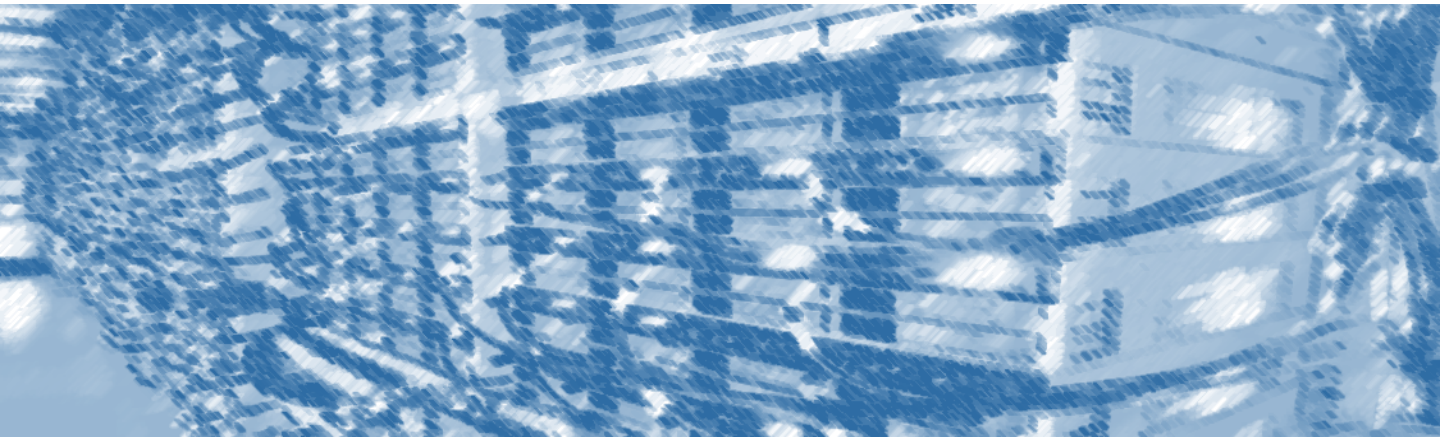
OPTOMIND



New Optics: Innovation in Data Centers

Introduction – Data Center Booming and Evolution

The recent progress in hyperscale data center is attributed to cloud computing, which requires high capacity data center infrastructures and machine-to-machine data traffic in server virtualization. The importance of high-speed interconnect continues to grow substantially, as it is a key technology in enhancing the efficiency of data center.

The latest Cisco Visual Networking Index indicates some noteworthy trends going into 2021:

- Annual global IP traffic will reach 3.3 zettabytes by 2021. In 2016, global IP traffic was 1.2 ZB per year and 96 exabytes (one billion gigabytes) per month.
- Global IP traffic will increase nearly threefold over the next five years and will have increased 127-fold from 2005 to 2021.

The data center market drives higher data rate per port, higher number of channels per port, and lower price to adopt advanced products much faster than before. According to the press release from Crehan Research, 25GbE customer adoption is considerably stronger than either 10GbE or 40GbE. 25GbE shipments surpassed 200 thousand ports in just a little over a year. 10GbE took about six years, and 40GbE about four years to reach the same level. Ethernet networking ramped faster than its predecessor in response to changing data center network traffic demands. Based on Crehan Research press release covering Ethernet switch shipment trends, 25GbE and 100GbE together will account for over half of all data center Ethernet switch shipments by 2021. They claimed, ”25GbE and 100GbE data center switch adoption is already experiencing exponential growth, with port shipments currently in the hundred-of-thousands per quarter.” 25 Gbps offers 2.5 times the 10 Gbps bandwidth at a small price premium, which can easily upgrade switches, network adapters, cables and transceivers in all applications.

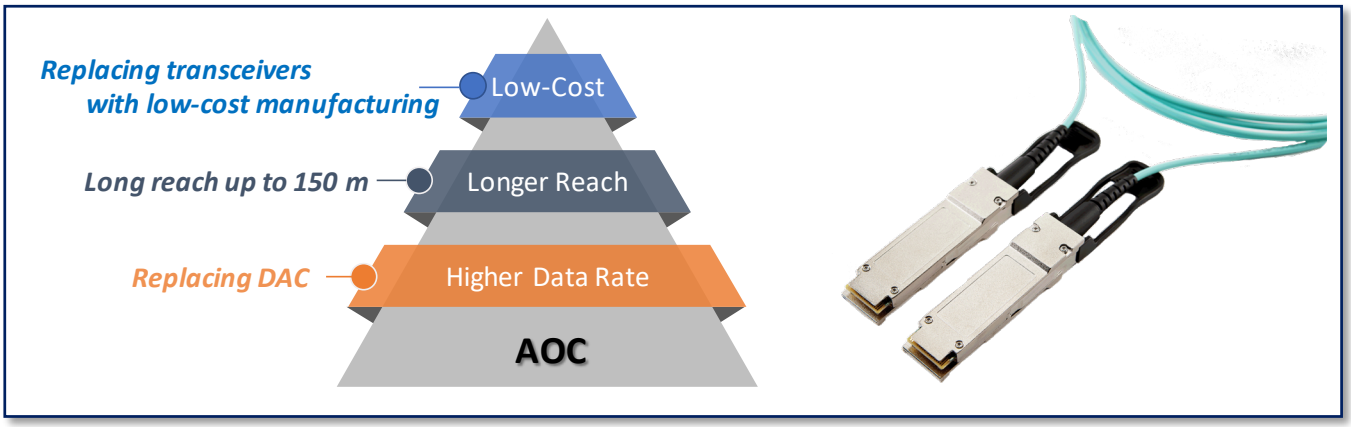


Figure 1 Optomind AOC – QSFP28 AOC

Modern data centers have standardized two types of form factors, which are SFP and QSFP. QSFP28-to-4×SFP28 AOC for top of rack (TOR) are now available for certain types of DAC, AOC and optical transceiver. Achieving the lowest total cost of ownership (TCO) in data center operation – minimizing the cost while maximizing the bandwidth – is the ultimate objective of all interconnect cable product providers.

What is an Active Optical Cable (AOC)?

Traditional optical transceivers convert electrical data signals into optical signals, then transmit the optical signals via optical fibers and change it back to electrical signals at receiving end. Optical transceiver is linked to a detachable optical connector to mate with an optical fiber via its receptacle, and the optical ferrule within the optical connector secures high precision optical aligned coupling. Small form factor pluggable (SFP) transceiver has been the most popular optical transceiver in data center networks for a long time. Direct attached copper (DAC) cable is used for short reach (1 to 5 m range) with the same form factor as SFP transceiver to perform the same function at a much lower cost.

AOC is a hybrid of DAC and optical transceiver. It resembles DAC but uses optical fiber as a transmission medium. AOC does not have a detachable optical connector, and its optical fiber is assembled inside the casing without a connector. Most AOCs derive from the optical transceiver and have a connector part inside as a fixture.

Figure 1 shows Optomind QSFP28 AOC product for data center application. QSFP28 AOC product can cover 10/25/40/50/100 Gbps. Optomind QSFP AOC attaches individual fibers directly into its optical engine instead of using a ribbon fiber. Consequently, its fiber cable can be thinner and more flexible than other AOCs utilizing ribbon fiber cables.

Optomind's QSFP28-to-4×SFP28 AOC does not use fanout junction fiber cable, commonly used in most AOC products in the market.

Figure 2 Optomind 28G family products (QSFP28, QSFP28 to 4 × SFP28 and SFP28 AOCs)

AOC Features and Advantages

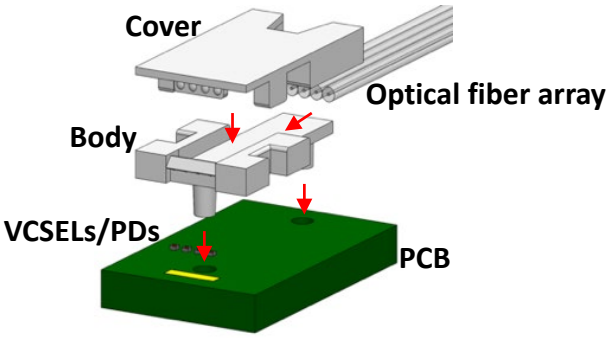
AOC is superior over DAC and optical transceiver in various aspects, some of which are listed below:

- Longer reach than DAC (less than 5 m at 25 Gbps) – up to 100 m or longer with multimode fiber technology (OM3 or OM4)
- Uses thinner and lighter cable than DAC; the same optical fiber as optical transceiver
- Less than half the pricing of two optical transceivers and a connectorized optical fiber cable
- Reduced component costs – no ceramic ferrule, ball lens, flexible printed circuit board
- Lower testing cost than optical transceiver – no optical testing required
- No standard optical design obligation – only electrical interface for connection
- Lower power consumption than optical transceivers
- Lower operating cost and higher reliability – no optical connectors to clean

Optomind 28G NRZ Family Products

Optomind 28G NRZ Ethernet/InfiniBand Products offer SFP28, QSFP28 and QSFP28-to-4×SFP28 AOCs that reach up to 100 meters using standard OM3 multimode glass fiber. Optomind 28G family products provide the most integrated all-in-one type optical engine which includes lens array, prism optics, fiber guide without ferrule type fiber connector and an enclosure packaging for protecting optical device and driver chipset. The optical engine is designed to enable an accurate optical coupling of optical device and optical fiber without any high precision assembly machine that delays the volume ramp-up and requires heavy capital investment in manufacturing.

Optomind AOC's DNA: New Optics



- ✓ Integrated Plastic Injection Mold Optics
- ✓ Fully–Passive Alignment and Coupling
- ✓ Concept of Tolerance Engineering
- ✓ Patented Self–Alignment Architecture

Optomind AOCs are not typical species of optical transceiver evolution but natural-born AOCs.

Figure 3 Optomind AOCs main features

Optomind AOC did not originate from an optical transceiver with its optical connector fixed inside but conceived exclusively as AOC. Most commercially available AOCs have evolved from optical transceivers. This implies that the conventional AOCs are manufactured by simply linking the optical ports of two optical transceivers with optical fiber and connector. Optomind's AOC attaches the fiber to integrated mold optics directly without any additional ferrule connector.

Optomind AOCs are:

- Highly scalable ramp-up manufacturing at high throughput
  - Precision aligned assembly mounting
  - Modular coupling
  - Integrated OSA with optimum tolerance
- Advanced all-in-one opto-mechanical packaging
  - Optics: Lens array, Prism
  - Fiber guide: Aligned assembly of fiber array
  - Encapsulation of optical devices and chipsets

DACs	Conventional AOCs	Optomind AOCs
✓ High-volume manufacturing with testing burden	✓ Difficulty in high-volume manufacturing	✓ High-volume manufacturing capability
✓ Lowest manufacturing cost	✓ Relatively high manufacturing cost	✓ Low manufacturing cost
✓ Economy of scale at low speed	✓ No economy of scale yet	✓ Economy of scale
✓ Limited performance	✓ High performance	✓ High performance
✓ Easy rapid ramp-up	✓ Difficulty in rapid ramp-up	✓ Very easy rapid ramp-up

Figure 4 Performance index at high data rate

Optomind's Optical Engine in Depth

Optomind's optical engine technology is an innovative catalyst which can promote photonics manufacturing to the extent of current electronics production. The key features of Optomind's optical engine technology is summarized below:

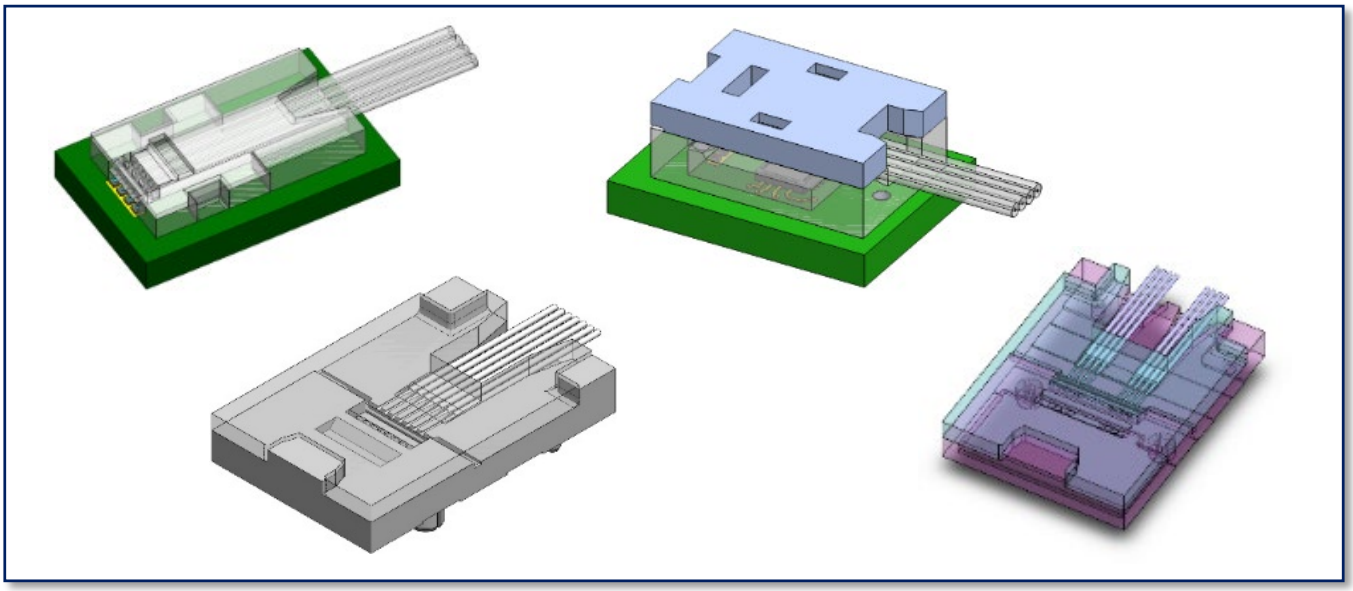


Figure 5 Optomind's optical engines – Proactive R&D capability

- Can implement integrated functions of optics and mechanics in a compact form-factor for specific custom applications
- Can construct optical aligned assembly without any high precision mounting machine
- Using discrete optical devices rather than array optical devices in a 'pick and place' manner
- Easy optical coupling to fibers – using a simple mechanical translator-based coupling station without vision-and-motion controlled high resolution equipment
- Applicable to plastic optical fiber (POF) as well as glass optical fiber (GOF)

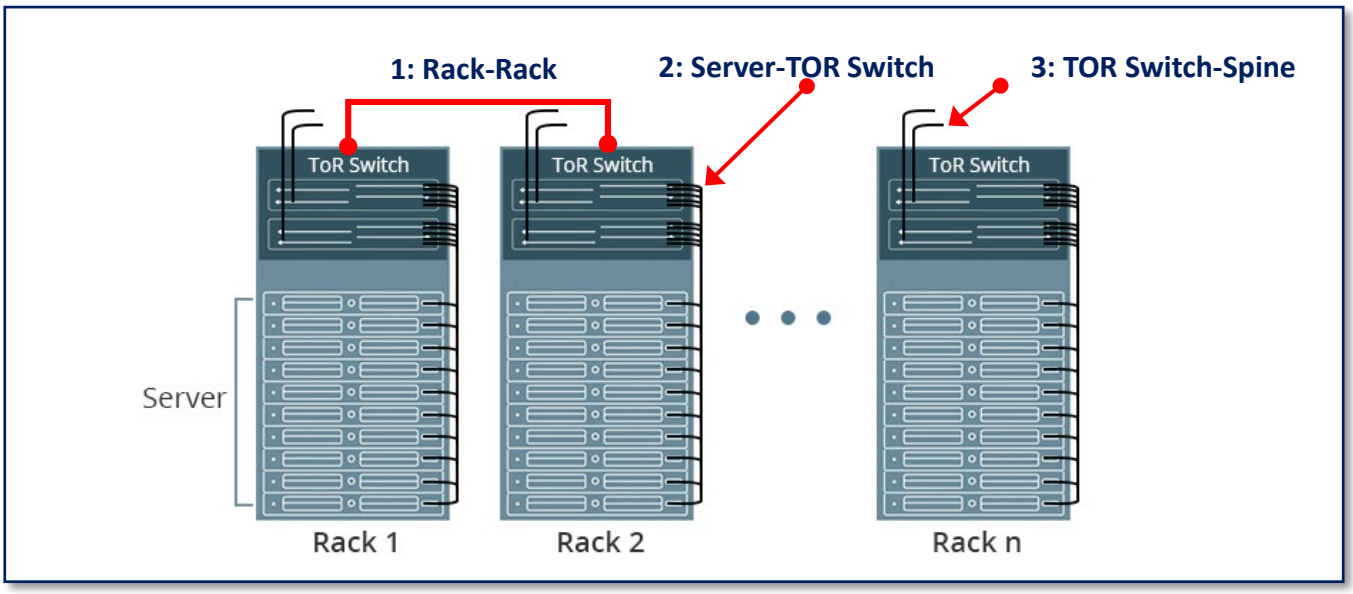


Figure 6 Optomind AOC in modern data centers

AOC Usage in Modern Data Centers

Optomind QSFP28, SFP28 and QSFP28 to 4 × SFP28 AOC products can be used in modern data centers. Top of rack (TOR) is one common architecture of switch-to-server connections. TOR is the most commonly used architecture in both colocation data centers and enterprise data centers.

1. Rack to rack – Optomind QSFP28, SFP28 and QSFP28-to-4×SFP28 AOCs can be used between rack interconnects.
2. Server to TOR switch – Optomind QSFP28, SFP28 and QSFP28-to-4×SFP28 AOCs can be used between servers and TOR switches.
3. TOR switch to spine switch – Optomind QSFP28 and SFP28 AOCs can be used between TOR switch and spine switch

Optomind

Optomind Inc. is a forerunner in development of advanced optical engines and their cost-effective high-volume manufacture, delivering finest optical interconnect solutions to both data center and non-data center applications as an active optical cable (AOC) or embedded optics.
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