Simultaneous 3 × 10-Gbps Optical Data Transmission in 1-µm, C-, and L-wavebands Over a Single Holey Fiber for Ultrabroad-Waveband Photonic Transport System

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Abstract: Simultaneous 3 × 10-Gbps error-free photonic transmissions with clear eye-openings are demonstrated in the 1-µm, C-, and L-wavebands by using an ultrabroad-waveband photonic transport system comprising a 3.3-km-long holey fiber transmission line.

OCIS codes: (060.2330) Fiber optics communications, (060.4510) Optical communications, (060.4005) Microstructured fibers, (140.5960) Semiconductor lasers.

1. Introduction

The ever-growing demand for high data transmission capacities necessitates the use of alternative wavebands and the development of methods to enhance the transmission capacities of existing photonic networks. Photonic transport systems in the C- and L-wavebands (C-band: 1530–1565 nm and L-band: 1565–1625 nm) have been extensively employed in conventional photonic networks [1]. Recently, we have focused on the development of a wavelength band shorter than the O-band (O-band: 1260–1360 nm), such as the 1-µm waveband, as a novel and attractive waveband for future photonic transport systems on the basis of the assumption that optical frequency resources greater than few tens of THz can be employed in the 1-µm waveband [2, 3]. Additionally, currently available ytterbium-doped fiber amplifiers (YDFAs) can be used as 1R repeaters in the 1-µm waveband [4]. High-performance and green photonic devices such as high-power lasers, quantum dot lasers [5, 6], YDFAs, and group-IV semiconductor-based high-speed photo-receivers are compatible with the 1-µm waveband.

By combining the 1-µm waveband with a conventional waveband such as the C- and L-wavebands, the expansion of usable optical frequency resources for future photonic network systems can be realized. Therefore, we propose an ultrabroad-waveband photonic transport system that is compatible with both the novel and conventional wavebands. In the proposed system, a developed holey fiber (HF) with a long distance of a few kilometers (typical length: 3.3 km) is used as the novel photonic transmission line for the ultrabroad waveband [7]. In this study, we successfully demonstrate simultaneous 10-Gbps optical data transmissions in the 1-µm, C-, and L-wavebands by using the ultrabroad-waveband photonic transport system.

2. Construction of ultrabroad-waveband photonic transport system

Figure 1 shows the experimental setup for the demonstration of the ultrabroad-waveband photonic transport system. Distributed feedback (DFB) semiconductor laser diodes with wavelengths of 1059.18 nm, 1550.44 nm, and 1569.80 nm were used as the light sources for the 1-µm, C-, and L- wavebands, respectively. Two LN modulators were used

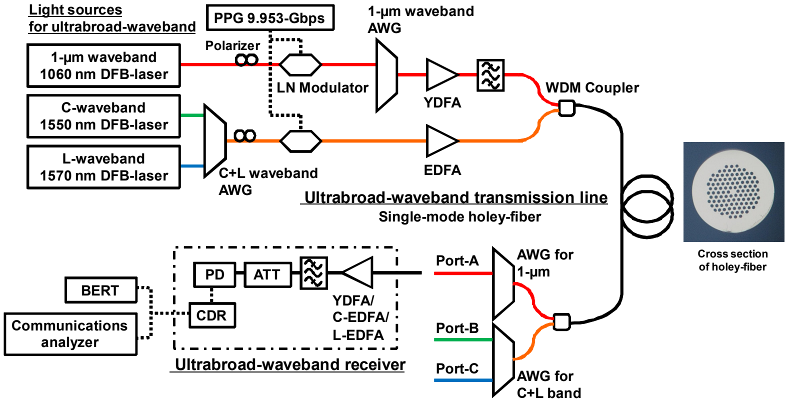

Figure 1 Ultrabroad-waveband photonic transport system with holey fiber as the transmission line

for creating a data stream in the 1-μm, C-, and L- wavebands. In this experiment, a pseudo-random binary sequence (PRBS, length: 2^7-1) data signal of a non-return-to-zero (NRZ) on-off keying (OOK) at 9.953 Gbps (OC-192, STM-64) was generated in each waveband. The modulated optical signal in the 1-μm waveband was amplified by using a YDFA after the optical signal is passed through an arrayed waveguide grating (AWG) device. The modulated optical signal in the C- and L-wavebands was also amplified by using an EDFA after combining the C- and L-wavebands by using the AWG device. These AWG devices are considered to play the role of a MUX for the multi-wavelength optical signals in the 1-μm, C-, and L-wavebands. Two WDM couplers were used at the ends of the transmission line for combining the optical signals of the 1-μm, C-, and L-wavebands. The use of a long-distance optical fiber as the transmission line is crucial to realize the ultrabroad-waveband photonic transport system. Therefore, we adopted a HF as a photonic crystal fiber for the transmission line of the ultrabroad-waveband photonic transport system. We previously reported on 1-μm-waveband photonic transmission over HF or hole-assisted fibers [3, 6]. HF is considered to be suitable for ultrabroad-waveband transmission owing to its endless single mode characteristic. Furthermore, the dispersion characteristics of the HF can be optimized by controlling the size of the holes and their distances from the fiber core [7]. The calculated zero-dispersion wavelength and dispersion value at 1550 nm were approx. 1200 nm and 31.3 ps/nm/km, respectively. The input powers to the WDM coupler of each waveband were fixed at 11.7 dBm (1-μm waveband), 12.2 dBm (C-band), and 8.3 dBm (L-band) in the present transmission experiment. A long-distance (3.3 km) HF was used for the transmission line. The estimated transmission losses of the HF were approx. 1.7 dB/km at 1 μm and 1.2 dB/km at 1.55 μm. The optical signals in the 1-μm, C-, and L-wavebands were separated through the WDM coupler after the transmission. Additionally, the AWG devices of the 1-μm, C-, and L-wavebands were used for a DEMUX operation. In other words, it was expected that the optical signals of each wavelength are clearly separated. The optical signal in the 1-μm waveband was further amplified by using a YDFA after transmission. The optical signals in the C- and L-wavebands were also amplified by using EDFAs. Optical band-pass filters positioned after the YDFAs and EDFAs were used for cutting off the amplified spontaneous emission (ASE) noise of the fiber amplifiers. The optical signals of each wavelength were detected by using a photonic receiver, which was developed by using a broad-waveband photodetector with an electrical clock-data recovery (CDR) circuit. The eye-diagram curves and bit error rate (BER) of the output electrical signal from the photonic receiver were measured by using a communication analyzer and BER tester, respectively. Additionally, the optical spectra before and after the transmission were also observed by using an optical spectrum analyzer (OSA).

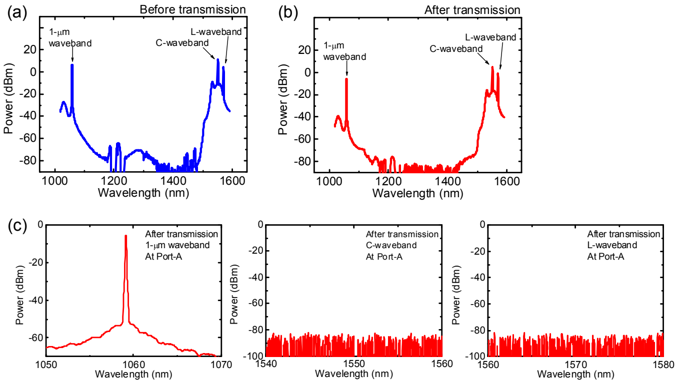

Figure 2 Optical spectra (a) before and (b) after transmission, and
(c) optical spectra in 1-μm, C-, and L-waveband at the receiving port-A of the 1-μm waveband

3. Transmission characteristics of ultrabroad-waveband photonic transport system

Figures 2 (a) and (b) show the optical spectra before and after the transmission line, respectively, in a wide wavelength range. Three peaks of the optical signals are clearly observed at the wavelengths of 1059.18 nm, 1550.44 nm, and 1569.80 nm, before and after transmission. The observation of these three peaks indicates that simultaneous photonic transmissions in the 1-μm, C-, and L-wavebands can be achieved over the HF transmission line. Figure 2 (c) shows an optical spectrum at the receiving port-A of the 1-μm waveband illustrated in Fig. 1. The peak at 1059.18 nm is also clearly observed at port-A. On the other hand, no peaks are observed at the receiving port-A in the wavelength range of the C- and L-wavebands. That is, it is expected that the cross-talk between the 1-μm and C- and L-wavebands is less than –70 dB. It is also confirmed that no cross-talk (<–70 dB) is observed at the receiving ports-B and -C shown in Fig. 1.

Figure 3 shows the eye-diagrams before and after transmission in the 1-μm, C-, and L-wavebands. After the transmission, clear eye-openings of the 9,953-Gbps signals can be observed in all the three wavebands. The dependencies of bit error rate (BER) on the received optical power in the 1-µm, C-, and L-wavebands are shown in Figures 4 (a), (b), and (c), respectively. A BER of less than 10^{-9} was clearly observed when the PRBS optical data signal at 9.953 Gbps was transmitted over the 3.3-km-long HF in the 1-µm, C-, and L-wavebands. Power penalties between the 3.3-km-long transmission line and the back-to-back are found to be 1.94 dB in the 1-µm waveband, 1.45 dB in the C-waveband, and 1.40 dB in the L-waveband. From these results, simultaneous and error-free 10-Gbps photonic transmissions over the 3.3-km-long HF are demonstrated in the 1-µm, C-, and L-wavebands. Additionally, it is believed that a transmission distance of this transport system may reach >10-km long, since a transmission loss will be decreased with further development of the HF in near future.

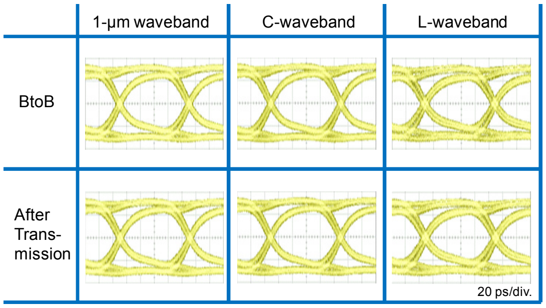

Figure 3 Eye diagrams before and after transmission in the 1-µm, C-, and L-wavebands.

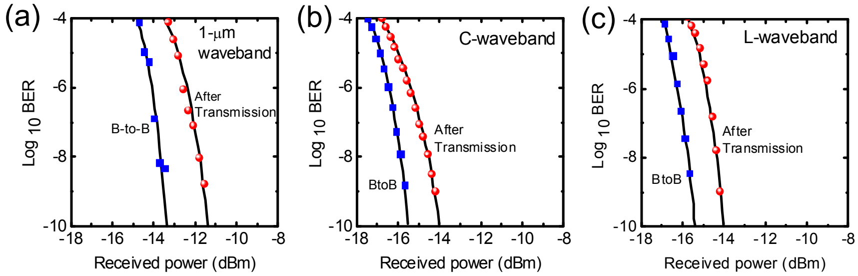

Figure 4 BERs vs. received power of 1-µm, C-, and L-wavebands.

4. Conclusion

We proposed an ultrabroad-waveband photonic transport system in order to expand usable optical frequency resources for enhancing the capacity of future photonic networks. We also proposed the use of a 1-µm waveband in the photonic transport system since the ultrabroad optical frequencies in its waveband are expected to have the potential to realize next-generation photonic networks. Simultaneous 10-Gbps photonic transmission in the 1-µm, C-, and L- wavebands was successfully demonstrated over a single and long HF transmission line. Clear eye-openings and error-free transmissions were successfully achieved in the 1-µm, C-, and L-wavebands. Additionally, low cross-talks (<–70 dB) were observed between the 1- µm and the C- and L-wavebands.

We believe that the demonstrated ultrabroad-waveband photonic transport system using the HF transmission line will represent a breakthrough in pioneering the usable optical frequency resources in ultrabroad wavebands such as the 1- to 1.6-µm wavebands.

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