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Co-Packaged Optics Gain Traction in Data Centers

— Optoelectronic Integration Enters the Adoption Phase —

Rieko Tsuji
Consumer Innovation Dept.
Technology & Innovation Studies Div.
Mitsui & Co. Global Strategic Studies Institute

Why This Technology?

2026 will mark the year when co-packaged optics (CPO), a form of optoelectronic integration, enters the full-scale mass production and practical roll-out phase. As power consumption continues to surge with the rapid expansion of AI data centers, expectations are high that CPO will dramatically improve power efficiency and curtail energy usage. A wave of product launches is underway, led by companies such as Broadcom (US) and Nvidia (US). While in Japan, NTT (Japan) has begun providing commercial samples based on its IOWN concept[1]. With major players moving to release products simultaneously, 2026 is likely to become a critical inflection point marking the start of competition for leadership in the next-generation AI infrastructure sector.

Summary

- CPO technology places electro-optical conversion functions—traditionally located away from the processor—in close proximity to the processor. By shortening the distances that electrical signals must travel, the technology significantly reduces power consumption, boosts data transmission capacity, and lowers latency.
- Fully realizing CPO requires advanced packaging technology. As such, silicon foundries and OSAT companies such as TSMC (Taiwan) are increasing in importance, driving the formation of an ecosystem that encompasses these companies.
- While challenges including heat management and the complexity of maintenance remain, Japanese companies possess advantages in optical packaging technologies and the component material sector, which present the keys to resolving these issues. Japanese companies are therefore expected to play central roles in next-generation AI infrastructure through active collaboration with major manufacturers in Japan and overseas.

1. What is CPO?

With the widespread use of generative AI, enhancing the computing capacity of data centers has become an urgent priority. Increasing communication speeds is a critical factor in boosting computing performance, alongside semiconductor miniaturization and other factors. However, under conventional methods in which most signals are transmitted electrically across server circuit boards[2], higher speeds exacerbate signal attenuation and noise, and compensating for these effects results in substantial power consumption. As optical transmission incurs far less energy loss during transmission than electrical signals, replacing electrical signal transmission with optical signal transmission is expected to resolve these power consumption challenges, and the collective term for such technologies is optoelectronic integration. In recent years, CPO, a type of optoelectronic integration technology, has attracted particular attention.

[1] An abbreviation of Innovative Optical and Wireless Network. The IOWN concept, put forth by NTT, is a next-generation communications infrastructure initiative that seeks to transform the entire information infrastructure—from networks through to computing—with a focus on optical technology to achieve ultra-high capacity, ultra-low latency, and ultra-low power consumption.

[2] Circuit boards are substrates with wiring on its surface or interior, onto which chips, capacitors, connectors, and numerous other electronic components are soldered.

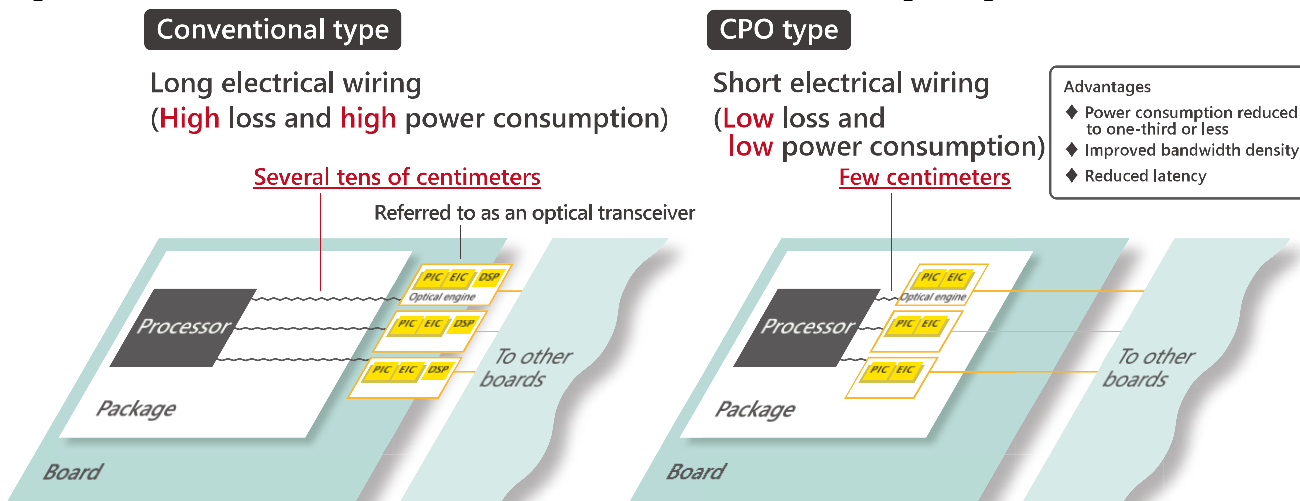
1-1. Technology

Optoelectronic integration progresses in stages depending on where electrical signals are replaced with optical signals. It is expected that, ultimately, even extremely short-distance inter-die[3] connections will be made optical, and as an intermediate step toward that goal, CPO technology places electro-optical conversion functions in very close proximity to the processor (e.g., CPU, GPU, ASIC) within communication devices that link together boards. In recent years, adoption of switch ASICs[4] used in power-intensive network equipment has progressed particularly rapidly, and around 2025, some data centers also began to incorporate the technology.

Conventionally, optical transceivers (modules detachable from the board) that convert electrical signals to optical signals were placed at the edge of the board, away from the processor. In CPO, the optical engine[5]—the core component of the optical transceiver—is integrated onto the same package[6] as the processor, enabling electrical-to-optical signal conversion within the package itself. This shortens distance that electrical signals must transverse from several tens of centimeters to just a few centimeters, minimizes losses resulting from the electrical wiring, and reduces power consumption to roughly one-third or even lower (Figure 1).

Research into CPO technology proceeded gradually through discussions and studies beginning in the late 2010s. However, at the time, few users were demanding higher communication speeds, and technologies for optical integration and implementation had not yet matured. For on-board transmission[7] of electrical signals, conventional copper wiring remained more advantageous in terms of

Figure 1: Difference between conventional boards and boards integrating CPO



Source: Compiled by MGSSI based on various sources

[3] Dies are small components, typically only a few millimeters in size, in which microscopic electronic circuits (such as transistors) are integrated onto a substrate such as silicon.
[4] An abbreviation of Application Specific Integrated Circuit. It refers to an integrated circuit (IC) designed and manufactured for a specific purpose or application. Switches connect communication equipment within a network and manage data transfer and routing. Switch ASICs are ASICs designed specifically for use in switches.
[5] Optical engines include photonic integrated circuits (PIC), which generate and manipulate optical signals, and electronic integrated circuits (EIC), responsible for electronic control, both of which are core components of an optical transceiver. While digital signal processors (DSP), responsible for correcting degraded electrical signals, are incorporated in conventional optical transceivers, they are generally not included in CPO.
[6] Packages protect semiconductor devices (including chips) from external elements and provide external terminals for electrical connections. They are typically black, square-shaped objects with leads extending outward in four directions.
[7] Even now, some argue that copper wiring remains more advantageous in terms of cost and reliability for short-distance communication, such as between GPUs rather than on-board.

both cost and reliability. In recent years, as data centers become faster, losses resulting from transmitting signals electrically have reached the point where they can no longer be ignored. However, advances in silicon photonics[8] and packaging[9] technologies have made it possible to increase the degree of integration between electrical and optical circuits, making implementation a realistic possibility.

1-2. Benefits and Challenges

The adoption of CPO offers the following technological and commercial benefits.

1. Significantly reduced power consumption: Replacing long electrical wiring on circuit boards with optical wiring can reduce power consumption to approx. one-third or lower in comparison with conventional optical transceivers.

2. Improved bandwidth[10] density: Large, detachable optical transceivers have conventionally been mounted on the front panel at the edge of the board, creating physical space constraints that limit the number of optical fiber connections. In CPO, optical fibers are drawn directly from the package, allowing for connections in higher density and a dramatic increase in data transmission capacity.

3. The potential for lower latency: Drastically shortening the distance between the processor and the optical engine either simplifies or eliminates complex DSP processing and related functions. This has the potential to lower transmission latency by tens to hundreds of nanoseconds[11] compared with conventional approaches.

Conversely, however, CPO technology also requires advanced mounting technologies and faces the following challenges.

1. Heat management: Sophisticated thermal countermeasures are required as heat-sensitive optical components (such as lasers) are placed in close proximity to heat-generating ASICs. The external laser source (ELS) approach, which places the failure-prone laser light source outside of the package, is becoming the mainstream solution.

2. Complexity in manufacturing and maintenance: With optical components and semiconductors integrated into a single package, replacing individual components becomes difficult once packaged. As components are no longer detachable, a failure in internal optical components may necessitate discarding the entire expensive processor, requiring extremely high levels of reliability.

2. Noteworthy Developments

CPO technology and optoelectronic integration are developing along two distinct paths: (1) application in switches that handle network connections between data center racks (board-to-board), and (2) realization of optical I/O technologies that use light for inter-package connections and for connections between chips and dies within packages. Figure 2 summarizes the approaches taken by major companies.

[8] Silicon photonics technology makes use of silicon semiconductor manufacturing processes to build large-scale optical circuits—such as optical waveguides and optical modulators—on silicon wafers.
[9] Packaging generally refers to back-end processes in semiconductor manufacturing. For CPO, it refers to integrating optical components and semiconductor chips into the same package, as well as the technologies that enable this integration.
[10] Bandwidth refers to the range of frequencies used in communication. In other words, it indicates the amount of data that can be transmitted and received within a given period of time.
[11] A nanosecond is equal to one billionth of a second. In other words, 100 nanoseconds correspond to one millionth of a second. It is sometimes abbreviated as "ns."

Figure 2: Trends among CPO-related companies

Company	Product shipment and supply status (as of January 2026)	Areas transitioning toward an optical approach ◎ Commercial shipments/sample supply confirmed ○ Plans confirmed – Outside scope/no public disclosure			Approach
		Board-to-board	Package-to-package/chip-to-chip	Die-to-die	
Broadcom	Has already shipped ethernet-ready CPO switches.	◎	○	–	・The company's strategy focuses on incorporating CPO for long-distance rack-to-board connections. ・Plans have also been announced for a conversion to optical short-distance connections (processors, HBM, etc.). ・The company has adopted TSMC's optoelectronic integration packaging technology, COUPE.
Nvidia	Market launch of CPO switches for InfiniBand scheduled for early 2026, and CPO switches for Ethernet scheduled for the second half of 2026.	◎	–	–	・The company's strategy focuses on incorporating CPO for long-distance rack-to-board connections. ・For short-distance connections (chip-to-chip/GPU-to-GPU), the company remains committed to using copper wiring (NVLink) wherever possible from the standpoint of cost and reliability. ・The company has adopted TSMC's optoelectronic integration packaging technology, COUPE.
Marvell Technology	Information on product shipments has yet to be disclosed. (Contributions to revenue from optoelectronic integration products are expected to begin in the second half of FY2028.)	–	○	○	・The company replaces electrical connections between chiplet-integrated packages with optical connections. Note: In December 2025, the company acquired the optoelectronic integration startup Celestial AI for USD 3.25 billion, and the optoelectronic integration-related technologies described here are those of Celestial AI.
Ayar Labs	Currently providing customers with optical I/O evaluation kits.	–	◎	○	・The company offers a general-purpose optical I/O chiplet, and aims to replace electrical wiring between packages with optical wiring. ・Collaboration is underway with Nvidia. ・Manufacturing is outsourced to GlobalFoundries.
Lightmatter	Announced that products will become available in summer 2025.	–	○	○	・Through a highly integrated approach, the company seeks to fully eliminate communication bottlenecks within packages and between dies by enabling optical data input and output directly beneath the die.
NTT (IOWN)	Market launch of CPO samples scheduled for 2026.	○	○	○	・In the process of developing optoelectronic integration devices for IOWN, the company aims to pursue joint design and mounting in collaboration with semiconductor vendors and materials manufacturers.

Source: Compiled by MGSSI based on various sources

2-1. Developments among Major Companies

Broadcom and Nvidia are leading the way in CPO technology.

• Broadcom: Drives the CPO switch market. Provides AI data centers with CPO switches that make use of TSMC's advanced processes and packaging technologies, with large-scale roll-out anticipated from 2026 onward.

• Nvidia: Pursues a unique strategy as the leader in the AI infrastructure sector. Announced products featuring CPO technology for use in switches, and considers CPO technology to be a core technology that underpins AI factories. Works to build a silicon photonics ecosystem that includes TSMC, Fabrinet (US), Senko Advance (Japan), Sumitomo Electric Industries (Japan), and similar companies. However, the company remains committed to using copper wiring wherever possible in GPU-to-GPU (NVLink) connections. This reflects the view that, in terms of cost and reliability, copper wiring still holds the advantage in short-distance connections.

• Startups: Ayar Labs, Celestial AI, and Lightmatter—all of which are US-based startups—are developing chiplets and light sources that leverage CPO technology in optical I/O solutions, with the goal of eliminating communication bottlenecks between processors and memory, as well as between multiple linked processors. This overcomes a longstanding challenge facing generative AI, which required increasingly significant expenditures of time and energy to transfer data between chips and memory as AI models grew larger.

• TSMC: Works to enhance its presence as the center of the ecosystem, as a contract manufacturer of optoelectronic integration products. Develops proprietary optoelectronic integration packaging technologies and provides major players such as Nvidia and Broadcom with 3D lamination technology. Also, together with the OSAT[12] company ASE (Taiwan), co-leads the Silicon Photonics Industry Alliance (SiPhIA) proposed by the international industry association SEMI to strengthen the supply chain for silicon photonics technologies, including CPO.

2-2. Developments in Japan

In Japan, NTT is researching optoelectronic integration under the IOWN concept and has published research findings on CPO devices. The government has also long promoted optoelectronic integration technologies, with the Ministry of Economy, Trade and Industry (METI) of Japan and NEDO playing central roles. In a NEDO project focused on enabling optical inter-chip communication invested a total of JPY 22.8 billion between 2014 and 2022. Recently, optoelectronic integration was identified as a priority technology in a document released by METI titled Current Status and Future of the Semiconductor and Digital Industry Strategy, which describes collaboration with the IOWN concept as a national-level vision. In addition, the Photonics-Electronics Integration Research Center was established at the National Institute of Advanced Industrial Science and Technology (AIST) in April 2025.

The incorporation of CPO technology requires alignment technology capable of connecting PICs and optical fibers with an extremely high degree of precision—to within a single micrometer (micron)[13]—as well as specialized connector links associated with the ELS approach. Japanese materials manufacturers, including Sumitomo Electric Industries, Senko Advance, and Fujikura (Japan), possess large shares of the global market along with the advanced technological capabilities required to supply these critical components.

3. Future Prospects

According to forecasts by the research firm IDTechEx, the overall CPO market is expected to exceed USD 20 billion (approx. JPY 3 trillion) by 2036. Along the timeline of adoption, 2026 is expected to be a transitional period in which CPO technology becomes increasingly incorporated into switches for hyperscalers while conventional optical transceivers remain in use. From 2027 onward, the scope of adoption is expected to expand as the manufacturing technologies mature. It is anticipated that optical I/O technologies will gain significant traction during the same period, with the market projected to rapidly expand at a compound annual growth rate of over 20%.

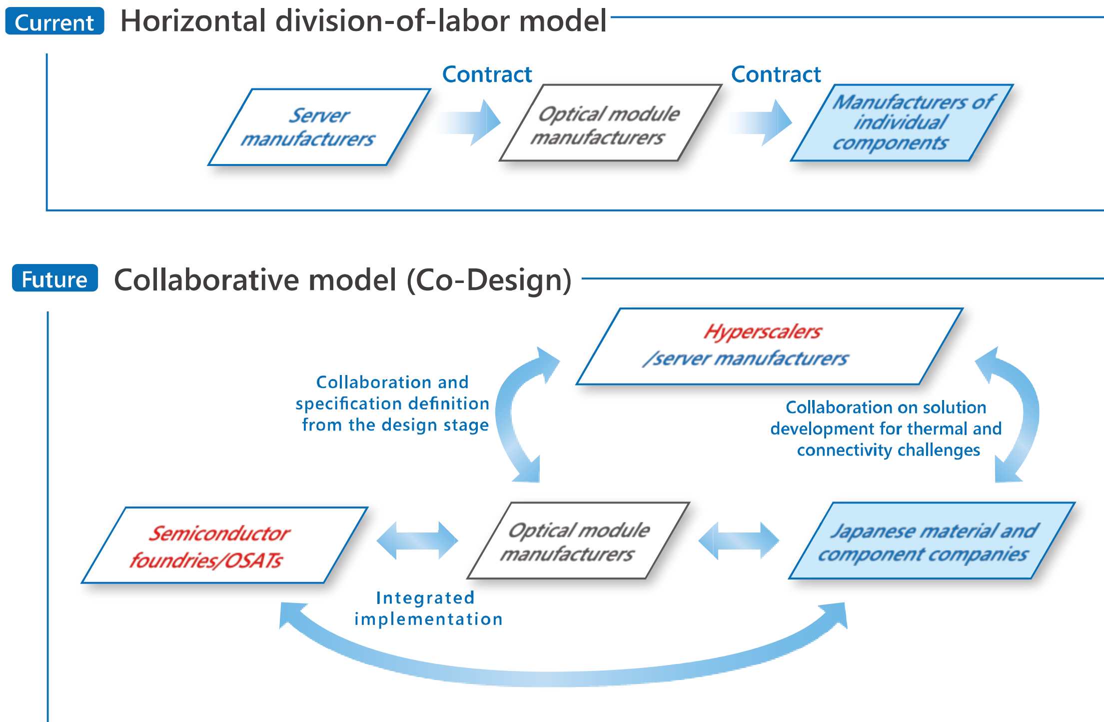
With CPO shifting the technology paradigm from individually inserting optical modules to integrating optical functions into semiconductor packages, semiconductor foundries (such as TSMC) and OSAT companies (such as ASE) now play critical roles within the supply chain. Optical module manufacturers (such as Broadcom) and component manufacturers (such as Sumitomo Electric Industries) that previously designed and developed optical transceivers will be required to collaborate more closely with foundries and OSAT companies.

Japanese companies are well placed to succeed in the particular materials and equipment sectors that present bottlenecks for CPO, including optical fiber mounting (alignment) technology, high heat-

[12] An abbreviation of Outsourced Semiconductor Assembly and Test, which refers to companies that specialize in providing semiconductor back-end processes such as packaging and final testing. As previously noted, packaging technology is also required in CPO.
[13] A micrometer (micron) is equal to one-thousandth of a millimeter. It is occasionally denoted by the symbol μ.

resistant materials, and glass substrates. The key to success in the next-generation data center market will likely be whether companies can deeply integrate into the ecosystems formed by optical module manufacturers and other players—not merely as suppliers, but as joint development partners addressing technical challenges (Figure 3).

Figure 3: Changes in business model



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