Performance Analysis of Wavelength Converter based on Cross-Gain Modulation for Varying SOA Active Length using ANFIS

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ABSTRACT
In the present work, we investigate the impact of active length variation of Semiconductor Optical Amplifier (SOA) on the performance of wavelength converter based on cross-gain modulation (XGM) for different SOA active length up to 0.0004m. The system performance has been analyzed by varying input power from -9 to 10 dBm. It is found that the system gives optimum performance at SOA active length of 0.0003 m when input power is of 0 dBm beyond which it degrades. Further, the fuzzy model of the system is developed using ANFIS (Adaptive Neuro-Fuzzy Inference System), for varying input power and performance is evaluated by comparing simulated results with fuzzy model and good correlation is achieved between them.

General Terms
Fuzzy based analysis of wavelength converter in optical system.

Keywords
XGM, SOA, Fuzzy Logic, ANFIS.

1. INTRODUCTION
Now a days wavelength conversion is a highly desired function for future broadband optical networks based on wavelength division multiplexed (WDM) architecture [1]. Cross-gain modulation XGM in semiconductor optical amplifiers is an efficient and simple technique to realize all-optical wavelength conversion [2] in comparison with cross-phase modulation [3] and four-wave mixing [4] techniques.

Ellis et al. [5] reported, 100 Gbit/s wavelength conversions using grating assisted cross-gain modulation in a 0.0002m long SOA but facet reflection degrades the performance. In order to suppress the facet reflection, Tiemeijier et al. [6] shown that an extremely low facet reflectivity up to the order of 10-6 or tilted active region, aspheric lens and isolator, should be utilized. Moreover, an SOA with a long active region had better be used in cross-gain wavelength conversion in order to achieve high output extinction ratio and high conversion bit rates [5] thus fabrication of the SOA will be more difficult. Furthermore, as we know, serious extinction ratio degradation exists in cross-gain wavelength up conversion based on the conventional scheme [7].

In this paper, XGM based wavelength conversion using SOA is simulated, in which the input CW probe power is varied from -9 to 10 dBm for different SOA active length. Based on the this scheme, results show that the output optical signal to noise ratio (OSNR) can be 61 dB at an active length of 0.0003 m where as 52 dB and 43 dB at an active length of 0.0002 and 0.0004 respectively. Further, the simulated results have been confirmed by using ANFIS fuzzy model. Here, in section 2, the system description and simulation parameters have been described. In section 3, the fuzzy model has been discussed. In section 4, comparison of results of the simulated system and the fuzzy model has been reported and finally in section 5, conclusions are made.

2. SYSTEM SIMULATION
The schematic of optical communication system simulation setup is shown in Figure 1. Pseudo-Random Bit Sequence (PRBS) generator with at bit rate 10 Gb/s has been used. The PRBS logical signal is converted into electrical signal using return to zero RZ (RZ) electrical pulse generator. It is further modulated by Mach-Zehnder (MZ) modulator modulates with an extinction ratio 20dB and CW probe optical source operating at 193 THz with line width = 10 MHz and input power = -9 to 10dBm.

After this, probe and pump signal are passed through the WDM mux and then launched into SOA. Then the input signal and the CW pump signal at 193.1 THz can be launched either co-directionally or counter-directionally into the SOA. A co-propagation scheme is considered here. The principle use of the cross-gain modulation in SOA is as modulated input signal that modulates the gain in the semiconductor optical amplifier via gain saturation effect. A continuous wave signal at the selected output wavelength is modulated by the gain variation. After the SOA, the continuous wave signal carries the same information as the modulated signal. Here, the active length of SOA is varied from 0.0002 to 0.0004 m. The output of the conversion stage is then connected to the demultiplexer and the 2 channels could be addressed independently at 193 THz and 193.1 THz frequencies. At the receiver, the signal is detected by a PIN photodiode (PD). It has responsivity of 0.7A/W and dark current = 10nA having thermal noise 79.99 W/Hz. It is then passed through the low pass Bessel filter with 3dB cut-off frequency = 0.75 × bit rate, order of the filter = 4, depth = 100dB. Thereafter, electrical signal that can be connected directly to the BER analyzer, which is used to measure BER, Q value, eye opening etc. We have also considered the ASE noise, shot noise, thermal noise, estimated receiver noise and ASE-ASE noise effects in the optical receiver.

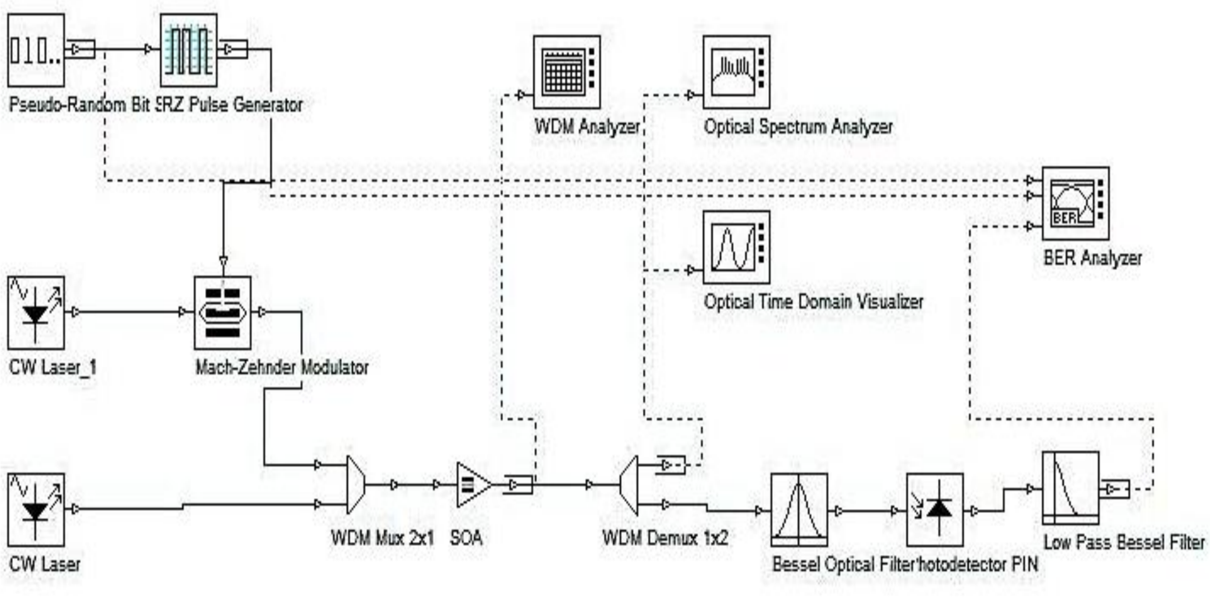


Fig 1: Simulation Setup of XGM based SOA wavelength converter

3. FUZZY MODEL

Here, Sugeno fuzzy model of XGM based wavelength converter system as shown in Figure 2 is developed using ANFIS (Adaptive Neuro-Fuzzy Inference System) for varying input power (input1) and SOA active length (input 2). The OSNR value [dB] acts as the output of the system.

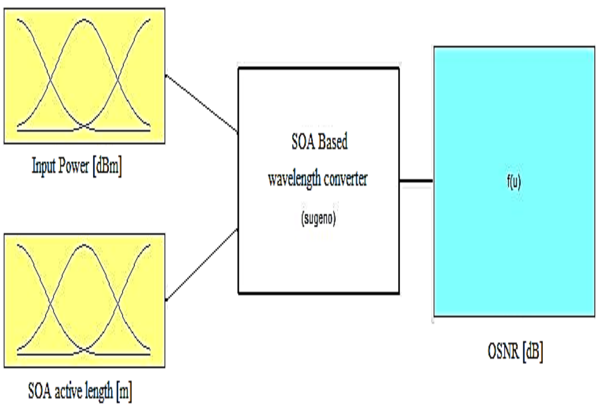
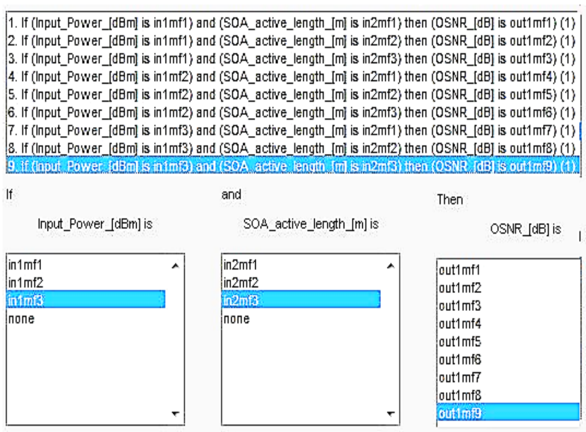


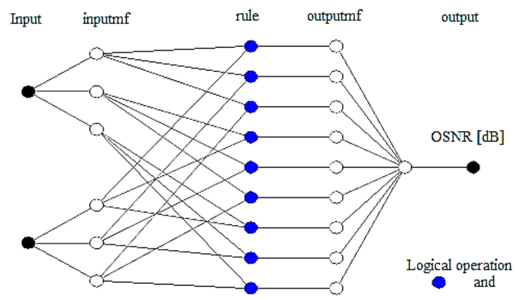
Fig 2: Sugeno based fuzzy model of XGM based wavelength converter system

The XGM based wavelength converter system model uses nine rules for fuzzy model without sub clustering and eighteen rules for fuzzy model with sub clustering [8-9]. Set of linguistic rules for fuzzy model without sub clustering are given below in Table 1.

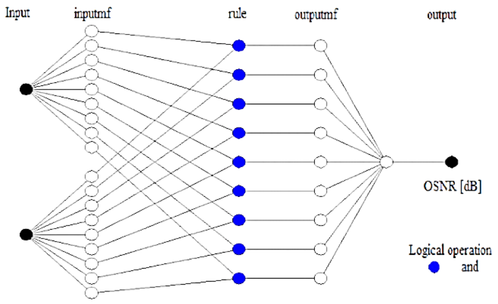
Table 1 Set of linguistic rules


1. If (Input_Power_[dBm] is in1mf1) and (SOA_active_length_[m] is in2mf1) then (OSNR_[dB] is out1mf1) (1)
2. If (Input_Power_[dBm] is in1mf1) and (SOA_active_length_[m] is in2mf2) then (OSNR_[dB] is out1mf2) (1)
3. If (Input_Power_[dBm] is in1mf1) and (SOA_active_length_[m] is in2mf3) then (OSNR_[dB] is out1mf3) (1)
4. If (Input_Power_[dBm] is in1mf2) and (SOA_active_length_[m] is in2mf1) then (OSNR_[dB] is out1mf4) (1)
5. If (Input_Power_[dBm] is in1mf2) and (SOA_active_length_[m] is in2mf2) then (OSNR_[dB] is out1mf5) (1)
6. If (Input_Power_[dBm] is in1mf2) and (SOA_active_length_[m] is in2mf3) then (OSNR_[dB] is out1mf6) (1)
7. If (Input_Power_[dBm] is in1mf3) and (SOA_active_length_[m] is in2mf1) then (OSNR_[dB] is out1mf7) (1)
8. If (Input_Power_[dBm] is in1mf3) and (SOA_active_length_[m] is in2mf2) then (OSNR_[dB] is out1mf8) (1)
9. If (Input_Power_[dBm] is in1mf3) and (SOA_active_length_[m] is in2mf3) then (OSNR_[dB] is out1mf9) (1)

If — Input_Power_[dBm] is: in1mf1, in1mf2, in1mf3, none
and — SOA_active_length_[m] is: in2mf1, in2mf2, in2mf3, none
Then — OSNR_[dB] is: out1mf1, out1mf2, out1mf3, out1mf4, out1mf5, out1mf6, out1mf7, out1mf8, out1mf9



(a)



(b)

Figure 3 ANFIS model structure (a) Without sub-clustering (b) With sub-clustering

Further, the ANFIS model structure for wavelength converter based on cross-gain modulation system without and with sub-clustering is represented in Figure 3(a) & (b) respectively.

4. RESULTS AND DISCUSSION

To estimate the performance, the OSNR values [dB] from the optical wavelength analyzer have been considered at 193.1 THz frequency.

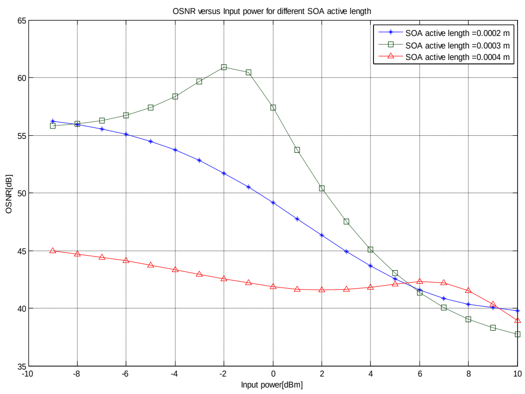


Fig 4: OSNR Value [dB] versus Input power [dBm] of XGM based wavelength converter for varying input power from -9 to 10 dBm at different SOA active length.

Figure 4 shows the graphical representation of OSNR value [dB] as a function of input power [dBm] ranging from -9 to 10 dBm and at different SOA active lengths that varies 0.0002 to 0.0004 m. It is quite evident from the Figure 4 that OSNR value is of 60.9 dB at an active length of 0.0003 m where as 52 and 42 dB at an active length of 0.0002 and 0.0004 respectively. Thus penalty required for two lengths is of 9 and 18 dB. For active length of 0.0003 m, an OSNR value decreases with the increase in input power and the system performance degrades if the active length is decreased and increased from 0.0003 m. The XGM based system gives optimum performance at SOA active length = 0.0003 m and input power = -2 dBm.

Figure 5(a) shows the rule viewer of fuzzy system without sub-clustering for a specific case when input power = 1 dBm and SOA active length = 0.0003 m, the output OSNR value [dB] obtained is 60.3, which is close to the OSNR value = 60.9 obtained by simulation.

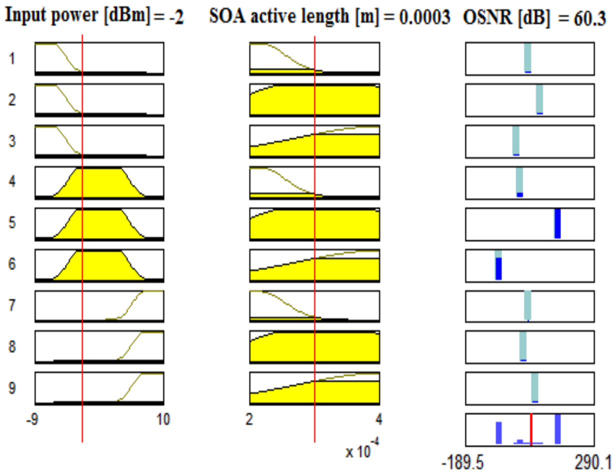


Fig 5 (a): Rules viewer of OSNR Value [dB] for input power of 1 dBm and SOA active length of 0.0003 m without sub-clustering

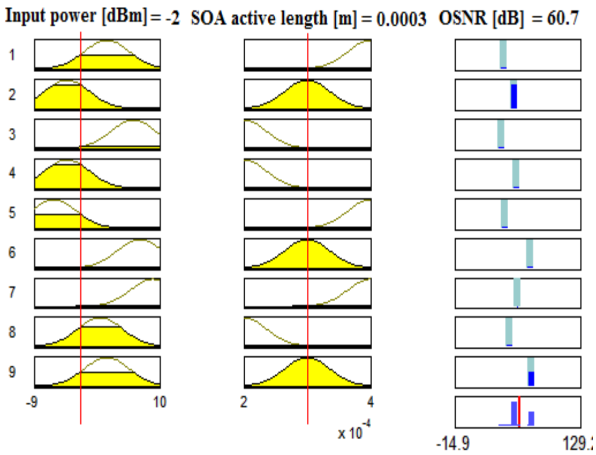


Fig 5(b): Rules viewer of OSNR Value [dB] for input power of 1 dBm and SOA active length of 0.0003 m with sub-clustering

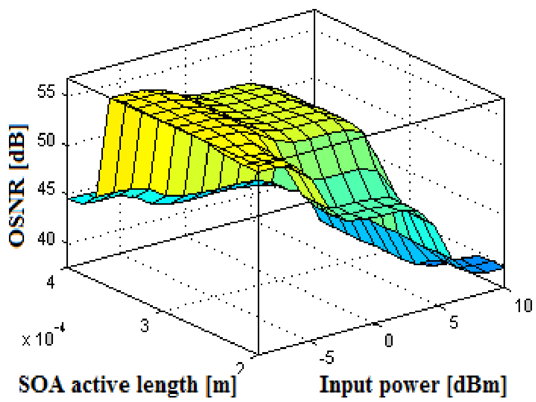


Fig 6(a): Surface representation of OSNR Value [dB] for input power and SOA active length without sub-clustering.

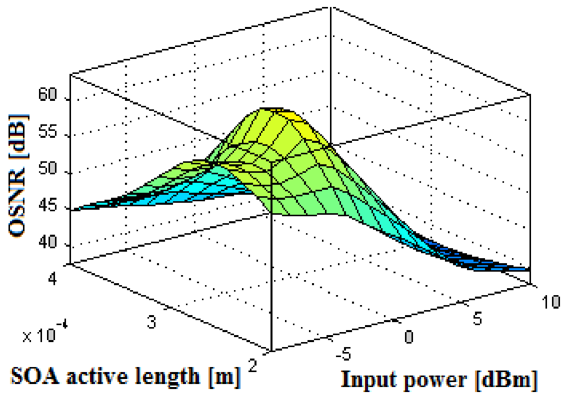


Fig 6(b): of OSNR Value [dB] for input power and SOA active length with sub-clustering

Figure 6(a) showing the surface plot for fuzzy system without sub-clustering endorses the results obtained from simulation. Also, the system performance is observed from the rule viewer of fuzzy system with sub-clustering for a particular case when input power = 1 dBm and SOA active length = 0.0003 m as shown in Figure 5(b). The output OSNR value [dB] for this case is 60.7, which is very near to the value of 60.7 obtained by simulation. Similarly, Figure 6(b) illustrates surface of the system for OSNR value showing variation in input power and SOA active length with sub-clustering. It can be clearly seen that the fuzzy model with sub-clustering gives outperforms the fuzzy model without sub-clustering. As the numbers of rules have been increased in the fuzzy model using sub clustering, this increases the number of parallel computations and thus accuracy.

The results obtained using ANFIS fuzzy model endorse the outcome of the simulated optical model of wavelength converter based on cross-gain modulation for varying SOA active length system.

5. CONCLUSION

The simulated OSNR values [dB] for varying SOA active length and input power have been obtained for wavelength converter based on cross-gain modulation system using RZ format data transmission. It is observed that with the increase in input power of the probe laser, and OSNR value improves for wavelength converter based on cross-gain modulation system up to 18 dB and maximum for SOA active length of 0.0003 m. This paper presents a comparison of the simulated data with the results obtained from ANFIS fuzzy model and it is observed that the findings of simulated optical model are quite close to the ANFIS based fuzzy model.

6. REFERENCES

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