World's first standard cladding diameter 19-core optical fiber with record transmission capacity

May 15 2023

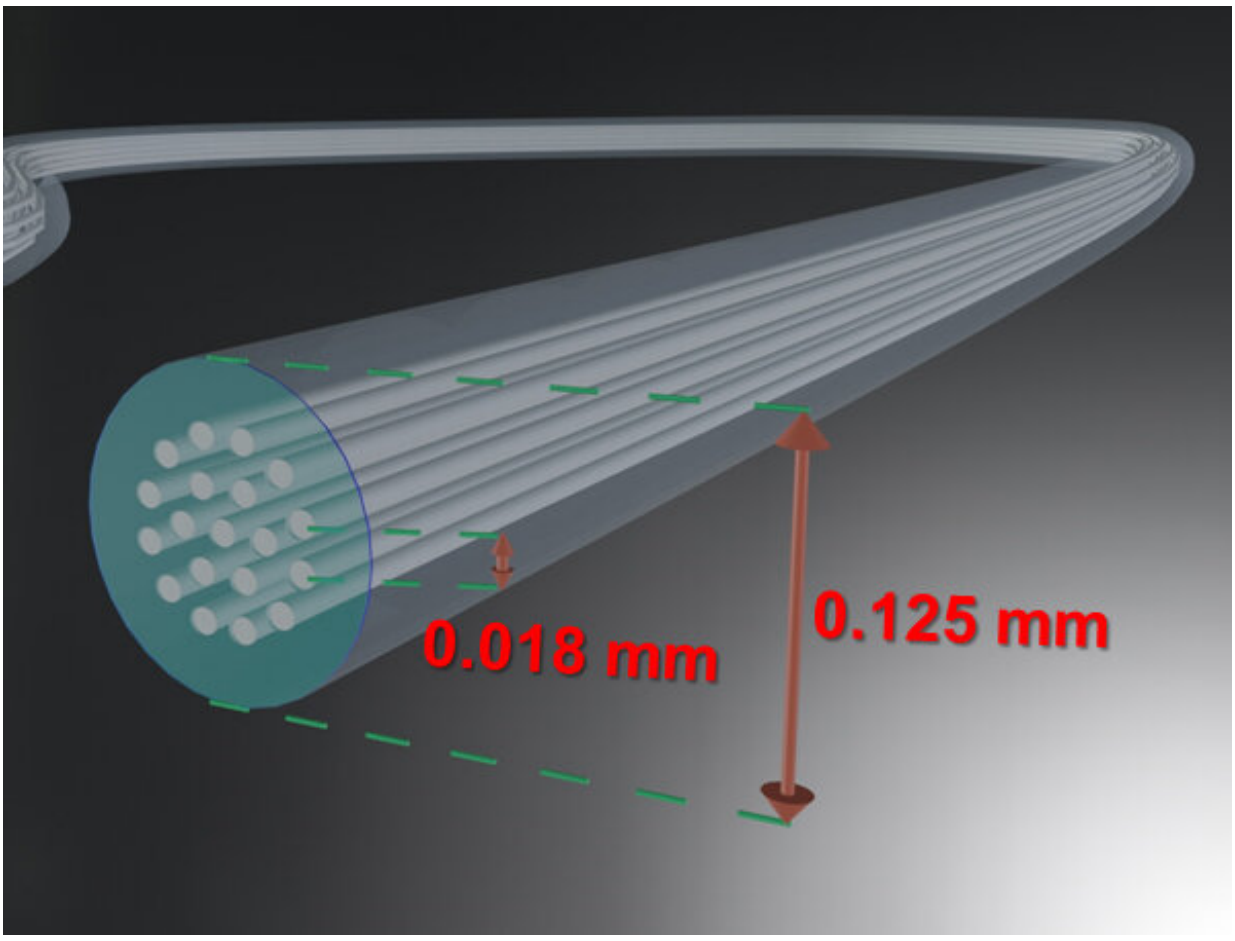
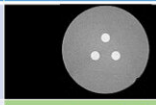
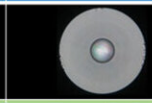
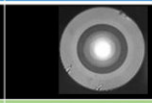
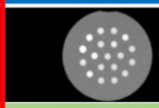


Image of the developed 19-core optical fiber. Credit: National Institute of Information and Communications Technology (NICT) and Sumitomo Electric Industries, Ltd.

A group of researchers from the National Institute of Information and Communications Technology (NICT, Japan) and Sumitomo Electric Industries, Ltd. (SEI, Japan) in collaboration with the Eindhoven University of Technology, University of L'Aquila, and Macquarie University has developed a 19-core optical fiber with a standard cladding diameter (0.125 mm), which has the largest number of cores among the standard cladding diameter multi-core fibers, and has demonstrated large-capacity transmission at a data-rate of 1.7 petabits per second over a distance of 63.5 km. A randomly coupled multi-core fiber design was used to achieve high core density, as well as a multiple input multiple output (MIMO) digital signal processing to eliminate inter-core signal interference.

In this experiment, the world record was achieved for the transmission capacity of an optical fiber with a standard cladding diameter, and the world's longest transmission distance was achieved among transmission experiments with a capacity of 1 petabit per second or more. This result shows the possibility of significantly reducing the power consumption of MIMO digital signal processing in transoceanic systems, compared to multi-mode fiber transmission. This fiber technology will contribute to the realization of future long-distance and large-capacity optical communication networks.

The results of this experiment were accepted as a post-deadline paper presentation at the 46th Optical Fiber Communication Conference (OFC 2023) and presented on Thursday, March 9, 2023. The article is titled "Randomly Coupled 19-Core Multi-Core Fiber with Standard Cladding Diameter."

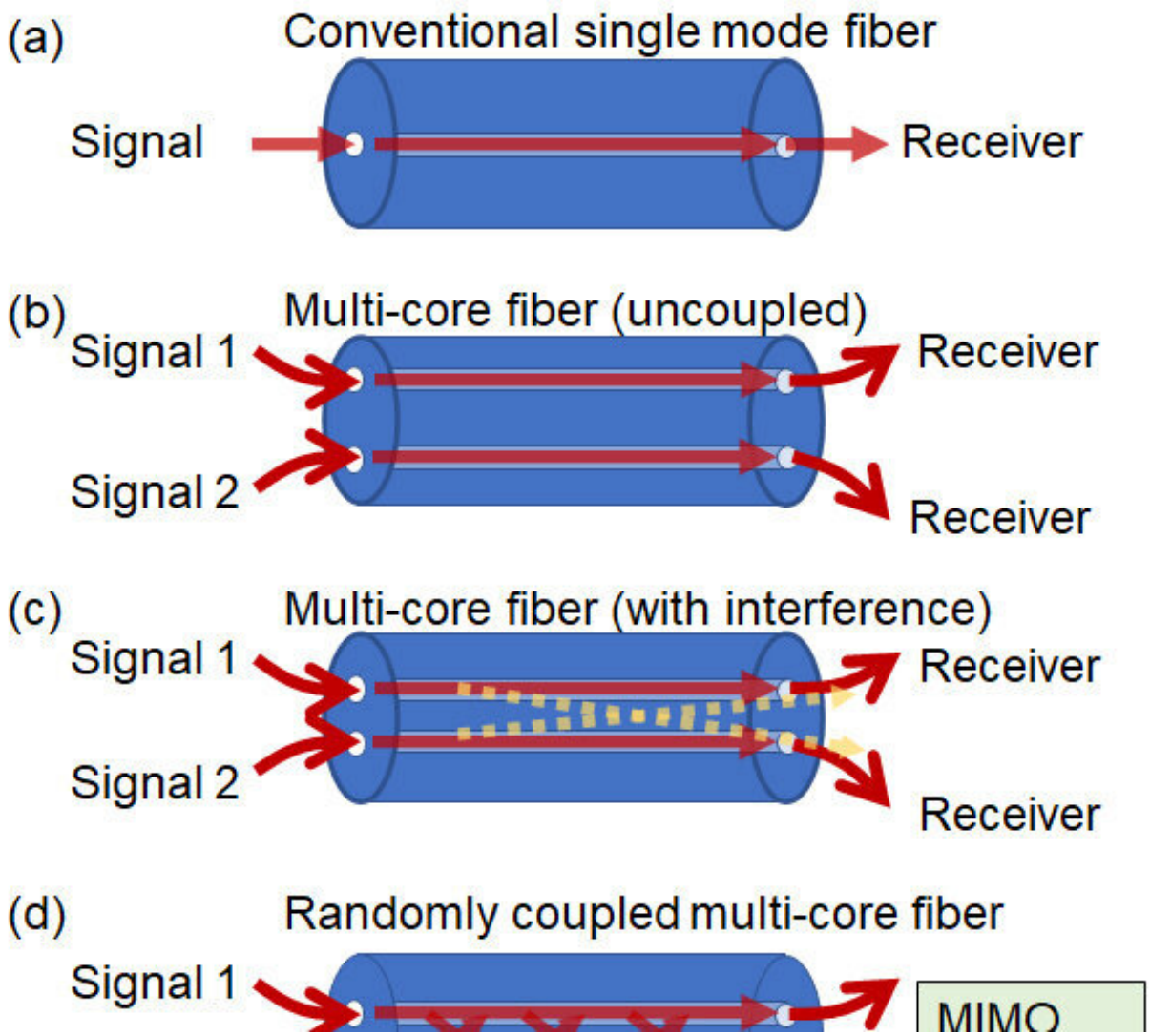
					Current result
Optical fiber	Randomly coupled 3-core fiber	15-mode fiber	Uncoupled 4-core fiber	55-mode fiber	Randomly coupled 19-core fiber
Cross-sectional view					
Achieved records	Mar. 2020 Product of data-rate and distance	Dec. 2020 Transmission capacity	May 2022 Transmission capacity	Sep. 2022 Transmission capacity	Mar. 2023 Transmission capacity
Transmission capacity (petabits/s)	0.17	1.01	1.02	1.53	1.7
Transmission distance (km)	2,040	23	51.4	25.9	63.5
Frequency band (terahertz)	9.0	9.6	20	4.6	9.5
Power consumption of MIMO processing	Small	Large	None	Large	Small

New optical fibers with a standard cladding diameter, and world records achieved by NICT. Credit: National Institute of Information and Communications Technology (NICT) and Sumitomo Electric Industries, Ltd.

Research on advanced optical fibers has attracted considerable attention to address ever-increasing traffic demands. NICT has achieved transmission capacities of 1.02 petabits per second for a standard cladding diameter uncoupled multi-core fiber, 1.53 petabits per second for a multi-mode fiber, and 0.17 petabits per second for a randomly coupled multi-core fiber.

However, in the case of an uncoupled multi-core fiber, the number of cores is limited to suppress signal interference between the cores, rendering an increase in capacity challenging. On the other hand, in the multi-mode fiber transmission, the propagation characteristics of each mode is significantly different, which poses a problem for long-distance transmission. Randomly coupled multi-core fiber overcomes these limitations by means of MIMO digital signal processing and is expected

to be a transmission medium for future long-distance and large-capacity optical communication systems. Precise core placement is needed, however, and the maximum number of cores in a randomly coupled multi-core fiber with a standard cladding-diameter was 12.

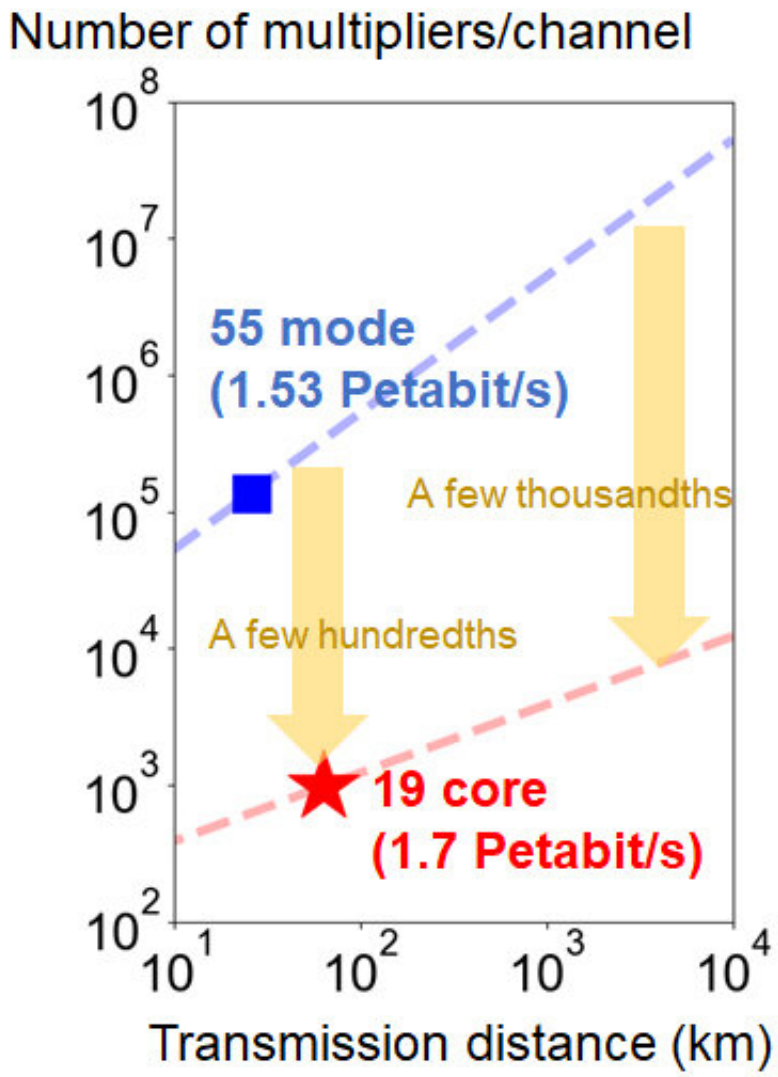


Conceptual images of optical fiber transmission schemes. Credit: National Institute of Information and Communications Technology (NICT) and Sumitomo Electric Industries, Ltd.

In this research, SEI designed and fabricated a randomly coupled 19-core fiber with a standard cladding-diameter, and NICT constructed a transmission system to demonstrate the maximum capabilities of this fiber. In the experiment, 1.7 petabits per second of data were transmitted for 63.5 km. Optimization of the core structure and layout enabled this fiber to accommodate the world's largest number of cores in a standard cladding diameter while achieving random coupling between cores (optical signal paths) and suppressing differences in propagation characteristics. Furthermore, Macquarie University has produced a three-dimensional laser-inscribed core multiplexer and demultiplexer, which can be used as an interface with conventional single-mode optical fibers.

To properly evaluate the transmission performance of randomly coupled multi-core fibers, it is necessary to receive signals from all cores and demodulate them simultaneously using MIMO processing. NICT constructed an optical transmission system that can simultaneously receive 19-core signals at a high symbol rate. Using commonly used wavelength bands (C and L bands) and polarization multiplexed 64QAM signals, NICT has demonstrated a total transmission capacity of 1.7 petabits per second over a transmission distance of 63.5 km. The difference in propagation time delay between optical signal paths is small, and the power consumption of signal processing can be greatly reduced.

In the "Beyond 5G" (6G) society, a cyber physical system supported by a large-capacity data communication infrastructure is required so that anyone can play an active role anywhere. On the other hand, to reduce the environmental impact, it is necessary to minimize the power consumption associated with data communications. Considering such social demands, the randomly coupled 19-core fiber in this study is one of the most promising candidates for the next-generation long-distance transmission medium.



Required number of multipliers per channel in MIMO digital signal processing versus transmission distance. Credit: National Institute of Information and Communications Technology (NICT) and Sumitomo Electric Industries, Ltd.

The researchers plan to extend the transmission distance and expand the wavelength band to increase capacity, develop new devices compatible

with the 19-core fiber, demonstrate advanced network functionalities such as switching, and investigate the feasibility of future deployment.

Provided by National Institute of Information and Communications Technology (NICT)