A symmetric 160 Gb/s Broadband TWDM-PON

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Abstract

This paper studies and designs a symmetric 160 Gb/s and improves the capacity of time and wavelength-division multiplexed passive optical network (TWDM-PON) for next-generation passive optical network stage 2 (NG-PON2). Distributed feedback (DFB) laser diode and tunable modulated grating Y-branch (MG-Y) laser with tuning range about 14.4 are used for downstream and upstream direction respectively, with intensity modulation. The evaluation of system performance is analyzed in terms of bit error rate (BER) verses received power. TWDM-PON achieved successfully an aggregated data rate of 160 Gb/s along 40 km bidirectional fiber at 1: 128 splitting without amplification and dispersion compensation.

Keywords: Next- generation passive optical network stage 2 (NG-PON), Time and wavelength- division multiplexed passive optical network (TWDM-PON) Optical link terminal (OLT), and Optical network unit (ONU).

1 Introduction

New high bandwidth services such as high-quality internet protocol TV (IPTV), online gamings require high data rate transmission for their application. Enhancement to the mid-term next-generation (NG-PON1) known as NG-PON2 has been proposed by FSAN as a solution for new services application. NG-PON2 is considered as the long-term generation of optical access networks, which allows the use of a new ODN, defined as the fiber plus

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the power splitter(s) put between OLT and ONUs. Generally, it aims for wide coverage, high bandwidth, and high transmission speeds through costs and energy savings and also to realize a higher capacity by allowing flexible bandwidth upgrade [1].

There are several candidates of NG-PON2 has been recently proposed in domain of PON including 40G TDM-PON, wavelength division multiplexing-PON (WDM-PON), time wavelength division multiplexed-PON (TWDM-PON) and orthogonal frequency division multiplexing-PON (OFDM-PON). However, the requirement of backward compatibility blocked off the way of WDM-PONs because they require wavelength selective optical distribution networks (ODNs). 40G TDM-PON is also out of consideration due to the cost pressure of 40G components in each user and the fiber chromatic dispersion would seriously limit the transmission distance [1, 2, 3]. Among of them, among which the time and wavelength division multiplexed passive optical network (TWDM-PON) proposal has attracted much research interest and has been selected by the Full Service Access Network (FSAN) as the base technology solution for NG-PON2 [4].

The main requirements of NG-PON2 candidates are to deliver 40 Gb/s However, TWDM-PON has been selected by full services access network (FSAN) community as an ultimate solution for NG-PON2 due to the capability of coexistence with the legacy PON technologies, reuse of the existing optical distribution network (ODN) and capacity aggregation by stacked the existing TDM-PON using wavelength domain [5]. A lot of advanced techniques have been investigated. 40/10 Gb/s downstream/upstream TWDM-PON based distributed feedback (DFB) downstream and thermally tuned DFB laser as colorless upstream laser [4]. Symmetric 40-Gb/s TWDM-PON based DFB downstream laser and thermally directly modulated upstream colorless laser has been demonstrated in [6,7] where four XG-PONs are stacked by using four pairs of wavelengths. 80/10 Gb/s downstream/upstream TWDM-PON based on tunable laser source (TLS) downstream laser and Reflective semiconductor optical amplifiers (RSOA) as upstream colorless laser [8]. 80 Gb/s TWDM-PON is demonstrated based short-cavity vertical-cavity surface-emitting colorless laser (SV-CSEL) colorless upstream laser [9].

In this paper, a symmetric 160 Gb/s TWDM-PON system for downstream and upstream, with compatibility support for TDM-PON configuration is demonstrated where 16 XG-PON are stacked by using 16 pairs of WDM wavelengths. The rest of this paper is organized as follows: Section 2 indicates the system architecture and simulation design set up.
Section 3 shows simulation results and discussion where the performance of the proposed laser is estimated. Finally, this paper is concluded in Section 4.

2 System architecture and simulation design

The TWDM-PON system architecture is shown in Fig. 1, where 16 TDM-based PONs are stacked by 16 wavelengths with 0.8-nm channel spacing to achieve the symmetric 160-Gb/s and capacity improvement. 16 transmitters at the optical line terminal (OLT) and 16 receivers at ONU operating under wavelengths from 1570.74 nm to 1580.74 nm separated by 0.8 nm. Each transmitter in downstream direction includes DFB laser diode with output power 10 dBm injected into mach-zehnder modulator (MZM) external modulator which is driven by 10 Gb/s pseudo-random bit sequence (PRBS) with length of \(2^{31} - 1\). Then, the signals are multiplexed by a. After the WDM Mux, the signals passed through the single mode fiber (SMF), the signals are distributed to each ONU by a splitter at the remote node (RN). At each ONU, the downstream signals pass through a tunable optical filter (TOF) with 0.8-nm bandwidth ONU to select the downstream wavelength and without pre-amplification component before being detected by positive-intrinsic-negative-transimpedance amplifier (PIN-TIA).

For uplink transmission, MG-Y injected into MZM type of external modulator, driven by 10 Gb/s PRBS with length of \(2^{31} - 1\) as upstream colorless laser source. MG-Y has 12 dBm stable output power with tunable wavelength range of ~14.4 nm, and the upstream wavelengths in our simulation are set at 1535 nm, 1547 nm. Each ONU can be tuned among 16 wavelength channels with 0.8-nm spacing. The upstream signals are combined using power combiner, and then passed through 40 km SMF. At OLT, the upstream signals are demultiplexed by WDM Demux before being detected by positive-intrinsic-negative-transimpedance amplifier (PIN-TIA).
3 Results and Discussion

To investigate the transmission performance of TWDM-PON system, we measured the bit error ratio (BER) for downstream and upstream directions. Also, the performance of the TWDM system is evaluated eye diagram signal measurements at various operating conditions. The measured BER is obtained at both ONU and OLT receivers for 16 wavelengths each carried 10 Gb/s data transmission using bi-directional transmissions. PS/Cs with splitting ratio 1:128 with loss of 25 dB was used to analyze the measured BER with different optical received power at the receiver side. Fig. 2 and 3 show the measured BER curves for downstream and upstream channels with the received optical power after 40 km SMF transmission respectively.

Fig.2 indicated the BER performance of the 16 wavelengths downstream from OLT to ONU versus received optical power at receiver side of ONU without preamplifier employed before detecting the signal by receiver where the power difference between downstream signals after transmission over 40 km SMF and splitting ratio 1:128 showed more than 2 dB power difference at BER of $10^{-9}$ between the 16 stacked wavelengths. This due to fiber dispersion and the channel transmission condition. The optical power launched into the transmission fiber is 10 dBm, the insertion loss of the filter is 3 dB, and the receiver sensitivity is -31.5 dBm, so the power budget in downstream direction is 38.5 dB.
Fig. 2. BER performance for downstream signals.

Fig. 3 shows the transmission performance of the proposed wavelength tunable colorless laser for TWDM-PON configuration from 1535 nm to 1547 nm where 16 stacked wavelengths spacing at 0.8 nm tuned over a certain range. The BER performance of the stacked upstream wavelengths is dedicated successfully a 160 Gb/s upstream data rate aggregation capacity from ONU to OLT without amplification. The upstream after transmission over 40 km SMF and splitting ratio 1: 128 showed more than 1 dB power difference at BER of $10^{-9}$ between the 16 stacked wavelengths utilized in upstream TWDM-PON. The optical power launched into the transmission fiber is 12 dBm, the, and the receiver sensitivity is -26.5 dBm, so the power budget in downstream direction is 38.5 dB.
Conclusion

In this paper, we have studied and demonstrated a symmetric 160 Gb/s TWDM-PON using stacking approach in NG-PON2 with compatible TDM-PON configuration to improve capacity aggregation. DFB laser and MG-Y tunable laser with about 14.4 tuning range are utilized for downstream and upstream directions respectively, where external modulation used for both of them. The performance evaluation is measured via BER versus the received power for downstream and upstream signals.

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