Field trials of WDM/OCDMA

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Abstract: Wavelength division multiplexing/optical code division multiple access (WDM/OCDMA) systems have been demonstrated in field trials in downtown Tokyo area. Multiport and SSFBG encoder/decoders, and DPSK modulation are key enabling techniques.

Keywords: Optical communication, Wavelength division multiplexing, Optical code division multiple access, field trial

Introduction

The rapid traffic growth in access network driving by triple play services creates the demand for abundant uplink bandwidth. Therefore, a high bit rate uplink is a requisite in order to meet the bandwidth requirements, leading to a proposal of Gigabit-symmetric FTTH [1].

In time-division-multiplexing (TDM) based passive optical network (PON), it would be difficult to provide gigabit class bandwidth with the uplink simultaneously to all the customers due to the nature of time-slot-based multiple access technique.

Wavelength division multiple access (WDMA) based PON solves the bandwidth scarcity problem of TDMA PONs by creating point-to-point links between OLT and each user. However, the number of the wavelengths is not sufficient for the multiple access system.

Optical code division multiple access (OCDMA) technique, which allows multiple users share the same transmission media by assigning different optical codes (OCs) to different users, is an attractive candidate for next generation broadband access networks. The OCDMA over WDM PON could be one promising solution to the symmetric high capacity access network with high spectral efficiency, cost effective, good flexibility and enhanced security [1]. Figure 1 shows the architecture of OCDMA over WDM PON, where OCDMA channels are overlaid on WDM grids. On each WDM grid λ_n (n=1,...,N), M users can be accommodated by individually assigning each user with a different OC_m (m=1,...,M). The same code sequence OC_m can be reused on all the WDM channels. The total number of users which can be accommodated in the PON becomes NxM.
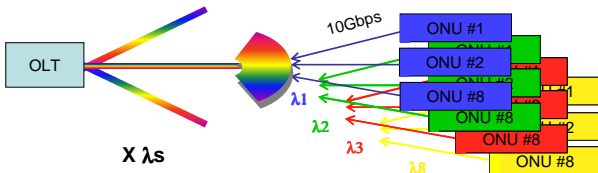

Figure 1 : Architecture of WDM/OCDMA system

2. Field trials of WDM/OCDMA

Figure 2 (a) shows the architecture of the proposed cost-effective WDM/OCDMA network, which uses a large scale multi-port encoder/decoder (E/D) in the central office, and a low cost E/D in the ONU. The multi-port E/D has very high PCR between auto- and cross-correlation signals, which can significantly suppress MAI and beat noise with a short OC [2]. The multi-port E/D with periodic spectral response can process multiple OCs in multiple wavelength bands with single device, and the cost will be shared by all the subscribers.

The field trials for multi-user WDM/OCDMA were carried out on an optical testbed of JGNII (Japan Gigabit Network II). The fiber used in the experiments is installed in the field between the laboratory in Koganei city and downtown Tokyo in a loop-back configuration as shown in Fig. 2(b). The total length is about 100 km.
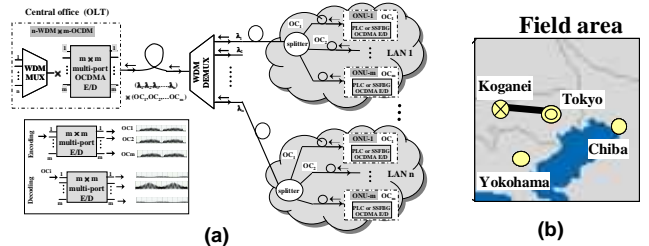

Figure 2 : (a) WDM/OCDMA system (b) Field fibre

The first WDM/OCDMA field trial used 16×16 ports, 200 Gchip/s multi-port E/D as encoder and tunable transversal filter (TVF)-type E/D as decoder [2]. The data were modulated using differential phase-shift keying (DPSK) modulation format and the data-rate is 10.7 Gbps. The using of DPSK data format and balanced detection enhanced the noise tolerance, and therefore the capacity, of the system. Signals of 3-WDM, 10-OCDMA have been transmitted over the field fibre with bit-error-rate (BER)<10^{-9}. The WDM channel spacing is 400 GHz, spectral efficiency (SE) is about 0.32 and 0.27 bit/s/Hz for B-to-B and field transmission, respectively.

With a large scale (50×50 ports, 500 Gchip/s) multi-port encoder/decoder and FEC, terabit payload capacity (1.24 Tb/s) asynchronous WDM/DPSK-OCDMA transmission field trial has been successfully demonstrated [3]. The 50x50 port E/D can generate 50 coherent time-spreading OCs with 50 chips and 500 Gchip/s. Figure 3(a) shows the photo, basic configuration, and waveform of generated 50-chip, 50-level phase shift OC. A multi-dimensional encoding/decoding configuration was employed as shown in Fig. 3(b) in the

experiment to minimize the WDM cross-talk. In this configuration, signals from different WDM channels go into different input ports of the encoder, therefore the multi-port encoder functions as both WDM multiplexer and OCDMA encoder simultaneously.

Payloads of 5 wavelengths (600GHz spacing) $\times$25-OCDMA users at 9.95328 Gbps/user have been successfully transmitted over 100 km field fibre with BER<10^{-9} and SE is ~0.41 bit/s/Hz for payload.
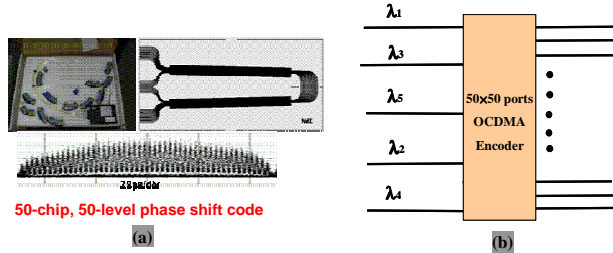

Figure 3 : (a) 50×50 ports multi-port encoder/decoder and (b) multi-dimensional configuration

Very recently, an OCDMA prototype has been developed by hybrid using multi-port and SSFBG en/decoders [4]. The 16-chip, 16-level phase-shifted SSFBG encoder/decoders have central wavelength of 1551 nm and chip length ~0.52 mm [5]. The 16 phase levels are generated by shifting the chip grating by a step of +/- λ/8. Figure 4 shows the photo of the SSFBGs, the encoding waveform, auto-correlation and cross-correlation.
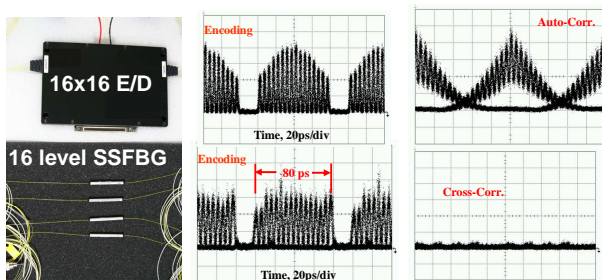

Figure 4 : 16-chip, 16-phase level SSFBGencoder/decoder

The prototype includes 10GbE interface OCDM transmitter (Tx) and receiver (Rx). Figure 5 shows the configurations and photos of OCDMA prototype. The OCDM Tx consists of mode-locked laser diode (MLLD), LiNbO3 phase modulator (LN-PM), and OCDM Tx board, which convert the inputted 10GbE signal into 10.3125 Gbps serial data with DPSK precoding and clock recovery. The MLLD generates ~1.8 ps pulses at repetition rate of 10.3125 GHz. The signal was modulated with DPSK format by LN-PM. The OCDM Tx is 19-inch x 3U sized rack and independently driven by the inputted 10GbE signal without the external synthesizer allowing full-asynchronous operation. OCDM Rx consists of an interferometer, dual-pin photo detector (PD), and OCDM Rx board, which converts the DPSK detected signal into 10GbE signal. At the ONU side, OCDM Rx includes the SSFBG decoder and is in 19-inch x 1U sized rack. The package of the SSFBG is 45 mm x 3 mm in size without temperature control.

Duplex, fully-asynchronous, 10Gbps, 8-user DPSK-OCDMA field trial has been successfully demonstrated on this prototype [4].
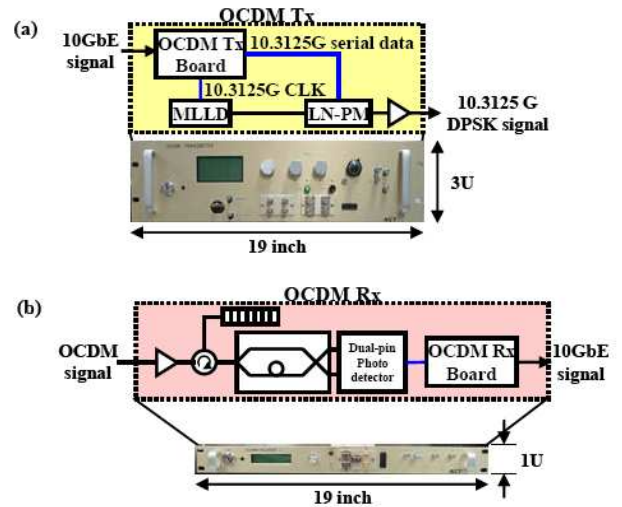

Figure 5 : Configurations and photographs of OCDMA prototype: (a) OCDM Tx and (b) OCDM Rx

3. Conclusion

The WDM/OCDMA is an attractive candidate for Gigabit-symmetric FTTH application. Field trials have been carried out in downtown Tokyo area with Terabit payload capacity, spectral efficiency ~0.41, and duplex, fully-asynchronous transmission respectively.

4. Aknowledgment

5. References

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