

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.

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.

- **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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Optical module

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