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National Institute of Information and Communications Technology
Fujikura Ltd.

Press Release

Successful Transmission of 1.2 Pb/s Over a 4-core 3-mode Optical Fiber with a Cladding Diameter of 0.16 mm

- Towards the early implementation of ultra-large capacity transmission with a new type of practical optical fiber -

【Points】

- ■4-core, 3-mode optical fiber with 0.16 mm diameter, standard single mode optical fiber size.
- ■Couplers capable of simultaneously cores and mode multiplexing/de-multiplexing.
- ■Progress to the practical realization of an over 1 Pb/s optical fiber.

The Network System Research Institute at the National Institute of Information and Communications Technology (NICT, President: Hideyuki Tokuda, Ph.D.) and Fujikura Ltd. (Fujikura, President: Masahiko Ito) jointly developed a 4-core 3-mode optical fiber with a cladding diameter of 0.16 mm. To enable optical transmission, a coupler that multiplexes/de-multiplexes the cores and modes simultaneously was also jointly developed by Hokkaido University (President: Toyoharu Nawa) and the MQ Photonics Research Center (MQ) at Macquarie University in Australia. The transmission test of 1.2 Pb/s was successfully conducted with 368 wavelength channels and a very high-density multilevel modulation format of 256 QAM.

Previous ultra-high capacity optical communications demonstrations exceeding 1 Pb/s required optical fibers with more than 12 cores and diameters exceeding 0.21 mm. In this work, we succeeded the world's first transmission experiment exceeding 1 Pb/s with an optical fiber having a diameter of less than 0.2 mm. The advantage of the smaller fiber is increased resistance to mechanical stress such as bending and pulling. It also uses the same size coating as currently deployed standard optical fibers and therefore can be easily cabled and connected. The experiment represents a big step forward towards the early implementation of ultra-large capacity optical communications.

The results of this demonstration were selected for presentation as a post-deadline paper at the 44th European Conference on Optical Communication (ECOC2018).

【Background】

In order to meet the exponentially increasing data traffic demand, research on ultra-high speed optical transmissions using new types of optical fiber, exceeding the transmission limit of conventional optical fibers, has been carried out across the globe. These new fibers can be multicore fibers containing multiple separate optical paths (cores) and multimode fibers supporting the propagation of multiple modes within a single core.

Up to now, a number of successful transmission experiments of large capacity and long distance have been reported for multicore fibers. However, these fibers have been thick and vulnerable to damage from mechanical stress such as bending and pulling. This weakness results in an increased probability of breakage during manufacturing and installation, and would also significantly complicate the fiber connection process.

【Achievements】

NICT successfully transmitted for the first time in the world 1.2 Pb/s in a 4-core 3-mode optical fiber. The fiber was designed by Hokkaido University and developed by Fujikura (Fig. 1). NICT built the transmission system using couplers developed by MQ.

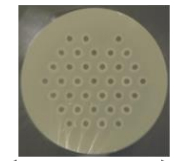
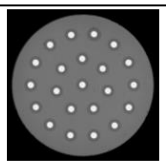
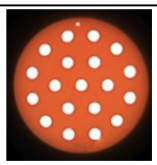
	Representative research results			This work	Standard optical fiber
	March 2015	October 2015	October 2017	September 2018	
Capacity (Pb/s)		2.15	10.16	1.2	Up to ~0.15
Number of Cores, Modes per core	36 cores, 3 modes	22 cores, 1 mode	19 cores, 6 modes	4 cores, 3 modes	1 core,1 mode
Cladding diameter	 0.3 mm	 0.26 mm	 0.267 mm	 0.16 mm	 0.125 mm
Coating diameter				0.25 mm	0.235～0.265 mm

Fig.1: Comparison between our 4-core, 3-mode optical fiber and other optical fibers

The transmission system is made up from the following four main technologies.

・4-core, 3-mode optical fiber with a cladding diameter of 0.16 mm

・Couplers that simultaneously multiplexe/de-multiplexe all cores and all modes.

・An optical frequency comb light source generating simultaneously 368 wavelength channels.

・256 QAM multi-level modulation technology with 8 bit of data in a single pulse.

The optical fiber has almost the same size as existing standard single-mode optical fibers and has the same coating diameter, therefore it can be easily cabled and installed using existing equipment. Furthermore, the transmission capacity has been demonstrated to exceed record transmission in conventional fibers by a factor of 8. Such a fiber maybe be suitable for transmission scenarios where ultra-large capacity and high spatial density optical transmission fibers are required, such as intra- and inter-data centers connections.

【Future Prospects】

We are promoting R&D of innovative technology that achieves the early adoption of international standardization by industry-academia collaboration for establishing next-generation optical communication infrastructure technologies which can smoothly accommodate traffic for big data and 5G services.

The results of this work were presented as a post deadline paper of the prestigious 44th European Conference on Optical Communication (ECOC2018), held in Rome, Italy from 23rd to 27th September, 2018.

【References】

Ruben S. Luís, Georg Rademacher, Benjamin J. Puttnam, Tobias A. Eriksson, Hideaki Furukawa, Andrew Ross-Adams, Simon Gross, Michael Withford, Nicolas Riesen, Yusuke Sasaki, Kunimasa Saitoh, Kazuhiko Aikawa, Yoshinari Awaji, and Naoya Wada, "**1.2 Pb/s Transmission Over a 160 μm Cladding, 4-Core, 3-Mode Fiber, Using 368 C+L band PDM-256-QAM Channels**," in Proc. 44th European Conference on Optical Communication (ECOC), September 2018, paper Th3B.3.

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Appendix

1. Transmission system developed this time

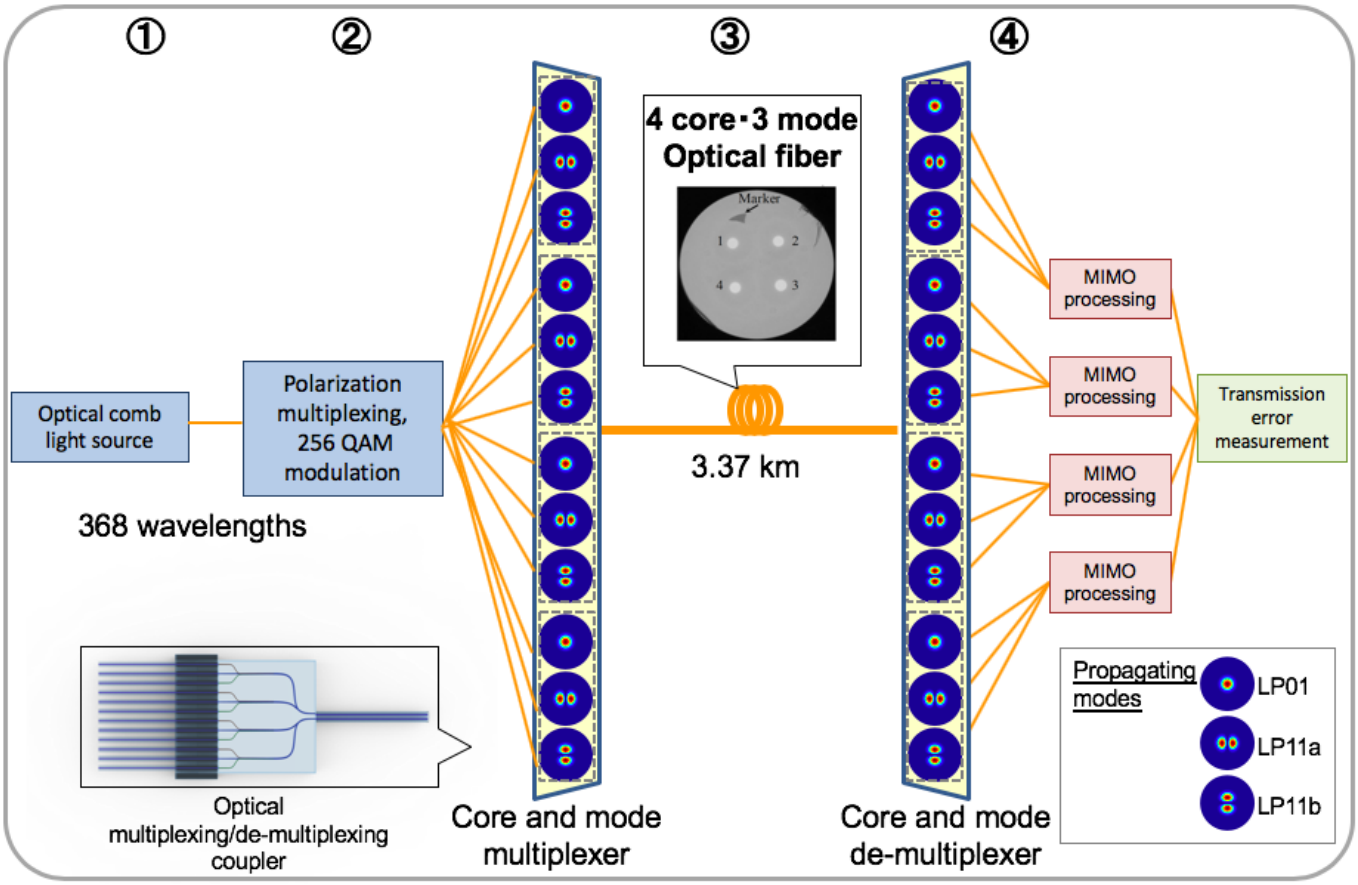

Fig.2: Schematic diagram of the transmission system

Fig.2 shows a schematic diagram of the mode-division multiplexed transmission system.

① A laser beam containing 386 different wavelengths is generated.

② Polarization-multiplexing with 256 QAM modulation is performed on each wavelength contained in the output light of the optical comb light source. This output light is then split into 12 independent pseudo-random spatial signals by adding different optical delay differences.

③ These 12 spatial signals are then simultaneously multiplexed to 4 cores with each core propagating 3 different modes (LP01, LP11a, LP11b).

④ After propagating through the 4-core, 3-mode optical fiber with a length of 3.37 km, the spatial signals in each core were then again optically separated and the data signal was separated by performing MIMO signal processing of 6×6 scale. Finally, the transmission error was measured.

2. Results of Experiment

In the experimental system shown in Fig. 2, verification was carried out to maximize the transmission capability (i.e., data rate) of the system by applying various coding such as error correction processing at the time of transmission and reception. By comparing 64 QAM, 128 QAM, and 256 QAM as the modulation format, we confirmed that the maximum transmission capacity could be obtained with 256 QAM as shown in Fig. 3.

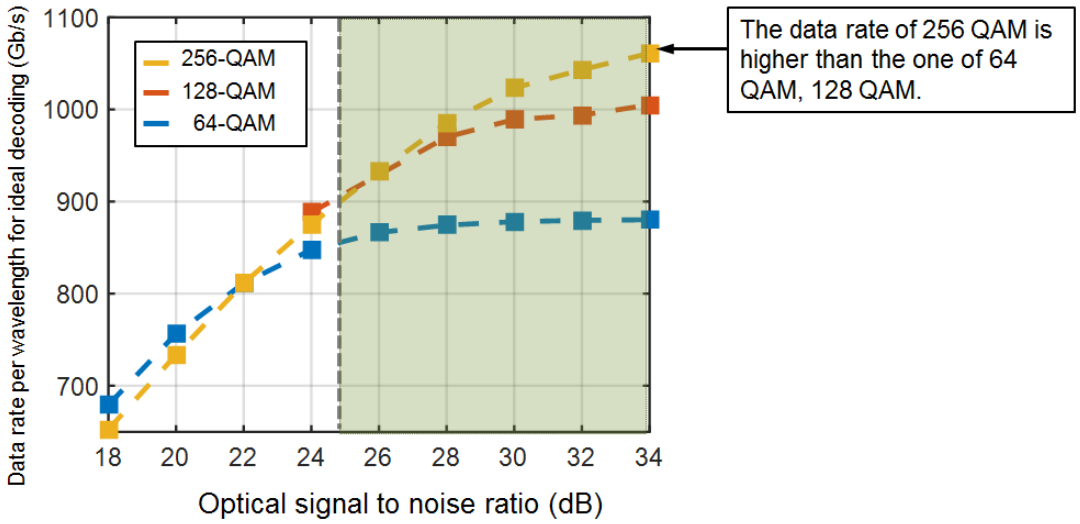

Fig.3: Comparison of modulation method

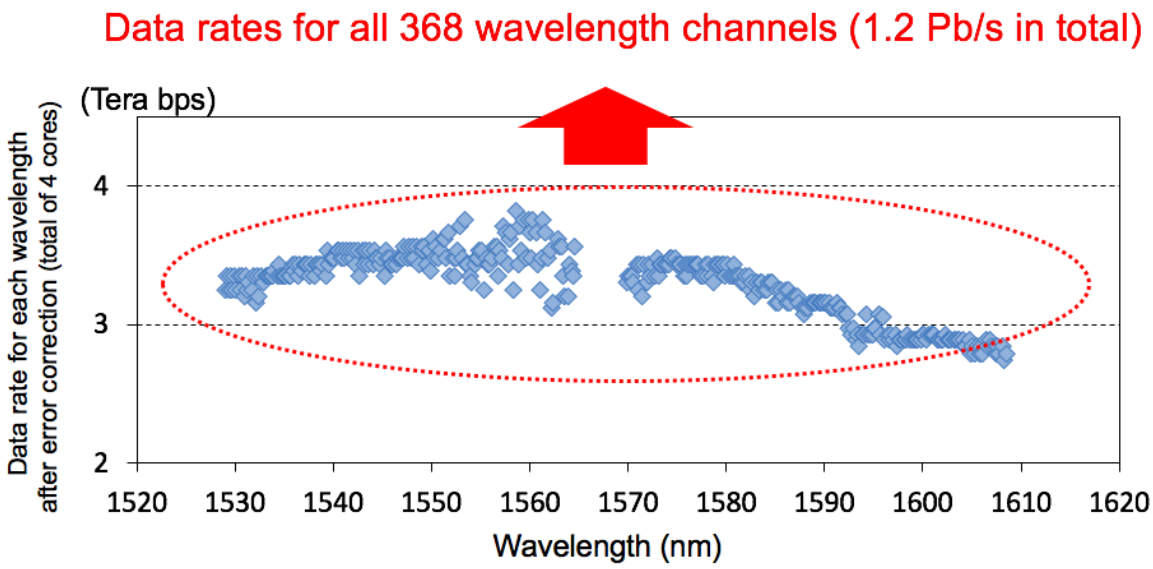

Fig.4: Data rate measurement result

Fig. 4 shows the result of the measured data rate after applying error correction. A slight wavelength dependence can be observed but stable data rates with good uniformity were obtained across all 368 wavelength channels realizing a total data throughput of 1.2 Pb/s.