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Effects of The Bias Current Reduction on The Behavior of an All-optical Logic Gate Based on Bistable DFB Laser Amplifiers

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ABSTRACT

In this paper, using the designed structure of an all-optical logic gate based on the two1550-nm cascaded distributed feedback (DFB) laser amplifiers, we discussed the effects of reducing the bias current injected to the lasers on the behavior of this logic gate. The result was that since this reduction leaded to a decrease in the input power intensities related to the switching points of the structure's transfer function therefore, we observed an increase in the logic gate's speed. Besides, a decrease in the bias currents leaded to a decrease in the consumed electrical power.
KEYWORDS: DFB Laser Amplifier, Optical Bistabilty, All-optical Logic Gate.

INTRODUCTION

Optical bistability in semiconductor laser amplifiers [1], due to its practical applications is so attractive. One of these applications is using it in design of an all-optical logic gate [2]. P. Wen et al [3] have demonstrated a low input intensity, high contrast optical AND gate based on optical bistability in a vertical-cavity semiconductor optical amplifier (VCSOA). A. Hurtado et al [4] have studied reflective bistability in VCSOAs and used it to develop a new logic gate. They have also used two bistable Fabry-Perot and distributed feedback (DFB) laser amplifiers [5] operating in reflection and trans-missive modes, respectively to demonstrate an-all optical logic gate.

In all these works only one of the two characteristics of an all-optical logic gate, i.e., the dissipated power or the speed has been discussed. Our aim of the study is using a design similar to that presented in [5], but with only DFB laser amplifiers, the effects of the bias current injected to the lasers on both these characteristics are discussed.

The scientific contributions of this paper are: 1) all-optical signal processing systems, and 2) all-optical switching systems.

MATERIAL AND METHODS

When a laser amplifier acts in the trans-missive mode, its characteristics illustrate an S-shaped bistable loop. In fact, optical switching in this mode occurs via the following positive feedback loop. An optical signal enters the amplifier with a center wavelength longer than that of a cavity resonance. An increase in the optical power within the amplifier increases the refractive index, and the stop-band (and cavity resonance) shifts to longer wavelengths. If the cavity resonance moves onto the signal wavelength, the internal optical power increases more. As a result, the refractive index continues to increase, and the stop-band shifts to even longer wavelengths. This positive feedback loop for the internal power moves the cavity resonance fully onto the signal wavelength. The reverse process occurs as follows. If the incident power is lowered so that the signal wavelength is at the peak of the cavity resonance, a small subsequent decrease in incident power will initiate the reverse positive feedback loop. In this case, the cavity resonance shifts away from the signal wavelength, and internal power switches downward. These two switching processes give rise to the common S-shaped hysteresis [6].

On the other hand, when the laser amplifier acts in the reflective mode, its characteristics for a low bias current shows an inverted-S-shaped bistable loop. Here, the correspondingly large internal powers saturate the gain enough that the reflectivity resonance is a dip during the switching process. As the reflectivity resonance shifts to longer wavelength, the reflected signal intensity drops accordingly. Thus, the reflected intensity switches downward even though the average internal intensity switches upward. This behavior gives rise to an inverted-S-shaped hysteresis [6]. Meanwhile, the effects of grating structures on the behavior of trans-missive and reflective bistable DFB laser amplifiers have been discussed in different papers such as [7], [8].

Using these two characteristics in the1550-nm DFB laser amplifiers, the structure of an all-optical logic gate as shown in Fig. 1 can be set up [5]. As seen in the figure, the first laser amplifier biased with I_{bias1} acts in the reflective mode when considering I_{in} and I_{ref1} as its input and reflected power, respectively. This laser amplifier introduces a bistable behavior for the logic gate's structure. On the other hand, the second laser amplifier biased with I_{bias2} acts in the trans-missive mode when considering I_{ref1} and I_{out} as its input and output power, respectively. This laser amplifier has the role of a power threshold detector to distinguish the state ON (logic "1") from the state OFF (logic "0") in the output of the structure. Meanwhile, the input signal to this structure is combined of two digital optical signals, *A*, and *B*, and a control signal, g_x by a 3-dB coupler. The experimental setup for this design is shown in Fig. 2 [9].

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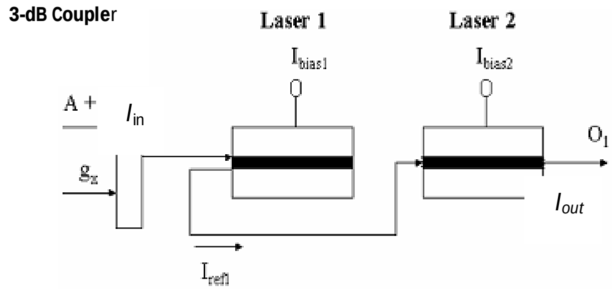


Fig. 1: The block diagram of the cascaded laser amplifier- based logic gate [5].

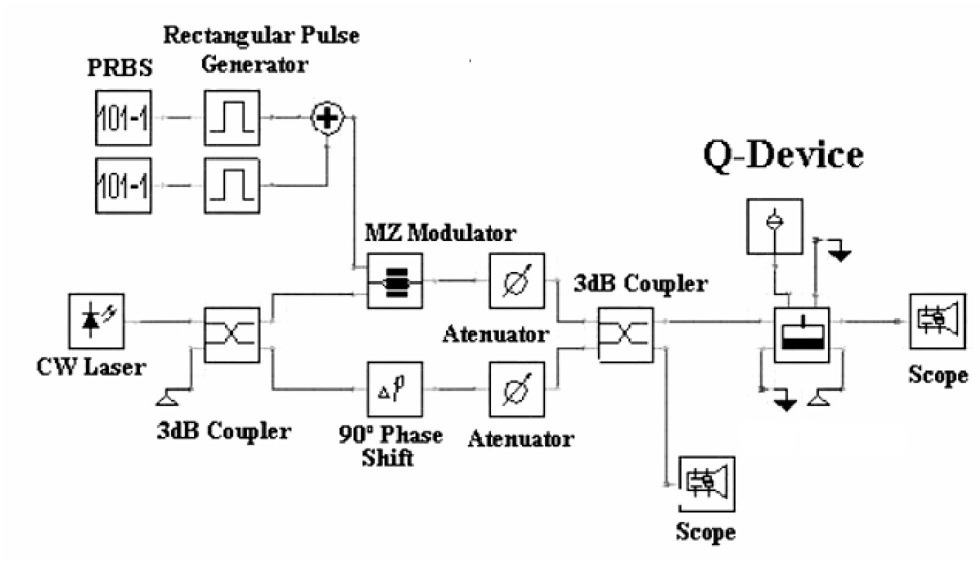


Fig. 2: The experimental setup for the design shown in Fig. 1 [9].

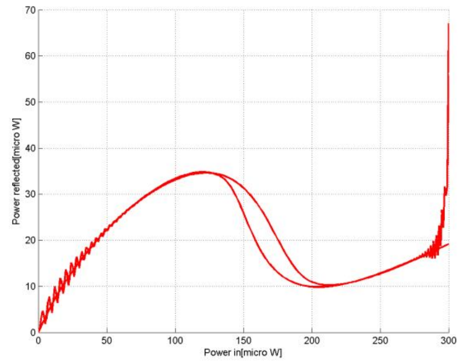
RESULTS AND DISCUSSION

First, using the physical parameters given in [5] such as the threshold bias current, I_{th} equal to 16.41 mA, we calculate the input-reflected power characteristics of laser 1, the input-output power characteristics of laser2, and the transfer function of the cascaded laser amplifiers. Therefore, as shown in Fig 3, the first laser amplifier has an inverted S-shaped loop bistable characteristics when its bias current is equal to $0.856I_{th}$, while injecting the bias current equal to $0.932I_{th}$, the second laser amplifier has an S-shaped loop bistable characteristics, and finally, the transfer function for the total cascaded laser amplifiers has three threshold switching powers equal to 45µw, 200µw, and 350µw [5].

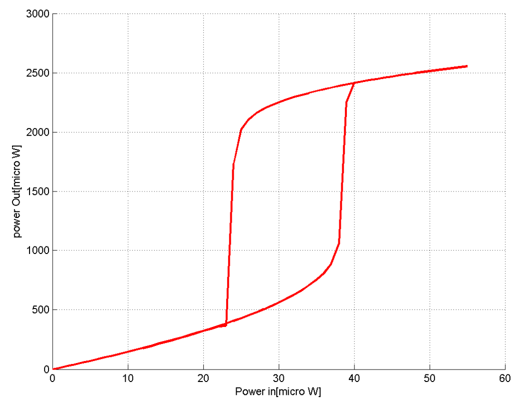
Next, we decrease the bias current injected to Laser 1 from $0.856I_{th}$ [5] to $0.79I_{th}$ without any change in the injected bias current to laser 2. The new bias current changes the input-reflected power characteristics of laser 1 as illustrated in Fig. 4. Therefore, as seen in Fig. 5, the new transfer function of the total structure has three threshold switching powers with the values of 9μw, 160μw, and 290μw.

This clearly helps the structure to act with a lower input optical power. To prove this point, we use the same approach presented in [5] as follows. Setting a reference power P_1 equal to 70 µw, then signals A and B can have an optical power equal toP_1 multiplied by 0 or 1 depending on the defined logic level for them, i.e., "0" or "1". Also, control signal g_x can be considered as g_0, g_1,g_2, g_3, and$g_4$with optical powers of $0.P_1$, $1.P_1$, $2.P_1$, $3.P_1$, and $4.P_1$, respectively. Therefore, as illustrated in Fig. 6, when we apply the optical power waveform for total input power A+B, and selecting g_0 as the control signal, then the structure operating as an OR logic gate [5] responses faster (about0.11 nsec) when its first laser amplifier is biased at the new reduced current. This result can be understood because the threshold switching powers for the total structure have been decreased by decreasing the bias current injected to laser 1. Meanwhile, a similar result can be gained if we decrease the bias current injected to Laser 2.

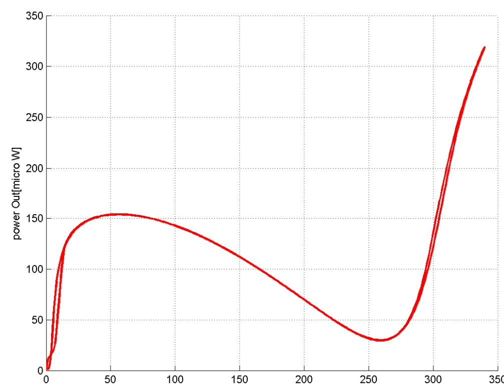
However, as mentioned above, a decrease in the bias currents can lead to a decrease in the distance of threshold switching powers from each other so that the structure may be more sensitive to noise.



(a)



(b)



(c)

Fig. 3: (a)The the input-reflected power of laser 1; (b) The input-output power characteristics of laser2; (c) The transfer function of the designed logic gate with the values given in [5].

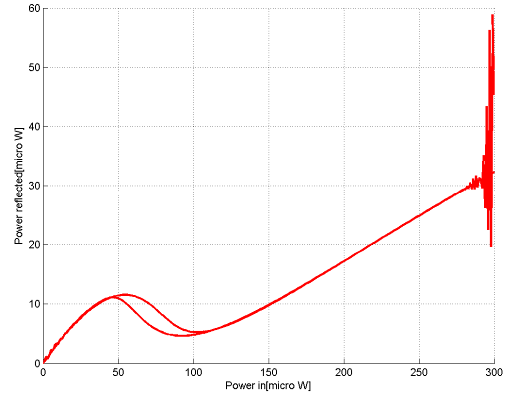


Fig. 4: The input-reflected power characteristics of laser 1 with the new bias current.

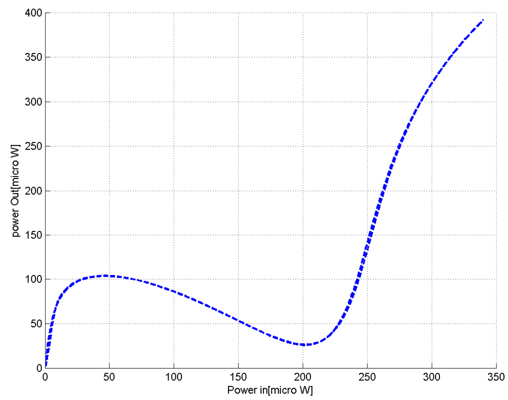
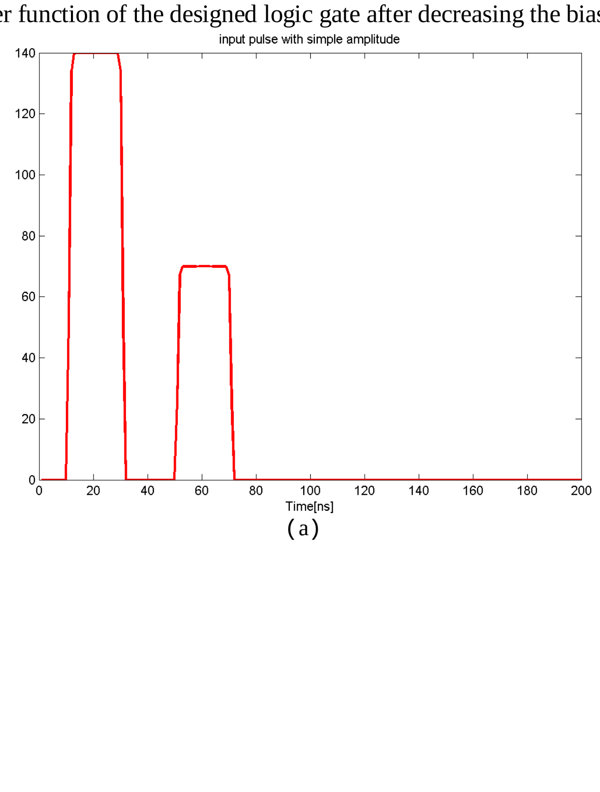
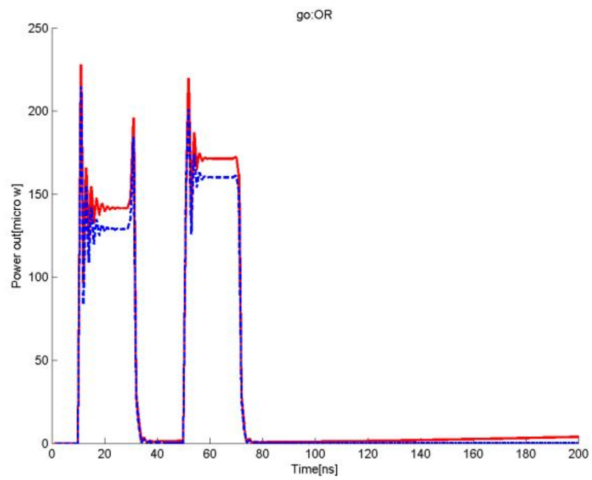


Fig. 5: The new transfer function of the designed logic gate after decreasing the bias current injected to laser 1.



(a)



(b)

Fig. 6: Time dependent pulses for : (a) Total input signal $A+B$, and (b) Output signal Q, while g_0 is selected as the control signal; and the bias current of Laser 1is chosen equal to 0.79I_{th}*(dotted line)* and equal to that of [5] (solid line).

CONCLUSIONS

In this paper, the operation of an all-optical logic gate designed by using two 1550-nm distributed feedback (DFB) laser amplifiers was reviewed. Then by a decrease in the bias current of the laser amplifiers, it was seen that the logic gate’s speed was increased (about0.11 nsec). Besides, a decrease in the bias currents leaded to a decrease in the consumed electrical power, although an increase in the gate's sensitivity to noise was predicted.

REFERENCES

[1] Otsuka K., and S. Kobayashi, 1983. Optical bistability and nonlinear resonance in a resonant-type semiconductor laser amplifier: *Electron. Lett.,* 19: 262-263.

[2] Yahya C.B., and M. Guizani, 1995. Optical bistable devices: Analysisand Applications: The fourth Saudi conference, 3: 87-93.

[3] Wen P., M. Sanchez, M. Gross, and S. Esener, 2003. Optical AND operation based on Vertical-Cavity Semiconductor Optical Amplifiers (VCSOAs): TRENDS IN OPTICS AND PHOTONICS SERIES, 90: 134-136.

[4] Hurtado A., A. Gonzalez-Marcos, and J. A. Martin-Pereda, 2005. Modeling Reflective Bistability in Vertical-Cavity Semiconductor Optical Amplifiers: IEEE JOURNAL OF QUANTUM ELECTRONICS, 41: 376-383.

[5] Hurtado, A., A. Gonzales-Marcos, and J. A. Martin-Pereda, 2005. All Optical Logic Gates with 1550 nm Fabry-Prot and distributed feedback semiconductor laser amplifiers: *Spanish Conference on Electron Devices:* 305-308.

[6] Maywar, D. N. M., and G. P. Agrawal, 1998. Effect of Chirped Gratings on Reflective Optical Bistability in DFB Semiconductor Laser Amplifiers: IEEE J Quantum Electron, 34: 2364-70.

[7] Aleshams, M, M. K Moravvej-Farshi, and M. H. Sheikhi,2008. Tapered grating effects on static properties of a bistable QWS-DFB semiconductor laser amplifier: Solid State Electron, 52: 156-163.

[8] Aleshams, M, 2012. Effect of Tapered Quarter Wavelength Phase-Shifted Grating on Reflective Properties of a Bistable DFB Semiconductor Laser Amplifier: Journal of Basic and Applied Scientific Researech, 2: To be published.

[9] González-Marcos A., 1993. Contribución al estudio de estructuras fotónicas para computación óptica y análisis de problemas conexos. Tesis Doctoral, Departamento de Tecnología Fotónica, ETSI Telecomunicación, Universidad Politécnica de Madrid.