Trends in 400G Optics

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IX Forum 12
Sao Paulo, December 2018
Finisar Corporation

- Optics industry leader with ~$1.3B annual revenue
- Broadest and most advanced product portfolio
- Vertically integrated with low cost manufacturing
- Experienced management team
- ~12,500 employees
- 1300+ issued U.S. patents
Finisar Facilities Worldwide

World’s Leading Supplier of Optical Communication Components and Subsystems
# Broad Product Portfolio and Customer Base

## DataCom
- **Products**
  - SFP
  - SFP+
  - QSFP/QSFP28
  - CFP2/CFP4
  - CFP
  - Optical Engine (BOA)
  - CXP
  - Active Optical Cables
  - XFP
  - X2/XENPAK

## Telecom
- **Products**
  - SFP
  - XFP
  - SFP+
  - CFP2-ACO
  - ROADM line card
  - WSS
  - WDM Passives
  - Amplifiers
  - High speed components
  - Tunable laser
  - CATV
  - PON
  - Coherent Transponder

## Customers
- **DataCom**
  - Brocade
  - Intel
  - Extreme Networks
  - Cisco
  - EMC
  - Juniper Networks
  - Dell

- **Telecom**
  - Huawei
  - Ericsson
  - ZTE
  - Ciena
  - Alcatel-Lucent
  - Avantica
  - Hitachi
  - 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

<table>
<thead>
<tr>
<th>First Deployed</th>
<th>Electrical I/O [Gb/lane]</th>
<th>Switching Bandwidth</th>
<th>TOR/Leaf Data Center Switch Configuration</th>
</tr>
</thead>
<tbody>
<tr>
<td>~2010</td>
<td>10G</td>
<td>1.28T</td>
<td>32xQSFP+ (40G)</td>
</tr>
<tr>
<td>~2015</td>
<td>25G</td>
<td>3.2T</td>
<td>32xQSFP28 (100G)</td>
</tr>
<tr>
<td>~2019</td>
<td>50G</td>
<td>6.4T</td>
<td>32 ports of 200G</td>
</tr>
<tr>
<td>~2020</td>
<td>50G</td>
<td>12.8T</td>
<td>32 ports of 400G</td>
</tr>
</tbody>
</table>

3.2Tb/s switches based on 100G QSFP28 modules being deployed in cloud data centers today.

Given the multiple switching ICs expected to be available, the market is likely to be fragmented in the future.

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

<table>
<thead>
<tr>
<th>Interface</th>
<th>Link Distance</th>
<th>Media type</th>
<th>Optical Technology</th>
</tr>
</thead>
<tbody>
<tr>
<td>400GBASE-SR2</td>
<td>100 m (OM4)</td>
<td>4f Parallel MMF</td>
<td>2x50G PAM4 850nm VCSEL</td>
</tr>
<tr>
<td>100GBASE-DX</td>
<td>500 m</td>
<td>2f Duplex SMF</td>
<td>100G PAM4 1310nm EML</td>
</tr>
<tr>
<td>400GBASE-SR8</td>
<td>100 m (OM4)</td>
<td>16f Parallel MMF</td>
<td>8x50G PAM4 BiDi (850 / 910nm) VCSEL</td>
</tr>
<tr>
<td>400GBASE-SR4.2</td>
<td>100 m (OM4)</td>
<td>8f Parallel MMF</td>
<td>8x50G PAM4 BiDi (850 / 910nm) VCSEL</td>
</tr>
<tr>
<td>400G-FR4</td>
<td>2 km</td>
<td>2f Duplex SMF</td>
<td>4x100G PAM4 CWDM EML</td>
</tr>
<tr>
<td>100G-FR</td>
<td>2 km</td>
<td>2f Duplex SMF</td>
<td>100G PAM4 1310nm EML</td>
</tr>
<tr>
<td>100G LR</td>
<td>10 km</td>
<td>2f Duplex SMF</td>
<td>100G PAM4 1310nm EML</td>
</tr>
</tbody>
</table>

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

**400GE interfaces standardized in IEEE 802.3bs**

**Next-Gen 100GE standardized in IEEE 802.3cd**

**Multimode 400GE objectives in IEEE P802.3cm**

**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

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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.
400G, 200G & 100G PAM4 Transceiver Demos at OFC/ECOC 2018

Additionally, several interoperability demos were done by the MSAs.
Is Pluggability Still a Requirement for Optics?

- Some optics are not pluggable; they are mounted directly on the system host PCB.
  - BOAs have been used for several years on core routers (inter-chassis) and supercomputers.
  - Very short host PCB traces enable low power dissipation and high port density.

- Higher bandwidth density can be achieved by:
  - More channels, e.g., up to 16 Tx and 16 Rx channels in a module.
  - Higher data rate per channel: 10G/ch and 25G/ch variants deployed today, 50G/ch in the future.

- The Ethernet industry view however is that **pluggable optics** will be preferred for 400GE.
  - Facilitates maintenance and pay-as-you-grow model.
Several New Interface Types and Form Factors to be Deployed

- Enabled by high I/O count and by 400G-DR4 to 100G-DR breakout interoperability, high-density 100G implementations will thrive in Leaf-Spine topologies.

- Large I/O Line Cards will have QSFP-DD or OSFP sockets. OSFP slots may use QSFP adapters.
Coherent systems 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) ER8 and eLR8 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 P802.3cn Task Force.

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.

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

  \[
  200G \text{ CFP2-ACO} \rightarrow 400G \text{ CFP2-DCO} \rightarrow 400G \text{ QSFP-DD DCO}
  \]

  400G DCO transceivers are expected to be plugged directly into switches and routers.
Coming Next: What Shape Will 800G Ethernet Take?

Switch 25Tb

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

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