post-show report

OFC 2017

The future of optical networking and communications

A MARKET OVERVIEW

SPONSORED BY:

65 YEARS 1952–2017 | IEEE ComSoc IEEE Communications Society

IEEE photonics Society

OSA The Optical Society | 100 Since 1916

Managed by OSA

Contents

Cignal AI
Active Insight

Andrew Schmitt is the founder and lead analyst at the market research firm Cignal AI and the author of this report. Cignal AI provides insightful analysis on the optical networking market's entire supply chain — from carriers and equipment manufacturers to chips and components. Please visit **https://www.cignal.ai/** for more information as well as free articles and downloads.

Introduction

The Optical Fiber Communication Conference and Exhibition (OFC) brings top industry leaders together to discuss and debate market trends, optical innovations, business opportunities, and industry shaping technologies. This world class event provides a unique global showcase of market direction across the networking and communications industry and adjacent sectors.

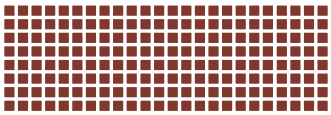
Innovators from around the globe convened at OFC 2017 to demonstrate, present, and discuss optical innovations for future networking growth segments such as the Internet of Things (IoT), artificial intelligence (AI), virtual reality (VR) and much more. Experts explored numerous global trends, including advances in coherent optical transmission, developments in datacenter networking, and advances in open optical networks.

Leveraging more than 340,000 square feet of exhibit space, OFC 2017 featured 663 exhibits from major international corporations such as ADVA, Ciena, Cisco, Coriant, Corning Incorporated, Finisar, Fujitsu Optical Components, Global Communication Semiconductors, Huawei Technologies USA, Juniper Networks, Mitsubishi International, Nokia, Oclaro and more. Technologies on display included optical transport systems, semiconductors for data transmission and switching, datacenter interconnects, optical components, network and test equipment, fiber cables and specialty fiber manufacturers.

14,500
ATTENDEES FROM
72
COUNTRIES

1/3
OF OFC ATTENDEES
are based outside
the United States

★★ **20%** ★★
OF ATTENDEES
ARE EXECUTIVES



663
EXHIBITING COMPANIES

OFC 2017 GENERATED
11,450
NEWS ARTICLES
reaching an audience of
5 billion*

*as of 4/4/17
Source: OFC 2017 Survey and Registration Data

The exhibition hall theaters featured business-focused programming with presentations by experts from major global brands, including Alibaba Group, AT&T, Cisco, Finisar, Facebook, Google, Juniper Networks, Nokia, Verizon and many others as well as key industry organizations such as Open Compute Project, Open Networking Foundation and the Consortium for On-Board Optics (COBO) to name a few.

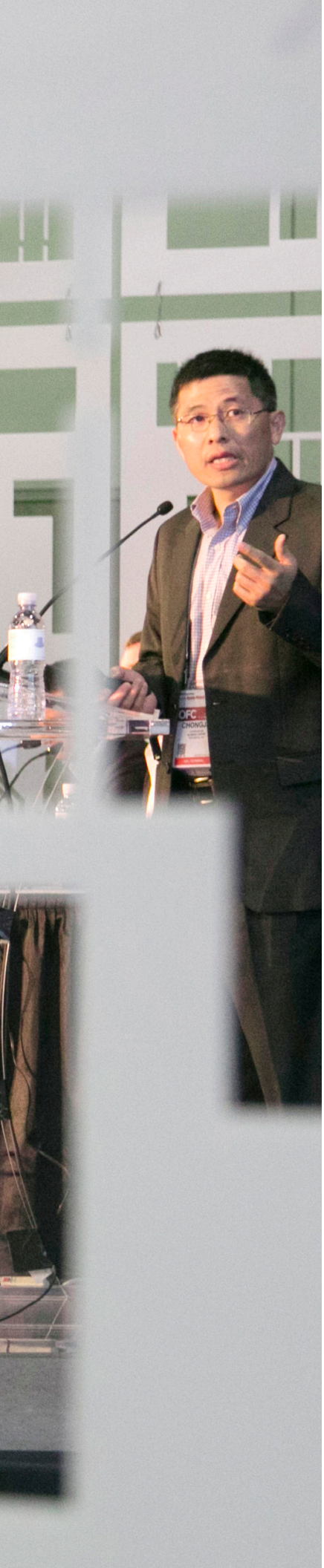
For more than 40 years, companies have attended OFC as it has grown into the largest optical communications event in the world. It is the one must-attend show for analyzing the future direction of the industry.

Each year, OFC showcases the most noteworthy developments in the optical industry, and this year was no exception. Companies utilized OFC as a venue to announce and demonstrate new products and solutions such as photonic integration, hardware disaggregation, and open management of large scale networks.

This report highlights and summarizes the 2017 developments in these areas.

- **Inside the Datacenter — 100G and the Road to 400G**
- **Building Towards 400G Coherent and Beyond**
- **Compact DCI — Not Just for Cloud and Colo**
- **Optical Networks — Open vs. Vertical Integration**
- **Outlook for 2017**

1 Inside the Datacenter — 100G and the Road to 400G



Inside the Datacenter — 100G and the Road to 400G

You've likely seen the photos of the massive, sprawling datacenters belonging to Facebook, Google, etc. Their monolithic racks of equipment stretch far into the distance. Unlike traditional incumbent network operators, who replace equipment every decade or so, these hyperscale computing operators practice something that Google calls "crop rotation" — the replacement of these expanses of hardware and equipment in a period of only 3-5 years. Crop rotation incorporating 100G network speeds inside the datacenter is now underway at virtually every major hyperscale operator, creating an industry-wide transition from 10G and 40G speeds to 100G.

QSFP28 NOT RAMPING FAST ENOUGH

Two components are enabling this transition to 100G: cutting-edge Tomahawk Ethernet switch silicon from Broadcom and 100G QSFP28 pluggable optics. The Tomahawk switch silicon is ready and available in volume. Despite this QSFP28 optics remain scarce.

The challenge with optics, one that has been present for decades, is that the needed manufacturing and testing to support high production volumes cannot scale at the speed of silicon. Much discussion at OFC took place about the short-term outlook for QSFP28 production, what technology will follow, and what can be done in the long term to improve manufacturability. Each component vendor is working to solve unique barriers to scaling production — from the availability of EML lasers to the test equipment needed to add manufacturing capacity.

Initially, demand from hyperscale datacenter operators centered around the PSM-4 version of the QSFP28 module supplied by Applied Optoelectronics, Luxtera, and others. These modules are widely available. But hyperscale tastes have shifted to the CWDM4 version, which uses a single fiber rather than the four-fiber parallel ribbon of PSM-4.

What is compounding the supply problem more than anything else is that demand is arriving from all sources concurrently. Unlike the transition to 40G several years ago, in which the hyperscale operators each transitioned at various times, now all of the hyperscale providers want to move lockstep to 100G as soon as possible. Demand for QSFP28 is skyrocketing as a result.

OFC speakers from Applied Optoelectronics, Finisar, Lumentum, Oclaro, and others all agreed that demand for QSFP28 optics would exceed supply before the end of 2017. These companies are vigorously attacking various manufacturing bottlenecks as they spend capital to expand capacity. Despite this, the demand for 100G QSFP28 optics coming from the large cloud and colo operators is surpassing the rate at which capacity is coming online.

Simple laws of supply and demand dictate that scarcity creates a healthy pricing environment for these 100G client components—they are not cheap to come by. Demand for 100G QSFP28 continues nonetheless because it is such a powerful alternative to 40G, the current speed in most hyperscale datacenters. The consensus among vendors is that even at current pricing levels, 100G is still cheaper than 40G from a total cost of ownership perspective. This gives component makers hope that even as supply increases, QSFP28 pricing will remain steady.

400G CLIENT FORMAT DEBATE RAGES

In a year of heated political debates, OFC had its very own in the discussion surrounding the format of choice for the next optical client speed — 400G. The two dueling optical module formats are QSFP DD (Double Density) and OSFP (Octal Small Form Factor Pluggable). Both formats may transmit 4x100G optical signals using PAM-4 modulation at 53 GBaud, but the OSFP format is slightly larger (32 modules versus 36 modules in a rack for DD). But that's where the facts end and the opinions start. What follows will be considered facts by some, opinions by others.

One of the advantages of OSFP — as a result of its larger size and depth — is a higher power specification, enabling it to accommodate longer reach formats, perhaps even coherent 400G at some point. It doesn't hurt that this is the format championed by Google. Cisco takes a different tack, coming out strongly for DD. Cisco went so far as to present a mechanical and thermal mock-up at OFC illustrating the viability of DD's recently expanded power specifications.

Cisco VP and General Manager Bill Gartner forcefully denounced OSFP when asked his opinion on the show floor. He refuted the proposition that the next generation format should be encumbered by much lower volume coherent applications, or now unknowable, far out in the future requirements, and emphasized the critical importance of backward compatibility that QSFP-DD provides. His views were echoed by Katharine Schmidtke, who is responsible for Optical Technology Strategy at Facebook.

Andy Bechtolsheim, Chief Development Officer of Arista Networks (which originated the OSFP concept), argued that Cisco failed to consider thermal performance at high elevations and the heat-flow through the PCB from high-power switch chips which together reduce the thermal performance of the QSFP-DD to well below 10W. He also said that 400G-DCO modules for datacenter interconnect represent a very significant market opportunity but require up to 15W power per module. Finally, he pointed out the QSFP-DD connector "barely works" at 400G but will not support the next-generation 800G electrical interface speeds that he felt were needed by 2019.

Conversations and presentations by component vendors were refreshingly free from political posturing. These companies are on the hook for designing and delivering products that are reliable, can be made in volume, and most importantly — are in demand by customers. There was a clear consensus here — component vendors have QSFP DD as the design target for high volume datacenter formats. If OSFP catches on, it will be easy to transfer the QSFP DD design to the bigger

OSFP format with more relaxed power specifications. But given a choice between the two, component vendors all preferred OSFP because it is an easier product to make. Bill Gartner, however, had this to say: "This isn't supposed to be easy."

> "OFC is the largest optical communications conference in the world and we're here because we can meet with our customers."
>
> ROBERT BLUM, DIRECTOR, STRATEGIC MARKETING & BUSINESS DEVELOPMENT, INTEL

While the module format debate has yet to be settled, the component ecosystem is rapidly aligning to deliver production grade 400G QSFP DD optics by early 2019. Optics vendors are working closely with the critical PAM-4 semiconductor components. Inphi was an early innovator in this regard, but now many other suppliers are emerging with GigPeak, MACOM, and Semtech making announcements at OFC. Further, both public and private demonstrations were made at the show by several vendors including Source Photonics.

100G CLIENTS IN TELECOM APPLICATIONS

Prior year OFC announcements and technical demonstrations foreshadowed the universal adoption of QSFP28 format even in longer reach, non-hyperscale applications such as the 10km LR format. The recent arrival of QSFP28 LR modules impacts the much lower volume market for telecom client optics formats such as CFP and CFP2.

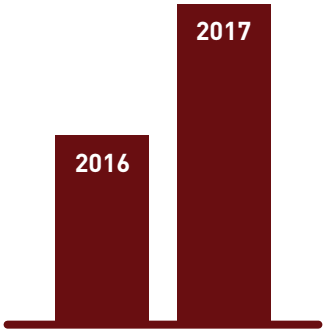
Lumentum, Oclaro, and Sumitomo Electric all demonstrated ER4 capability in the QSFP28 format, allowing distances as far as 40km to be spanned with QSFP28 optics. This application is currently the domain of the much larger CFP formats, and Oclaro highlighted its interoperability between the new QSFP28 and old CFP formats.

Growth in the larger CFP and CFP2 formats is stalling as OEMs move new designs to the smaller QSFP28 format, happy to leverage the massive volume the format will have due to hyperscale demand. Investor concerns were voiced at the show about excess CFP and CFP2 LR4 inventory, particularly at Chinese telecom OEMs such as Huawei and ZTE, concerns that appear to be valid. But demand for these formats will not disappear, given that telecom hardware has much longer life cycles than hyperscale.

EARLY ADOPTERS — 200G AND 400G

There are those who need immediate improvements in speed and density, and they simply cannot wait for 400G QSFP DD in 2019. For these users, there are two options: CFP8 and 200G QSFP28.

Finisar, NeoPhotonics, and Oclaro have all demonstrated 400G solutions using a CFP8 format that they claim will be production grade by the end of the year. The CFP8 format uses an 8x25 Gbaud optical interface using 50G PAM-4 modulation. The lower baud rate of this approach makes its implementation more feasible than QSFP DD in the near term, and the components needed to make this happen are accessible now.



150
NEWS RELEASES RESULTED IN
12,000+
MEDIA PLACEMENTS — A
70% increase
OVER OFC 2016

And yet, the big question at OFC 2017 was who the customers for CFP8 were, and — more importantly — whether their volume was significant enough to justify the R&D required to bring this product to market. IP switch and router companies will be the first to introduce this format, as well as some of the WDM transport vendors who are introducing 400G systems in 2018. Will these applications alone create enough demand for CFP8 before the QSFP DD (and yes, the OSFP too) reaches the market in 2019?

Component vendors are hedging their bets. The CFP8 is a great test vehicle for 400G, and if there is a delay in bringing QSFP DD to market, the CFP8 will become much more relevant. There is no expectation that CFP8 would be a high-volume format but rather that it would be more of an interim luxury good helping smooth the path to much higher volume formats.

But not all end users are waiting for 400G or interested in using the larger CFP8 format. Another alternative to waiting for QSFP28 DD is 200G, with the existing QSFP28 module being sped up with PAM-4 capabilities to double its capacity.

As with 100G, the switch silicon for 200G and 400G will beat the optics to market. 200G QSFP provides a way to tap this capacity sooner and de-risk the transition to challenging 400G QSFP formats. Broadcom's upcoming switches with faster I/O to enable 200G will be joined by startups such as Barefoot Networks, which had a compelling demonstration of its new switch that can capitalize on 200G. Like CFP8, the technology is there — the question is whether the demand warrants yet another stopover on the road to 400G.

Google thinks the answer to this question is yes. Just as 40G was a stopover from 10G to 100G, 200G could serve the same purpose on the path to 400G. Google, with its considerable ability to buy large amounts of product now, has the attention of component makers. Most of these folks are keeping their developments quiet, except Luxtera, which used OFC to announce a 200G-specific part.

2

Building Towards 400G Coherent and Beyond

Building Towards 400G Coherent and Beyond

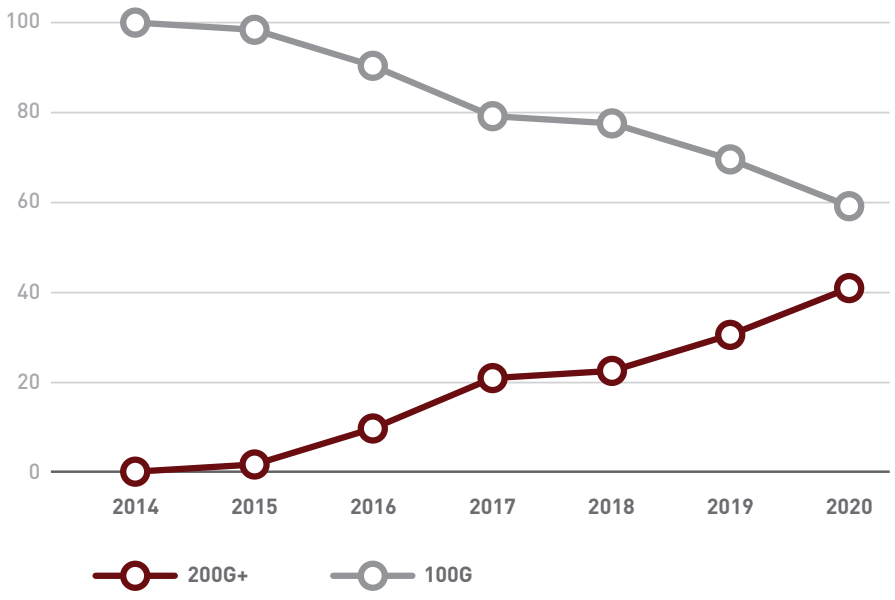
Datacenter interconnect (DCI) was the first application mentioned at OFC when component vendors detailed their plans for faster coherent WDM transmission. From Facebook and Nokia, which presented a joint paper on a record-breaking trans-Atlantic coherent transmission, to several component vendors discussing plans for 400G 80km inter-datacenter connectivity, the needs of hyperscale players were cited first and foremost. It was as if there were no other customers of importance to be mentioned!

These cloud and colo customers do push the edges of technology harder than other customer segments, yet during 2016 they accounted for only a small fraction of coherent deployments. The vast majority of coherent ports were deployed by Chinese incumbent carriers and incumbent, wholesale, and cable MSO operators in the West. Roughly half of all coherent ports built in 2016 were attributable to Chinese equipment makers Fiberhome, Huawei, and ZTE alone. Despite OFC 2017's widespread discussion of faster 200/400/600G coherent technology, almost all the ports shipped during 2016 were 100G.

The market will transition to speeds beyond 100G, starting with rapid coherent 200G growth in 2017. Ciena and Nokia currently lead the market in 200G deployments, but companies such as ADVA, Cisco, Coriant, Fujitsu, and Huawei are touting their production rollout of 200G coherent technology. Consequently, this availability from a wider component and equipment supply chain will create an inflection point this year in the proportion of coherent ports that are 200G or faster.

While 200G will be the leading-edge speed for 2017 production shipments, 400G single wavelength coherent technology will be shipping from a few select equipment vendors like Ciena and Nokia by the end of this year. Multiple component vendors will sample DSPs and pluggable components to the broad market in this time frame. This widespread production availability of 400G coherent technology sets up another demand inflection point in 2019. This isn't the limit, though — many companies seek to stretch to even faster speeds.

PROPORTION OF COHERENT PORTS THAT ARE 200G OR FASTER



Source: Cignal AI, Optical Applications Report (2H16)

SETTING THE BAR HIGH — 600G COHERENT

There were multiple announcements at OFC centered on pushing the coherent envelope to 400G and beyond. 600G gained consensus as the maximum target speed.

600G speed is achieved by combining two optical polarizations of 64 Gbaud signals with 64-QAM modulation, bringing eight potential symbols per transmitted bit. This is a staggering raw data rate of 768Gbs, and after removing a 28% over speed for forward error correction, this yields an effective data rate of 600G. Though details are scarce, the effective reach of this speed is expected to be short — around 100km or so.

Both Fujitsu and NeoPhotonics announced discrete components and ACO modules designed to support coherent transmission at speeds of up to 600G. Initial designs use Lithium Niobate, which is the highest performing material technology for modulation, though the companies have plans to transition to InP using more photonic integration. Other companies such as Elenion, Lumentum, and Oclaro had previously announced 400G capable components as they too are working to even faster speeds and higher levels of monolithic design in InP or Silicon Photonics.

Acacia made an exciting announcement regarding a major milestone for photonic integration. The company developed new packaging techniques for its silicon photonic integrated circuits (PICs) by leveraging conventional ball-grid-array (BGA) semiconductor technology used in traditional semiconductors.

This announcement also hints at the possibility of the PIC being co-packaged with the DSP silicon itself, which should improve density, performance, and manufacturability.

In conjunction with its BGA technology announcement, Acacia outlined the roadmap for its coherent DSP. It is a beast of a chip, providing a 2x600G DSP dual wavelength WDM interface and support for client interfaces on board — essentially creating a full optical transponder line card on a chip. Acacia did not provide guidance on its DSP availability, but ADVA did announce a future product based on Acacia's DSP that it expected to be sampling to customers at the end of 2017. Several other equipment OEMs at the show expressed interest in the Acacia DSP and were impressed with the devices' proposed capabilities.

CIENA RELEASES ITS 400G WAVELOGIC DSP INTO THE WILD

Every OFC has one blockbuster announcement each year, one that sparks discussion and debate in the show aisles, session hallways, and during client dinners. This year, Ciena was the one to make such an announcement. The company struck deals with three component vendors — Lumentum, NeoPhotonics, and Oclaro — to sell its WaveLogic 400G DSP so these three may manufacture and sell optical modules to the broad market. The vendors are working to commercialize the Wavelogic Ai as a standard product and expect to sample 5x7 modules at the end of 2017 (though different sources provide different timelines on this). The three companies may sell these modules to anyone without restriction — including Ciena competitors or network operators who wish to build white box equipment.

> “OFC is really the preeminent trade show for the optical communications industry. It has all of the suppliers and customers, all the way up through the value chain. By bringing the whole industry together for a week it really enables innovation across the whole supply chain.”
>
> RAY MORONEY, VP AND BUSINESS LINE MANAGER, MACOM

On paper, Ciena has an impressive product; a 400G 56 Gbaud solution announced last year that has evolved from a long history of DSP development. Ciena will itself bring equipment using the DSP to market in mid-2017. Some observers at OFC noted that the Ciena solution would reach the broad market at the same time as other solutions from Acacia, Inphi, and NTT Electronics. But there is a distinction; Ciena should be earlier to market with silicon, and the platform available in 1Q18 should have a solid nine months of testing and debug time under its belt while the other solutions are just reaching the lab for the first time.

The subject of the long-term implications of Ciena's announcement generated a great deal of debate amongst OFC attendees, and conclusions from conversations with attendees lacked consensus. Though there does not appear to be a significant downside for the parties involved, it just isn't clear where the design wins will originate. Ciena stated its intent to win share in China, yet much of the country is moving to CFP-DCO, a format which is not supported in the initial announcement. Nonetheless, component vendors welcomed the entry of such a credible DSP veteran to the market in that it helps ensure a competitive marketplace. Furthermore, 400G WaveLogic Ai DSP is just the first step. Both Ciena and its three module partners all said during direct discussions that they would continue their relationships together for subsequent developments in the future.

METRO DCI — THE 400G OPPORTUNITY

While OFC held no specific announcements regarding the OIF 400ZR (80km) specification under development, it was clear that component makers are sharpening their tools in preparation to begin work delivering products. The OIF 400ZR (80km) specification is designed to bring full vendor interoperability to coherent interfaces for reaches up to 80 to 120 km, at speeds up to 400G, and to make the technology available in multiple form factors. Coherent interoperability is a feature that has eluded the market, but it becomes increasingly important in the metro as different equipment types and vendors are more likely to be interconnected.

The desired form factor, requested by hyperscale operators such as Microsoft, is a DCO pluggable that can occupy the same socket used by short reach client interfaces — QSFP DD or OSFP (detailed earlier in this report).

The incorporation of coherent 400G technology into DCO modules as compact as these will push the limits, particularly in regards to DSP power consumption. Component vendors are hesitant, as the high cost of developing the required 7nm DSP silicon to make the OSFP application work is a mighty big pill to swallow. Wary of this expense, these vendors turn in hope to the hyperscale computing companies, such as Google and Microsoft, to help shoulder the size of this investment. Licensing a 400ZR chip could also be the next step for Ciena and its partners.

3

Compact DCI — Not Just for Cloud and Colo

Compact DCI — Not Just for Cloud and Colo

Spending by cloud and colo network operators — particularly hyperscale datacenter companies — is now the fastest growing source of capex for computing and networking equipment. The needs of these network operators redefined hardware architectures for computing, storage, and networking over the past decade. As these architectures were implemented, the supply chain felt a ripple effect as the operators pursued the white box model and built much of their own equipment.

Equipment vendors that did not adapt to customers' hyperscale needs lost the opportunity to serve this market. Optical transport equipment companies, wanting to avoid the same fate, learned from this example and instead proactively architected and delivered products that were precisely designed for connecting large-scale datacenters, creating a new hardware category.

COMPACT DCI PLATFORM	INTRODUCED
Infinera Cloud Xpress	September 2014
Ciena Waveserver	May 2015
ADVA Cloudconnect	June 2015
Fujitsu T-Series	August 2015
Cisco NCS 1000	November 2015
Coriant Groove G30	December 2015
Huawei OSN 902	June 2016
Nokia PSI-2T	March 2017

Source: Cignal AI, Optical Applications Report (2H16)

EVOLUTION OF COMPACT DCI

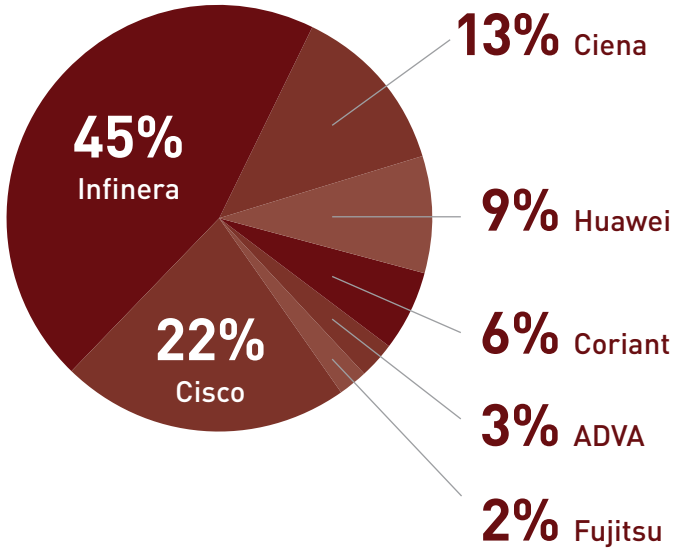
This new market is known as Compact DCI. Its platforms embrace the "rack-and-stack" model preferred by cloud and colo operators because it allows them to quickly scale out new equipment and thereby more easily build and manage large networks.

It's no longer just about DCI though. In 2017, more traditional operators are exploring this format to determine if they can achieve more flexible networks by coupling these Compact DCI transponders with open line systems and open ROADMs. AT&T, NTT, and several cable MSOs are among those investigating this format right now.

As the Compact DCI market gained traction, Infinera had an early lead. Now that this sector represents most of the growth in the WDM transport market, it has attracted other vendors — and they are gaining sales. Cloud and colo operators couldn't be happier to have such an eager group of suitors — it keeps the market competitive and technically advanced. These customers leverage their buying power over the Compact DCI

providers; they are not afraid to change suppliers more rapidly than traditional incumbent operators. As a result, this segment will have more volatile market share shifts than other segments.

COMPACT DCI HARDWARE MARKET SHARE (4Q16)



Source: Cignal AI, Optical Applications Report (2H16)

EXPANDING THE COMPACT DCI MARKET

Compact DCI commanded many announcements and activities during this year's OFC. Nokia jumped into the mix by taking its production-grade coherent technology from its traditional PSS chassis-based transport system and incorporating it into a compact DCI chassis. The resulting PSI-2T has an impressive 250G of capacity per wavelength and provides a total of 1T of coherent transport. Nokia's move puts it into good company with Cisco, which is already shipping 250G per lambda capability in its NCS1000. Yet, other vendors, such as Ciena with its Waveserver Ai, are already looking ahead to 400G. Nokia has a history of selling its coherent technology outside of the DCI sector and will actively position this Compact DCI system to customers beyond the cloud and colo sector.

Compact DCI is not a strategic focus for Juniper Networks. Instead, it chooses to offer coherent transport to its established customers, most of which are more traditional operators. Juniper announced a 1.2T coherent line card that fits into its QFX10000 L2 Ethernet spine switch. This is not a Compact DCI platform, but it is worth noting that it is the first instance of high density coherent transport being made available in the datacenter switches itself. Juniper also announced a new 2x200G line card upgrade to its 7800 optical transport system, originally built by BTI Systems (acquired by Juniper) which had a long history of supplying cloud and colo operators.

Fujitsu presented several new DCI advancements during OFC. It expanded its 1Finity line of compact DCI products with the T400, providing high density 10GbE to 100GbE aggregation to feed existing T-series T100 and T300 coherent transport platforms. The T-series is just one of several compact DCI functions made by Fujitsu including ROADMs (L-series) and L2 switches (S-Series). Fujitsu introduced the C200, a new controller card designed to virtualize disaggregated hardware by allowing operators to control Compact DCI systems, Open ROADMs, and open line systems. As a major supplier to large incumbent operators, Fujitsu is in a unique position to bring the benefits of compact DCI to these more traditional markets.

DIRECT DETECT ONE YEAR LATER

Hands down, Ciena's DSP announcement stole the show at this year's OFC. One might remember that just one year ago at OFC 2016, it was Inphi who everyone was talking about post-show. Inphi, in conjunction with Microsoft, announced the ColorZ, a QSFP28 form factor module providing up to 80km of reach. ColorZ allows existing pluggable ports that are designed for short reach clients to span much larger distances, thereby altogether eliminating the need for standalone compact DCI chassis. Recall that the design specifications for the controversial OSFP were developed to accommodate a similar application for coherent 400G. Now, Inphi is beginning to make good on ColorZ's promises. It shipped several thousand units of ColorZ in 4Q16, and will ship more as the product is currently ramping up for its lead customer, Microsoft.

> "OFC clearly demonstrates how optical communications technology is a force behind everyday exchanges. It is exciting to be a part of a community which has broad reaching impact on how we communicate with each other."
>
> ARLENE SMITH, PROGRAM MANAGER, AVO PHOTONICS, INC.

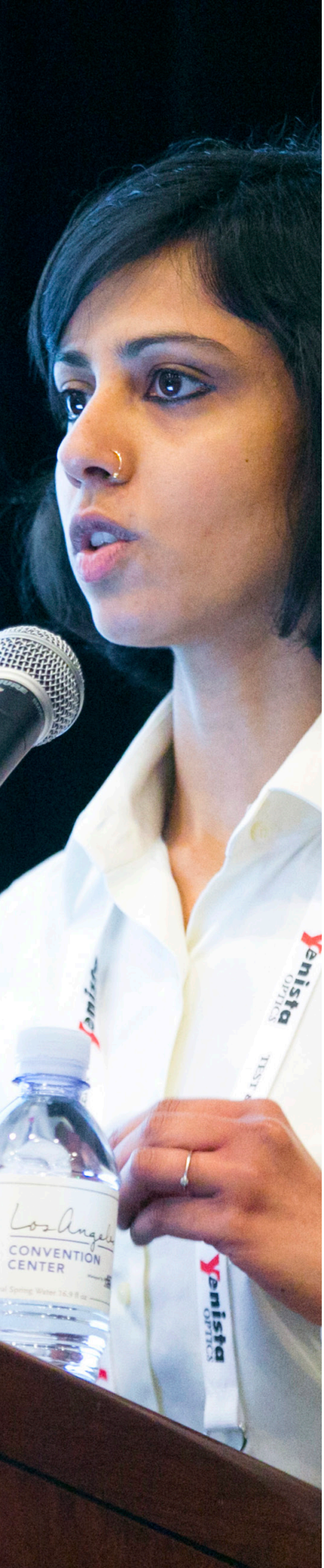
On other fronts, Ranovus emerged to announce a 200G CFP2-DCO based on Direct Detect. Its product is a non-coherent, less expensive alternative to the Acacia coherent CFP2-DCO and is suitable for applications in which less performance is required. It also has greater spectral efficiency than the Inphi ColorZ. It is undergoing trials now, and is expected to be in production by mid-2017. Ranovus' 200G CFP2-DCO is based on quantum dot laser technology, and we anticipate that it will have some interesting applications for other areas in the future.

Direct detect has some downside. It requires complex optical link engineering to function, particularly for longer distances. Two vendors, ADVA and Coriant, made announcements regarding their intent to remove the inherent operational complexity in Direct Detect. ADVA announced that it is shipping an open line system (OLS) that includes features for operators who wish to deploy ColorZ in existing equipment (ADVA did not, as some have mis-reported, go so far to say that it is selling the ColorZ with its systems.)

Meanwhile, Coriant demonstrated an OLS in conjunction with Inphi's ColorZ and Dell/EMC as part of its Groove G30 Compact DCI platform. Both ADVA and Coriant's open line systems support open optical networks, which was the final theme at OFC this year.

4

Optical Networks — Open vs. Vertical Integration



Optical Networks — Open vs. Vertical Integration

Historically, the optical market was vertically integrated; optical hardware and software were deployed only from a single vendor. But now, network operators have a multitude of options when architecting and deploying networks. Operators can use a line system from one vendor, and choose transponders and chassis from many other vendors. They can operate multiple network management and control planes in parallel, or find ways to unify them using either in-house or outside vendor software. Finally, if a critical component isn't available, one can write the code or design a white box.

Hardware disaggregation allows for a "mix and match" that creates the best solutions, but the network operator must be willing to absorb the inherent integration and software complexity created. It was evident at OFC this year that incumbent equipment vendors are carefully crafting their products for both the open and vertically integrated models.

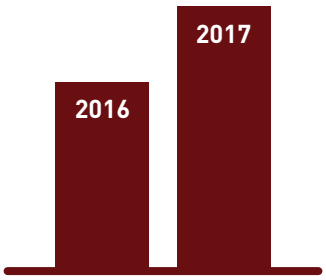
In the open model, vendors design equipment and software that is more open and independently controlled. This enables hardware disaggregation by operators and enables greater customization of their networks. Examples include AT&T's CORD initiative and open ROADM, or the work being done at the Telecom Infra Project.

The traditional, vertical model is different. To offset the loss of customization, vendors emphasize their benefit to the customer through innovative pricing techniques, the reduction of unneeded margin in network design, or by offering hardware and software packages that provide the best cost and performance when used exclusively.

FACEBOOK'S VOYAGER PLATFORM

Voyager was a lightning rod in debates about open and white box optical networks at OFC. ADVA and Facebook are advocates and highlighted that numerous proof of concepts (POCs) and use cases were underway in customer labs. Detractors, who would prefer no attribution, characterized Voyager as "a solution in search of a problem to solve," and derided it as a physical manifestation of the (perceived) disdain hyperscale vendors have for conventional optical suppliers.

Facebook designed Voyager's first revision by using off-the-shelf components from Acacia and Broadcom. The hardware resembles a Compact DCI chassis and provides 800G of coherent transport paired with 1.2T of client interfaces, joined together with an Ethernet switch fabric. Voyager allows the market to modify its design just as one might modify open source software.



100+

REGISTERED MEDIA/ANALYSTS — A

40% increase

OVER OFC 2016

ADVA offers Voyager for sale in conjunction with its OLS and network software. The company announced that nine network operators were currently trialing the platform. One offered a first-hand impression, and expressed a lack of enthusiasm for the product itself. The trial experience, however, was deemed enlightening and educational, with the operator realizing how ultimately dependent it was on the tightly integrated systems of traditional hardware vendors and how little the operator really understood when trying to close optical links and make them work reliably. Using Voyager was a raw experience, something like building a PC from scratch as opposed to buying one from Dell preloaded with Microsoft Windows. When asked about Voyager's cost, the operator could not answer; pricing had never been discussed.

In the opinion of this network operator, Voyager is not a viable long-term option in its current form, unless a customer places great value on the deep customization it offers. This degree of customization may be a high priority for Facebook, but from the operator's point of view, the challenge of making Voyager operational in their network outweighs any benefits.

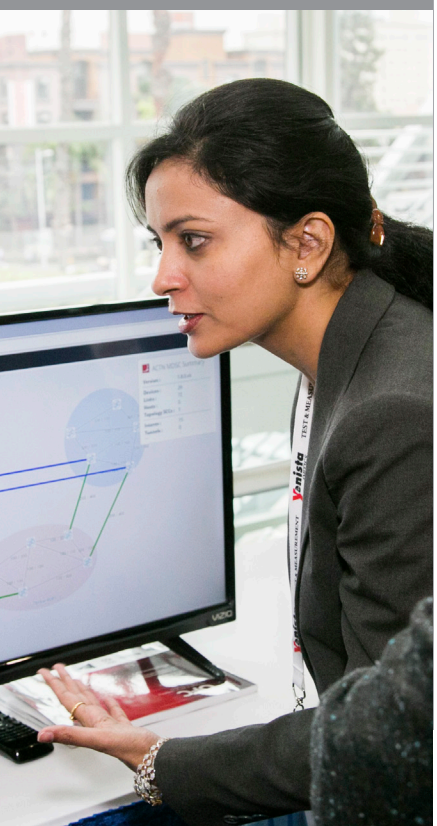
If Voyager is to continue to gain traction in the market, it will need to win advocates beyond ADVA and Facebook, and it will be interesting to hear from future users about their motivation for using it. The reaction of most of the OFC attendees was that Voyager did not meaningfully address any deep industry problem, and the actions taken by incumbent vendors to build open Compact DCI chassis negate whatever threat it could pose to the status quo. If it is to succeed, Voyager must evolve into something more extraordinary.

OPEN ROADM AND LINE SYSTEMS

The OLS is the first step in implementing a more open model for optical transport. Network operators in the submarine optical market pioneered this concept by connecting a new transponder vendor to both ends of existing undersea cables to upgrade them from 10G to 40G or 100G. Ciena and Infinera both entered the submarine market this way despite owning no boats and having no undersea expertise.

This concept is currently being extended to terrestrial networks, where existing amplifiers and ROADMs from one vendor can work with several different transponder systems. Vendors are opening the software interfaces to their amplifiers and ROADMs, allowing for agnostic external control and coordination.

These days, most equipment vendors now offer open line systems and are working with initiatives such as Open ROADM. ADVA and Coriant announced such products, mentioned earlier. Fujitsu, a key AT&T partner, announced hardware designed to better control a mix of equipment, including Open ROADMs deployed within its network. Other companies, like Infinera, which sold substantial amounts of equipment early on to the cloud and colo community, embraced the open concepts these operators demanded. Now they have mature products to sell.



Led by vendors such as AT&T, the Open ROADM initiative details specifications and control interfaces which allow the construction and deployment of what is a "generic" optical switch. This approach lets AT&T, which is deploying Open ROADM, to mix and match transponder and ROADM suppliers within a single network.

An advantage of this approach is that it eliminates the long-standing practice of large carriers isolating equipment suppliers to specific domains — the practice of only deploying one vendor in a specific city or zone to guarantee interoperability and consistent operation. As reported by *FierceTelecom*, Kathy Tse, Director of Photonic Technology Planning for AT&T, noted "You're able to mix and match different ROADMs and transponders, and it's very critical to have the transponders interoperate because you're talking about a flexible network."

The flexibility to select different vendors and cherry pick the best technology is one of the biggest advantages of open networks, as well as the negotiating leverage it gives operators over the supply chain. It also frees operators from the monolithic release cycles of vendors, in which advances can be slow to trickle out.

OPTIMIZING THROUGH VERTICAL INTEGRATION

Implementing and deploying open networks with many different vendors does have a downside, and it is margin stacking. By definition, interoperability requires all vendors to drop performance to the lowest common denominator to work together. The worst case operational specifications for each vendor must be assumed when integrating different components and systems. As a result, it becomes difficult to fine tune for maximum performance.

Several vendors, all of whom are also making a big push to open their networks, also announced hardware and software solutions that seek to optimize the performance of these networks. And the performance of these systems is optimal when the end-to-end solution can be assumed to be vertically integrated from a single vendor.

Infinera is one company that has a history of making vertical integration a priority. It used OFC to announce its Instant Networks, a major expansion of its Instant Bandwidth feature, which allowed operators to dynamically turn up extra capacity in Infinera hardware on a "link-by-link" basis. This process involves licensing unused wavelengths inside the highly integrated photonic circuits the company uses as building blocks for its network. The result is virtual capacity that can be enabled and moved flexibly, particularly when paired with automated capacity engineering. This type of approach would simply not be possible in an open network, and relies on tight vertical integration of custom Infinera hardware, software, and commercial agreements. Instant Networks has the potential to be both more efficient and flexible than an open network — but one must hand the keys to the kingdom to Infinera.

A week before OFC, Ciena unveiled Liquid Spectrum, a tool for automating planning in optical networks. It uses the deep performance monitoring feature sets built into Ciena hardware such as WaveLogic Ai. It extracts more capacity from the network by optimizing coherent modulation

> I have attended OFC each year for the past 16 years and will continue coming back for the unique business and technical insights it provides. There is no other optical communications conference that brings together all of the key players across optical systems, components and sub-systems, academia, and global network operators, all under one roof.

STERLING PERRIN, PRINCIPAL ANALYST, HEAVY READING

and wavelength spacing routing, and by removing extra margin from the network when it isn't needed. This is accomplished through additional software applications built into Ciena's Blue Planet software, which can operate in a multi-vendor environment. However, Liquid Spectrum works best if it is operating on the highly instrumented Ciena photonic layer. Coriant made a very similar announcement with its Aware technology presentations at OFC.

The simultaneous advances in open optical networking and tighter hardware/software vertical integration will continue to provide better and more competitive options.

Outlook for 2017

Through its many meetings, discussions, and presentations among customers, vendors, and engineers, OFC sets the stage for the coming year's market events. Here's what should be watched:

- **The Rollout of 100G QSFP28 in the Datacenter.** As demand shifts from 40G to 100G in hyperscale datacenters, will vendors successfully match capacity with demand? Historically, this has been a tricky task with aggressive customer ordering inevitably creating excess supplier capacity. This time could be different, as the technology to make these modules lies in the hands of only a few players who know this game well.
- **Coherent 100G Deployments Surge in the West.** Lower cost metro coherent technology is now widely available and should catalyze deployment of 100G and 200G coherent in more applications than ever before. Certainly, the cloud and colo operators are at the vanguard of adopting the new technology, but we expect to see other operator types jump in as well to drive coherent growth faster than last year's 30% in the West. China will also grow again, but nowhere near the 2x increase it experienced in 2016.
- **CDC ROADMs Go Mainstream.** Pricing for component technology for colorless, directionless, and contentionless ROADMs has been reduced. When these prices are coupled with the proliferation of open line systems and open ROADMs, now is a compelling time to refresh the common equipment, especially in metro networks. China is also finally making a move to deploy ROADMs in its vast networks and CDC ROADMs will be important there as well.
- **Evolution of Vertical Integration, Open Systems, and White Boxes.** There will be more aggressive adoption of open optical architectures by operators seeking to bring increased flexibility to their networks. Sales of Compact DCI platforms will more than double in 2017, as purchases from more traditional operators combine with those of hyperscale customers. Expect more software announcements as vendors realize that owning the management and control plane is as important, if not more important, than having the best optical hardware technology.

QUESTIONS?

Contact OFC

Another great OFC this year —
looking forward to OFC 2018 in San Diego!

OFC 2017 Corporate Sponsors and Exhibitors

With the breadth of companies who participate at OFC, attendees receive a complete picture of the entire optical communications industry.

OFC 2017 CORPORATE SPONSORS

AC Photonics, Inc. · ColorChip SystemOnGlass · CORNING · EXFO · FINISAR · GoFoton · HUAWEI · infinera · intel · JABIL AOC Technologies · JUNIPER NETWORKS · Mellanox Technologies · NEXTROM Krill Gruppe · NTT Electronics · OIF · OZ Optics online shop.ozoptics.com www.ozoptics.com · PhoenixX Software · PICOMETRIX a LUNA company · Precision Optical Transceivers · samtec · SAN DIEGO convention center · santec · SUMITOMO ELECTRIC · Tektronix · VPIphotonics Design Automation · XILINX · Yenista OPTICS

OFC 2017 EXHIBITORS

2 F i b e r
Communication • 3M Electronics
Materials Solutions Division • 7 Pennies Consulting •
AC Photonics • Acacia Communications • Accelink Technologies &
WTD • Adamant • ADSANTEC • ADVA Optical Networking • Advanced Connectek
• Advanced Fiber Resources • Advanced Microoptic Systems • Advantest • AEMtec •
Agilecom Fiber Solutions • Agiltron • AIM Photonics • Aitelong Technology • AKSH Optifibre
Limited • Albis Optoelectronics • Alight Technologies APS • Allwave Lasers Devices • Alnair Labs •
Altera • AM Compass Group • America Ilsintech • American Technical Ceramics • AMETEK Electronic
Components & Packaging • AMICRA Microtechnologies • Amonics • Amphenol • Anaren Ceramics • Anritsu
Company • Anritsu Microelectronics Fabrication Center • AnShan Gworld Opto Technologies • A-One Technology • APAC
Opto Electronics • APAT Optoelectronics • APEX Technologies • Apogee Optocom • Applied Optoelectronics • Applied Thin-
Film Products • Aragon Photonics Labs • Arden Photonics • Ardent Concepts • Arrayed Fiberoptics • ARtech • ARTEK • ASI/Silica
Machinery • Asia Optical • ATOP • Auxora • AVIC JONHON OPTRONIC TECHNOLOGY • Avo Photonics • Axetris AG • AXSUN Technologies
• Bandwidth10 • Beijing Grish Hitech • Berlin Partner für Wirtschaft und Technologie • BKTEL Photonics • BL Innovative Lighting • Bola
Technologies • Brimrose of America • Bristol Instruments • Broadcom Limited • BROLINK Technologies (Dong Guan) • Browave • BrPHOTONICS
• Cabling Installation & Maintenance • Cadence Design Systems • CAILabs SAS • CALIENT Technologies • Cambridge Industries USA • Canadian
Photonics Fabrication Centre • Canovate Elektronik Endustri Ticaret AS • CEA-LETI • Centera Photonics • Century Opticomm • Changsha Saneway
Electronic Materials • ChemOptics • Chemtronics • Cheng Yueg Enterprises • Chengdu HTLL Electronical Equipment • Chengdu Huajing Keli Industry •
Chengdu Qianhong Communication • Chengdu Superxon Communication Technology • Chengdu Tsuhan Science & Technology • Chengdu Xinruixin Optical
Technology • Chiral Photonics • Chroma ATE • Chromis Fiberoptics • Chuxing Optical Fiber Application Technologies • Cicor Group • CIENA • Cisco Systems •
CN-J Technology • CoAdna Photonics • CODIXX AG • Coherent Solutions • ColorChip • COMOSS Electronic • Compex • COMWAY Technology • Connected Fibers •
Connor Manufacturing Services • CorActive High-Tech • Coriant • Corning • COSEMI Technologies • COSET • CreaLights Technology • Crestec • Crowntech Photonics
• CST of America • DATA-PIXEL • Densenlight Semiconductors PTE • Deviser Instrument • Diamond USA • DiCon Fiberoptics • Dimension Technology • Dini Group •
Direct Optical Research Company • Discovery Semiconductors • DITF (Diablo Industries Thin Film) • Domaille Engineering • Dongguan FSG • Dongguan Mentech Optical
& Magnetic • Dowslake Microsystems • Dreamtel Technologies • D-Tech Optoelectronics • East China Research Institute of Microelectronics (ECRIM) • East Photonics • East
Point Communication Technology • East Tender Optoelectronics • ECOC 2017 • EFFECT Photonics • EGIDE • EKINOPS • Elaser Technologies • ELCON Systemtechnik • Elenion
Technologies • Elite Communications • Embedded Systems Engineering • Emcore • Enplas • Eoptolink Technology • EOSPACE • E-Photics (Shenzhen) Communications •
EpiPhotonics • Epoxy Technology • ES-TECH INTERNATIONAL • Ethernet Alliance • EXFO • Experior Laboratories • Fabrinet • Femto Technology (Xi'an) • Fermionics Opto-
Technology • Ferrotec USA • Fiber Instrument Sales • Fiber Optic Center • Fiber Plus International • Fibercore • FiberFin • FiberLabs • Fiberon Technologies • Fiberpark Technology
• Fiberpon Technology • Fiberpro • FIBERUA • Fibre Systems • ficonTEC (USA) • FINETECH • Finisar • Fisba Photonics • FISBA • Fischer Connectors • Flyin Optronics • FOCI Fiber
Optic Communications • Focuz Manufacturing • Fomerica Optoelectronics • Foxconn Interconnect Technology • Fraunhofer Heinrich Hertz Institute • Fraunhofer Institute for Photonic
Microsystems • Fraunhofer IZM • Fujian Hitronics Technologies • Fujikura • Fujitsu Network Communications • Fujitsu Optical Components • Gannon & Scott • General Photonics • Gigac
Technology • GigPeak • Glenair • Glimmerglass • Global Communication Semiconductors • Global Optical Communication • Global Optical Technology • GlobalFoundries • Gloriole
Electroptic Technology • GLsun Science and Tech • Go!Foton • Goldtel • Gould Technology • Gowanda Electronics • GPD Optoelectronics • Guangdong Tumtec Communication Technology
• Hengtong Optic-Electric • Hirose Electric USA • Hisense Broadband • Hitachi Cable America • Hitachi High Technologies America • HJ3-W • HOLOEYE Photonics AG • HTD Fibercom,
Limited • Huangshi Sunshine Optoelectronic • Huawei Technologies USA • HUBER+SUHNER Cube Optics AG • Hunan Guanglian Photoelectricity Technologies • HYC • Hyc-solution • IBM
Canada • ID Photonics • IEEE Communications Society • IEEE Photonics Society • IEEE Xplore Digital Library • IHP • II-VI EpiWorks • II-VI Marlow • II-VI Photonics • Imagine Solutions Group
• Industrial Fiber Optics • iNEMI-Intl Elec Manufact Initiative • Infinera • Information Gatekeepers • Ingeneric • INLC Technology • Inneos • INNO Instrument • Innolight Technology •
Innovative Micro Technology • INO • InPhenix • Inphi • Inphotech • Institute of Energy Efficiency • INTEC E&C • Intel • inTEST Thermal Solutions • Intlvac • IOSolution • IP Light • IPDiA • IQE
• Ironwood Electronics • ISE Labs • IXBLUE • Jabil • Jabil AOC Technologies • JETX • JENOPTIK Optical Systems • JGR Optics • Jiangsu Etern • Jiangxi Daishing POF • Jiangxi Ruiyuan Precision
Machining • Johanson Technology • Juniper Networks • Kaiam • Keio Photonics Research Institute (KPRI) • Kelvin Nanotechnology Limited • Keopsys • Keysight Technologies • Kingfisher
International • Knowledge Development for POF, SL (KDPOF) • Knowles Capacitors • Kohoku America • Korea Optron • Krell Technologies • KS Photonics • KST World • Kyocera America •
Kyosemi Opto America • Lanjian Electronics • Leoni Fiber Optics • Letel Group • LEW Technicues • LiComm • LiGenTec SA • Light Brigade • LightCounting • Lightel Technologies • Lightip
Technologies • Light-on Fiber-Optic Devices • LightSmyth Technologies • LIGHTWAVE • Linktel Technologies • Linstar Telecom-Optic Equipment • Lintes Technology • LioniX International •
Liverage Technology • Lorom America • LUCEDA Photonics • Luceo Technologies • Lumentum • Luna Innovations • Luvantix ADM • LuxarTECH • Luxtera • Mackin Technologies • MACOM •
Masimo Semiconductor • Maxim Integrated Products • MaxLinear • MEL Telecom, (ICSN) • Mellanox Technologies • Menara Networks • MetalLife • Micram Microelectronic • Microlap
Technologies • Micron Optics • Microsemi • Mindrum Precision • Mitsubishi Electric US • Mitsubishi International Polymer Trade • ModuleTek Limited • Molex • MoSys • MPB Communications •
MPI • MPNICS • MRSI Systems • MultiLane SAL • Murata Electronics • Nanjing Eulong • Nanometer Technologies • nanoPrecision Products • Nanosystec • National Research Council of Canada
• NEC • Necsel IP • NEON Photonics • NeoPhotonics • Netcope Technologies • Network Telecom Information • New Ridge Technologies • Newport • NGPON2 Forum • Ningbo Feitian Electron
Technology • Ningbo GEYIDA Cable Technology • Ningbo Lanze Telecommunication Equipment • Ningbo Yuda Communication Technology • Nippon Electric Glass • Nissin Kasei USA • Nistica •
Nokia • Norland Products • Notice • Novoptel • nPoint • NTT Advanced Technology • NTT Electronics America • NTT Electronics • Nufern • Nuphoton Technologies • O/E Land • Octaro • OE
Solutions • OFS • OgMaXium • O-Net Communications (Shenzhen) • Oki Gate • Optic Technology • OpTek Systems • Optelian Access Networks • Optella • Optellent • Optelligent • Optic River
Communication • Optical Connections • Optical Interworking Forum • Optics Fans • Optilab • Optiwave Systems • OptiWorks • Opto Marine • OptoMedia • Optoplex • OptoScribe • OptoTest
• Optoway Technology • Optowell • Optowide Technologies • Optronics, The • Opwill Technologies • OrangeTek • OSA • OSI Laser Diode Corporation • OSI Optoelectronics • OSRam • Otrans
Communication Technologies (Tongzhou) • Orsent Technologies • Oxford Fiber • OZ Optics • Pacific Microchip • Pacific Opto Electronic Technology • PacketLight Networks • Palomar
Technologies • Passive Plus • P-CUBE • PE Fiberoptics • Peak Optoelectronics (Suzhou) • PETRA • PFC Flexible Circuits • Philips • PI-L-M Photonics • Phoenix Photonics • PhoenixX Software
• Photon Delta • Photon Design • Photon Kinetics • Photonic Lattice • Photonics Media/Laurin Publishing • PI (Physik Instrumente) LP • Picometrix • Plastic Optical Fiber Trade Organization
• PLC Connections • POINTek • Polaris Electronics • Polatis • PPI • Precise-TEC • Precision Optical Transceivers • Presidio Components • Presto Engineering • PriTel • ProLabs • Promet
Optics • Proximion AB • Prysmian Group • PSC-SC • QianXin High Technology • Qorvo • R&D Interconnect Solutions • RAM Photonics • Ranovus • Raysung Photonics • Reflex Photonics •
Reichenbach International • RMT • Rockley Photonics • Rosenberger North America • Rosendahl Nextrom • Samtec • Santec USA • Sanwa Electronics USA • SCHOTT Electronic
Packaging • Sedona Systems • Seikoh Giken • Semtech • SENKO Advanced Components • SETO/LOGOS • Shanghai Changyue Communications • Shanghai Lonboom Limited • Shaoxing
ZKTel Equipment • Sharetop Technology • Shenzhen 6com Technology • Shenzhen ADTEK Technology • Shenzhen Allopto Limited • Shenzhen Chinaopticcable • Shenzhen C-Light
Network Communication • Shenzhen DYS Fiber Optic Technology • Shenzhen Ensure Precision Machine • Shenzhen Eternal Science Development • Shenzhen Fibercan Optical •
Shenzhen Fiberroad Technology • Shenzhen Fibershow Communication, • Shenzhen Gigalight Technology • Shenzhen Gongyao Electronics Technology • Shenzhen Hi-Optel
Technology • Shenzhen HKT Electronic Sci. & Tech. • Shenzhen Huayu Optical Communication Tech. • Shenzhen Hytera Communications • Shenzhen KamaxOptic Communication
• Shenzhen Lasun Network Cabling • Shenzhen OlinkPhotonics • Shenzhen Optical Network Telecom • Shenzhen Opway Communication • Shenzhen Oscom Technology •
Shenzhen Puhuixin Technology • Shenzhen SDG Information • Shenzhen Sinovo Telecom • Shenzhen Solar Valley Scitech Dev • Shenzhen Terawan Technology • Shenzhen
TIBTRONIX Technology • Shenzhen TORCH Telecom Technology • Shenzhen U1 Telecommunicatons • Shenzhen Wahleen Technology • SHENZHEN XIANGTONG • Shenzhen
YiGuDian Technology • Shenzhen Youngsun Com Optical Fiber Cable • SHF Communication Technologies AG • Shibuya • Shineway Technologies (China) • Showmark •
Sichuan Huiyuan Plastic Optical Fiber • Sichuan Jiuzhou Optio-Electronics • Sichuan Tianyi Comheart Telecom • Sichuan Trixon Communication Technology • Sicoya
• SiFotonics Technologies • Silex Microsystems • Skorpios Technologies • SMART Photonics BV • SmartOptics AS • SOC America • Socionext • Somacis • Sony
Semiconductor Solutions • Source Photonics • Springer • Stars Microelectronics (Thailand) PCL • State of the Art • STRONG Technologies • Sumitomo Bakelite
• Sumitomo Electric Device Innovations USA • Sumitomo Electric Industries • Suncall America • Sunstar Communication Technology • SUSS MicroOptics SA
• Suzhou TFC Optical Communication • SVI Public Company Limited • Synopsys • SZOPT Communication • T Plus, • T&S Communications • Taconic •
Taihan Fiberoptics • Takfly Communications • TDK • Tecdia • Technohands • Tech-X • Tecnisco • Tektronix • Teledyne LeCroy • Telescent • TeraXion •
Texas Instruments • The 41st Inst of China Electronics Tech Goup • The Light Connection • Thor Group • Thorlabs • Tianjin Eloik Communication
Equipment Technology • Timbercon • Tocom Technology • Tomoegawa • Topstone Communication • Toto USA • TowerJazz • TransPacket AS •
Triformix Solutions (Su Zhou) • Triple Play Communications • TRS-RenTelco • U-Flex • ULTRA TEC • Unioriental Optics • Unisky Creacom
Technology • US Conec • VAPEL • VeEX • VI Systems • ViaSat • Viavi Solutions • VICTORIES • Viking Technology a Division of Sanmina •
Vishay Intertechnology • VLC Photonics SL • Vlink Optics • VPIphotonics • W2 Optronics • Wanjun Engineering SDN BHD • Wavetek
Microelectronics • Wen Global Solutions • WingComm • Wooriro • Wuhan Aroptics-Tech • Wuhan Fortune Technology • Wuhan
HuaGong Genuine Optics Tech • Wuhan RayOptek • Wuhan Yilut Technology • Wuhan Yusheng Optical Devices • Wuxi
Taclink Optoelectroincs Technology • XDK Communication Equipment (Huizhou) • Xelic • Xenoptics • XFS
Communications • Xgiga Communication Technology • Xiamen Freeform Optical Techonlogy • XiaMen Guangte
Communication Technology • Xilinx • XTXH Precision Tooling (Shenzhen) • XYZTEC • Yangtze Optical
Fibre & Cable Joint Stock • Yelo Limited • Yenista Optics • Yixing City Jitai Electronics • Yokogawa
of America • Yuetsu Seiki • Yuyao Huijia Communication Equipments • YuYao Liangpin
Telecom Equipment • Zeus • ZG Technology(ShenZhen) • ZGT Optical Comm •
ZheJiang Tribrer Communication Technology • Zhengzhou Shijia
Technology • Zhongshan Meisu Technology • Zhuzhou
Jiabang Refractory Metal • ZTE

exhibit · submit · register

OFC 2018

The future of optical networking and communications

TECHNICAL CONFERENCE
11 – 15 March 2018

EXHIBITION
13 – 15 March 2018
San Diego, California, USA

OFCConference.org
@OFCConference
#OFC18

SPONSORED BY:

65 YEARS 1952–2017 | IEEE ComSoc IEEE Communications Society

IEEE photonics Society

OSA The Optical Society | 100 Since 1916

Managed by OSA