Press release

Keio University

May 29, 2025
Keio University

Multi-Core Plastic Optical Fiber Technology Developed for Next-Gen AI Data Centers Successfully Transmits 106.25 Gbps Per Core

A team of researchers at Keio University (President: Kohei Itoh) has successfully developed a multi-core graded-index plastic optical fiber (GI-POF)[1] capable of ultra-high-speed data transmissions at up to 106.25 Gbps per core. This technology will enable high-density, low-latency, and high-capacity optical communications essential for next-generation AI data centers. Research was conducted by a team from the Keio Frontier Research & Education Collaborative Square (K-FRECS) at Shin-Kawasaki including Project Professor Yasuhiro Koike (Director of the Keio Photonics Research Institute) and Project Senior Assistant Professor Kenta Muramoto.

With the rapid growth and integration of generative AI in recent years, data centers responsible for large-scale computation are increasingly demanding ultra-high-capacity and low-latency communication technologies than ever before. In particular, short-reach optical interconnects for large clusters of GPUs and other accelerators play a critical role in determining overall system performance in AI data centers.

To meet these needs, the Keio research team has developed a technology to fabricate high-speed GI-POF with a multi-core structure in a single step. The multicore GI-POF developed using this method enables ultra-high-speed data transmission of over 100 Gbps per core, while significantly reducing costs by eliminating the complex multi-core fabrication processes required for conventional glass optical fibers. The team also demonstrated that using the GI-POF greatly reduces signal noise and transmission errors compared to glass optical fibers. This indicates the technology's potential to simplify signal compensation, thereby enabling low-latency and energy-efficient optical communication.

These results were accepted and presented in two papers at OFC 2025 (The Optical Fiber Communication Conference and Exhibition), the world's largest international conference in the field of optical communications.

1. Background and Findings

In recent years, the rapid development of generative AI (artificial intelligence) has driven the construction of large-scale computing environments in data centers, linking together numerous GPUs (graphics processing units) and other accelerators. As a result, the volume of data exchanged between these computing devices (i.e., inter-node communication) has increased dramatically, creating a need for ultra-high-capacity links operating at 800 Gbps to 1.6 Tbps. Such interconnections are typically short-reach, ranging from a few to several tens of meters—either within a rack (the housing for computing equipment) or between adjacent racks. This has increased the importance of high-capacity, high-density short-reach optical communication. In these applications, VCSELs (vertical-cavity surface-emitting lasers)[2]—which are under active research and development particularly in the United States—have been adopted on a wide basis, making the development of optical fibers compatible with VCSELs increasingly important.

In modern high-performance data centers, high-capacity communication exceeding 800 Gbps is typically achieved by transmitting data in parallel over multiple optical fibers (e.g., 100 Gbps over 8 fibers to reach 800 Gbps). However, conventional optical fibers that are made of glass are generally manufactured individually, necessitating extra steps to achieve multi-fiber conversion (i.e., bundling multiple optical fibers together) such as ribbonizing[3] the fibers and the use of specialized multi-fiber connectors[4], significantly increasing production and installation costs. As data rates continue to scale to 1.6 Tbps, 3.2 Tbps, and beyond, the number of required optical fibers is expected to increase further, raising concerns over greater complexity and cost in the manufacturing process.

In their studies, the Keio research team proposed a method for fabricating multi-core GI-POF (graded-index plastic optical fiber) using an extrusion process, leveraging the properties of plastic materials, to achieve high-capacity communication. As shown in Figure 1, the extrusion process allows for the fabrication of multi-core GI-POF in a single step regardless of the number or arrangements of the cores (the optical pathways) or the external shape by designing the die block accordingly. This eliminates the need for ribbonizing fibers and installing multi-fiber connectors as required in conventional glass optical fibers, making multi-fiber implementation far more cost-effective (estimated at 1/10 to 1/100 of the cost). Figure 2 shows cross-sections of a 61-core circular GI-POF and a 4-core rectangular GI-POF that were fabricated using the single-step extrusion process.

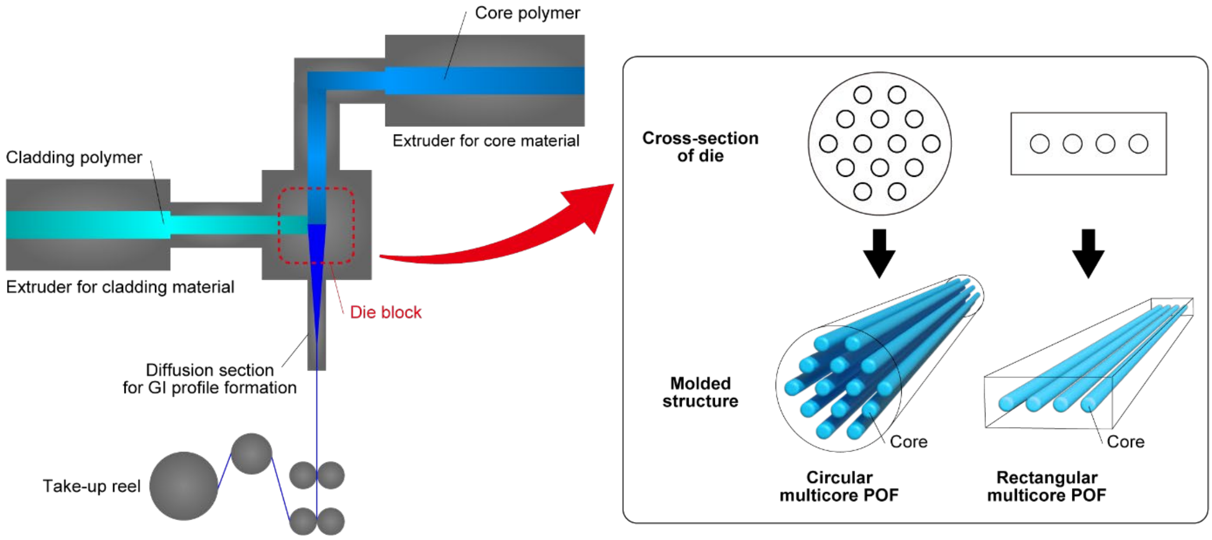

Figure 1: Schematic illustration of the multi-core GI-POF extrusion process
(Source: Y. Koike and K. Muramoto, OFC 2025, W3C.7)

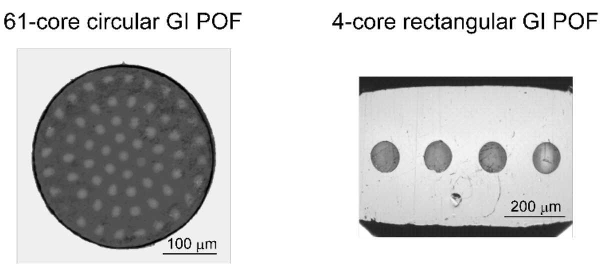

Figure 2: Cross-sections of a 61-core circular GI-POF (left) and a 4-core rectangular GI-POF (right)
(Source: Y. Koike and K. Muramoto, OFC 2025, W3C.7)

Furthermore, by combining the 61-core circular GI-POF with a VCSEL, the research team successfully transmitted a PAM4 (4-level Pulse Amplitude Modulation)[5] signal at up to 106.25 Gbps per core. This data rate is compatible with the signal specifications for state-of-the-art AI data centers. As shown in Figure 3, high-quality signal transmission was confirmed even for distances of up to 30 meters, with minimal degradation observed in the eye diagram[6] and its corresponding TDECQ[7]. Experiments have also confirmed that the multi-core GI-POF exhibits minimal variations in transmission characteristics among its multiple cores, demonstrating that the single-step extrusion process ensures excellent manufacturing reproducibility and reliability.

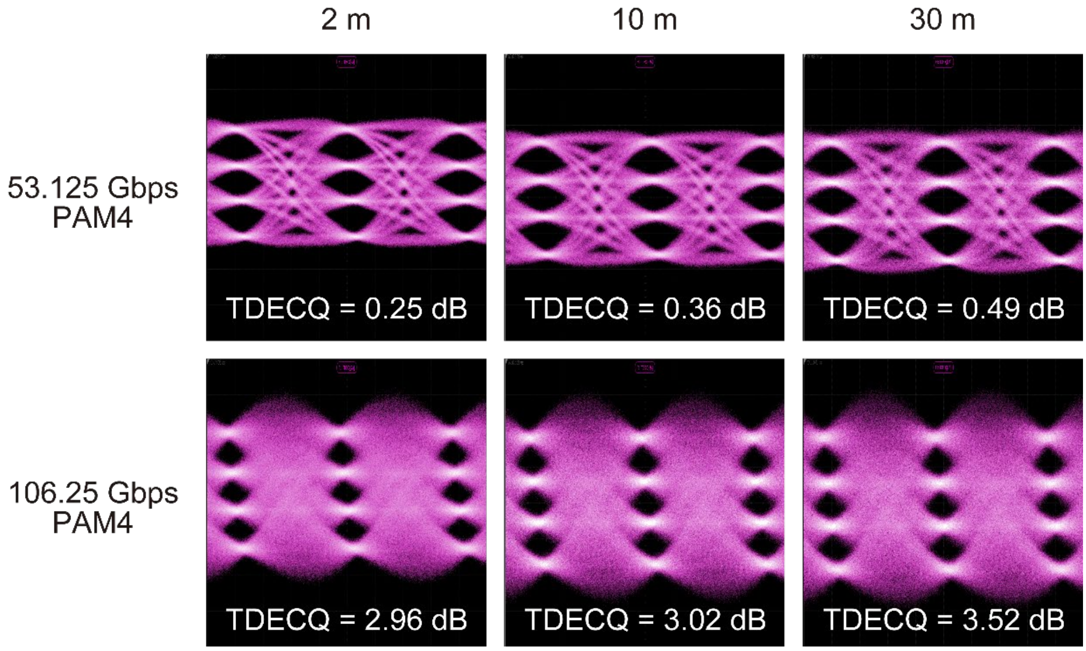

Figure 3: Transmission waveforms of up to 106.25 Gb/s PAM4 signals with the multi-core GI-POF
(Source: Y. Koike and K. Muramoto, OFC 2025, W3C.7)

The Keio research team also demonstrated that the GI-POF significantly improves transmitted signal quality with VCSELs compared to conventional glass optical fibers. A comparison of BER (bit error rate)[8]—a key metric for data transmission quality—showed that, under identical conditions, the GI-POF was able to reduce the BER to as low as 1/10,000 to 1/100,000 of that observed with conventional glass optical fibers.

The GI-POF features microscopic heterogeneous structures within the core, which randomize the properties of the light, helping to suppress interferometric noise throughout the fiber. As a result, additional noise countermeasures, such as precise fiber end-face polishing and lens alignment at connectors and coupling interfaces, are no longer necessary. This is expected to significantly reduce both equipment costs and installation complexity.

Additionally, the significant improvement in BER with the GI-POF suggests the potential to reduce reliance on DSP (digital signal processing)[9] for error correction, which could lead to lower communication delays (latency) and reduced power consumption. This is especially critical for data centers designed for generative AI, where multiple GPUs and other accelerators operate in parallel, and even slight latency can significantly impact the overall processing performance (throughput) of the system. The proposed technology is expected to address key bottlenecks in next-generation AI infrastructure.

2. Glossary

*1 GI-POF

Abbreviation for "Graded-Index Plastic Optical Fiber." The cores of these optical fibers have a structure in which the refractive index gradually decreases from the center to the outer edges, helping to equalize the propagation speeds of different modes (paths of light) and reduce modal dispersion, enabling high-speed data transmission. Because it is made from plastic materials, the GI-POF is flexible and lightweight, and allows for single-step fabrication of multi-core structures via an extrusion process. In addition, microscopic heterogeneous structures within the GI-POF core effectively suppress interferometric noise, enabling stable, low-noise data transmission throughout the fiber.

*2 VCSEL

Abbreviation for "Vertical-Cavity Surface-Emitting Laser." VCSELs are widely used in high-density, short-reach optical interconnects, especially in data centers, due to their low power consumption, small size, and high integration potential. In particular, due to ease of optical coupling, VCSELs pair well with multimode optical fibers (MMFs) with core diameters of approximately 50 μm, making the VCSEL-MMF configuration the standard for most short-reach communications, typically ranging from a few meters to several tens of meters.

In contrast, single-mode optical fibers (SMFs) that have core diameters smaller than 10 μm, which are used in long-haul trunk lines, are difficult to optically couple with VCSELs and require more expensive components. Therefore, SMFs are rarely used in short-reach applications.

*3 Ribbonizing

A process in which multiple optical fibers are aligned and bonded into a flat, ribbon-like structure. Because each optical fiber must be fed out one by one, precisely aligned, and fixed in place, the process is labor-intensive and expensive.

*4 Multi-fiber connectors

Specialized connectors designed to interface multiple optical fibers simultaneously. Common types include MT (Mechanical Transfer) connectors and MPO (Multi-Fiber Push-On) connectors. Installing these connectors with ribbonized optical fibers requires a complex, multi-step process, including peeling off the outer coating from all fibers, inserting each fiber into individual ferrule holes, and bonding them in place. In addition, all fiber end-faces must be polished uniformly, which demands high precision and skill. These factors limit mass production and increase costs.

*5 PAM4

Abbreviation for "4-level Pulse Amplitude Modulation." PAM4 is a multi-level modulation format that can transmit 2 bits of data with a single symbol (signal transition). While conventional binary modulation transmits data at two levels, "0" or "1," PAM4 expresses signals at four levels, such as "00," "01," "10," and "11." This allows twice the data rate to be transmitted over the same bandwidth, making it widely used in high-capacity optical communication systems. However, because the voltage difference between each level becomes smaller, PAM4 is more susceptible to noise and requires more precise transmission technology.

*6 Eye diagram

An eye diagram is a visual representation used to assess the quality of high-speed digital signals, typically displayed on an oscilloscope by overlaying multiple waveforms. It is called an "eye diagram" because the waveform is reminiscent of an eye. The wider and cleaner the eye opening, the better the signal quality, indicating lower distortion and noise. An eye diagram is one of the standard tools for signal integrity assessment in optical communication.

*7 TDECQ

Abbreviation for "Transmitter and Dispersion Eye Closure Quaternary." TDECQ is a metric used to quantitatively evaluate the waveform quality of PAM4 signals, representing how much the eye diagram has degraded from the ideal waveform, expressed in decibels (dB). The smaller the value of the TDECQ, the less noise and distortion, indicating a better signal quality.

*8 BER

Abbreviation for "Bit Error Rate." BER is a metric that indicates the percentage of digital information (bits) that is transmitted incorrectly in a digital communication system. The lower the BER, the better the transmission quality. For example, if the BER is 10^{-6}, one bit error occurs for every million bits transmitted.

*9 DSP

Abbreviation for "Digital Signal Processing." DSP is a technology used to electronically compensate for signal distortion and noise during transmission, playing a crucial role in maintaining the quality of high-speed communications. However, DSP processing introduces power consumption and latency, which are problematic in AI data centers where ultra-low latency and high-power efficiency are crucial. As such, reducing DSP load is becoming increasingly important.

3. Research Papers

The following two papers were accepted and presented at OFC 2025 (The Optical Fiber Communication Conference and Exhibition).

■ Paper One:
N × 106.25 Gb/s PAM4 Transmission Using Multicore Graded-Index Plastic Optical Fiber
Authors: Yasuhiro Koike, Kenta Muramoto
Presentation ID: W3C.7

■ Paper Two:
Ultra-Low Bit Error Rate Plastic Optical Fiber Link with Enhanced Optical Return Loss Tolerance and Alignment Robustness for Advanced PAM4 Transceiver Design
Authors: Kenta Muramoto, Yasuhiro Koike
Presentation ID: M3J.7

4. Acknowledgments

These research results were obtained from the commissioned research (JPJ012368C08001) by National Institute of Information and Communications Technology (NICT), Japan.

*Please direct any requests or inquiries to the contacts listed below in advance of any press coverage.
*We have sent this news release to the MEXT Press Club, Science Press Club, and the city news and cultural divisions of other media outlets.

Inquiries regarding this press release:
Keio University Office of Communications and Public Relations (Contact: Sagisaka)
Tel: 03-5427-1541
Fax: 03-5441-7640
Email: m-pr@adst.keio.ac.jp
https://www.keio.ac.jp/en/