SOA AT 1550 nm TESTING IN BIDIRECTIONAL 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 the bidirectional passive optical network (PON). The measurement was focused on possibilities of using SOA designed for 1550 nm in the laboratory PON working with wavelengths of 1490/1550 nm for the downstream traffic and 1310 nm for the upstream traffic. The influence of the driving current and the temperature on the gain was tested. A measurement at working wavelengths was aimed at verifying the spectral width of SOA. The measurement has shown that an individual amplifier for each separate direction must be used.

Keywords: Bidirectional optical networks, semiconductor optical amplifier, temperature stabilization

1. INTRODUCTION

Passive optical networks are characterized by one optical port in the central office being shared by several end users. Passive optical splitters are used for optical signal division; their insertion loss increases with increasing number of output ports and it leads to shortening the transmission distance. Data is transfer bidirectional in one fiber, the wavelength for the downstream traffic is 1490 nm, the wavelength for an analog signal is 1550 nm and the wavelength for the upstream traffic is 1310 nm. The whole distance for EPON 802.3ah networks is limited up to 10 km.

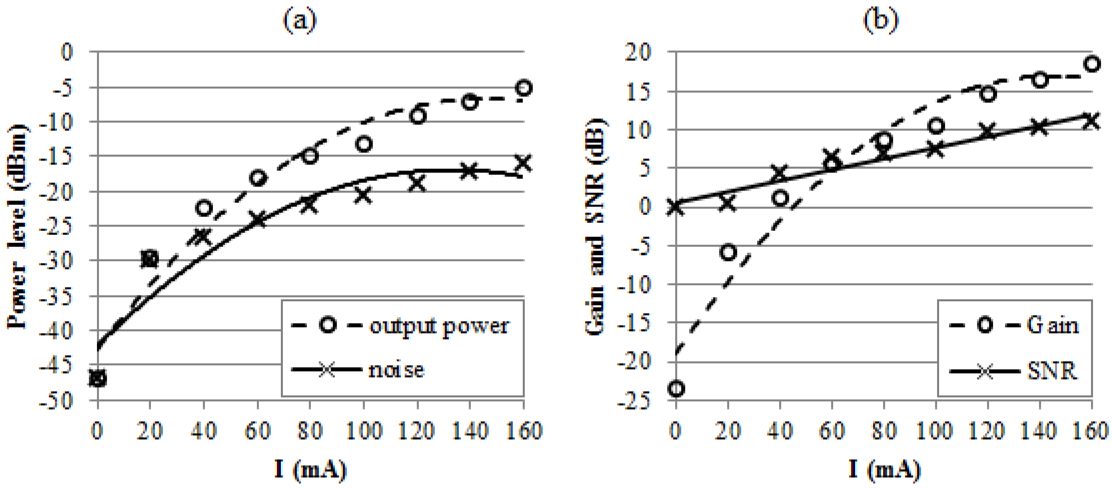
Optical fiber amplifiers (OFA) are currently used as in-line amplifiers to compensate for optical fiber losses. SOAs have become key elements in optical access networks thanks to their lower prices and compactness. SOAs have a lower gain, up to 30 dB, a higher insertion loss of 6-10 dB, and a higher 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 [1]. As with all amplifiers, at high output powers the SOA gain saturates [2]. SOAs can amplify a signal in both directions so that it does not matter which optical port is used as the input. On the other hands, manufacturers do not guarantee simultaneous bidirectional traffic.

Applications of SOAs can be classified into three classes: 1) Post-amplifier or booster connected directly behind the transmitter to increase transmitter power, 2) in-line amplifier placed at the input port of the splitter to compensate for optical fiber losses, and 3) preamplifier placed in front of the receiver to amplify low signal level prior to receiving [1].

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.

2. INLUENCE OF DRIVING CURRENT AND TEMPERATURE ON GAIN

A driving current of up to 400 mA must be connected to drive the SOA. Then output power depends on the driving current. The temperature must be exactly 25°C and it should not vary during the operation. SOA cooling is based on the principle of thermo-electric cooling (TEC), the so-called Peltier cooling [4]. We used a Laser Diode Controller by the ILX Lightwave Company for setting the current and stabilizing the temperature. This device had a limited setting of driver current only up to 200 mA and the real current limitation was 160 mA. Therefore, we measured the influence of the driving current on the gain. Figure 1 (a) shows the dependence of the output power and the noise on the driving current. For better illustration, figure 1 (b) shows the dependence of the gain and signal to noise ratio (SNR) on the driving current.

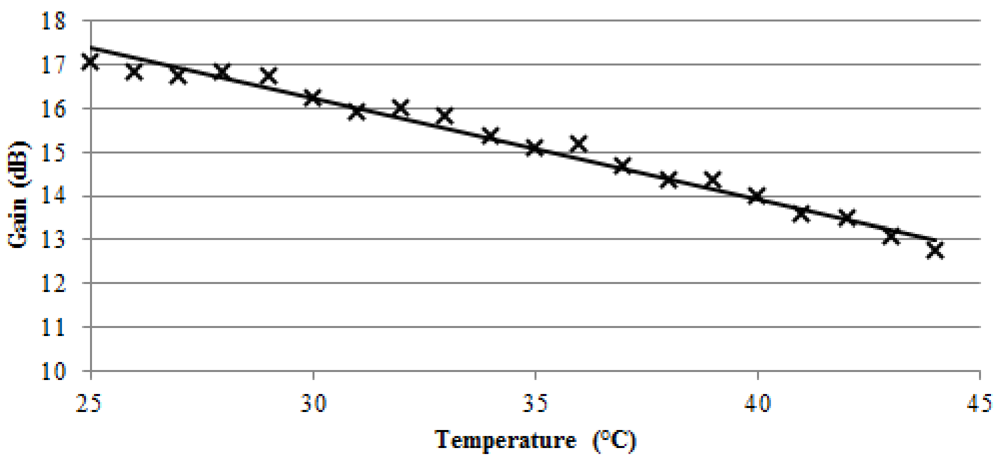


Obrázek 1: Dependence of (a) output power and (b) gain on the driving current.

A Distributed Feedback (DFB) laser with an output power of -23.6 dBm at a wavelength of 1550 nm was used for this measurement. The low power was chosen to avoid saturation at a high output power from an amplifier. The temperature was stabilized at 25°C. SOA started amplify from a driving current of 50 mA. As expected, the highest gain, 18.6 dB, was achieved for the highest driving current, 160 mA. SNR increases with increasing current and it achieves the maximum value of 11 dB for a driving current of 160 mA. We can estimate that the gain and SNR might grow with increasing driving current. The real gain is 3.1 dB lower than given by the manufacturer.

The operation temperature should be in the range of 0-70°C and the recommended value is 25°C. We tested if temperature must be accurate and constant. We used the same DFB laser as in the previous measurement with a transmitter power of -21.5 dBm. The driving current was set to 150 mA. The output power was -4.43 dBm at a temperature of 25°C so that the gain was 17.07 dB. We changed temperature in the range from 20 to 40°C and the resulting dependence is given in Figure 2. The Laser Diode Controller does not allow setting a higher temperature and, in keeping with the manufacturer’s recommendation, lower temperatures were not set.

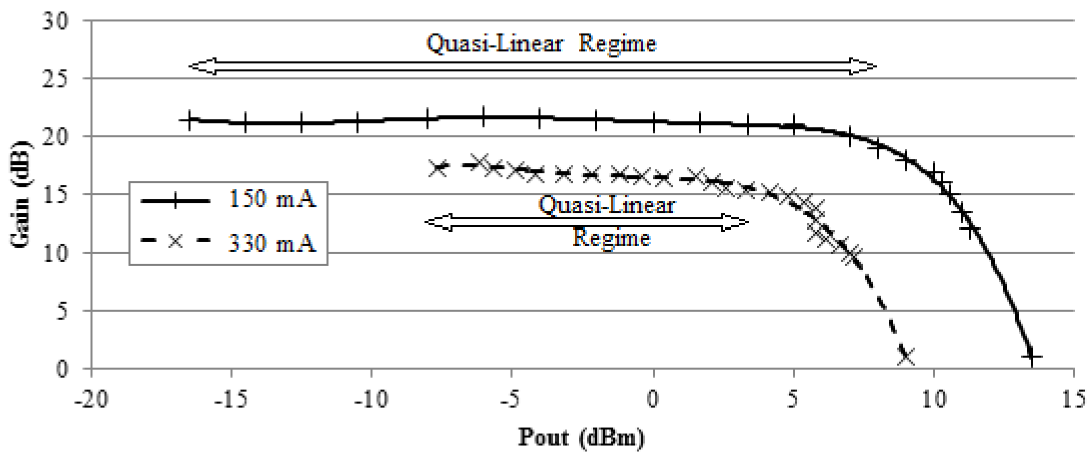
The curve in Figure 2 shows a linear fall of the gain while the temperature grows. The current source and then the temperature stabilization were turned off after the measurement was finished and the input optical signal was disconnected. Subsequently, the temperature rose to 38°C, which corresponded to the gain falling by 2.74 dB (see Figure 2). We did not test a make of the current source and the optical signal source without temperature stabilization because of potential damage to the amplifier. The measurement proved that maintaining an accurate temperature during the operation is necessary. Concerning the influence of a changed central wavelength while changing the temperature, there was no shift of the central wavelength and it was at 1550 nm during the measurement.



Obrázek 2: Dependence of gain on temperature.

3. MEASUREMENT OF THE DEPENDENCE OF THE GAIN ON THE OUTPUT POWER

The maximal gain was influenced by a lower driving current of the Laser Diode Controller. It can be supposed that the saturation power was going to be lower than 8.3 dB given by the manufacturer. A tunable DFB laser working at a wavelength of 1550 nm was used, the driving current was set to 150 mA and the temperature was stabilized at 25°C. The dependence of the gain on the output power is shown in Figure 3. The full line represents values given by the manufacturer and the dashed line represents the values measured.

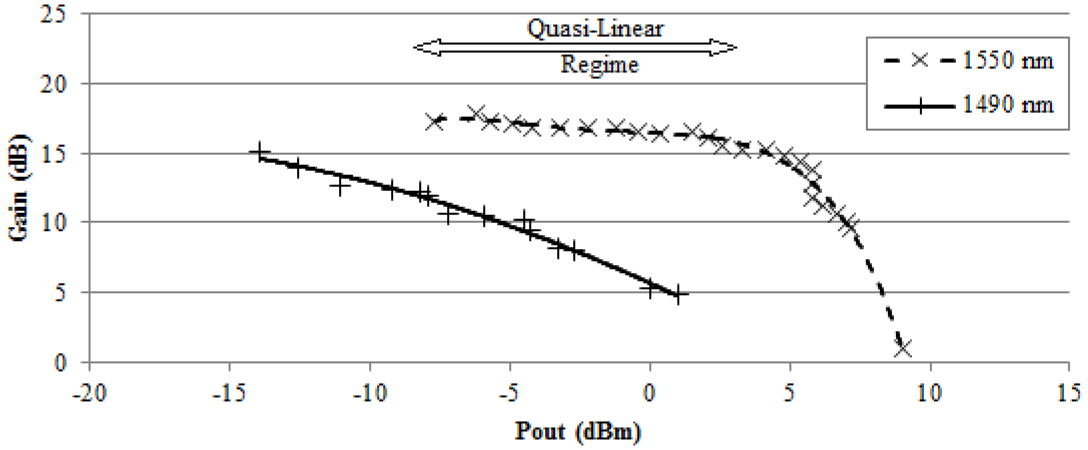


Obrázek 3: Dependence of gain on output power for different driving currents.

The amplifier woks in quasi-linear regime up to an output power of 1 dBm and then the gain falls rapidly. The saturation power for a 3 dB fall corresponds to an output power of 4.2 dBm. The gain was 15.2 dB at this output power. This means that the input power to the amplifier should be lower than -11 dBm. The amplifier can work properly under these conditions only. If we compare the saturation power 8.3 dBm measured by the manufacturer with the driving current 330 mA, then the saturation power fall by 4.1 dB when the lower driving current 150 mA is used.

4. SPECTRAL WIDTH AND TRANSMISSION OF SEVERAL WAVELENGTHS TOGETHER

We performed measurements at wavelengths of 1310/1490/1550 nm to verify the possibility of using an amplifier in the PON. The spectral dependence of gain according to the manufacturer is measured for only the 1490-1550 nm range. The gain at a wavelength of 1490 nm is 3 dB lower than at a wavelength of 1550 nm. The gain at a wavelength of 1310 nm is not given by the manufacturer so that it was measured to verify if the amplifier can be used for both directions. Figure 5 shows the dependence of the gain on the output power. The full line represents the gain at a wavelength of 1490 nm and the dashed line represents the gain at a wavelength of 1550 nm.



Obrázek 4: Dependence of gain on output power for different wavelengths.

At a wavelength of 1550 nm the amplifier works in quasi-linear regime up to an output power of 4 dBm with a gain of 17 dB. The gain at a wavelength of 1490 nm falls linearly when the output power increases. Saturation at a wavelength of 1490 nm begins from the output power of -8 dBm. It corresponds to an input power of -20 dBm and a gain of 12 dB. The input signal was not amplified when we tested the amplifier at a wavelength of 1310 nm but, what is more important, the signal was completely suppressed and there was only noise at the output of SOA.

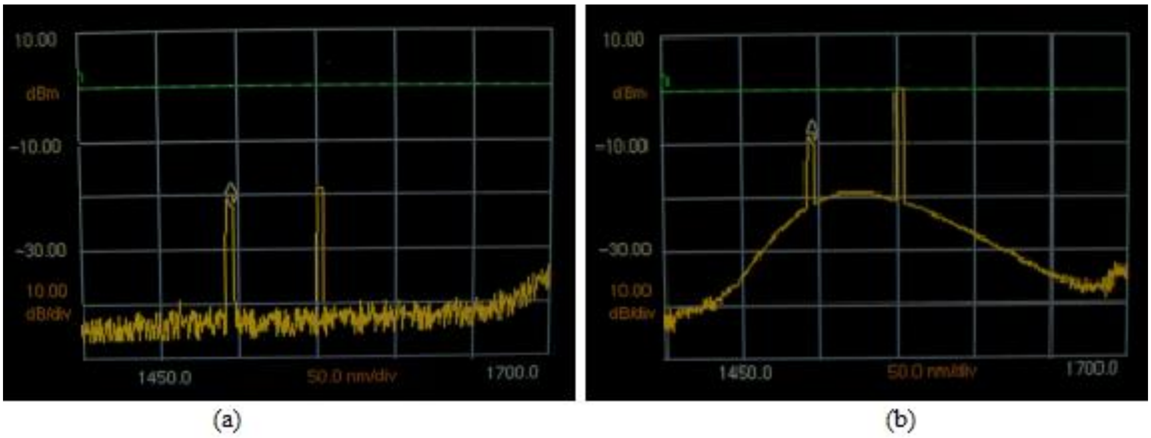
Finally, the measured amplifier can work at wavelengths of 1490 and 1550 nm that are at wavelengths for the downstream traffic but it is not capable of working at a wavelength of 1390 nm that is at a wavelength for the upstream traffic. The amplifier cannot be used in the bidirectional traffic because of the total suppression of the signal at a wavelength of 1310 nm. A bidirectional signal has to be divided into two separated directions using separate amplifiers [5].

Bidirectional transmission was not tested as we established that the amplifier cannot work at a wavelength of 1310 nm. Therefore, the transmission of several wavelengths in the same direction was performed.

5. SIMULTANEOUS AMPLIFICATION SEVERAL WAVELENGTHS

We confirmed in the previous measurement 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 PON simultaneously so we tested the amplification several wavelengths together. The parameters of Laser Diode Controllers were set as in previous measurements, the driving current to 150 mA and the temperature to 25°C. Signals at wavelengths of 1490 nm and 1550 nm with an input power of -20 dBm and -18 dBm, respectively, were connected at the input port of the amplifier. Output powers at wavelengths of 1490 nm and 1550 nm were -7 dBm and 0 dBm, respectively. The spectral characteristics are shown in figure 5 (a) input signals and (b) output signals.

To achieve an optimal amplification the input power into the amplifier should be around -20 dBm. The Optical Line Termination (OLT) in the laboratory has the transmitter power of 0 dBm. Hence, the power budget between the OLT and the downstream amplifier can be 20 dB. It corresponds to a length of 100 km if Single Mode (SM) fiber with an attenuation coefficient of 0.2 dB/km is used. The influence of dispersions (chromatic and polarization mode) must be considered when such a length is concerned. The best placement of the amplifier is at the input port of a splitter [5].



Obrázek 5: Spectral characteristic of (a) input signals and (b) output, amplified signals at wavelengths of 1490 nm and 1550 nm.

6. CONCLUSION

The main aim was to verify the possibilities of using of a supplied amplifier working at a wavelength of 1550 nm in the laboratory PON in order to extend the distance between an OLT and Optical Network Terminations (ONT). Data transmission in PON is bidirectional with a wavelength distance of 180 nm. The amplifier cannot amplify simultaneously both directions because of the narrow spectral width. On the other hand, the spectral width is wide enough to amplify both wavelengths of 1490 nm and 1550 nm together. In any case, bidirectional optical fiber must be divided into two one direction fibers to amplify each direction in a separate amplifier [5]. We confirmed that the distance can be extended up to 100 km. Currently manufactured amplifiers are designed for use at wavelengths of 1310 nm and 1550 nm. It is possible to use an amplifier designed for a wavelength of 1550 nm for amplifying at a wavelength of 1490 nm, but the gain will be lower and so will the saturation power.

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