



Latest Trends in Data Center Optics

RIPE 74

Budapest, May 2017





Finisar Corporation

World's Largest Supplier of Fiber Optic Components and Subsystems

- Optics industry leader with \$1B+ in annual revenue
- Founded in 1988
- IPO in 1999 (NASDAQ: FNSR)
- 14,000 employees
- Best-in-class broad product line
- Vertically integrated with low cost manufacturing
- Significant focus on R&D and capacity expansion
- ~30% market share
- Experienced management team
- 1300+ Issued U.S. patents



Broad Product Portfolio and Customer Base

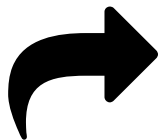
	DATACOM	TELECOM
PRODUCTS	 <p>SFP SFP+ QSFP/QSFP28 CFP2/ CFP4 CFP</p> <p>Optical Engine (BOA) CXP Active Optical Cables XFP X2/XENPAK</p>	 <p>SFP XFP SFP+ CFP2-ACO Coherent Transponder</p> <p>ROADM line card WSS WDM Passives Amplifiers</p> <p>High speed components Tunable laser CATV PON</p>
CUSTOMERS	 <p>EMC² where information lives[®] intel extreme networks CISCO</p> <p>BROCADE JUNIPER NETWORKS DELL</p> <p>NetApp[®] IBM EMULEX[®] We network storage H3C ITolP Solutions Expert</p> <p>hp invent QLOGIC[®] ORACLE Mellanox TECHNOLOGIES</p>	 <p>HUAWEI ERICSSON ZTE中兴 CIENA</p> <p>Alcatel-Lucent ADVA[™] Optical Networking HITACHI Inspire the Next</p> <p>NOKIA eci FUJITSU infinera NEC</p> <p>Coriant[®] cyan transmode</p>

100G is Just Beginning



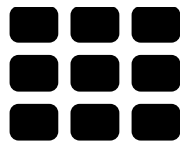
TIMELINE

Large industry investment in 400G will take time; 200G may be here sooner.



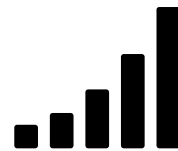
LIFECYCLE

Large 100GE QSFP28 deployments in Data Centers have just started and will have a very long tail...



CONFUSION

Too many 100G optical interfaces in the market is an issue.



DEMAND

Broad-based optical suppliers investing heavily to address mainstream market needs for 100G.







COST

Heavy focus on cost-effective upgrade from 10/40G to 25/100G Ethernet on existing fiber plant.

Beyond the 3.2Tb/s Switch

- Unprecedented growth in bandwidth demand is already pushing the industry to work on numerous technologies and standards to support future **6.4T and 12.8T switches**.
- 50G, 200G and 400GE Standards are being defined by IEEE.
- Modulation is moving from NRZ to **PAM4** for both electrical and optical interfaces.
- Optics suppliers are investing large R&D \$\$ on supporting these new rates.
 - New transceiver module form factors (**CFP8, QSFP56, QSFP-DD, OSFP, SFP56**).
 - Advanced VCSELs, InP DFB lasers and Si Photonics technologies.
 - ICs and manufacturing test platforms that support PAM4 modulation.

Mainstream 1RU Ethernet Switch Roadmap

FIRST AVAILABLE	ELECTRICAL I/O [Gb/LANE]	SWITCHING BANDWIDTH	TOR/LEAF DATA CENTER SWITCH CONFIGURATION	
~2010	10G	1.28T	 <p>32xQSFP+ (40G)</p>	
~2015	25G	3.2T	 <p>32xQSFP28 (100G)</p>	3.2Tb/s switches based on 100G QSFP28 modules starting to be deployed in data centers today.
~2017 ~2018	25G 50G	6.4T	 <p>32 ports of 200G</p>	Given the multiple switching ICs expected to be available, the market is likely to be fragmented in the future.
~2020	50G	12.8T	 <p>32 ports of 400G</p>	

50G, 200G and Next-Gen 100G Ethernet Standardization

200GE interfaces being standardized in IEEE 802.3bs

INTERFACE	LINK DISTANCE	MEDIA TYPE	TECHNOLOGY
200GBASE-SR4	100 m	8f Parallel MMF	4x50G PAM4 850nm
200GBASE-DR4	500 m	8f Parallel SMF	4x50G PAM4 1300nm window
200GBASE-FR4	2 km	Duplex SMF	4x50G PAM4 CWDM
200GBASE-LR4	10 km	Duplex SMF	4x50G PAM4 LAN-WDM

50GE interfaces being standardized in IEEE 802.3cd

INTERFACE	LINK DISTANCE	MEDIA TYPE	TECHNOLOGY
50GBASE-SR	100 m	Duplex MMF	50G PAM4 850nm
50GBASE-FR	2 km	Duplex SMF	50G PAM4 1300nm window
50GBASE-LR	10 km	Duplex SMF	50G PAM4 1300nm window

Next-Generation 100GE interfaces being standardized in IEEE 802.3cd

INTERFACE	LINK DISTANCE	MEDIA TYPE	TECHNOLOGY
100GBASE-SR2	100 m	4f Parallel MMF	2x50G PAM4 850nm
100GBASE-DR	500 m	Duplex SMF	100G PAM4 1310nm

400G Ethernet Standardization

400GE interfaces being standardized in IEEE 802.3bs

INTERFACE	LINK DISTANCE	MEDIA TYPE	TECHNOLOGY
400GBASE-SR16	100 m	32f Parallel MMF	16x25G NRZ Parallel
400GBASE-DR4	500 m	8f Parallel SMF	4x100G PAM4 Parallel
400GBASE-FR8	2 km	Duplex SMF	8x50G PAM4 LAN-WDM
400GBASE-LR8	10 km	Duplex SMF	8x50G PAM4 LAN-WDM

Future 400GE interfaces based on 50G and 100G PAM4 channels are already being discussed:

400G-LR4

10 km

duplex single mode fiber

400G-FR4

2 km

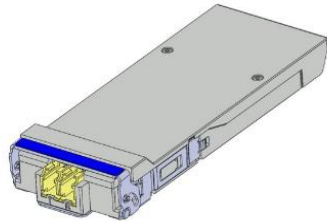
duplex single mode fiber

400G-SR4.2

100 m

8f parallel multimode fiber

400GE CFP8 and QSFP-DD Optical Transceiver Modules



CFP8 is the *1st-generation* 400GE module form factor, to be used in 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

Several vendor demos at OFC in March 2017

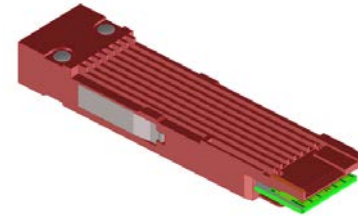


Image source:
QSFP-DD MSA

QSFP-DD (and similar) modules being developed as *2nd-generation*, for higher port-density.

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

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

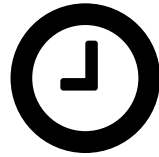
Host is backwards compatible with QSFP28

The Challenge of Ramping of 100G Ethernet



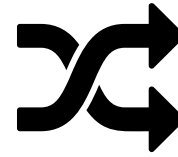
TRACTION

Even though tens of thousands of links been deployed in routers and DWDM transport clients since 2011, it is only now that 100G Ethernet is ramping in very large volumes and very high port densities in data centers.



DELAY

Industry fragmentation of 100G caused delay in large investment in manufacturing capacity and cost reductions of main interface codes.



DEPLOYMENT

BUT several million 100G QSFP28 and 25G SFP28 optical modules are expected to be deployed in the next 2 to 3 years.



HIGH DEMAND

Optics suppliers are facing the challenge of supporting the 25G/100G market ramp – Currently supply is constrained, lead-times are long.

100G Optical Standards and MSA Proliferation

- LOTS of interface choices in the market.
- Proliferation is impacting interoperability, multi-sourcing, cost reductions through consolidated volume ramp – causing confusion and slowing down buying decisions.
- Choose broadly supported, standards or MSA-based optics (e.g., 100G CWDM4).
- Engage with [broad-based optics suppliers](#) to help navigate the available choices – remove technology bias.

- Standards alphabet soup!

SR4, eSR4, SR10, 4xSR, 10xSR, 12xSR, LR4, LR4-Lite, eLR4, PSM4, 4xEDR, Omni-Path, 4xPCIe4, ER4, ER4f, FC-PI-6 128G FC, 4x32G FC SMF, 4x32G FC MMF, OTU4, CWDM4, eCWDM4, SWDM4

100-128 Gb/s

Current 25G and 100G Optical Modules in the Market



25GE Optical Transceivers

- Used for 25GE server ports and also on some Ethernet switch ports
- SFP28 form factor is standardized by SFF-8402 (SFF Committee)
- It has a 1-lane, retimed 25G I/O electrical interface
- Supports up to 1.5W power dissipation
- SR (100m, 300m) and LR (10km) are mainstream



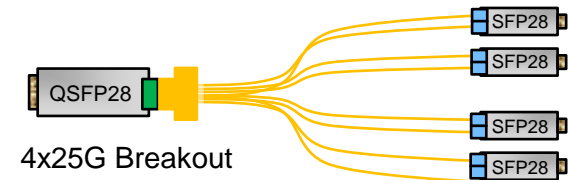
100GE Optical Transceivers

- QSFP28 is the 100GE module form factor of choice for Ethernet switches
- QSFP28 form factor is standardized by SFF-8665 (SFF Committee)
- It has a 4-lane, retimed 25G I/O electrical interface (CAUI-4)
- Supports up to 3.5W power dissipation
- SR4 (100m, 300m), SWDM4 (100m+), CWDM4 (2km) and LR4 (10km)



Active Optical Cables in QSFP28 and SFP28

- Cost-effective integrated cabling solutions for in-rack and rack-rack connections

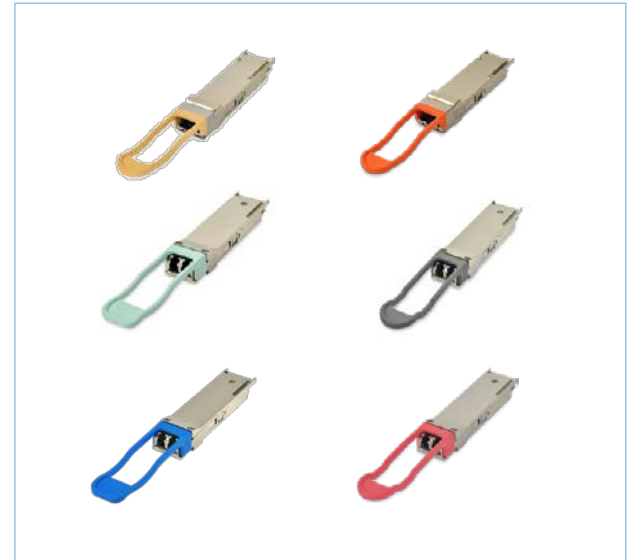


Types of 100G QSFP28 Modules in the Market

	PARALLEL (MPO)	DUPLEX (LC)
MULTIMODE	SR4 & 4x25G-SR 70/100m SR4 without FEC 30/40m eSR4 200/300m	SWDM4 75/100m 150m on OM5
SINGLE MODE	PSM4 500m	LR4 / eCWDM4 10km CWDM4 2km eLR4 20km ER4f 40km

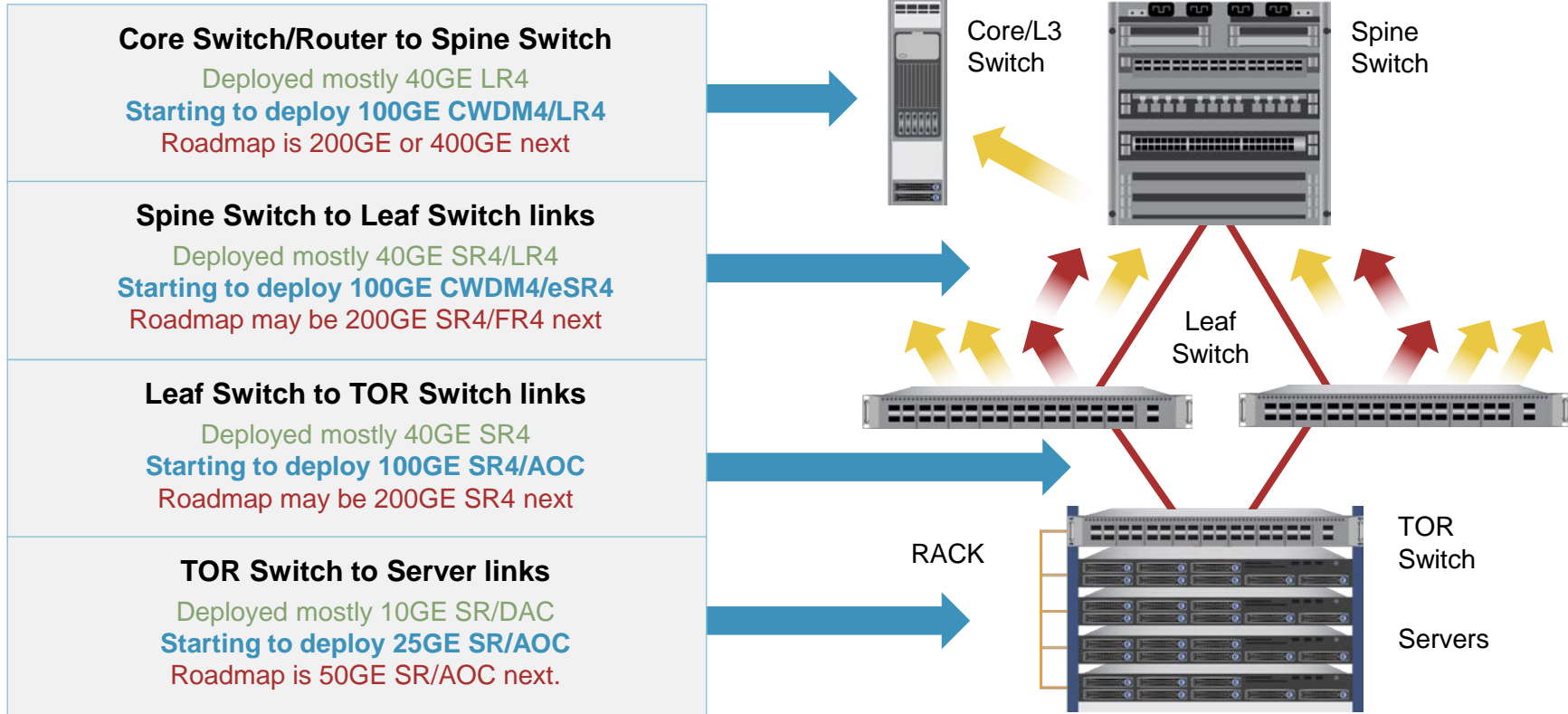
BLACK = Standardized IEEE interfaces

RED = MSA and Proprietary interfaces



Multimode distances refer to OM3/OM4; Single mode distances refer to SMF28

Typical 100GE Deployments in the Data Center



Responding to 100G Market Needs: CWDM4-OCP

- Large data center users like Facebook want a **cost-effective**, 'lite' 100G QSFP28 module which is best adapted to their specific, **well-controlled infrastructure conditions**.
- Using a CWDM4 interface over duplex single mode fiber infrastructure together with a more limited reach of 500m and a narrower case temperature range of 15-55°C provides an **optimized solution** for this need.
- Facebook has recently submitted **the CWDM4-OCP specification** as a contribution to OCP.

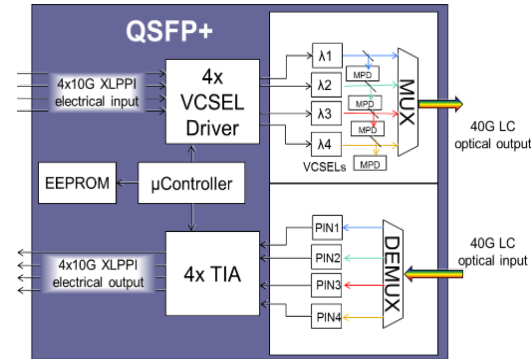
http://www.opencompute.org/wiki/Networking/SpecsAndDesigns#Facebook_-_CWDM4-OCP



OPEN
Compute Project

Responding to 100G Market Needs: SWDM4

- Non-hyperscale data center and enterprise users want to upgrade to 40G and 100GE using their **existing 10G fiber infrastructure**.
- SWDM enables the transmission of 40G (4x10G) and 100G (4x25G) **over existing duplex multimode fiber with LC connectors**. It uses four different wavelengths in the 850nm region, optically multiplexed inside the transceiver.
- Finisar is a founding member of the **SWDM Alliance**.
- 40G and 100G QSFP SWDM4 modules are already available and have been publicly demonstrated by vendors.



swdm4™

Coherent Transmission for DCI Applications

- 100G/200G DCI 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 “pizza box” for DCI applications, which use **pluggable Coherent CFP2** optical modules.



PacketLight PL-2000AD



Fujitsu 1FINITY T100 &
T300



Cisco NCS1000

- A white-box ODM switch vendor has recently announced an **open** optical packet switch for DCI applications at the OCP Summit.
- Optical vendors are working on next-generation pluggable coherent modules to support **400G/600G** DCI applications.

The Future of 100G Ethernet

- 25G/100G is providing a **very cost-effective upgrade** from 10G/40G and will be the mainstay of Ethernet over the next 5 years.
- A very large number of 100G SR4, CWDM4 and LR4 ports will have been **deployed in the next 2-3 years**.
- These multi-source interfaces are likely to be the **volume/cost leaders** in mainstream deployments over the next 5+ years.
- SWDM4 will enable upgrading to 100G **using existing duplex multimode fiber**.
- 'Lite' 100G variants can **provide benefits** in controlled environments.
- **Coherent technology** being used for DCI applications at 100G/200G and beyond.
- Align with broad-based suppliers to **avoid technology bias**.



FINISAR[®]

Thank You / Q&A

Christian Urricariet

christian.urricariet@finisar.com

