

Dispersion-Compensation-Free, Long-Reach OCDMA-PON System with Passive Remote Node at Arbitrary Position using Single Multi-port Encoder/Decoder

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Abstract: We propose flexible, long-reach OCDMA-PON system, which deploys a remote node with single multi-port E/D. 10Gbps, 4-user, OCDMA transmission both up- and down-link are experimentally demonstrated over 59km SSMF without inline dispersion compensation.

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1. Introduction

Optical code division multiple access (OCDMA) is one promising candidate for the next generation FTTH system [1]. It has unique features of full asynchronous transmission, low latency access, soft capacity on demand as well as optical layer security. Recently, for the coherent time-spreading (TS-) OCDMA, the multi-port OCDMA encoder/decoder (E/D) has the unique capability of simultaneously processing multiple time-spread optical codes (OCs) with single device, 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 E/Ds [2]. Meanwhile, the phase-shifted superstructured fiber Bragg grating (SSFBG) E/D is another attractive TS-OCDMA E/D for the optical network unit (ONU) because it has the polarization independent performance, low and code-length independent insertion loss, compactness as well as low cost for mass production [3]. Therefore, hybrid using different types of the E/D in an OCDMA network is expected to significantly improve the system flexibility and performance [4, 5]. However, in all these experiments, the total chromatic dispersion of the transmission fiber is almost zero using a pair of a standard single mode fiber (SSMF) and a dispersion compensation fiber (DCF). In the real system, it is difficult to provide the dispersion compensation for each user because of its high cost and complexity. In addition, the future optical access system will expect to support the long-reach over 60 km SSMF transmission.

In this paper, we propose the flexible, long-reach OCDMA-PON system, which deploys a remote node (RN) with a multi-port E/D between OLT and ONU. With this configuration, 10 Gbps, 4-user, OCDMA transmission both up- and down-link are experimentally demonstrated over 59 km of the SSMF without inline dispersion compensation for the first time.

2. Configuration and demonstrations

Figure 1 shows the configuration of the proposed long-reach OCDMA-PON system. A RN with single multi-port E/D is deployed between OLT and ONUs instead of an optical passive splitter. It is used as a decoder and splitter for the downlink and as an encoder and combiner for the uplink. Therefore, each ONU does not need any E/D. It can reduce costs and devices. In the demonstration, we use 16-chip, 16-level phase-shifted OCs, which correspond to the OCs generated from the 16x16-port encoder with input 1, 5, 9, 13 ports, output port 8, respectively. The duration of the generated OCs is ~80 ps (chip-rate: 200 Gchip/s). In other words, each OC has 200 GHz (1.6 nm) spacing spectrum component. Therefore, to transmit the SSMF, each OC is susceptible to the chromatic dispersion due to the difference between each spectrum component. To solve this issue, we employ a rectangular shape optical band pass filter (OBPF) after the encoder to extract only one spectrum component from OC to reduce the chromatic dispersion effect.

Figures 1 (i, ii) show the experimental setup of down- and up-link transmission, respectively. In downlink, a mode-locked laser diode (MLLD) generated 1.8 ps optical pulses at the repetition rate of 10.71 GHz with the central wavelength of 1551 nm. The generated signal was modulated by a LiNbO₃ intensity modulator (LN-IM). The frame contains 2³¹-1 pseudo random bit sequence (PRBS) payload and forward error correction (FEC) parity. Please note that the use of FEC at 10Gbps in FTTH systems will likely become a real-world scenario because of the low-cost. The FEC is Reed-Solomon code (RS(255, 239)). The data rate is 10.71 Gbps (10 G for payload + 7% FEC overhead). The generated data was split into 4 branches in a truly-asynchronous manner with equal power, random delay, and random bit phase, and launched into multi-port encoder, which generates 16-chip (200 Gchip/s), 16-level-phase-shifted OCs. For investigating the system performance in the worst scenario where the interference becomes

most serious, polarization controllers (PCs) were placed to align the polarization states of all the signals. These 4 signals were multiplexed and then passed through a tunable OBPF (TOBPF) (Alnair Labs.: BVF-100), which is set to 2.1 nm bandwidth. These OCDM signals were launched into 36 km SSMF and decoded by the multi-port decoder at the RN. The decoded signals from the different output-port of decoder were transmitted over 23 km SSMF and detected by an O/E converter at each ONU. For the bit error rate (BER) measurement, the detected signal was recovered by the clock-and-data-recovery (CDR) circuit and forwarded to the error detector (ED). On the other hand, in uplink 10.71 Gbps PRBS signals from each ONU were transmitted over 23 km SSMF and encoded by multi-port encoder at the RN. At the same time, these encoded signals were multiplexed, and then launched into 36 km SSMF. At the OLT, the transmitted signals were decoded and measured BER as well as downlink case. Insets in Fig. 1 (i) and (ii) show waveforms at each point in case of down- and up-link.

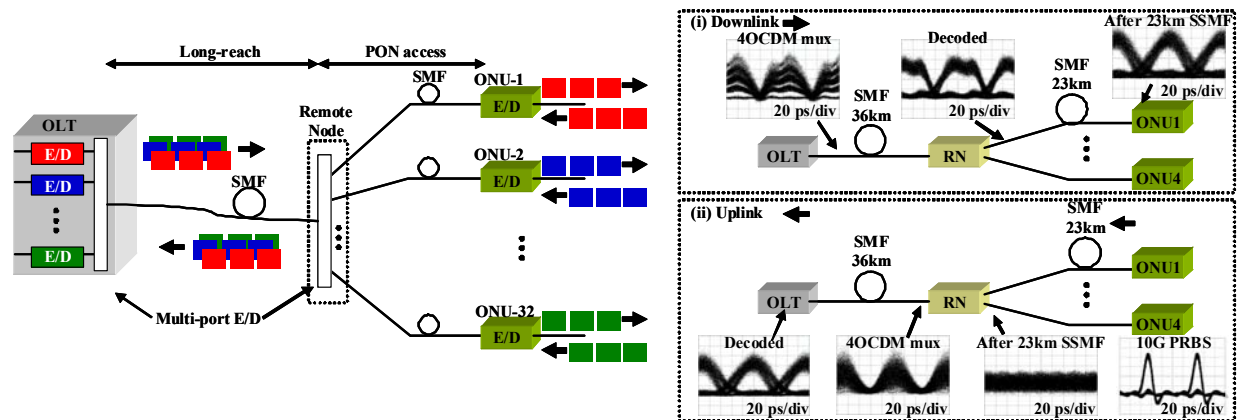


Fig. 1. Configuration of proposed long-reach OCDMA-PON system and experimental setups and results: (i) downlink and (b) uplink.

Figure 2 (a) shows the measured total chromatic dispersion of the SSMF. The total chromatic dispersion at 1551 nm is around 1190 ps/nm. Figures 2 (a) and (b) show the measured BERs in case of (b) downlink and (b) uplink with/without FEC, respectively. Error free ($\text{BER} < 10^{-9}$) transmissions have been achieved for all codes of both down- and up-link with FEC, respectively.

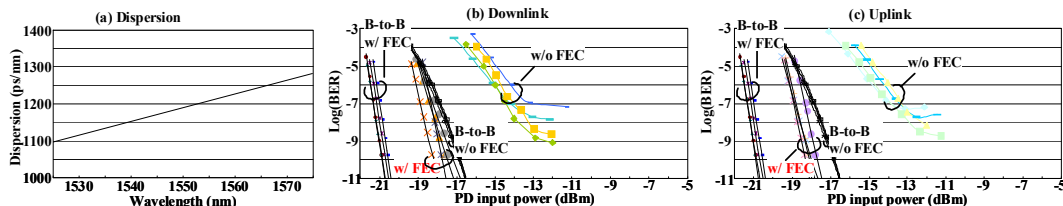


Fig. 2. (a) Total chromatic dispersion of the 59km SSMF and measured BER results (b) downlink and (b) uplink.

3. Conclusion

We have proposed the flexible, long-reach OCDMA-PON system, which deploys a RN with a multi-port E/D between OLT and ONU. Error free transmission of asynchronous, 4-user, 10 Gbps OCDMA system both up- and down-link are experimentally demonstrated over 59 km of the SSMF (long-reach: 36 km, PON-access: 23 km) without inline dispersion compensation for the first time.

4. References

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