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ASE and Cross-Gain Modulation Limitations in a Four-Channel CWDM Transmission System using a SOA

Ahmad Atieh*, Paul Vella
BTI Photonic Systems Inc
2191 Thurston Drive Ottawa, Ontario
Canada, K1G 6C9

ABSTRACT

The dominant limiting factors affecting the performance of an amplified 10-Gbps CWDM data transmission system with an inline semiconductor optical amplifier (SOA) are investigated. More than 3 dB of system penalty at a BER of 1×10^{-9} can be attributed to ASE and cross-gain-modulation (XGM) effects.

Keywords: SOA, cross-gain modulation, ASE, CWDM amplifier, CWDM transmission system

1. INTRODUCTION

Coarse wavelength division multiplexing (CWDM) transmission systems offer cost-effective means of delivering broadband optical services within applications such as metropolitan and enterprise networks. In order to extend system reach or maintain reach in applications where a large number of passive optical components are used, the transmitted signals will need to be regenerated. However, since regeneration can be costly, less expensive alternatives have been investigated involving different amplification technologies including semiconductor Optical Amplifiers (SOAs) [1, 2].

However, SOAs suffer from high NF (about 8 dB) and spurious effects such as those arising from cross-gain modulation (XGM) [3]. As well, ASE beat noise at low input power levels plays an important role in CWDM systems because of the relatively large bandwidth of MUXs and DEMUXs, which is about 15 nm. XGM effect results from fast gain dynamics of the SOA (~100 ps). For a multi-channel data transmission system, XGM manifests itself as an imprint of data from the other channels on the saturated channel's signal due to carrier depletion.

In this work, we investigate the effects of ASE beat noise and XGM on data transmission in an amplified CWDM telecommunication system. An SOA-based inline amplifier, operating in the wavelength range between 1460 nm and 1540 nm, is used to amplify input signals in the range between -26 dBm to -15 dBm. We will report on the dominant impairment factors and associated power penalties when both ASE beat noise and cross-gain modulation effects are present.

2. EXPERIMENT SETUP

Fig. 1 shows a block diagram of the experimental setup used in the amplified CWDM data transmission system. Four CWDM channels are multiplexed and modulated with an OC-192 formatted signal at 10Gbps using an external Mach-Zehnder modulator. The signals are then multiplexed and propagated through a 5-km SMF-28 fiber to decorrelate the channels. A pseudo-random bit sequence of 2^{31}-1 word length is used in the experiment. The input power levels of each of the four channels are adjusted using a voltage controlled attenuator (VOA) in order to cover the range -15 dBm to -26 dBm per channel. The modulated signals are launched into the SOA and a demultiplexer is used to isolate the channel under test. A band-pass tunable filter (~0.8 nm) is used after the demultiplexer to filter out most of ASE getting through the DEMUX.

*aatieh@btiphotonics.com; Tel: 613 248 9154; Fax: 613 248 9156; www.btiphotonics.com

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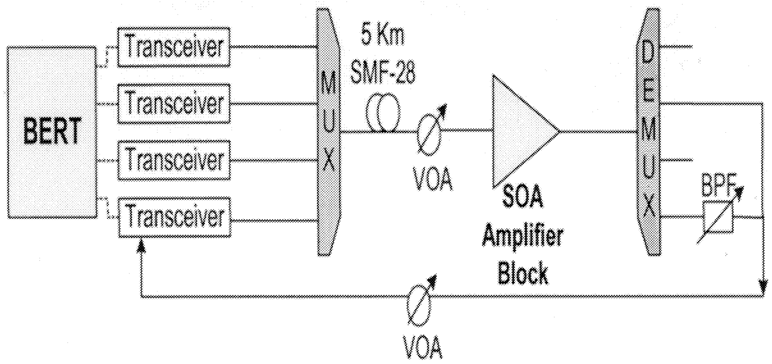

Fig. 1. Block diagram of the experimental setup. BERT: Bit-error rate test equipment; VOA: Voltage controlled attenuator; MUX/DEMUX: Multiplexer/Demultiplexer; SOA: Semiconductor optical amplifier; BPF: Band pass filter.

3. RESULTS AND DISCUSSION

The SOA used in the CWDM amplifier has a gain profile with flatness of 7 dB across the operating wavelength range of 1460 nm to 1540 nm. The maximum gain is 25 dB at 1470 nm as shown in Fig. 2. The 1470-nm channel saturates much earlier than the other channels at an input power level of about -18 dBm as illustrated in Fig. 3. The measured NF for the different channels versus composite output power is shown in Fig. 4. The noise figure for the 1470-nm channel is relatively higher because the SOA gain ripple is much higher at this wavelength.

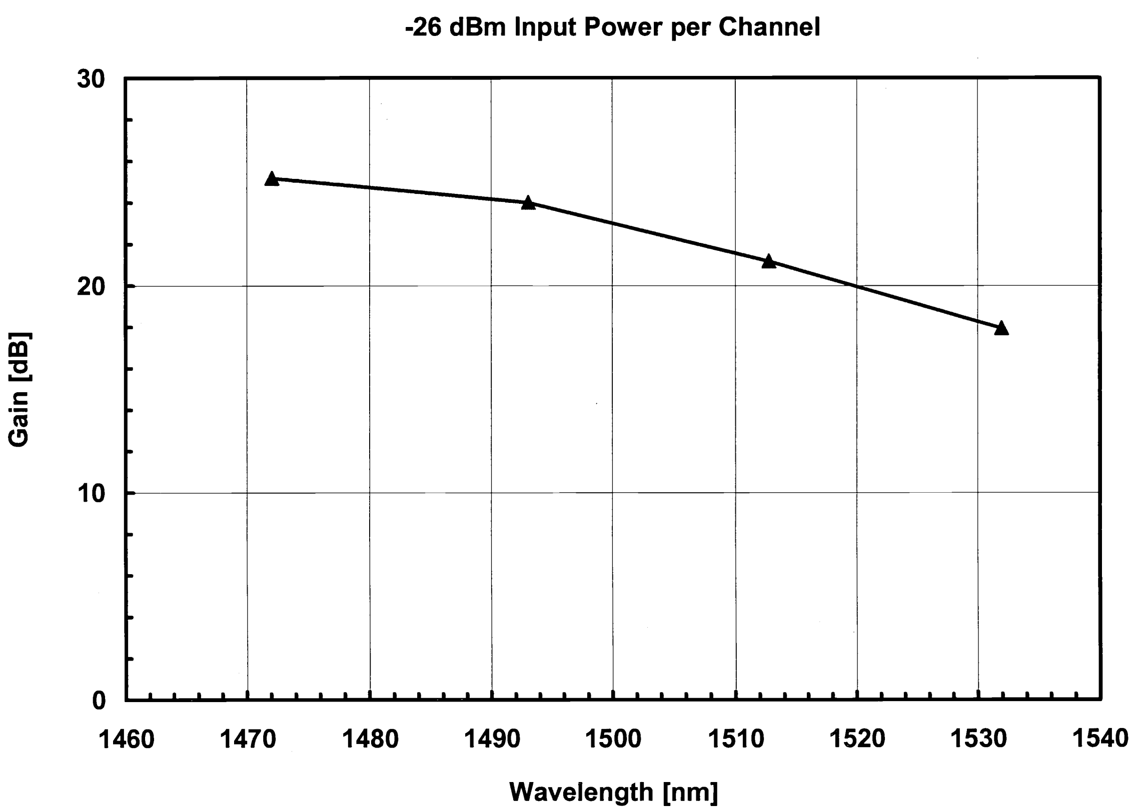

Fig. 2. Measured gain profile for the SOA amplifier under test.

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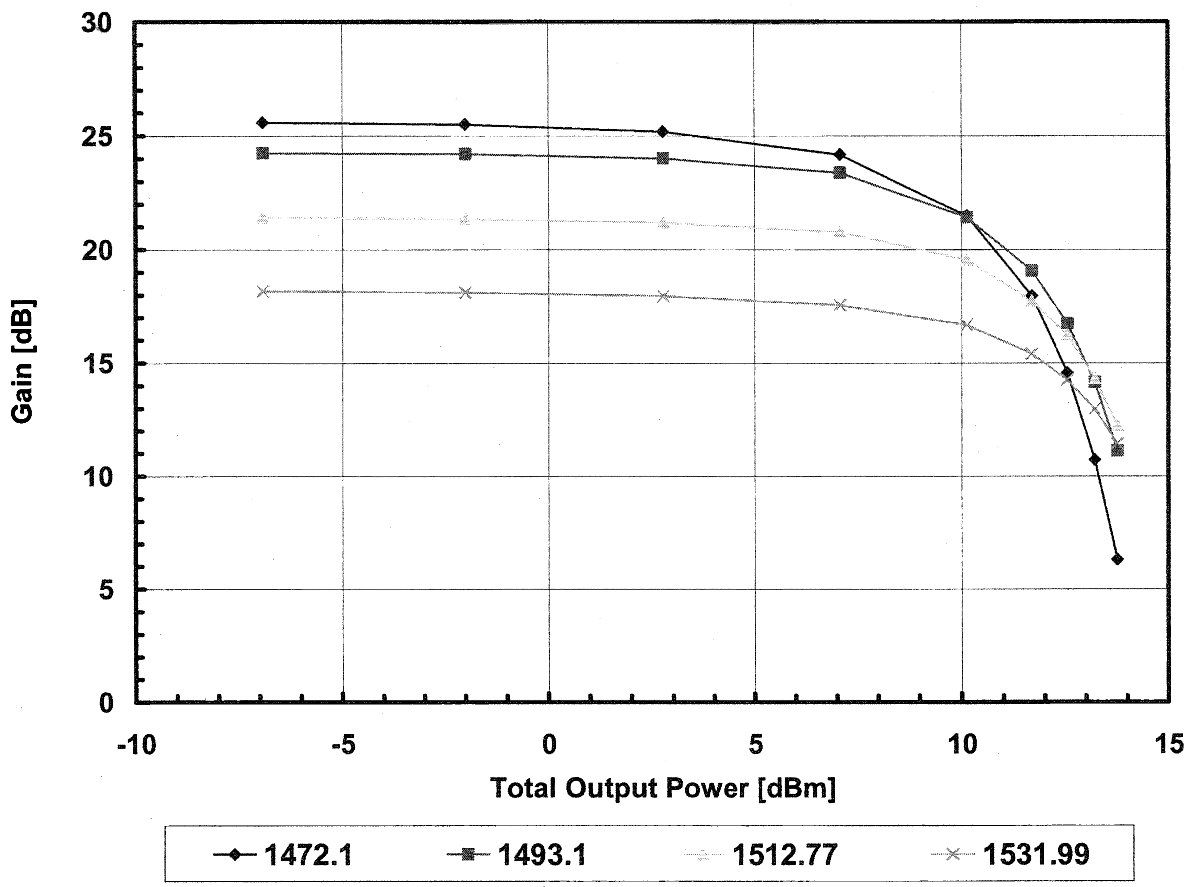

Fig. 3. Measured gain versus composite output power (with equal input power per channel) for different wavelengths launched into the SOA.

Since the primary system impairment in a SOA-based multi-channel system arises from ASE-related noise, an experiment was carried out to determine the ASE levels associated with the various combinations of channels undergoing amplification. The results are shown in Fig. 5, where it is seen that the channel capable of least gain, that at 1530 nm, exhibits the highest level of ASE. It is also noted that for composite input power levels of –15 dBm, the level of ASE associated with single-channel operation at 1490 nm and 1470 nm and with all multi-channel combinations is the same to within $\pm$0.25 dB.

To study the effect of cross-gain modulation, a BER experiment was conducted on the 1470-nm channel, both when operating as a single-channel and under multi-channel conditions. The results are summarized in Fig. 6. Since we have seen in the previous Section (see Fig. 5) that the ASE levels associated with the channel combinations in Fig. 6 are virtually equal, the power penalties measured relative to the 1470-nm, single-channel BER at 1×10^{-9} are due to XGM effects. As much as 2.8 dB of power penalty for 3- and 4-channel amplification can be attributed to XGM. For the 2-channel amplification in Fig. 6, a 1.3-dB penalty due to XGM is indicated.

While the main contributor to system impairments is the ASE, it is important to realize that this effect can be reduced through the use of ASE filters. Not so for XGM-related impairments.

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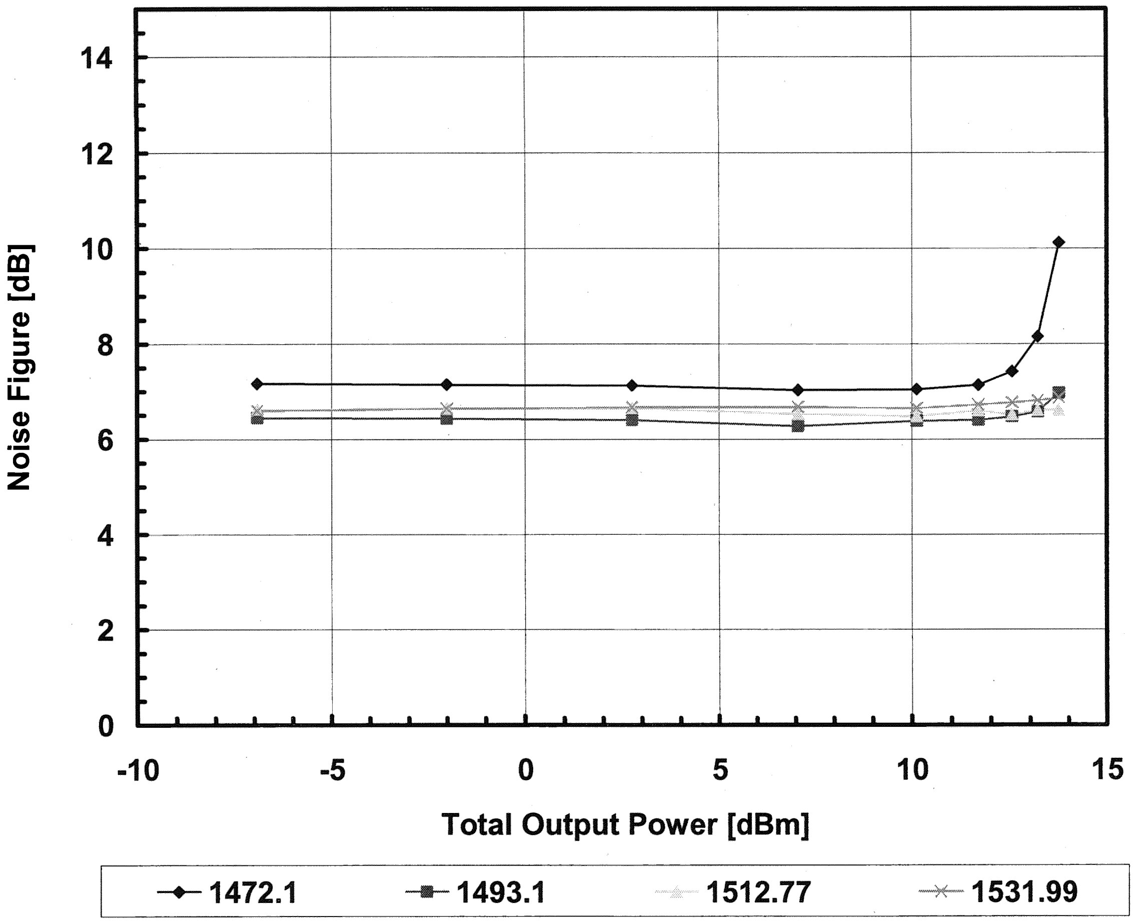

Fig. 4. Measured noise figure versus composite output power for different wavelengths launched into the SOA.

The system performance at lower input power levels of -23 dBm per channel is shown in Fig. 7. System penalties were compared at a BER of 1×10^{-9} for cases when only ASE beat noise is present (1-channel of -23 dBm), when two channels with a composite power level of -20 dBm was amplified, and when ASE is filtered out from the channel being monitored (2-channel case) using a 0.8-nm narrow-band tunable filter. In all these cases, the monitored signal is at 1530 nm. The dominant impairment factor in these scenarios results from the ASE contribution because the signals launched into the amplifier are at a relatively low input power of -23 dBm per channel. The experiment was repeated for input power level of -26 dBm per channel and for a composite power level of -23 dBm.

As shown in Fig. 7, an improvement in system performance of 0.5 dB is obtained when two channels are launched into the amplifier relative to a single-channel launch of -23 dBm. This is the result of the larger SNR and lower ASE power present for the 2-channel case. On the other hand, a system degradation of 1 dB is observed for the case of -26 dBm per channel (two channels) compared to the -23 dBm single channel.

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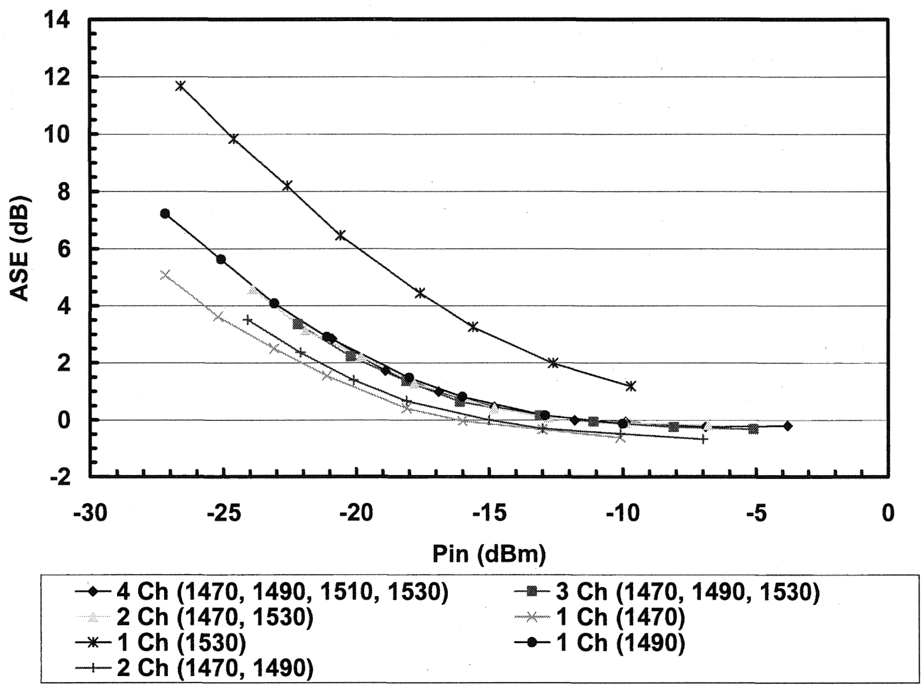

Fig. 5. Calculated ASE (dB) as function of input power for different channel combinations launched into the SOA

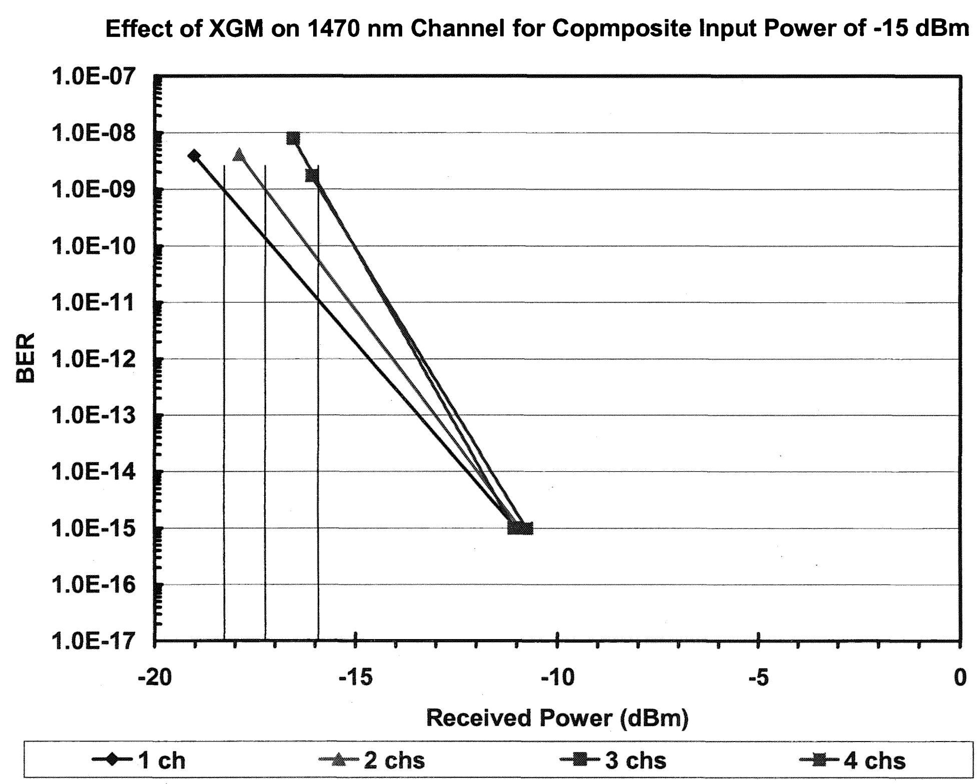

Fig. 6. Measured BER for different channel combinations taken at a composite power level of -15 dBm

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Fig. 8 illustrates the combined effect of ASE beat noise and XGM for a 4-channel transmission experiment when input power per channel is -21 dBm. The same measurement was repeated for different input power levels per channel. As shown in Fig. 9, over 3 dB of system penalty was measured at 1530 nm for the case when -26 dBm of input power was launched into the SOA in comparison to the case when an ASE filter was used. This penalty drops to about 1 dB at -21 dBm input power per channel.
The major parameter that contributed to system degradation resulting in high system penalty for the -26 dBm per channel case is larger ASE beat noise, which resulted in lower SNR at the output of the SOA. While, much lower ASE presented for the second input power case of -21 dBm per channel, which resulted in higher SNR caused reduction in the system penalty. Note that higher XGM effect does not deteriorate the system much at high input power level (-15 dBm composite) which leads to the conclusion that ASE impairments are more sever than those of XGM nonlinear effect.

3. CONCLUSIONS

It is found that ASE beat noise and relative SNR are the dominant performance limitation at low input power levels, while XGM effect is the dominant effect at high input power levels. It is possible to operate SOA deeper into saturation with incurring much of system penalty. However, both effects introduce over 3.0 dB of system penalty at a BER of 1×10^{-9} in comparison to an ASE-filtered CWDM system.

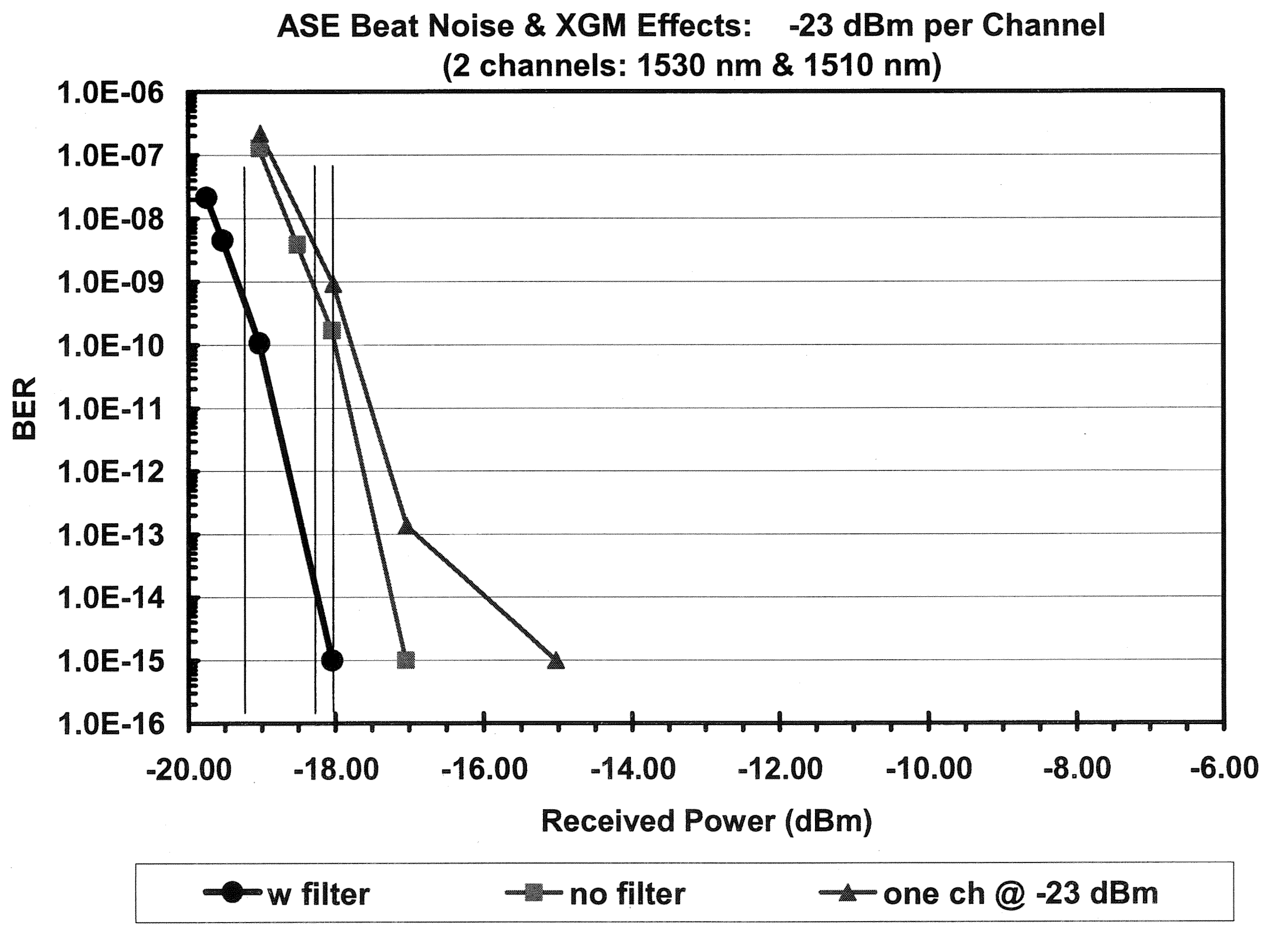

Fig. 7. Measured BER at 1530 nm when two channels are launched into the SOA with -23 dBm per channel, with and without filter. For comparison, the BER for single-channel, at 1530 nm and –23 dBm, is plotted.

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REFERENCES

1. P. Iannone et al, OFC'2003, ThQ3, pp. 548-550, 2003.
2. M. Dagenais et al, OFC'2003, MF69, pp. 85-87, 2003.
3. M. Bachmann et al, Electron Lett, Vol 32, No 22, pp 2076-2078, 1996.

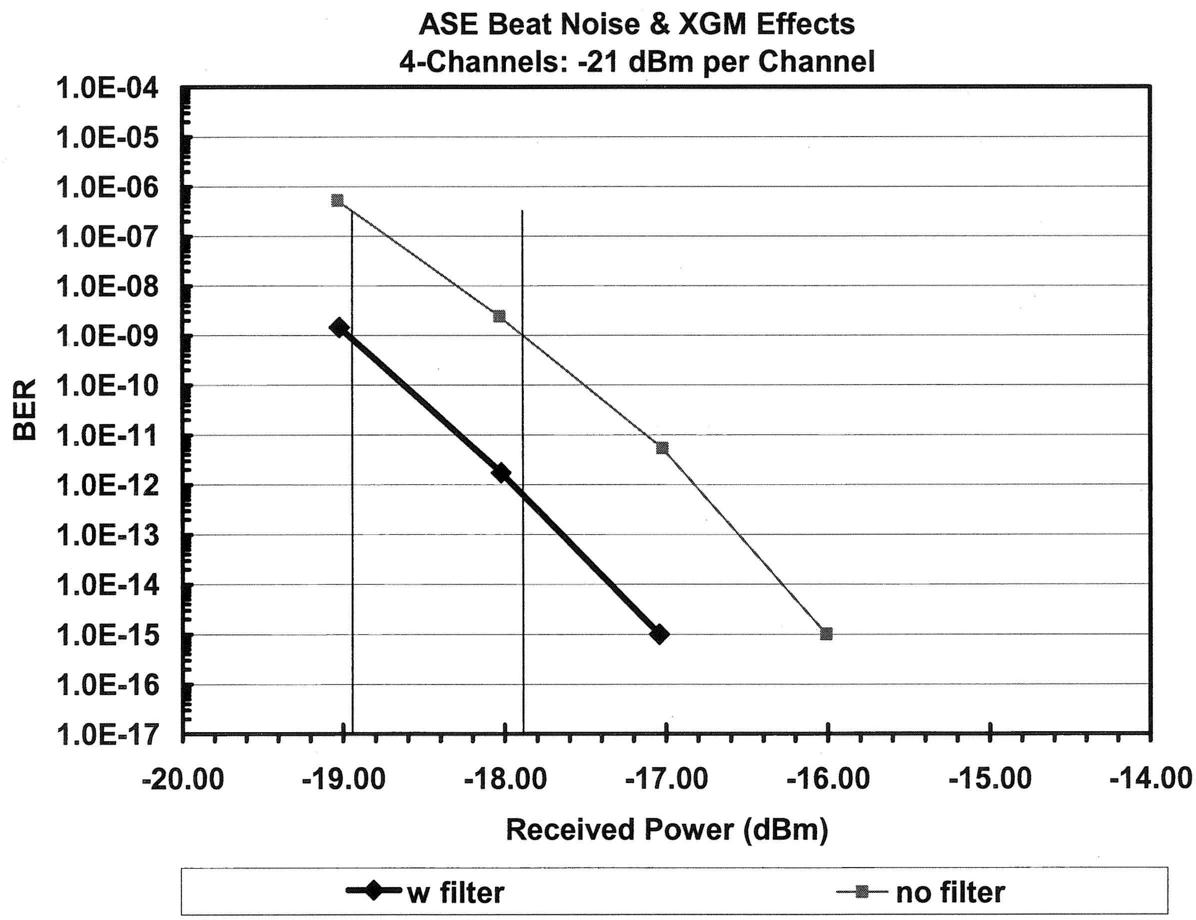

Fig. 8. Measured BER at 1530 nm with and without filter in 4-channel transmission of -21 dBm per channel.

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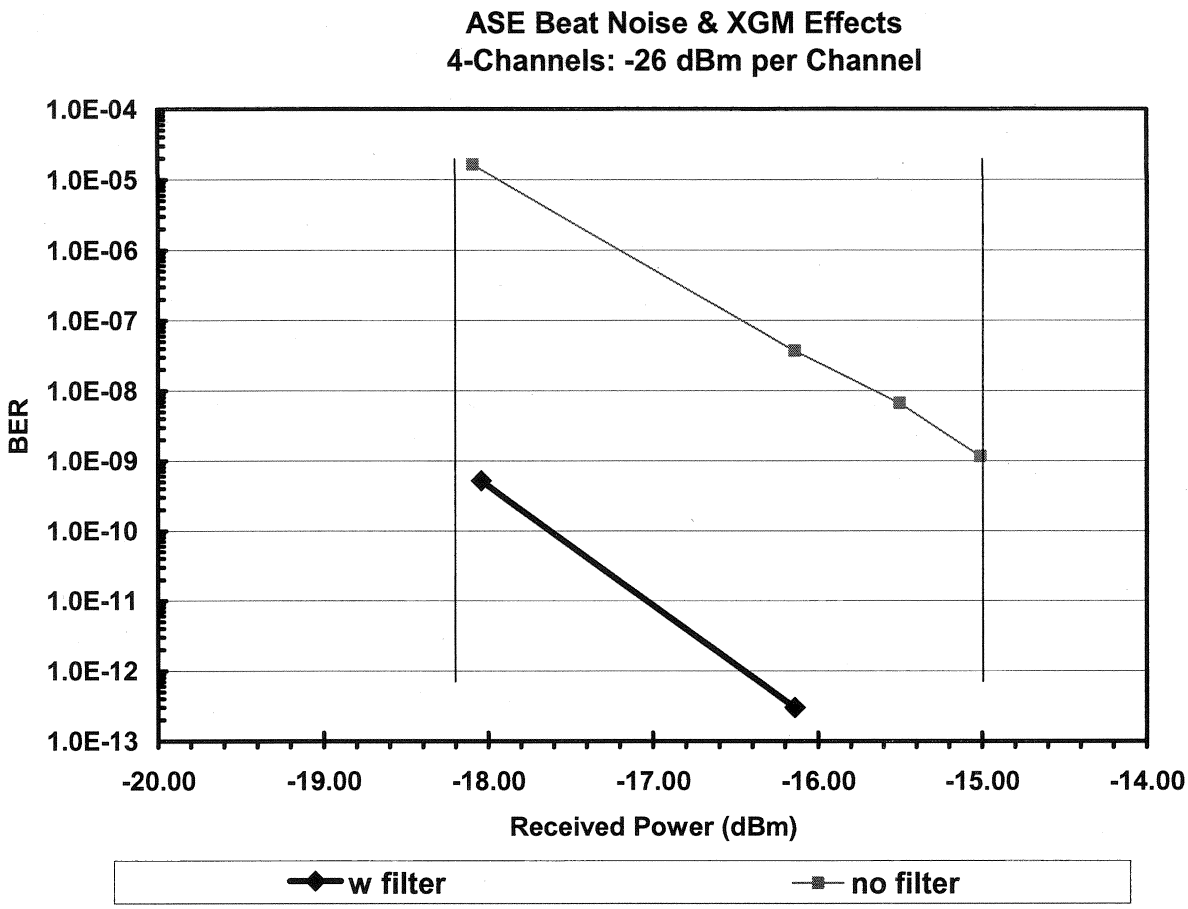

Fig. 9. Measured BER at 1530 nm with and without filter in 4-channel transmission of -26 dBm per channel.

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