Novel Concept for All-Optical Flip-Flop Operation in a Single DBR Laser Diode

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***Abstract*— We demonstrate experimentally all-optical flip-flop operation in a standard tunable DBR laser diode by injecting pulses with the same wavelength but of different amplitude and duration. Switching speeds of 50 ps are achieved.**

***Index Terms*—DBR lasers, All-optical flip-flops, Optical bistability**

I. Introduction

ALL-OPTICAL flip-flops draw more and more attention as potential elements in all-optical packet switching schemes to cope with the massive bandwidth requirements resulting from the huge growth of upcoming telecommunication services [1]. Several concepts for all-optical flip-flops have been proposed so far, but most of them require two or more coupled lasers [1-3] or an external holding beam [3,4]. Another option is to make use of saturable absorbers [5], but these devices have the disadvantage of having a rather large footprint resulting in a large power consumption and due to the slow carrier lifetime in the absorber section, the repetition rate is also limited. A recently proposed alternative is based on ring or disk lasers, in which switching is obtained between the clockwise and counter-clockwise direction. Such lasers can be switched very fast and don't require an external CW beam [6]. However, fast switching and single mode operation is only obtained if the ring/disk radius is sufficiently small. This makes the fabrication difficult and results in strong, uncontrollable variations of the lasing wavelength.

In this article we demonstrate experimental results on an all-optical flip-flop composed of a standard tunable DBR laser. No external CW beam is required since we use the well-known bistability that is obtained in the tuning characteristics of such a laser [7]. Such an AOFF has already been proposed in [8], with the switching between two wavelengths in the bistability being based on injection locking at those two wavelengths. Here, in contrast, we show AOFF operation by injecting pulses at the same wavelength but with different amplitude and duration. We can also obtain relatively fast flip-flop operation with switching speeds below 50 ps and pulse energies of 2-4 pJ. Because there are many different hops with a bistability, the tunability of the DBR laser makes it straightforward to match the lasing wavelengths of the laser to the WDM system.

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II. Concept

The all-optical flip-flop that we propose can be either a 2 or 3-section DBR laser diode, or any other variant of the classical DBR laser diodes such as the SG-DBR or the MG Y-laser. If the lasers are long enough and the reflection spectra from the Bragg gratings are broad enough, then the lasers show a bistability in the wavelength vs. tuning current characteristics at high power levels. The physical origin is the so-called Bogatov effect, an asymmetric gain suppression due to the four wave mixing between main mode and side mode.

Flip-flop operation is obtained by using pulses of the same wavelength (corresponding with the highest branch of the bistability) but with different duration and amplitude. A long pulse is used to injection-lock the laser at that wavelength. With a shorter pulse, we can make the DBR-laser switch back to the lower branch. This lower branch corresponds to a lower carrier density in the gain section. Hence, by depleting the gain section using a short pulse, the laser will automatically relax back to the state with the lowest carrier density and thus the lower branch.

III. Experimental results

The bistability as a function of the tuning current is depicted in Fig. 1. We see that the laser can operate in a bistable region with a width of 0.5 mA at a wavelength of 1561.3 nm and 1560.7 nm. The active gain section has a current of 100 mA.

When we inject pulses at 1561.3 nm, we can obtain flip-flop operation at the other wavelength as depicted in Fig. 2. The long pulses of 100 ps act as reset-pulses because they injection-lock the laser. The short and strong pulses (10 ps) act as set-pulses because they bring the laser in depletion and back to the state with the lower carrier densities (at 1560.7 nm). Switching in less than 50 ps was obtained with set-pulses of 2 pJ and reset-pulses of 4 pJ.

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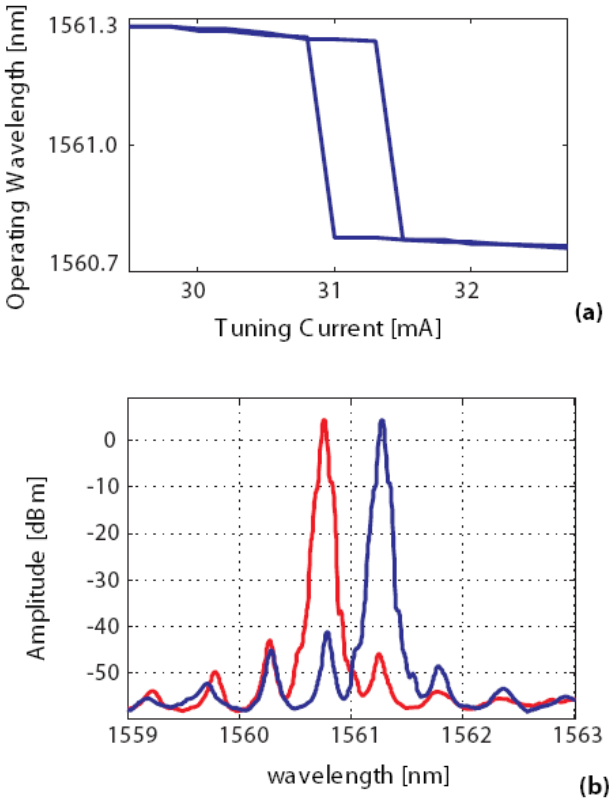

Fig. 1. (a) Bistability in operating wavelength as a function of the tuning current; (b) optical spectrum of the two different states.

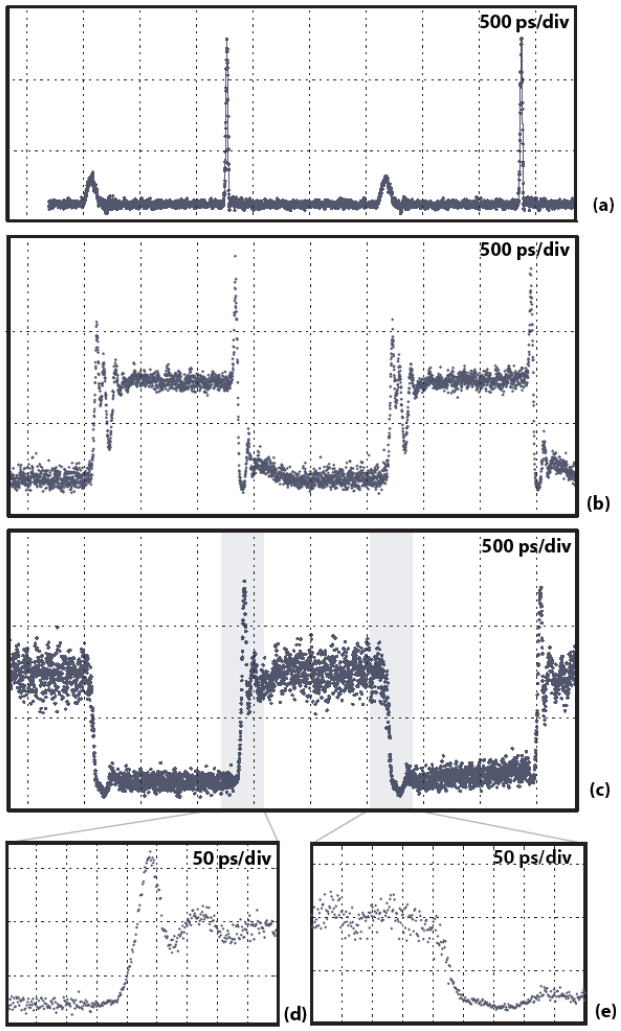

Fig. 2. Experimental results on all-optical flip-flop operation. (a) Injected pulses at 1561.3 nm; (b) output at 1561.3 nm; (c) flip-flop output at 1560.7 nm; (d) switch-on; (e) switch-off.

IV. Conclusion

We demonstrated experimentally a novel concept for flip-flop operation in a single DBR-laser. Using pulses with different duration and amplitude but with the same wavelength, we obtain switching times less than 50 ps with pulse energies of a few pJ.

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References

[1] M. Hill. H. de Waardt, G. Khoe, H. Dorren, 'All-optical flip-flop based on coupled laser diodes', IEEE Journ. Quant. El., Vol. 37, pp. 405-413, 2001.

[2] A. Malacarne, J. Wang, Y. Zhang, A. Das Barman, G. Berrettini, L. Poti, A. Bogoni, '20ps Transition Time All-Optical SOA-Based Flip-Flop Used for Photonic 10Gb/s Switching Operation Without Any Bit Loss', IEEE JSTQE, Vol. 14, pp. 808, 2008.

[3] W. D'Oosterlinck, F. Öhman, J. Buron, S. Sales, A. Pérez Pardo, A. Ortigosa-Blanch, G. Puerto, G. Morthier, R. Baets, 'All-Optical flip-flop operation using a SOA and DFB laser diode optical feedback combination', Optics Express, 15(10), p.6190-6199, 2007

[4] K. Huybrechts, G. Morthier, R. Baets, 'Fast all-optical flip-flop based on a single distributed feedback laser diode', Optics Express, 2008

[5] M. Takenaka, K. Takeda, Y Kanema, Y Nakano, 'All-optical switching of 40 Gb/s packets by MMI-BLD optical label memory', Optics Express, Vol. 14, pp. 10785-10789, 2006.

[6] B. Li, M. Memon, G. Mezosi, G. Yuan, Z. Wang, M. Sorel, S. Yu, ,All-Optical Response of Semiconductor Ring Laser to Dual-Optical Injections', IEEE Phot. Techn. Lett., Vol. 20, pp. 770-772, 2008.

[7] D. Syvridis, G. Guekos, S. Pajarola, M. Tsilis, 'Large optical bistabiltiy and self pulsations in a 3 section DBR laser diode', IEEE Phot. Techn. Lett., Vol. 6, pp. 594-596, 1994.

[8] S. Matsuo, T. Kakitsuka, T. Segawa, H. Suzuki, 'Optical Flip-flop Operation Using a DBR Lasers', Proc. CLEO/Pacific Rim, paper ThA3-3, Seoul, Korea, August, 2007.