NEWS RELEASE

NTT

NIPPON TELEGRAPH AND TELEPHONE CORPORATION

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14 Tbps over a Single Optical Fiber: Successful Demonstration of World's Largest Capacity

- 140 digital high-definition movies transmitted in one second -

Nippon Telegraph and Telephone Corporation (NTT, Chiyoda Ward, Tokyo, President and CEO is Norio Wada) has successfully demonstrated the ultra-large capacity optical transmission of 14 Tera bits per second (Tera is one trillion) over a single 160 km long optical fiber. The value of 14 Tbps (111 Gbps x 140 ch) greatly exceeds the current record of about 10 Tbps and so claims the record of the world's largest transmission capacity.
This result was reported as a post deadline paper in the European conference on optical communication (ECOC) that was held in Cannes, France from September 24 to 28.

1. Background
The present core optical network is an optical transport network with about 1 Tbps capacity. Based on the wavelength-division-multiplexing (WDM) of signals with the channel capacity of 10 Gbps, it uses optical amplifiers with the bandwidth of about 4THz. The data traffic has been doubling every year due to the rapid spread of broadband access. We must lower the cost and raise the capacity of the core network while maintaining its reliability as the dominant communication infrastructure.
10 Tbps transmission over a single optical fiber has been achieved in the laboratory. However, it was necessary to use linear amplifiers that covered two or three amplification bands because of the limited range of existing amplifiers, and this multi-band configuration is not cost-effective. To increase the transmission capacity, we had to achieve two goals simultaneously: WDM transmission with high spectral efficiency and optical amplifiers with greatly enlarged bandwidth.

2. Outline of experiment
Our experiment used the carrier suppressed return-to-zero differential quadrature phase shift keying (CSRZ-DQPSK)[*1] format and ultra-wide-bandwidth amplifiers. 70 wavelengths with 100-GHz spacing were modulated at 111 Gbps using the CSRZ-DQPSK format and then multiplexed and amplified in the bandwidth of 7 THz. In addition, each 111 Gbps signal was polarization-division-multiplexed so the number of channels was doubled to 140. This yielded the total capacity of 14 Tbps (Figure 1).
160-km transmission was successfully achieved by amplifying these signals in newly developed optical amplifiers.
NTT demonstrated in this experiment, for the first time, that it is possible to transmit 100 Gbps signal with forward error correction[*2] bytes and management overhead bytes of the OTN[*3] frame over long distances allowing the construction of large capacity optical networks that offer 10 Tbps or more.

3. Core technologies

(1) CSRZ-DQPSK modulation format and high-speed optoelectronic device technologies (Figure 2)

These technologies make it possible to generate dense WDM signals with bit rates of 100 Gbps and beyond per channel and transmit them over long distances. DQPSK is a phase modulation format with four phase states. Its benefits include its high spectral efficiency and excellent receiver sensitivity; both superior to those offered by the conventional binary intensity modulation (ON-OFF-keying) format. The combination of this format with pulse modulation (CSRZ), developed by NTT, enhances the sensitivity, and enables dense WDM long-distance transmission. To realize a CSRZ-DQPSK signals at 100 Gbps or above, we had to overcome the problems of the complicated configuration of the transmitter block and the difficulty of raising the modulation speed. The Mach-Zehnder interference type, lithium niobate (LN) modulator has been used as a binary intensity or phase modulator in high-speed transmitters, but there is a trade-off between driving voltage and bandwidth and it was considered to be virtually impossible to raise the operation speed to at least 100 Gbps. To overcome these problems, NTT newly developed a hybrid integration technology that yields silica-based planar lightwave circuits and LN lightwave circuits[*4]. Both devices simplify the configuration and support the fast modulation speed of 111 Gbps.
While the conventional binary intensity modulation format uses a photodiode in the receiver, the DQPSK receiver needs a pair of balanced photodetectors, usually realized by integrating two high-speed photodiodes, making it difficult to achieve high-speed operation, high sensitivity, and uniform conversion efficiency, simultaneously. NTT improved the structure of the photodetector with the result that the new balanced receiver offers high-speed operation at over 50 GHz as well as high sensitivity.
InP ICs, which can be operated at over 50 GHz were used in multiplex and demultiplex circuits and the waveform shaping part to generate high-quality 111 Gbps DQPSK signals.

(2) Ultra-wide-band inline optical amplification technology (Figure 3)

It is necessary to expand the bandwidths of the optical amplifiers in order to amplify the 10 Tbps or more signal in one optical fiber. While most fibers have bandwidths in excess of 10 THz, conventional amplifiers have bandwidths of approximately 4 THz. This means that it was necessary to divide the channels into two bands (C and L band) or three bands (S, C, and L band) [*5], amplify each band separately, and then remultiplex the bands.
NTT succeeded in extending the bandwidth of an L-band amplifier so that it was 1.75 (7 THz) larger than that of convention amplifiers. By improving the amplification medium and configuration of the amplifier, NTT was able to achieve a low noise characteristic,.

4. Future schedule

NTT aims to construct a 10 Tbps-class large capacity core optical network that excels in terms of its economy and quality; it will promote the realization of a long-distance transmission system that supports 100 Gbps high-speed channels.

Terminology

*1: CSRZ-DQPSK
Abbreviation of Carrier Suppressed Return to Zero Differential Quadrature Phase Shift Keying. Modulation format in which CSRZ pulse modulation is added to differential quadrature phase modulation; it is appropriate for high-density WDM long-distance transmission.

*2: Forward error correction code
Code to detect an error caused during transmission and to correct it in the receiver by adding redundant arithmetic data to the transmitted signal. The international standard ITU-T G.709 recommendation adopts the Reed-Solomon (255,239) code as an error correction code for high-quality transmission.

*3: OTN
Abbreviation of Optical Transport Network. The international standard for optical network using WDM system (ITU-T G.709 recommendation).

*4: Silica PLC
Planer lightwave circuit formed on fused silica that includes an optical waveguide. This technology can integrate complex passive optical devices into small areas and is used to realize multiplex and demuliplex devices for WDM systems, Mach-Zehnder type optical switches and so on.

*5: C band, L band and S band
Wavelength band classification for optical communication standardized in ITU-T. C (Common) band is from 1530 to 1565 nm, L (Long) band is from 1565 to 1625 nm, and S (Short) band is from 1460 to 1530 nm. The current practicable bandwidth in the L-band is 35 nm (about 4THz) centered on about 1590 nm.

- Figure 1 Technology to achieve the large capacity of 10 Tbps class transmission
- Figure 2 CSRZ-DQPSK format and high-speed device technology for achieving bandwidth compression and high sensitivity
- Figure 3 Amplification bandwidth extension technology in L-band optical amplifier

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