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Trends in 400G Optics for the Data Center

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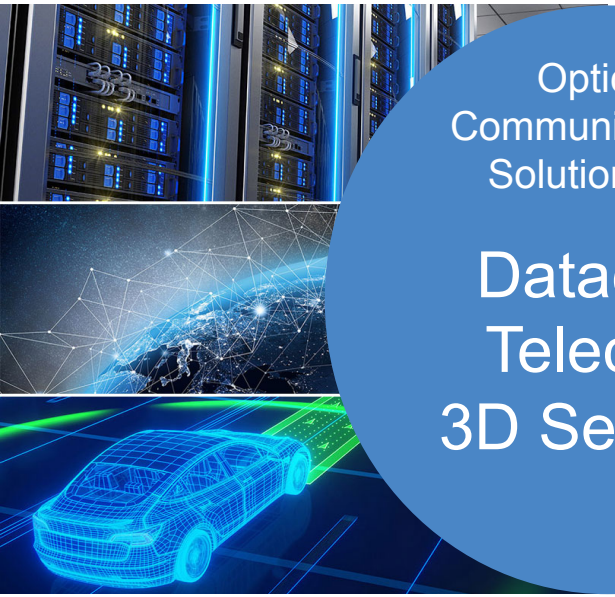
Finisar Corporation



Optical Communications Solutions for

Datacom
Telecom
3D Sensing

$1.3+ Billion
Revenue
FY18

Optical Components Market Leader
(Source: Ovum)

~12,000+
Employees Worldwide

1,000+
World-Class Engineers

30 YEARS
1988-2018
History of innovation

1,300+
US Patents

Finisar Facilities Worldwide

Broad Product Portfolio and Customer Base

DATACOM

PRODUCTS

CUSTOMERS

EMC² where information lives
intel
extreme networks
CISCO
BROCADE
JUNIPER NETWORKS
DELL
NetApp
IBM
EMULEX We network storage
H3C IToIP Solutions Expert
hp invent
QLOGIC
ORACLE
Mellanox TECHNOLOGIES

TELECOM

PRODUCTS

CUSTOMERS

HUAWEI
ERICSSON
ZTE中兴
CIENA
Alcatel·Lucent
ADVA Optical Networking
HITACHI Inspire the Next
NOKIA
eci
FUJITSU
infinera
NEC
Coriant
cyan
transmode

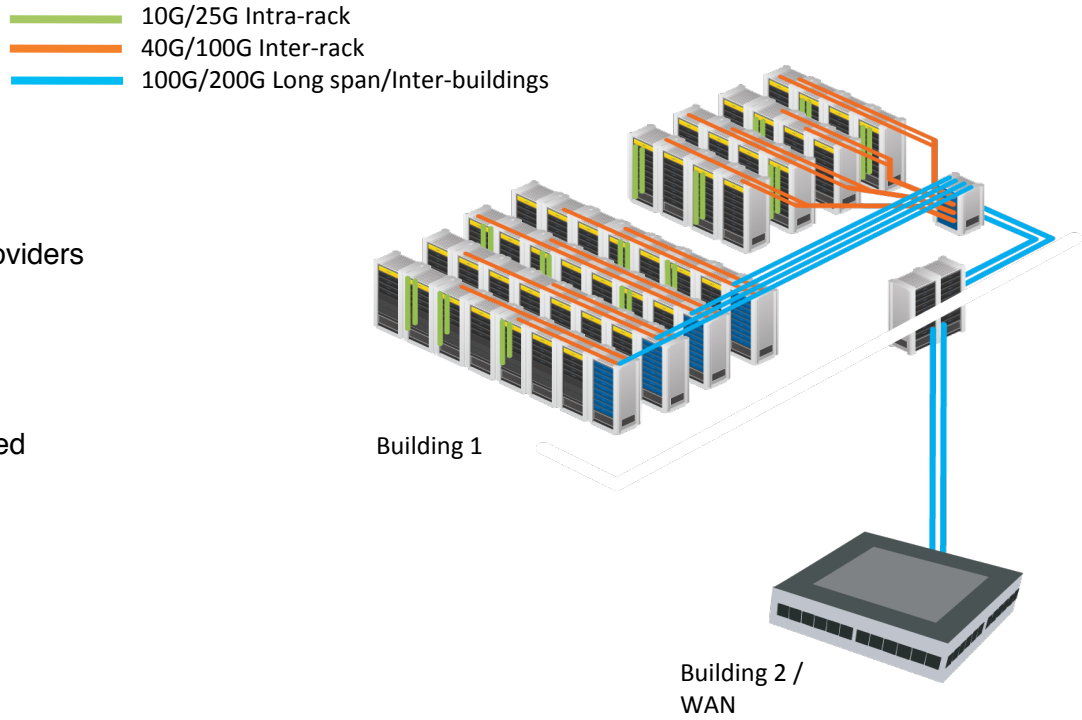
Data Center Connections are High Volume Drivers

- Due to the ongoing large increases in bandwidth demand, Data Center connections are expected to move from 25G/100G to 100G/400G

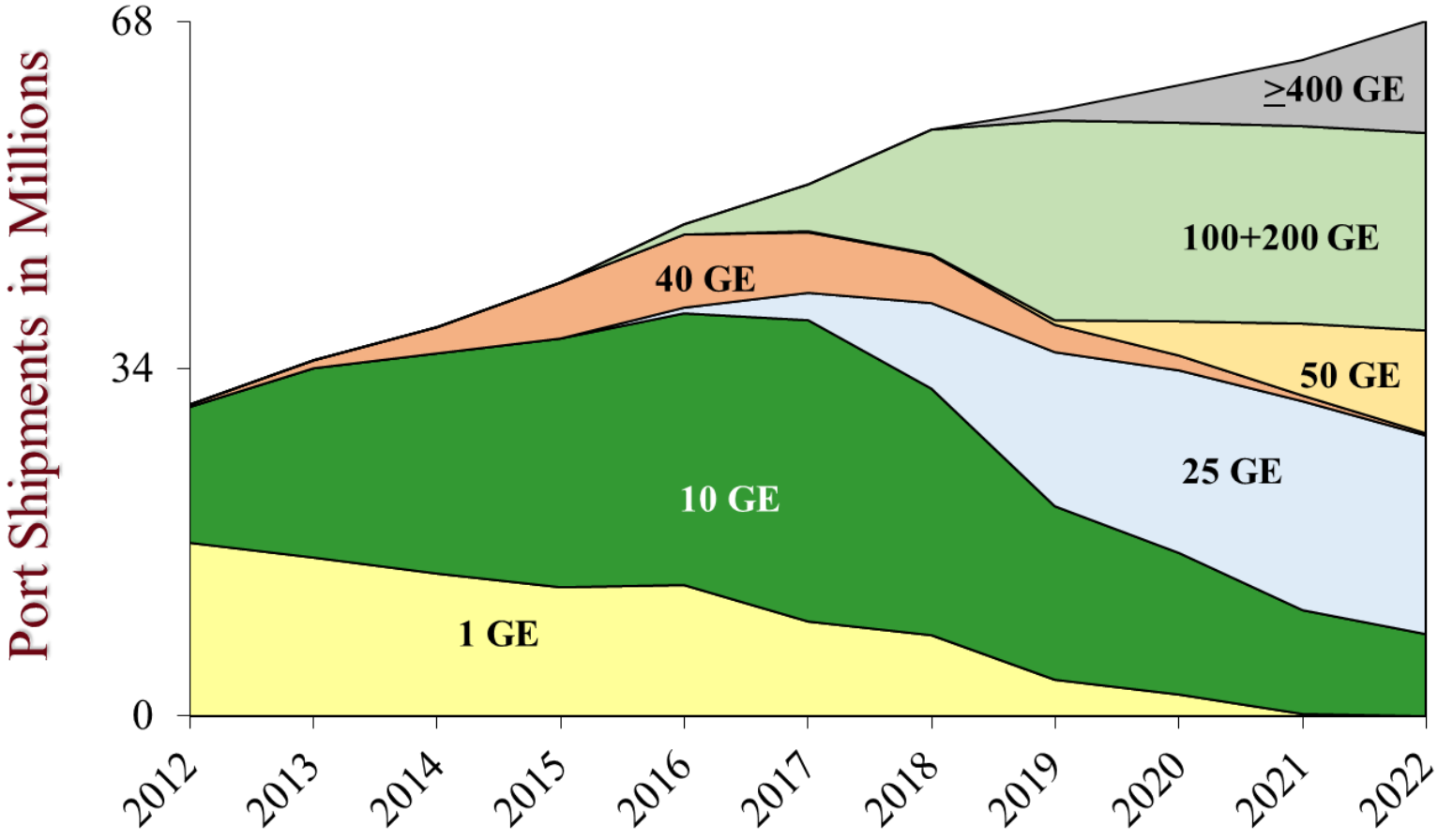
- Within the Data Center Racks
  - 10GE still being deployed
  - **25GE** starting to be deployed in volume
  - **100GE** (or 50G) will follow

- Between Data Center Racks
  - 40GE still being deployed
  - **100GE** starting to be deployed in volume
  - **400GE** will follow at large Cloud Service Providers

- Long Spans/DCI & WAN
  - 10G DWDM/Tunable still being deployed
  - **100G/200G Coherent** starting to be deployed
  - **400G** will follow – Then 600G or 800G

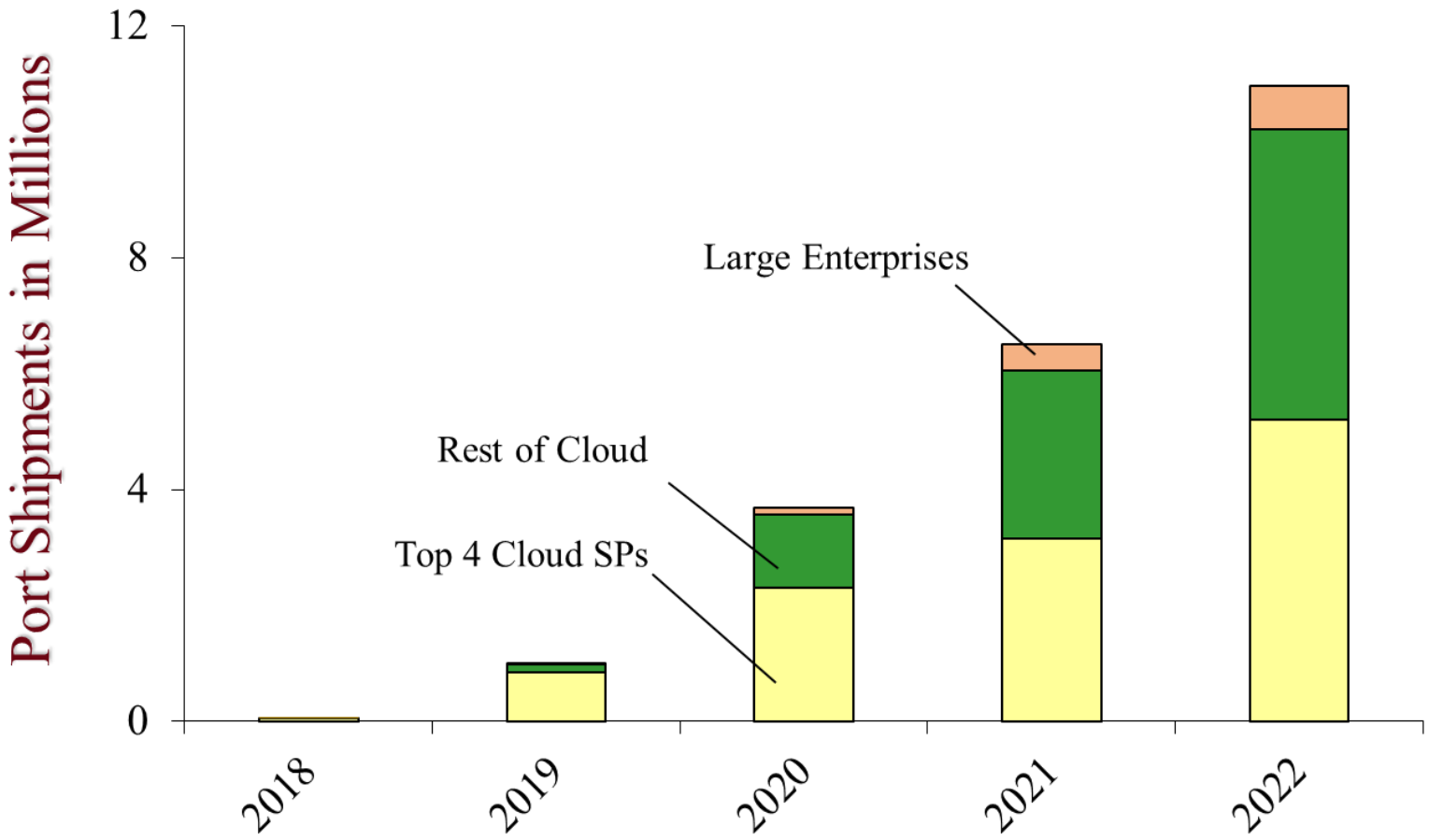


Forecasted Data Center Ethernet Port Shipments



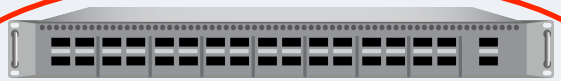
Source: Dell'Oro, 2018

Forecasted 400GE Shipments by Market Segment



Source: Dell'Oro, 2018

Mainstream 1RU Ethernet Switch Roadmap

First Deployed	Electrical I/O [Gb/lane]	Switching Bandwidth	TOR/Leaf Data Center Switch Configuration	
~2010	10G	1.28T	 32xQSFP+ (40G)	
~2015	25G	3.2T	 32xQSFP28 (100G)	3.2Tb/s switches based on 100G QSFP28 modules being deployed in cloud data centers today.
~2019	50G	6.4T	 32 ports of 200G	Given the multiple switching ICs expected to be available, the market is likely to be fragmented in the future.
~2020	50G	12.8T	 32 ports of 400G	

Large growth in bandwidth demand is pushing the industry to work on technologies and standards to support future 12.8T switches.

400G and Next-Gen 100G Ethernet Optical Standardization

Interface	Link Distance	Media type	Optical Technology
400GBASE-SR16	100 m (OM4)	32f Parallel MMF	16x25G NRZ Parallel VCSEL
400GBASE-DR4	500 m	8f Parallel SMF	4x100G PAM4 Parallel (SiP)
400GBASE-FR8	2 km	2f Duplex SMF	8x50G PAM4 LAN-WDM (DML)
400GBASE-LR8	10 km	2f Duplex SMF	8x50G PAM4 LAN-WDM (DML)

SR16 not expected to be deployed

400GE interfaces standardized in IEEE 802.3bs

Interface	Link Distance	Media type	Optical Technology
100GBASE-SR2	100 m (OM4)	4f Parallel MMF	2x50G PAM4 850nm (VCSEL)
100GBASE-DR	500 m	2f Duplex SMF	100G PAM4 1310nm (EML)

Next-Gen 100GE standardized in IEEE 802.3cd

Interface	Link Distance	Media type	Optical Technology
400GBASE-SR8	100 m (OM4)	16f Parallel MMF	8x50G PAM4 850nm (VCSEL)
400GBASE-SR4.2	100 m (OM4)	8f Parallel MMF	8x50G PAM4 BiDi 850 / 910nm (VCSEL)

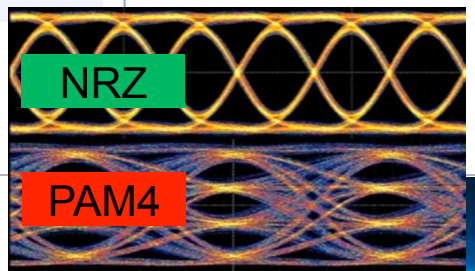
Multimode 400GE standardized in IEEE P802.3cm

Interface	Link Distance	Media type	Optical Technology
400G-FR4	2 km	2f Duplex SMF	4x100G PAM4 CWDM (EML)
400G-LR4	10 km	2f Duplex SMF	4x100G PAM4 CWDM (EML)
100G-FR	2 km	2f Duplex SMF	100G PAM4 1310nm (EML)
100G LR	10 km	2f Duplex SMF	100G PAM4 1310nm (EML)

100GE/400GE interfaces standardized in IEEE P802.3cu

- VCSEL technology to be used <100m
- Silicon Photonics to be used <1km
- DML/EML technology to be used <40km

SWDM to enable 400GE over Duplex MMF in the future



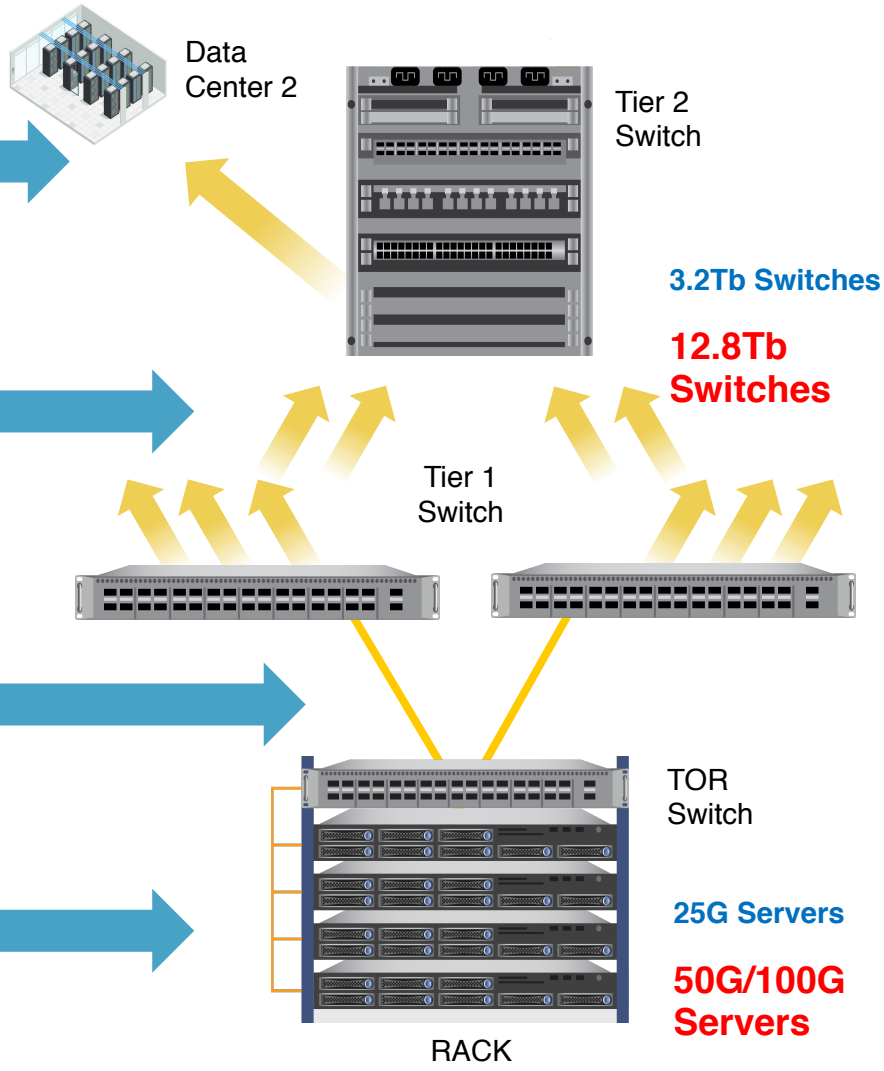
400G Ethernet Is Taking Shape in the Cloud Data Center

Metro DCI (< 80km)
Deploying 100G/200G Coherent
Roadmap is 400GE LR8/ER8, ZR Coherent

Tier 2 Switch to Tier 1 Switch links
Deploying 100GE CWDM4/PSM4
Roadmap is 400GE FR8/FR4/DR4

Tier 1 Switch to TOR Switch links
Deploying 100GE SR4/AOC
Roadmap is 400GE DR4/SR4.2/SR8/AOC

TOR Switch to Server links
Deploying 25GE SR/AOC/DAC(3m)
Roadmap is 50GE/100GE SR/AOC

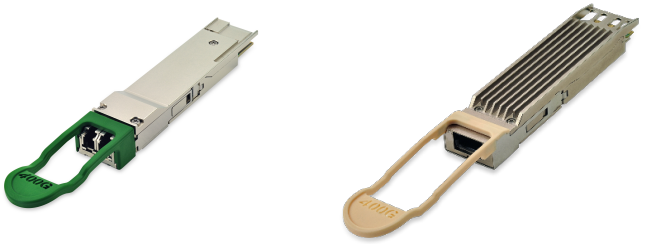


400GE Optical Transceiver Form Factor MSAs

CFP8 is the *1st-generation 400GE* module form factor, to be used in core routers and DWDM transport client interfaces.

Module dimensions are **slightly smaller than CFP2**

Supports either **CDAUI-16** (16x25G NRZ) or **CDAUI-8** (8x50G PAM4) electrical I/O



QSFP-DD and OSFP modules being developed as *2nd-generation 400GE,* for **high port-density data center switches**.

Enable **12.8Tb/s** in 1RU via 32 x 400GE ports

Support **CDAUI-8** (8x50G PAM4) electrical I/O only

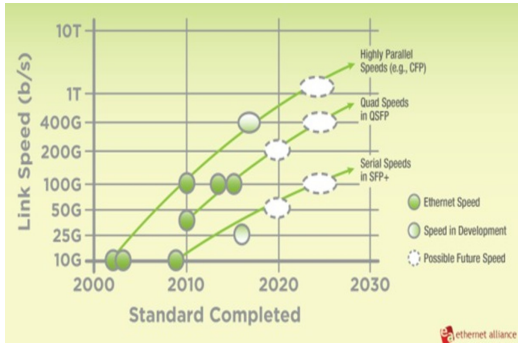
QSFP-DD host is backwards compatible with QSFP28

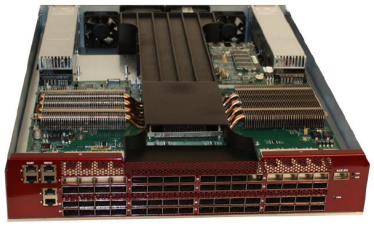
General Trends in Data Center Optical Interconnects

- Continuous increase in bandwidth density
- Increasing adoption of optics in Server-to-TOR Switch links
- Low-latency optics for certain niche cognitive-computing applications
- Maturity of key technologies
  - High-speed VCSELs
  - Silicon photonics
- Arrival of coherent optics for data center interconnects

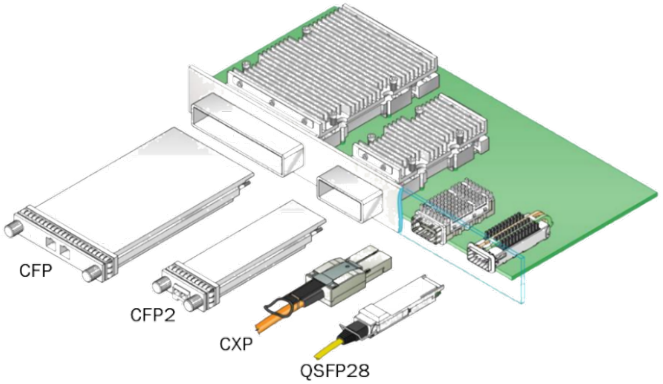
The Market Demands Continuous Improvement in Bandwidth Density

Module Type	# of I/O lanes	Electrical I/O	I/O Baud Rate	Module BW	Width (mm)
SFP+	1	10Gb/s-NRZ	10G	**10Gb/s**	13
QSFP+	4	10Gb/s-NRZ	10G	**40Gb/s**	18
QSFP28	4	25Gb/s-NRZ	25G	**100Gb/s**	18
QSFP56	4	50Gb/s-PAM4	25G	**200Gb/s**	18
QSFP-DD / OSFP	8	50Gb/s-PAM4	25G	**400Gb/s**	18
Form factor?	8	100Gb/s-PAM4	50G	**800Gb/s**	?





256 x 25G Switch System – 2 RU
(64 x QSFP28 interfaces)



Optical Technologies for Next-Generation Data Centers

- Short Reach (0 to 100 meters)
  - Higher bandwidth VCSELs
  - VCSELs with sparing capability
  - VCSELs with low RIN
- Intermediate Reach (500 meters to 2 km)
  - Silicon photonics
- Long Reach (10 km and beyond)
  - DML/EMLs
  - Low-power coherent optics

400G, 200G & 100G PAM4 Transceiver Demos at OFC/ECOC

400G QSFP-DD LR8/FR8 (10km)

400G QSFP-DD AOC (70m)

100G QSFP28 DR/FR (2km)

200G QSFP56 FR4 (2km)
2x200G OSFP FR4 (2km)
400G QSFP-DD DR4 (500m)
400G QSFP-DD FR4 (2km)
400G OSFP SR8 (100m)

Additionally, several interoperability demos were done by the MSAs

80km DCI Space: Coherent vs. Direct Detection

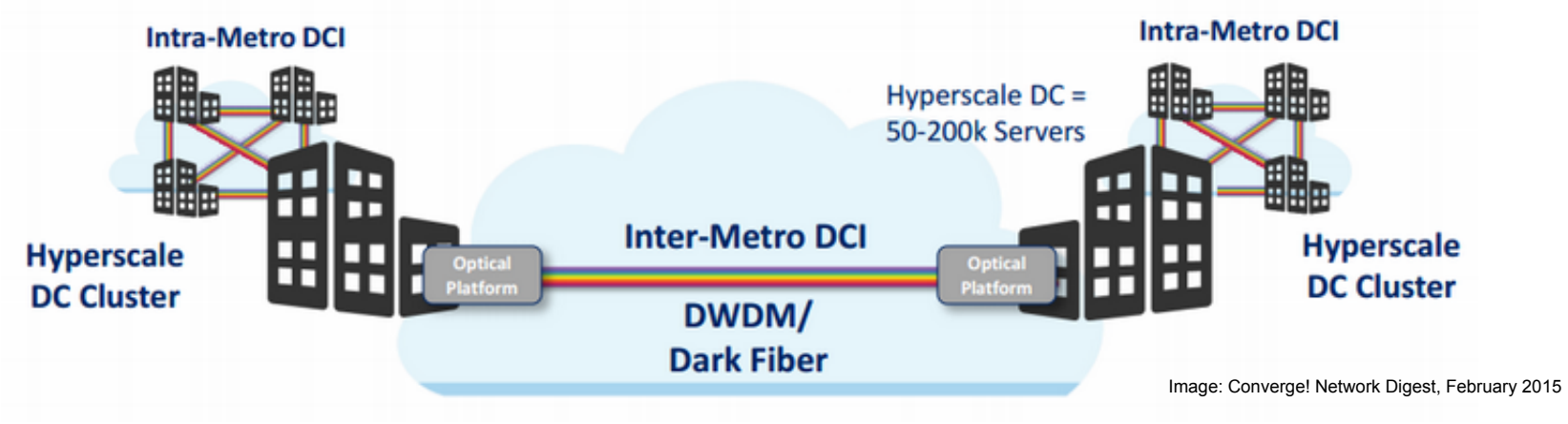
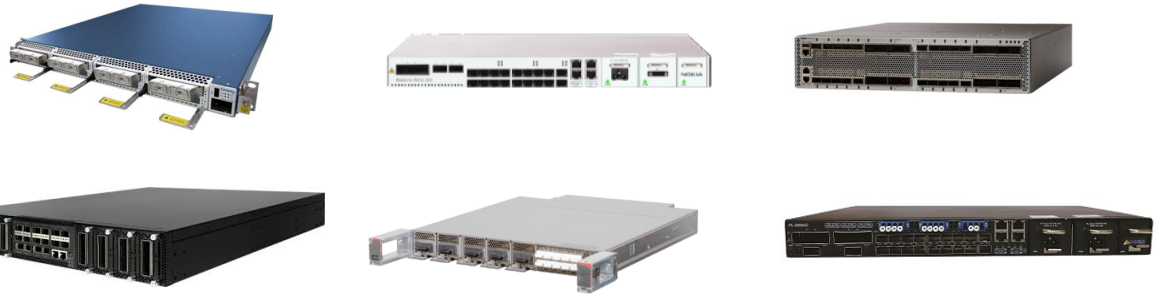


Image: Converge! Network Digest, February 2015

- Coherent interfaces are likely to capture the 80km market at 400Gb/s and higher rates.
- For 40km and shorter reaches, direct detection may be lower power and cost than coherent for the next few years. Example: 8x50Gb/s (PAM4) 400GBASE-ER8 modules.
- Currently coherent technology is about 2x higher power and cost relative to 100Gb/lane direct detection.
- Standardization work by OIF 400ZR IA and IEEE P802.3ct Task Force (400GBASE-ZR).
- Aggressive innovation will be required to maintain long-term trends to support 1.6 Tb/s ~2024.

Coherent Transmission for DCI Applications

- 100G/200G links require a transponder box to convert to coherent optical transmission in order to support 80~100km and beyond.
- Several system OEMs provide a 1RU transponder box for DCI applications, most of which use pluggable Coherent CFP2-ACO optical transceivers.



CFP2-ACO

ACO = Analog Coherent Optics

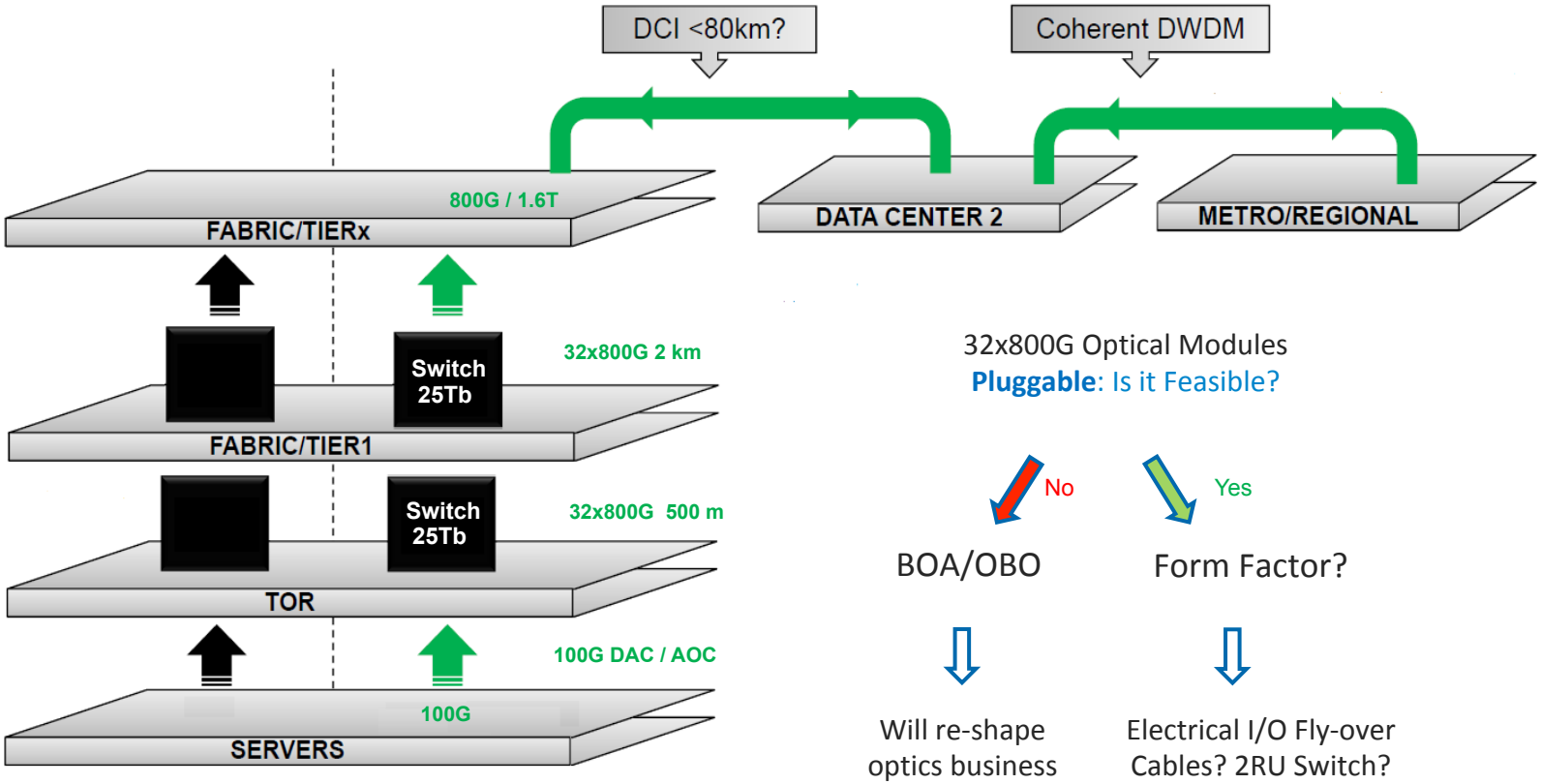
DCO = Digital Coherent Optics

- Expected coherent transceiver evolution is driven by improvements in optical packaging and DSP power dissipation:

200G CFP2-ACO → **400G CFP2-DCO → 400G QSFP-DD DCO**

400G DCO transceivers are expected to be plugged directly into switches and routers

Coming Next: What Shape Will 800G Ethernet Take?



32x800G Optical Modules
Pluggable: Is it Feasible?

No → BOA/OBO → Will re-shape optics business model

Yes → Form Factor? → Electrical I/O Fly-over Cables? 2RU Switch?

100G PAM4 electrical I/O being standardized in IEEE P802.3ck

FINISAR

Thank You

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