



# 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



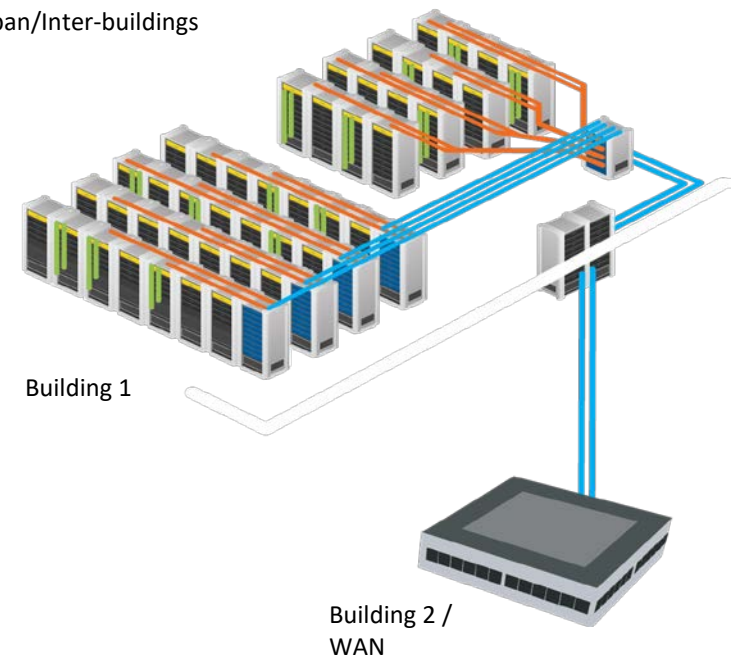
# Broad Product Portfolio and Customer Base

	DATACOM	TELECOM
PRODUCTS	 <p>SFP, SFP+, QSFP/QSFP28, CFP2/CFP4, CFP, Optical Engine (BOA), CXP, Active Optical Cables, XFP, X2/XENPAK</p>	 <p>SFP, XFP, SFP+, CFP2-ACO, Coherent Transponder, ROADM line card, WSS, WDM Passives, Amplifiers, High speed components, Tunable laser, CATV, PON</p>
CUSTOMERS	 <p>EMC<sup>2</sup> where information lives, Intel, Extreme Networks, Cisco, Brocade, Juniper Networks, Dell, NetApp, IBM, EMC, H3C IT/ITP Solutions Expert, HP invent, QLOGIC, ORACLE, Mellanox TECHNOLOGIES</p>	 <p>HUAWEI, ERICSSON, ZTE中兴, CIENA, Alcatel-Lucent, ADVA Optical Networking, HITACHI Inspire the Next, NOKIA, eci, FUJITSU, infinera, NEC, Coriant, cyan, transmode</p>

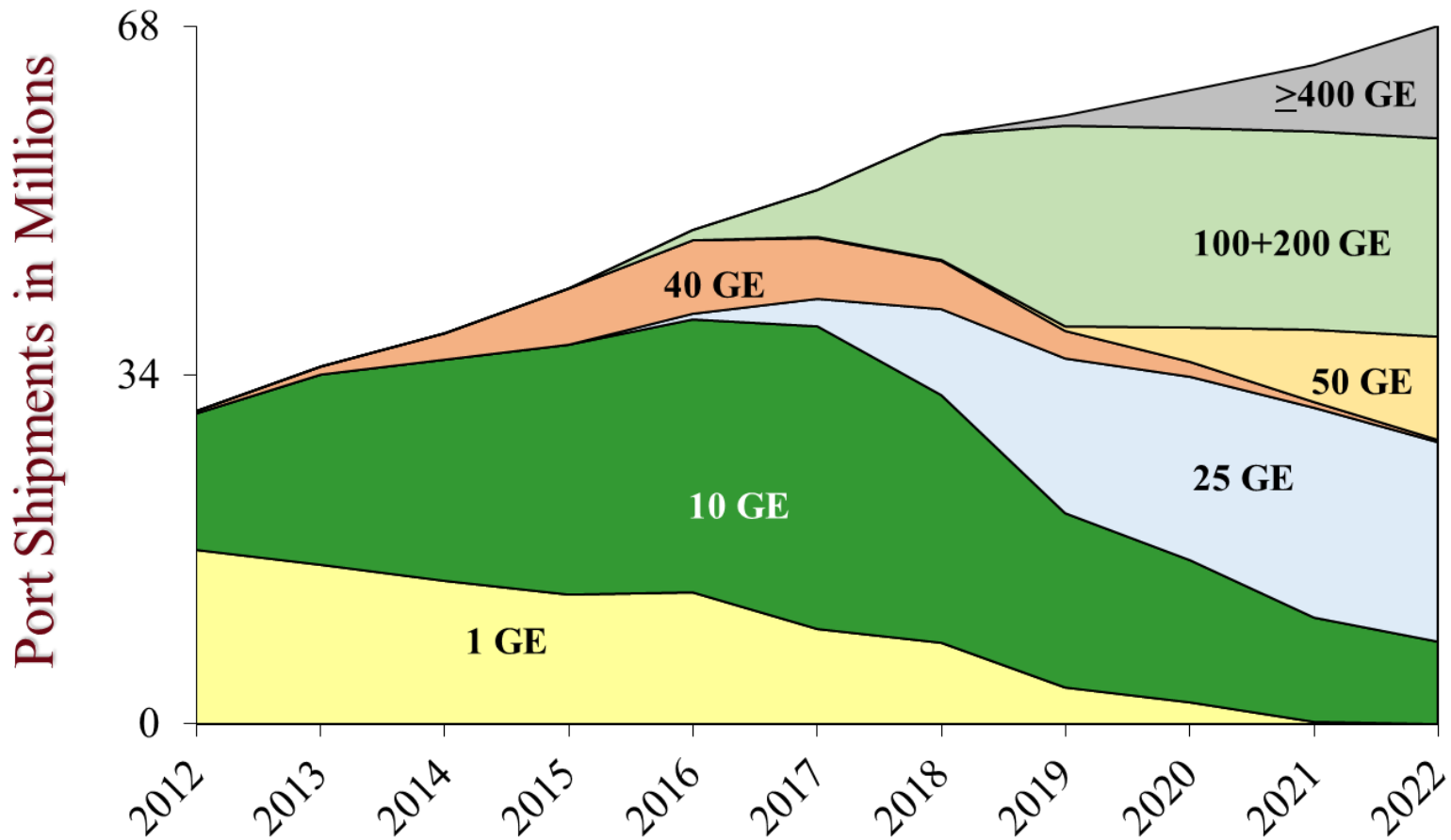
# Data Center Connections are High Volume Drivers

- 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

— 10G/25G Intra-rack  
— 40G/100G Inter-rack  
— 100G/200G Long span/Inter-buildings



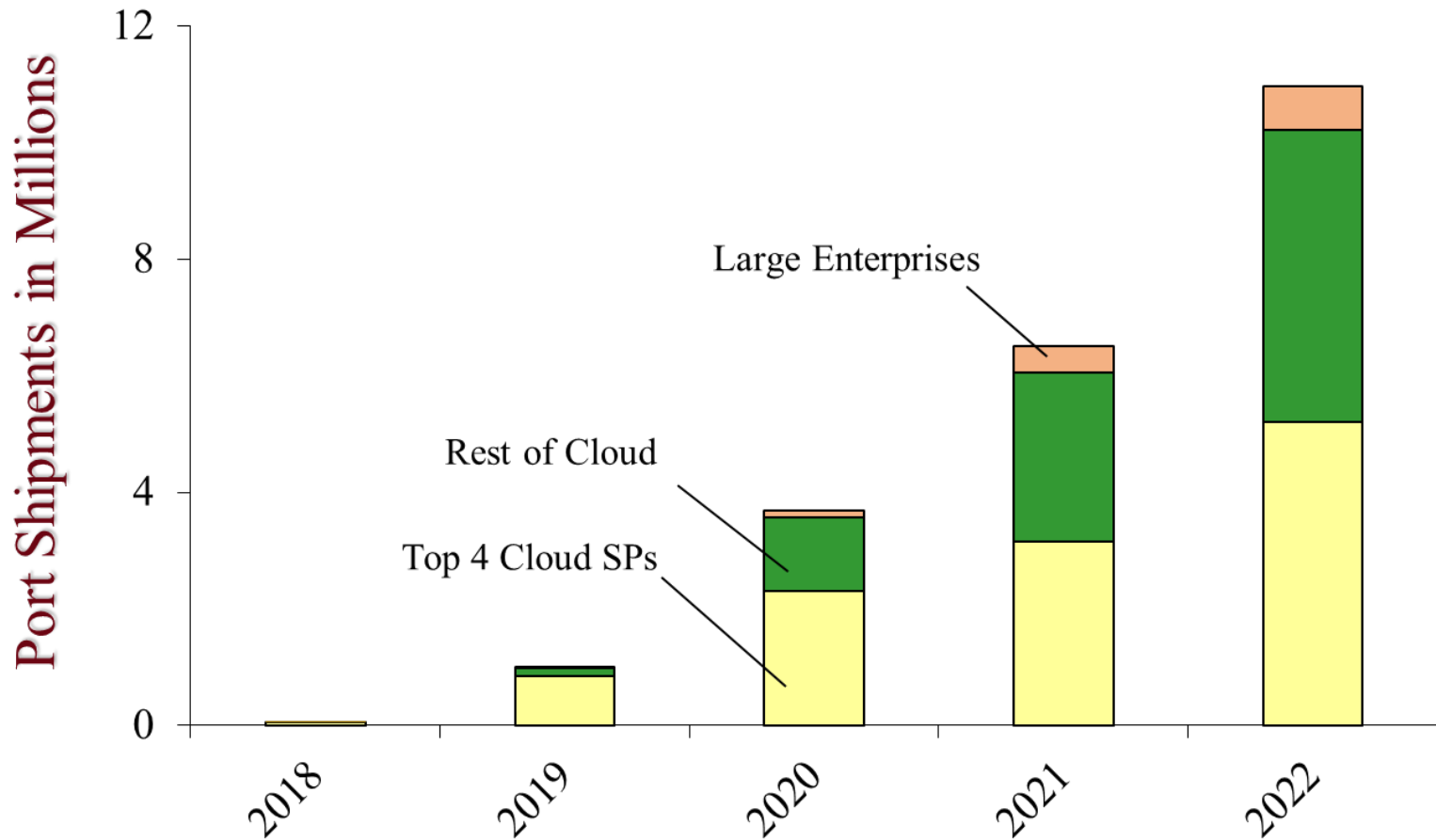
# Forecasted Data Center Ethernet Port Shipments



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 <small>SR16 not expected to be deployed</small>
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)

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)

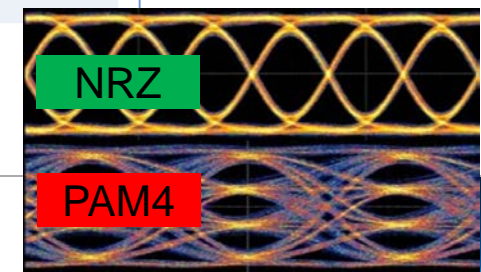
Multimode 400GE standardized in IEEE P802.3cm

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	

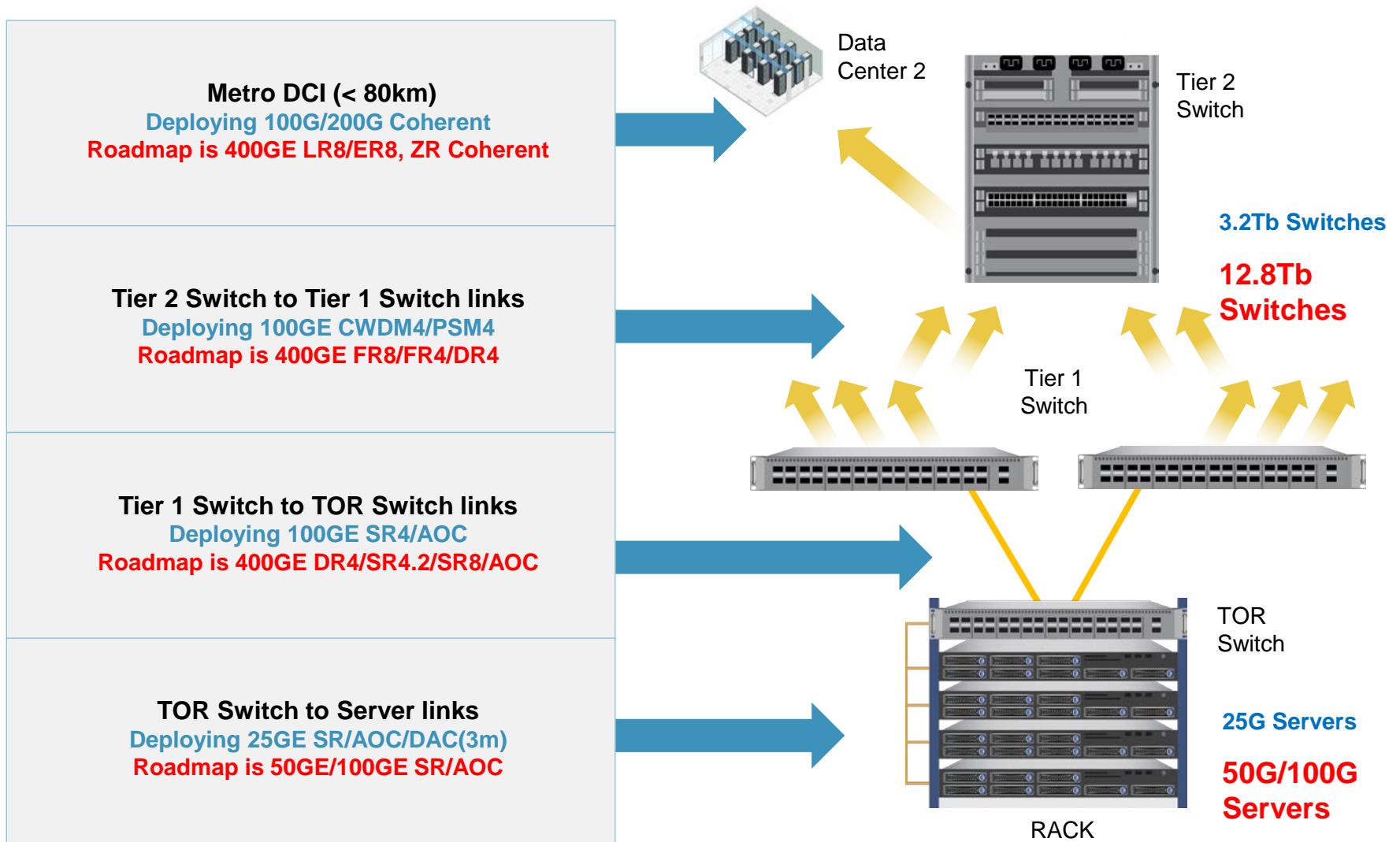
100GE/400GE interfaces standardized in IEEE P802.3cu

- 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



# 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**.

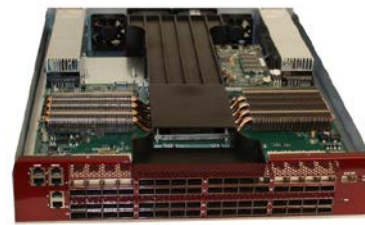
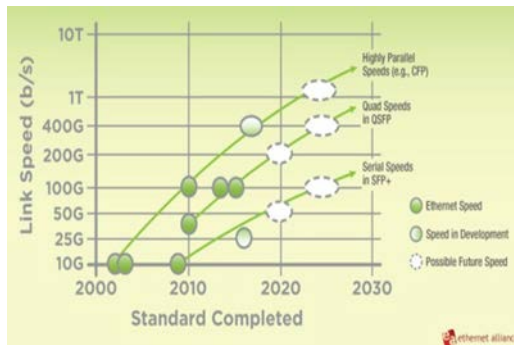
Enable **12.8Tb/s** in 1RU via 32 x 400GE ports  
Support **CDAUI-8** (8x50G PAM4) electrical I/O only  
QSFP-DD host is backwards compatible with QSFP28

# General Trends in Data Center Optical Interconnects

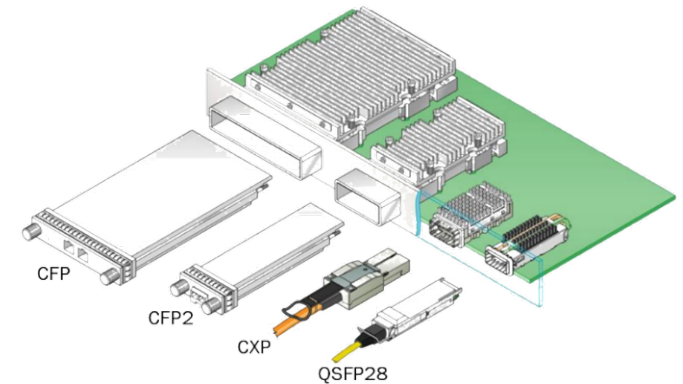
- Continuous increase in bandwidth density
- Increasing adoption of optics in Server-to-TOR Switch links
- Low-latency optics for certain niche cognitive-computing applications
- Maturity of key technologies
  - High-speed VCSELs
  - Silicon photonics
- Arrival of coherent optics for data center interconnects

# 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	<b>10Gb/s</b>	13
QSFP+	4	10Gb/s-NRZ	10G	<b>40Gb/s</b>	18
QSFP28	4	25Gb/s-NRZ	25G	<b>100Gb/s</b>	18
QSFP56	4	50Gb/s-PAM4	25G	<b>200Gb/s</b>	18
QSFP-DD / OSFP	8	50Gb/s-PAM4	25G	<b>400Gb/s</b>	18
Form factor?	8	100Gb/s-PAM4	50G	<b>800Gb/s</b>	?



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)

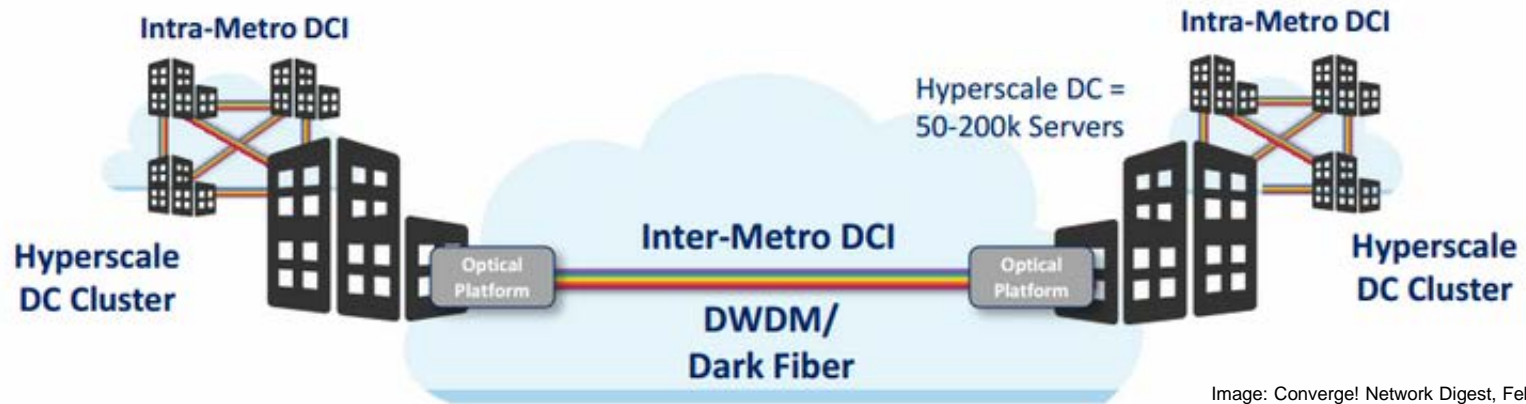


200G QSFP56 FR4 (2km)  
 2x200G OSFP FR4 (2km)  
 400G QSFP-DD DR4 (500m)  
 400G QSFP-DD FR4 (2km)  
 400G OSFP SR8 (100m)

**Additionally, several interoperability demos were done by the MSAs**



# 80km DCI Space: Coherent vs. Direct Detection



- **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

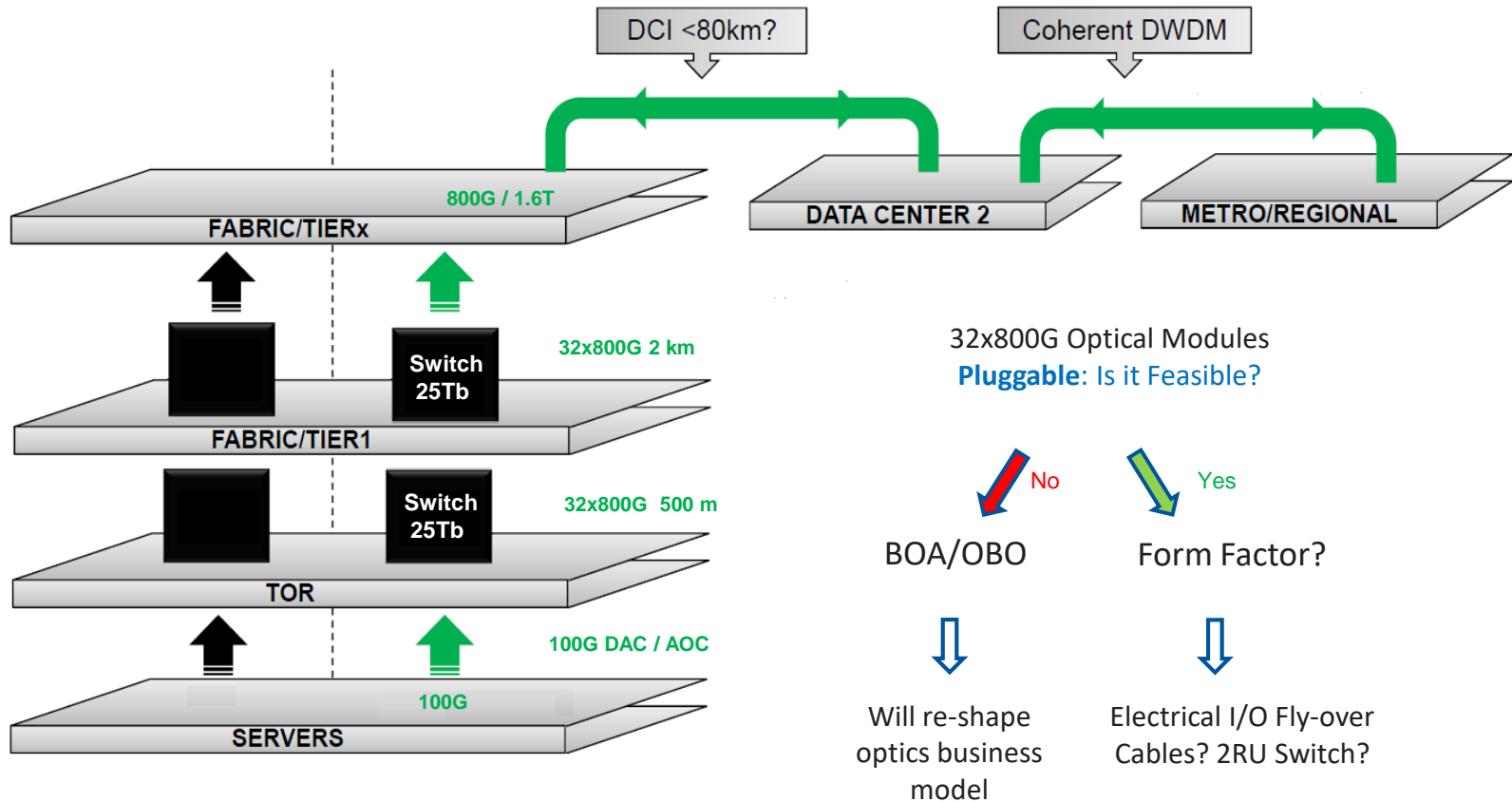
- Expected coherent transceiver evolution is driven by improvements in optical packaging and DSP power dissipation:

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?



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



**FINISAR®**

Thank You

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