Optical Interconnect Products Inside Optical Modules



Overview

All AI Data Center Interconnects Will Be Optical Within 5 Years InP and SiPho join CMOS as critical technologies.

Key Takeaways

Optical modules integrate laser drivers, modulators, transimpedance amplifiers, and optical engines to enable high-speed, low-latency data transmission in data centers and telecom networks.

Key Optical Interconnect Technologies

Linear Pluggable Optics (LPO): LPO modules remove the digital signal processor (DSP) to reduce power consumption and latency, relying on the analog performance of host-side SerDes. While they support high-speed transmission, LPO modules face challenges in signal integrity, bit error rates, and multi-vendor compatibility, making them more suitable for closed-system environments.

Near-

Packaged Optics (NPO): NPO places the optical engine and processing chip (xPU) side-by-side on the same PCB or substrate, minimizing electrical path length to a few centimeters. This reduces channel loss, improves signal integrity, and supports speeds of 800G and above.

NP

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O modules feature independent thermal management, allowing better temperature control and easier maintenance.

Co-

Packaged Optics (CPO): CPO integrates the optical module directly onto the same substrate as the xPU, reducing energy per bit to as low as 5 pJ/bit. External laser sources (ELS) are often used to avoid thermal degradation from high-power chips.

CP

O solutions require precise optical alignment and robust thermal design to maintain performance at high data rates.

Core Components Inside Optical Modules

Laser Drivers: Control the intensity and modulation of the laser light, enabling high-speed optical signaling. Optical Modulator Drivers: Convert electrical signals into modulated optical signals for transmission over fiber. Transimpedance Amplifiers (TIAs): Amplify the weak optical signals received by photodiodes into electrical signals for processing.

Optical Engines: Include lasers, modulators, and photodiodes packaged together, often with integrated silicon photonics for compact, high-bandwidth operation. External Laser Sources (ELS): In some CPO designs, lasers are housed outside the high-heat environment of the chip to improve reliability and serviceability.

Applications and Integration

Optical modules are widely used in data center interconnects (DCI), high-performance computing, and telecom networks. Products like Marvell's COLORZ 400/800 modules leverage coherent DSP and silicon photonics to connect metro and regional data centers efficiently, supporting speeds up to 800 Gbps over long distances. Modules are designed for pluggable form factors (QSFP-DD, OSFP) and comply with industry standards such as Ethernet, InfiniBand, and OIF specifications.

Future Directions

Research programs focus on hybrid bonding, 3D wafer-scale photonic interposers, and heterogeneous integration to further increase bandwidth, reduce latency, and improve energy efficiency. These next-generation optical modules aim to integrate multiple parallel optical channels closer to xPUs while managing thermal challenges in high-density environments. In summary, optical interconnect products inside modules combine laser drivers, modulators, TIAs, and optical engines with advanced packaging technologies like LPO, NPO, and CPO to deliver high-speed, low-latency, and energy-efficient data transmission for modern computing and networking applications.

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Article Content

Optical Interconnect Technology Analysis: LPO, NPO,

Exploring optical interconnects for AI data centers: LPO for low-power, short-distance links, NPO for high-density, near-package connections,

Optical Interconnect

In this chapter, state-of-the-art optical interconnect technologies for supercomputers and data centers (DCs) are presented with optical devices and CMOS circuits, which are going to be fundamental

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XPO-LPO Optical Transceiver | Optical Interconnect

Amphenol''s XPO (200G per lane) optical modules incorporate both LPO and LRO solutions, which adopt standard MPO optical ports and are

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