ISSN: 2321-8169
383 – 386

A Review on Adjustable Gain Clamping in Semiconductor Optical Amplifier

Hardeep Kaur
PG Research Scholar
Electronics and Communication Engineering Dept.
PEC University of technology, Chandigarh
harrybansal5@yahoo.co.in

Dr. Neena Gupta
Head of Department
Electronics and Communication Engineering Dept.
PEC University of technology, Chandigarh
neenagupta@pec.ac.in

Abstract-Semiconductor optical amplifiers (SOAs) are a research curiosity in wavelength division multiplexed (WDM) based all-optical networks as they exhibit huge potential in high speed optical switching and gating applications andcan provide, in addition, broadband amplification of signals. However, their use in WDM systems has been severely hampered due to the effect of gain saturation occurring in conventional SOAs which ultimately results in inter-channel crosstalk. Moreover, ultra-fast gain dynamics of SOA along with gain saturationtogether lead to signal distortions even in single-channel transmission. Therefore, for proper operation, the amplifier must provide constant gain with respect to input power variations. Also, to improve the applicability of SOAs in switched environment, there must be a provision for varying the clamped gain. Thus, in this paper, various gain clamping and adjustable gain clamping techniques which have been proposed and perceived till date have been reviewed. Also, the findings of the various papers are tabulated therein.

Keywords*:Gain clamping, gain adjustment, gain clamped semiconductor optical amplifier (GC-SOA), adjustable gain clamped semiconductor optical amplifier (AGC-SOA), output saturation power, noise figure.*

*****

I. INTRODUCTION

Communications can be comprehensively characterized as the exchange of data from one place to another. In optical fibre communications, this exchange is accomplished by utilizing light as the data bearer. Optical fibre communication technologies have seen a tremendous growth in the last quarter century. This development has been made conceivable by the advancement of new optoelectronic innovations to utilize the tremendous potential data transfer capacity of optical fibre.

Optical technology is the ruling transporter of worldwide data. This technology has the capability to realise such future networks that would fulfil the demand of boundless data transfer capacities capable of conveying information data of any sort. Thus, much of the advancements in optical fibre communications system have been made possible by the emergence of optical amplifier.

Optical amplifiers can be predominantly classified into Fibre amplifiers and Semiconductor amplifiers [1, 2]. The former has had a tendency to overwhelm the customary framework applications such as in-line amplificationso as to counterbalance for the various losses occurring inside the fibre. However, the advancements in the fabrication process and device design has lead semiconductor optical amplifier as a great contender for its use as a basic amplifier and also as a functional element in the expanding optical communication networks.

Semiconductor optical amplifiers (SOAs) are small in size as compared to fibre amplifiers. An SOA also offers a wide wavelength range of operation, higher potential for integration, reasonable price and high gain. Currently, there are systems that provide upto 200 wavelength channels each operating at 10 Gb/s. All these high capacity systems employ wavelength division multiplexing (WDM) [3] as a means to utilize the large bandwidth of optical fibre. Thus, an amplifier must provide a fixed gain not depending upon the number of wavelength channels being amplified. However, it must also not exhibit any transient effects in the output power of the various channels. Therefore, an SOA can address all these issues of the extending network scenarios as long as it is made to work in the linear regime of operation.

However, in dense wavelength division multiplexed systems (DWDM), there occurs gain saturation of conventional SOA leading to nonlinear signal distortions and inter-channel crosstalk which ultimately limits its performance. To overcome these difficulties, various gain-clamped semiconductor optical amplifiers (GC-SOAs) have been proposed and illustrated. Gain clamping is a method used to linearize the gain of an SOA, provide power independent gain and hence expand its dynamic range of operation. The operation of gain clamping in SOA is accomplished by a lasing oscillation introduced at a wavelength which is out of band from the signal wavelengths being amplified. This results in locking of the carrier density. Lasing mode power

changes in accordance to the changes in the input signal power resulting in ultimately fixing the gain of the amplifier.
The application of gain clamped devices is restricted as it provides fixed gain which cannot be adjusted. This restricts its applicability in switched environment. Therefore an advanced version of gain clamped semiconductor optical amplifier called adjustable gain-clamped semiconductor optical amplifier (AGC-SOA) has been proposed and demonstrated. AGC-SOA not only performs the task of pinning up of gain but also provides variable gain adjustment.

II. TECHNIQUES USED FOR GAIN CLAMPING

- Distributed Bragg Reflectors DBR [4] or Distributed Feedback gratings DFB [5] are monolithically integrated into the SOA. This results in incorporating longitudinal lasing oscillations. However in this technique, the gain is fixed by the device design and even the wavelength of the internal laser being used is predetermined.
- Using Vertical Cavity Side Emitting Laser, VSCEL structure [6] for transverse lasing oscillations.
- Using an amplified spontaneous emission (ASE) reflector [7, 8] in which the backward ASE power generated is reflected by the feedback gratings (FBG) and gets amplified while passing through the SOA as shown in fig.1. The gain clamping operation is performed by compensating effect between signal and ASE. The pitfalls of the lasing induced gain clamping methods have been overcome in this scheme.

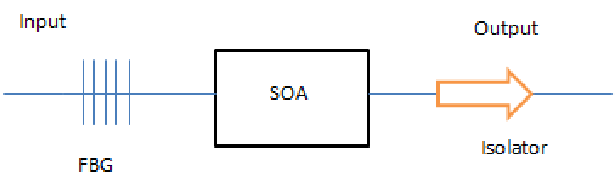

Fig.1. Schematic diagram of the proposed GC-SOA

- Monolithically integrating GC-SOA in a Mach-Zehnder interferometer (MZI) configuration [9].
- Using a range of linear and ring external cavities .
- Employing narrow bandwidth filters in the feedback loop to control the light generated by ASEof the SOA [10].

III. TECHNIQUES USED FOR ADJUSTABLE GAIN CLAMPING

A. Ring Cavity Topology

This design [11, 12, 13] as shown in fig.2 uses two activeamplifier regions. The data path is defined through signal SOA i.e. SOA1. SOA2 forms the control SOA. The laser cavityconsists of both SOA1 and SOA2. The combinationof the complex gain provided by both the SOAs sets the condition for the onset of lasing. SOA1 is provided with a fixed current during operation. Thus, as the drive current to SOA2 changes, the gain imparted by SOA1 also changes and hence this allows signal amplification by SOA1 at a clamped gain varied by SOA2.

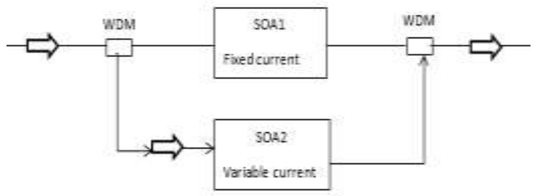

Fig.2. Counter propagating ring AGC-SOA

B. Fibre Grating Wavelength Tuning Method

In this methodology [14], the semiconductor optical amplifier consists of two similar, active fibre gratings at each end. A continuous supply of current is provided to the gain section during operation. Wavelength tuning of the gratings is performed by infusing bias current into them. Thus, by tuning the grating wavelength, the lasing oscillation conditions can be regulated and in turn the gain can be adjusted. Therefore, the structure simplicity of this method as shown in fig.3 helps it to be useful in modulation at high data rates.

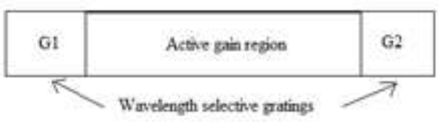

Fig.3. Conceptual schematic of AGC-SOA

C. Using **variable electrode tunable lasers** which includes three [15] as well as four [16] contact tunable laser.

IV. LITERATURE SURVEY

Quereshi et al. [10] demonstrated a simple design of gain-clamped semiconductor optical amplifier. The intensity of the feedback light generated by amplified spontaneous emission was automatically controlled by using a thin film tunablebandpass filter in the feedback loop. It has been presented experimentally that the proposed amplifier had good gain fixing characteristics. The dynamic gain variations in an SOA have also been reduced significantly using this technique. The performance of GC-SOA has been examinedby employing feedback laser at variable wavelengths.

ISSN: 2321-8169
383 – 386

Kim et al. [18] illustrated a gain-clamped semiconductor optical amplifier which had gratings of different lengths atboth ends of the active waveguide region. With differentcombinations of grating lengths, the gain and noise characteristics of the SOA have been studied. There were in total four sample chips fabricated for the experiment. Two out of the four were symmetric whereas the other two were asymmetric gratings. It has been shown that as the length of the symmetric gratings was increased, it exhibited higher side mode suppression ratio (SMSR), lower gain and larger saturation output power. Also for asymmetric gratings, higher saturation output power and lower noise figure was obtained when the input signal was put into the longer grating side.

Another gain clamping scheme using an amplified spontaneous emission reflector has been experimentally illustrated by Ahn et al. [7]. This technique of gain clamping was free from any lasing induced pitfalls. Both the input FBG type GC-SOA and output FBG type GC-SOA have been studied in this technique.

Michie et al. [11] illustrated the operation of an AGC-SOA which uses ring cavity topology. This type of sub system finds its application in packet and burst mode environment where there is a need for linear amplification of wavelengths and power equalization of the channels or bands.

Davies et al. [17] demonstrated an adjustable gain clamped semiconductor optical amplifier by using a sampled grating laser in which the feedback from the gratings was tuned by current injection. Variable gain clamping of 14 dB has been achieved using this novel technique in the EDFA operating window i.e. 1530 to 1545 nm operating range.

Akbar et al. [14] illustrated fibre grating wavelength tuning method for monolithic integration of an adjustable gain clamped semiconductor optical amplifier. In this technique, the gain of the amplifier was varied without much loss of saturated output power. Tuning of the grating wavelength gave an opportunity for adjusting the lasing thresholdconditions. Also, this technique did not have any influence on gain bandwidth and polarisation sensitivity of the SOA.

Thus, the important findings of the various papers reviewed in literature survey are tabulated in Table.1.

Table.1. Findings of the literature survey

Reference No	Technique Used	Finding(s)
[7]	Amplified spontaneous emission reflector	• Fixed gain of about 18 dB
[8]	ASE reflected by Fibre Bragg grating	• Gain clamped at 20 dB • Noise figure approximately 5 dB
[10]	Bandpass filter in the feedback loop	• Steady state transient ratio reduces from 0.353 to 0.048 upon channel add drop at 20.9 kHz
[11]	Ring cavity topology	• Gain adjustment dynamic range >30 dB • Noise figure=7.5 dB • No significant power penalty for 8 channels separated by 200 GHz.
[14]	Fibre grating wavelength tuning method	• Adjustable gain over a range of 4 dB • Max. saturated output power= 21 dBm • Noise figure= 8 dB
[15]	Variable three-contact tunable laser	• Gain variation of about 10dB • Noise figure=7.9 dB
[17]	Tunable sampled grating laser	• Range of variable gain= 12 dB • Gain flatness better than 4 dB over a wavelength range of 1530-1545 nm
[18]	Distributed Bragg reflectors with different lengths on both sides of active region	• Higher saturation output power and lower noise figure when input signal put into longer side

ISSN: 2321-8169
383 – 386

V. CONCLUSION

The effective cost and easy deployment features of SOAs make them an appealing candidate for extending the range of Passive Optical Networks (PONs) in particular. However, the noise penalty, inter-channel crosstalk and the effects of gain saturation at high optical power are the major problems imposed by SOA. Therefore, the concept of gain clamping in SOA has been investigated and recognised as an attractive approach to reduce thenonlinearities induced by gain saturation. For monolithic designs, as the gain parameter is fixed during manufacturing therefore, adjustable gain clamping is an alluring solution to this problem which is highly being investigated and perceived.

REFERENCES

[1] Desurvire, Emmanuel, and Michael N. Zervas. "Erbium-Doped Fiber Amplifiers: Principles and Applications." (1995): 56-58.

[2] Olsson, N.Anders. "Semiconductor optical amplifiers." Proceedings of the IEEE 80.3 (1992): 375-382.

[3] Spiekman, L. Hl, J. M. Wiesenfeld, A. H. Gnauck, L. D. Garrett, G. N. Van Den Hoven, T. Van Dongen, M. J. H. Sander-Jochem, and J. J. M. Binsma. "Transmission of 8 DWDM channels at 20 Gb/s over 160 km of standard fiber using a cascade of semiconductor optical amplifiers." IEEE Photonics Technology Letters 12, no. 6 (2000): 717-719.

[4] Park, Jongwoon, Xun Li, and Wei-Ping Huang. "Performance simulation and design optimization of gain-clamped semiconductor optical amplifiers based on distributed Bragg reflectors." IEEE journal of quantum electronics 39, no. 11 (2003): 1415-1423.

[5] Park, Jongwoon, Xun Li, and Wei-Ping Huang. "Gain clamping in semiconductor optical amplifiers with second-order index-coupled DFB grating." IEEE journal of quantum electronics 41, no. 3 (2005): 366-375.

[6] Francis, D. A., S. P. DiJaili, and J. D. Walker. "A single-chip linear optical amplifier." Optical Fiber Communication Conference.Optical Society of America, 2001.

[7] Ahn, Joon Tae, Jong Moo Lee, and Kyong Hon Kim. "Gain-clamped semiconductor optical amplifier based on compensating light generated from amplified spontaneous emission." Electronics Letters 39.15 (2003): 1140-1141.

[8] Jia, Xin-Hong, Zheng-Mao Wu, and Guang-Qiong Xia. "Gain-clamped semiconductor optical amplifiers based on compensating light: Theoretical model and performance analysis." Optics communications 268.1 (2006): 138-145.

[9] Holtmann, Ch, P-A. Besse, J. Eckner, and H. Melchior."Monolithically integrated gain-clamped semiconductor optical amplifier exploiting Mach-Zehnder interferometer configuration."In Optical Communication, 1996.ECOC'96. 22nd European Conference on, vol. 3, pp. 199-202. IEEE, 1996.

[10] Qureshi, KhurramKarim, H. Y. Tam, C. Lu, and P. K. A. Wai. "Gain control of semiconductor optical amplifier using a bandpass filter in a feedback loop." IEEE Photonics Technology Letters 19, no. 18 (2007): 1401-1403.

[11] Michie, Craig, Tony Kelly, Lin Liu, and Ivan Andonovic. "Adjustable gain-clamped semiconductor optical amplifiers (AGC-SOA)."In Asia Communications and Photonics Conference, pp. AS1D-1.Optical Society of America, 2012.

[12] Liu, Lin, et al. "Packet equalisation in PONs using adjustable gain-clamped semiconductor optical amplifiers (AGC-SOA)." Photonics Global Conference (PGC), 2010.IEEE, 2010.

[13] Liu, Lin, Craig Michie, Anthony E. Kelly, and Ivan Andonovic. "The dynamic gain modulation performance of adjustable gain-clamped semiconductor optical amplifiers (AGC-SOA)." Journal of Lightwave Technology 29, no. 22 (2011): 3483-3489.

[14] Akbar, Jehan, Opeoluwa A. Odedina, Craig Michie, Ivan Andonovic, and Anthony E. Kelly. "Monolithic adjustable gain-clamped semiconductor optical amplifier." Journal of Lightwave Technology 31, no. 16 (2013): 3023-3027.

[15] Sosabowski, J., A. R. Davies, R. V. Penty, and I. H. White."Gain-clamped SOA with 1-11 dB variable gain based on a three-contact tunable DBR laser."In Lasers and Electro-Optics Europe, 2003.CLEO/Europe. 2003 Conference on, p. 162. IEEE, 2003.

[16] Davies, A. R., et al. "Variable gain operation of a gain-clamped sampled grating laser amplifier." Lasers and Electro-Optics, 2002. CLEO'02. Technical Digest. Summaries of Papers Presented at the. IEEE, 2002.

[17] Davies, A. R., K. A. Williams, R. V. Penty, I. H. White, M. Glick, D. McAuley, and P. J. Williams. "Broadband gain clamped semiconductor optical amplifier with variable gain operation using a sampled grating laser." In Optical Communication, 2002.ECOC 2002. 28th European Conference on, vol. 2, pp. 1-2. IEEE, 2002.

[18] Kim, Hoin, Jeongseok Lee, Inkuk Yun, Seungwoo Kim, Hyuncheol Shin, Seongtaek Hwang, Yunje Oh, and Changsup Shim. "A gain-clamped SOA with distributed Bragg reflectors fabricated under both ends of active waveguide with different lengths." IEEE Photonics Technology Letters 16, no. 4 (2004): 999-1001.