A new optical decision circuit based on optical feedback between a laser diode and a semiconductor optical amplifier

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Simulation and experimental results of a new optical decision circuit are presented. The circuit consists of a semiconductor optical amplifier and a DFB laser diode in a mutual feedback scheme. The simulations show a very steep optical decision characteristic that is both wavelength independent and easily tunable by adjusting one of the drive currents or the coupling factor between the SOA and the laser diode. The measurement results show a good agreement with the simulation results. They show again a very steep transfer function that can be tuned by adjusting the drive current of the laser diode

Introduction

As the demand for bandwidth keeps increasing the call for all-optical networks becomes louder. In these networks all-optical decision circuits and more in particular all-optical regenerators will be key components. Several regeneration circuits have been discussed over the past few years. These schemes include amongst others bistable lasers based approaches [1] and devices based on saturable absorbers [2]. The most promising group of regenerators is however the one based on semiconductor optical amplifiers (SOA) and more in particular the integrated interferometric schemes using SOA's. Both high-speed operation [3,4] and steep decision characteristics [5,6] have been obtained using these schemes but unfortunately not with the same device. An additional setback is the influence of environmental changes like temperature and pressure on the non-linear effects in these integrated interferometric devices.

Here we show simulation and measurement results of a new all-optical decision circuit that is based on the mutual optical feedback between a laser diode and an SOA. A steep optical decision characteristic is obtained and it is believed that with the proper design of the circuit high-speed operation can be obtained. Moreover since the device is based on feedback the influence of environmental changes can be limited.

Principle of operation

A schematic representation of the all-optical decision circuit is shown in Fig. 1.

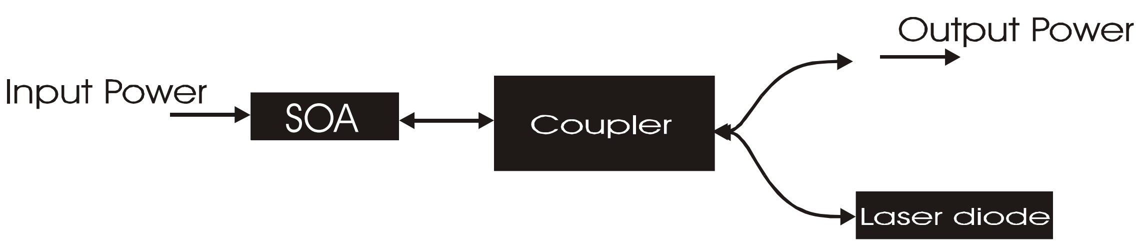

Fig. 1 Schematic representation of the optical decision circuit.

The circuit consists of an SOA connected to a laser diode by means of a splitter/combiner. A fraction of the output power of the SOA is injected into the laser diode. The same fraction of the laser power is injected back into the SOA. The fraction of the output power of the SOA that is not coupled to the laser will give us the output power of the circuit.
When a low input power is injected into the SOA the output power of the SOA will also be low. Hence little power is injected into the laser diode resulting in a high laser output power injected back into the SOA. In this state the SOA is saturated by the light coming from the laser diode resulting in a low gain for the input signal due to the asymmetric carrier distribution in the SOA. When the input power rises the output power of the SOA also rises and more power is injected into the laser diode. As a result the laser output power becomes smaller giving rise to a more symmetric carrier distribution in the SOA and a higher gain for the input signal. At a certain point the output power of the SOA becomes large enough to cause a significant drop in the laser output power. At this point the longitudinal spatial hole burning in the SOA flips from the state where it is mostly determined by the laser light to the state where it is mostly determined by the input signal. A large step in the output power occurs at the time of the flipping of the longitudinal spatial hole burning.

Simulation results

Simulations were performed on the described optical decision characteristic, using commercially available software [7]. The same set-up is used as shown in Fig. 1. Both the laser diode and the SOA have a length of 500µm. The SOA is a bulk SOA and the laser diode is an AR-coated λ/4 shifted Distributed Feedback laser diode (DFB). In Fig. 2 different simulated static decision characteristic are shown.

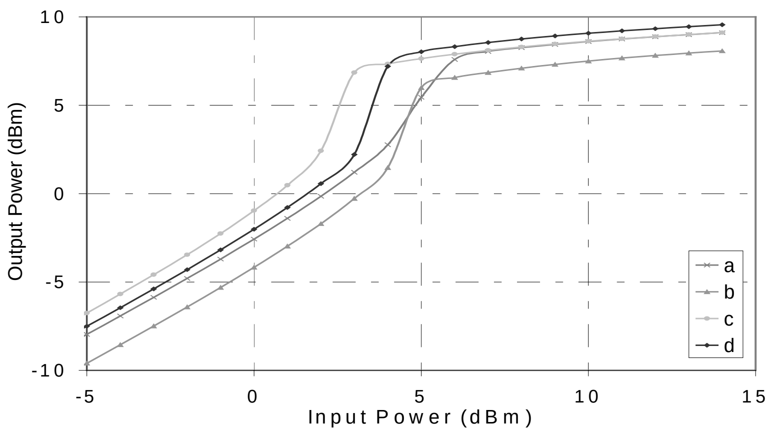

Fig. 2 Calculated static decision characteristics for different coupling factors and drive currents of both SOA and laser diode. (a) x=0.5, I_{laser}=120mA and I I_{SOA}=90mA, (b) x=0.6, I_{laser}=120mA and I_{SOA}=90mA, (c) x=0.5, I_{laser}=120mA and I_{SOA}=80mA, (d) x=0.5, I_{laser}=130mA and I_{SOA} =90mA.

It can be seen that by tuning one of the drive currents or the coupling factor between the SOA and the laser diodes both the steepness of the step as the decision point (the position where the step occurs) can be changed. A step of more then 5dB could be obtained over an input power range of about 1dB. As for low input power the output power rises the noise suppression at the zero-level could be difficult. At the one-level a reasonably flat level determined by the output saturation power of the SOA is obtained.

Experimental results

Next to the simulations the device was also tested experimentally using a discrete SOA and laser diode. The coupler/combiner is a fixed 60/40 coupler (x=0.4). The DFB laser diode used is a fiber-pigtailed DFB laser without isolator and with AR-coated facets. Since the DFB laser is normally integrated with an isolator and the fiber to chip coupling is optimized for use with an isolator omitting the isolator leads to a significant decrease in fiber to chip coupling. Because of this only a relative small fraction of the SOA light that is injected into the fiber of the laser diode is actually coupled to the laser chip itself. In order to obtain a step in the output power of the laser diode the drive current was kept low. The laser power going back to the SOA was amplified with an Erbium Doped Fiber Amplifier (EDFA).
In Fig. 3 we show an experimentally obtained optical decision characteristic. The signal wavelength is 1550nm and the laser wavelength is 1560nm. The drive currents for SOA and laser are 150mA and 22mA respectively.

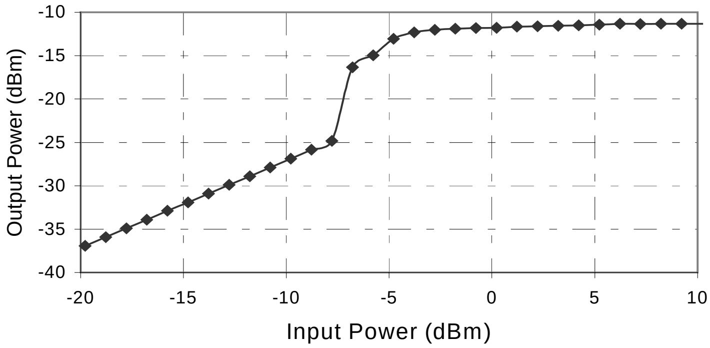

Fig. 3 Experimental static decision characteristic.

The output power exhibits a very steep step of about 10dB over an input power range of 1dB. It can be seen that the experimentally obtained characteristic corresponds to the characteristics obtained in the simulations. We observe the same slow rising slope at low input powers and the flat one-level for higher input powers.

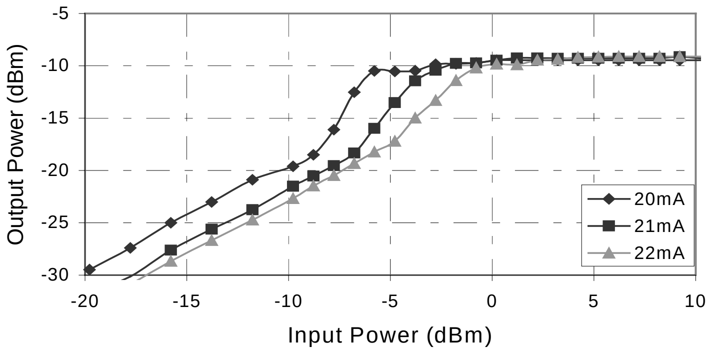

Fig. 4 Tuning of the decision point by adjusting the drive current of the laser diode.

To move the decision point only the drive currents of the SOA and the laser diode could be varied, since the coupler/combiner has a fixed value. In Fig. 4 it is shown that the decision point can be moved by adjusting only the drive current of the laser. A shift of about 4dB with 2mA change in the current of the laser diode was obtained.
Since these experiments were done with a discrete set-up the distance between the laser diode and the SOA was rather big, giving rise to a high roundtrip time. This relative high roundtrip time makes it difficult to perform dynamic measurements.

Conclusion

A new optical decision circuit was proposed. The circuit is based on mutual optical feedback between an SOA and a DFB laser diode and can easily be implemented. Both numerically and experimentally a very steep optical decision characteristic was obtained.

Acknowledgement

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