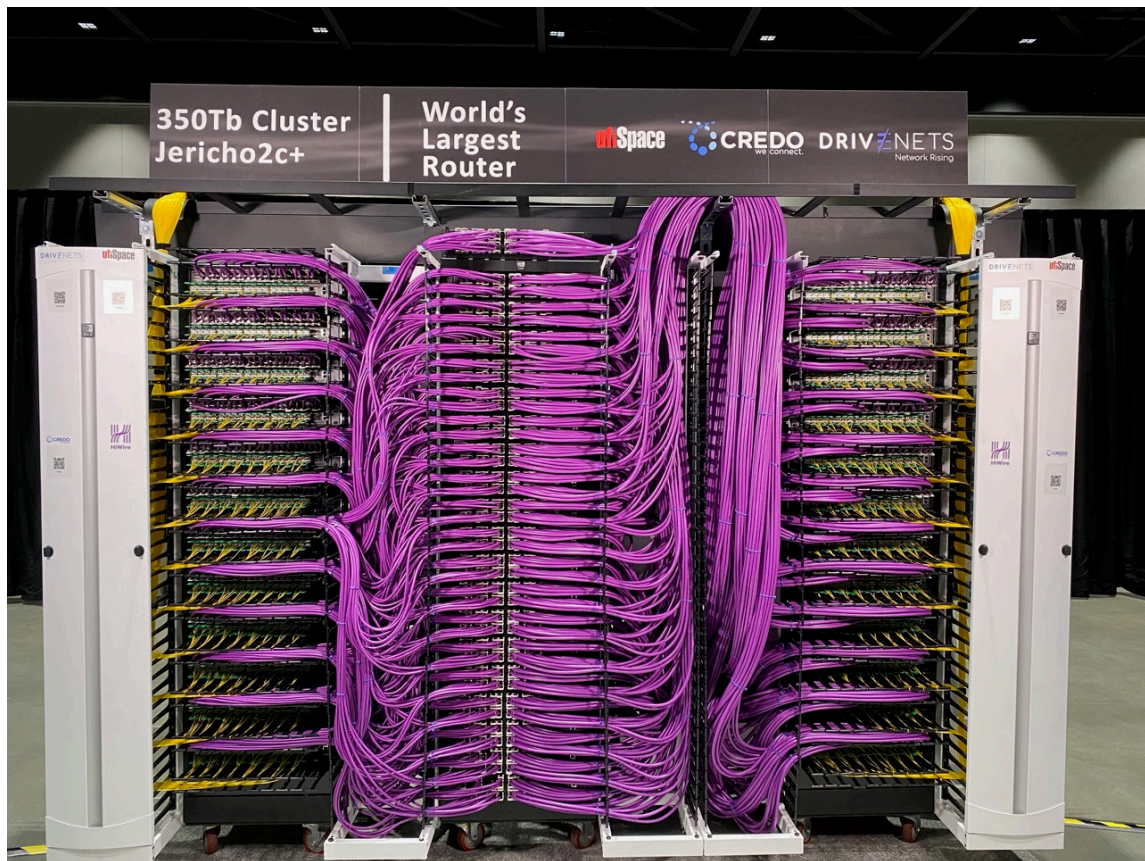




# HIGH SPEED CABLES, EMBEDDED AND CO-PACKAGED OPTICS

DECEMBER 2022



*Source: Exhibit at OCP Summit 2021, photo by LightCounting*

## Table of Contents

<b>Abstract</b> .....	<b>5</b>
<b>Executive Summary</b> .....	<b>6</b>
Growth in Sales of AOCs and DACs will continue in 2024-2027, after a pause in 2023 .....	6
Networks in AI Clusters and HPCs need a lot more bandwidth.....	7
Access to Memory is another bottleneck for AI Clusters and HPCS .....	8
co-packaged optics is the right solution for HPCs and AI Clusters.....	9
Cloud Companies see their Future in AI .....	10
<b>Chapter 1: AOCs, DAC, AECs and Fly-over cables</b> .....	<b>12</b>
AOC Advantages from the Buyer’s Perspective .....	12
AOC Disadvantages from a Buyer’s Perspective .....	12
AOCs vs. Direct Attach copper Cables (DACs) .....	12
AECs vs. DACs and AOCs .....	14
AOC Advantages from the Manufacturer’s Perspective .....	16
<i>Closing Off Photonics to the Outside World</i> .....	16
AOC Transceiver MSA’s .....	17
<i>QSFP Form Factor Family</i> .....	17
<i>QSFP-Double Density – Extending the legacy</i> .....	18
<i>SFP</i> .....	18
<i>CXP</i> .....	18
<i>Mini SAS HD</i> .....	19
Flyover Connections Using Twinax Cabling .....	20
<b>Chapter 2: Embedded Optical Modules (EOMs) and Near-Package Optics (NPO)</b> <b>25</b>	
What Is An Embedded Optical module?.....	25
Potential benefits of EOMs .....	26
Reduced Chip-to-Module Interconnect Challenges? .....	26
Reduced power consumption? .....	27
Thermal management.....	28
Faceplate or Backplane Density .....	29
<i>Ruggedness</i> .....	31
Main EOM Adoption Limiting Factors .....	31

<i>EOMs are an Evolving Transceiver Market Segment</i> .....	32
<i>The EOM business is commercially complex!</i> .....	32
<i>EOMs Are Not New</i> .....	34
EOM Products and Trends .....	34
<i>Line Rates shifting from 10Gb/s to 25Gb/s</i> .....	34
<i>Number of Channels Vary</i> .....	34
<i>Simplex devices giving way to Duplex</i> .....	35
<i>Connectors for EOM PCB attach</i> .....	35
<i>No standard yet for EOM Fiber attach</i> .....	36
<i>EOM Thermal Issues Challenging but Options Exist</i> .....	37
<i>HP Labs built VCSEL-based CWDM EOMs for The Machine</i> .....	37
Near Package Optics (NPO).....	39
<b>Chapter 3: Co-Packaged Optics (CPO)</b> .....	<b>40</b>
What Is Co-Packaged Optics?.....	40
Co-packaged Optics is the Logical Next Step.....	40
ARPA-e ENLITENED Program.....	42
IBM Awarded Two Development Contracts for ARPA-E ENLIGHTENED Program .....	42
DARPA PIPES Program -Photonics in the Package for Extreme Scalability.....	43
Broadcom’s plans have to be taken seriously.....	46
Why start with 25 Tb? .....	48
The new ecosystem.....	49
<b>Chapter 4: Applications and Markets</b> .....	<b>51</b>
The AOC Market Expands .....	51
EOM and CPO Markets continue to Evolve.....	51
High Performance Computing and AI Clusters .....	52
HPC Market’s continued Growth.....	53
Key AOC and EOM Customers: The Top 500 HPCs.....	53
Leading Supercomputers using AOCs: some examples .....	56
The Future Market for Optical Interconnects in Supercomputers .....	61
HPE EX supercomputer architecture that uses ‘200GbE’.....	63
Fujitsu Supercomputers ditched EOMs for AOCs.....	64

HPE Supercomputers (non-Cray).....	65
Good AOC Opportunities in Mid-range HPC Clusters .....	66
Cloud Providers Now Offer HPC Systems.....	67
Artificial Intelligence systems continue to scale .....	67
New CPU-Memory-Accelerator Fabrics bring New Opportunities .....	70
<i>CXL</i> .....	72
<i>NVLink</i> .....	73
UCle.....	73
Core Routing Systems .....	74
<i>The Future Market for Optical Interconnects in Core Routers</i> .....	75
<i>As the core router market expands so does optical Interconnect deployments</i> .....	75
Cloud Data Centers .....	79
<i>Server-to-Switch Links Create AOC Opportunities</i> .....	79
100G and 200G SerDes Open Up countless opportunities .....	80
Military/ Aerospace/ Other Applications .....	81
<b>Chapter 5: Forecast and Analysis .....</b>	<b>87</b>
AOC Forecast by Market Application.....	88
<i>How AOCs are used in each market segment:</i> .....	88
AOC/DAC Unit Shipments Forecast and Analysis.....	90
AOC Pricing Forecast and Analysis.....	93
Forecast for sales of AOCs, DACs and AECs .....	94
EOM and CPO Forecast.....	96
External laser Modules .....	98
CPO Forecast by Application.....	99
Product Dashboard Feature.....	99

## Abstract

This report examines the optical interconnect segments that have long served as data bridges between elements of large systems or clusters.

**Active Optical Cables (AOCs)** embed optical transceiver technologies into enclosed cables that hide the high-speed optics behind two transceiver ends with an electrical interconnect presented to the outside. This factor enables creating high aggregate data rate links at costs significantly below that of two separate connectorized transceivers and fibers. AOCs gained market share by offering longer reaches than passive **Direct Attached Copper (DACs)** and **Active Electronic Copper (AEC)** cables, also examined in this report.

This report also examines the product segment that embeds optical interconnect technologies inside computer and communication systems with **Embedded Optical Modules (EOMs)**. As data rates reach 100Gbps, reducing the length of PCB traces on circuit boards becomes even more critical. Placing on-board optics into one package with ASICs offers a solution for the future. This approach creates a new set of products known as **Co-Packaged Optics (CPO)**.

The report includes historical data (2016-2022) and forecast (2023-2027) for shipments, revenues and average selling prices for the products mentioned above. We analyze technologies, market trends, protocol transitions, data rates, and MSAs for InfiniBand, Ethernet and other protocols. Application segments are reviewed in detail and 20 categories of products are individually tracked, forecasted and mapped into four application segments: High Performance Computing (HPC) and AI Clusters, Cloud data center compute nodes, Core Routing & Optical Transport, and lastly Military/Aerospace applications.

The report is based on confidential sales information and detailed analysis of publicly available data released by leading component and equipment manufacturers. It incorporates new information from numerous interviews across both the supply chain and the consumption side of the industry.

**This LightCounting market report contains material that is a confidential, privileged, company product for the sole use of the intended recipients being LightCounting clients and subscribers. Any review, reliance on, redistribution by others or forwarding without LightCounting's expressed permission is strictly prohibited.**

For more information, go to: [www.lightcounting.com](http://www.lightcounting.com)

Or follow us on Twitter at: [www.twitter.com/lightcounting](https://www.twitter.com/lightcounting)