicholl**, OIF Physical and Link Layer Working Group – Management Co-Vice Chair and Cisco kindly provided detailed, joint responses to the questions.



How, when and where did the CMIS originate?



CMIS originated in the Quad Small Form Factor Pluggable-Double Density Multi-Source Agreement (QSFP-DD MSA) advisor's group, led by a small group of management experts to harmonise the management interface for the new QSFP-DD and Octal Small Form Factor Pluggable (OSFP) module form factors. The original group published CMIS 3.0, the first public version of CMIS, in 2018. They updated and maintained the CMIS specification up to and including CMIS 5.1 when ownership transitioned to OIF.



Why did the OIF adopt the CMIS, and what OIF initiatives does it slot into?



The QSFP-DD MSA initiated the CMIS effort to address an industry need for commonality in managing pluggable modules, and it was broadly and successfully adopted across the industry. Adopting CMIS to build on and extend the specification was an ideal expansion of OIF's work.

OIF has always strived to provide useful interface standards that further optical module interoperability. In the past, these standards have primarily been focussed on optical and electrical interfaces, but the management interface is also required to build inter-operable optical modules.



What does the CMIS aim to facilitate?



CMIS provides the required tools to manage optical modules in a common way. Common interfaces reduce development effort and integration time, leading to faster market introduction of new technologies. The team that maintains and updates CMIS draws on industry experts from module vendors, host vendors and service providers, leading to a specification that addresses the needs of all layers of the optical module ecosystem.



In this context, how does the OIF operate/work to advance the CMIS standard?



The OIF management track advances CMIS through regular updates to the standard that are driven by member companies. Member companies can submit project start contributions for major work items or technical contributions for small/medium work items. These contributions are reviewed by the management track team during OIF quarterly meetings for project starts and weekly meetings for technical contributions. If the team accepts a work item, the item will ultimately be included in a new draft of the CMIS specification which then follows the standard OIF balloting and comment resolution process.

In addition, OIF uses white papers, industry conferences and webinars to discuss CMIS-based topics. Leaders from OIF are regulars on conference panels, discussing various management topics. The team has published, and will continue to publish white papers on management challenges, solutions and visions for the future. OIF is hosting a series of webinar tutorials that provide technical education on various CMIS topics, with each webinar drawing hundreds of participants. Details of OIF webinars are available from the organisation's website.



Why do we need the CMIS?



A single common management interface reduces development effort for host and module vendors, leading to faster technology introduction. Common code bases allow for faster module integration and higher software quality. Reduced module integration times benefit service providers by reducing operational expenses and accelerating end-product time-to-market.



Is the CMIS application space expanding?



Yes, CMIS is continually evolving to add new applications and functionality. Some changes are more incremental like adding support for



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- IP-68 rated
- Up to 450N pulling force
- UV and weather-resistant materials

EASY TO USE

- Small 19mm diameter housing paired with push-pull boot enables tight connector spacing
- Blind-mate features on housing prevent ferrule contamination and damage

DIRECTCONEC™ BOOT

- Push-n-click insertion enables simple and secure installation
- Twist-to-release extraction using only the boot, allowing easy, one-handed removal, even with gloves



Common interfaces reduce development effort and integration time, leading to faster market introduction of new technologies.



Fibre Channel and coherent optics. Other additions are much larger like the addition of link training functionality and support for co-packaged optics.

JW **What are a couple of important OIF CMIS achievements/milestones so far?**

OIF Publishing the first version of CMIS under OIF was an important milestone. CMIS 5.2 was released quickly, showing that OIF's process can meet the timing needs of the industry. CMIS 5.2 provided Fibre Channel enhancements that were important to that industry segment and showed that the OIF management track was servicing all types of optical modules.

The CMIS interop demos and CMIS webinars have both been successful in sharing technical information on how CMIS works with the broader industry. Through these events, OIF has raised awareness of what CMIS is and how it works.

JW **How widely is CMIS being adopted and what plans are in place to further adoption?**

OIF CMIS has been chosen as the management interface for nearly all new optical module projects in the past few years. CMIS is the management interface for the QSFP-DD and OSFP module form factors, which together represent the majority of the optical module market for 400Gbps and 800Gbps data rates. This is due to the strong technical underpinnings of the specification and the willingness of the OIF team to evolve the specifications to meet the needs of new technologies.

Looking forward, OIF has been active in preparing for the management needs of future optical modules. Current contributions and projects are considering the addition of higher-speed management interfaces, including Improved Inter-Integrated Circuit (I3C) and Gigabit Ethernet. In addition, there have been multiple contributions and discussions about moving from a register-based interface to an object-based/message-based interface.



What are the challenges to further adoption?



The transition to new interfaces and concepts will be the biggest challenge for CMIS. Such as convincing host and module vendors to add new interfaces like I3C and Ethernet to host sockets and modules across the industry and changing to a message-based solution. Finding a transition plan that supports the existing management interface and allows the industry to move towards future management interfaces will be a challenge.



What work is currently underway on the spec and what is the future roadmap?



CMIS 5.3 is in the final stages of being published and work is beginning to define content for the next version. Coherent-CMIS (C-CMIS) is about to start a new version adding support for 800G/1600G. Link training will be an active area in the coming years as electrical interfaces

continue to increase in speed. Co-packaging is a new area for CMIS and will likely evolve in the coming years. Support for Linear-drive Pluggable Optics (LPO) and Retimed Tx Linear Rx (RTLX) optics are being added. Work on transitioning the industry to higher speed management interfaces like I3C and Ethernet is on-going.

Readers may be interested in two OIF CMIS-related White Papers announced in June 2024. One is a CMIS White Paper on Management of Smart Optical Modules and the other deals with CMIS-Based Out-of-Band Messaging for Link Training.

OIF white papers are not standards but are intended to identify industry challenges, understand requirements and stimulate discussion on potential solutions. The outcome of a white paper may or may not lead to an OIF project.



Ian Alderdice

OIF Physical and Link Layer Working Group – Management Co-Vice Chair and Ciena



Gary Nicholl

OIF Physical and Link Layer Working Group – Management Co-Vice Chair and Cisco

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SOFTWARE-DEFINED ACCESS NETWORKS

UNLOCKING THE POTENTIAL OF FTTH IN A COMPETITIVE LANDSCAPE

The rush to roll out FTTH coverage and provide a range of services has created a number of issues for network operators, including network overbuild, demands for higher bandwidth, lower latency, and the need to control costs. In this article, **Filip De Greve**, Product marketing Director for Nokia Fixed Networks explains how Software-Defined Access Networks (SDAN) can meet these, and many other challenges.

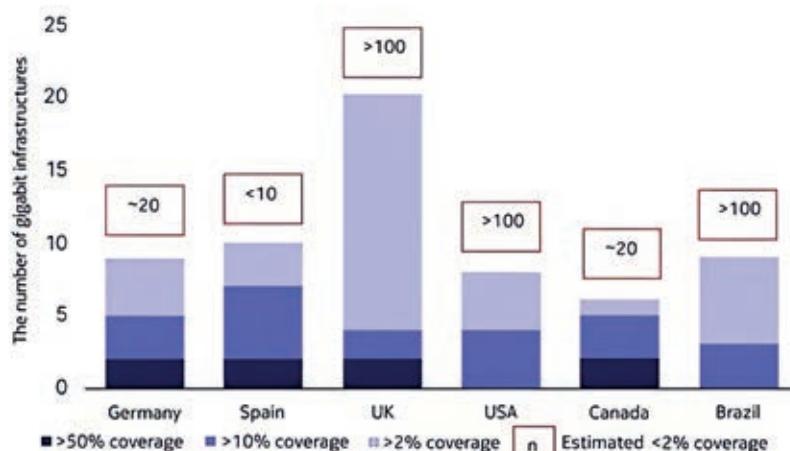
In the fast-evolving world of broadband, fibre-to-the-home (FTTH) has emerged as the gold standard for high-speed, low-latency connectivity. Its unparalleled capacity to meet the demands of our increasingly connected digital world has attracted a surge of investment from both established operators and new entrants. However, this momentum has led to unforeseen challenges: network overbuild, market fragmentation, and shrinking profit margins. As the FTTH landscape becomes more crowded and complex, operators are seeking innovative solutions to maintain their competitive edge and ensure sustainable growth.

Enter software-defined access networks, which promise to transform how FTTH networks are designed, deployed, and managed. By leveraging the principles of software-defined networking (SDN), cloud platforms, and network automation, SDAN offers a path to increased automation, enhanced operational efficiency, and new revenue streams. As a result, it can help FTTH operators navigate the challenges of today's market while positioning themselves for future success.

THE FTTH LANDSCAPE

The appeal of FTTH is clear. Applications requiring higher bandwidth and lower latencies such as cloud gaming, 4K/8K video streaming, and augmented reality are continually becoming more

The number of FTTH and HFC infrastructure plays, by coverage ambition, selected countries, 2023



Source: Analysys Mason

Figure 1

prevalent, increasing its demand. FTTH's future-proof infrastructure, technology-leading sustainability, and comparatively low operating costs make it an attractive investment option for those looking to capitalise on this trend.

However, the push to deploy FTTH has led to some unintended consequences. Multiple operators are now competing for the same finite pool of customers due to high levels of network overbuild across markets. This is particularly evident in countries like the U.K., where over 100 alternative network operators (altnets) are active, many with ambitions

to pass just 2% or less of total national premises.

This fragmentation creates several challenges including increased competition and pricing pressure (leading to falling margins), inefficiencies due to duplicated infrastructure, and difficulties in achieving economies of scale, particularly for smaller operators. The traditional approach to network management, with its reliance on manual processes and siloed systems, is ill-equipped to handle the complexities of this new landscape. This is where SDAN comes into play.

SDAN IS A GAME-CHANGER FOR BROADBAND OPERATORS

At its core, SDAN extends the principles of SDN to the access network, creating a more flexible, programmable, and automated infrastructure. This approach offers several key benefits for FTTH operators.

1. Reduced operational expenses (OpEx)

One of the most immediate and tangible benefits of SDAN is its ability to streamline network operations and reduce OpEx. Specifically, by automating routine tasks such as service provisioning, configuration management, and fault resolution, SDAN significantly reduces the need for manual intervention. This not only lowers labour costs but also minimises human error, leading to more reliable network performance.

For example, SDAN enables zero-touch provisioning, allowing new services to be activated without the need for on-site visits. This can dramatically reduce the time and cost associated with service activation, improving both operational efficiency and customer satisfaction.

2. Enhanced network visibility and control

SDAN provides operators with unprecedented visibility into their network performance and resource utilisation. Collecting and analysing near real-time telemetry data from across the network enables more proactive management and optimisation. This enhanced visibility allows operators to proactively identify and resolve issues prior to impacting service quality, utilise actual usage patterns to optimise resource allocation, and make more informed decisions about network expansion and upgrades.

3. Multi-vendor integration

In today's diverse FTTH ecosystem, operators often find themselves managing equipment from multiple suppliers. SDAN's open and programmable interfaces make it easier to integrate and manage multi-vendor environments, thus reducing the complexity and cost associated with network heterogeneity. This flexibility also equips the network for future demands, allowing operators to more easily adopt new technologies and services as they emerge.

4. New revenue streams through service differentiation

Perhaps the most exciting aspect of SDAN is its potential to enable new revenue streams through service differentiation. By leveraging network slicing and dynamic resource allocation, operators can offer a range of tailored services to meet diverse customer needs.

These could include premium residential packages designed for gaming or work from home performance needs; business services with stringent SLAs and on-demand bandwidth scaling; 5G mobile transport, backhaul, mid-haul and even front-haul; wholesale services that allow virtual network operators (VNOs) to offer their own branded services over a single fibre infrastructure.

These differentiated services not only command higher prices but also help operators stand out in a crowded market.

5. Flexible wholesale platform

For infrastructure providers, SDAN opens up new possibilities in the wholesale market. By creating a more flexible, programmable network environment, SDAN enables innovative Network-as-a-Service (NaaS) models. These models allow infrastructure providers to offer virtual network slices to multiple service providers, with each service provider tenant able to dynamically provision and manage their own services. Wholesalers can also look at creating new partnership opportunities with content providers and other digital players providing services over a dedicated virtual network slice. This approach can help smaller operators achieve greater scale and reach, while also maximising the utilisation and monetisation of their network assets.

CHALLENGES AND CONSIDERATIONS OF IMPLEMENTING SDAN

While the benefits of SDAN are compelling, implementation is not without its challenges. Operators considering SDAN should be aware of several key considerations.

Initial investment. Transitioning to an SDAN architecture may require significant upfront investment in new hardware, software, and training.

Organisational change. SDAN represents a fundamental shift in how networks are managed, requiring new skills and potentially new organisational structures.

Security. As networks become more software-defined and programmable, ensuring robust security measures becomes even more critical.

Standardisation. While progress has been made, further standardisation efforts are needed to ensure interoperability across different vendors and implementations.

Legacy integration. For many operators, integrating SDAN with existing legacy systems and processes will be a crucial challenge. Despite these challenges, the potential benefits of SDAN make it a compelling proposition for FTTH operators looking to gain a competitive edge in today's market.

LOOKING AHEAD

SDAN will play an increasingly important role in the FTTH landscape. By enabling greater automation, flexibility, and service innovation, SDAN helps operators address the immediate challenges of network overbuild and margin pressure while also better positioning them for future growth. We can even expect to see SDAN enabling more advanced use cases, such as ultra-low latency services, application-aware network optimisation, or deeper integration with edge computing resources for improved service delivery.

In the face of increasing competition and market fragmentation, SDAN offers a set of opportunities for differentiation, cost reduction and revenue generation, hence maximising the return on investment in an FTTH infrastructure. A shift to SDAN not only addresses the immediate challenges of today's market but also positions operators to capitalise on the emerging opportunities of our increasingly connected world. ☺



Filip De Greve, Product marketing Director for Nokia Fixed Networks

Filip De Greve is based in Antwerp, Belgium and is Product Marketing Director for the Fixed Networks division at Nokia. In that role, he is focused on the go-to-market for innovative fixed access broadband solutions. Filip has over 20 years' experience in the telecommunications industry. He previously held various roles on service provider and supplier side. As subject matter and project management expert, he has extensive experience in providing leadership in technical consultancy, project management, customer delivery, program office and product marketing. Filip holds a Ph.D. in the Telecommunications and Information Technology from the University of Ghent, Belgium.



THE RISE OF COHERENT PLUGGABLES: WHAT'S NEXT?



As the demand for bandwidth continues to increase and the need to reduce the cost of optical transport becomes more pressing, a new breed of pluggable optics has emerged – 400G coherent pluggables. **Fady Masoud**, Senior Director, Solutions Marketing, Infinera reads the runes.

This new generation leverages 7-nm CMOS technology and cutting-edge opto-electronics to deliver 400 Gbps in pluggable form factors such as QSFP-DD and CFP2, thus redefining business and network economics by reducing power consumption, simplifying the network, and enhancing service flexibility, all of which contribute to a significant reduction in total cost of ownership.

However, deploying coherent pluggables comes with its own set of challenges that need to be addressed to unlock their full potential. These include:

Complex in-host management: When deployed in a host device other than a WDM platform, the management of current coherent pluggables represents organisational and operational challenges. Organisational challenges arise in terms of which team (optical or IP) will manage the coherent pluggables, normally part of the optical network but now hosted in the IP domain. Operational challenges can also be exacerbated as new features and capabilities are added to coherent pluggables. Today's host devices generally have limited management schemes supporting basic functions, such as setting laser frequency, spectrum width and launch power.

Deployment over single fibre: PON networks, which use a single fibre for service delivery, are rapidly becoming the access technology of choice across the globe. While PON networks are highly suitable for residential services, the technology falls short in keeping up with the ever-increasing demand for capacity triggered by next-generation business services and 5G mobile transport. Access networks for enterprise services can greatly benefit from the high capacity enabled by coherent pluggables; however, coherent pluggables cannot be deployed

over a single fibre because the technology uses the same wavelength frequency for each transmission direction.

Deployment over legacy infrastructure:

Today's optical infrastructure is the result of more than 25 years of network buildouts and expansions; hence, it consists of a mix of technologies and capabilities including ROADM, optical amplifiers and filters. The network may only support 50 GHz fixed grid, or it may support variable flexible-grid channel assignments. To deploy and operate broadly in such diverse environments requires coherent pluggables to be flexible and programmable.

Lack of troubleshooting tools: Issues that may arise during the deployment and operation of coherent pluggables can be challenging due to the lack of specialised tools and diagnostics specifically designed for these advanced transceiver modules.

Lack of automation features: Manual operations cannot keep up with the growing number of end sites and constant service churn of today's metro networks. Emerging coherent pluggables must support automation features to accelerate service turn-up, streamline network operations, and reduce human error.

RAISING THE BAR WITH INTELLIGENT COHERENT PLUGGABLES

A new breed of intelligent coherent pluggables, such as XR optics, driven by the Open XR Optics forum, has been introduced to the optical networking market to overcome the operational challenges mentioned above. They leverage digital subcarriers to enable higher optical performance; new optical configurations like point-to-multipoint, including a 4 x 100G coherent breakout; and new deployment models, such as single-fibre working. They also offer

numerous optical transport features that for the longest time have been limited to fully featured optical transport platforms.

The operational challenges that face coherent pluggables today touch every aspect of the service delivery cycle. To overcome these challenges the new generation of coherent pluggables was designed and built around the principle of complete and remote software programmability. Key functions can be set through software to enable successful deployment and optimised performance over any given link in any given application.

Programmable functions include modes (ZR, ZR+, XR), baud rate, spectrum, launch power, modulation, transmission fibre (single fibre or fibre pair), and traffic flows (asymmetrical, symmetrical).

The combination of software programmability, embedded system-level features, and a new paradigm for management overcome current operational challenges with:

Enhanced optical performance: By leveraging vertical integration and software-configurable building blocks, this generation of coherent pluggables delivers record-breaking optical performance by tuning each building block, such as the digital signal processor (DSP) and the transmit-receive optical sub-assembly (TROSA), around the optimal performance for each application. This translates into significant capex/opex savings for network operators enabled by network simplification and the elimination of regen sites and their associated costs.

Easier management: To overcome the complex management challenge, the Open XR Forum published specifications for a dual management approach. Coherent pluggables can be managed through the host device for basic configurations like setting frequency, power, and modulation but can also be

managed independently of any router support for more sophisticated optical functions to optimise performance and expand optical configurations, including point-to-multipoint configuration and operation over single fibre (Figure 1). Dual management decouples the pluggable from the host development cycle and provides management uniformity regardless of the type of host device. This enables fast access to advanced optical features, without disrupting the network by having to upgrade the router or host operating system.

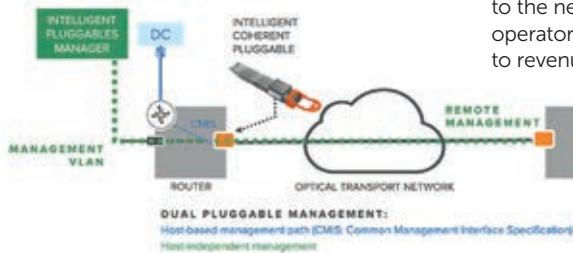


Figure 1: Dual management architecture

Deployment over single-fibre working

working: By leveraging digital subcarriers for downstream and upstream traffic flows, intelligent coherent pluggables can be deployed over a single fibre, with traffic flows that can be symmetrical or asymmetrical (Figure 2). This enables PON network operators to take a phased and business-paced approach to adding high-capacity business services over their existing GPON/XGS-PON/NG-PON2 infrastructures without network or service disruption. Moreover, service agility can be enhanced by providing dynamic/ automated service operations, including capacity increase in minutes and remote diagnosis and troubleshooting, all while leveraging existing PON building blocks such as splitters, filters and amplifiers.

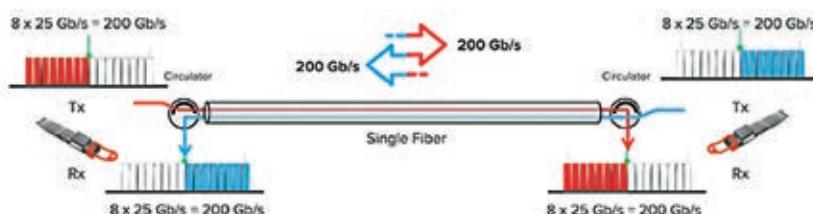


Figure 2: Deployment over single-fibre working

Seamless deployment over legacy infrastructure

Infrastructure: By leveraging software-configurable building blocks and selecting the right modulation, baud rate, launch power, spectrum width, and many other factors, network operators can maximise transmission capacity over the most challenging network configurations, including cascaded ROADM, narrow-band filters, single fibre spans, etc. This maximises ROI through the deferral of capex associated with upgrading infrastructure to support conventional coherent pluggables that is often complex, very costly, and time consuming.

Streamlined operations through automation

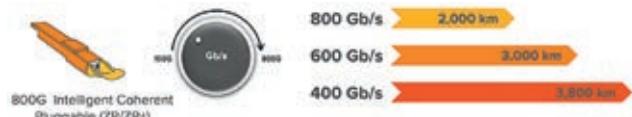
Intelligent coherent pluggables: Intelligent coherent pluggables are designed around meeting the ever-growing demand for bandwidth and the relentless increase of network sites, especially in metro and access networks as they are fuelled by the proliferation of metro data centres and compute sites. With many sites and constant churn, manual interventions simply cannot keep up with demand. Intelligent coherent pluggables are equipped with secure and automated processes that accelerate adding them to the network. As a result, network operators can benefit from faster time to revenue, higher network reliability by reducing human-caused outages and cost-efficient network operations.

WHAT'S NEXT?

The evolution of coherent pluggable transceivers is set

to take a significant leap forward with the introduction of 800G coherent pluggables, which are poised to complement the current 400G versions by providing a cost-effective and efficient optical transport solution for aggregated traffic and data centre interconnect. These next-generation pluggables represent a transformative step in network technology, offering unprecedented performance and efficiency leveraging cutting-edge 3-nm-based CMOS technology and support for advanced features like open probabilistic constellation shaping and multi-vendor interoperability.

These 800G intelligent coherent



Dual management: Emerging 800G intelligent coherent pluggables support host-based (I2C/CMIS-compliant host interface) and host-independent management, as described in the "Management of Smart Optical Modules" white paper posted on the OIF website, thus ensuring consistent and central management with the rest of the optical domain, accelerating feature development by decoupling it from the development cycle of the host OS while taking advantage of all the advanced optical functions embedded into the pluggable.

Easy deployment over legacy

infrastructure: Just like their predecessors, 400G intelligent coherent pluggables, this next generation also leverages full programmability for seamless deployment over existing legacy infrastructure. By selecting the right modulation, launch power, and many other factors, network operators can maximise transmission capacity over the most challenging network configurations, including cascaded ROADM.

CONCLUSION

Intelligent coherent pluggables are redefining network economics by reducing power consumption, simplifying the network, and enhancing service flexibility. The optical networking industry is on the cusp of a transformative leap with the advent of 800G intelligent coherent pluggables that further raise the bar of capacity and performance and mark a major milestone in the history of the optical networking industry, propelling it into an exciting future of next-generation connectivity. ☺

pluggables are not only about their maximum bit rate (800G); they are also about enabling lower bit rates to be transported over unprecedented distances using coherent pluggables and their compact form factors (eg QSFP-DD). This includes 400G over 3,800 km, 600G over 3,000 km and 800G over 2,000 km.

Interoperability: 800G intelligent coherent pluggables are designed to be compatible with the previous generations of coherent pluggables, 400G ZR, and 400G ZR+, so an 800G pluggable operating at a 400 Gbps bit rate can be connected to any 400 Gbps coherent pluggable. They are designed to meet and exceed 800G ZR and 400G ZR OIF standards and to be interoperable with any OIF-compliant ZR transceiver. Moreover, they are designed to be multi-vendor interoperable through Open ROADM 6.0 for the "open probabilistic shaping FEC" and compliant with OIF 800G ZR (OIF 2021-144-15), OIF 400G ZR (Implementation Agreement 2.0), and OpenZER Rev 3.0.

FTTR-B Opens New Horizons for Micro and Small Enterprises

Boosting Enterprise Connectivity and Revenue

Fiber to the room (FTTR) technology is driving a new wave of fiber transformation, experiencing explosive growth in China. FTTR empowers operators with the ability to guarantee bandwidth, leverage their installation and maintenance expertise, and penetrate the MSEs (Micro and Small Enterprises) market. Traditionally, over 90% of MSEs build their networks using open-market equipment, lacking unified standards for design, deployment, and O&M. This results in bandwidth bottlenecks, poor Wi-Fi coverage, frequent network failures, and fault localization issues, hindering digital transformation.

ZTE FTTR-B SOLUTION

To address these challenges, ZTE has launched the FTTR to business (FTTR-B) solution, enabling MSEs to build all-optical enterprise networks using PON technology. The FTTR-B main optical network terminal (ONT) serves as the core device, integrating functions of an access gateway, router, access controller (AC), integrated access device (IAD), and POE switch, simplifying network architecture. The solution replaces traditional copper-based connectivity with a point-to-multi-point (P2MP) fiber-based optical distribution network (ODN), offering compact devices, robust environmental adaptability, and reduced maintenance needs. Fiber, with its longer lifespan and lower cost, significantly reduces network construction costs and supports superfast deployment, ultimate user experiences, and ultra-simplified O&M.

As a leading global provider of integrated communication solutions, ZTE is dedicated to creating value for both operators and users.

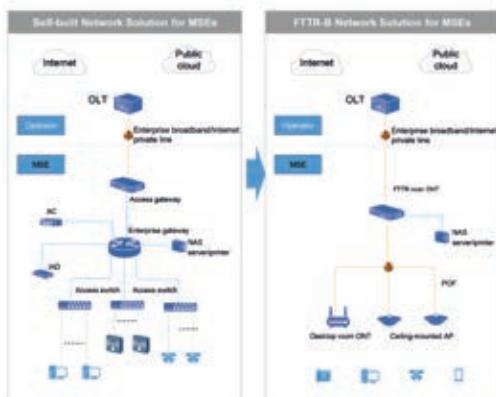


Fig. 1. Evolution of network solutions for MSEs

FTTR-B Helps Operators Reap Value in Installation, Maintenance and Management Services and Develop Value-Added Services

• Network Revenue and Customer Retention:

FTTR-B transforms enterprise connectivity from single-point broadband to a comprehensive all-optical network, enhancing coverage and connectivity. This upgrade increases customer loyalty, triples ARPU, and reduces network churn by 80%.

• Installation and Maintenance Services:

FTTR-B offers new revenue streams for operators by enabling them to maintain enterprise networks. Basic services include speed tests, on-site visits, and reports. Advanced services, such as quality analysis and network optimization, further improve customer retention and generate additional revenue.

• Telecom Services: FTTR-B integrates network and cloud services, enabling one-hop cloud access via VxLAN/IPsec. This supports value-added services like video acceleration, office application acceleration, and user-specific website acceleration, increasing telecom service revenue.

unified authentication. With D-WLAN distributed Wi-Fi technology, terminal device access has increased by 10%, business latency has decreased by 40%, and seamless roaming with 10ms handoff has been achieved.

• Ultra Simple O&M:

The FTTR-B solution provides one-stop O&M, covering planning, installation, acceptance, maintenance, and optimization. The O&M app simplifies installation and maintenance, offers fast service provisioning, and standardizes network acceptance. AI and big data technologies ensure efficient enterprise networks by providing bandwidth differentiation and application acceleration. Unified user authentication policies streamline access and enable targeted advertisements and personalized offerings.

• Green & Sustainable Development:

Fiber networks consume less energy compared to traditional copper networks. The ASIC chip reduces energy consumption by 70% compared to FPGA, saving 50-70% on annual energy costs. ZTE's end-to-end visualized cloud management platform optimizes network performance with one click, reducing

maintenance costs by 45%. FTTR-B uses durable fiber networking and seamlessly upgrades to 10G PON and 50G PON systems without modifying the

ODN network, meeting network needs for the next 30 years and facilitating the hotel's intelligent transformation and sustainable development.

MARKET POTENTIAL AND GROWTH

FTTR-B presents substantial opportunities for operators to expand within the enterprise market. By the end of 2023, the bidding scale for FTTR-B in China surpassed 600,000 sets, predominantly targeting small and micro enterprises. Over 80 carriers have introduced FTTR-B packages, serving approximately 200,000 users. China Unicom aims to onboard over 1 million MSEs in 2024, projecting a revenue increase of USD 4.8 billion.

Deploying FTTR-B solutions allows operators to expand their MSE cloud customer base, increase service revenue, and enhance customer loyalty. FTTR-B all-optical networking is poised to help operators explore new growth avenues in the MSEs market.

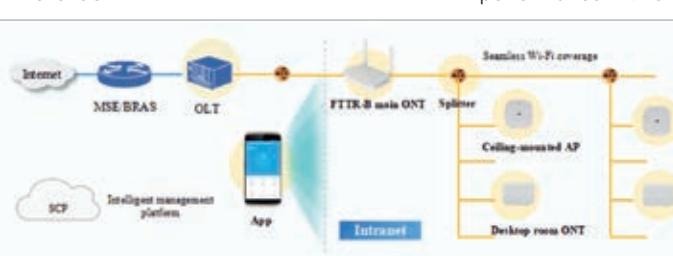


Fig. 2. FTTR-B solution for MSEs

FTTR-B Builds an All-Optical Enterprise Network with Upgraded Access Bandwidth, User Experience, and O&M Capability

• Simple & expandable network:

The FTTR-B enterprise network features a simplified two-layer P2MP architecture, maximum support 128 APs networking and 1000 terminals connections, various installation methods, and flexible power supply. ZTE's FTTR gateway integrates mini OLT, Mesh controller, and IP PBX functions, simplifying the network architecture and reducing equipment needs. The industry's first FTTR room ONT with integrated Set Top Box (STB) functionality, and ceiling-mounted Access Points (APs) catering to diverse installation scenarios, boasting ease of installation.

• Ultimate User Experience: The FTTR-B network offers 2Gbps bandwidth through wired and wireless connections, low latency, flexible capacity expansion, and

TEST AND MEASUREMENT: COMPANIES ARE RISING TO THE CHALLENGE OF AI



How are test and measurement companies rising to the challenge of the impact of AI on optical networks and components, and how is AI changing their product set? **Antony Savvas** considers this evolution in the market, and how the test and management ecosystem will change going forward.

Optical test equipment is used to evaluate and ensure the performance of optical networks and systems, using tools like optical power meters, spectrum analysers, and network testing kit. Key drivers for growth for the market include advancements in fibre optics, increasing demand for high-speed internet, regulatory changes driving wider deployment of optical networks, and increased investments by telcos in their infrastructure.

OBSTACLES

But the high cost of advanced test equipment, as well as the fast pace of technological change in 5G and IoT, for instance, can be obstacles to addressing optical demand. However, increasing automation and the use of artificial intelligence in testing processes lay the possibility to streamline testing and enhance accuracy. And developing smart optical testing equipment in response to the demands of AI among service providers, can reduce human error and improve efficiency in the midst of a test and measurement skills crisis.

xzProviders of hand-held and bench top AI testing kit and services include the likes of EXFO, Corning, Anritsu, Yokogawa Electric, Keysight Technologies, Fluke, AFL, Aplab, Spirent, Tektronix, Optikos, VIAVI, Gold Lite, and a host of others.

REQUIREMENTS

Hamdy Farid, senior vice president of Product at connectivity intelligence specialist Ookla, says of testing requirements: "Gathering and providing data alone is no longer enough for test and measurement companies. The next wave of advancement involves transforming data as a raw commodity into actionable insights and predictive analytics, that can help providers understand how to deliver better real-world connectivity experiences to consumers."

Farid says Ookla is "actively leveraging" AI to help improve connectivity across a variety of use cases, helping it to solve common, yet costly, network planning and optimisation use cases, like automatically identifying and providing recommendations to solve overshooting cells and using cluster analysis for anomaly detection. "From an end-user perspective, it helps us to identify where to prioritise network optimisation or expansion to benefit the most users," Farid says.

AI PARADOX

VIAVI's chief technology officer Sameh Yamany outlines the paradox facing the industry. He says: "Artificial intelligence is having a profound impact on the network ecosystem. Increased data volume and complexity, maintaining high reliability and performance for intensive AI functions, and security

against increasingly complex threats are just some of the challenges posed by AI, when it comes to optical networks and components. But the solution to many of the challenges posed by AI actually lies within AI itself. Network test and measurement companies are now taking an 'AI testing AI' approach, leveraging the enormous analysis and automation potential of AI to provide lab-based testing, real-time insights, predictive maintenance, and more."

Yamany says AI has "revolutionised" network test and monitoring capabilities, allowing providers to facilitate things like automated anomaly detection, root cause analysis, network stress testing, and performance optimisation. This is leading to more precise and faster testing capabilities, allowing for "better handling" of high-speed network requirements, and more efficient troubleshooting, reducing the burden on field deployment teams, says Yamany.

As for the kinds of things players are able to better test using AI, enhanced performance metrics such as latency, jitter, and packet loss can now be monitored in real-time. "There is also a focus on thoroughly validating the performance and integrity of next-generation transceivers like 800G and 1.6Tb, and high-density fibre optic components, which are particularly crucial for supporting AI and ML applications in data centres and cloud environments," he adds.

OPTIMISATION

For optimising AI networks through testing, Ram Periakaruppan, VP and GM, network test and security solutions at Keysight, says you have to be strategic.

"To properly optimise AI networks, no single product will do everything. At one end of the development cycle, before a new AI accelerator chip is even cast into silicon, test solutions must integrate with chip emulation environments and recreate the large AI networks in which this new chip will operate," Ram says. "At the other end of the cycle, you have to rely on simulation environments to assess the performance of tens of thousands of GPUs that collectively work to train an AI model. In between, lies a huge set of test cases where it's critical to execute highly accurate, hardware-based emulations of AI racks to carefully calibrate system performance."

Tying these together is a shared framework that defines an AI workload and the resulting network traffic, and which ensures test cases are "portable" throughout AI system development, deployment, and operation, adds Ram.

DEEPER INSIGHTS

So what are companies now testing for? Testers in the AI ecosystem are looking for deeper insights that connect system-level aggregates with performance of low-level components in the AI cluster. For example, says RAM, the job completion time of a training batch has a tighter integration with business fundamentals, and it almost directly translates into cost.

"During that batch, there are multiple collective data exchanges over the network. So we must drill down into each collective completion time, which is dependent on congestion control metrics, load balance efficacy, and ensuring no packet loss across the fabric," he explains.

Some AI models are known to be network bound, but you can't simply optimise networks and necessarily

expect them to perform better.

Measuring job completion time means the test device must emulate the full workload since each AI model has its own unique way of distributing work and coordinating results. "Not only is the measurement changing, but what the test system must create is also changing," Ram says.

CHANGING PRODUCT SET?

So with a wider take-up of AI, is their a greatly changing product set in the testing arena? Yokogawa Test & Measurement told Optical Connections: "We're addressing AI's impact on optical networks by developing advanced tools and solutions. But currently, AI isn't drastically changing our product sets. We're closely monitoring AI developments to integrate useful advancements when ready. And we're exploring how AI can improve predictive maintenance and data analysis in our products, gradually incorporating AI without major disruptions."

Aniket Khosla, VP of Wireline Product Management at Spirent, said of new products, "Test and measurement companies are introducing new solutions to test the capability of the AI infrastructure. We are adding products to test the efficiency of Collective Communications Library algorithms in transmitting data, for instance."

T&M EVOLUTION

As for the test and measurement ecosystem changing going forward, Ookla's Farid says, "Over the last 12 months, we've seen AIOps start to surface in the industry with the objective of automating processes across the organisation and proactively addressing issues before they materialise." This covers the likes of network capacity, root cause analysis, and quality of experience. We've also observed a strong push from the TM Forum to evolve existing models and operations to include AI, such as an AI/ML

framework and AI governance, and establish a link between AI/ML, open data architecture and intent-based autonomous networks."

While the promise of AI is "impressive and real", there is no "silver bullet, single answer" for the test and measurement sector, but the overarching trend is clear, Farid says. "AI can help test and measurement providers move from simply gathering and providing data, to more effectively and efficiently solving the biggest connectivity issues for the greatest number of users."

Yamany from VIAVI confirms, "Moving forward, expect the T&M ecosystem to become more integrated with AI and machine learning, leading to more proactive and predictive network management solutions. Future developments will likely focus on automated, scalable testing solutions that can adapt to the rapid advancements in optical networking technologies, fostering a new age of efficiency and innovation in high-speed data transmission and connectivity."

"The T&M ecosystem for Ethernet must expand beyond just networking, because AI is a systems problem," says Ram from Keysight. "You can perform basic functional network component testing that passes in isolation yet fails when the same component is deployed in a realistic AI system. To properly recreate what that system looks like, test equipment requires a workload perspective, otherwise the tester simply won't stress the component in a meaningful way. This systems approach is the largest departure for the T&M ecosystem, along with the idea that test products span the complete development cycle, from pre-silicon to deployment, and yet share test cases and data models that apply throughout."

Like in most industries and sectors, the advent of AI is creating a challenge for the optical test and measurement industry, but it does seem up for that challenge. ☺



Hamdy Farid

Senior Vice President of Product at Ookla.



Sameh Yamany

Chief Technology Officer at VIAVI.



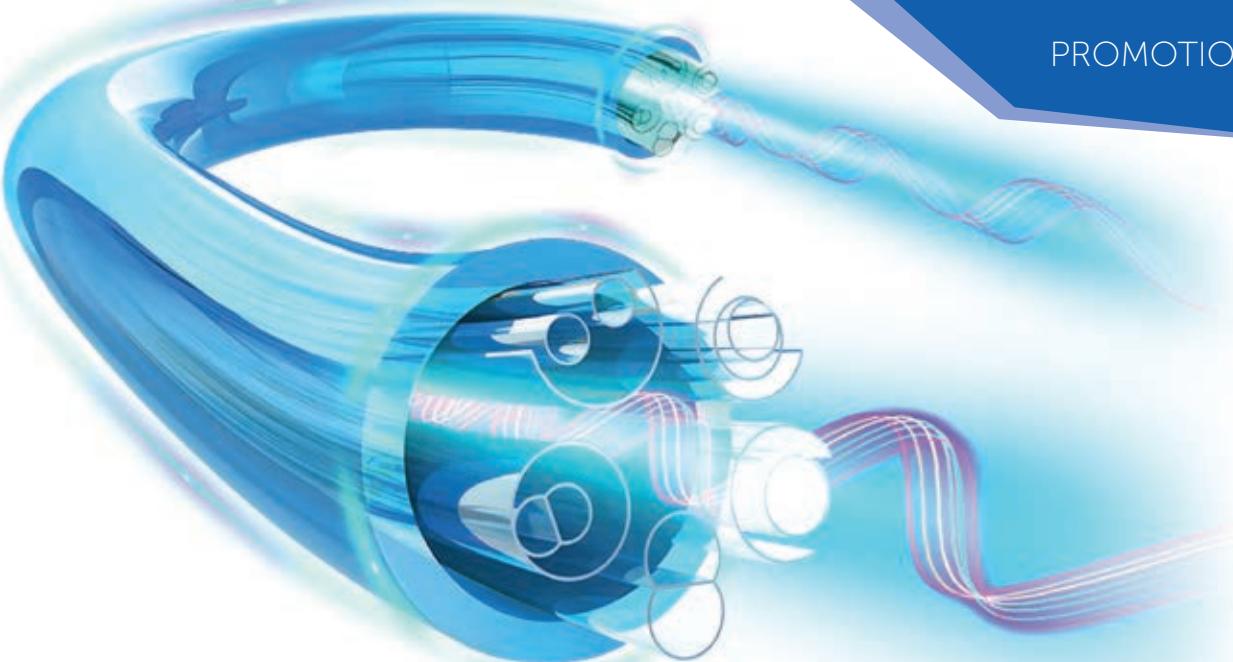
Ram Periakaruppan

VP and GM, Network Test and Security Solutions at Keysight.



Aniket Khosla

VP of Wireline Product Management at Spirent.



Linfiber Tech Unveils LinearCore™:

The Next-Generation Hollow-Core Fiber Cable for Low-Latency, High-Capacity Optical Networks

Linfiber Tech. announces its hollow-core fiber cable solution Linearcore™ featuring an innovative anti-resonant hollow-core fiber (AR-HCF) structure with loss of 0.5 dB/km in C+L band, offering 30% lower latency than standard silica glass fibers.

Optical fibers have formed the backbone of global communications. While solid-core fibers have pushed performance close to its fundamental limits, hollow-core fiber (HCF) are emerging as a game changer for next generation optical communication, thanks to their unique "4 low metrics": low latency, low loss, low dispersion and low nonlinearity – all of which address key bottlenecks in current communication systems. Under a HCF link, oDSP could be significantly simplified, as there is minimal need for nonlinear and dispersion compensation. Latency is enhanced at both the optical and electrical layer, enabling increased distance/spacing between data centers. Fewer or even no amplifiers and repeaters are required, since much higher power could be injected at the input. All of these lead to reduced energy consumption and overall system cost.

Over the past 20 years of AR-HCF development, the core members of Linfiber Tech have been at the forefront of research, making several foundational contributions. In 2010, Linfiber's founder and CEO, Yingying Wang, developed the world's first hypocycloid-core HCF (CLEO 2010 PDP CPDB4) during her PhD study at University of Bath, UK under the supervision of Prof. Fetah Benabid. This innovation reduced loss levels by more than an order of

magnitude, from 1000 dB/km to 40 dB/km—a landmark achievement that catalyzed the rapid development of low-loss AR-HCF over the following 15 years. By 2018, the team had developed the world's first conjoined-tube AR-HCF, further reducing loss to 2 dB/km (Nat. Commun. 9, 2828). In 2022, they achieved the world's first 0.1 dB pluggable hollow-core to solid-core connector (Opt. Ex., 30, 15149). Most recently, in 2024, Linfiber reduced the transmission loss to 0.1 dB/km (Advanced Photonics Congress JTh4A.3).

In Jun. 2024, Linfiber provides China Mobile with HCF cable for 800G transmission test network in Guangdong province. The cable achieved remarkable performance metric over a 20 km link, including self-splice loss of <0.2 dB, hollow-core to solid-core connection loss of <0.3 dB, and an installed cable loss of 0.6 dB/km (including connectors and splices). This pilot project successfully implemented HCF technology in real-world engineering environments, overcoming challenges such as tension, compression, moisture, and outdoor splicing. It not only optimized dedicated line latency by over 30% but also demonstrated an 800G wide-spectrum optical transmission system based on the C+L band. Over the 20 km link, it achieved an ultra-high capacity transmission test of 128 Tb/s full-duplex single-fiber transmission, laying a solid foundation for the next generation

HCF communication. These technical advancements highlight Linfiber Tech's superior capabilities and comprehensive expertise in HCF technology.

Currently, Linfiber's cables have achieved the lowest loss of 0.1 dB/km, and its commercial cable products Linearcore™ features an innovative structure (patent-pending) offer a loss of 0.5 dB/km in C+L band. O-band products are also available with loss level under 1 dB/km. Linfiber provides customers with a complete solution for inter- and intra-datacenter low-latency connections, including HCF cables, SMF28-HCF connectors, HCF-HCF splicing technique and a series of HCF characterization technique. Linfiber Tech actively seeks strategic partnerships with upstream and downstream enterprises in the industry chain to jointly advance the industrialization of HCF technology. With its profound expertise and extensive practical experience, Linfiber Tech is well-prepared to provide HCF solutions for AI clusters, data centers, and telecommunications networks.

For more information, visit www.linfiber.com, email sales@linfiber.com, or go to Prof. Yingying Wang's invited talk at ECOC conference M2D.2 on Monday Sep. 23rd.

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DEBUNKING SIX FIBRE OPTIC FACE CLEANING MYTHS



Maintaining pristine fibre optic end faces is critical for ensuring optimal network performance and reliability. Fibre optic networks rely on the precise transmission of light signals, and any contamination or damage to the end faces of the connectors can significantly affect the quality of these signals. Despite the importance of this process, numerous myths and misconceptions persist, often leading to improper cleaning practices and degraded signal quality. In this article, **Liam Taylor**, European Business Manager, Fibre Optics at MicroCare UK Ltd and a member of IEC/SC 86B Working Group 4, debunks some of the most common fibre optic end face cleaning myths, and provides insights into best practices, to help you achieve the best possible results for your fibre optic connections.

MYTH 1: CLEANING IS ONLY NECESSARY IF THERE'S A VISIBLE PROBLEM

Some technicians believe that fibre optic end faces only need cleaning if there's an evident issue, such as a visible smudge or signal loss. Even microscopic contaminants can significantly impact performance. Routine cleaning of fibre optic end faces should be a standard practice, even if no immediate problems are apparent. Regular maintenance prevents the accumulation of contaminants that can degrade signal quality over time.

Cleaning every fibre connection is a preventative measure that not only extends the lifespan of the fibre optic components but also reduces the likelihood of unexpected network disruptions, ultimately saving time and resources in the long run.

MYTH 2: A SIMPLE WIPE WITH A CLOTH IS SUFFICIENT

One of the most pervasive myths is the belief that a quick wipe with a cloth or tissue is enough to clean a fibre optic end face. This is a dangerous misconception. Common cloths and tissues can leave behind lint, dust, and other contaminants, worsening the

problem rather than resolving it. Using ordinary cloths or tissues can introduce new contaminants to the end face. These materials are often made from fibres that can shed and become lodged on the connector, creating additional barriers to effective signal transmission. Instead, use specialised lint-free wipes and cleaning solutions designed specifically for fibre optics to ensure thorough and effective cleaning. These tools are engineered to remove microscopic particles and residues that can disrupt signal transmission.

MYTH 3: DRY CLEANING IS ALWAYS ENOUGH

While dry cleaning methods like using a dry wipe or fibre optic cleaning tool can be effective in removing loose dust and particles, they may not be sufficient for oils, residues, or more stubborn contaminants. Plus, dry wiping fibre end faces creates static electricity, which attracts dust and other contaminants to the end face, further complicating the cleaning process. This static attraction can result in more frequent cleanings and increased risk of signal degradation due to residual particles. A combination of wet and dry cleaning is often necessary to achieve the best results. Wet the wipe,

cleaning stick or click-to-clean end face cleaning tool with a suitable cleaning fluid first, then use the cleaning tool to remove any remaining fluid and contaminants. This dual approach ensures that static electricity is removed from the end face and all types of contaminants are effectively addressed.



Wet-to-Dry Cleaning: A combination of wet and dry cleaning is often necessary to achieve the best results.

MYTH 4: ALL FIBRE OPTIC CONNECTOR CLEANING FLUIDS ARE THE SAME

Another widespread myth is that any cleaning fluid can be used for fibre optics. The truth is, using the wrong cleaning fluid, such as isopropyl alcohol (IPA), can leave residues or even damage the end face. IPA is not recommended because it can leave a thin film that attracts dust and moisture, leading to contamination and signal loss.

Always use high-purity, non-residue forming cleaning fluids specifically formulated for fibre optic cleaning. These specialised fluids evaporate quickly and leave no trace, ensuring the end face is perfectly clean and ready for optimal signal transmission. This rapid evaporation rate also allows you to continue with your work without significant downtime, increasing overall productivity. Additionally, opt for a non-flammable and non-hazardous cleaning fluid to ensure safety in various environments without the need for special handling or storage procedures.

MYTH 5: FIBRE OPTIC CLEANING TOOLS ARE ALL THE SAME

Not all fibre optic cleaning tools are created equal. Using the wrong tools can result in inadequate cleaning or even damage to the end face. Investing in high-quality, purpose-built cleaning tools is crucial for ensuring the cleaning process is thorough and safe, protecting the integrity of your fibre optic connections. Here are some of the best fibre optic cleaning tools:

Fibre Optic Cleaning Swabs or Sticks

Fibre optic cleaning swabs or sticks are designed for precise cleaning of fibre optic end faces, especially in hard-to-reach places. These swabs are available in assorted sizes to match different connector types, ensuring compatibility with a wide range of fibre optic systems. They are engineered to clean the entire end face, including the core, cladding, and ferrule edge, providing comprehensive cleaning and maintaining the integrity of your fibre optic connections.

Fibre Optic Cleaning Wipes

Fibre optic cleaning wipes are high-quality, lint-free wipes designed to effectively remove dust, oils, and other contaminants from fibre optic connectors, splices, and other components. These wipes are suitable for use in various cleaning applications and come in convenient packaging, making them easy to use both in the field and on the bench.

Fibre Optic Cleaning Fluid

Fibre optic cleaning fluid is a high-purity, fast-drying solution that effectively dissolves and removes contaminants from fibre optic connectors and splices. Safe for use on all types of fibre optic



Touchless Cleaner: Automated touchless cleaners offer unparalleled convenience and efficiency in maintaining fibre optic connectors and splices.

components, this cleaning fluid ensures thorough and efficient cleaning. It comes in no-spill packaging, allowing for controlled application and minimal waste.

Fibre Optic Click-to-Clean Tools

Fibre optic click-to-clean tools are innovative devices designed for cleaning connectors in adapters and on jumpers. These tools are simple and efficient, providing up to 1,000 cleanings per tool. They are available for various connector types, including SC, LC, MU, and MPO, ensuring compatibility with a wide range of fibre optic systems.

Investing in these high-quality end face cleaning tools and fluids ensures that your fibre optic cleaning process is effective and safe, maintaining the performance and reliability of your connections. Don't fall for the myth that all cleaning tools are the same—choose the best for your fibre optics.

Automated Touchless Fibre Optic Cleaning Tools

Automated touchless cleaners offer unparalleled convenience and efficiency in maintaining fibre optic connectors and splices. These innovative tools ensure thorough cleaning without physical contact, minimizing the risk of damage or contamination. Their user-friendly design speeds up the cleaning process, saving valuable time for technicians, while their environmentally friendly cleaning fluid is safe for both users and the planet.

While some may view automated fibre optic cleaners as a luxury, their benefits make them a necessity. They save time, reduce human error, and provide consistent cleaning quality. Although the initial investment may be higher, the long-term savings from reduced maintenance and improved performance justify the expense. Automated touchless cleaners are especially advantageous in high-volume environments where consistent and efficient cleaning is crucial.

These cleaners deliver 360° full end face cleaning without physical contact, eliminating the risk of scratching or pitting. They use a precise micro-dose of atomised cleaning fluid delivered with pressurised air, ensuring thorough and effective cleaning every time. Designed for flexibility and convenience, they can operate on rechargeable lithium-ion

batteries or an AC power supply with an international adapter, making them suitable for both field and bench use. Their interchangeable cleaning tips accommodate various end face sizes and configurations, ready to tackle any cleaning challenge.

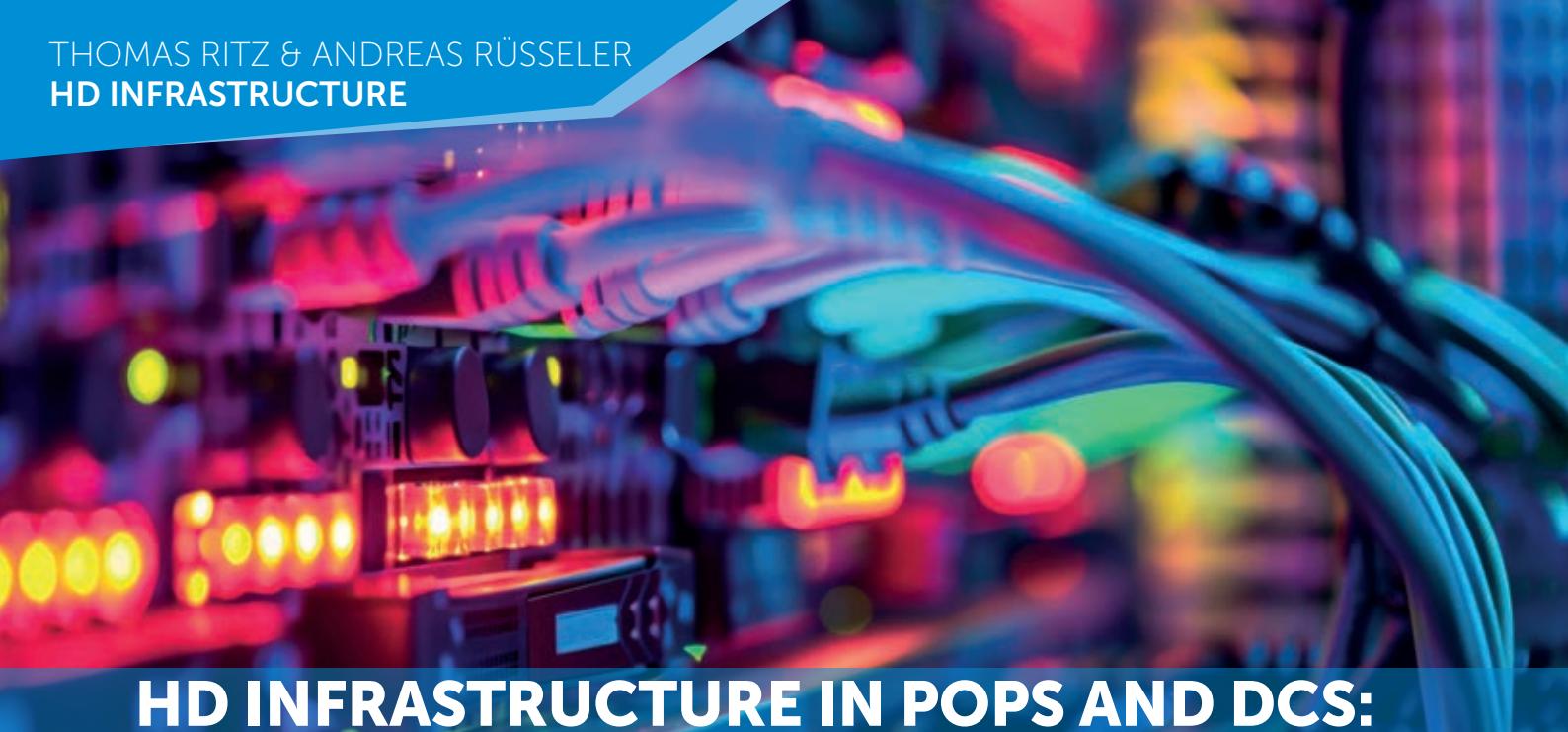
Investing in automated cleaners improves cleaning efficiency, reduces errors, and ensures consistent high-quality results. These tools are essential for anyone serious about maintaining optimal fibre optic performance, proving that their benefits far outweigh the initial costs.

MYTH 6: CLEANING IS A ONE-TIME TASK

One of the most misleading myths in fibre optic maintenance is the belief that cleaning is a one-time task. Fibre optic end face cleaning is an ongoing maintenance activity crucial for ensuring the long-term reliability and performance of your network. Regular inspection and cleaning are essential to ensure long-term reliability and performance of fibre optic connections. Incorporating scheduled cleaning into your maintenance routine can prevent unexpected signal degradation and downtime.

CONCLUSION

Debunking these six common fibre optic end face cleaning myths highlights the importance of proper cleaning practices in maintaining best network performance and reliability. Fibre optic networks depend on the precise transmission of light signals, and even microscopic contaminants can significantly affect signal quality. By understanding and addressing these myths, technicians can ensure their cleaning practices are effective and safe. Using high-purity, non-residue forming cleaning fluids, specialised cleaning tools, and incorporating regular maintenance routines are essential steps in achieving pristine fibre optic end faces. Investing in high-quality cleaning solutions, including automated touchless cleaners, can save time, reduce human error, and provide consistent, high-quality results. Ultimately, debunking these myths empowers you to maintain the integrity of your fibre optic connections, ensuring the best possible performance for your network. ☺



HD INFRASTRUCTURE IN POPS AND DCS: BENEFITS AND CONSIDERATIONS

As networks scale up to meet ever-increasing demands, getting the most out of available space is more important than ever. 'Bandwidth hunger' will continue to grow but the cabling backbone and in-building infrastructure required to meet demand can't just be replaced every few years. It's crucial to plan for significantly more fibre ports and cables at access points and in data centres. R&M's **Thomas Ritz** and **Andreas Rüsseler** look at high-density infrastructure as a possible solution.

When it comes to meeting current and future needs, High Density (HD) network infrastructure is essential. HD cabling and racks support more connections, upgrades, and expansions without increasing physical footprint. By optimising space usage and equipment management, they reduce costs related to installation, maintenance, and downtime. Service providers and DC operators can increase the number of connections without major reconfiguration or adding physical infrastructure and get access to advanced features that make network management and maintenance easier.

HD AT POINT OF PRESENCE (POP)

At the Point of Presence (PoP), multiple providers house equipment, enabling data exchange between their fibre networks. PoPs benefit significantly from higher density, as it helps them handle the required huge number of connections between users and networks. A PoP can be a room in a building, or an outdoor concrete box measuring just a few metres. It contains Fibre Distribution Frames, used for fibre termination, cross-connection, splicing, and management, as well as Optical Distribution Frames (ODFs), designed for high-density fibre termination.

How to ensure your PoP high-density rack and cabling solution is efficient, scalable, and reliable?

Cables that combine a very high fibre count with easy handling are a must. That means avoiding full-size connectors and finding ways to minimise or simplify repeat unplugging and reconfiguration. It should be easy to (un)plug connectors, change polarity, unlock connectors from SFP transceivers, and protect cables, patch cords, ferrules, and housings from environmental effects.

Obviously, space is at a premium in PoPs - there's no permanent on-site staff presence. Connectivity solutions should have minimal space, maintenance, and management requirements. HD maximises port capacity, boosts the number of connections, and supports more robust, redundant designs, improving network performance and reliability. It becomes easy to add backup devices and create multiple redundant paths for data transmission. If one path fails, data is rerouted through another, minimising downtime. Bandwidth usage can be optimised, and traffic distributed evenly across the network, reducing congestion, and improving overall performance. Furthermore, leveraging redundant connections means maintenance and upgrades can be carried out more smoothly, with minimal interruptions.

HD IN THE DATA CENTRE

Where 40G/100G requires eight fibres in parallel pairs, DCs continue to move to 400G/800G, requiring 16 or 32 pairs, which significantly boosts cable density. Data centre architectures are moving toward spine-leaf and fibre-dense mesh networks, and EoR/MoR and ToR solutions. The integration of AI accelerators is also increasing. These developments require high-density products, smart migration, preconfigured solutions, and monitoring/asset management.

Hyperscale, Mid-Sized, and Edge DCs can all benefit from higher density cabling and racks for several critical reasons. Regardless of size, every data centre currently needs to optimise space usage to accommodate more connections without boosting size and energy requirements. High-density setups maintain footprints while enhancing energy efficiency, helping ensure compliance with regulatory, reporting and auditing requirements, and environmental goals. Modular designs make it easy to incrementally add capacity without overhauling existing setups. Higher density solutions also enable more robust network designs with better redundancy options - essential for maintaining uptime and reliability.

Hyperscale DCs, which support vast amounts of data processing and storage, need to scale especially

rapidly. HD provides the flexibility to expand capacity without extensive physical changes and supports advanced management features, allowing for more efficient resource allocation and load balancing. Hyperscale DCs are enormous, so any opportunity for saving on operational and maintenance costs, or cut emissions, immediately benefits from huge economies of scale. Consolidating equipment into fewer racks can lower costs associated with physical infrastructure, such as racks, cabling, and networking components, while improved energy-efficiency can reduce emissions - and expense - in large DCs.

By maximising use of existing space, mid-sized DCs can defer or avoid expansions or the need to move to larger facilities. HD equipment allows more servers, storage, and networking components to be housed in the same physical footprint - crucial for DCs with limited space compared to hyperscale facilities. Many HD solutions come with management software that provides detailed insights into system performance, health, and resource utilisation, supporting proactive maintenance and optimisation. New HD equipment also helps mid-sized DCs keep up with larger or more 'niche' competitors, offering more competitive and comprehensive services, higher availability, improved performance, and faster provisioning. Some mid-sized DCs may need to invest in upgrading monitoring, cooling, or power systems to support high-density deployments. However, optimized versions of such features are often pre-integrated in higher density racks.

Getting more connections in the same space is crucial to EDGE data centres that are often very small and located in hard-to-reach environments. These require low latency and high performance due to their proximity to end-users. HD solutions' ability to handle high data throughput efficiently achieves exactly these goals while enabling faster access to large datasets, which is critical for applications typically supported by EDGE facilities, such as video streaming, gaming, and real-time data analysis. The improved latency and performance centres contribute to a better overall user experience, which is key for consumer-facing applications. HD also ensures EDGE DCs can process more data locally, reducing the need to send large volumes of data back to centralised DCs. That means higher Quality of Service for users, and faster, and more reliable access to applications and services.

IN SHORT...

As demand for bandwidth, data storage and processing grows exponentially, largely due to the proliferation of digitisation, organisations need to offer more connections, scalability, and flexibility while keeping in control of network management and cost. HD solutions increase connections, scalability, and flexibility in the same physical space. That makes it possible to grow perfectly in sync with data and processing demands without expanding the physical footprint or complexity of cable management. Increased density also offers greater scalability. Operators can more easily and cost-effectively accommodate varying needs of different clients and applications.

Looking specifically at PoPs, high-density equipment maximises use of available space by allowing more fibre terminations, network switches, and other essential components to be housed in the same footprint. PoPs can now handle more connections and services without physical expansion. As the number of subscribers grows, traditional equipment may struggle to scale efficiently, leading to performance bottlenecks. What's more, HD solutions often have advanced cable and port management systems designed in. This reduces clutter, improves airflow, and makes it easier to trace and manage connections, simplifying maintenance and troubleshooting. By also addressing power consumption, heat dissipation, operational costs, upgrades, and network performance, HD equipment significantly enhances PoP efficiency and effectiveness leading to more robust and scalable network infrastructure that can meet growing demands.

In DCs, HD addresses common issues while enhancing overall efficiency, performance, and sustainability. The option to scale vertically within existing space provides a more straightforward path to increase capacity and performance as demand grows. Packing more compute, storage, and networking capacity into a smaller or identical footprint maximises use of available space, delaying or eliminating physical expansion, while enabling robust failover and backup systems. It can reduce overall power consumption, cooling requirements, and energy costs. Consolidating resources also simplifies infrastructure, making it easier to manage, monitor, and maintain.

There are a few considerations to be addressed, though. Staff may need training to manage and maintain HD equipment, and the existing network infrastructure may require upgrades, which requires specific knowledge of (legacy) standards, platforms, and devices. You'll also need to plan the layout to maximise space usage while ensuring the easiest access for maintenance and troubleshooting, and implement a robust system for monitoring, labelling, and documenting everything with 100% accuracy in real-time. More connections also necessitate advanced network management tools and practices, as well as enhanced security measures. Although HD may require a greater initial outlay, TCO is reduced through optimised infrastructure and operational costs and savings in time, effort, real estate, and energy consumption. And of course, you need to invest in high-quality, low-maintenance cabling and racks from reputable manufacturers to ensure reliability and longevity. ☺



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MBA, Market Manager Public Networks,



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CMO, R&M



Make it EPIC!

Driving Competitiveness of
European Photonics Industry
through an International Network

Hamamatsu Photonics' InGaAs Photodiodes: Illuminating the Future of Optical Communications

In the dynamic landscape of optical communications, the evolution of data transmission technologies has reached new heights, propelled by innovations such as InGaAs photodiodes. Among the pioneers in this field, Hamamatsu has taken center stage, revolutionizing the industry with its cutting-edge photodiode technology.

At the heart of optical communication lies the InGaAs photodiode, a crucial component enabling the conversion of light into electrical current. Hamamatsu Photonics, with its expertise in photonics technical design and production, has harnessed the full potential of InGaAs technology. Combining high speed, high sensitivity and low noise with impressive spectral responses, their InGaAs photodiodes offer new possibilities in data transmission.

EXPANDING THE DETECTION SPECTRUM

Traditional Silicon Photodiodes were limited to detecting ultraviolet and visible light. However, Hamamatsu's InGaAs photodiodes mark a significant leap forward by extending the detectable spectrum into the realm of infrared light. This expanded range creates new possibilities for applications, making it an indispensable tool in the rapidly evolving telecommunications landscape.

The surge in data demand has driven engineers to seek efficient emitters and detectors with high-speed capabilities. Optical communication, leveraging light for data transmission, has emerged as a key solution. Hamamatsu's commitment to this paradigm is evident in its InGaAs photodiodes, which play a pivotal role in the quest for high efficiency and speed.

The utilization of near-infrared light in optical communication represents a technological breakthrough. Hamamatsu's InGaAs photodiodes, with their varying cutoff wavelengths, allow for the detection of longer wavelengths compared to traditional Silicon counterparts. This enhancement not only facilitates faster data transmission but also opens avenues for improving transmission quality and reducing energy consumption in data centers.

SPEEDING UP COMMUNICATION: HAMAMATSU'S ULTRA HIGH-SPEED INGAAS PIN PHOTODIODE

Recognizing the paramount importance of speed in optical communication, Hamamatsu has developed an ultra-high-speed InGaAs PIN photodiode. Complementing the existing 25 Gbps and

50 Gbps models, this latest innovation is a testament to Hamamatsu's dedication to advance the frontiers of data transmission.

The ultra high-speed InGaAs PIN photodiode operates from a low reverse voltage, ensuring efficiency and reliability. The company's optical design and manufacturing expertise are evident in the integration of techniques that maximize light capture in a small photosensitive area, maintaining an exceptional Signal-to-Noise (S/N) ratio.

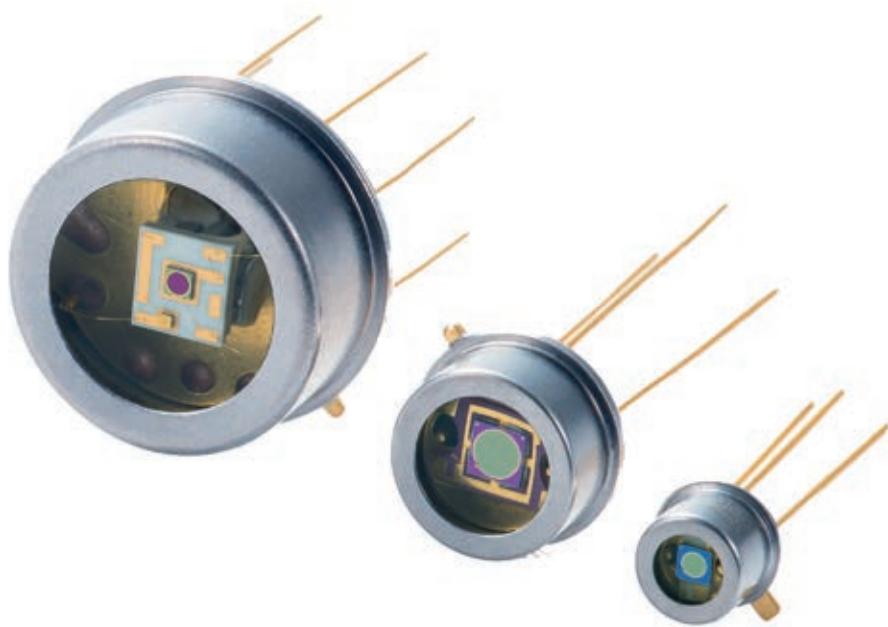
TAILORING SOLUTIONS FOR TOMORROW'S CHALLENGES

While near-infrared light offers immense potential, it also presents challenges that demand innovative solutions. Hamamatsu, drawing on its extensive experience, not only provides a range of InGaAs photodiodes but actively engages in ongoing innovation to meet the challenges of tomorrow.

In the realm of optical communications, Hamamatsu Photonics' InGaAs photodiodes shine as beacons of technological advancement. From expanding the detection spectrum to pioneering ultra high-speed solutions, Hamamatsu's commitment to excellence is evident. As engineers and innovators look towards the future, Hamamatsu Photonics remains a steadfast partner, offering a diverse range of InGaAs photodiodes and continually pushing the boundaries of what is achievable in the world of optical communication.

Step into the future with Hamamatsu Photonics and illuminate the path to high-speed, efficient data transmission.

Learn more about our InGaAs photodiodes <https://bit.ly/3SDNpVf>



HAMAMATSU
PHOTON IS OUR BUSINESS

DAVID CREASEY EPIC CEO INTERVIEW

In this interview, **Antonio Castelo**, PhD, EPIC's Technology Manager for Bio-Medical and Lasers, talks to **David Creasey**, CEO of Wasatch Photonics, a US supplier of gratings, spectroscopy, and OCT products.

AC What's the background to your appointment as CEO at Wasatch Photonics?

DC In 1998, I completed a PhD in Chemistry at Leeds University in the UK that focussed on remote instrumentation for atmospheric sensing. This was followed by a period of postdoc research, during which I got to see how various companies around the world were developing instrumentation for real world applications. This was a valuable learning experience because although I was, and still am, passionate about science, I came to realise that without monetization, science remains just a hobby.

In 2001, I was very fortunate to join Edinburgh-based Photonic Solutions as a laser service engineer where, for the next 9 years, I was responsible for OEM sales and new business development. This was another valuable learning experience as I met some very capable and talented academics and learnt the importance of understanding exactly what the customer wanted from the technology we provided. Then, in 2010, I joined Ocean Optics, a supplier of miniature spectrometers. I started as Sales Manager responsible for sales in the Europe, Middle East, and Africa, and in 2012, I moved to the US after being promoted to VP responsible for global sales and marketing. I stayed at Ocean until I was appointed CEO of Wasatch Photonics in 2016.

AC How has the company developed?

Wasatch Photonics was founded in 2002 in Logan, Utah at the foot of the Wasatch Mountains, hence its name. The aim was to produce disruptive volume phase

holographic (VPH) grating technology, for laser pulse compression, astronomy, spectral imaging, and optical coherence tomography (OCT), for researchers and OEMs. In 2010, the company formed a new division in North Carolina to produce spectrometers and systems for spectroscopy and OCT. Nowadays, we have a workforce of 70, and we produce some of the most sensitive compact spectrometers in the world, covering OCT, Raman, NIRS, and fluorescence spectroscopy. These, together with our high-performance gratings, are used in research labs around the world. We also work with OEMs serving the defence and security, materials processing, sensing, analytical instrumentation, medical, and energy markets. And as a vertically integrated supplier, we have the expertise and resources to create bespoke products.

AC What were the main challenges when you started at Wasatch?

DC At Ocean Optics, I was responsible for year-on-year growth, as well as the development of several new spectrometer and application-ready products. Wasatch took me on to do the same for them - basically to grow the company. The main challenge was that although the company had made great strides in developing the technology, we did not have any commercialisable products or the infrastructure to scale up. Accordingly, my first priority was to revamp the product line so we could monetise the technology. This involved modernizing the facility and hiring new personnel to build quality management, finance, and supply chain systems that would enable us to go out and scale the business.

AC How difficult was it to recruit the right people?

DC While the name Wasatch means something in Utah, it doesn't resonate in North Carolina - to the extent that a lot of people thought we were not US based. Nevertheless, I was fortunate in being able to leverage the contacts I had made in the industry, who, together with Wasatch's Supply Chain Director, helped me create profiles and job descriptions, and assisted me in the recruitment process itself. I inevitably fell victim to the Goldilocks effect, i.e., hiring somebody with a particular skill set who turned out not quite right, i.e., too hot, then hiring somebody with the entire opposite skill set who turned out too cold, and then looking for someone in the middle. I got a few things wrong, but in general, we've been successful in creating a talented workforce that is now double the size it was in 2016.

AC How has the spectroscopy sector evolved in recent years?

DC Until recently, our two leading applications were threat detection following 9/11, and OCT for ophthalmology. But in the last 5 years, there has been an acceleration of Raman spectroscopy applications due the availability of compact, portable instruments, more sophisticated data analysis, and greater understanding of what the technique has to offer. Nowadays, we provide Raman systems for applications such as the analysis of next-generation materials like graphene; food quality; pharma quality control; the detection of hazardous gases; and for biomedical applications like diagnostics for bacterial detection, non-invasive testing of blood quality, and the detection of infectious diseases and cancer.

AC How involved are you in data analysis to help understand what's happening in the process?

DC A large part of our recruitment is now in this area as we are spending an increasing amount of time discussing what goes on between the front of our instrument and the customer's sample. Our focus is on helping customers design their experiment to get the right result, and then enabling them to interpret their results to find the answer they require. Helping customers through this process of turning science into answers is key for our future development.

AC How do you see the future of Wasatch Photonics?

DC Fortunately, we are in an opportunity-rich environment, with opportunities of two types. The first are what I call "keeping the lights on" opportunities, which will give us some short-term impact. The others are bigger opportunities with longer term implications. Obviously, for sustainable growth we need to consider both types. But with opportunities come decisions, which basically means placing some heavy bets on some of these application areas. This in turn means getting the right balance between the scientific and commercial voices within the company, and in some cases, we will have to get better at saying 'no'. But in making these decisions, we are fortunate in having a very healthy and growing academic business with an ever-increasing loyal band of customers, who are now starting to do a lot of our marketing for us through their publications and through word of mouth.

AC If you started again, what would you do differently?

DC Although I'm very proud of the success our product line has enjoyed, in the beginning, I think I was too ambitious and too much of a perfectionist. What I wanted to do was to create a perfect portfolio of products before we hit the market, which took too long and added undue stress to the staff and on the cash flow as we ended up being late to the party. I've since learned a lot about the 80/20 principle - that is, to focus on getting 80% of the portfolio right really quickly and worry about the other 20% later. So, if I started again, I'd release parts of the product line as an entity sooner, rather than waiting for the whole portfolio to be complete.

AC What's your advice for the next generation of entrepreneurs?

DC I'd recommend adopting the three principles that have guided me throughout my career and got me to where I am today. The first is curiosity and a thirst for knowledge about your chosen technology and its applications that can do something meaningful, and which can therefore be monetized to create a business. Second, make sure you have good mentors who will look out for you and give you the opportunities to develop and succeed in your career. Finally, and this comes from my passion for sport, is the awareness that you can't do it on your own. You need to create and be part of high performing teams. From product development to shipments and support, it takes having the full team on board to keep the promises we make to our customers. ☺



David Creasey, CEO of Wasatch Photonics

Driving Competitiveness of European Photonics Industry through an International Network



UPCOMING EVENTS

EPIC Activities at ECOC
VIP Networking Reception & Career Booth
23-26 September 2024, Frankfurt, Germany

EPIC Technology Meeting on Laser Microprocessing: New Developments and Applications at Light Conversion
25-26 September 2024, Vilnius, Lithuania

EPIC VIP Breakfast and Techwatch at W3+Fair
26 September 2024, Jena, Germany

EPIC Online Technology Meeting on Neuromorphic Cameras
7 October 2024, Online Event

EPIC Technology Meeting on Photonics for Quantum Technology at Quantum Effects
8 October 2024, Stuttgart, Germany

Day of Photonics
21 October 2024

EPIC Online Technology Meeting on Industrial Laser Processes for Automotive and Electro-Mobility
21 October 2024, Online Event

EPIC Online Technology Meeting on Photonics Technologies for Advanced Light Sources
28 October 2024, Online Event

EPIC Online Technology Meeting on Photonic Sensor Systems
4 November 2024, Online Event

EPIC Members Delegation to India
5-9 November 2024, Mumbai, India

EPIC Technology Meeting on Microelectronics and Photonics – Two Sides of One Coin
11-12 November 2024, Munich, Germany

EPIC Online Technology Meeting on AI in Optics: Design, Simulation and Manufacturing
18 November 2024, Online Event

EPIC Technology Meeting on Photonics Technologies for Medical Diagnosis and Treatments at ICFO
3-4 December 2024, Barcelona, Spain

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FRANKFURT WELCOMES ECOC 2024!

23 - 25 SEPTEMBER 2024, Messe Frankfurt, Germany

Frankfurt am Main, the global hub for commerce, culture, education, tourism and transport in the former West Germany, plays host to this year's ECOC Expo and Conference. The exhibition will once again showcase the latest products and services, as well as providing an unrivalled opportunity to meet and network with key suppliers and industry leaders. Join colleagues, customers and peers, along with international exhibitors, for three days of networking, sharing ideas, learning and developing new business leads. Visitors to ECOC 2024 can expect the full panoply of events including the ever-popular Market Focus, the FTTx Focus, Industry Awards and the Product Focus.



MARKET FOCUS SESSIONS

Now in its 18th year the Market Focus Theatre, sponsored by Acacia, now part of Cisco, has become one of the highlights of the ECOC Exhibition attracting the world's best speakers from the industry globally. Every year the Market Focus is a focal point of the show and has become a key event to get up-to-date knowledge from across the industry in key technical areas and discover the latest commercial trends in optical communications.



PRODUCT FOCUS SESSIONS

The Product Focus theatre, sponsored by Open XR Forum, will once again be one of the focal points of the exhibition hall and a place to hear about the latest innovations and product announcements. Product Focus features presentations covering the latest innovative products, live demonstrations and technology announcements. The Product Focus sessions will run parallel to Market Focus. Each 30-minute session can be for any use - a live product demonstration, panel discussion, presentation, a pre-recorded video or a Q&A session. The Product Focus theatre is also home to the ECOC Exhibition Industry Awards.



The ECOC Exhibition Industry Awards return for 2024 once again, emphasising technology and product commercialisation; they highlight significant achievements in advancing the business of optical communications, transport, networking, fibre-based products, photonic integration circuits and related developments.

New for 2024, the Awards Committee has established the first competition for Post Deadline Awards. A key criterion for the Post Deadline Awards is world class products and technology. Results need to demonstrate that the product or technology is clearly state-of-the-art and best-in-class. The winners will be announced live at the exhibition in the Product Focus Theatre on Tuesday 24th September.



FTTx FOCUS

The FTTx Focus area will showcase a range of fibre-related products and brings together the very latest fibre to the 'x' in eight dedicated zones each focusing on a specific area of fibre, where exhibitors will display new and existing products.



THE CONFERENCE

The ECOC 2024 Conference will be celebrating its 50th edition and is also taking place in Frankfurt, in the heart of the Rhine-Main metropolitan region of Germany, on 22nd – 26th September 2024. The European Conference on Optical Communication (ECOC) is the continent's largest event in the field and one of the most prestigious and traditional events on optical communications worldwide.

ECOC, as one of the leading conferences on optical communications, attracts scientists and researchers from across the world. Not only top universities, but also the world's biggest and most influential companies present their astonishing breakthroughs from materials and devices to systems and networks, and their insightful visions for the future. ECOC is the key meeting place to share knowledge, exchange ideas, foster innovation and start collaborations on a global level.

Situated on the Main river, Frankfurt is one of the major financial centres of the European continent, with the headquarters of the European Central Bank, Deutsche Bundesbank, Frankfurt Stock Exchange, Deutsche Bank, DZ Bank, KfW, Commerzbank, DekaBank, Helaba, and several cloud and fintech startups, and other institutes. Frankfurt's DE-CIX is the world's largest internet exchange point, and Messe Frankfurt is one of the world's largest trade fairs.



ECOC 2024 MARKET FOCUS

KEY TECH AND COMMERCIAL TRENDS



Sponsored by



Now in its eighteenth successful year, the ECOC Market Focus has grown to become one of the focal points of the show and a popular platform to gain industry knowledge and insight into the latest technologies available. Market Focus showcases the very latest news and developments from leading organisations within the fibre optics community. A full list of Market Focus presentations and scheduled times is available on the exhibition website and in the show guide, but here are the Editor's picks.

SELECTED MARKET FOCUS HIGHLIGHTS

World class performance for 200Gbps PAM4 and 400Gbps PAM4 lanes from electro-optic polymer modulators

Michael Lebby, Lightwave Logic Inc

Electro-optic (EO) polymer modulators are a hot topic in the industry today as the industry strives to increase modulation speed while reducing optical network equipment power consumption, driven by G-AI needs to upgrade hyperscaler datacenters. Polymer modulators are now showing world class performance for 200Gbps PAM4 lanes, with initial results at 400Gbps PAM4 lanes and headroom for 800Gbps lanes as polymers have significant bandwidth capability. This enables not only 4 channel by 200Gbps PAM4 lanes for 800Gbps pluggable transceivers today, but also 4 channel by 400Gbps PAM4 lanes for 1.6Tbps pluggable transceivers soon.

Datacenter Optics in the Age of AI – Market Overview and Update

Scott Wilkinson, Cignal AI

Datacenter optics growth rates have exploded as AI requires exponentially more connectivity and bandwidth. In this presentation, we track the unprecedented rise in datacenter

optics shipments and forecast growth for the future based on hyperscale capex, end-user demand, and supplier capacity. As 1.6TbE modules begin shipping in volume, what does the future look like for 800GbE? Explosive growth cannot continue indefinitely, so when will growth in spending slow? What optics reaches and technologies will be required for next generation datacenters? Does the bandwidth growth inside the datacenter translate to bandwidth growth outside the datacenter, and will it drive Telecom growth?

Optics for AI/ML Architectures

Mark Nowell, Cisco

Building networks to address the AI/ML workloads creates new and additional challenges for the optical module industry to enable optimized solutions. This presentation will cover many of the leading approaches that are being considered such as higher speed optics, higher speed ports, lower power and denser solutions and the consequent system design challenges. Learn how these solutions can potentially address escalating power and cost concerns associated with higher speeds.

Novel coherent technology implementation approaches with 3nm-based 800Gb/s pluggables and 1.6Tb/s performance

Bilal Riaz, Ciena

As the industry strives to deliver tangible efficiency improvements in network scale, cost per bit and energy reduction, innovative technology approaches are required. This session describes new networking opportunities resulting from the use of 3nm CMOS-based design implementations for both 200Gbaud 1.6Tb/s performance-optimized transceivers as well as 140Gbaud 800Gb/s QSFP-DD800 and OSFP transceivers.

Next Generation Photonic Integration and Packaging Solutions with Photonic Wire Bonding (PWB) and Facet-Attached Micro-Optical Elements

Sebastian Skacel, Vanguard Automation

Photonic wire bonding allows to combine the complementary strengths of different optical integration platforms in advanced photonic multi-chip modules leading to compactness with high performance and great design

flexibility. The technique relies on highly precise direct-write 3D laser lithography for printing of freeform single-mode waveguides between optical dies, thereby offering a path towards fully automated mass production without the need for active alignment. 3D nano-printing can also be used to fabricate facet-attached beam-shaping elements on optical chips and fibers, allowing for low-loss coupling with high alignment tolerance and for wafer-level probing of optical devices.

100G PAM4 Analog CDR for SFP112 modules – enabling 6G front haul architecture

Raza Khan, Semtech

In wireless front haul where latency variation is extremely critical, a traditional DSP will not enable the 6G architectures. An alternative approach is looking back at how analog architectures used to dominate in NRZ modulations. We believe the road for analog is only starting, and are scalable to 100G PAM4 and beyond. A 100G analog CDR would enable lower power, near-zero latency variation and low cost – a true innovation that is required for 6G's demanding architectures. Semtech has decades of analog experiences and is at the forefront of developing such differentiated solutions to enable the MOPA community as well as our system vendor partners with a path forward for their 6G architectures and beyond.

Advancing optical technologies toward 224Gbps/lane for AI

Haifeng Shao, Huawei technologies co. Ltd, China

The explosive growth of AI large language models is driving the evolution of optical components from 112Gbps/lane to 224Gbps/lane. This transformation affects all optical technologies including retimed modules, linear modules, pluggable or CPO formfactors, all must meet the AI engine massive bandwidth requirements. This presentation will review the latest HiSilicon advancements in 224Gbps/lane optical chips technologies, including VCSEL&PD, EML&PD and high-power DFB laser source for silicon photonics engines. We will also present details on how to construct the streamlined package that enhances the overall system performance reducing the crosstalk and BER floor.

Liquid cooled pluggable optical transceivers

Mike Bishop, Ciena

As the functional density of equipment continues to increase and equipment power starts to exceed 40 KW per rack, air-cooling is starting to reach some fundamental limitations in performance, power consumption, and acoustic noise. Liquid-cooling on the other hand, is well suited to manage power up to 100KW

per rack and is a highly efficient heat transfer technology which can produce significant energy savings in comparison to air-cooling. This presentation discusses hybrid Liquid-Air cooling technologies and how they could be integrated into routing and optical platforms. A novel design for a liquid-cooled pluggable transceiver is also presented.

Multi-gigabit Optical Transceiver Design for Automotive

Alberto Rodríguez Pérez, KD

In the realm of Advanced Driver Assistance Systems (ADAS) and Autonomous Vehicles (AV), seamless sensor-to-AI connectivity is paramount. IEEE Std 802.3cz revolutionizes this with speeds up to 50 Gb/s on multi-mode fiber, tailored for automotive use. Central to this is the optical transceiver, but traditional designs fall short in automotive applications. This presentation highlights the need for fresh approaches, covering multi-protocol capabilities, technology nodes, analog-digital design, and photonics integration. By addressing these challenges, we advance automotive connectivity for a safer, more efficient future.

Evolution of Optical Interconnection in the Era of Intelligent Computing Networks

Junjie Li, IPEC & China Telecom

AI-driven massive model training puts forward higher requirements on the ultra-large scale, ultra-low latency, ultra-large bandwidth, and ultra-high reliability of the new generation of intelligent computing data center networks, and the optical interconnection technology of data center clusters is also developing simultaneously. This presentation mainly introduces some new cutting-edge transceivers such as 800G/B800G CPO, LPO, LRO and networking technologies towards IDC and DCI applications, followed by thinking of any potential technology of optics for future infrastructure construction of China Telecom data centers.

Will You Need CPO In 3 Years?

Rajiv Pancholy, Broadcom Inc.

AI/ML cluster sizes are growing exponentially, making optics essential to interconnect tens of thousands of GPUs. Bandwidth, power, latency, and cost demands expected in five years are now required much sooner. Additionally, folded CLOS, Dragonfly, and Torus interconnect architectures, supporting higher radix requirements, present challenges in density, fiber routing, and thermal management, all aimed at achieving the lowest cost per compute. At ECOC 2024, we plan to present the status of Broadcom's Co-Packaged Optics technology platform, addressing the challenges for current and next-generation developments supporting both scale-up and scale-out interconnects.

Path to carbon zero

Andrea Di Giglio, Telecom Italia

ICT footprint is huge and, without any dramatic intervention the situation will explode. However, ICT seems to be aware of this issue, and the biggest ICT companies are aiming to find a common path (the agreement is 50% saving by 2030, net zero goal by 2050). This path has been also recommended by ITU-T for Telco and ICT enterprise. This path should be in line with the P2 scenario of IPCC which foreseen a global reduction of GHG of about 90% by 2050, which aims to stay below the 1.5 degrees increase mentioned before. To contribute to this general scenario, the project IPCEI CIS (Cloud Infrastructure & Services), funded by the European Union – NextGenerationEU, has among its main goals, the implementation of solutions and technologies aimed to guarantee the Cloud Edge Continuum for new application services, optimizing the energy and resource efficiency. The main topic of the speech is to understand problems and provide solutions how to measure, predict and minimize the CO₂ emissions for a cloud environment.





Michael Lebby, CEO at Lightwave Logic, accepts the Most Innovative Product ECOC 2023 Award.

ECOC 2024 EXHIBITION INDUSTRY AWARDS

In conjunction with Optical Connections

Launched in 2020, to celebrate the 25th anniversary of the event, ECOC introduced the ECOC Exhibition Industry Awards in conjunction with Optical Connections. The awards return for 2024 and once again emphasise technology and product commercialisation; they highlight significant achievements in advancing the business of optical communications, transport, networking, fibre-based products, photonic integration and related developments. Winners will be announced live at the Product Focus Theatre at ECOC Exhibition on Tuesday 24th September. Good luck to this year's nominees!

AWARD CATEGORIES 2024

AWARD FOR BEST FIBRE/FIBRE COMPONENT PRODUCT

Fibre and its connectivity are among the forefront of optical communications technologies. This award identifies technology, product, or process innovations that distinguishes and/or drives lower cost, improve ease of installation, improve reliability, increase connectivity density and scalability. Innovative fibre designs, fibre management systems, fibre adapters, trays, modules and connection systems.

AWARD FOR DATA CENTRE INNOVATION/BEST PRODUCT

Broad based. Patch panels, switches, transceivers, servers, fibre, etc. Demonstrate lower cost, lower power consumption, thermal management commercial viability. Innovative packaging/line card and co-packaging solutions. SW solutions that increase security efficiency and can help reducing footprint and power consumption.

AWARD FOR MOST INNOVATIVE PON/5G/FTTx PRODUCT

This should be broad-based. Fibre, connectivity, installation, transmission gear, high speed, environmental design, etc. HW and SW solutions to increase bandwidth capacity, its management and overall scalability.

AWARD FOR OPTICAL TRANSPORT

Optical networking continues to focus on higher capacity to lower transmission cost. Higher speed, modulation/coding, longer reach, higher wavelength density, multiplexing schemes. Innovative use of electronics and software to enable more competitive photonics solutions in the network. Advanced designs that permit for example: longer reach, higher capacity with fault tolerant, error correcting, dispersion management system design. Use of higher performance optical components and co-packaging designs to enable multi-100 Tbps capacities in switches and routers.

POST DEADLINE AWARDS

At Market Focus we attract the world's leading technology companies to submit entries for the prestigious Market Focus Awards. In 2023, we noticed that many companies developing the last products, either announced their products at the ECOC Exhibition, or released information on them via press releases just a few days before the ECOC Exhibition started. Starting in 2024, the Awards Committee has established a new competition of Post Deadline Awards where applicants can submit their entries in two broad value-chain categories:

- Optical materials, components, packages, modules etc.
- Optical Systems, networks, standards, architecture etc.

A key criterion for the Post Deadline Awards is world class products and technology. Results need to demonstrate that the product or technology is clearly state-of-the-art and best-in-class.

The winners will be announced live at the exhibition in the Product Focus Theatre on Tuesday 24th September.

2023 ECOC EXHIBITION INDUSTRY AWARD WINNERS

Best Fibre/Fibre Component Product Award:

Ram Photonics

Data Centre Innovation/Best Product Award:

Marvell

Most Innovative Product – Pon/5g/FTTx Award:

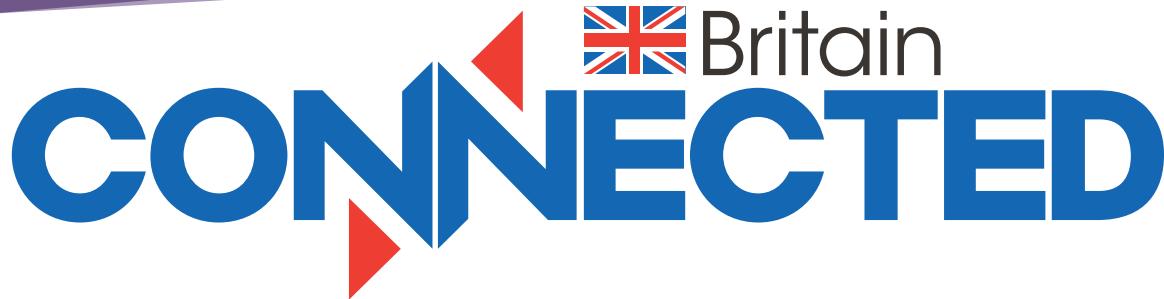
Huawei Technologies

Optical Transport Award:

China Mobile

Winners in the sub-category awards included **Ciena**, for WaveLogic 6; **Keysight**, for its multiport test solution; **Coherent** for its 200Gbps Pam4 chip; **Infinera** for its ICTR-64 TROSA; and **Lightwave Logic** for its Hybrid PIC platform.

Nominations will be considered and voted on by the Market Focus Committee, which reviews the progress of advanced technologies from research to commercialisation including volume production as well as new and innovative products.



THE FUTURE OF CONNECTIVITY

11th - 12th September, 2024, ExCel London

Now in its 10th year, Connected Britain, the UK's biggest digital economy event is where the UK's connectivity leaders from across the public and private sectors come to meet. With the numbers of speakers, exhibitors and visitors up from 2023, and 13 streams, this year's event bound to be the best one ever.

The 13 streams feature C-level speakers from companies including Nokia, BT, STL and Ericsson, along with representatives from some of the UK's many altnets, local and regional authorities and academics. During the event, just about every aspect of the UK's communications industry will be examined and future challenges addressed.

CONNECTED BRITAIN STREAMS

Keynotes: Where is the UK connectivity sector headed? How can the UK position itself as a technology leader? How is digital infrastructure benefitting communities and businesses across the UK? What obstacles lie ahead for delivering ubiquitous connectivity and how does the industry overcome them? Find out at the Connected Britain keynotes.

Digital Britain: In an increasingly digital world, the future of work is changing. New skills are needed, new mindsets, new partnerships. Is the UK taking the right steps to close the "skills gap"? What is needed both from government and the private sector to ensure that the UK remains a technology and business leader?

Connected Networks: New for 2024, the Connected Networks Stage will explore strategies for building, expanding, and future proofing communications infrastructure whilst also exploring the technologies which are driving innovation.

Connected Infrastructure: Digital connectivity is the cornerstone of the UK's ambitions when it comes to intelligent transport system, smart utility networks, EV charging and more. The potential is huge, so how can the UK capitalise on these exciting opportunities?

Gigabit Britain: Taking strategic look at the commercial and regulatory context for the deployment of next-generation communications infrastructure in the UK.

Gigabit Britain is the best place to learn about the state of play for the fixed and mobile sectors whilst also understanding what new technology opportunities might be around the corner.

Project Rollout: Focussing on the realities of building communications infrastructure. Key themes will include the technologies enabling network rollout, engineering strategies, supply chain issues and public-private partnerships.

Connected Society: Keeping people connected has never been more important. Tackling the digital divide, promoting digital inclusion, developing the provision of digital public services, providing support for those who need it most is crucial to delivering a more connected and inclusive Britain.

Smart Britain: Smart Britain will focus on the delivery of smart places, the growth and regeneration of the UK's cities, towns, and rural communities, and shine a spotlight on the key stakeholders who are shaping these developments.

Connected Industries: From manufacturing to logistics, from healthcare to the creative industries, next-generation communications infrastructure is enabling exciting new use cases. Connected Industries will bring together CSPs, technology providers, enterprises, and the public sector to explore how cross-sector partnerships and connectivity are driving innovation.

Connected Enterprise: From SMEs through to large-scale enterprises, the demands of private and public sector enterprise customers are constantly evolving. Connected Enterprise will explore the evolution of the UK's enterprise market, the technologies that are re-shaping B2B communications as well new products and services.



Connected Britain 2023

Image: Total Telecom

Local Authority Showcase: Local authorities are the driving force behind the innovative technology projects and trials which are underway across the UK to solve key challenges covering everything from mobility to housing, from healthcare to town planning. The Showcase Stage is a platform for digital champions from across the UK's public sector to share their successes as well as their challenges and to learn from their peers.

Innovate Britain: The Innovate Britain stage will offer a celebration of innovation. Startups will have chance to pitch their idea to potential investors, partners, and customers. Investors, accelerators, scaleups and SMEs will share their insights into the keys for business growth and success.

Tech Britain: Tech Britain will delve into the latest innovations in the technology sector and what exciting new opportunities these developments unlock for businesses.

Awards and Afterparty: Connected Britain is not all work and no play however. **The Connected Britain Awards** recognise the most significant and innovative organisations, solutions and programmes that are shaping Britain's digital future. The Awards ceremony takes place on Day 1, Wednesday 11th September, on the Keynote Stage at 6.20pm - 7pm.

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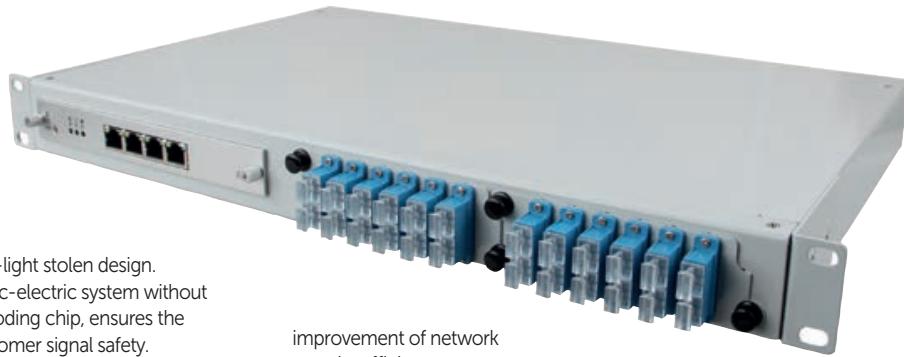
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KOC Communication Co. Ltd FRMS Fibre Monitoring System

Based on our new patent design of 2*2 Tap Waveguide Chip, we integrated N - 2*2 PLC splitter in one mini type PLC splitter. Each 2*2 PLC Splitter is 98:2 non-uniform channel and both end 2% ports are for downlink/uplink channel monitoring. FRMS fibre monitoring system is a flexible design which can be easy to integrate into customer's fibre ODF system for in-line real time monitoring.

Features:

- Continuous real time fibre path monitoring.
- Uses 2% operating light for in-line monitoring.
- 2% operating light only used for event monitoring, such as fibre link disconnect /power abnormal drop down at any time.



- Anti-light stolen design.
- Optic-electric system without decoding chip, ensures the customer signal safety.
- Customized package design.
- After an alarm, the backup router quickly and accurately searches and queries, so as to avoid manual search delays and line disconnection time.
- Access to the network management system and connection with operations and maintenance enable quick troubleshooting and

improvement of network security efficiency.

- Effective cleaning and management of dummy, to reduce duplicate investments and the elimination of resource waste.

In one typical application, the PLC splitters can be integrated into a standard 12fo fibre splice tray. Each tray can be used for

monitoring 12 fibre channels. For one 4U ODF unit, there are 6pcs trays totalling 72 fibre channels. Also, each 4U monitoring control unit can be used to monitor a maximum of 1,152 fibre channels.

See us at ECOC 2024 booth B52.

New linear amplifier from Anritsu

Anritsu Corporation has started sales from July 24 of its AH15199B 140 Gbaud Wideband/High-Output (2 Vpp) Linear Amplifier (pictured), developed to evaluate optical transmissions devices in the generation of beyond 1Tbps. The linear amplifier features a wideband frequency response of 200 kHz to 135 GHz at a -6 dB bandwidth and can amplify 140 Gbaud PAM4 signals to 2.0 Vpp. The high-gain amplification of +15.5 dB and low jitter fluctuation of 300 fs from the actual signal timing support amplification of even high-quality input signals attenuated during transmission.

The AH15199B can amplify 140 Gbaud PAM4 signals from various signal sources, such as DSPs, and can directly drive modulators and other devices requiring high amplitude.



Therefore, it is a suitable driver for evaluating optical modulators for 800GbE and 1.6TbE digital coherent system, now the focus of attention as next-generation transmission systems, as well as for IM-DD (Intensity Modulation-Direct Detection) systems used widely in optical communications.

Anritsu says the next-generation Ethernet standard IEEE802.3 supporting high-speed networks will use digital coherent methods, such as 800GBASE-LR1 (for 10 km), 800GBASE-ER1-20 (for 20 km), and 800GBASE-ER1 (for 40 km), as well as the IM-DD method. The OIF (Optical Internetworking

Forum) is studying specifications for optical transmission technologies, such as 800ZR, 1600ZR, as well as coherent technology to support increased optical network capacity and accelerate growth of "beyond 1 Terahertz" systems.

See us at ECOC on booth C1

Lumentum's 130+ Gbaud Smart TROSA



Enables field deployment of optical systems using data rates of 800Gbps per lambda

InP-based 130+ Gbaud Smart Transmitter Receiver Optical Sub-Assembly (TROSA) product addresses the

growing need from cloud data centre operators for high-performance optical solutions that support the rapid influx of data traffic and increasing bandwidth requirements driven by new AI/ML applications.

- Suitable for QSFP-DD, OSFP & CPF2
- Fast module development and design-in for simple module manufacturing with reduced electro-optical calibration and testing

- Suitable for baud rates up to 130+ Gbaud
- On-chip integrated SOA enabling output optical power well exceeding 0dBm

See us at ECOC 2024 booth A24

Revolutionary S185 EndView by FITEL elevates standards for splicing Hollow-core and Multi-core fibers

Our revolutionary FITEL S185 EndView Splicer aligns fibers with complex internal structure seamlessly. The S185EDV employs an End View system designed for splicing fiber with complicated internal structure such as Hollow Core, PCF and more. These fibers can be very difficult to align using a traditional Side View splicer. Viewing the cross sections images of the fibers gives more detail about the internal structure providing more control to the user for precise splicing results.

Our Composite Image Technology overlays both End View fiber images into one picture, allowing the user to verify the alignment and fine tune to their exact requirements.

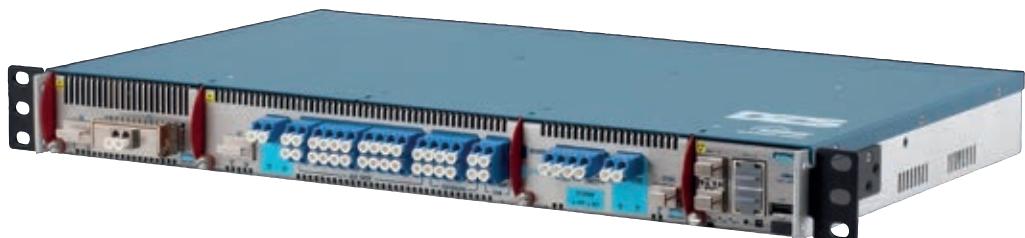
Furukawa Electric Europe Limited

See us at ECOC on Stand B56



DZS' 100G/400G Remote In-Band management

DZS demonstrated what it believes is the world's first remote in-band management capabilities for next-generation 100G/400G optical transport on its Saber 4400 platform (pictured) during Fibre Connect 2024 in Nashville in July. The company says with this breakthrough capability to power next-generation compact optical transport form factor modules, including the popular Quad Small Form Factor Pluggable Double Density Digital Coherent Optical (QSFP-DD DCO) transceiver, DSS is arming service providers with a powerful, flexible, and cost-effective way to bring up to 400G optical transport to the network edge to support emerging bandwidth needs.



It adds that by offering in-band management, the Saber 4400 eliminates the need for dedicated fibre or channels to manage these smaller, more powerful transceivers both locally and remotely. Additional key benefits include reducing space requirements for dedicated management devices in remote cabinets and their associated power consumption while improving time-to-market and flexibility. Further efficiencies

can be achieved by leveraging the DZS Xtreme Transport Cloud Manager to deliver remote in-band management and administrative capabilities to all (including third-party) coherent optical equipment.

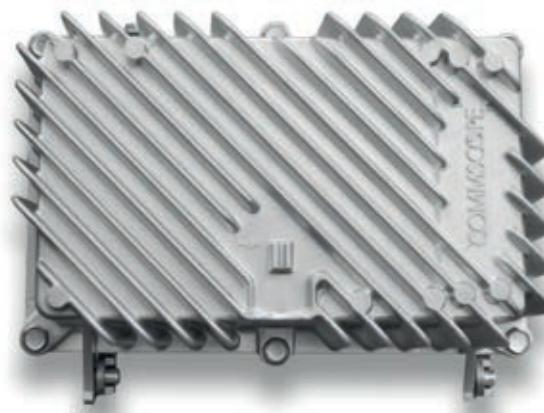
The addition of in-band management functionality to the Saber 4400 eliminates the need for service providers to allocate additional fibre or channels for managing onsite and remote coherent optics

deployments. It also mitigates the need for additional local equipment to physically manage the system, fibre, space and power for temperature control, thereby optimising deployment efficiency and cost-effectiveness. This capability, says DZS, further improves the economics of optical transport deployment and opens a new path for service providers to enable much needed higher bandwidth at the network edge.

CommScope's 1.8 GHz DOCSIS 3.1 Amplifiers now shipping

CommScope says its STARLINE® 1.8 GHz Extended Spectrum DOCSIS®(ESD) amplifiers announced in October are general availability. Available immediately, the BLE® 180 Line Extender and MB180 MiniBridger® amplifiers offer operators a simple and economical solution for introducing ESD to DOCSIS 3.1 networks as well as a clear path to DOCSIS 4.0. Both amplifiers support ultra-high-split operation of up to 1794 MHz in the downstream and up to 684 MHz in the upstream to maximize network reliability and data rates.

CommScope is currently shipping orders of the new ESD amplifiers to major customers.



The company is developing Full Duplex DOCSIS (FDX) amplifiers that also use the STARLINE form factor, offering MSOs two paths to DOCSIS 4.0 operation from the same family of amplifiers. CommScope is also developing DOCSIS 4.0 ESD and FDX models of its

NC4 and OM4 Series optical nodes, which will provide MSOs with a full portfolio of active components that support both common DOCSIS 4.0 network technologies.

"We designed the STARLINE 1.8 GHz ESD amplifiers for MSOs to upgrade their

networks in anticipation of next-generation architectures like DOCSIS 4.0, while fully monetizing their current network assets and better serving their consumers today," stated Guy Sucharczuk, SVP & President Access Network Solutions. He continued, "By deploying the amplifiers in mid-split or high-split 1.2 GHz networks now, MSOs can optimize the performance of their DOCSIS 3.1 networks while taking an important step in future-proofing, before eventually upgrading taps and nodes. This incremental approach defers the costs per homes passed associated with an immediate DOCSIS 4.0 network upgrade—the perfect way to both plan for the future and protect an investment in next-generation technology."

TiniFiber[®], FiberFox partner for new arc fusion splicers

TiniFiber, which manufactures patented TiniFiber Micro Armor Fiber optical cabling solutions, has partnered with FiberFox America Inc. to unveil two new arc fusion splicer systems that it says will help installers speed the precision, low-loss splicing of the company's compact, lightweight and durable armoured fibre optic cables. Providing Active Core Alignment and V-groove splicing respectively, the Mini 6S+ (pictured) and Mini 12R+ are, the company says, the industry's smallest arc fusion splicers and both come with two batteries as standard. The Mini 6S+ uses six motors to directly align fibre cores for reliable single strand splices, while the Mini 12R+ can handle up to 12 ribbon fibre strands simultaneously.

TiniFiber says both of the new systems offer comprehensive



touchscreen control and feature a two-CCD camera system for high-accuracy fibre alignment. The units are fully compatible with Splice-On Connector (SOC) technology and are supplied with a thermal stripper, precision cleaver, cleaning kit and all of

the consumables needed to get up and running immediately.

The Mini 6S+ measures 4.88 x 4.85 x 5.43 inches (124 x 123.2 x 138mm) and weighs 3.4lbs (1.54kg). Typical splice loss is from 0.01dB to 0.04dB depending on cable type and

a 'quick mode' will deliver a single mode splice time of just six seconds. Up to 90 splice programs and up to 32 heating programs can be configured by the user and onboard memory accommodates saving up to 10,000 splice records and 2,000 splice images. The Mini 12R+ has similar dimensions as the Mini 6S+ and weighs 3.05lbs (1.38kg). Typical splice loss is from 0.02dB to 0.08dB depending on cable type; typical splice time is 15 seconds. Up to 140 splice programs and up to 38 heating programs can be configured by the user and the unit's splice memory supports up to 5,000 records. Each unit is supplied as a kit inside a protective yellow hard carry case and will come with a 3-pack of FastTrack Calibration Services, performed in the USA. Services include – demo loaner, factory refresh, software updates, replace electrodes, clean optical components, diagnostic and performance test.

R&M expands FTTH splice closure portfolio

Reichle & De-Massari (R&M), has launched new FO distribution high-density splice closures SYNO S series and ZOONA STP12, which offer two to three times the fibre capacity of conventional distribution splice closures for FTTH connections, says the company. The SYNO S-400HD accommodates 2,304 ribbon fibres and 384 single-fibre splices. The leading model is the SYNO S-500HD with a capacity of 3,456 ribbon fibre and 576 single fibre splices in a 25x70-centimetre housing. The modular tray concept of the SYNO S series splice closures gives network operators flexibility in terms of FTTH connections. Technicians can also configure the splice closures on-site as required. Each tray can be

equipped with holders for single fibre or ribbon fibre splices or splitters, and the segmented cable entry bays with SYNO gel seals are also freely configurable. This means that FTTH companies can implement all kinds of topologies and applications with a single system. They can plan the network with different cable types to suit the premises. In the future, cabling can be densified or changed quickly on demand, as the splice closures can be opened in just a few simple steps.

The outdoor splice closure ZOONA STP12 with a capacity of up to 144 single fibre splices. The compact ZOONA splice closures are used in masts and facades as well as in niches and shafts. The ZOONA144 is a cost-efficient solution for gradually expanding or quickly increasing the density of the FO infrastructure on

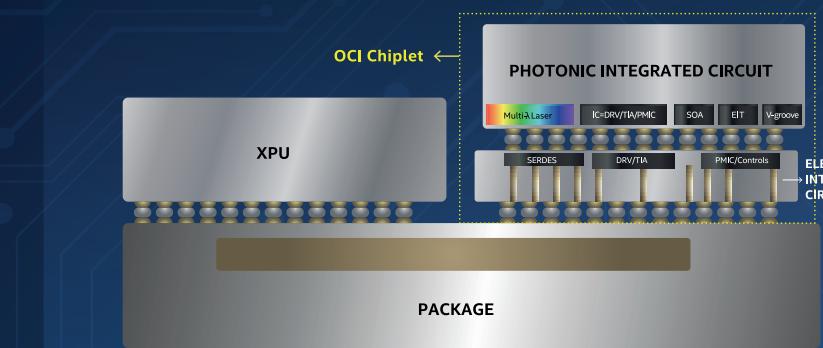


the last mile to customers. Technicians can prepare the splice closures for installation within minutes without special tools and specialist training. This is why the ZOONA is particularly suitable for time-critical roll-outs. The mechanical QIKseal

developed by R&M is self-explanatory. The high-density splice closures SYNO S-400HD and ZOONA STP12 round out the R&M portfolio for the FTTx market. It covers all network levels from the central office and PoP to the service area interface.



SILICON PHOTONICS OPTICAL COMPUTE INTERCONNECT (OCI)



Multi-Terabit optical I/O solutions delivering the energy-efficient bandwidth and reach required to scale next-generation compute platforms and AI/ML clusters

