



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 IToIP 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 in the Data Center is Just Beginning



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, with a very long tail...



HIGH DEMAND

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

100G Optical Standards and MSA Proliferation

- LOTS of interface choices in the market.
- Proliferation has impacted interoperability, multi-sourcing, cost reductions through consolidated volume ramp. This causes confusion and slows down buying decisions.
- Many broadly supported, standards or MSA-based optics (e.g., 100G CWDM4).
- Engagement with broad-based optics suppliers helps navigate the available choices – Removes 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

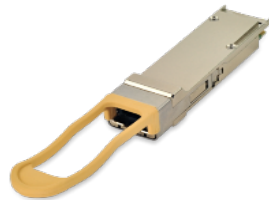
100-128 Gb/s

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



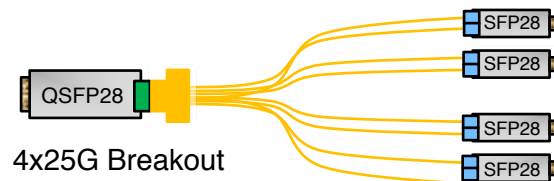
100GE Optical Transceivers

- 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

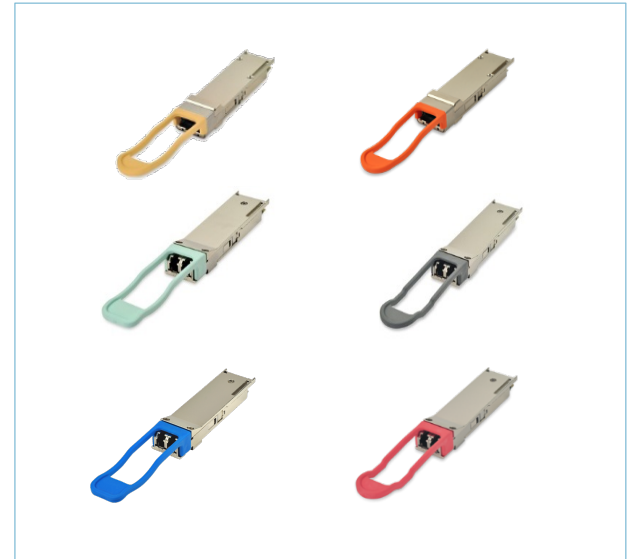


Types of 100G QSFP28 Modules in the Market

	PARALLEL (MPO)	DUPLEX (LC)
MULTIMODE	SR4 & 4x25G-SR 70/100m SR4 low-latency (FEC-less) 30/40m eSR4 200/300m	SWDM4 75/100m 150m on OM5
SINGLE MODE	PSM4 500m	LR4 / eCWDM4 10km CWDM4 2km eLR4 20km ER4f 40km

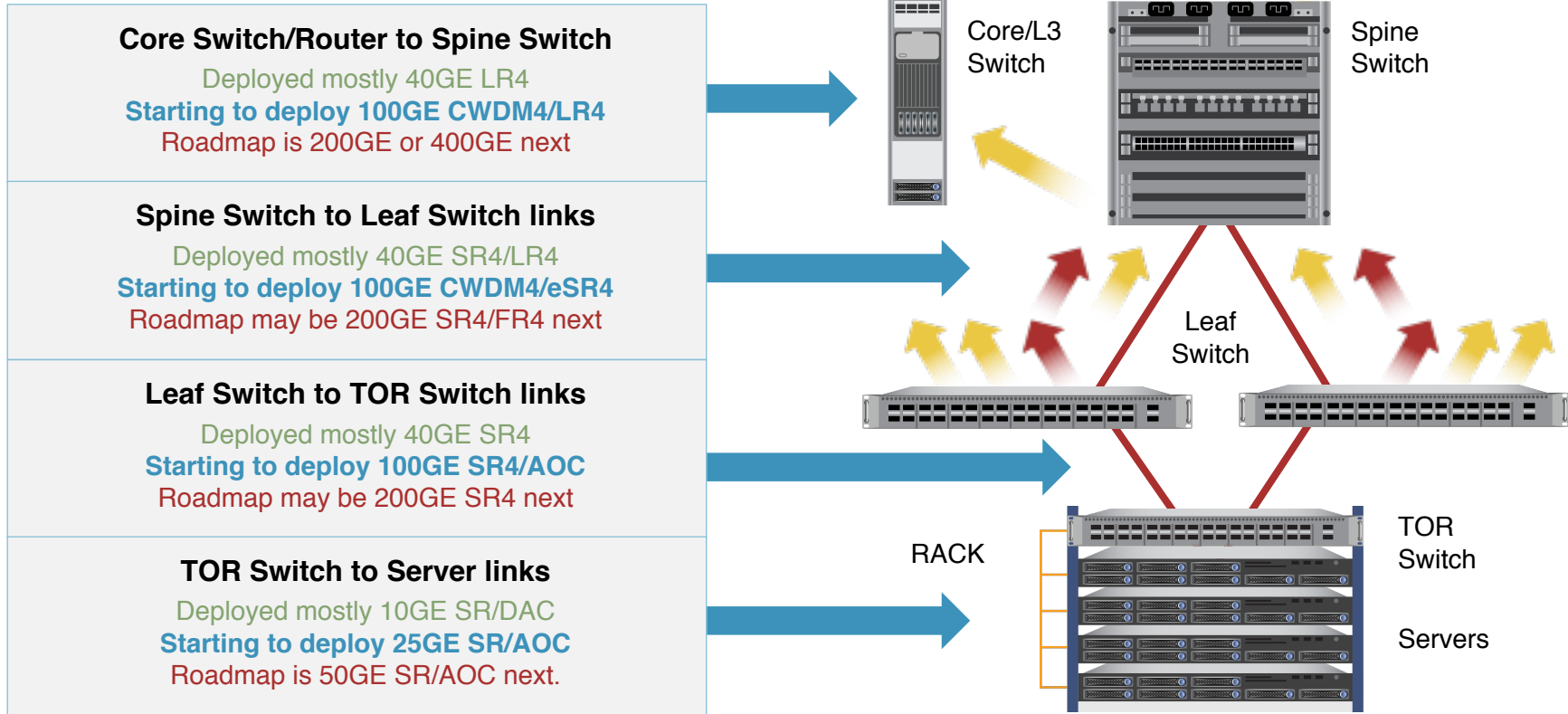
BLACK = Standardized IEEE interfaces

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.

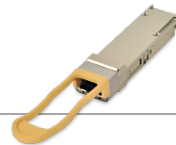
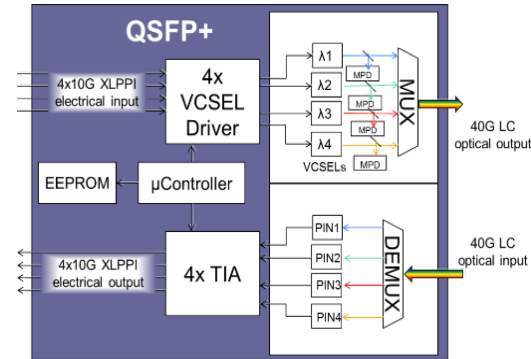
http://www.opencompute.org/wiki/Networking/SpecsAndDesigns#Facebook_-_CWDM4-OCP



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 and MSA**.
- 40G and 100G QSFP SWDM4 modules are already available and have been publicly demonstrated by optical 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 2017.
- Optical vendors are working on next-generation pluggable coherent modules to support **400G/600G** DCI applications.

Beyond 100G and 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, QSFP-DD, QSFP56, 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	25G	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.
~2018	50G			
~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



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 Future of 100G Ethernet

- 25G/100G are 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.
- The industry is already working on **200G and 400G** for next-generation Data Centers.



FINISAR[®]

Thank You / Q&A

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