

A Flexible Fiber Access Network using Superchannel Coherent Optical Orthogonal Frequency Division Multiplexing

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Abstract— We report the feasibility of 100 Gbps per channel QPSK signal transmission to employ the concept of flexible network on fiber access network by using polarization division multiplexed coherent optical orthogonal frequency division multiplexing (PDM-CO-OFDM) based superchannel signal, self-coherent detection and incorporated with wavelength selective switch (WSS), which is replaced the passive optical splitter in an installed FTTx network in order to respond the various demand from different optical network units (ONUs). The computer simulation results of transmission over c-band demonstrate the achievable bit rate and over the maximum performance of switching characteristic at 16 symbol and 15 ps under BER 10^{-4} , consecutively.

Keywords— optical fiber transmission, coherent optical orthogonal frequency division multiplexing (CO-OFDM), flexible network, superchannel, optical coherent detection, polarization division multiplexing (PDM), digital signal processing (DSP), fiber access network.

I. INTRODUCTION

In this present, communication technology has more demand using bandwidth from the user and the advance of technology which higher efficiency for support the several of using such as respond the demand of technology ultra high definition (4K) and super hi-vision (8K) video transmission. Plus, The Telemedicine is another one of communication technology that will be the important role soon. Hence, passive optical network (PON) can respond the demand of subscribers because it can grant the data rate at 10 Gbps from 10GE-PON (IEEE) and XG-PON (ITU-T) standard [1, 2]. Nowadays, downstream and upstream from NG-PON2 (ITU-T) standard [3] can grant the data rate of 40 Gbps and 10 Gbps, consecutively. In fact, there is an available bandwidth at 12.5 THz. The transfer of data in high quality but there is a limited of bandwidth, so it has to design each of signal channels very closely.

There are 2 types of the OFDM modulation via single mode fibers. First, direct-detection optical OFDM [4] use the non-complicated receiver for making the channel spacing equals to the Nyquist frequency. The number of bit per

symbol depend on the modulation that make the channels have space less and the numbers of channel are increasing. Second, coherent optical OFDM [5] became the important path to transfer the signal operate with the polarization-division multiplexing (PDM) which enhance the bandwidth efficiency to be more than double. The channel of coherent optical OFDM is sine function which each of them includes many subcarriers overlapping. [6] By the way, the chromatic dispersion and polarization mode dispersion [7] can be compensated by electrical digital signal processing (DSP) [8].

In this work, we studied about the parameters that make performance limit over C-band by observing the number of symbol and switching characteristic of WSS. We demonstrate that our fiber access network can achieve the number of symbol and switching characteristic at 16 symbol and 15 ps over C band for the 100-Gbps per subscriber based PDM-CO-OFDM signal using self-coherent detection and WSS, by the assistance of the optical coherent detection followed by the off-line DSP.

II. CO-OFDM SYSTEM CONCEPT

There are many types of CO-OFDM cooperate with wavelength selective switch (WSS). For instance, a flexible grid WSS has a function about filter and spectrum equalizer [9]. In case, using it with higher rate of data at 40 Gbps or 100 Gbps can use the channels together. In this paper, the system using a self-coherent detection instead of local oscillator (LO) reduces the cost of subscriber receiver cooperate with active WSS for select or transfer the wavelength as many as the supported users over CO-OFDM superchannel.

In Figure 1, the CO-OFDM transmitter, located at OLT, generates CO-OFDM signal. The bit rate is sent at 100 Gbps per channel and is coded at symbol mapping. Afterwards, the discrete CO-OFDM signals are generated by using inverse fast fourier transform (IFFT) process. They are converted back to serial signal at digital to analog conversion (DAC). Then, the radio frequency (RF) of the signal is electrically modulated by up-conversion and used I/Q modulator to form CO-OFDM signal using two external mach-zehnder modulators (MZM).

Then, the signals transmit through the single-mode fiber (SMF) ITU-T G.652.D. A WSS replaces the passive optical splitter in PON in order to respond the different bandwidth for the various demands of optical network units (ONUs), the WSS is controlled and optimized the channel and bandwidth allocation by a dynamic wavelength and bandwidth allocation (DWBA) algorithm. The CO-OFDM signal must switch at the border of the symbolic CO-OFDM signal. For example, the first subscriber needs to download the large files, and then WSS allocate the 16 symbols to the user. The second subscriber needs to download the small files which request the bit rate less than the first user. WSS provide 4 symbols to the second user. Each user would receive the difference amount of wavelength and symbol. It depends on the demand of the bit rate in each user. Finally, the CO-OFDM signal is allocated to all ONUs for different services.

In terms of the receiver, we extract carrier signal form CO-OFDM signal by using band pass filter. The coherent receiver can detect the signal for demodulation CO-OFDM and transfer to the DSP for solving the dispersion of signal. Next, decode the signal at symbol mapping. Finally, change back to the serial signal and calculate bit error rate (BER) by eye-diagram analyser.

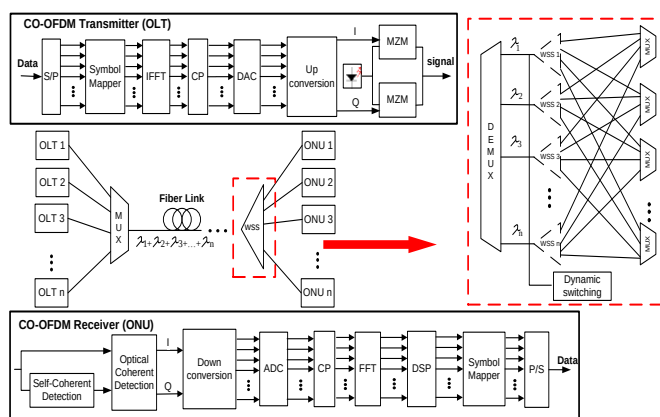


Figure 1. Configuration of CO-OFDM Transmission

III. SIMULATION SET UP

We analyse limitation of the PDM-CO-OFDM system performance by OptiSystem software as shown in Figure 2.

The system which transfers the signal by PDM-CO-OFDM is shown in Figure 2. The signal that transfers into the both axis of CO-OFDM signal transmission is generated by continuous-wave (CW) laser. It is modulated the quadrature phase shift keying (QPSK) with the data rate of 100 Gbps per channel, sequence length at 8192 bit, and uses polarization splitter to separate the signal transfer to the axis.

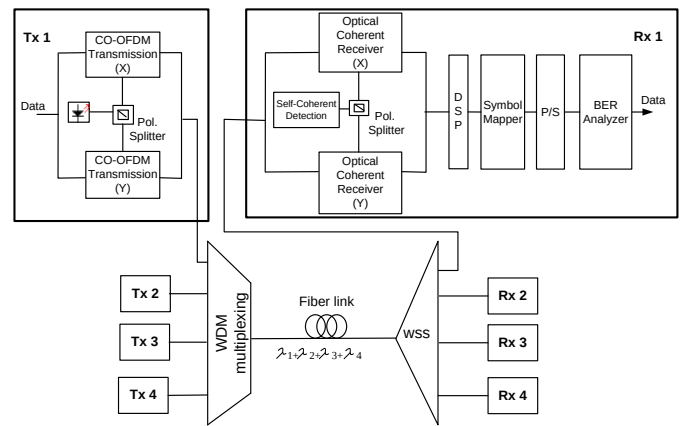


Figure 2. PDM-CO-OFDM system

Then, CO-OFDM signal are created by IFFT at the different numbers of subcarrier those are 128, 256, 512 and 1024 which shown in Table 1 and no cyclic prefix. Then, up-conversion modulates RF at 50 GHz. After that, multiplexing will combine all the signals by WDM multiplexing and de-multiplexing will spilt them to each ONUs by WSS. WSS is controlled by the dynamic switching for transferring many wavelengths from SMF to the users.

At the receiver, the optical coherent detection converts CO-OFDM signal to electrical signal following by balance detection with thermal noise at $12.83 \text{ pA}/\sqrt{\text{Hz}}$ and dark current at 10 nA. Then, down-conversion modulates RF at 50 GHz. Finally, the DSP compensates dispersion which neglect the polarization mode dispersion (PMD) and nonlinearity effect because the transmission transmits short distance in access network.

TABLE 1. PARAMETERS OF WSS FOR PDM-CO-OFDM

Number of symbol	Sequence length (bit)	Number of subcarrier
4	8192	1024
8	8192	512
16	8192	256
32	8192	128

IV. SIMULATION RESULTS

Figure 3 shows the relativity between BER and receive power for wavelength at 1525 nm. From the simulation results of PDM-CO-OFDM cooperate with WSS. There are many kinds of WSS, so we selected 4 types which shown in Table 2. The main parameter which limits performances at 1525 nm is

attenuation. It can compensate all dispersion by DSP. Therefore, the result of CO-OFDM transmission, which has 8 symbols and less time constant, has the transmittal performance over wavelength at 1525 nm of Back-to-Back and fiber better than the high time constant under BER 10^{-4} . The best sensitivity of receiver optical power is -22.11 dBm for Back-to-Back and -21.9 dBm for fiber.

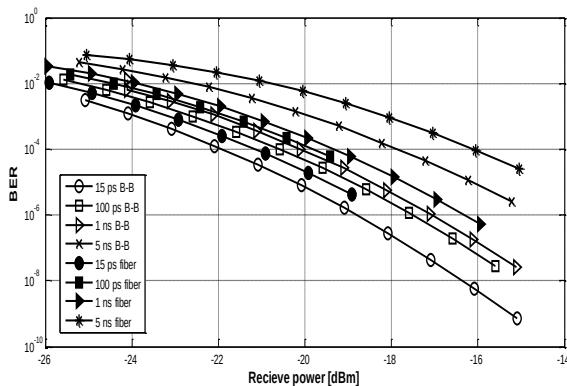


Figure 3. The relativity between BER and receive power for wavelength at 1525 nm.

TABLE 2. TYPES OF WSS

Sequence length (bit)	time constant
GaAs photonic crystal cavity	15 ps
GaInAs/InP multiple quantum well switch (MQW)	100 ps
semiconductor optical amplifier (SOA)	1 ns
electro-optic	5 ns

From the result as shown in Figure 3, the time constant at 15 ps has the highest efficiency for switching the signal faster than the others. Figure 4, shown the relativity between BER and receive power for GaAs photonic crystal cavity at 1525 nm. We found that transmission of the bit rate at 100 Gbps per subscriber use the numbers of symbol such as 4 symbols, 8 symbols, 16 symbols and 32 symbols. It should be noted that the wavelength at 1525 nm can sent the maximum of symbol at 16 symbols which the sensitivity of receiver optical power is -21.4 dBm for Back-to-Back under BER 10^{-4} .

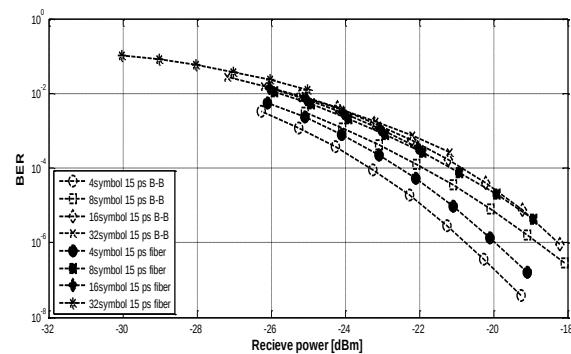


Figure 4. The relativity between BER and receive power for GaAs photonic crystal cavity wavelength at 1525 nm.

V. CONCLUSIONS

We have studied a PDM-CO-OFDM signal transmission using the self-coherent detection cooperated with the WSS. By simulation results, we show that the achievable data rate of 100 Gbps per channel. In our single network was massively completed the number of symbol and switching characteristic at 16 symbol and 15 ps. The main point of the performance limitation was caused by the maximum loss wavelength at 1525 nm (c-band), this can support for different maximum data rates of 100 Gbps per channel of a fiber access network by the concept of the flexible network.

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