Simulation of SOAs optical bandwidth widening based on selective filtering

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***Abstract*—In this work, we present simulation results of SOAs optical bandwidth widening. Results are based on SOA model associated to an optimization algorithm in order to design the spectrally selective filter. A widening of 60% is achieved.**

Keywords- SOA; optical bandwidth widening; optimization

I. Introduction

In optical networks, there is a need for amplifying a wide frequency range in order to provide low-cost solutions. As nowadays amplifiers are bandwidth limited, a natural idea that could come would be to use two amplifiers, each amplifying a different frequency range which is not really cost-effective as it consists finally in duplicating the amplifying stage. One more suitable solution is to provide a component with a very wide optical bandwidth. The French ANR (*Agence Nationale de la Recherche*) AROME project has been launched to realize this goal. One of the solutions proposed within this project is presented here and consists in a reflective semiconductor optical amplifier (RSOA) having a spectrally selective reflectivity. Moreover, its symmetrical structure is preferred in networks for bidirectional transmissions.

The simulation results we show here are based on a semiconductor optical amplifier (SOA) model developed under Agilent Technologies ADS, reference software for electrical circuit design allowing various simulation types (DC, AC, time-domain, Harmonic Balance…). The SOA model is associated with a gradient algorithm in order to design and optimize the spectrally selective filter.

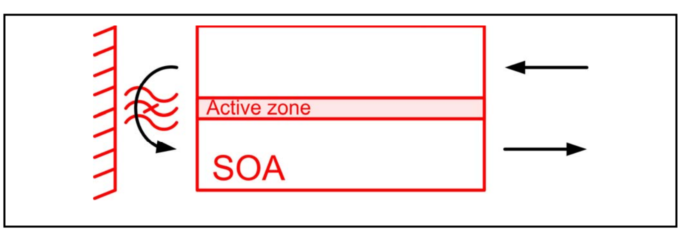

Figure 1. Principle of the equalized SOA (ESOA): it is a reflective SOA (RSOA) with spectral selectivity at one facet.

II. Principle of the widening method

The principle of SOAs optical bandwidth widening is resumed in Figure 1. . It is mainly based on the structure of RSOAs. The difference is here in the left facet coating. In the case of RSOAs, this coating is either absent (~30% - reflectivity) or a high-reflectivity coating (~99% - reflectivity). In our case, the coating should be especially designed in order to compensate the gain spectral profile and then be an optical band-stop filter. The principle of flattening and equalization we describe here has already been employed successfully on erbium-doped fiber amplifiers (EDFA) [1]. Applied to SOAs, it is theoretically possible as coatings are based on the superposition of several layers of dielectric materials. It can be possible to design a special combination of these layers in order to obtain the desired behavior. It is not the point of this work to study the technological feasibility or issues of this technique, we just consider it possible. As we said, the key point of our technique is to ensure that the spectrally selective facet compensates the round-trip gain over a wide optical frequency range.

Equation (1) gives the total equalized SOA (ESOA) gain ($G_{ESOA}(\lambda)$) as a function of the simple-pass SOA gain ($G(\lambda)$) and reflectivity properties ($R(\lambda)$). It should be noted that we make some assumptions in order to obtain this simple equation: the SOA gain is the same in the propagating and counter-propagating ways and there is no polarization dependence. The polarization independence can be a crucial point especially for non-integrated components, which is not the case in our study.

$$G_{ESOA}(\lambda) = (G(\lambda))^2\, R(\lambda) \qquad (1)$$

The need for simulations in order to obtain the suitable parameters of such a reflectivity comes from the complexity of the SOA behavior. In fact, the SOA gain and amplified spontaneous emission (ASE) spectral profiles will be affected by the value of the reflectivity. As a result, someone calculating a reflectivity profile from a given SOA gain profile and putting it at one SOA facet would not have a suitable flattened gain. The main point is that as we have a reflective structure, the ASE and signal coming back in the active zone will change the carrier density and affect the component global behavior.

III. SIMULATION PRINCIPLE AND RESULTS

We have used our own SOA model [2] which has been implemented under Agilent Technologies ADS software, reference software for electrical circuit design allowing various simulation types (DC, AC, time-domain, Harmonic Balance…). For this study, our SOA model has been simplified (steady-state and no phase) and takes into account spectral behaviors, which implies having a spectral dependence of the ASE. It also takes into account the carrier density spatial dependence through several calculus sections. The reflected total ASE power is not negligible and must also be taken into account. Another constraint on the model is that it must fit to real components in order to be used as a reference for the reflectivity calculation and then to have a realistic reflectivity profile. Key points are the material gain and spontaneous emission spectral profiles [3].

Figure 2. presents the global algorithm used in this work. First it should be noted that finding the operating point of the SOA is not obvious. It is done by an ADS internal algorithm, which calculates the operating carrier density in each calculus section knowing all inputs and taking into account all other calculus sections as they are interdependent. Second, a gradient algorithm is used to find the best spectral profile reflectivity parameter in order to flatten the SOA spectral gain. The SOA operating point must be re-calculated each time the reflectivity parameters are updated. The algorithm ends when either the widest bandwidth is reached or when the maximal amount of iteration steps has been reached. The reflectivity spectral profile we use in this study is a second order Gaussian. The parameters of the reflectivity that can be optimized are its peak wavelength, its bandwidth and its minimal value.

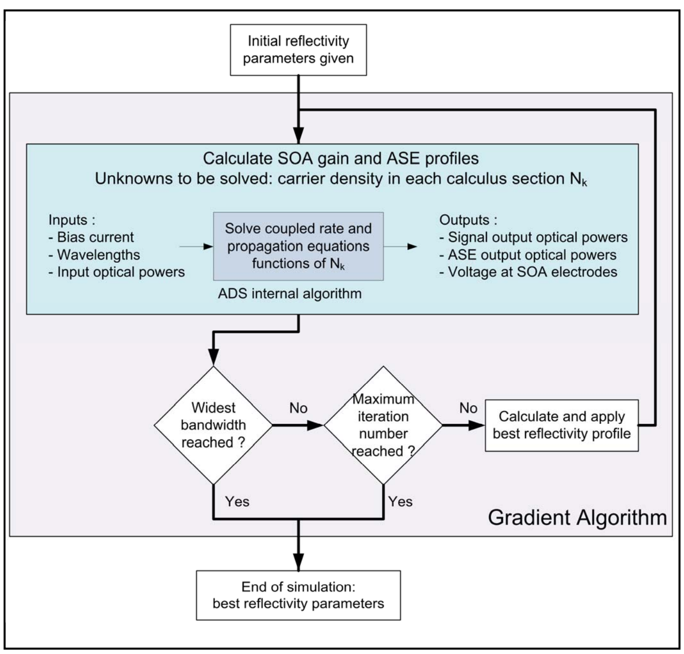

Figure 2. Presentation of the algorithm used to find best spectral profile reflectivity parameters.

Figure 3. presents the comparison between three simulation results made with a commercial SOA. We show the initial SOA simple-pass gain (dashed curve), the optimal ESOA gain (solid curve) and the ideally equalized ESOA gain (dotted curve). The -3-dB bandwidth for each curve is respectively 54.6 nm, 88.5 nm and 110.6 nm. The ideally equalized ESOA gain demonstrates the widening potential of our method if an ideal reflectivity is employed (in this case, $R(\lambda) = G_{ESOA}(\lambda) / (G(\lambda))^2$ where $G_{ESOA}(\lambda)$ is a constant). The bandwidth is however limited because we consider that there is a maximal reflectivity of 0.3 that cannot be exceeded. The optimized ESOA gain curve clearly shows an enhanced bandwidth and we can clearly see the effect of the reflectivity which acts as a band-stop filter.

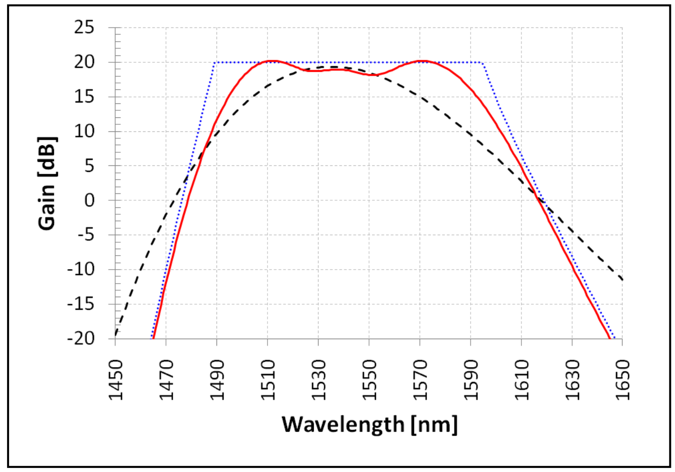

Figure 3. Comparison between simple-pass SOA gain (dashed curve), optimized ESOA gain (solid curve) and ideal ESOA gain (doted curve).

IV. CONCLUSION

We have presented the ability of our system to handle spectral reflectivity optimization in order to widen SOAs optical bandwidth. We will then present simulation results showing SOAs optical bandwidth widening as a function of the type of SOA (bulk, MQW) and as a function of the reflectivity profile. We will also show that our algorithm permits to define other goals such as maximal gain. We will theoretically discuss the consequences of such goals on bandwidth and noise factor.

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