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Cross Gain Modulation Suppression in SOA Using Polarization Diversified Loop

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Abstract: We proposed and demonstrated a new cross-gain-modulation reduction scheme using semiconductor optical amplifier in a polarization-diversified loop. We achieve ~2.5-3-dB improvement in Q values as compared with the measurements obtained from direct amplification by SOA.

1. Introduction

Semiconductor optical amplifier (SOA) is an attractive device for optical networking systems owing to its compactness, potentially low cost, and ultra wide gain bandwidth. Unlike erbium doped fiber amplifier, however, the fast gain dynamics of the SOA limits its use as an inline amplifier for DWDM system. In particular, the crosstalk derived from cross gain modulation (XGM) corrupts the transmitting signals and prohibits an error free operation. Several schemes for the suppression of XGM were reported in the past, including gain clamping of SOA [1], operating SOA in the linear regime [2], reducing the fluctuation in the total input power into SOA through a complimentary channel [3] or through dispersion [4], and the use of unmodulated reservoir channel [5]. Also, it is well known that the effects arising from XGM can be reduced in the presence of large number of WDM channels [5]. In this paper, we propose a new means to further reduce XGM by the use of a polarization-diversified loop (PDL) which effectively increases the number of WDM channels into the SOA. The proposed scheme allows equal splitting of input signals into the SOA from both directions. The asymmetric positioning of SOA in the loop causes different arrival time of the propagating and counter propagating signals to de-correlate the input bit patterns for each wavelength channel, effectively doubling the number of channels in the SOA. Our experimental results show that at least a 2-dB improvement in the Q value as compared to that obtained from direct amplification by SOA in a 20-channel WDM system.

2. Experiment Setup

The experimental set-up is shown in Fig. 1. 20 channels with wavelengths starting at 1546.6 nm and with 100-GHz channel spacing are multiplexed

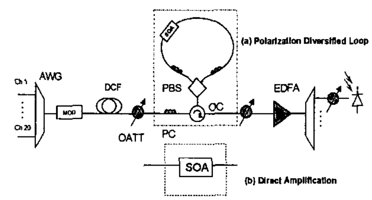

Fig.1. Experimental set-up. (a) and (b) represent the amplifiers with the proposed polarization diversified loop configuration and the direct amplification, respectively. AWG: Array Waveguide grating; DCF: Dispersion Compensating Fiber; OATT: Optical Attenuator; PBS: Polarization beam splitter; SOA: Semiconductor Optical Amplifier; OC: Optical Circulator; PC: Polarization Controller; MOD: $LiNbO_3$ amplitude modulator.

using an array waveguide grating (AWG). The optical inputs are then modulated by a $LiNbO_3$ modulator using 10-Gbit/s 2^{31}-1 NRZ PRBS. The channel-by-channel bit streams are decorrelated by a 3-km dispersion compensation fiber (DCF) as shown. Input power into the SOA is adjusted by an optical attenuator after the DCF. The saturation output power of the SOA is about 7 dBm.

Results from the PDL configuration are compared with that obtained from the direct amplification configuration. In direct amplification configuration shown in Fig.1 (b), the total input and output power are 3 dBm and 7 dBm, respectively. For the loop configuration shown in Fig. 1(a), the input signal is equally split into two directions by using a polarization beam splitter. The input power into the SOA in each direction is −6 dBm corresponding to a total of 3 dBm input power into the SOA. The fiber-to-fiber gain is about 6 dB. The relatively low gain value is due to the total insertion loss of 2 dB by the circulator and the polarization beam splitter. The polarization controllers inside the loop are adjusted so as to obtain the maximum output signal. The amplified output from the loop is again attenuated and pre-amplified by the EDFA before the demultiplexer and the receiver.

3. Result and Discussion

Fig.2 shows the measured Q values obtained from the experiments using both direct amplification and configuration. We also observed that the inband crosstalk from four-wave mixing (FWM) is different for the loop and the direct amplification configuration as shown in the inset of Fig. 2. It is recorded that at channel 1, the FWM crosstalk is about 22.6 dB for the case of direct amplification and is about 2 dB lower for the PDL case. But this difference diminishes as channel number increases. This can be explained by the combined effect of much weaker FWM at wavelengths away from the gain peak (~ channel 5 at 1550 nm) and also the smaller FWM effects at the edge channels.

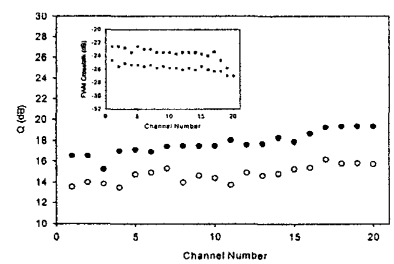

Fig.2. Measured Q values. Solid: Polarization diversified loop, Open: Direct amplification. Inset: FWM crosstalk

To isolate the Q-value improvement from XGM reduction, BER measurements were taken for channel 20, at which the inband crosstalk from FWM is about the same (27 dB) for both loop and direction amplification configuration. Any BER improvement can only be derived from XGM reduction. The results are shown in Fig. 3. The insets are the inverted eye diagrams for both amplification schemes (inverted amplifier is used at the receiver end). For the direct amplification, there is a BER floor near the BER of 10^{-9}, whereas the loop configuration shows no floor. In Fig. 2, we can see the improvement in Q value of channel 20 is about the same compared with the other channels. Therefore it can only be concluded that the XGM is the dominant factor for the error floor in the WDM system using SOA as inline amplifier.

It should be noted that power fluctuation of 0.1-0.25 dB is observed, which may be attributed to the long fiber loop length. Using 3-dB coupler instead of polarization beam splitter has the advantages of polarization independence as well as low cost, easy integration, and low insertion loss, however power fluctuation is even more severe. Waveguide integration of SOA and 3-dB coupler will make the

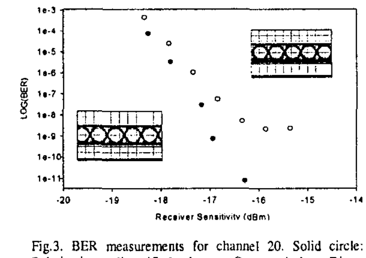

Fig.3. BER measurements for channel 20. Solid circle: Polarization diversified loop. Open circle: Direct amplification. Insets show the eye diagrams of each amplification scheme respectively.

scheme a practical solution.

4. Summary

We proposed and demonstrated a new cross-gain-modulation reduction scheme using SOA in a polarization-diversified loop. We achieve ~2.5-3-dB improvement in Q values as compared with the measurements obtained from direct amplification by SOA.

6. Reference

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