Full-Duplex Demonstration of Asynchronous, 10Gbps x 4-user DPSK-OCDMA System using Hybrid Multi-port and SSFBG En/Decoder

Nobuyuki Kataoka(1), Naoya Wada(1), Xu Wang(2), Gabriella Cincotti(3), Tetsuya Miyazaki(1), and Ken-ichi Kitayama(4)
1 : National Institute of Information and Communications Technology
4-2-1, Nukui-Kitamachi, Koganei-shi, Tokyo 184-8795, Japan, (e-mail: n_kataoka@nict.go.jp)
2 : Heriot-Watt University, 3 : University of Roma Tre, 4 : Osaka University

Abstract

We experimentally demonstrate error-free (BER<10^{-9}) transmission of full-duplex, asynchronous, 10Gbps x 4user DPSK-OCDMA system on same wavelength using hybrid multi-port and SSFBG en/decoder.

Introduction

In future access networks, a symmetric multi-Gigabit fiber-to-the-home (FTTH) service is required to meet the needs of future applications (p-to-p, etc.) [1]. Current time division multiple access (TDMA)-based PON system would be difficult to simultaneously provide all the customers with a gigabit-class bandwidth uplink, due to the nature of the timeslot-based multiple access protocol. Optical code division multiple access (OCDMA) is one promising candidate for gigabit-symmetric FTTH [1-2]. It has unique features of full asynchronous transmission, low latency access, soft capacity on demand as well as optical layer security. There are two different approaches for the multi-user coherent OCDMA system: synchronous and asynchronous OCDMA. In the synchronous OCDMA, proper timing coordination is required to carefully avoid the overlaps between signal and interferences [3-4]. In contrast, the asynchronous capability is essential in practical OCDMA systems [1-2, 5]. Recently, for the coherent time-spreading (TS-) OCDMA, the multi-port OCDMA encoder/decoder has the unique capability of simultaneously processing multiple time-spread optical codes (OCs) with single device [6], which makes it a potential cost-effective device to be used in the optical line terminal (OLT) of an OCDMA network to reduce the number of encoder/decoders [2]. Meanwhile, the phase-shifted superstructured fiber Bragg grating (SSFBG) encoder/decoder is another attractive TS-OCDMA encoder/decoder, which has the ability to process ultra-long TS-OC with polarization independent performance, low and code-length independent insertion loss, compactness as well as low cost for mass production [7]. Hybrid using different types of the encoder/decoder in an OCDMA network is expected to significantly improve the system flexibility and performance [8]. Very recently, we have successfully demonstrated a field trial of duplex, fully-asynchronous, 10 Gbps, differential phase shift keying (DPSK-) OCDMA system [9]. However, it’s not full-duplex but separate fibers were used for the up- and down-link.

In this paper, we experimentally demonstrate error-free (BER<10^{-9}) transmission of full-duplex, asynchronous, 10-Gbps x 4-user DPSK-OCDMA system on the same wavelength using hybrid a single multi-port en/decoder at the OLT and SSFBG en/decoders at each ONU without the optical thresholding, polarization multiplexing, and FEC for the first time.

Experiment of full-duplex OCDMA system

Figure 1 shows the experimental setup and results of the full-duplex OCDMA system. Each ONU consists of an OCDM transmitter/receiver (Tx/Rx), the SSFBG en/decoder, circulators, and a 3 dB coupler. The OCDM Tx mainly consists of a mode-locked laser diode (MLLD), a $LiNbO_3$ phase modulator (LN-PM), and erbium-doped fiber amplifiers (EDFAs). The MLLD generated 2.0 ps optical pulses at the repetition rate of 10.3125 GHz with the central wavelength of 1551 nm. The generated signal was modulated with the DPSK format by the LN-PM. The data were 2^{23}-1 pseudo random bit sequence (PRBS) as shown in Fig. 1 (i, vii). An OCDM Rx consists of a fiber based interferometer and a dual-pin photo diode that perform the DPSK detection. In this experiment, we used the clock-and-data recovery (CDR) circuit and the error detector (ED) after the DPSK detection for the bit error rate (BER) measurement. On the other hand, the OLT consists of OCDM Txs/Rxs, the multi-port optical en/decoder, and a 3 dB coupler.

In downlink, we employed 2 OCDM Txs, which were asynchronously driven, at OLT. Each Tx output was split into 2 branches in a truly-asynchronous manner with equal power, random delay, random bit phase and launched into the multi-port encoder, which simultaneously generates four 16-chip (200 Gchip/s) OCs as shown in Fig. 1 (ii). These 4 OCDMA signals were multiplexed (as shown in Fig. 1 (iii)) and then launched into 50 km transmission fiber, which was composed of a fiber pair of a single mode fiber (SMF) with a reversed dispersion fiber (RDF). After the fiber transmission, these OCDMA signals were split into 4 ONUs. Total loss budget from the OCDM Tx at the OLT to Rx at each ONU was 25 dB, including 3 dB

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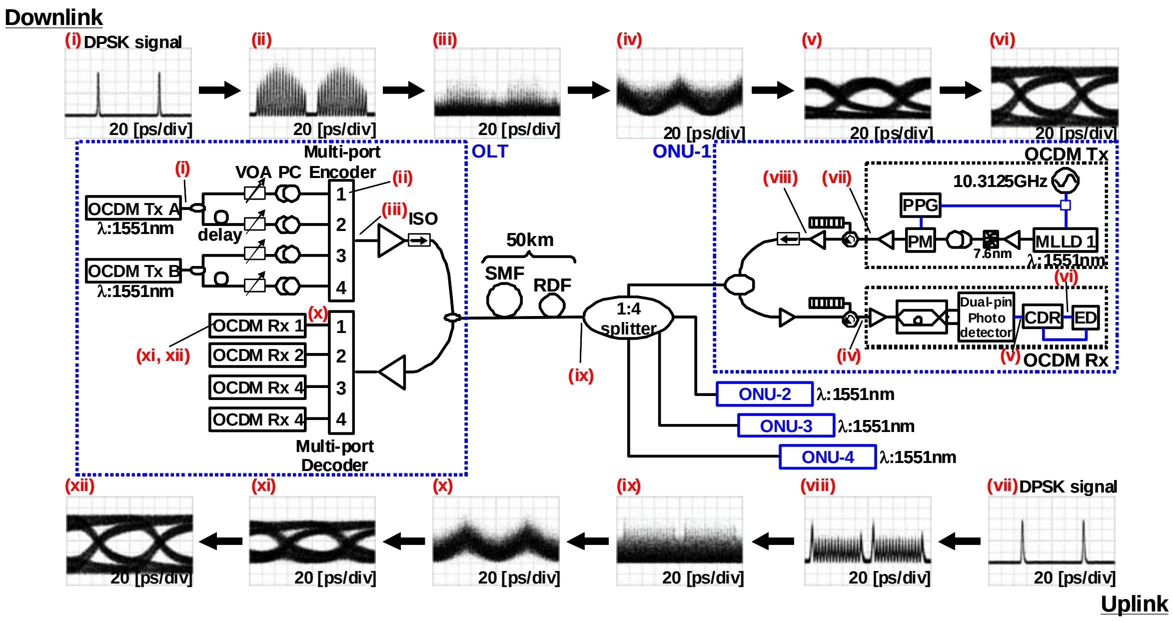

Figure 1: Experimental setup and results.

couplers, connectors, 50 km fiber, and the passive splitter. At each ONU, the received signal was decoded by the 16-chip, 16-phase-shifted SSFBG decoder as shown in Fig. 1 (iv). The decoded signal was detected by the OCDM Rx. Insets (v, vi) in Fig. 1 show the eye diagrams of signals after the DPSK detector and CDR, respectively. Finally, we measured BER performances.

In uplink, we employed 4 OCDM Txs. It can be fully-asynchronous transmission for 4 users. These outputs were launched into 4 different SSFBG encoders, which were the same codes as downlink, respectively. Inset (viii) in Fig.1 shows the waveform of the generated OC. The 4 OCDMA signals were asynchronously multiplexed as shown in Fig. 1 (ix), and then launched into 50 km fiber. At the OLT, the 4 OCDMA signals were decoded by the multi-port decoder simultaneously. The decoded signal was detected the same method as downlink case. Insets

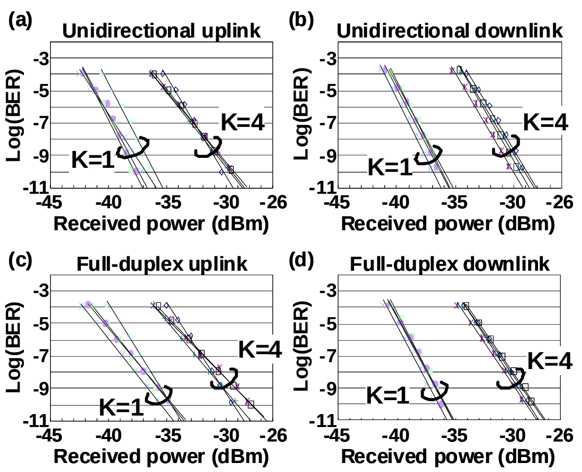

Figure 2: BER performances after 50 km transmission (a) unidirectional uplink, (b) unidirectional downlink, (c) full-duplex uplink, and (d) full-duplex downlink.

(x, xi, and xii) in Fig. 1 show the eye diagrams of signals after the OCDM decoder, DPSK detector, and CDR, respectively.

Figures 2 show BER performances of down- and up-link after 50 km fiber transmission in case of unidirectional and full-duplex. Error free (BER<10^{-9}) transmission has been achieved for all the users of all channels after 50 km transmission. The power penalties of up- and down-link BERs between unidirectional and full-duplex were 1.0 and 0.6 dB in average, respectively. They were caused by back reflected noises resulting from connectors, couplers, and other optical devices.

Conclusions

We have experimentally demonstrated error free (BER<10^{-9}) transmission of full-duplex, fully-asynchronous, 10Gbps x 4-user DPSK-OCDMA system on the same wavelength using hybrid multi-port and SSFBG en/decoder. A key enabler for cost-effective configuration is full-duplex. A promising deployment scenario would be to overlay this full-duplex OCDMA system onto existing WDM PON system for the system scale-up on demand [1].

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