"Cross Gain Modulation" effect of SOAs for different modulation formats

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***Abstract*— Due to the compact, potentially low-cost, ultra wide available bandwidth characteristics, semiconductor optical amplifier (SOA) is very attractive amplifying device in low-cost optical network systems. In that application, the SOA must be necessarily operated at the saturation level to obtain the required optical signal-to-noise ratio (OSNR) at the receiver. However, cross-gain modulation (XGM) effect resulting from its fast carrier dynamics limits its use in wavelength-division-multiplexed (WDM) optical network systems. Only a few methods are proposed and demonstrated to overcome this XGM effect [3]. They require a specific operation condition such as polarization multiplexing, large number of WDM channels that statistically decreases the total power fluctuation or operating the SOA in a weakly gain suppressed regime far from the gain peak. My objective is to compare the cross gain modulation effect in OOK, Manchester, Doubinary and DPSK modulation format in SOAs.**

***Keywords*- Cross-gain modulation (XGM), Wavelength Division Multiplexing (WDM), differential phase-shift keying (DPSK), semiconductor optical amplifier (SOA), Optical Signal to Noise Ratio (OSNR).**

I. Introduction

A novel dual-input Mach–Zehnder modulator was used in conjunction with a wavelength modulation scheme to remove the cross-gain modulation in the semiconductor optical amplifier (SOA). Eight 10 Gb/s wavelength-division-multiplexed channels are transmitted over 75 km of dispersion-shifted fiber with a semiconductor optical amplifier as an in-line amplifier, with less than 1.5-dB penalty [1]. Cross Gain Modulations is one of the non-linear effects that can arise inside a semiconductor optical cavity (as a SOA). It takes place when a high power signal (called Pump) is injected into the SOA, depleting most of the carriers present in the active region when it is amplified, if we simultaneously inject a lower power signal (Probe) in the SOA it will be attenuated due to the absorption of the carriers. In the case where pump and probe are binary signals modulated in amplitude, the XGM causes that the output probe signal can be interpreted as the logic function *(Probe)AND(NOT(Pump))*, this response has been extensively referenced in the literature [4]. Compared with erbium-doped fibre amplifiers (EDFAs), semiconductor optical amplifiers (SOAs) offer a number of advantages for high-capacity transmission systems. These advantages include compactness, low cost, low power consumption, ease of integration with other devices, and ultra wide gain spectrum. However, SOAs suffer from cross-gain modulation (XGM), which results in crosstalk penalty for wavelength-division-multiplexing (WDM) signals [1]. This is due to its relatively low saturation energy and gain recovery time comparable to the bit period. Conventional ON–OFF-keyed (OOK) signals, such as return-to-zero (RZ) and non return-to-zero (NRZ) formats, have long consecutive "1" or "0" bit, which has high randomness. Hence, they are susceptible to XGM effect in SOAs. Recently, the wavelength modulation technique is proposed to reduce the XGM effect of the NRZ signal in SOAs [3]. However, dispersion in the transmission system limits the effectiveness of this technique. The RZ differential phase-shift keying (RZ-DPSK) signal has periodical amplitude and data is represented in phase only. Therefore, in intensity it is equivalent to (2^1-1) the pseudorandom binary sequence (PRBS) signal. Pattern effect as a result of XGM in SOAs can be reduced effectively by using DPSK signal [2]. By combining Manchester and duobinary signals together, the dispersion tolerance capability of the resulting signal is increased by nearly three times and this makes it a potential candidate for long-haul transmission [10]. The maximal consecutive “1” or “0” in the Manchester & duobinary signal is only two bits, which is equivalent to (2^2-1) PRBS signal. As a result, the Manchester & duobinary signal should also suffer less XGM effect in SOAs compared with that of conventional OOK signals like NRZ and RZ.

II. SYSTEM DESIGN & IMPLEMENTATION

This Paper provides a complete description of the design of the system that how to compare the cross gain modulation (XGM) in SOAs using OOK, Manchester, Duo-binary and DPSK signals using optical communication systems design software (Optisystem 7.0).

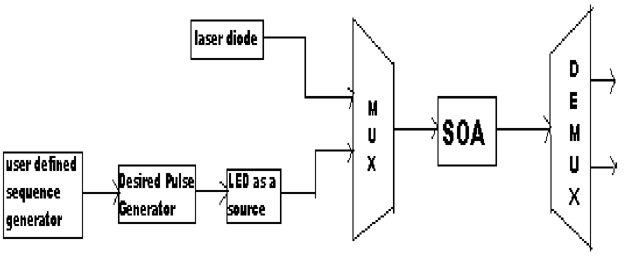

Fig. 1 System Design

Here I designed the above system using optisystem software for OOK, DPSK, Duo-binary & Manchester signal format as a desired pulse generator. Here I am multiplexing high power signal (pump signal) at 1550 nm wavelength from laser diode & low power signal (probe signal) at 1540 nm from LED. Then this multiplexed signal is transmitted through SOA (Semiconductor Optical Amplifier) and then demultiplexes it. Here I am checking the power level of low power signal (probe signal) & high power signal (pump signal) at SOA input & output to check for XGM effect.

III. RESULTS & ANALYSIS

For RZ signal format, I am getting the probe signal power of -74 dBm and pump signal power of -61.844 dBm. Here we are able to see that there is a 30 dBm improvement in power level.

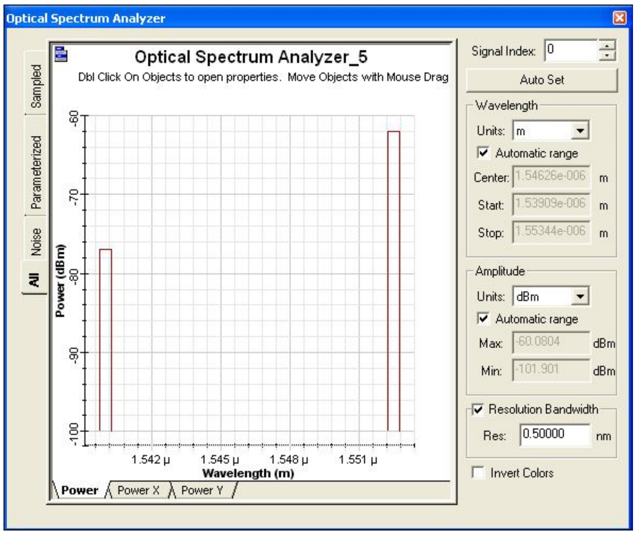

Fig. 2 SOA output shown in spectrum analyzer for RZ

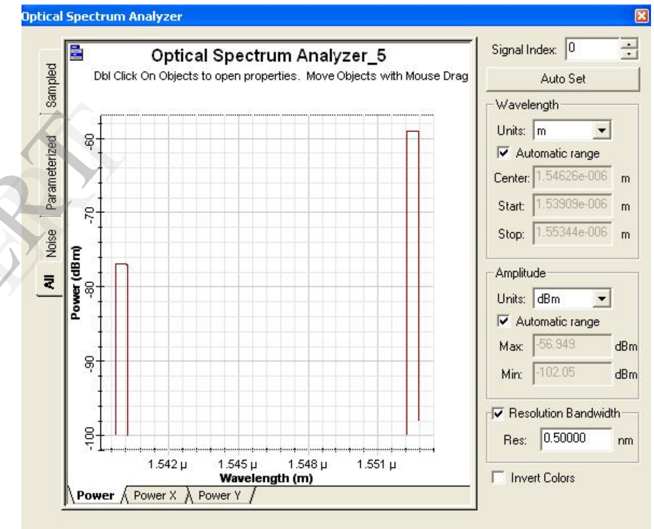

Fig. 3 SOA output shown in spectrum analyzer for NRZ

For NRZ signal format, I am getting the probe signal power of -73 dBm and pump signal power of -59.929 dBm. Here we are able to see that there is a 3 dBm improvement in power level of pump signal and 1dBm improvement of power level of probe signal compared with RZ signal format.

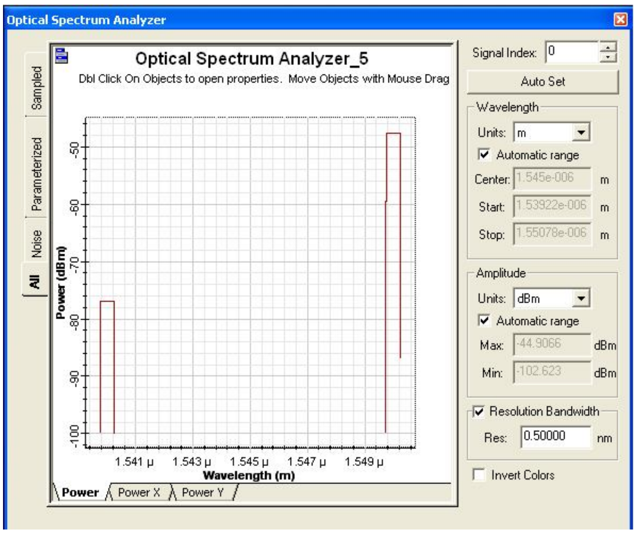

Fig. 4 SOA output shown in spectrum analyzer for DPSK

For DPSK signal format, I am getting the probe signal power of -76 dBm and pump signal power of -47.525 dBm. Here we are able to see that there is a 11 dBm improvement in power level of pump signal and 3 dBm decrement of powerlevel in probe signal compared with NRZ signal format.

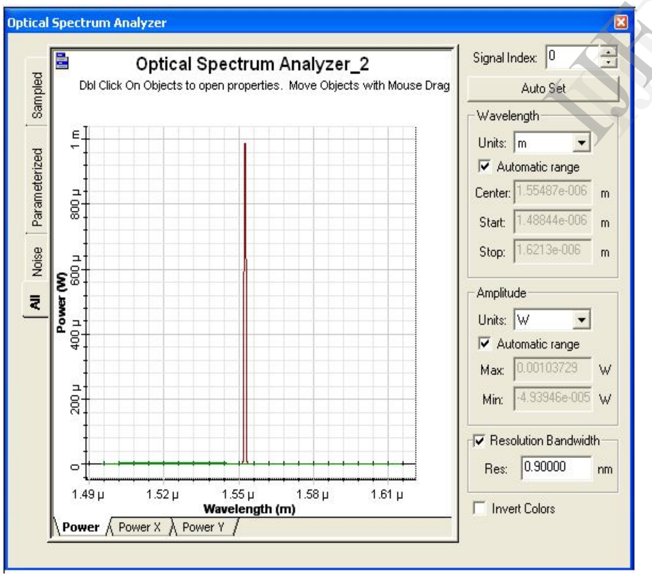

Fig. 5 SOA output shown in spectrum analyzer for Duobinary

For Duo-binary signal format, I am getting the probe signal power of -56 dBm and pump signal power of 0.242 dBm. Here we are able to see that there is a 47 dBm improvement in power level of pump signal and 20 dBm improvement of powerlevel in probe signal compared with DPSK signal format.

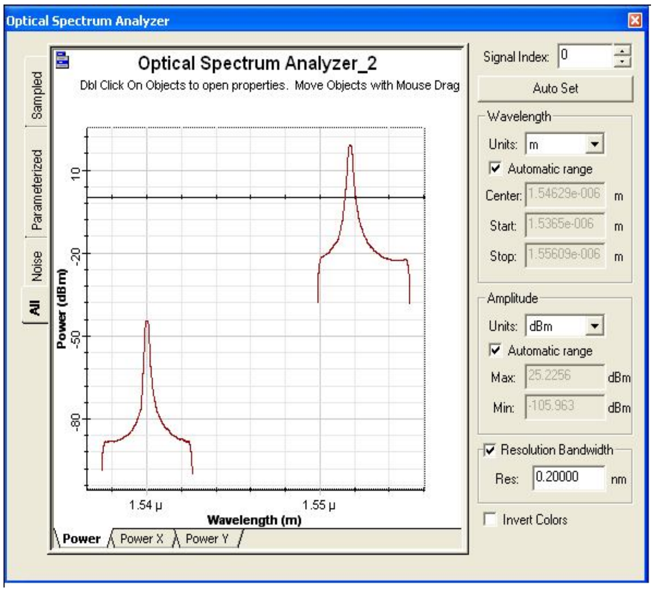

Fig. 6 SOA output shown in spectrum analyzer for Manchester

For Manchester signal format, I am getting the probe signal power of -44 dBm and pump signal power of 19.777 dBm. Here we are able to see that there is a 19.5 dBm improvement in power level of pump signal and 12 dBm improvement of powerlevel in probe signal compared with Duo-Binary signal format.

Following table shows that Manchester signal has highest power for both the signals, Pump as well Probe signal, compared to all. So, it is used to remove cross gain modulation (XGM) effect.

TABLE I
CUMULATIVE RESULTS

Sr. No.	Modulation Format	SOA Output Power (Pump signal)		SOA Output Power (Probe signal)
		dBm	Watts	dBm
1	RZ	-61.844	654.03 pw	-74
2	NRZ	-58.929	1.28 nw	-73
3	DPSK	-47.525	17.68 nw	-76
4	DUO-BINARY	0.242	1.057 mw	-56
5	MANCHESTER	19.777	95.022 mw	-44

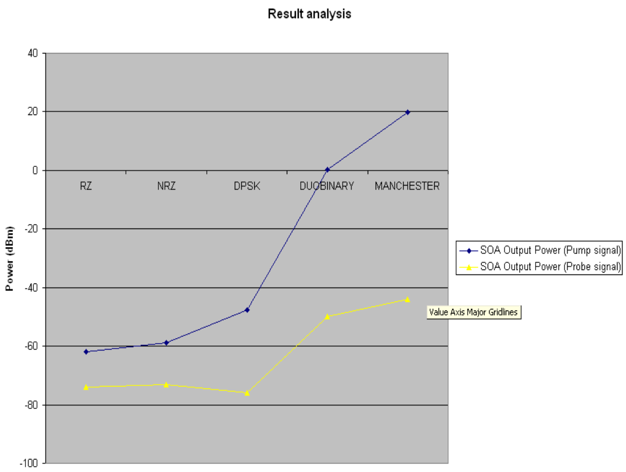

Fig. 7 Result analysis using line chart

IV. CONCLUSION

From the design and the implementation of the system presented in this document it can be concluded that this system could solve many of the challenges that are faced by cross gain modulation effect (XGM) in semiconductor optical amplifiers (SOAs) in optical communication system. Because of the flexibility and ease of designing by using the optical communication system design software, presented system could be adapted for any application for long haul optical communication in which semiconductor optical amplifiers are used. Here the cross gain modulation (XGM) effect in SOAs using OOK, Manchester, duo-binary & DPSK coding is investigated and compared. For future this system can solve many technological challenges.

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