Transceiver Market Overview and Trend of Technology

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Table of Contents

- Market Overview [China and Rest of World]
- 5G Overview
Market Overview
[China and Rest of World]
The Wave of Big Changes

- AI
- Cloud
- Big Data
- 4th Industrial Revolution
Exponential Data Growth ➔ The Best Platforms are Needed

We Live in a World of Data

More Devices
More Applications
More Data

Data Needs to be Accessible Always and in Real-Time

Business Intelligence
Internet of Things
Healthcare

Data-Intensive Simulations
Smart Cars
National Security
Future Optical Connectivity

Expected Form Factor Evolution for Optical Transceivers

- **Key word**
  - ✔ Low power consumption and high-temp operation
  - ✔ High density integrated
  - ✔ High speed: more than 1THz
  - ✔ Lower cost
Business models change with time

- Long Haul Transport required complex, high-end optics.
- FTTH – low speed, but very low cost and very high volume.
- Data Centers – high speed, but very low cost and high volume.
If applications continue to move to shorter distances, new business models may emerge.
Business Trend for Optics Component: China vs Rest World

Includes transceivers, modulators, coherent receivers and WSS modules

- Sales to China increased from 11% of the total market in 2010 to 31% in 2015.
- It was down to 25% in 2017, but it will recover to 27%-29% in 2018-2023.
- The product mix and the customer base in China will change significantly by 2023.

Source: LightCounting
Sales of optical transceivers for deployments in China

- Demand from cloud datacenters will boost sales of AOCs and Ethernet transceivers
- Sales of optical fronthaul and backhaul optics will also increase.
- Demand for FTTx, DWDM and SONET/SDH modules will decline.
Manufacturing of Optics in China

  - 100% of components and chips for 100G-600G coherent optics will be manufactured domestically, including DCO and ACO DWDM modules.
  - CDC-F ROADMs – 100% will be made in China
  - 30% of components and chips for 200GbE QSFP56 and 400GbE OSFP/QSFP-DD will be made in China
  - 50% of 10G EML chips and 30% of 25G EML chips will be made in China
    » Full translation of the Roadmap is available to LightCounting Clients

- ZTE set up a new R&D center for developing optical components after paying $1 billion in fines to the US government in 2017.

- Huawei is accelerating internal manufacturing of optics with a focus on Silicon Photonics
Market Trend for Each Applications

Figure 3-1: Sales of Telecom Optical Transceivers (Historical Data and Forecast)

- SONET/SDH
- CWDM / DWDM
- Wireless Infrastructure
- FTTx

Source: LightCounting
Transceivers Sales Record for 3-years

- ZTE effect
- 5G start

Wireless growth continued in H1
WDM and FTTx remained in range
Shipment of Optical Transceivers for Applications

- 10G PON will be deployed
- 5G investment from 2019 to 2024
- Increase the 400G both line card and client side

Source: LightCounting Market Report
Sales of Optical Transceivers: Revenues for applications

- Increase the 400G both line card and client
- 10G PON will be deployed
- 5G start

Source: LightCounting Market Report
5G Overview
What is 5G?

Comparing 4G and 5G

- Latency: 10 ms → <1 ms
- Data Traffic: 7.2 Exabytes/Month → 50 Exabytes/Month (2021)
- Peak Data Rates: 1 Gb/s → 20 Gb/s
- Available Spectrum: 3 GHz → 30 GHz
- Connection Density: 100 Thousand Connections/Km² → 1 Million Connections/Km²

Source: Qorvo
Evolving the Wireless Networks

<table>
<thead>
<tr>
<th>3G</th>
<th>Backhaul only</th>
</tr>
</thead>
<tbody>
<tr>
<td>4G</td>
<td>Fronthaul Backhaul</td>
</tr>
<tr>
<td>5G</td>
<td>Fronthaul Midhaul Backhaul</td>
</tr>
</tbody>
</table>

5G Backhaul, Midhaul, and Fronthaul based network architecture

Source: Xilinx
Deployment Plan for 5G Mobile Network

- **KOREA**
  - 2019: 3.5GHz
    - KT
    - SKT
    - LG U+
  - 2020: 28GHz
    - KT
    - SKT
    - LG U+
  - 2021: Near 28GHz
  - 2022: Over 28GHz
    - KT
    - SKT
    - LG U+

- **JAPAN**
  - 2020: DoCoMo
    - KDDI
    - SB
  - 2021: DoCoMo
    - KDDI
    - SB
  - 2022: DoCoMo
    - KDDI
    - SB

- **USA**
  - 2020: Verizon
    - AT&T
    - T-Mobile
    - Sprint
  - 2021: Verizon
    - AT&T
    - T-Mobile
    - Sprint
  - 2022: Verizon
    - AT&T
    - T-Mobile
    - Sprint

- **CHINA**
  - 2020: CMCC
    - CTC
    - CUC
  - 2021: CMCC
    - CTC
    - CUC
  - 2022: CMCC
    - CTC
    - CUC
Main Carrier’s 5G Service Roadmap.

3.5GHz Frequency Auction for 5G in South Korea

- South Korea: KT / LG Uplus to have 5G (4.5G) running for PyeongChang 2018
- South Korea: SK Telecom launches 5G service (2H 2019)
- North America: AT&T launches 5G Evolution (late 2018) Ericsson 5G CRAN / Intel 5G Mobile
- Japan: NTT Docomo, KDDI, Softbank launches 5G services (2020)
- Europe: EU-wide 5G launch (2020)
Front-haul Solutions by NEMs.

- Major NEMs for Fronthaul Solutions
  - Nokia
  - Ericsson
  - Fujitsu
  - Samsung/NEC
  - Huawei

- 4G Solutions are focused with CWDM and DWDM solutions using CPRI 2/8 along with B&W
- 5G Solution can be utilized with
  - 10Gbps and 25Gbps multi-rate modules
  - B&W BIDI, DWDM (fixed and tunable)
  - In addition to CPRI 2/10, eCPRI is a key enabler using Ethernet modules
- OPTICS used will be dictated by CSP’s network architecture
Migration Scenario for 5G Network

Migration Scenario I: Korea Mobile

4G Macro Cell
(National wide Network)

5G Macro Cell
(National wide Network)

Migration Scenario II: Maybe Japan Mobile operator

4G Macro Cell
(National wide Network)

4G Macro Cell
(National wide Network)

5G Macro Cell
(National wide Network)

2015~2019 in Japan
Wireless Target Products – China Plan for 5G

Backhaul (Aggregation Layer)
- 400G DCO
- 800G DCO

Mid-haul (Access Layer)
- 50G QSFP28
- 100G QSFP28

Distribution Unit

Current 5G Fronthaul
- 25G SFP28
- 25G CPRI
- 25G SFP28
- WDM for CPRI
- 25G CWDM/LWDM
- 25G SFP28
- NRZ
- NRZ

Future 5G Fronthaul
- 50G QSFP28/SFP56
- 50G CPRI (PAM4)
- 50G QSFP28/SFP56
- PAM4
- 2x50G SFP-DD/DSFP
- 100G CPRI (PAM4)
- 2x50G SFP-DD/DSFP
- PAM4

Massive MIMO
Active Antenna Unit (AAU)
Japan 5G Network Plan: NTT Docomo

New frequency assignment (CY18: 1.7GHz, CY19: 3.4GHz)

- eMBB (enhanced Mobile Broadband)
- URLCC (Ultra Reliable & low latency communications)
- mMTC (Massive Machine Type Communications)

Current
- Urban: LTE-A (4G)
- Rural: LTE (3.9G)

Future
- Urban: 5G
- Rural: LTE-A (4G)
- Rural: LTE (3.9G)
Transceiver for 5G Mobile Network

- Mobile Front Haul: 10G SFP+ gray optics, 10G SFP+ WDM, 25G SFP28, 25G WDM, 100G QSFP28 PAM4
- Mid-Haul: 50G QSFP PAM, 100G QSFP PAM4
- Back Haul: 400G DCO, 800G DCO
Ethernet still the biggest market segment; FTTx, WDM round out the Top 3. Optical interconnects, Wireless will have fastest growth in next five years.
Optical Transceivers Forecast for Wireless: Quantity

Source: LightCounting Market Report

Increase 25G from 2019
Optical Transceivers Forecast for Wireless: Revenue

Increase 25G from 2019
Increase 50/100G from 2021
# 25Gbps Transceiver Portfolio for 5G Network

<table>
<thead>
<tr>
<th>TRx</th>
<th>LD/PD</th>
<th>파장</th>
<th>Platform</th>
<th>전송 거리</th>
<th>구동온도</th>
<th>TRx type</th>
</tr>
</thead>
<tbody>
<tr>
<td>SFP28 LR</td>
<td>DFB/PIN</td>
<td>1270/1330nm</td>
<td>Un-cooled TO</td>
<td>10km</td>
<td>-40~85deg</td>
<td>BiDi</td>
</tr>
<tr>
<td>SFP28ER</td>
<td>DFB/APD</td>
<td>1270/1310nm</td>
<td>Cooled TO</td>
<td>30km</td>
<td>-40~85deg</td>
<td>BiDi</td>
</tr>
<tr>
<td>Lite/ER</td>
<td>EML/APD</td>
<td>1270/1310nm</td>
<td>Cooled box</td>
<td>30km</td>
<td>-40~85deg</td>
<td>BiDi</td>
</tr>
<tr>
<td></td>
<td>EML/APD</td>
<td>L-WDM 12λ</td>
<td>Cooled box</td>
<td>30km</td>
<td>-40~85deg</td>
<td>Duplex</td>
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<tr>
<td></td>
<td>EML/APD</td>
<td>1270/1310nm</td>
<td>Cooled TO</td>
<td>30km</td>
<td>-40~85deg</td>
<td>BiDi</td>
</tr>
<tr>
<td></td>
<td>Tunable/APD</td>
<td>O/C Band</td>
<td>Cooled box</td>
<td>15km/20km</td>
<td>-40~85deg</td>
<td>Duplex</td>
</tr>
</tbody>
</table>

Un-cooled

Cooled

25G BiDi/Duplex
# 25G SFP28 LWDM for 30km

- Operates over I-temp
- LWDM duplex transceivers
- EML transmitter and APD receiver
- 24.4 and 25.78Gb/s data rates supported with 30km links

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Optical Power</td>
<td>0 to 6dBm</td>
</tr>
<tr>
<td>Optical Extinction Ratio</td>
<td>Min. 4dB</td>
</tr>
<tr>
<td>Wavelength</td>
<td>Refer to slide 27.</td>
</tr>
<tr>
<td>Transmitter and Dispersion Penalty</td>
<td>Max. 1.5dB</td>
</tr>
<tr>
<td>Average Rx sensitivity</td>
<td>Max. -19.0dBm (BER 5X10^-5)</td>
</tr>
<tr>
<td>Maximum Input Power (Overload)</td>
<td>Min. -4dBm</td>
</tr>
<tr>
<td>Receiver Damage Threshold</td>
<td>Min. -3dBm</td>
</tr>
<tr>
<td>Supported high data rate with CDR on</td>
<td>24 to 25.78G</td>
</tr>
<tr>
<td>Supported low data rate with CDR on</td>
<td>Typ. 10.3125G</td>
</tr>
<tr>
<td>Supported data rate with bypassed mode</td>
<td>1 to 25.78G</td>
</tr>
<tr>
<td>Power consumption</td>
<td>Max. 2.0W</td>
</tr>
</tbody>
</table>
25G SFP28 Duplex LR

- Operates over I-temp
- 1310nm un-cooled DML and PIN receiver
- Built-in dual CDRs
- 24.33G and 25.78G with 10km data links
- Capable with 28.05G over S-temp

### Parameters Specification

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Specification</th>
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</thead>
<tbody>
<tr>
<td>Optical Modulation Amplitude</td>
<td>-4 to 2.2dBm</td>
</tr>
<tr>
<td>Optical Extinction Ratio</td>
<td>Min. 3.5dB</td>
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<tr>
<td>Wavelength</td>
<td>1310 ± 15nm</td>
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<tr>
<td>Transmitter and Dispersion Penalty</td>
<td>Max. 2.7dB</td>
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<tr>
<td>Rx sensitivity in OMA</td>
<td>Max. -11.3dBm (BER 5X10^-5)</td>
</tr>
<tr>
<td>Maximum Input Power (Overload)</td>
<td>Min. 2dBm</td>
</tr>
<tr>
<td>Receiver Damage Threshold</td>
<td>Min. 3dBm</td>
</tr>
<tr>
<td>Supported data rate with CDR on</td>
<td>24.33 to 25.78G 24.33 to 28.05G(ST)</td>
</tr>
<tr>
<td>Supported data rate with bypass mode</td>
<td>8.5 to 24.2G</td>
</tr>
<tr>
<td>Power consumption</td>
<td>Max. 1.2W</td>
</tr>
</tbody>
</table>
25G SFP28 ER-Lite BIDI for 30km

- Operates over I-temp
- 1270 and 1310nm EML and APD receiver
- 24.33G and 25.78G data rates supported with 30km links

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Specification</th>
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<tbody>
<tr>
<td>Average Optical Power</td>
<td>0.5 to 6dBm</td>
</tr>
<tr>
<td>Optical Extinction Ratio</td>
<td>Min. 4dB</td>
</tr>
<tr>
<td>Wavelength</td>
<td>1270 ± 10nm 1310 ± 10nm</td>
</tr>
<tr>
<td>Dispersion Penalty</td>
<td>Max. 1.5dB</td>
</tr>
<tr>
<td>Average Rx sensitivity</td>
<td>Max. -18.0dBm (BER 5X10^{-5})</td>
</tr>
<tr>
<td>Maximum Input Power (Overload)</td>
<td>Min. -4dBm</td>
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<td>Typ. 10.3125G</td>
</tr>
<tr>
<td>Supported data rate with bypassed mode</td>
<td>1 to 25.78G</td>
</tr>
<tr>
<td>Power consumption</td>
<td>Max. 2.1W (Max. 2.0W, -20-85°C)</td>
</tr>
</tbody>
</table>
Thank You