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Return-to-Zero Direct Modulation of a Gain-Switched Semiconductor Laser

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Abstract

We demonstrate stable return-to-zero direct pulse modulation of a gain-switched DFB semiconductor laser at a data rate of 2.5 Gbit/s. The effects of change in drive conditions on eye diagrams of the outputs are explored and an optimum operating regime is determined.

I. Introduction

Picosecond optical pulse sources are attractive for optical communications, such as optical time-division multiplexing and soliton transmission. One technique for generating short, optical pulse trains using semiconductor lasers is gain-switching.[1] However, directly modulated gain-switched laser outputs can exhibit strong pattern dependence, which limits the achievable bit error rate (BER). This can be eliminated using a suitable RF current waveform which ensures that the carrier density at the start and end of each bit period is equal, independent of the data transmitted.[2]

Several schemes to overcome the pattern dependence of directly modulated gain-switched lasers have been reported.[3-6] Here, we use a simple direct modulation scheme in which NRZ data deliberately combined bias current and sinusoidal RF signal is injected into the laser. To determine the optimum operating regime, it is important to study the effects of variations in the driving conditions. We present results of systematic examination of the eye diagrams to variations in drive parameters. At the optimum conditions, we generates nearly pattern-independent optical pulse trains at sequence lengths of 2^{23}-1 bits. The first reported measurements at 2.5 Gbit/s are shown and the sensitivity of the eye diagram to drive conditions is examined.

II. Direct Modulation Scheme

When a semiconductor laser is biased near threshold, and a large signal RF current is applied, the output consists of a train of picosecond optical pulses. This method of short pulse generation is referred to as gain-switching, and each pulse corresponds to the first spike of the laser's relaxation oscillation.[1] For low error rate performance under direct modulation, a suitable current waveform must be applied to the laser in order to generate an optical pulse for a data '1', and no pulse for a data '0', while ensuring that the carrier density at the beginning of each data bit is the same in order to avoid patterning effects.

Our scheme employs a non-return-to-zero (NRZ) data waveform for direct modulation, in addition to the bias and sinusoidal RF currents used to gain switch the laser.[5-6] The bit period of the data is equal to the frequency of the sine wave. The data and RF signals are synchronized, then summed and amplified, and added to the bias to modulate the laser. For a data '1', the increased current applied to the laser produces a pulse, whereas for a data '0', the current applied to the laser is not sufficient to generate a pulse. For a given RF level, the values of the bias and data signals are adjusted to achieve pattern independence. Then, each drive parameter was varied to confirm its sensitivity to the eye diagram. Our scheme is known to be simpler than other approaches because it uses the NRZ output of the pattern generator directly, and does not require the use of a high speed AND gate.[6]

III. Experiments

The experimental configuration shown in Fig. 1 was used to investigate the performances of a gain-switched DFB laser under direct modulation. The DFB laser operated at 1.55μm and had a threshold current of 16.2 mA. A 2.5 GHz sinusoidal signal and a synchronized 2.5 Gbit/s NRZ pseudo-random bit stream (PRBS) were summed then amplified, and used to modulate the laser.

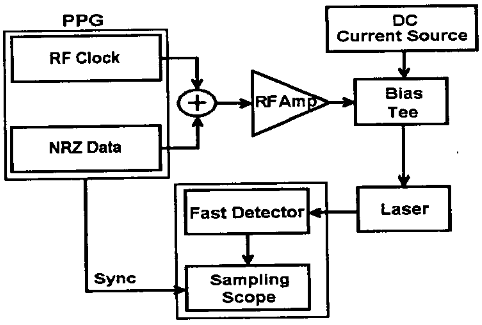


Fig. 1. Experimental set-up. PPG : pulse pattern generator

First, we fixed RF power at a certain level, say at 26 dBm, which is good to achieve gain switching of the laser. Then, the bias level and amplitude of the data waveform were adjusted, by inspection of the eye diagram, to minimize the pattern dependent effects and maximize the extinction ratio of the output pulses. The modulated outputs were measured by a sampling scope connected with a fast detector. We investigated the dependence of the eye diagram on the laser drive parameters.

The optimum pulse modulation, as shown in Fig. 2, was obtained with a bias current of 18.6 mA, a RF power of 25 dBm, and a data power of 5 dBm. We can see fairly clear eye diagram. First, we examine the dependence for bias currents in the range 14 to 21 mA with the data and RF powers held constants at 25 dBm and 5 dBm. Eye diagrams at bias currents of 14.3 to 20.6 mA are shown in Figure 4. For bias levels below 18 mA, the bias is insufficient to compensate for the loss of carriers through stimulated emission. This causes pattern dependent amplitude and timing fluctuations. For bias levels above 19 mA, the high carrier density results in generation of weak pulses during data'0' bits, causing a power penalty at the receiver. Next, we examined the eye diagram for data powers in the range 2 to 10 dBm with the bias current and RF power held constants at 18.6 mA and 25 dBm, respectively. For low data powers, the drive currents for data '1' and data '0' bits are too similar, so gain-switching occurs for both cases, causing a power penalty, as shown in Fig 5(a). A high data power causes large variations in the carrier density, resulting in pattern dependent amplitude and timing fluctuations, as shown in Fig 5(b). Finally, we examine the dependence for RF powers in the range of 16 to 26 dBm with the bias current and NRZ power held constants at 18.6 mA and 5 dBm. Even though the eye diagrams show relatively low sensitivity to the change in the RF power, both low and high RF powers cause large variations in the carrier density, resulting in pattern dependent amplitude and timing fluctuations, as shown in Fig 6.

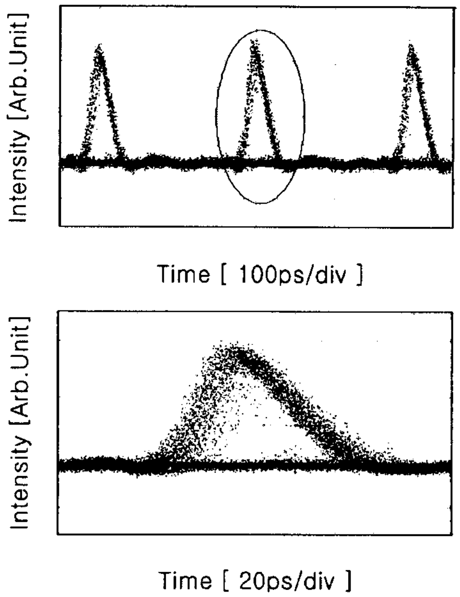
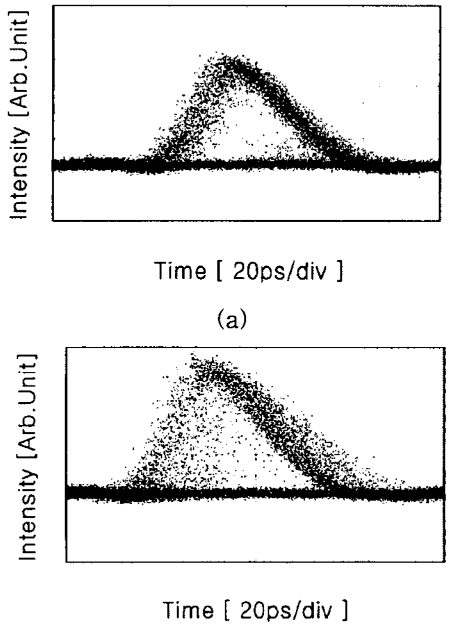


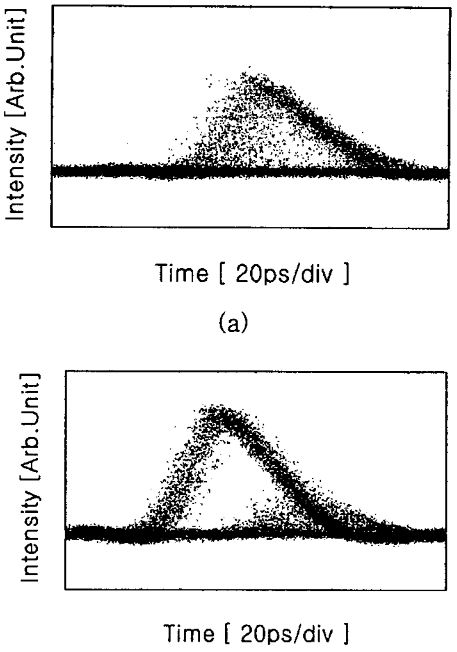
Fig. 2. Eye diagram of directly modulated gain-switched with a bias current of 18.6 mA, a RF power of 25 dBm, and a NRZ power of 5 dBm.



(a)

(b)

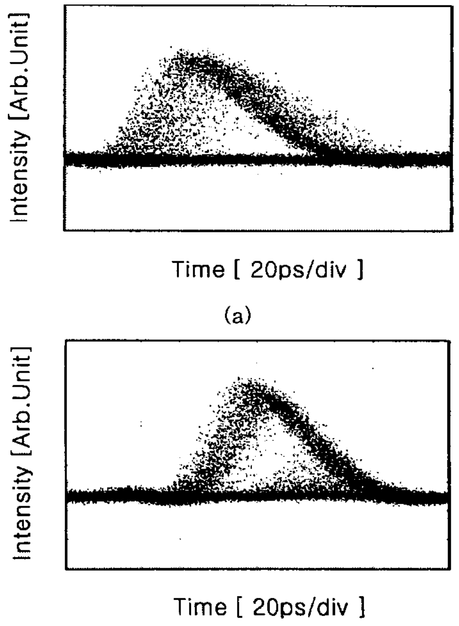
Fig. 3. Dependence of eye diagram on bias current (data power = 5 dBm, RF power = 25 dBm) : (a) 14.3 mA, and (b) 20.6 mA.



(a)

(b)

Fig. 4. Dependence of eye diagram on data power (bias current = 18.6 mA, RF power = 25 dBm) : (a) 2.5 dBm, and (b) 9 dBm.



(a)

(b)

Fig. 5. Dependence of eye diagram on RF power (bias current = 18.6 mA, NRZ power = 5 dBm) : (a) 17 dBm, and (b) 26 dBm.

IV. Conclusion

For the first time, we have demonstrated low pattern dependent direct modulation of a gain-switched semiconductor laser at a data rate of 2.5 Gbit/s. To eliminate data pattern dependent effects, the laser is operated by a current waveform which deliberately combines bias, RF sinusoidal, and NRZ data currents. The effects of change in each drive parameter on the eye diagram of the outputs are explored and the optimum operating regime is determined. Fairly clear eye diagram is obtained with a bias current of 18.6 mA, a RF power of 25 dBm, and a data power of 5 dBm. The experimental results show moderate tolerance to variations in drive conditions, even though the eye diagram is more sensitive to the bias and NRZ data current and relatively less sensitive to the RF current.

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[References]

[1] K. Y. Lau, "Gain switching of semiconductor injection lasers," Appl. Phys. Lett., Vol. 52, No. 4, pp. 257-258, Jan. 1988.

[2] R. S. Tucker, J. M. Wiesenfeld, A. H. Gnauck, and J. E. Bowers, "8 Gbit/s return-to-zero modulation of a semiconductor laser by gain-switching", Electron. Lett., vol. 22, no. 25, 1329-1331, Dec. 1986.

[3] K. Habara and K. Kikuchi, "Pulse code modulation of a gain-switched LD and its application to a high-speed electrooptical time multiplexer", J. Lightwave Technol., vol. LT-5, no. 10, pp. 1426-1432, Oct. 1987.

[4] R. F. O'Dowd and D. M. Byrne, "Semiconductor laser precision gain switching experiment for Gbaud ternary optical signaling", IEEE J. Quantum Electron. vol. 25, no. 6, pp. 1568-1574, Jun. 1989.

[5] M. J. L. Cahill, G. J. Pendock, and D. D. Sampson, "Low error rate return-to-zero direct modulation of gain-switched lasers", Optical and Quantum Electron., vol. 28, no. 9, 1181-1185, Sept. 1996.

[6] S. I. Myong, S. H. Lee, D. S. Seo, and N. Kim, "RZ data generation by direct modulation of a gain-switched semiconductor laser", J. Kor. Inst. of Comm. Sci., vol. 23, no. 3, pp. 613-622, Mar. 1998.