OFC

The future of optical networking and communications

2023 Post-Show Report

An Overview of the Market

IEEE ComSoc IEEE Communications Society

IEEE Photonics Society

OPTICA Formerly OSA

Content

LIGHTCOUNTING

The name alone is what sets us apart and what defines us as a company. Nineteen years ago, LightCounting began with an analyst team focused on research for high speed interconnects for the datacom, telecom and consumer communications markets. We tracked deployments of optical connectivity in mega datacenters of cloud companies over the last decade. In early 2020, LightCounting initiated coverage of the market for wireless infrastructure with the focus on 5G deployments and its impact on the rest of the networking infrastructure and the industry supporting it.

From that time our research team has grown to cover the whole supply chain from optical and semiconductor components, to modules and sub-systems. We have been defining and refining the market intelligence mix ever since, to offer our clients a unique perspective on the industry landscape ahead and a clear roadmap to navigate it with.

LightCounting.com

1 Hot Topics of OFC 2023

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Optical connectivity for AI Clusters, linear drive pluggable transceivers and co-packaged optics attracted the most attention at OFC this year. Several new start-up companies emerged from stealth mode and shared their visions for new products and technologies. Many also focused on developing devices for optical connectivity in AI Clusters.

The early success of ChatGPT and other generative AI apps certainly contributed to the new focus on AI at OFC. The current slowdown in infrastructure spending of the cloud companies has already impacted the business of chip suppliers. Transceiver vendors are bracing for a slower year as well. Yet, investments in AI hardware for the cloud have remained strong, and these are likely to accelerate in 2023. Are there new opportunities for suppliers of optics?

The panel discussion on "Optics for Future AI Systems" was held in a fully packed theater at the OFC Exhibition, with even more people left standing than those sitting in seats. Having Andy Bech Tolsheim among the panelists helped to draw a crowd. Andy introduced a new exciting topic - linear drive pluggable transceivers. Discussions on the linear drive technology started at OIF at the end of 2022, but it was a surprise to a majority of OFC attendees.

1

LINEAR DRIVE PLUGGABLES

NVIDIA was the first to present the idea of linear drive optics at OIF last October. The idea is pretty simple, as illustrated in the chart below, which compares Co-Packaged Optics (CPO) and linear drive pluggables. In both cases, one of the two DSPs is removed from the link, reducing power consumption. CPO moves the optics closer to the ASIC, but linear drive pluggable optics remain at the front panel of the switch. According to Broadcom, its new 100G SerDes for T5 switches is capable of delivering signals across 12 inches of copper traces on PCBs to drive the pluggable optics without any additional retimers or DSPs. Andy presented test results for 64 ports of a 51.2T switch equipped with linear drive pluggable transceivers to show that it works.

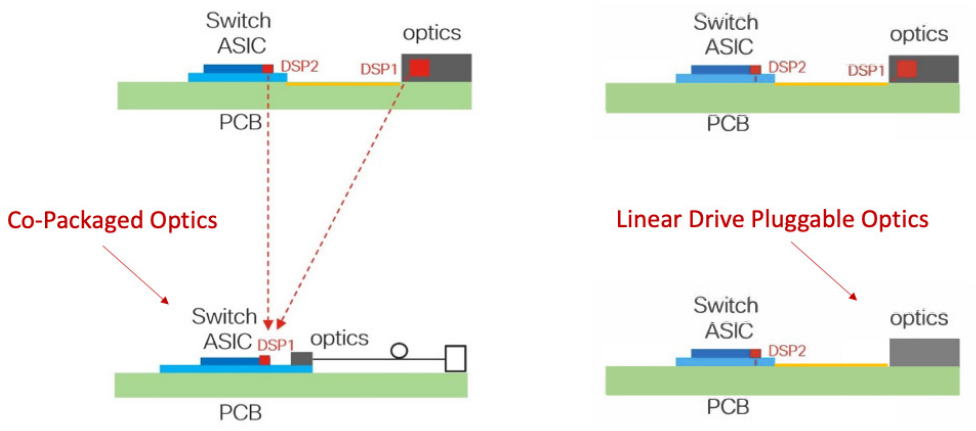
This is a very pleasant surprise. For comparison, 50G SerDes on T3 and T4 switches required pluggable optics with DSPs and additional retimers on some of the PCB traces to restore signal integrity. Improvements in the performance of modulators, receivers, drivers and TIAs also contributed to the success of linear drive pluggables, but the SerDes and new PCB materials are the true enablers.

Let us not get carried away by enthusiasm, though, as there are still many questions on how successful the linear drive transceivers will be. Increased complexity and cost of PCBs is one of the issues, and how and where to test all the pluggable transceivers, PCB traces and SerDes remains to be defined.

Yet, the linear drive offers an alternative to co-packaged optics by substantially reducing power consumption, as illustrated in Figure 1.

There is very little doubt that pluggable transceivers and CPO will deliver further improvements in power consumption at 200G per lane, as illustrated by arrows in Figure 1. Whether the linear drive approach even works at 200G per lane is still being determined. LightCounting hosted a special webinar to discuss the linear drive technology at OFC. A registration link and recording of the event can be found on LightCounting.com.

Figure 1



1

CO-PACKAGED OPTICS AND RELATED PRODUCTS

Cisco had a very impressive demo of a CPO prototype. Although not a product yet, it delivered remarkable performance and confirms Cisco's commitment to this new technology. As illustrated in Figure 1, Cisco's CPO has the same power efficiency as Broadcom's solution – about 7pJ/bit.

Cisco's demo included two switches running next to each other, shown in Figure 2. One was fully populated with pluggable optics, and the other was entirely populated by CPO. Most of the channels were looped back together, but there were a couple of channels where they were monitoring the traffic to prove that it was really operating over a 2 km reach with FR4-type devices.

The demo included two monitors (not shown in Figure 2), measuring the power consumption of the two switches running in parallel. It demonstrated 22% power savings by CPO on their first try. With improvements, Cisco expects to increase this number to 25% or 30%. There is more information available on Cisco's blog.

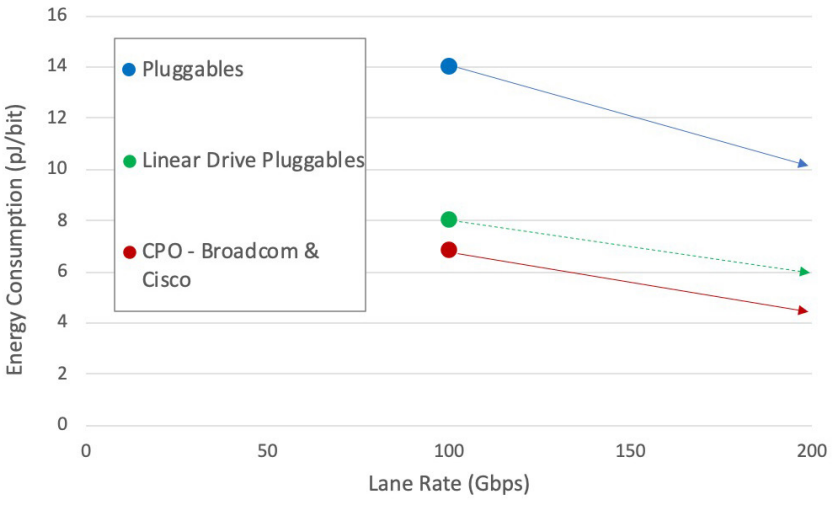
This demonstration certainly adds a lot more credibility to CPO technology. We now have two huge companies, Broadcom and Cisco, fully committed to bringing CPO to Ethernet switches. Both companies are believed to be supplying switching ASICs to Meta. Establishing a more diverse ecosystem for CPO will take a while, but two suppliers are better than one.

Broadcom also continues to make progress on CPO and presented several live demos at OFC, including a 51T switch with several channels of CPO running on it, delivering very low power consumption. Broadcom also had a live demo of a fully functional CPO 25.6T product, shown last year by their partners Tencent and Ruijie Networks.

Ragile Networks is starting production of NPO and CPO-equipped switches for trials and product qualifications. While they are not yet ready for massive deployments, Ragile reports a lot of interest from the community in its products.

Intel had a live demo of an open compute interconnect – a CPO developed for compute and AI applications. Intel discontinued its Barefoot Networks Ethernet switches, but they continue to explore the application of silicon photonics for AI interconnects. Intel demonstrated 4 terabits of bandwidth in each direction in highly parallel solutions of 64G per channel.

Figure 2



1

Coherent presented another live demo of CPO. It was developed in partnership with IBM for an ARPA-E-funded project. It is based on 16 x 56G VCSELs, delivering 4Tbps connectivity (in each direction) with 3.8 pJ/bit power consumption.

Ayar Labs also had a live demo of their product, which is 4 terabits bi-sectional with two terabits in each direction.

Ranovus presented a demo of CPO interoperability with a third-party 800G-DR8 OSFP transceiver. Their solution uses micro-ring modulators to reach a record low power consumption (less than 5pJ/bit for a CPO compliant with Ethernet standards).

Ayar Labs, Coherent/IBM, and Intel CPO achieved even lower power consumption, but their optics do not conform to the IEEE standards. These may not apply to Ethernet switches but could find other applications in AI clusters.

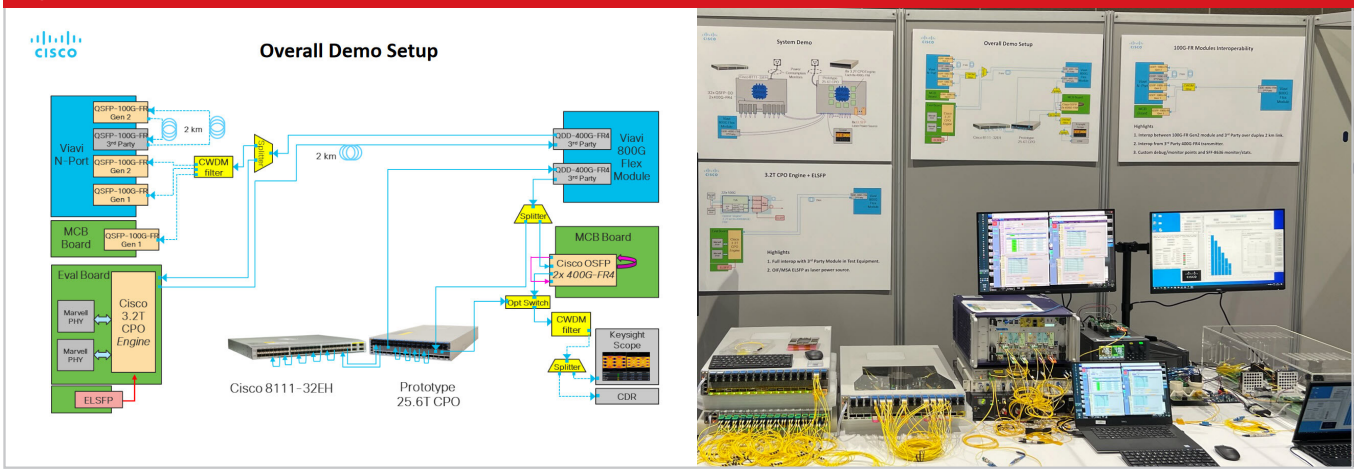
Fiber connectors and other technologies for connecting fiber arrays is a critical supporting technology. Efficiency is still a problem, and it's even more of a challenge because you have to align multiple fibers simultaneously. A startup company, Nubis Communications, started discussing its products publicly just ahead of OFC. They have a technology for a 1,000-fiber connector, but that's not what they're using on their current products. Their first product is more modest, with 32 fibers, which still pushes the limits of parallel fiber connectivity.

Teramount and Tower Semiconductor announced a collaboration based on Teramount's 'PhotonicPlug' technology for the simultaneous connection of a large number of fibers to the chip and Tower's silicon photonic 'Bump-ready' wafers. Avicena demonstrated an MTP-style connector that works with 2x331 element fiber bundles.

In a postdeadline paper titled "High-power O-band Quantum Dot Distributed-Feedback Laser for Pluggable DR4/DR8 Optical Transceivers and Remote Laser Modules," Innolume and Alfalume announced the availability of 1.3 μm high-power uncooled QD Lasers that deliver CW power exceeding 300mW at 85°C. Even at 105°C, there is minimal reduction in the output power. It is an excellent example of a fundamentally new technology (quantum dots) delivering superior laser performance at higher temperatures.

OIF continues to work on co-packaged optics. Near packaged optics (NPO) was a "warm-up project," and CPO is their new focus. Their work on developing specifications for the external laser is widely accepted by the industry and used in many demos. Now they are defining specifications for the engines themselves and the way they are co-packaged on the same substrate.

Figure 3



2 PAM4 Scales Up and Down

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Technology demonstrations and IC announcements showed that PAM4-based direct-detect optics are extending both to higher data rates and into new applications, including mobile fronthaul. Marvell's announcement that it is sampling a 1.6T PAM4 DSP for OSFP-XD modules grabbed the most attention. The Nova DSP 'gearboxes' 16x100Gbps PAM4 host-side lanes into 8x200Gbps PAM4 optical-interface lanes. Marvell says the chip handles 200G/wavelength links up to 10km using LR FEC and supports KP4 FEC for low-latency DR4/FR4 links. Built with 5nm CMOS process technology, Nova integrates laser drivers for EML and silicon-photonic modulators. Marvell completes the design with companion quad-channel 112Gbaud TIAs, also available for sampling. It estimates that 1.6T module power will be less than 28 watts or 14 watts per 800G port.

2

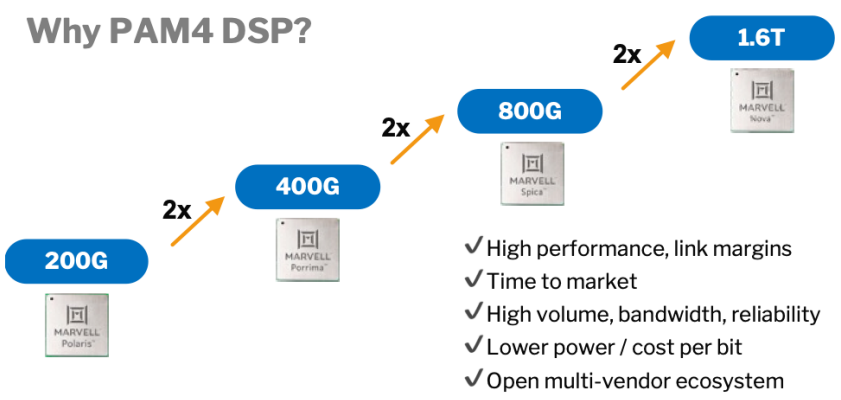
Although Marvell was first to sample a 1.6T DSP, other vendors demonstrated test chips or related 112Gbaud components. Broadcom demonstrated a DSP test chip transmitting 200Gbps PAM4 into a Semtech 112Gbaud driver IC driving a Broadcom EML. On the receiver side, a Semtech TIA fed into a Keysight system implementing a software-based receiver. Finally, Intel demonstrated a silicon-photonic transmitter IC (PIC) for 200G/lambda PAM4 with hybrid-laser integration and micro-ring modulators (MRMs). The company has shipped more than eight million optical modules using its hybrid-laser technology.

Outside of optical modules and active optical cables (AOCs), PAM4 DSPs also enable active electrical cables (AECs). Credo Technology incubated the AEC market, and at OFC, it demonstrated 800G AECs interoperating with its Screaming Eagle 1.6T retimer chip. Sampled in 4Q22, Screaming Eagle can retime 16x100Gbps PAM4 channels for OSFP-XD applications or gearbox 8x100Gbps lanes into 16x50Gbps lanes. Handling electrical channels with up to 40dB insertion loss, the chip enables 1.6T AECs with reach of up to 2.75m over 32AWG twinax.

With 800G optical modules now shipping in high volume, IC vendors are driving down cost and power for second-generation designs. Broadcom announced sampling of Cygnus, its first 5nm CMOS 800G DSP, targeting module power under 11 watts for SMF and 10 watts for MMF. Intended for QSFP-DD and OSFP modules, Cygnus connects 8x100Gbps PAM4 host-side lanes to 8x100Gbps optical-interface lanes, and it supports FEC termination for 800G Ethernet. Cygnus is the industry's first 5nm DSP to integrate TIAs in addition to drivers, reducing power through integration. Broadcom claims that TIA integration reduces power more than moving from 7nm to 5nm process technology. It also designed the chip to fit four die into the OIF's 3.2T co-packaged optical-engine footprint.

Cygnus competes with Marvell's Spica Gen2, which sampled in late 2022 and is also manufactured in 5nm CMOS. Although Marvell relies on discrete TIAs, it claims 800G module power of fewer than 12 watts. It offers a companion octal-channel 56Gbaud TIA and a quad-channel linear driver for VCSEL-based optics; the DSP integrates modulator drivers for SMF designs. MaxLinear, meanwhile, was the first to sample a 5nm DSP for 8x100G PAM4 optical modules. At OFC, it announced the production availability of its Keystone 800G DSP, which the company says dissipates only 5.7 watts. The chip integrates a single-ended driver for EMLs and a differential driver for silicon-photonic modulators.

Figure 4



2

To lower the cost and power of PAM4 links, some vendors have designed analog alternatives to DSPs. Macom pushed this approach to 100G/lambda with its Pure Drive chip set, which it demonstrated in an 800G QSFP-DD MMF module at OFC. At the same time, Semtech is applying its Tri-Edge 50G/lambda PAM4 analog CDRs to 50Gbps links for 5G fronthaul links. Several vendors are also pursuing linear equalizers as an alternative to DSP-based retimers for copper cabling. Active copper cables (ACCs) using equalizers at each end promise lower cost and power than AECs utilizing a pair of DSPs. ACCs are most attractive for well-defined racks where the end customer connects a small set of qualified systems.

Overall, OFC showcased a healthy and innovative ecosystem around PAM4 technology. Most importantly, sampling ICs validate 200G/lambda PAM4 as the leading path to 1.6T optical modules for intra-data-center links. At 100G/lambda, three separate 5nm DSP designs represent a massive investment by IC vendors and continue to drive down 800G-module power. For short-reach data-center links, AOCs, AECs and ACCs offer additional cost and power savings opportunities, foreshadowing the decline of passive copper cabling (Direct Attach Copper, or DAC).

3 Progress in Coherent Optics

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Ciena, Fujitsu, Nokia and Infinera announced new coherent DSP and modules ahead of OFC 2023, while Cisco (Acacia) reported the first shipments of their new 1.2Tbps single-channel coherent pluggable modules. The performance of these solutions is summarized in Figure 5.

Nokia announced PSE-6s DSP chip and 130Gbaud optics, enabling 1.2T per wavelength solutions. Nokia used these new components to design a 2.4T line card, combining two wavelength channels. Their DSP design allows framing of three 800GbE channels onto two 1.2T wavelengths.

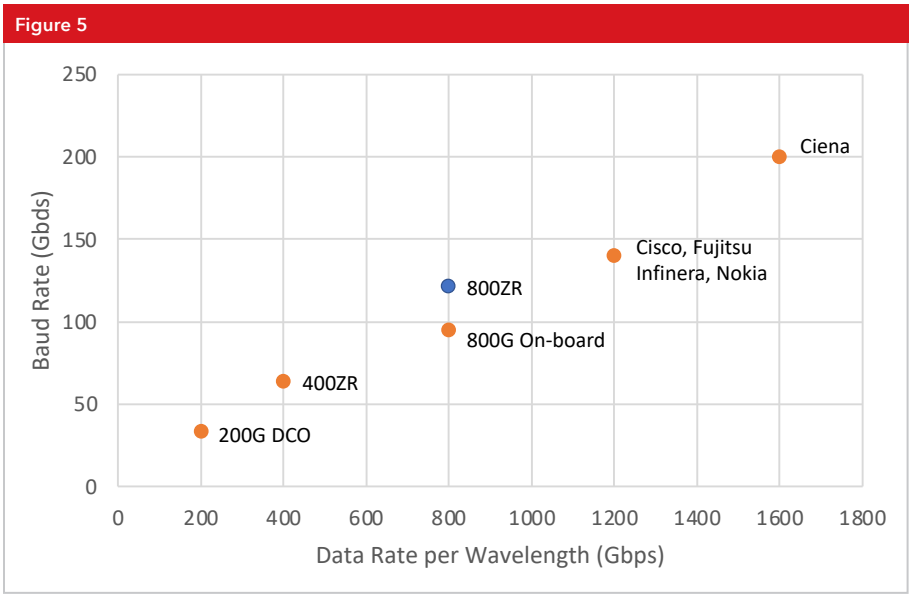
Ciena's new coherent DSPs – WaveLogic 6 Extreme and WaveLogic 6 Nano – support up to 1.6T per wavelength. This will be the first product with 200Gbaud optics. WaveLogic Nano will be combined with 120-140Gbaud optics for pluggable 800ZR modules. Ciena is using InP and thin-film LiNbO3 optics in their coherent products. These materials offer advantages in speed and performance, but silicon photonics is the best for integration with electronics.

Improvements in spectral efficiency are marginal, but the new coherent products will significantly reduce power consumption and cost.

While coherent transmission has to date been used mainly for high-speed DWDM networks, it also has the potential to move into edge and access networks, including connectivity to datacenters and within enterprise campus networks.

Coherent (formerly II-VI and Finisar) surprised the industry by announcing very low-power 100G coherent DSP technology in June 2022. This product is designed with 100G ZR transceivers in QSFP28 form factor, making these modules compatible with a vast number of QSFP28 ports deployed in datacenters and enterprise networks. Coherent hosted a live demo of 100ZR in QSFP28 form factor, running at 5W of power consumption.

Figure 5



4 Access Network Evolution Continues

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25G VS. 50G PON – WHAT'S NEXT?

Discussions on this topic reinforced the prevailing view that the Chinese operators will skip 25G PON and deploy 50G PON next, while Western operators are embracing 25G (symmetric) as the next step above XGS PON.

This is partly because China's 10G deployment is winding down, and those OLTs are not '25G ready' – a majority are CombiPON OLTs with XGS and GPON capability. On the other hand, most Western operators are on the front end of 10G PON deployment and can install 25G-ready XGS-PON, which can be upgraded to 25G PON simply by replacing one transceiver with another. Nokia and Ciena both have this capability today; no doubt the other major PON vendors will also.

50G CombiPON

Several leading transceiver manufacturers showed "50G PON transceivers" in their display cases. Discussions revealed that these are prototypes, and the specs for such devices are not finalized yet. We did hear that the big Chinese telcos are asking vendors for 50G CombiPON devices with 50, 10 and 1G capability in a QSFP form factor. The manufacturers admitted this is a challenging target, and discussions are ongoing to work out tradeoffs between carriers' wants and needs on one hand and vendors' technical and commercial capabilities.

100G PON – WHEN AND HOW?

There were multiple technical sessions presenting the results of experimental 100G coherent PONs. However, Vincent Housma and Dora van Veen of Nokia made a compelling case for using low cost, high volume components used in datacenter optics to build the next generation 50G and 100G PONs without resorting to coherent modulation. 200G PON could then be achieved by multiplexing two wavelengths of 100G PON. With this logic, Coherent PON would only be needed once speeds of 400G were desired, which, according to their analysis, is likely a decade or further away.

In discussions with Infinera, the idea of a variable rate PON was floated. The idea is that Infinera's XR optics could operate over existing ODNs and PONs systems without interference, by utilizing the center C-band wavelengths that existing PONs avoid. Infinera's XR modules can be programmed to operate at speeds of 50, 100, 150 and 200G using subcarriers. We haven't delved into the technical or economic feasibility of this approach, but the concept is certainly interesting.

CableLabs's Haipeng Zhang also presented a proposal for a variable rate coherent PON, using different modulation formats for different distances – QPSK to deliver 100G service at long distances, 16QAM for 200G services at intermediate distances and 64QAM for 300G services at short distances. Data rates of up to 300Gbps were demonstrated over 50km links with 1x32 splits. Guoqiang Li of Fudan University gave a presentation addressing variable rate PON via modulation-format switching.

Finally, CableLabs's Zhang also presented separately a concept for a low-cost 100G PON based on substituting a Fabry-Perot laser for the more traditional External Cavity Laser.

4

FIBER-TO-THE-ROOM

As much as Fiber-to-the-Room appears to be a technology searching for a solution, it continues to get some airtime at conferences, and OFC was no exception. And while support from stalwart advocate Huawei has not waned, what was new at OFC was that "Mr. Access" Philippe Chanclou of Orange Labs was shining a spotlight on it, giving a MarketWatch talk suggesting FTTR would be an excellent way to provide interference-free backhaul for WiFi extenders located in different rooms of a house. We shall see.

FRONTHAUL

Fujitsu's active fronthaul system takes short-reach grey optical links from RUs and electrically multiplexes them into 100G streams, which are then transported over 100G DWDM waves to the BBU site, where they are de-multiplexed back to 25G streams before handing off to the BBU.

Fujitsu's passive fronthaul solution simply multiplexes colored 25G wavelengths originating at RUs and combines them via a passive mux onto a single fiber. Tunable 25G optics with an I-temp rating are ideal for this solution.

MOPA (the Mobile Optical Pluggables Alliance) released an updated spec (Technical Paper 2.1) on 09 March 2023, that includes a new optical fronthaul proposal using 50G 48-channel DWDM in the O-band using SFP56 form-factor, 15 km reach, I-temp optics. This blueprint is explicitly proposed for passive and semi-active DWDM single-fiber RU-DU links. The paper contains a total of 19 different blueprints for network architectures for various fronthaul scenarios. Clearly, when it comes to fronthaul, one size does NOT fit all.

Nokia presented a study that concluded that XGS and 25G PON technology is well-suited for small-cell xhaul due to the overlap in physical locations between small-cell sites and residential FTTx fiber runs.

6G fronthaul will need 100G in all parts of the xhaul – fronthaul, middlehaul and backhaul – per Philippe Chanclou of Orange Labs.

5 Optical Satellite Communications

5 Optical Satellite Communications

The availability of lost-cost launch vehicles is ushering in the era of private, commercial business ventures in earth orbit, dubbed "New Space." Traditional radio communications use a "bent pipe" architecture where each satellite connects directly to the ground using RF technology. This radio-based solution is bandwidth limited, and having to download data to a limited number of ground stations can create lags of an hour or more between data collection/origination by a satellite and receipt of that information on the ground.

Satellite operators are looking at optical communications to relieve this bandwidth bottleneck and improve latency. Part of the solution involves creating satellite-to-satellite networks via free space optics among LEOS constellations, and another part is building robust relay networks to connect LEOS to MEOS to ground with continuous real-time communications.

There were at least two technical sessions and a Market Watch session on this topic at OFC, a large increase from a year ago. This is a new and exciting market for the optics industry and will undoubtedly continue to grow in importance. Jack Jian Xu of Coherent likened a LEOS satellite to a mini-datacenter and said that in a typical constellation they are 2,000-5,000 km apart. This is the distance free space optics must operate over to connect LEOS in orbit.

6 OFCnet

6 OFCnet

This year's OFC saw the inauguration of OFCnet, a high-performance network built by volunteer companies to support live demonstrations, proofs of concept and emerging technologies at the conference.

Ciena's Marc Lyonnais, one of the founders of OFCnet, has a dozen years of experience building SCinet, a similar high-performance network built alongside the annual supercomputing conference.

But there are differences between the two networks: SCinet supports supercomputing applications and demonstrations, whereas OFCnet focuses solely on the science of networking.

6

NETWORK ARCHITECTURE

Lumen provided three dark fibers to the San Diego Convention Center for OFCnet.

Sites connected to OFCnet included CENIC (Corporation for Education Network Initiatives in California), the US Department of Energy's science network (ESnet), Northwestern University and its center for advanced internet research (iCAIR), and links to the universities of Bristol and Amsterdam. Here 400-gigabit and 800-gigabit wavelengths were used.

On the show floor, network users included the OIF and Ethernet Alliance, systems vendors such as Adtran, Ciena, Cisco and Nokia for their booth demonstrations and research and education labs. One demonstration example was Adtran's, which demonstrated its FSP 3000 open line system (OLS) implementing different services on a fiber as part of the concept of spectrum-as-a-service.

Three booths on the exhibition floor were dedicated to OFCnet, including one on quantum networks. This was the first time so many quantum companies were present at OFC, says Lyonnais.

Quantum networking demonstrations included the University of Bristol showcasing the remote operation of its quantum key distribution network around the city of Bristol and also ID Quantique showing its QKD system interoperating with Ciena's booth. An OFCnet booth was also allocated to the OpenROADM MSA and NTT Labs.

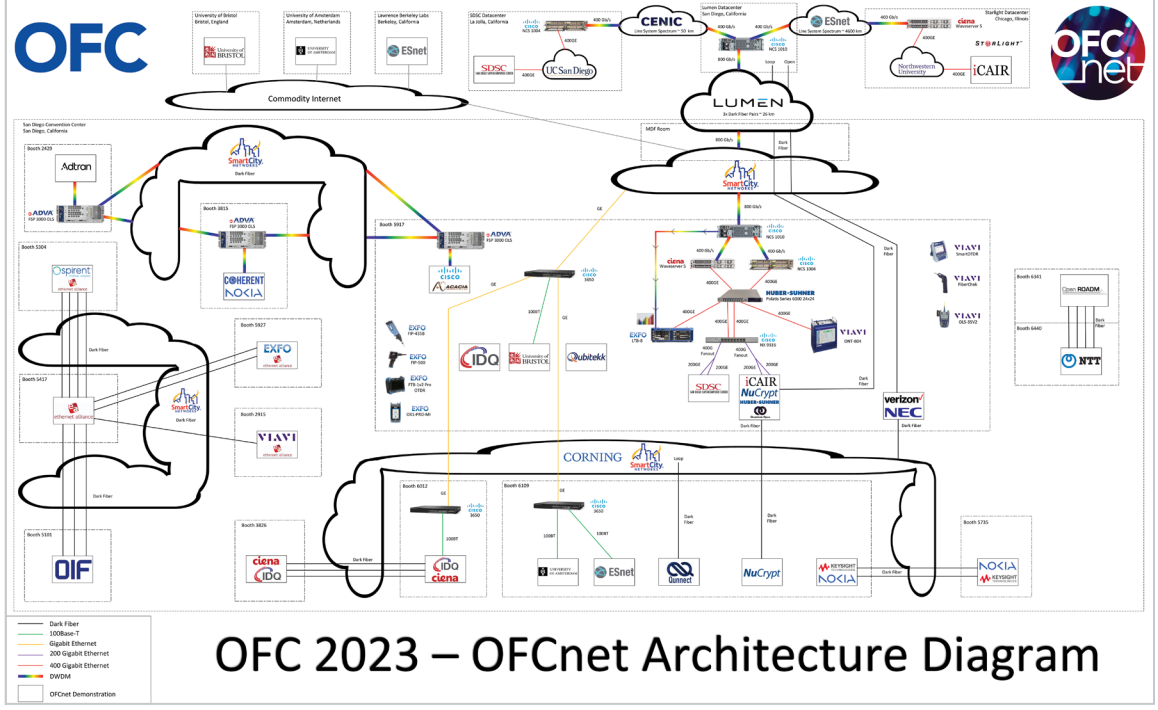
There is a three-year plan for OFCnet, including more floor space and issuing calls for demonstrations and presentations.

OFCnet will also be used as a platform for discussions on the state of networking, including DevOps and analytics, and to demonstrate leading-edge technologies such as holograms, augmented reality and the metaverse. The aim is for OFCnet to act as a yearly incubator and science accelerator for technologies and explore the implications for the network.

The networking team allocated six days to get the demonstrations up and running before the show. "What's fun about building a network is when things are going wrong because if not, it's boring," quips Lyonnais.

But he notes that networking is getting trickier and highlights the expertise now needed for troubleshooting.

Figure 6



OFC 2023 – OFCnet Architecture Diagram

7 End-Customer Perspective: ICPs and CSPs

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There was a heightened pace of technological development at this year's OFC. Companies are executing their plans and delivering products.

Developments included 200-gigabit optical lanes, 800-gigabit optical modules and emerging 1.6-terabit optical building blocks. Such growth in optical performance metrics is significant and not confined to client-side optics.

Several optical transport vendors detailed their latest coherent modems that deliver 800-gigabit wavelengths over distances greater than 2,000km, that support 1.2 terabit wavelengths and soon 1.6-terabit ones. Such rates and distances are possible due to an increase in the symbol rate of coherent modems.

7

At last year's OFC, the highest baud rate of an announced coherent product was 140 gigabaud, a jump from existing optical transport systems operating at 90-107 gigabaud. This year, Ciena announced its 200 gigabaud WaveLogic 6 Extreme.

Increasing the baud rate is the favored way to reduce the cost of transporting traffic. But doing so requires increasing the bandwidth of all the components of the coherent modem: the coherent digital signal processor (DSP), the analog front-end and the coherent optics. This is an expensive undertaking and a considerable engineering challenge.

Looking at these developments from the operators' perspective – the communications service providers (CSPs) – explains only partly the wares on display at OFC.

The CSPs want what they have always wanted: technologies to scale their networks to accommodate traffic growth and do so cost-effectively. Power consumption is now a vital issue for CSPs, especially as they look to reduce costs. But the internet content providers (ICPs) – the hyperscalers – now drive the optical market and have quickened the pace of optical technology development overall.

Figure 7 shows the requirements and motivations of the optical market's main end customers: the ICPs and CSPs.

Both end customers drive the marketplace, but increasingly the hyperscalers are the instigators of innovation while the CSPs are the followers.

The notable developments at OFC driven by the hyperscalers include 800 gigabit and 1.6 terabit pluggable optics developments, co-packaged optics (as demonstrated by Broadcom, Cisco, Coherent and Ranovus), optical engines (demonstrated and announced by Ayar Labs and Nubis Communications), the re-emergence of optical switching and Intel's demonstration of its multi-terabit, optical compute interconnect technology for xPUs (CPUs, GPUs, etc.) and advanced chips.

Developments in coherent modems for ultra-long haul optical transport or for access, such as the emerging 100-gigabit 100ZR, address CSPs's needs, but even here, the hyperscalers cannot be ignored.

Linking equipment between buildings of a data center campus or over more considerable distances using terrestrial or submarine networks are critical concerns for the hyperscalers. Moreover, the massive advance in coherent pluggable optics in recent years has been driven by the hyperscalers, of which the CSPs have been beneficiaries. One example is IP over DWDM, with pluggable 400ZR optics added to IP routers.

Figure 7. The driving requirements of the ICPs and CSPs.

	ICPs: Trailblazers	CSPs: Followers
Motivation	Scaling data centers, workload acceleration	Cost savings: power, transport
Priorities	Ecosystems and supply chain Differentiation to address individual needs	Addressing emerging pinch-points in their networks New revenue

Source: LightCounting

7

PLENARY SESSION

One goal of the OFC organizing committee at this year's event was to remind the optical community of the impact of the technology it develops. As Ramon Casellas, a General Chair for this year's OFC, put it: "We are trying not to forget what we are doing and why we are doing it."

To this aim, the committee invited Patricia Obo-Nai, CEO of Vodafone Ghana, to give the plenary session opening talk.

Obo-Nai highlighted Vodafone's work in providing digital services that directly impact people's lives. Examples cited include using mobile phones to give people access to banking so that people could save and have access to credit while giving women financial independence

Other schemes include providing access to school educational material during the pandemic and weather information to aid farmers. Vodafone Ghana, working in collaboration with the government, has also organized transport that saves women's lives by getting them to care during childbirth.

"When we use the technologies that we have, we will not just use it to drive profits; we are using it to drive social change," says Obo-Nai.

The world's leading CSPs, except for the Chinese operators, have struggled to grow their revenues for over a decade due to fierce competition and highly regulated markets. The bulk of their customers have access to smartphones, advanced infrastructure and a choice of digital service providers. The pandemic may have highlighted the crucial role of telecoms, but Obo-Nai's talk raises the question whether CSPs can do more to drive social change for all its users.

CSP REQUIREMENTS

BT, talking to LightCounting, said that 1.6-terabit wavelengths will not be needed for the foreseeable future. For now, 400-gigabit wavelengths suffice for its core network.

CSPs are excited about 100ZR coherent optics, the first example being a low-power pluggable module developed by ADVA (now merged with Adtran) and Coherent that was demonstrated at Adtran's stand.

BT views 100ZR as a welcome addition alongside XR Optics, which offers point-to-multipoint communications for metro and access networks. The CSP plans to assess the two for applications such as mobile fronthaul. XR Optics allows 400 gigabits of bandwidth to be split up in sub-carrier increments of 25 gigabits, but now 100ZR is an alternative for the power and cost-conscious metro-access.

BT notes how power savings has become a significant issue; it now holds weekly meetings on the topic. One OFC topic of interest for the operator is photonic integration. It is not a new topic, but photonic integration is now pervasive, and BT is investigating how it could benefit its network.

The operator highlighted start-up iPronics' smartlight processor, an optical programmable array of Mach–Zehnder interferometers. Such a device could be used for switching, dispersion compensation or even as an alternative to a DSP IC, thereby saving power, says BT, which will perform a techno-economic assessment of the technology.

Meanwhile, Verizon says OFC is a welcome show as it allows them to catch up with its smaller suppliers. One topic of interest for Verizon is whether advances in the optical performance of pluggable ZR+ optics could displace the embedded coherent optics it uses today.

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Every route Verizon turns up carries 500-gigabit or 600-gigabit traffic instead of 400-gigabit and using embedded coherent optics significantly reduces the cost per bit. Verizon expects the gap between embedded and pluggables to remain at the 800-gigabit generation. So, both coherent module offerings will continue to be used. But there may come a time when pluggable coherent optics are 'good enough.'

As for upping the baud rate, that remains key for long haul, says Verizon, but less so for metro and certainly not for access.

COHERENT AT THE NETWORK EDGE

At Optica's Executive Forum event run alongside OFC, several CSPs were asked about their coherent optics plans at the network edge.

AT&T, for example, expects to keep increasing gigabit services offered to residences as part of its XGS-PON and 25G PON roadmap, and there is an opportunity at the first aggregation point for coherent optics. "Coherent is on my mind," admits the AT&T spokesperson.

For now, AT&T has no coherent optics in that part of its network. KDDI also confirmed that it has no need for coherent in the access part of its network at present, as did the wireless infrastructure firm, American Tower.

Separately, Verizon said that for access, it is using 10 gigabit links, and it uses grey optics when 100 gigabit is used. One application where coherent could be of use is daisy-chained mobile sites over a dark fiber that is connected to a switching center-located router. But according to Verizon, these are typically 20km apart, so standard long-range optics can be used.

NEW MARKETS

At the Executive Forum session on optical fiber, speaker Mark Englund, CEO of Fibersense, discussed how deployed fiber can be dual-purpose – the transmitting of data and also as a sensor network – promising CSPs a welcome second revenue stream.

"[Fiber] is one of the only big pieces of infrastructure out there [other infrastructures being water, electricity, roads] that has a genuine second use," says Englund. "You can convert that optical fiber infrastructure by simply adjusting what is on the end of it." This allows objects and events in the vicinity of the fiber to be detected.

Fibersense cites several sensing use cases using fiber deployed in cities, for example, from detecting an excavator at risk of digging up a cable or damaging a water pipe, to tracking individual vehicles. Englund cited one metropolitan network that was making more revenue from sensing than telecoms. "That is a precedent, [albeit] a very small precedent today," says Englund.

Another topic raised was Microsoft's acquisition of hollow-core fiber start-up, Luminosity, late last year. It was noted that it was a hyperscaler, not a CSP, that brought the technology in-house. It is another example of an ICP leading in what traditionally has been the CSP domain.

8 Quantum Developments

8 Quantum Developments

An OFC double-session workshop addressed whether optics has a role in scaling out future quantum computing architectures.

The first quantum workshop addressed quantum computing systems, while the second part looked at materials and devices.

The systems session was led by quantum computer players Microsoft, IBM, PsiQuantum and IonQ, while the second session involved researchers. Devices and materials are clearly at a less developed, more experimental stage.

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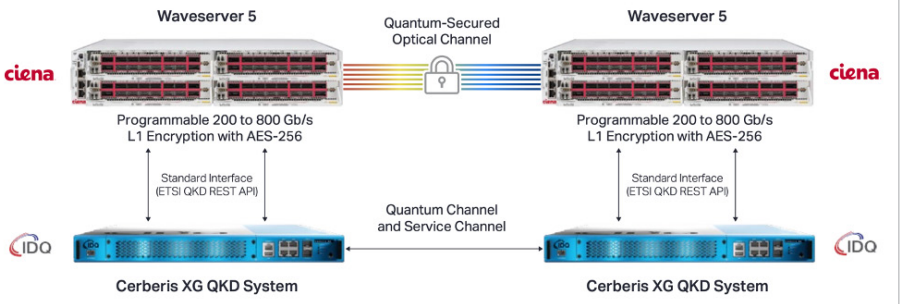
The sessions highlighted that quantum systems for tasks like computing must interface with the real world. Quantum computers continue to scale and now have some 1,000 quantum bits (qubits). But quantum computing needs a million qubits to solve big problems and deliver an advantage compared to traditional computing. Optics is seen as a way for quantum computers to be interconnected so that machines can be coupled to reach the number of qubits needed for a quantum computational advantage.

The issue is that such coupling is highly complex. Quantum computers are still based on various technologies, and interfacing them to optics can involve complex transducers. Effectively an atom qubit needs to resonate with a photon qubit so it can be sent over a fiber to resonate with an atom qubit in a second quantum computer – this way a large-scale network of quantum computers could be built. UK start-up Nu Quantum, present at OFC, is tackling just this issue.

So, will optics have a role to play in scaling out future quantum computing architectures? The answer is yes. But don't bank on quantum computing as a meaningful market for photonics just yet.

Figure 7. Ciena's Waveserver 5 adds an extra layer of encryption protection using QKD



QUANTUM KEY DISTRIBUTION

Two common data encryption schemes are used based on symmetric or asymmetric keys to create a secure link between sites. Public key cryptography is an asymmetric scheme based on a uniquely related public and private key. In contrast, symmetric schemes use the same key at each link end to lock and unlock the data. The Advanced Encryption Standard uses symmetric keys typically 256-bits long (AES-256); the more bits, the more secure the encryption.

A symmetrical key must get to the recipient without being compromised. Here, an asymmetric key can be used to encrypt the symmetric key for transmission to the destination prior to secure communication. The general worry, however, is that once quantum computers exist, they will crack public key algorithms.

Quantum key distribution addresses this concern by encoding the key using photons. If the adversary measures the photon in transit, they change its parameters. The transmitter and receiver typically reserve a small number of the key's photons for detecting a potential eavesdropper. If the receiver detects photons that were not sent, an alert is issued that the link has been compromised.

At OFC, Ciena showcased its Waveserver 5 alongside ID Quantique's Cerberis XG quantum key distribution (QKD) system. The Waveserver 5 can send 6.4Tbit/s of encrypted data in a 2-rack-unit box and, coupled with the Cerberis system, which has a reach of up to 90km, can send the AES-256 key using QKD.

At OFC, ID Quantique demonstrated its Cerberis system talking to Ciena's Waveserver 5. ID Quantique also showed its system detecting unwanted monitoring of the line, each time halting the quantum key transmission.

BT, which is trialing a three-node network for QKD in the Greater London area, revealed at OFC that it would announce that a large bank is using the network. There will also be a data center cloud element to the announcement, which BT says is an industry first.

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Recognizing Dr. Ming-Jun Li

Corning's Ming-Jun Li was this year's recipient of the John Tyndall Award for his many contributions to advancing fiber optic communications, including playing a leading role in developing low-bend-radius optical fibers.

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25-Year Anniversaries

OIF has been "extracting order from the chaos of our industry" for a quarter of a century. Yet, the real hard work is just starting. The industry is at a crossroads. Linear drive and CPO are two examples of the many diverging trends. We are looking forward to OIF's 25-year anniversary with many more accomplishments under their belts.

Stephen Hardy celebrated 25 years at Lightwave. He is the most reliable and objective voice in the industry. He has hinted on retiring later this year, but we will try to talk him out of taking an easy path forward.

11 Outlook for 2023

In terms of financial results, this year may not be fun, but it should not be a disaster either. At least, we all hope so. This is "the year of efficiency," and it is not only about improving power efficiency of optical I/Os.

Punished by the financial markets, some of the big companies are re-evaluating their expectations for a bright future and their ability to do whatever they want.

The good news is that there is more talent available for other employers. Nurturing strong competitors is the best strategy for maintaining healthy markets. Let us see what fair competition in the cloud can do for all of us.

This year may not be fun, but the future for optics is bright. It is lighting up our world now, and there is much more to come. Keep innovating and take calculated risks.

Save the Date

Come back to the event that drives the industry

OFC

The future of optical networking and communications

Technical Conference
24 – 28 March 2024

Exhibition
26 – 28 March 2024

San Diego Convention Center
San Diego, California, USA

ofcconference.org

IEEE ComSoc IEEE Communications Society
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