Demonstration of 2.5Gbps SPE-OCDMA transmission using time domain spectral phase en/decoding with LCFBG

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Abstract-Novel time domain spectral phase encoding/ decoding scheme using LCFBG was experimentally demonstrated for 16chips, 40GHz/chip optical codes. Error free transmission over 50km with 2.5Gbps OOK data has been successfully achieved.

Introduction

Optical code division multiple access (OCDMA) technique is very attractive for broadband multiple access network. Hybrid OCDMA/WDM can provide a solution for future gigabit-symmetric FTTH system [1].

The coherent OCDMA that the encoding/decoding operations are performed based on the amplitude/phase of optical field is now receiving increasing attention with the progress of reliable en/decoder devices. In the spectral phase encoding time spreading (SPECTS) OCDMA system, the short pulse is encoded by spectral phase encoder to give a phase shift pattern to its spectral components resulting pulse spreading in time domain [2]. The decoding is to give the complementary phase shift pattern to the corresponding spectral components by the proper spectral phase decoder to recover the original signal. Generally, the wavelength stability requirement of the laser source and spectral phase encoder/decoder is very stringent for the sake of spectral efficiency in the SPECT-OCDMA systems [3].

Recently, we proposed a novel time domain spectral phase encoding OCDMA scheme, and experimentally demonstrated 16chips, 20Gchip/s SPE by using a pair of dispersive fibers and a high speed phase modulator [3]. This technique is very robust to the wavelength drift of the laser source which exists in the common SPECT-OCDMA system. However, using dispersive fibers in the scheme is not very desirable because of the high insertion loss, and poor compactness. Moreover, the stretched SPE signal can be longer than one bit duration that will degrade the performance, therefore, an optical filter is needed to cutoff the tail of the input spectrum to avoid the significant overlap between two adjacent stretched SPE signals and improve the performance [3].

Linearly chirped fiber Bragg grating (LCFBG) can be used in the time domain SPED scheme and has the advantages of good compactness, low insertion loss, serving as dispersive component as well as an optical filter simultaneously to cut the residual spectrum [4]. In this paper, we demonstrate the generation and recognition of different 16chips, 40GHz/chip spectral phase encoded optical codes using time domain SPED scheme with LCFBG and transmit the 2.5Gbps SPE-OCDMA signal over 50 km fiber with BER<10^{-9}.

Encoding/decoding experiment

Figure 1 shows the experimental setup. The 1.9ps optical pulse trains with center wavelength of 1550.28nm was generated by a mode locked laser diode (MLLD) at repetition rate of 10GHz. An intensity modulator (IM) driven by a 2^7-1 pseudo random bit sequence (PRBS) data was used to modulate the signal and generate 2.5Gbps OOK data.

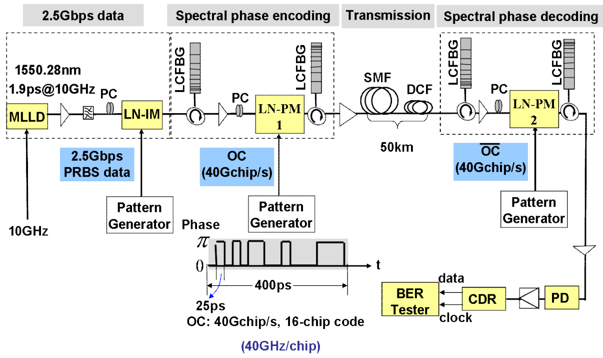

Fig.1 Experimental setup of the SPED scheme using LCFBG

Figures 2 (a) and (b) show the spectrum and auto-correlation trace of the original 2.5GHz pulse trains, respectively. The pulse width of the input pulse is about 1.9ps which covers ~6nm spectral range. A LCFBG with 3dB bandwidth of ~4.5nm and dispersion slope of about -80ps/nm was used to stretch the input optical pulse. Different spectral component will be spread into different position in time domain (4.5nm bandwidth corresponds to ~360ps after stretching). Fig. 2(c) shows the spectrum of the stretched pulse after the LCFBG. The spectral components outside the LCFBG's reflection bandwidth have been cutoff to avoid the overlap between adjacent stretched pulses to improve coding and transmission performance (without this filtering, the 6nm bandwidth will be spread over 480ps time span that induces overlap between the adjacent stretched pulses). [3]. Fig.2 (d) shows the waveform of the stretched pulse which exhibits similar profile with the spectrum. The stretched pulse spread over ~360 ps time span that is smaller than one bit duration of 400ps due to the cutoff

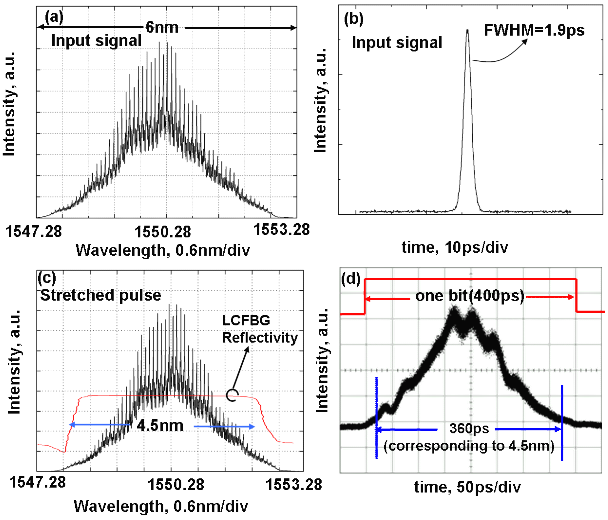

Fig.2 Spectrum (a) and auto-correlation trace (b) of the input pulse before LCFBG, and spectrum (c) and waveform (d) of the stretched pulse after LCFBG

of the LCFBG. A phase modulator driven by 16 chips, 25ps/chip (40Gchip/s) optical code patterns (corresponding to 16chips, 40GHz/chip spectral code patterns) then phase modulates the stretched optical pulse. By adjusting the optical delay, the optical code pattern can precisely modulate the desired spectral component of the stretched pulse. The second LCFBG with opposite dispersion was used to compress the stretched pulse and generate the SPE signal. The decoding section has the same configuration as the encoding part but the phase modulator was driven by the complementary code $\overline{OC}$.

We have tested five different optical codes OC1~OC5 patterns in the experiment: 111000100110101, 1010101010101010, 1111000011110000, 11111111 00000000 and 1110101100100010. Figure 3 shows the spectrum (upper trace) and waveform (middle trace) of the encoded signal, and the waveform of the decoded signal (lower trace) for the five codes. The decoded signals exhibit well defined auto-correlation peak with pulse width of ~2.49ps, 2.32ps, 2.57ps, 2.57ps and

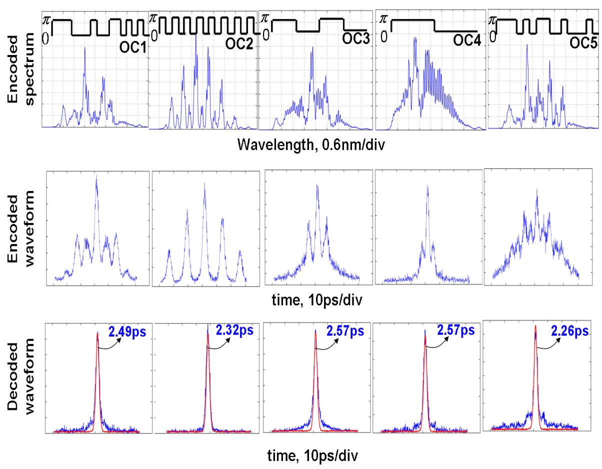

Fig.3 Encoded spectrum (upper row), waveform (middle row) and decoded waveform (lower row) for five codes

2.26ps, respectively. The red lines in each figure of the lower trace are for the original input pulse. The broadening of the decoded pulse is negligible in the experiment which verifies the excellent decoding performance of the SPED scheme with LCFBG.

OOK data transmission experiment

In the transmission experiment, 2.5Gbps 2^7-1 PRBS OOK data was generated by the intensity modulator before the SPE. A span of single mode fiber (SMF) and dispersion compensation fiber (DCF) with total length of about 50km was used as the transmission fiber. The correctly decoded signal was detected by a photon diode (PD) followed by a 2.5GHz clock and data recovery circuit (CDR). We have tested all the five optical codes in the experiment and the measured bit-error-rate (BER) for the back-to-back (B-to-B) and transmission cases are shown in Figure 4, from which we can see the BER performance for all the codes are almost identical. Error free transmission (BER<10^{-9}) has been achieved for all the codes that demonstrate the feasibility of our proposed time domain SPED scheme using LCFBG for OCDMA application. The power penalty is about 0.6dBm after 50 km transmission comparing to B-to-B.

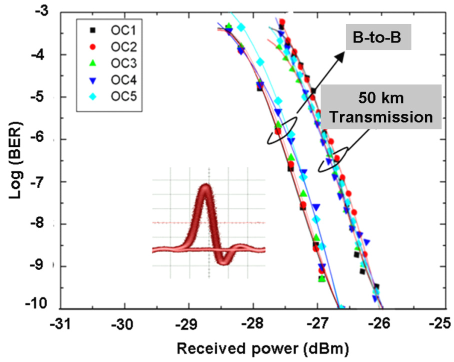

Fig.4 BER performance for different optical codes

Conclusions

The proposed time domain SPED scheme uses LCFBG as the dispersive component as well as an optical filter to improve the coding and transmission performance. It is also very compact and compatible with the optical fiber system. In the experiment, 16chips, 40GHz/chip SPE optical codes have been generated and recognized correctly using the proposed scheme. 50km error-free transmission for 2.5Gbps PRBS OOK data has been successfully demonstrated. This scheme can be applied to OCDMA system to improve the flexibility and security.

References

1. K. Kitayama, X. Wang, and N. Wada, J. Lightw. Technol, 24(4): 1654~1662(2006)
2. Andrew M. Weiner, Zhi Jiang and Daniel E. Leaird, Journal of optical networking, 6(6): 728~755(2007)
3. Xu Wang and Naoya Wada, Optics Exp. 15(12): 7319~ 7326 (2007)
4. Xu Wang and Naoya Wada, ECOC 2008, P.3.11, 5:121~122, September, Brussels, Belgium.