Optical Transceivers for Datacom & Telecom Market 2021

Market and Technology Report 2021
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  - EEL – Comparison of DML and EML
  - Comparison of EEL (DFB & FP) and VCSEL
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**Key parts of optical transceiver: 400G QSFP-DD DR4**

- Preview
- TOSA
- TOSA – InP Lasers
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- Laser driver
- ROSA
- Electronic Board
- Cost estimate

**Key parts of optical transceiver: 100G QSFP28 CWDM**

- Preview
- TOSA
- TOSA – InP Lasers and Photodiodes
- TOSA – Spatial Multiplexer and Fiber Optic Coupler
- TOSA – Fiber Optic Coupler
- ROSA
- Electronic board
- Cost estimate
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- Market shares
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- Manufacturing aspects

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- Recent trends

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- U.S. vs. CHINA – Optical transceiver market
- How could decoupling China from the U.S impact the laser and photonics industry?

**Conclusion**
SCOPE OF THE REPORT

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In Scope

Out of Scope

Optical Communication

Optical Transceivers
- Technology
- Industry
- Market

Datacom

Telecom

Optical Communication

Optical Fibers, Connectors, Equipment, Services

Datacom

Telecom

Yours needs are out of scope of this report?
Contact us for a custom study:
WHAT WE GOT RIGHT AND WRONG

✓

• Globally we covered all trends in Datacom and Telecom
• We have achieved to link material platforms with different types of optical modules – well structured in the report.

✗

• In the first version of the OT report 2020 we have identified the key global players. The high number of players shows how fragmented the optical modules industry is. Despite the effort to find all top players on the market in 2020, we have additionally recognized important players in 2021, which mostly operate at Chinese market.
  • Hisense Broadband, Broadex, Luxshare, CIGtech, Crealights
• To avoid changing the market model significantly the revenues top players for 2018 and 2019 were adjusted to the overall revenue
• The OT market size for 2019 was estimated based on quaternal and annual results of key players. In 2020, when we were collecting data for 2019, some of the players’ results had not been completely available. For this reason, some of our estimates were inaccurate.
• As a result, the overall impact on market figures was negligible. The market size for 2018 and 2019 have slightly increased - less than 1%. The market share has also been minimally impacted (~1%). As the new key Chinese players have been recognized the ranking was updated accordingly.
Yole’s market forecast model is based on the matching of several sources:

**Comparison with existing data**
- Monitoring of corporate communication
- Using other market research data
- Yole’s analysis (consensus or not)

**Comparison with prior Yole reports**
- Recursive improvement of dataset
- Customer feedback

**Top-down approach**
- Aggregate of market forecasts
  - @ System level

**Bottom-up approach**
- Ecosystem analysis
  - Aggregate of all players’ revenues
    - @ System level

**Market**
- Volume (in M units)
- ASP (in $)
- Revenue (in $M)

**Preexisting information**
- Information Aggregation

**Primary data**
- Reverse costing
- Patent analysis
- Annual reports
- Direct interviews

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- Press releases
- Industry organization reports
- Conferences

**Semiconductor foundry activity**
- Capacity investments and equipment needs
In fiber-optic communication technology there are many terms that may need explanation. Please refer to the glossary in the appendix.
<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>MLSE</td>
<td>Maximum Likely Sequence Estimator</td>
</tr>
<tr>
<td>MMF</td>
<td>Multimode Fiber</td>
</tr>
<tr>
<td>MPO</td>
<td>Multi-fiber Push On (Connector)</td>
</tr>
<tr>
<td>MSA</td>
<td>Multi-source Agreement</td>
</tr>
<tr>
<td>MSO</td>
<td>Multi System Operator (Cable Operators)</td>
</tr>
<tr>
<td>μP</td>
<td>Micro Processor</td>
</tr>
<tr>
<td>OADM</td>
<td>Optical Add/Drop Multiplexer</td>
</tr>
<tr>
<td>OCM</td>
<td>Optical Channel Monitor</td>
</tr>
<tr>
<td>OMA</td>
<td>Optical Modulation Amplitude</td>
</tr>
<tr>
<td>OSA</td>
<td>Optical Subassembly</td>
</tr>
<tr>
<td>OSNR</td>
<td>Optical Signal To Noise Ratio</td>
</tr>
<tr>
<td>OT</td>
<td>Optical Transceiver</td>
</tr>
<tr>
<td>OTN</td>
<td>Optical Transport Network</td>
</tr>
<tr>
<td>PAM</td>
<td>Pulse Amplitude Modulation</td>
</tr>
<tr>
<td>PCI</td>
<td>Peripheral Component Interconnect (Protocol)</td>
</tr>
<tr>
<td>PCIe</td>
<td>PCI Express (Protocol)</td>
</tr>
<tr>
<td>PDM</td>
<td>Polarization Division Multiplexing</td>
</tr>
<tr>
<td>PMD</td>
<td>Physical medium dependent</td>
</tr>
<tr>
<td>PMD</td>
<td>Polarization-mode Dispersion</td>
</tr>
<tr>
<td>PON</td>
<td>Passive Optical Network</td>
</tr>
<tr>
<td>PSM</td>
<td>Parallel Single Mode</td>
</tr>
<tr>
<td>QDR</td>
<td>Quad Data Rate</td>
</tr>
<tr>
<td>QSFP+</td>
<td>Quad Small Form-factor Pluggable Plus (Optical Transceiver)</td>
</tr>
<tr>
<td>QSFP-DD</td>
<td>QSFP Double-density</td>
</tr>
<tr>
<td>RF</td>
<td>Radio Frequency (Over Fiber)</td>
</tr>
<tr>
<td>ROADM</td>
<td>Reconfigurable Optical Add/Drop Multiplexer</td>
</tr>
<tr>
<td>RoHS</td>
<td>Restriction of Hazardous Substances</td>
</tr>
<tr>
<td>ROSA</td>
<td>Receive Optical Subassembly</td>
</tr>
<tr>
<td>RU</td>
<td>Rack Unit</td>
</tr>
<tr>
<td>SAS</td>
<td>Serial Attached SCSI</td>
</tr>
<tr>
<td>SDM</td>
<td>Space-division Multiplexing</td>
</tr>
<tr>
<td>SFF</td>
<td>Small Form-factor (Optical Transceiver)</td>
</tr>
<tr>
<td>SFP</td>
<td>Small Form-factor Pluggable (Optical Transceiver)</td>
</tr>
<tr>
<td>SFP+</td>
<td>Small Form-factor Pluggable Plus (Optical Transceiver Capable Of 10G)</td>
</tr>
<tr>
<td>SMF</td>
<td>Single Mode Fiber</td>
</tr>
<tr>
<td>SONET/SDH</td>
<td>Synchronous Optical Networking/Synchronous Digital Hierarchy (Protocols)</td>
</tr>
<tr>
<td>SR</td>
<td>Short Reach</td>
</tr>
<tr>
<td>SW</td>
<td>Short Wavelength</td>
</tr>
<tr>
<td>SWDM</td>
<td>Shortwave Wavelength Division Multiplexing</td>
</tr>
<tr>
<td>T2DOC</td>
<td>Transceiver To Transceiver Digital Optical Communication</td>
</tr>
<tr>
<td>TIA</td>
<td>Trans Impedance Amplifier</td>
</tr>
<tr>
<td>TOSA</td>
<td>Transmit Optical Subassembly</td>
</tr>
<tr>
<td>WSS</td>
<td>Wavelength Selective Switch</td>
</tr>
<tr>
<td>VCSEL</td>
<td>Vertical Cavity Surface Emitting Laser</td>
</tr>
<tr>
<td>VOA</td>
<td>Variable Optical Attenuator</td>
</tr>
<tr>
<td>VSR</td>
<td>Very Short Reach</td>
</tr>
<tr>
<td>XFP</td>
<td>10G Pluggable Form Factor (Optical Transceiver)</td>
</tr>
</tbody>
</table>

In fiber-optic communication technology there are many terms that may need explanation. Please refer to the glossary in the appendix.
COMPANIES CITED IN THIS REPORT

- Acacia Communication, Accelink, Adtran, ADVA, Alibaba, Amazon Web Services, Apple, Applied Optoelectronics Inc. (AOI), Arista, ATOP, AZ by CyrusOne, Baidu, Broadcom, Champion ONE, Ciena (Cyan), Cisco, ColorChip, Dell, E.C.I. Networks, Ekinops, Emcore, Eoptolink, Facebook, Fiberhome, Finisar (now II-VI), Foxconn Interconnect Technology (FOIT), Fujitsu Networks, Fujitsu Optical Components, Gigalight, Google, HG Genuine Optics, Hisense Broadband, Huawei, HUBER+SUHNER Cube Optics AG, IBM+Softlayer Cloud Services, II-VI, Infinera (Coriant, Transmode), InnoLight, Inphi, Intel, IPG Photonics (Menara Network), J.P. Morgan, Juniper Networks, Lumentum, MACOM, Mellanox, Microsoft, NEC, NeoPhotonics, Nokia (Alcatel Lucent), NTT Electronics, Oclaro, OE Solutions, Oplink (MOLEX), Padtec, Rackspace, Ranovus, Renesas (Integrated Device Technology), Rockley Photonics, Sicoya, Skorpios Technologies, Source Photonics, ST, Sumitomo, Tencent, Verizon, Xtera, Yahoo, ZTE, and more.
Dr. Martin VALLO, Market & Technology Analyst

Dr. Martin Vallo is a Technology & Market Analyst specializing in solid-state lighting technologies within the Photonics, Sensing & Display division at Yole Développement (Yole). With 9 years’ experience in semiconductor technology, Martin is currently involved in the development of technology & market reports as well as the production of custom consulting projects at Yole.

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Pars Mukish holds a Master’s in Materials Science and Polymers from ITECH in France and a Master’s in Innovation and Technology Management from EM Lyon, also in France. He is a Business Unit Manager at Yole Développement, the ‘More than Moore’ market research and strategy consulting company, as senior market and technology analyst in the fields of LED, OLED, lighting technologies, and compound semiconductors. He performs technical, economic, and marketing analyses. In 2015, Pars was named business unit manager for emerging sapphire, LED/OLED, and display/lighting activities.

Previously, he worked as marketing analyst and techno-economic analyst at CEA, a French research center for several years.

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Dr. Eric Mounier, Fellow Analyst

With more than 25+ years of experience within the semiconductor industry, Eric Mounier, PhD. is Fellow Analyst at Yole Développement (Yole). Eric is daily providing deep insights into current and future semiconductor markets and innovative technologies such as Si photonics, MEMS, quantum computing and new type of sensors.

Based on a relevant methodology expertise and strong technological background, he is closely working with the overall teams at Yole to point out disruptive technologies and analyze business opportunities.

Eric Mounier has a Semiconductor Engineering Degree and a Ph.-D in Optoelectronics from the National Polytechnic Institute of Grenoble (France).

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Impact of Recent Macroeconomic Trends – the COVID-19 Pandemic
IMPACT OF COVID-19

New types of bandwidth demand

COVID-19 Trends

New Virtual Experiences

Work from Home

Security

Telemedicine & Virtual Fitness

Electronic Payment

Socialize & Learn from Home

Play from Home

Stream from Home

Shopping, Food, Meal Delivery

Data and Traffic Explosion

New behavior emerging out of the COVID-19 crisis driving new types of bandwidth demand.

62% rate
SOURCE: Thomson Reuters Eikon

▲2,000%+
SOURCE: Zoom

▲75%
SOURCE: CBNC

▲52%
SOURCE: GlobalWebIndex

▲35%
SOURCE: Zscaler

▲322%
SOURCE: Statista

▲50%
SOURCE: CNN

▲100%
SOURCE: Teladoc

Courtesy of Inphi and other industrials
Global economic downturns (also related to COVID-19)

• The global economy have higher level of uncertainty.

• It is difficult to estimate growth or contraction in various parts, sectors, and regions of the economy, including optical communications, semiconductor, and other markets.

• Economic downturns is related to decreases in the rate of consumption or use of products along the supply chain. Such conditions could have adverse effect on demand for products integrators as well as on demand for suppliers’ products.

• Adverse changes that may affect operating results:
  • disruption in the credit and financial markets in major markets
  • adverse effects of slowdowns in the U.S., European, or Chinese economies,
  • reductions or limited growth in consumer spending or consumer credit
  • global trade tariffs

• Furthermore, adverse changes may negatively affect sales of products, commodity prices, the financing availability, and costs associated with manufacturing and distributing products.
The trend is to accelerate the increase in the average number of devices and connections per household and per capita.

- Each year, various new devices with increased capabilities and intelligence are introduced and adopted in the market.
- The average number of devices and connections per capita will grow from 2.4 in 2018 to 3.6 by 2023.

**Global device and connection growth (Market share 2018 → 2023)**
- Other (2% → 4%)
- Tablets (4% → 3%)
- PCs (7% → 4%)
- TVs (including game consoles) (13% → 11%)
- Non-Smartphones (14% → 5%)
- Smartphones (27% → 23%)
- Machine-to-Machine (M2M) (33% → 50%)

(Source: Yole & Cisco Annual Internet Report)
Macro-trends – Drivers

Global traffic growth is mainly driven by high-resolution video streaming services.

**Data-centric applications**
- Cloud services
- Industrial automation traffic

**Emerging applications**
- Connected car
- Automated logistics & manufacturing
- AR/VR

**Video streaming at higher-definition (4k or 8k)**

**Global internet video traffic**
- UHD Video (3% → 22%)
- HD Video (46% → 57%)
- SD Video (50% → 21%)

**Video data rates of today and the future**

Source: Cisco Annual Internet Report

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Optical transceiver revenue growth forecast by segment (2020 vs. 2026)

- **Datacom**
  - 2020: $5.3B
  - 2026: $5.8B
  - CAGR 14%

- **Telecom**
  - 2020: $4.3B
  - 2026: $15.1B
  - CAGR 19%
OPTICAL TRANSCEIVER MARKET

DATACOM OT shipment forecast (2017-2026) 1/2

- The vast volume of optical transceivers for data centers depends on …

High demand continues:
- Xx
- Xx
- Xx

The OT shipments in datacom segment is expected to grow from xx Munits in 2020 to xx Munits in 2026. CAGR 2020-2026 = xx%.
The total shipments of OT for telecom is highly impacted by deployment of wireless OTs over the period.
OPTICAL TRANSCEIVER INTRODUCTION – TECHNOLOGY & TRENDS

Notations & Terminology – PMDs for 100G OT and above – Overview

PMD = Physical medium dependent

Source: Gigalight
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### Optical Transceiver Introduction – Technology & Trends

#### Form factors – Mapping by application | data rate | reach

- Use cases for different optical modules.
- Different form factors and data rates can be used for other applications.
- Typical example: 100G optical transceiver has wide range of form factors to target different types of networks – applications.

<table>
<thead>
<tr>
<th>Form factors</th>
<th>10G-25G</th>
<th>40G</th>
<th>100G</th>
<th>200G</th>
<th>400G/800G</th>
</tr>
</thead>
<tbody>
<tr>
<td>SFP</td>
<td>XFP</td>
<td>SFP+</td>
<td>SFP28</td>
<td></td>
<td></td>
</tr>
<tr>
<td>QSFP</td>
<td>QSFP+</td>
<td>QSFP28 – SR/DR/FR/ CWDM/PSM</td>
<td>xx</td>
<td>xx</td>
<td></td>
</tr>
<tr>
<td>CFP2-LR/ER</td>
<td>CFP4-LR/ER</td>
<td>QSFP28 – LR/ER/WDM</td>
<td>xx</td>
<td>xx</td>
<td></td>
</tr>
<tr>
<td>5”x7” x 4”x5” module</td>
<td>x  module CFP-DCO</td>
<td>xx</td>
<td>xx</td>
<td></td>
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</tr>
</tbody>
</table>

### Applications

<table>
<thead>
<tr>
<th>Datacom</th>
<th>Telecom</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;10 km</td>
<td>&lt;120 km</td>
</tr>
<tr>
<td>LAN/ Intra DC</td>
<td>METRO Access/Inter DC</td>
</tr>
</tbody>
</table>

- Increase of transmission speed
**OPTICAL TRANSCEIVER INTRODUCTION – TECHNOLOGY & TRENDS**

Key trends – Evolution from FPP to CPO 1/2

### 2019

- **12.8 Tbps**
- 32x 400G QSFP-DD or OSFP
- **QSFP-DD** W: 18.35 mm, L: 89.4 mm and T: 8.5 mm
- **OSFP** W: 22.58 mm, L: 107.8 mm and T: 13.0 mm

Evolution toward CPO optical modules

### 2023/2024

- **51.2 Tbps**
- 8x optical modules for CPO
- **CPO optical module** W: ~20 mm, L: ~60 mm

The standard organizations do not intend to define a fixed form factor for the ELS module.

Evolution toward CPO assembly with pluggable ELS modules on the switch PCBA
Due to the ongoing large increases in bandwidth demand, data center connections are expected to move from 25G/100G to 100G/400G.

Rapid evolution of DSPs for optical communication technologies shorten life cycle of the single mode and the multimode optics used in the DCs.
KEY PARTS OF OPTICAL TRANSCEIVER – 100G QSFP28 CWDM

Module housing

Optical transceiver

Electronic board

ROSA

TOSA

Courtesy of System Plus Consulting
KEY PARTS OF OPTICAL TRANSCEIVER – 100G QSFP28 CWDM

Cost estimate (3/3)

Transceiver module $xx

- Material Cost
- Assembly cost
- Manufacturing cost
- R&D/G&A/Profit

Total Material Cost $xx

- TOSA
- Electronic Board
- Scrap cost

TOSA $xx

- IC
- InP photodiodes (4x)
- InP Lasers (4x)
- Spatial multiplexer
- Fiber Optic Coupler

ROSA $x

- InP Photodiode
- AWG
- TIA Die
- Fiber Optic Coupler
**Laser diode – EELs vs. VCSELs – Attributes and parameters – 1/2**

<table>
<thead>
<tr>
<th></th>
<th>EEL</th>
<th>VCSEL</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Wavelength</strong></td>
<td>Any material systems 650, 780, 850, 1300, 1500nm low to moderate yield</td>
<td>Primarily GaAs devices 650nm low yield 850nm high yield 940nm high yield 1300nm very low yield</td>
</tr>
<tr>
<td><strong>Speed</strong></td>
<td>Xx</td>
<td>Xx</td>
</tr>
<tr>
<td><strong>Optical beam</strong></td>
<td>Xx</td>
<td>Xx</td>
</tr>
<tr>
<td><strong>Electrical to optical power conversion</strong></td>
<td>Xx</td>
<td>Xx</td>
</tr>
<tr>
<td><strong>Modal characteristics</strong></td>
<td>Xx</td>
<td>Xx</td>
</tr>
<tr>
<td><strong>Processing</strong></td>
<td>Xx</td>
<td>Xx</td>
</tr>
</tbody>
</table>
Different laser diode technologies are present in optical communication sector depending on transmission distance and speed.

### Laser diode - Comparison of EEL (DFB & FP) and VCSEL

#### Transmission Speed

<table>
<thead>
<tr>
<th>Transmission Distance</th>
<th>850 nm LED Multi Mode</th>
<th>850 nm VCSEL</th>
<th>PAROLI* Multi Mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>xx m</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>xx m</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>xx km</td>
<td>1.3 µm Fabry-Pérot</td>
<td></td>
<td>1.55 µm DFB Single Mode</td>
</tr>
<tr>
<td>xx km</td>
<td>Single Mode</td>
<td></td>
<td>Externally Modulated</td>
</tr>
</tbody>
</table>

*PAROLI = Parallel optical link

#### Transmission Distance

<table>
<thead>
<tr>
<th>Laser Diode Technology</th>
<th>InGaAsP/InP</th>
<th>InGaAsP/InGaP</th>
<th>AIGaAs/AlAs</th>
<th>InGaAsN/GaAs</th>
</tr>
</thead>
<tbody>
<tr>
<td>DFB</td>
<td>++</td>
<td>+</td>
<td>–</td>
<td></td>
</tr>
<tr>
<td>FP</td>
<td>++</td>
<td>–</td>
<td>++</td>
<td>–</td>
</tr>
<tr>
<td>VCSEL</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>+</td>
</tr>
</tbody>
</table>

*PAROLI = Parallel optical link
OPTICAL TRANSCEIVER INDUSTRY

Market shares - 2018-2020 evolution - DATACOM & TELECOM 1/3

2018

- Strong growth of Chinese players - particularly InnoLight.
- Lumentum completed acquisition of Oclaro in the end of third quarter.

2019

- Finisar is wholly owned by II-VI – combined revenue.
- Lumentum strengthened after the acquisition of Oclaro and returned to 2nd position.
- Lower demand from major cloud companies - InnoLight impacted.

2020

- II-VI – increased share.
- Broadcom has reacquired the optical transceiver and technology assets Avago Technologies sold to Foxconn Interconnect Technology.
The US – China trade war and the new small vendors that have emerged on the market recently caused decline in some of the TOP15 players’ revenues.

In this analysis, it is important to understand that all revenues have been converted to USD (for comparison) and fiscal years of all players have been unified to calendar year. As a result the revenues presented are dependent on annual exchange rate and unified fiscal years.
### OPTICAL TRANSCEIVER INDUSTRY

#### Strategy - Product portfolio of key suppliers

<table>
<thead>
<tr>
<th></th>
<th>DATACOM</th>
<th>TELECOM</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ethernet</td>
<td>Fibre channel</td>
</tr>
<tr>
<td>II-VI (+Finisar)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lumentum (Oclaro)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Foxconn Interconnect Technology (FIT)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HG Genuine Optics</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acclink</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sumitomo</td>
<td></td>
<td></td>
</tr>
<tr>
<td>InnoLight</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Source Photonics</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cisco (Acacia)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fujitsu Optical components</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MOLEX (Oplink)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NeoPhotonics</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Macom</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HUBER+SUHNER Cube Optics AG</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NTT Electronics</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Different strategies are also projected into the product portfolio and segment interest.

Optical Transceivers for Datacom & Telecom Market 2021 | Sample | www.yole.fr | ©2021
Supply chain - **InP platform** - The different models in **DATACOM**

- **Model I**
  - IFVI
  - LUMENTUM

- **Model II**
  - HIPLN
  - IQE
  - Masiqin
  - SWI

- **Model III**
  - Hisense Broadband

- **Model IV**
  - GCS
  - PINLINNET
  - IntelliEPI

- **Model V**
  - Sivers Semiconductors
  - FUJITSU FUJITSU OPTICAL COMPONENTS

- **Sumitomo Electric**

- **Equipment**
  - CISCO
  - HUAWEI
  - ERICSSON
  - NOKIA
  - ZTE
  - Infinera
  - ARISTA
  - Tencent

- **Operator**

**OPTICAL TRANSCEIVER INDUSTRY**

- Non-exhaustive list,
- No direct link between companies
- Infinera has its InP fab, Huawei is building an InP fab in Wuhan China.
- Silicon photonic uses InP laser. Intel has internal Epi wafer development capability.
U.S. VS. CHINA – OPTICAL TRANSCEIVER MARKET

- Chinese DC operators heavily invested into the local optics products which leads to steep growth of Chinese transceiver market.
- China wants to maintain its economic growth by ensuring a secure and controllable technology supply chain as well as building domestic technology sectors to be self-sufficient in those U.S. parts impacted by tariffs.
- American companies cannot sell in China or become targets of consumer boycotts. The loss of revenue for American photonic companies will far exceed that of their Chinese counterparts.

### U.S. vs. CHINA – Optical transceiver market

<table>
<thead>
<tr>
<th>Year</th>
<th>U.S. market</th>
<th>China market</th>
</tr>
</thead>
<tbody>
<tr>
<td>2017</td>
<td>CAGR = 9%</td>
<td>CAGR = 24%</td>
</tr>
<tr>
<td>2020</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### U.S. players
- Optics & Electronics component designers and manufacturers
- Patent portfolio
- Standard leaders

#### Chinese players
- High volume deployment
- Cost drivers
- High domestic demand

#### Characteristic
- Looking at other markets to leverage know-how and material platforms foundries → LiDAR for automotive, 3D sensing for consumer
- Mostly focus on Datacom/Telecom markets
InnoLight’s 400G QSFP-DD Optical Transceiver

Intel Silicon Photonic 100G PSM4 QFSP28 Transceiver

Intel Silicon Photonic 100G CWDM4 QFSP28 Transceiver
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