14-Tbit/s over a Single Optical Fiber—Demonstration of World's Largest Capacity

NTT has successfully demonstrated ultrahigh-capacity optical transmission of 14 Tbit/s over a single 160-km-long optical fiber. As this greatly exceeds the current record of about 10 Tbit/s, NTT is claiming to have set a new world record for transmission capacity. Composed of 140 channels each carrying 111 Gbit/s, it is equivalent to transmitting 140 digital high-definition movies in one second.

The present core optical network is an optical transport network (OTN) with a capacity of about 1 Tbit/s. It is based on wavelength division multiplexing (WDM) of signals with a channel capacity of 10 Gbit/s and uses optical amplifiers with a bandwidth of about 4 THz. To increase the transmission capacity, two goals had to be achieved simultaneously: WDM transmission with high spectral efficiency and optical amplifiers with greatly enlarged bandwidth.

NTT used the carrier suppressed return-to-zero differential quadrature phase shift keying (CSRZ-DQPSK) format and ultrawide-bandwidth amplifiers for the experiment. 70 wavelengths with a spacing of 100 GHz were modulated at 111 Gbit/s using the CSRZ-DQPSK format and then multiplexed and amplified in a bandwidth of 7 THz. In addition, each 111-Gbit/s signal was polarization division multiplexed, so the number of channels was doubled to 140. This yielded a total capacity of 14 Tbit/s. The 160-km transmission was successfully achieved by amplifying these signals in newly developed optical amplifiers.

In addition, this experiment demonstrated, for the first time, that it is possible to transmit a 100-Gbit/s signal with the forward error correction bytes and management overhead bytes of the OTN frame over long distances. This will allow the construction of optical networks with capacities of 10 Tbit/s or more.

■ Key technologies

(1) CSRZ-DQPSK modulation format and high-speed optoelectronic device technologies: DQPSK is a phase modulation format with four phase states. Its benefits include its high spectral efficiency and excellent receiver sensitivity; both are 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. NTT newly developed a hybrid integration technology for silica-based planar lightwave circuits and lithium niobate lightwave circuits. Both devices simplify the configuration and support the fast modulation speed of 111 Gbit/s for the CSRZ-DQPSK format. It also improved the structure of the photodetector with the result that the new balanced receiver operates at over 50 GHz and has high sensitivity for 111 Gbit/s CSRZ-DQPSK demodulaton. InP integrated circuits, which can be operated at over 50 GHz, were used in the multiplexing and demultiplexing circuits and the waveform shaping part to generate high-quality 111-Gbit/s DQPSK signals. These technologies make it possible to generate dense WDM signals with bit rates of 100 Gbit/s and beyond per channel and transmit them over long distances.

(2) Ultrawideband inline optical amplification technology: NTT succeeded in extending the bandwidth of an L-band amplifier to 7 THz, which is about 1.75 times that of conventional amplifiers. Low noise characteristics were achieved by improving the amplification medium and the amplifier's configuration.

NTT aims to construct a 10 Tbit/s-class core optical network that excels in terms of economy and quality. This will lead to a long-distance transmission system that supports 100-Gbit/s channels.

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