Demonstration of Optical Thresholding from a Semiconductor Optical Amplifier Coupled to a Laser Diode

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Abstract *A very steep optical decision characteristic is experimentally demonstrated using a new photonic circuit based on the optical feedback between a SOA and a laserdiode. Also tuning of the decision or threshold point is shown*

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Introduction

Several new photonic functions such as optical packet header processing, optical signal regeneration,… require an optical threshold or decision circuit. Many of the optical decision circuits presented so far are based on interferometers and still have a few drawbacks. E.g. it is not so easy to make them polarisation independent since both the refractive index change and the gain have to be equal for both TE and TM polarisation in this case. They also either exhibit a non-steep decision characteristic [1,2] or are not capable of very high-speed operation [3]. Other proposed implementations are based on bistable laser diodes. These devices typically exhibit a very steep characteristic, but they are also limited in speed to a few Gb/s [4].

We therefore present an optical decision circuit that obtains a steep decision characteristic without making use of interferometric structures and with potential for high-speed operation. The circuit is based on a semiconductor optical amplifier in a feedback scheme with a DFB-laser. The design can more easily be made polarisation independent and with the proper SOA and laser design it should be capable of high-speed operation.

In [5] we demonstrated the principle using simulations. In this paper we present experimental results obtained with the new proposed scheme. These results show a very sharp optical decision characteristic that can easily be tuned.

Principle

The new photonic circuit (which can be implemented as an integrated circuit) is shown schematically in Figure 1. It consists of a travelling wave semiconductor optical amplifier (TW-SOA) of which a part of the output is injected in a laser diode. An equal fraction of the laser light, emitted from the front facet of the laser diode, is injected into the r.h.s. facet of the SOA. To avoid that the signal injected into the laser is reflected back into the r.h.s. facet of the SOA, the laser should be an AR-coated DFB laser with a Bragg wavelength sufficiently different from the signal wavelength.

The operation of the circuit is based on the spatial hole burning inside the SOA. At low signal input power, the signal injection into the laser diode is weak, the laser diode emits a high power and hence a high power is injected at the r.h.s. facet of the SOA. The spatial hole burning in the SOA is then such that the carrier depletion is especially strong on the l.h.s. of the SOA. However, when the input signal power increases, the injection into the laser diode increases, the laser power decreases and so does the injection of laser power into the SOA. The injection of power into the SOA thus becomes more evenly distributed over both facets and the spatial hole burning decreases and is characterised by a more symmetric carrier density distribution. This lower spatial hole burning results in a higher gain for the input signal, which in turn results in a larger injection into the laser diode, a decreased laser power and a decreased injection at the r.h.s. facet of the SOA. This last effect results in a further decrease of the spatial hole burning and hence a further increase of the gain for the signal and eventually a further reduction of the laser power. At a certain input power, this multiplicative effect is so strong that the spatial hole burning flips from being predominantly determined by the laser power to being predominantly determined by the signal power. It is exactly this flipping of the spatial hole burning which results in a very sharp decision characteristic.

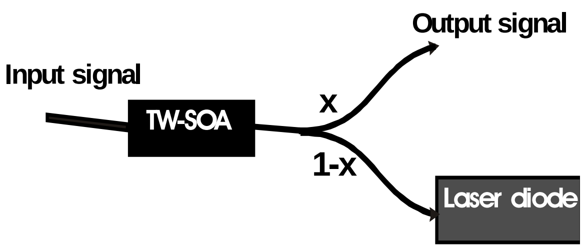

Figure 1: schematic of the new optical decision circuit

At low input powers the high injected power from the laser results in a suppression of the signal output power. When a high signal power is injected in the

SOA, and as a result the laser power drops significantly, the output signal power rises very quickly resulting in a very sharp optical decision characteristic.

Furthermore, since the SOA is always in saturation in this configuration, a high possible speed can be obtained if we can avoid the laser switching off at high input powers. This is done by setting the currents of the SOA and laser together with the coupling factor (1-x) such that the output saturation power of the SOA multiplied with that coupling factor (1-x) forces the laser to operate just above threshold. In this way, we avoid the turn-on delay of the laser at switch-on. Obviously, also a fast laser with a large 3-dB modulation bandwidth must be chosen to get high-speed operation.

Experimental Results

Simulations [5] showed a very steep transfer function that could easily be tuned by adjusting the current of the laser diode and/or SOA. The experimental results shown below confirm the simulations. To do the measurements a discrete set-up, consisting of a fiber-pigtailed SOA and DFB-laser diode (without isolator), was used. A very steep transfer function is shown in Figure 2. One can see an initial step of about 10 dB over an input power range of 1dB.

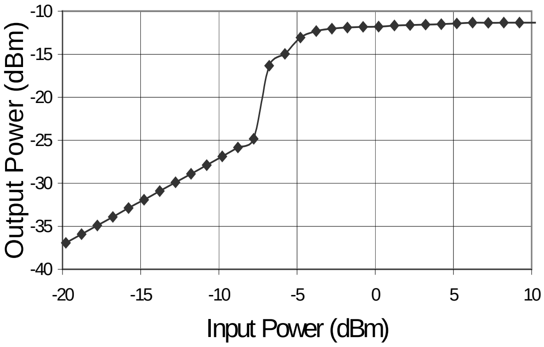

Figure 2: Experimental optical decision characteristic of a semiconductor laser in a feedback scheme with an SOA

The wavelength of the laser is 1560 nm while the signal wavelength is 1550 nm. For low input powers the output power raises slowly due to the decreasing laser power injected in the SOA at higher input powers. For high input powers a flat output power level is obtained of which the height is determined by the output saturation power of the SOA.

The adjustability of the decision point has been studied as well. In Figure 3 it is shown that tuning the current of the laser diode can move the decision point. By tuning the current of the laser diode with 2mA the decision point can be shifted over 5dB in input power. The same effect can also be obtained by tuning the current from the SOA.

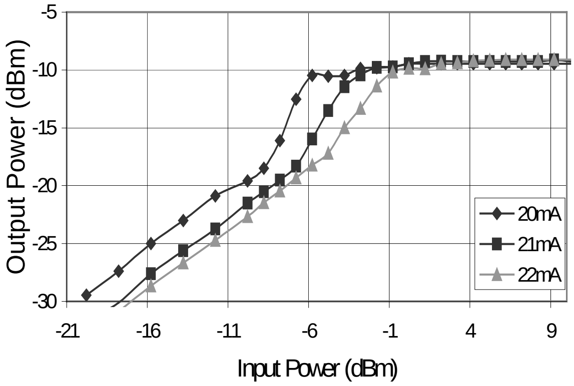

Figure 3: Example of the adjustability of the decision point of the newly proposed optical decision circuit.

Dynamic measurements will be performed in the near future but since the device is based on the feedback between two components special care has to be taken to reduce the roundtrip time between the laser and SOA. The discrete set-up will severely limit the speed of the device due to the relatively long fiber connections between the two components. To come to high speeds an integrated version of the device will have to be made.

Conclusions

We proposed a new type of optical decision circuit based on the optical feedback between a laser diode and an SOA. For the first experimental verification the optical decision characteristic was measured resulting in a very steep transfer function. It was also shown that the decision point could easily be shifted. The next step is doing some low-speed dynamic measurements.

Acknowledgement

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