Method for polarization effect suppression in semiconductor optical amplifiers

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Abstract - *In this paper a new method is demonstrated for the suppression of polarization dependent operation of a semiconductor optical amplifier (SOA). This scheme averages out the polarization dependency by integrating a polarization converter in between two half SOAs. The concept is investigated with simulations and the operation is experimentally demonstrated.*

Introduction

In SOAs the polarization dependent behaviour can be problematic, leading to different propagation, amplification and non-linear phase shifts for the two orthogonal polarizations. To overcome this problem, different approaches can be applied. One approach is to remove polarization dependency by changing the properties of the material [1] or the geometry of the waveguides [2]. This can be very hard and even impossible, and furthermore will always be compromising with respect to optimal performance for one of the polarization states. These strategies are all focussed on equalizing the gain between the two polarizations. The refractive index, and hence the phase transfer, is not equal in these cases.

An obvious solution is polarization diversity: the input polarization is split and subcircuits are created for each of the two polarization states. This is a bulky solution.

In this paper an alternative solution is presented, based on on-chip polarization handling: the polarization is changed halfway the SOA and hence the polarization properties are averaged out. In this way, components optimized for one certain state of polarization and the overal performance of the device is polarization independent.

Principle

In a PESSOA (Polarization Effect Suppression in Semiconductor Optical Amplifiers) device, on-chip polarization manipulation is employed to avoid polarization dependency. The principle is depicted in Fig. 1. A polarization converter (PC) is placed halfway in an SOA, causing any arbitrarily polarized signal at the input to experience TE-amplification and TE-phase shift in one half of the device, but TM-amplification and TM-phase shift in the other half. The net effect is in principle polarization independent, both for amplification and phase shift.

Simulations

VPI transmission maker is used to investigate the performance of the PESSOA structure and compare it to a standard SOA. The SOA model is a simple rate equation model. The SOA is polarization independent, but a polarization dependent gain (PDG) is obtained

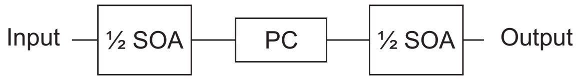
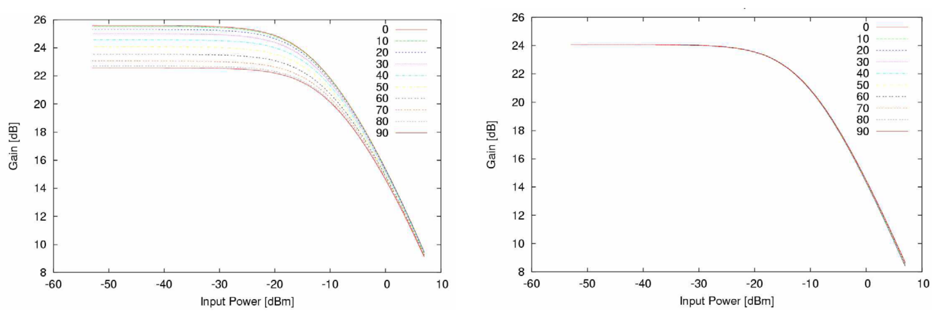


Figure 1: Schematic of PESSOA (Polarization Effect Suppression in Semiconductor Optical Amplifiers).

by placing a polarization dependent attenuator, having 3 dB difference in attenuation, in front of the SOA. The polarization converters are ideal components.

In this article only the dependence of the gain is considered. In Fig. 2, the gain as a function of input power is plotted for the two cases: the standard SOA and the PESSOA. From the plots it is clear that in the linear regime of the SOA complete compensation



(a) Standard SOA

(b) Cascade PESSOA

Figure 2: Simulated gain in SOA and PESSOA.

can be achieved for PESSOA. As the device saturates, the PESSOA averages the transfer and still full compensation is obtained. This is advantageous over a polarization diversity solution in which polarization dependency is present in saturation, because the SOAs do not receive the same power at their inputs and hence their saturation is not equal. It is anticipated that the phase transfer, specially for non-linear operation of the SOAs is also polarization independent in the PESSOA case.

Design and fabrication

The PESSOA devices are designed to be integrated in an active-passive butt-joint integration scheme [3] extended with polarization handling capability. The extended generic platform is obtained by adding polarization converters, based on the design in [4].

The active layerstack used for the SOAs contains 8 unstrained InGaAs quantum wells and 9 strained InGaAs barriers centered in a 500 nm thick Q1.25 waveguide layer. The passive waveguide is a 500 nm thick Q1.25 layer. The layers are grown on an N-InP substrate. The topcladding consists of a 1.5 µm thick P-InP layer. The top contact is made on a 100 nm InGaAs layer, this layer is selective removed on the passive waveguides.

All the waveguides used in the PESSOA devices are 3 µm wide. The SOAs are 2 µm wide, both are shallowly etched, 100 nm into the waveguide layer. The SOAs and the passive waveguides are connected using 150 µm long tapers. The waveguides enter the active region at an angle of 10° to avoid reflections from the butt-joint interfaces. Furthermore

the waveguides are placed at an angle of 7° with respect to the facets of the chip, again to avoid reflections from the facets without the need for anti-reflection coating.
The SOAs fabricated in this way are very polarization dependent for low injection currents.
The fabrication is similar to the fabrication described in [4], all waveguides but the polarization converters are defined using optical lithography, the converters are defined using Electron Beam lithography (EBL). The EBL written patterns are aligned to optically defined alignement marks. The fabrication is extended with a process for the active components. To this end, as a first step, the contactlayer is removed everywhere but on the active region. After the process as described earlier, the chip is planarized and passivated by multiple layers of polyimide. A top P-contact and a backside N-contact consisting of Ti, Pt and Au are deposited. The P-contact is made approximately 1 μm thicker by means of electro-plating. A microscope photograph of the finished chip is shown in Fig. 3.

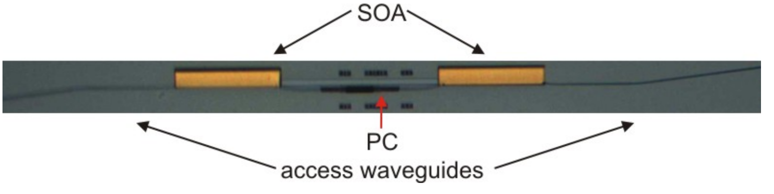


Figure 3: Photographs of the fabricated PESSOA devices.

Measurements

The PDG of the PESSOA is measured with a transmission measurement and compared to a normal SOA processed on the same chip. The PESSOA consists of 2 SOAs with a length of 800 μm each. The standard SOA is 1500 μm long.
A tuneable laser with a polarization maintaining fiber output is used. The light is fed to the input of the devices by using a polarization maintaining lensed fiber. The laser is modulated at a frequency of 1 kHz to be able to detect the light using a lock-in amplifier and to isolate the light from the ASE coming from the SOA.
The power input in the SOA is -15 dBm and hence the small-signal gain is studied. The gain as a function of wavelength is recorded for both TE and TM polarized light. The PDG for both the PESSOA and the standard SOA are plotted in Fig. 4. The measurements demonstrate the principle of PESSOA. A clear improvement is indicated. For a wavelength of 1515 nm a maximum compensation of the PDG of 12 dB is obtained. The compensation works well over a large wavelength range.
Some problems in the realization have to be overcome. The polarization converter has an efficiency of approximately 80% and thus a complete compensation is not possible. The PESSOA has larger losses and hence a lower absolute gain as compared to a regular SOA. The low compensation for wavelengths longer than 1525 nm has to be investigated further.

Conclusions

The PESSOA concept is introduced to improve the polarization independent behaviour of SOAs. It is an averaging solution, in which a polarization converter is placed halfway an

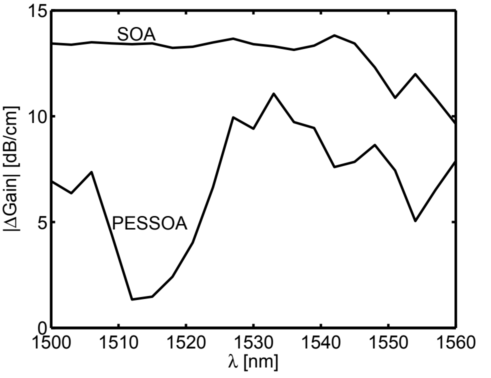


Figure 4: Comparison of the polarization dependent gain as a function of wavelength for PESSOA and a regular SOA.

SOA.
The device is simulated and compared to a standard SOA. The PDG is fully compensated both in the linear and in the saturated regime.
PESSOA devices are fabricated in a generic active-passive integration scheme. The performance of the concept is experimentally demonstrated: the polarization dependent small signal gain is reduced for 12 dB.
Some improvements are required in the process to achieve full compensation and lower losses. The feasibility of a true polarization independent SOA without the need for large circuitry is demonstrated.

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