Experimental Demonstration of All-optical Flip-flop operation with a single Distributed Feedback Laser Diode

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Abstract: Dynamic all-optical flip-flop operation is observed for a single distributed feedback laser diode using the spatial hole burning effect. Bistabilities with extinction ratios of up to 35 dB are obtained. For the flip-flop operation, we demonstrate repetition rates up to 1.25 GHz using pulses of 0.5 pJ.

Keywords: All-optical flip-flop, Distributed feedback laser, Optical bistability

1. Introduction

Due to the increasing need for fast and agile networks, packet-switched optical networks draw more and more attention [1]. All-optical flip-flops offer one of the main functionalities in realizing these networks by acting as temporary memory elements which store the header information while the payload is routed to the output port. Flip-flops are designed as bistable elements with the ability to switch between the two states by using positive optical pulses. Several designs for optical flip-flops have been proposed so far, however they are often relatively complex and/or slow [2,3]. Here we report on the experimental demonstration of a novel design for an all-optical flip-flop based on a single Distributed FeedBack (DFB) laser diode [4].
By injecting continuous wave (CW) light – with a different wavelength than the lasing light – into a DFB laser diode, a bistability can occur due to a non-uniform distribution of the carriers (i.e. spatial hole burning effect). Moreover switching by using optical pulses is possible, resulting in all-optical flip-flop operation with repetition rates up to 1.25 GHz and for pulses with energy below 0.5 pJ.

2. Paper format

The bistability we observe when injecting CW-light into a DFB-laser arises from the strong influence of the carrier distribution on the threshold characteristics for lasing. In one of the states the laser is lasing and the injected light experiences a weak amplification due to gain clamping. In the other state the injected light is strongly amplified resulting in a non-uniform distribution of the carriers. This effect is called spatial hole-burning and increases the threshold for lasing, causing the laser to switch off. Therefore all the injected carriers in the device are used to amplify the injected light.
The bistability can be exploited for all-optical flip-flop operation (Figure 1). To make the device operate in the bistable regime, CW-light is injected in the DFB-laser. Switching from the lasing to the non-lasing state can be done by injection of a small pulse at the same side of the device as the CW-light. By injecting a pulse from the other side, the uniformity of the carrier distribution will be restored and the laser will switch on again.

Figure 1 : Schematic of principle

3. Bistability

Using static measurements, we have observed the bistability experimentally in an anti-reflection coated, $\lambda/4$-shifted DFB-laser with a length of 400 μm provided by Alcatel-Thales III/V-labs. The laser operates at a wavelength of 1553.7 nm and we inject light with a wavelength of 1543 nm. We observe that the bistability widens with increasing current and the extinction ratio is up to 35 dB (Figure 2). For lower values of the injected current (≤ 100 mA), no bistability was observed.

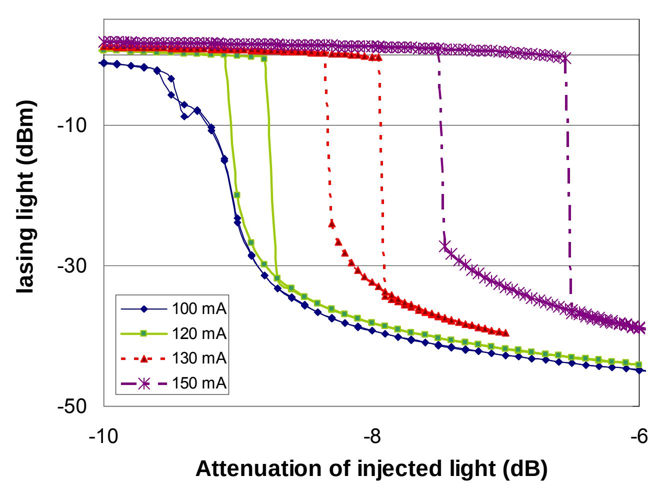

Figure 2: Measured bistability for a $\lambda/4$-shifted DFB-laser of 400 μm and different injection currents.

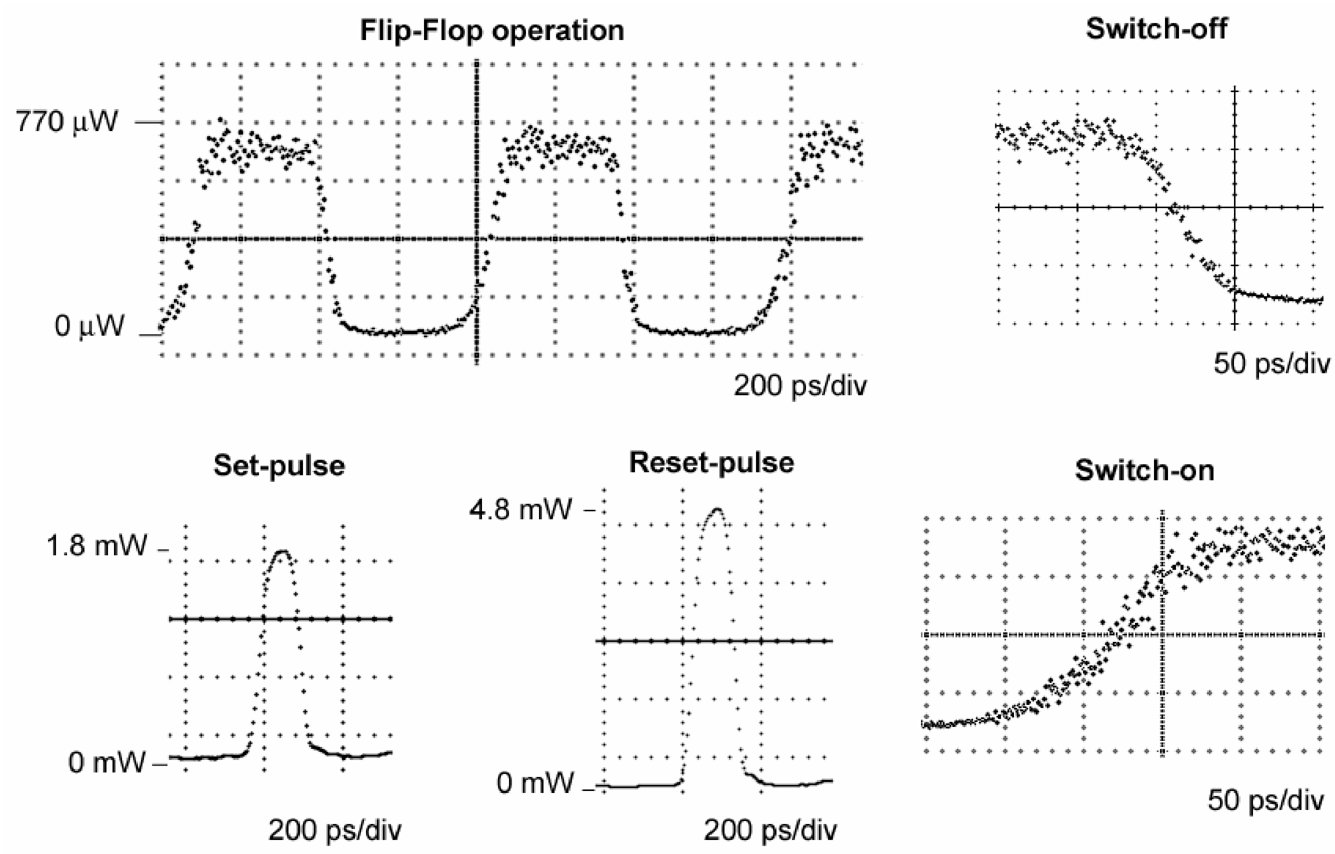

Figure 3: All-optical flip-flop operation using pulses of 100 ps with energy less than 0.5 pJ. Repetition rates up to 1.25 GHz can be obtained and the switch-on time of the laser is only 120 ps.

4. Flip-flop operation

To obtain flip-flop operation we switch between the two states of the bistability by injecting optical pulses in the device. To operate in the bistable regime, we inject CW-light of 900 µW at a wavelength of 1543 nm. The reset-pulses have an energy of 0.5 pJ and are sent at the same side as the CW-light. They will switch the laser off by disturbing the uniformity of the carrier distribution. The set-pulses on the other hand are weaker (0.2 pJ) and are sent on the other side of the device to restore the uniformity in the cavity again. We demonstrate flip-flop operation here with pulses of 100 ps length and repetition rates up to 1.25 GHz. The switch-on time of the device is 120 ps and the switch-off time 50 ps.

5. Conclusion

We demonstrated all-optical flip-flop operation in a single DFB-laser diode. Repetition rates up to 1.25 GHz can be achieved using pulses of 100 ps with less than 0.5 pJ.

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