Mainstream Pluggable Optical Modules

Overview

Opinion: Pluggable optical modules will remain the mainstream in the. While CPO solutions have already been launched by giants like NVIDIA and Broadcom.

Key Takeaways

Pluggable optical modules are compact, hot-swappable transceivers that convert electrical signals to optical signals and are essential for high-speed data center and AI network connectivity.Overview

Pluggable optical modules, also known as small form-factor pluggables (SFPs), are standardized removable devices that enable network equipment like switches, routers, and servers to connect to fiber optic networks. They convert high-speed electrical signals into light pulses for transmission and back into electrical signals upon reception, supporting flexible, scalable, and upgradeable network architectures . These modules range in size from approximately 2 inches to over 5 inches and allow for easy hot-swapping without replacing the entire device .

Types and Technologies
• SFP, SFP+, QSFP, OSFP: Traditional pluggable modules vary by speed and form factor. SFP and SFP+ support lower speeds (1–25G), while QSFP and OSFP modules support 400G to 1.6T for modern AI and hyperscale data centers .

• DSP-based Modules: Conventional high-speed modules include Digital Signal Processors (DSPs) for signal equalization and error correction, enabling longer transmission distances and multi-vendor interoperability .

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• Linear Pluggable Optics (LPO): LPO modules remove the DSP and rely on analog linear drivers and transimpedance amplifiers (TIA), with signal equalization handled by the host-side SerDes. This reduces power consumption by 30–50%, lowers latency, and cuts costs, but typically supports shorter distances and requires a controlled ecosystem .

• Near-Packaged Optics (NPO): NPO integrates the optical engine and processing chip on the same PCB or substrate, minimizing signal loss and crosstalk. It supports high-bandwidth 800G+ links with improved thermal management and easier maintenance compared to Co-Packaged Optics (CPO), .

• Co-Packaged Optics (CPO): CPO tightly integrates optics with the switch ASIC, offering higher data rates and power efficiency, but increases system complexity and reliability requirements .

Applications

Pluggable optical modules are widely used in:

• Data centers: Connecting servers, switches, and storage with high-speed fiber links.

• AI and hyperscale networks: Supporting 400G–1.6T links for back-end AI workloads .

• Telecom and enterprise networks: Enabling flexible upgrades and high port density without replacing hardware .

Advantages

• Hot-swappable and modular: Easy to replace or upgrade without downtime.

• Scalable: Supports incremental network upgrades.

• Energy-efficient options: LPO modules reduce power consumption and latency.

• High-speed support: Modern modules handle 400G, 800G, and beyond, with PAM4 modulation and breakout capabilities for lower-speed interfaces .

Considerations

• Distance limitations: LPO modules have shorter reach due to lack of DSP-based equalization.

• Ecosystem compatibility: Multi-vendor interoperability may be limited for newer architectures like LPO and NPO .

• Thermal management: High-speed modules require careful heat dissipation, especially in CPO designs . In summary, mainstream pluggable optical modules continue to evolve from traditional DSP-based SFPs and QSFPs to advanced LPO, NPO, and CPO solutions, balancing speed, power efficiency, and system complexity to meet the demands of modern data centers and AI networks .

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