Press release

Keio University

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Keio University

The World's First Error-Free POF (Plastic Optical Fiber) Transmission

The all-in-one solution for data transmission energy expenditure, delays, and cost.

In a new development from the Keio Frontier Research & Education Collaborative Square (K-FRECS) at Shin-Kawasaki's Keio Photonics Research Institute (KPRI), Professor Yasuhiro Koike and his research team have created a plastic optical fiber that all but eliminates errors in data transmissions (hereinafter, "Error-free POF"), a discovery expected to have positive implications for data centers, automobile manufacturers, medicine, and other technologies related to short-distance data transmission. In addition, they have successfully transmitted data at 53 gigabits per second without using current error correction techniques typically required when using Four-level Pulse Amplitude Modulation (PAM4*[1]), a next-generation standard technology in data center communications.

While the age of AI and IoT has increased demand for fast and reliable data transmission, faster transmission speeds present a challenge for accuracy. Most modern data transmission systems utilize error correction schemes such as FEC*[2] (Forward Error Correction) or wave-shaping circuits in order to correct data errors that occur during transfer. However, this comes with added costs, including higher energy consumption and communication delays.

The newly developed Error-free POF renders such error correction schemes and waveform shaping circuits unnecessary, thus reducing energy consumption, delays, and cost all at once (Slide A). The applications for this new technology go far beyond data center energy efficiency. The high-capacity real-time data transmission capabilities of Error-free POF pave the way for advancements in multiple fields such as the automobile industry, medicine, and robotics, making it a highly anticipated core technology of next-generation information industries (Slide B).

Portions of the research results were recently published on August 1, 2021 in *Optics Letters,* an international academic journal, while specific details will be announced in November, 2021 during the International Conference on Plastic Optical Fibers (POF2021).

Research Background

In recent years the processing capabilities of servers and computers have skyrocketed, increasing demand for high-capacity data transfers within and between devices. Electrical cables are most commonly used for this type of short-distance data transmission, though the faster that data is transferred via cable, the greater the electromagnetic interference and signal level loss. Wave-shaping circuits and FEC schemes can be used to combat transmission inaccuracy. However, this type of signal processing is a large factor in energy consumption and transmission delays.

Also, with the advent of AI and IoT, worldwide data traffic has increased consistently, reinforcing the need for data centers and the like to implement PAM4, a multilevel signal modulation format that expands data transmission capacities. The introduction of PAM4 technology would drastically increase data transmission capacities, but also deepen the problem of transmission signal clarity because it is more susceptible to noise than conventional two-level modulation format. Currently, most data centers get around this problem by using glass optical fiber cables which have a much lower signal level loss and negligible electromagnetic noise. However, noise types specific to fiber-optics communications such as modal noise and reflection noise still necessitate FEC or wave-shaping circuits when using PAM4. In other words, using current communications technologies, it has been impossible to both avoid the extra energy consumption and data transmission delays inherent in error-correction and wave-shaping circuits while also meaning the present demand for large-capacity data transfers.

The newly developed Error-free POF solves this root issue. By eliminating the need for FEC or wave-shaping circuits, the Error-free POF will enable the world's first power saving, real-time, low-cost communications system. This revolutionary Error-free POF is expected to become a hallmark technology of the coming *Sustainable Development Goals* (SDGs) society.

Research Details

The Keio Research team's proposed graded-index plastic optical fiber (GI-POF) was developed as a short-distance fiber optics cable capable of combining flexibility, safety, and high-speed gigabit data transmission. After careful analysis of the transmission characteristics of POF, their research revealed that it is possible to greatly reduce both noise and distortion in data transmission over optical fiber by forming microscopic heterogeneities*3 in the core of the POFs, causing forward light scattering that induces efficient mode coupling*4. Building upon this discovery they were able to develop a superior high-speed Error-free POF with minimal noise interference (Figure A, Left). In experiments they successfully completed a short-range data transmission at 53 gigabits per second on a PAM4 signal without the use of FEC (Figure A, Right: The eye pattern measured by a N1092C oscilloscope from Keysight Technologies).

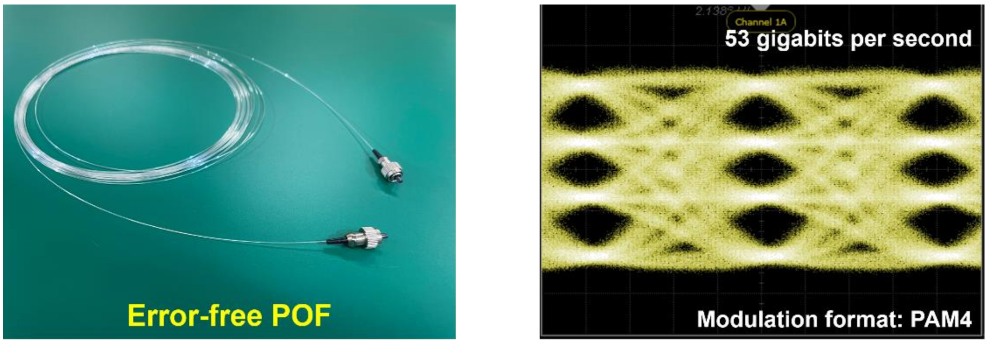

Figure A: Error-free POF (left) and Error-free PAM4 Transmission Waveform at 53 gigabits per second (right)

Up until now, the loss from light scattering in fiber optics made it unsuited for long-distance transmissions. So while plastic optical fibers have been a flexible and low-cost medium capable of delivering high speeds, their excessive scattering loss has rendered them inferior to glass fibers. However, this research changes all of that. In short-range transmissions (approximately 100 meters or less), researchers have managed to harness the plastic optical fibers' light scattering to cause mode coupling, providing an extremely stable signal transmission that not even glass fibers have been able to achieve. This discovery has led to the revolutionary development of the Error-free POF technology that has overturned previous assumptions.

The development of Error-free POF paves the way for top-quality data transmission without resorting to FEC and wave-shaping circuits, at last realizing high-speed, power-efficient, and real-time data transmission. The error-free transmission technology is rooted in light scattering, a trait intrinsic to the microscopic material makeup of the plastic optical fibers. In essence, it is truly a "material revolution" for communications systems by plastic optical fibers. This invention is not only expected to contribute to energy conservation at data centers. It will also have varied applications in technologies that require its low-power, real-time transmission capabilities such as self-driving automobiles, robotics, high-definition video data transmission, and more. Error-free POF will lead the next generation wave of information industrial technology.

Glossary

*1 PAM4 (Pulse Amplitude Modulation with 4 Levels)

A next-generation data transmission method that data centers and other communication infrastructures have begun to adopt. In conventional modulation systems two signal levels (0, 1) were used to transmit data (Figure B, Left), but PAM4 uses 4 levels (00, 01, 10, 11), effectively doubling transmission speeds (Figure B, Right). However, because the extra levels reduce the difference between the signals, PAM4 transmissions are more susceptible to transmission loss and noise than current modulation systems.

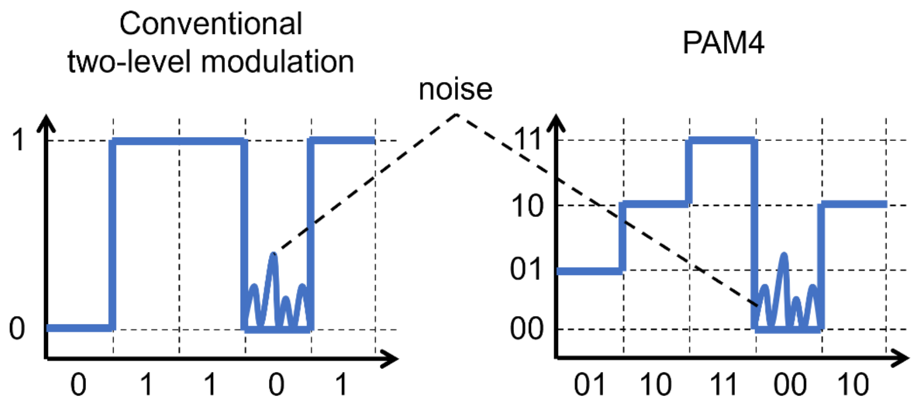

Figure B: A diagram of the conventional binary transmission (left) and PAM4 (right)

*2 FEC (Forward Error Correction)

A common method of correcting transmission errors. By using FEC, errors in received data can be detected and corrected, but processing the signal results in higher power consumption and communication delays.

*3 Microscopic Heterogeneities

This refers to the refractive index fluctuations in the range of a submicron (1/10,000 mm) to a micron (1/1000 mm) meter. When such refractive index fluctuations exist in a substance, the light's interference effect causes scattering which becomes forward light scattering.

*4 Mode Coupling

A phenomenon in which propagating light in an optical fiber in one specific mode (light path) syncs to another mode. In plastic optical fibers, microscopic heterogeneities in the structure of the materials can induce forward light scattering that then can cause efficient mode coupling.

Relevant Publications

[1] Y. Koike, *Fundamentals of Plastic Optical Fibers*, Wiley-VCH, 2015. DOI: 10.1002/9783527646500

[2] A. Inoue and Y. Koike, "Low-noise graded-index plastic optical fiber for significantly stable and robust data transmission," *Journal of Lightwave Technology*, vol. 36, no. 24, pp. 5887–5892, Dec. 15, 2018. DOI: 10.1109/JLT.2018.2877386

[3] Y. Koike and K. Muramoto, "Error-free PAM-4 transmission by a high-speed plastic optical fiber without forward error correction," *Optics Letters*, vol. 46, no. 15, pp. 3709–3712, Aug. 1, 2021. DOI: 10.1364/OL.433885

Slides

Slide A

Error-free POF will change Communication Systems

The problem with current communications systems
= data error correction

- **In order to correct transmission errors, most systems must use special encoding or wave-shaping circuits.**
- **However, these safeguards greatly increase 1. transmission delays 2. energy consumption 3. cost.**

Error-free POF (plastic optical fiber) solves issues 1-3 all at once.

By forgoing data correction techniques
and thus reducing costs, delays, and energy consumption,
“Error-free POF will change the very core of communications systems.”

Slide B

The impact of Error-free POF

Data Centers:

With the recent focus on Digital Transformation (DX), data transmissions have skyrocketed, creating an energy crisis for data centers.

Self-driving Automobiles:

In order to ensure self-driving vehicles are as safe as possible, real-time data transmission is an absolute necessity.

Robotics:

In a field that focuses on precision and accuracy, real-time data transmission is a vital component, especially with regard to manufacturing and medical robots.

Video Data Transmission:

Real-time large-capacity data transmission is vital to the immersive quality of 4K and 8K imaging technologies.

The energy-saving real-time data transmission made possible by Error-free POF will make this technology a cornerstone of next-generation information industries.

*Please direct any requests or inquiries on press coverage to the contact information provided below in advance.

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