Bidirectional WDM-PON system with OFDM downlink and uplink transmission using TWSOA remodulation

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Abstract— Rapid increase of global data traffic and massive deployment of new networks are becoming a key environmental, social and economic issue. The access network consumes about 70% of overall network energy. Passive Optical Networks (PON) has been considered to be one of the most promising solutions for access networks due to its immense bandwidth and low cost infrastructure. The combination of Orthogonal Frequency Division Multiplexing (OFDM) and WDM-PON technique is a subject of great interest to increase the system capacity and dispersion tolerance. A 20-Gb/s downlink signal transmission based on an OFDM signal and a 2.5-Gb/s uplink signal transmission using remodulation of a semiconductor-optical-amplifier are realized.

INTRODUCTION

The combination of an exponential increase in bandwidth-intensive applications and customer base has resulted in the rapid increase of fiber networks in the access network segment in recent years. In terms of fiber access technology, the point-to-multipoint passive topology in the form of the Passive Optical Network (PON) has been proven to be beneficial to both customers and operators. With the popularity of broadband services of the terminal users, such as Internet video, online gaming, high-quality Internet Protocol TV (IPTV), etc., the demands of bandwidth in access networks is rapidly increasing. Rapid increase of global data traffic and massive deployment of new network is becoming a key environmental, social and economic issue.

To address this issue, great effort has been expended on researching the high-speed, cost-effective, flexible bandwidth allocation and future-proof NG-PON system. Among these techniques, WDM based PON systems have attracted a great deal of research and development interest, due to their capable of providing cost-effective way for increasing the overall bit rate and transmission reach of networks.

The Orthogonal Frequency Division Multiplexing (OFDM) is widely considered as one of the strongest candidate for WDM-based PON system, owing to its unique advantages of superior tolerance to chromatic dispersion impairments, dynamic provision of multi-granularity bandwidth allocation both in time and frequency domains, and fully exploiting the rapid advances in modern digital signal processing technology.

SYSTEM MODEL

In the bidirectional WDM-OFDM-PON system each OLT consist of transmitter and receiver units are multiplexed by an arrayed waveguide grating (AWG) or bidirectional WDMMUX to achieve aggregate data rates for downstream. Before the AWG the downstream and upstream data signals are correctly routed using a bidirectional circulator. The basic block diagram of bidirectional WDM-OFDM-PON system is shown in the Figure 1.

In each transmitter Pseudo Random Binary Sequence (PRBS) generator is used to generate 10Gbps data to drive the OFDM modulator using the QAM sequence coder. Depending on the type of OFDM (either direct detection or Coherent detection) modulator there should a Local Oscillator in the ONU. Direct-Detection Optical OFDM (DDO-OFDM) looking into a simple realization based on low-cost optical components and CO-OFDM aiming to achieve high spectral efficiency and receiver sensitivity.
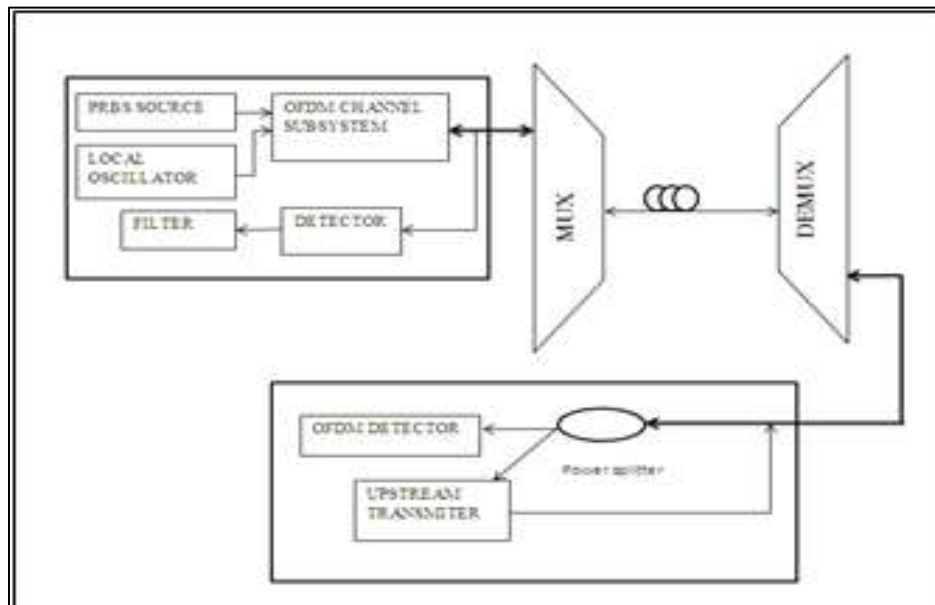
Fig: 1 Basic block diagram of Bidirectional WDM-OFDM-PON System with uplink transmission with SOA remodulation.

The spectral efficiency can be further improved by using higher order QAM modulation. The practical implementation of coherent OFDM system, the optical spectral efficiency will be reduced by needing a sufficient guard band between WDM channels. This guard band can be avoided by using orthogonally across the WDM channels.
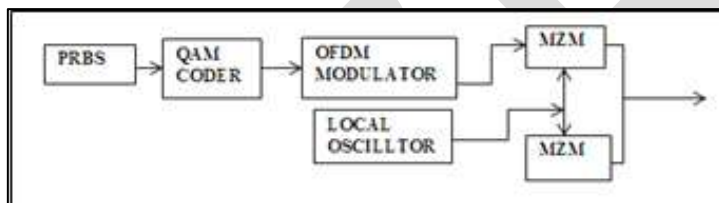

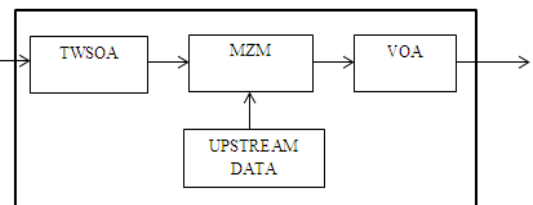Fig: 2 OFDM Channel structure

Fig:3 Uplink remodulation at ONU

At the ONU the signal is split into two portions. One portion is used for detection of OFDM downlink signal; the other portion is used for generating the uplink signal by SOA remodulation of the optical carrier. The upstream signal transmission is done by using a travelling wave semiconductor optical amplifier (TWSOA) with a Mach-Zender modulator. The upstream data can be detected using pin photodiode circuitry in the OLT. In the case of bidirectional data transmission, bidirectional fibers are used. The structure of OFDM channel and uplink remodulation is shown in Figure 2 and Figure 3.

DESIGN AND SIMULATIONS

It provides an easy user interface which is common to many other electrical engineering tools. The OptiSystem software is suitable to be used to model and simulate fiber optic system, free space optic system, OWC system and also the advanced communication systems including OFDM modulation.

In the OLT the PRBS is coded and modulated using QAM encoder and OFDM modulator respectively. In coherent detection system a Continuous Wave laser and two Mach-Zehnder modulators are used to up-convert the RF data to the optical domain. At the ONU demultiplexed signal is detected using coherent detector circuitry which incorporates a local oscillator. The detected signals are demodulated and decoded using OFDM demodulator and QAM decoder.
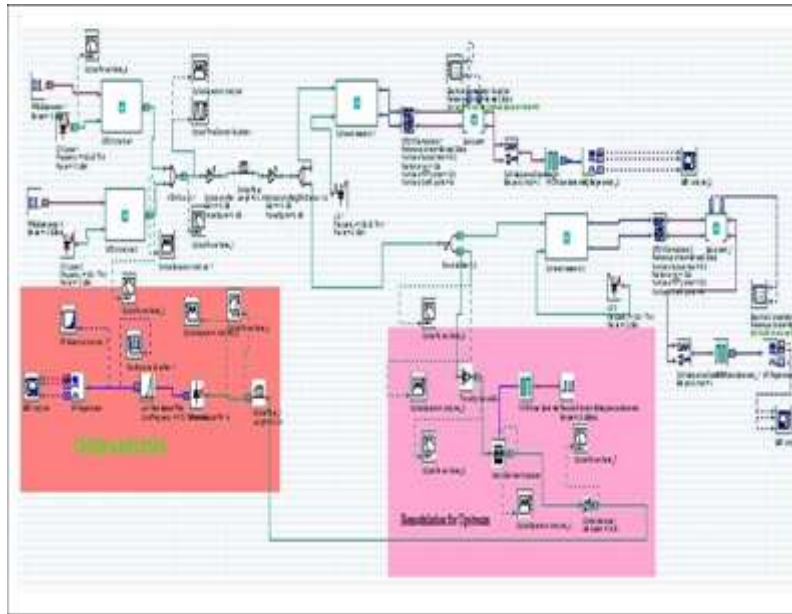
Fig:4 Simulation diagram of bidirectional WDM-OFDM-PON

For the downstream OFDM transmission the modulation part contains two MZMs. The bit stream is generated by a PRBS generator and mapped by a 4-QAM encoder. The resulting signal is modulated by an OFDM modulator. The OFDM modulated signal is fed to two MZMs through two low pass filters . The local oscillator frequencies 193.05 THz and 193.1 THz are used for each of the OLT. The optically modulated signals are combined using a multiplexer and given to fiber.
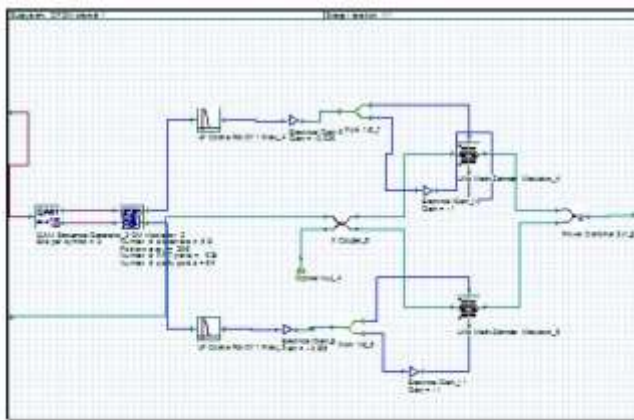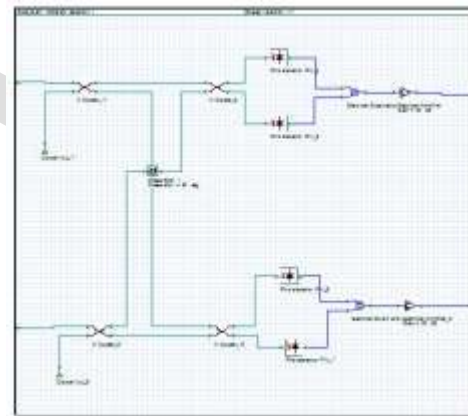

Fig: 5 OFDM transmitter section

Fig:6 OFDM detection section

At receiver there are four detectors. Using the received signal and reference local oscillator signal here occurs a frequency mixing process which obtains the required data signal. The balanced detectors perform the I/Q optical to electrical conversion and also perform the noise cancellation. Electrical amplifiers are used to adjust the signal intensity. This data is demodulated and decoded using the OFDM demodulator with similar parameters as the OFDM modulator and QAM decoder. The detailed simulations of the transmitter and receiver subsystems are shown in Figure 5 and Figure 6.

For the upstream data transmission, one part of the downstream signal is remodulated using TWSOA and transmitted through fiber. At the OLT the upstream data is detected using detector circuitry. The simulation diagram for the bidirectional transmission is shown in the Figure 4.

RESULTS AND DISCUSSIONS

Simulation is done with the OptiSystem V.12 software and the entire block for the optical detection systems are set as per the previous section to do simulation. A fixed data rate of 10Gbps and 10dBm power PRBS data is given as the input data to the coherent detection system. For the two channel system, the output from the multiplexer and demultiplexer is shown in the Figure 7.
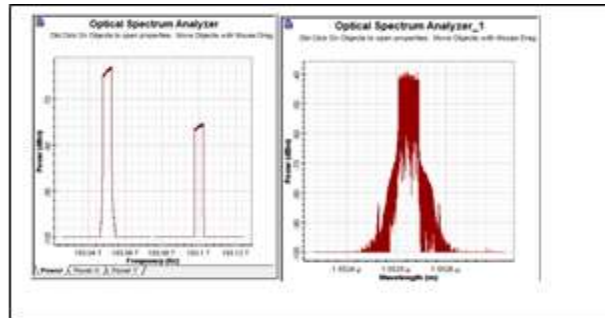

Fig: 7 Spectrum output from the multiplexer and demultiplexer

The downstream data transmission is done by OFDM modulation. Figure 8 shows the input and output constellations diagrams of downstream data transmission for 50km distance.
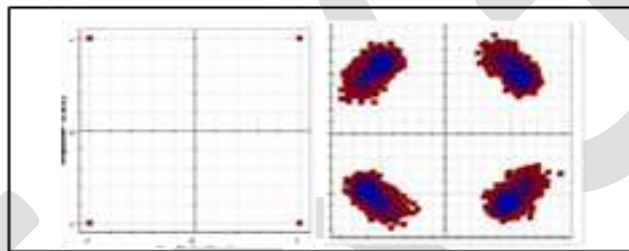

Fig:8 Input and output constellations diagrams of downstream data transmission

The upstream data transmission is done by the remodulation of downstream signal. The different stages are shown in the Figure 9. From the observations the uplink signal gets with -6.5dBm receiver sensitivity.
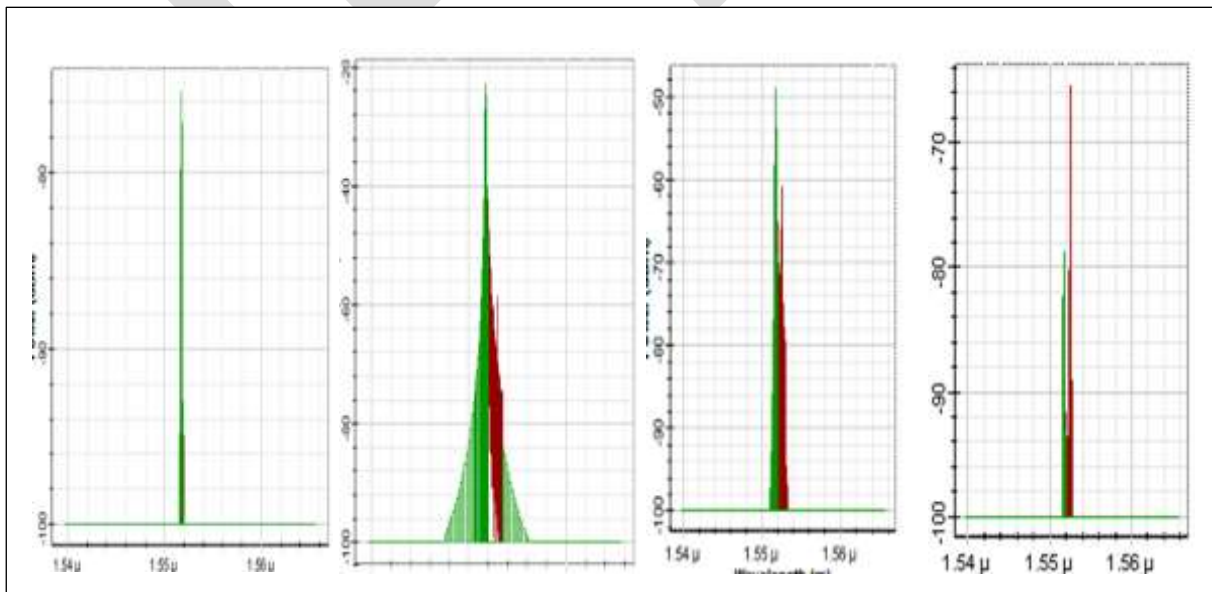

Fig:9 (a) received pulse at ONU (b) amplified pulse at ONU (c)retransmitted pulse from ONU (d) received pulse at OLT

CONCLUSION

 Provisioning broadband services for downloading and uploading high definition data has become a difficult requirement for data providers. An easy way to provide multipath, which are used in most broadband systems between transmitters and receivers, is to use OFDM. Here an OFDM bidirectional WDM-PON is designed that is modulated by QAM for the downstream, and uses a travelling wave semiconductor optical amplifier to remodulate the downstream signal into upstream signal. OptiSystem software from Optiwave is used to simulate the bidirectional WDM-OFDM-PON systems.

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