World's First Ultra High-Speed Optical Fiber Switch with Power Amplification Features

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Ultra high-speed signal processing verified at 640 gigabits per second

Fujitsu Laboratories Ltd. and Fraunhofer Institute for Telecommunications, Heinrich-Hertz-Institut (HHI) today announced their development of the world's first ultra high-speed optical fiber switch with optical amplification features using nonlinear optical effects of optical fiber, and succeeded in ultra high-speed optical signal processing at 640 gigabits per second (Gbps). The newly developed optical fiber switch features amplification capabilities of 100 times and more over a wide wavelength range, and enables ultra high-speed switching at over 1 terabit per second.

The technology developed for this new ultra high-speed fiber-optic switch will be the foundation for realization of future-generation ultra high-speed optical processing, such as ultra high-speed optical data transmission and ultra high-speed optical switching, which employ ultra high-resolution optical waveform monitors (optical sampling oscilloscopes) and all-optical technology.

Background

Optical signal processing has the potential to realize high-speed/high-capacity processing at speeds which are 100 to 1000 times or beyond faster than that of conventional electronic signal processing. Such ultra high-speed optical signal processing will enable ultra high-speed photonic networks.

In the past, optical amplifiers (erbium-doped fiber amplifiers: EDFAs) had a significant impact on optical communications. Today, over 15 years since the development of EDFAs, there is much anticipation for the realization of optical signal processing with not only optical amplification capabilities but additional features as well.

Technological Challenges

An optical switch is one of several essential elements of fundamental technology required for optical signal processing in photonic networks of the future. Although conventional optical switches operated at high-speed, they had big power losses. Therefore, signal quality degradation was a serious problem even after the compensation of losses.

Newly Developed Technology

This new technology developed by Fujitsu Laboratories and Heinrich-Hertz-Institut led to the development of an ultra high-speed optical switch with amplification capability for signal processing that utilizes highly nonlinear optical fibers(1). By exploiting the highly nonlinear optical effect, the optical switch has potential to operate at ultra high speeds of 1 terabit(2) or greater per second, and at the same time is able to amplify the power of optical signals by optical parametric amplification. As the optical switch can perform both optical switching and optical amplification simultaneously, this optical switch is the world's first of its kind capable of ultra high-speed optical switching with extremely low noise levels. The length of the highly nonlinear optical fibers used in the switch is 20-30 meters, a size for practical use.

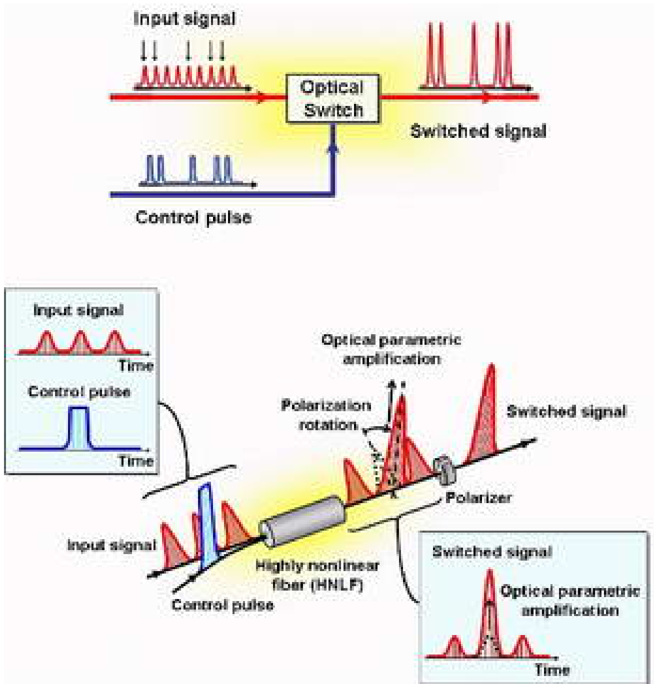

Figure: Functions of new optical switch (upper diagram) and conceptualized diagram of switching principle (lower diagram: input signal is amplified timed with control pulse, as shown in the insets)

Results

Using this newly developed optical switch, Fujitsu Laboratories and Heinrich-Hertz-Institut developed an ultra high-resolution optical waveform monitor that significantly outperforms the time resolution of conventional waveform monitors, which rely on electronic circuits. They also succeeded in observing waveforms at ultra high speeds up to 640Gbps with ultra high resolution. Ultra high speed signals at 640Gbps were also successfully received as a 64-channel 10 Gbps signal.

Fujitsu Laboratories and Heinrich-Hertz-Institut confirmed, that the optical switch output was amplified to roughly six times (7.6 decibels) the power of the initial input signal in the entire 1530-nanometer to 1565-nanometer wave bandwidth (C Band), which is the most commonly used in backbone optical communications. With the optimization of the nonlinear fiber, the amplification rate for the optical switch can be expanded to 100 times (20 decibels) or more than the initial signal, thereby enabling design of devices to cover wider bandwidths.

The optical switch does not rely on data modulation formats, which was confirmed by switching phase-modulated signals.

Future Developments

Fujitsu Laboratories and Heinrich-Hertz-Institut anticipate that this new optical switch will enable use in applications such as the following, as an integral part of next generation ultra high speed photonic networks:

- Ultra high-speed optical data transmission
- Ultra high time resolution optical waveform monitors (high-fidelity optical sampling oscilloscopes)
- Optical regeneration(3)

Fujitsu Laboratories and Heinrich-Hertz-Institut will continue to enhance higher functionality and packaging technologies for this switch, and conduct further research to realize its practical application.

Glossary

(1) highly nonlinear optical fibers: A single-mode optical fiber that has a distinctive structure that increases the nonlinear optical effect. It produces ten times the nonlinear optical effect of conventional optical fibers. In the future, with the use of photonic crystalline fibers and other

nano-optical devices, it is expected that the performance will be enhanced tenfold above current levels.
(2) terabit: Tera is equivalent to 10 to the 12th power. One terabit is equivalent to 1000 gigabits.
(3) Optical regeneration: Technology whereby a degraded optical signal is brought back to its original quality. It consists of Re-amplification, Re-timing, and Re-shaping, and is often referred to as 3R Regeneration.