SEMICONDUCTOR OPTICAL AMPLIFIERS IN WDM-PON

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Abstract: Semiconductor optical amplifiers (SOA) have become more popular in optical networks. We tested if SOA can be used in bidirectional passive optical networks based on wavelength division multiplexing (WDM-PON). First part, the measurement was focused on possibilities of using SOA designed for 1550 nm in the laboratory PON working at wavelengths of 1490/1550 nm either way. Second part, the simulation was performed to prove the possibility of amplifying several wavelengths with narrower spectral width together. The measurement and the simulation have shown that SOA is able to work in the next-generation WDM based PON.

Keywords: passive optical networks, semiconductor optical amplifier, wavelength division multiplexing

1. INTRODUCTION

Vast deployment of fiber to the home (FTTH) is underway to accommodate the explosion in bandwidth demand driven by the extreme growth in Internet services. FTTH is typically realized by gigabit-class passive optical network (PON) systems, such as gigabit Ethernet PON (GE-PON) standardized by IEEE [1] and gigabit-capable PON (G-PON) standardized by ITU-T [2]. Both GE-PON and G-PON provide a point-to-multipoint access between one optical line terminal (OLT) and several optical network units (ONUs) through the use of time-division multiplexing (TDM) to pass downstream signals from the OLT to the ONUs, and time-division multiple access (TDMA) to multiplex upstream signals from the ONUs to the OLT. All these systems are based on the same idea of time sharing the optical medium by TDMA. However, it has been realized that using wavelength division multiplexing (WDM) offers an alternative method of sharing the capacity of a PON between multiple users and would offer advantages in terms of capacity, low latency and service transparency. One example of the new PON systems based on WDM technologies is the WDM-PON, in which each ONU uses a different wavelength in each direction to communicate with the OLT. Such advanced WDM-based PON systems can be alternatives to higher speed TDM-based PON systems.

Optical fiber amplifiers (OFA) are currently used as in-line amplifiers to compensate optical fiber losses. SOAs have become key elements in optical access networks thanks to their lower prices and compactness. SOAs have a lower gain, up to 30 dB, a higher insertion loss of 6-10 dB, and a higher noise figure of 7-12 dBm, in comparison with OFAs. Semiconductor optical amplifiers are driven by an electric current unlike OFAs driven by an optical pump source. The input signal is amplified in the active region via stimulated emission. The output signal is accompanied by noise, the so-called amplified spontaneous emission (ASE). This noise is produced by the amplification process [3]. As with all amplifiers, at high output powers the SOA gain saturates [4]. SOAs can amplify a signal in both directions so there is an advantage for use in bidirectional networks. On the other hands, manufacturers do not guarantee simultaneous bidirectional transmission.

An SAC20 10P188 amplifier tested in the laboratory has been supplied by Alphion Company. The parameters of the amplifier measured for a driving current of 330 mA and a temperature of 25°C are the following: Peak wavelength 1507 nm, Peak gain 21.7 dB and $P_{SAT,3\,dB}$ 8.3 dB.

We tested if the SOA is capable to amplify bidirectional signal first. After that we simulated amplification of SOA in bidirectional WDM-PON.

We confirmed in the previous measurement [5] that SOA can work at a wavelength of 1550 nm and with a lower gain at a wavelength of 1490 nm. Both wavelengths are used in traditional PON simultaneously so we tested the amplification several wavelengths together because WPM-PONs use several wavelengths. It was proved that to achieve an optimal amplification the input power into the amplifier should be around -20 dBm in order to avoid saturation. Then SOA can amplify several wavelengths together. Next measurement was focused on bidirectional amplification.

2. BIDIRECTIONAL AMPLIFICATION

An OLT was used as a source at a wavelength of 1490 nm from one direction and a tunable distributed feedback (DFB) laser was connected as a source at a wavelength of 1550 nm to opposite direction. An optical spectral analyzer was used for measurement.

From one direction at a wavelength of 1490 nm a power level at the input of the SOA was -20 dBm and an output power was -7 dBm, hence the gain of 13 dB. The spectral characteristics are shown in figure 1 (a) an input signal and (b) an output signal. From second direction a power level at the input of the SOA was -18.6 dBm and an output power was 0 dBm, hence the gain of 18.6 dB. The spectral characteristics are shown in figure 1 (c) an input signal and (d) an output signal.

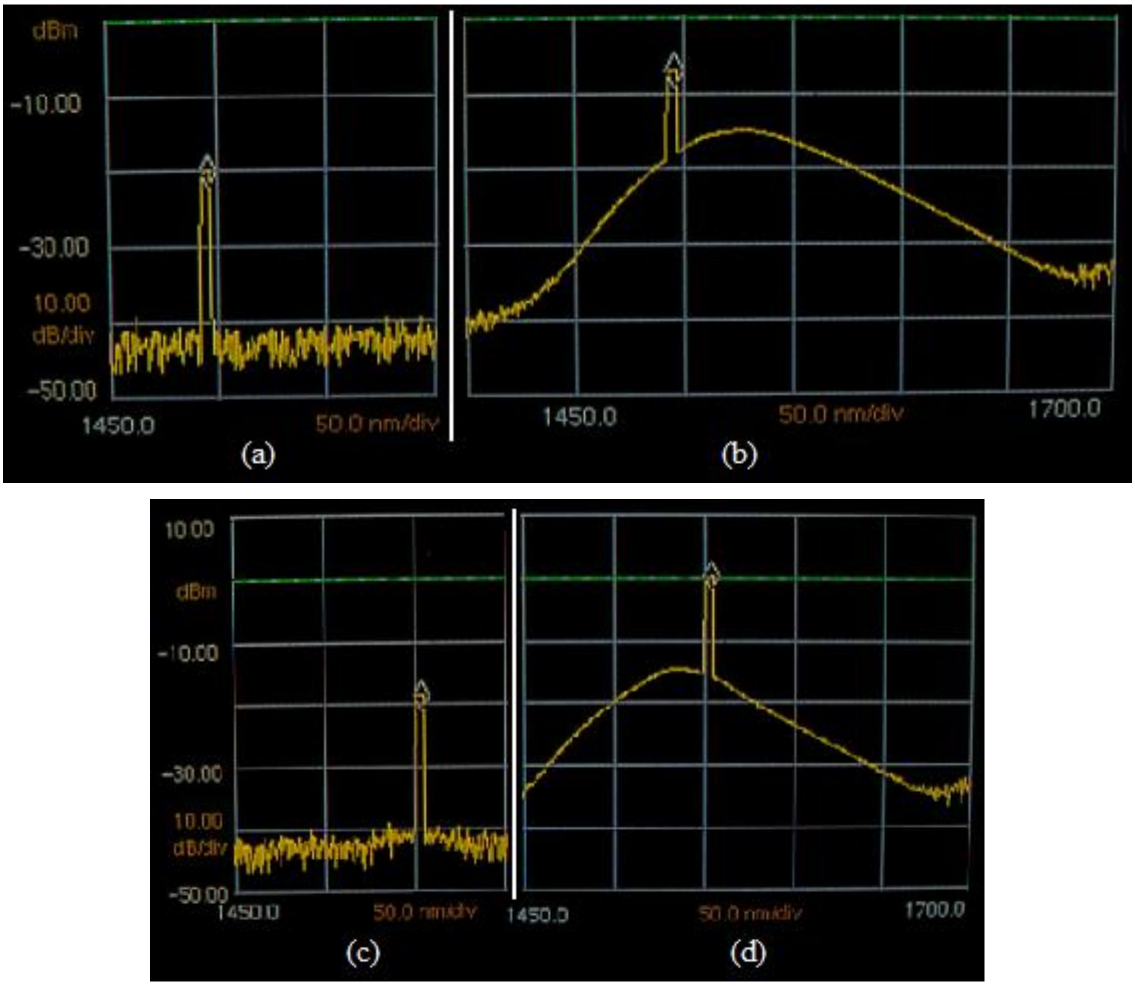

Figure 1: Spectral characteristic of (a) input signal @1490 nm, (b) output signal @1490 nm, (c) input signal @1550 nm and (d) output signal @1550 nm.

3. SIMULATION OF SOA IN WDM-PON

Software OptiSystem 6.0 by Optiwave Company was used for simulations. Further simulations with SOAs have shown the possibility of extending the transmission distance. There is necessary in standard PON system to consider using of a pair of amplifiers for both the downstream traffic and the upstream traffic. A pair of amplifiers placed in front of the splitter works in the function of an in-line amplifier and this configuration allows extending the distance up to 70 km [5]. Previous simulations comparing modulation formats in WDM-PON shown that communication over long distance is the main advantage of WDM-PON in comparison with PON. The transmission distance can be extended up to 63 km without amplifiers [6]. The aim of simulation was investigate if the transmission distance of WDM-PON can be extended by using semiconductor optical amplifiers.

Figure 2 shows system configuration. The passive optical network based on the wavelength division multiplexing with a 1:8 AWG has been chosen for simulation. Optical pulses from the OLT are generated by using the Mach-Zehnder Modulator with 2.5 Gb/s bit rate. Transmission wavelengths are different for each end unit and the spacing between wavelengths is 0.8 nm. The optical pulses at different wavelengths from lasers are passed to the circulators. A circulator serves to separate wavelength for the downstream and upstream traffic. All downstream signals are combined in the first 8:1 AWG into one optical fiber. The pulses travel through a 60 km link comprising the single mode fiber (SMF) with an attenuation coefficient of 0.24 dB/km. Spectral characteristic for the downstream traffic can be seen in figure 3 (a). Then SOA with gain of 15 dB is connected and next 60 km of SMF is connected behind SOA. Amplified spectrum is shown in figure 3 (b). At the end of the link the second 1:8 AWG is connected. The insertion loss of AWGs is much lower in comparison with a passive optical splitter used in PON. The main advantage of AWG is that the insertion loss is 3 dB and it does not increase with the increasing number of output ports as for passive optical splitters.

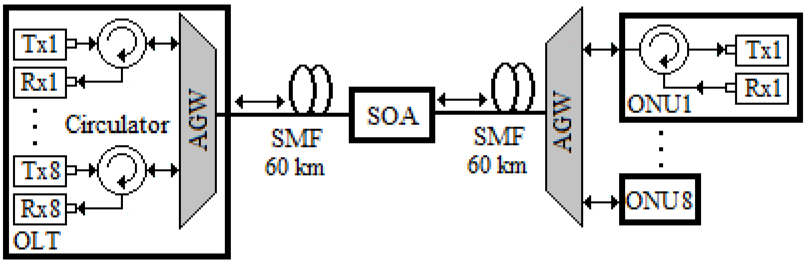

Figure 2: Simulation configuration

The output power from both the OLT and the ONT was set at 0 dBm. The maximum fiber length without using an amplifier was tested in the first simulation. The BER was 10^{-9} for the length of 60 km. Then the SOA was connected and the distance was extended twice. A power level after passing through a 60 km link was around -17 dBm (shown in figure 3 (a)). And figure 3 (b) shows spectrum after amplification with a power level around -2 dBm, hence the gain of 15 dB. After passing next 60 km of optical link the received signal had a power level of -19 dBm and the BER was 10^{-7}. Similar results were achieved in opposite direction because the amplifier was placed in the middle of the whole optical link. Therefore, the SOA worked in the function of an in-line amplifier. The input level was low enough to avoid saturation [7].

4. CONCLUSION

The main aim was to verify the possibilities of using of a supplied amplifier working at a wavelength of 1550 nm in WDM-based PON. Two amplifiers working at different wavelengths must be used for each direction in standard PON because of the narrow spectral width [7]. WDM-based PON works with more channels in range of a wavelength of 1550 nm so the possibility of using one amplifier for both directions was tested. Simulations proved that the SOA is capable amplifying several wavelengths and measurement proved amplification in both directions together even if it is not guaranteed by the manufacturer. If the SOA was used in WDM-PON the transmission distance would be extended twice up to 120 km. SOA must be used in the function of an in-line amplifier to avoid saturation with high input power.

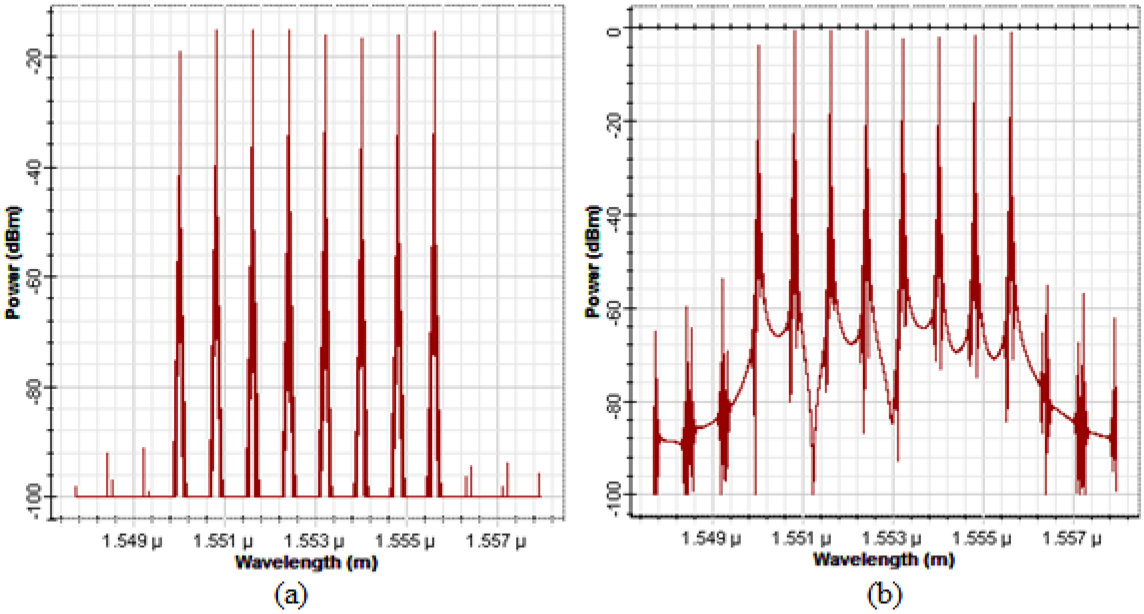

Figure 3: Spectral characteristic after passing a 60 km link (a) and after amplification (b)

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