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Conversion of Semiconductor Optical Amplifier as an Oscillator: A simulation experiment

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Abstract

A scheme to convert Semiconductor Optical Amplifier as an Oscillator by optimizing SOA parameters is proposed and experimentally studied. This paper investigates the performance of SOA based Oscillator which operates at signal wavelength of 1550 nm and generates output power of about 20 µW. The oscillator is designed using a spectral filter and a gain to compensate for filtering losses. The SOA works as an element and favors the formation of ultrashort pulses.

Keywords: Semiconductor optical amplifier, Nonlinear characteristics, Passive optical network, Erbium-doped fiber amplifier.

Introduction

Semiconductor optical amplifier has been used extensively as a potential gain medium in various systems such as dense wavelength division multiplexing, WDM passive optical networks, optical sensors, and others [1]. Among the gain media used by different configurations, SOA is found to be more competitive compared to erbium-doped fiber amplifier (EDFA) not because of the SOA characteristics such as gain, noise figure (NF), saturated output power but most importantly of its nonlinear characteristics that put SOA at a greater advantage[2]. In realization of the practical usage of SOA, it is found to be more attractive than the scattering effects because of its physical parameters[3]. The small and compact size of SOA chip can be handled without much hassle in contrast to Raman amplifier which requires high pump power. This paper shows that the application of semiconductor optical amplifiers (SOAs) is not limited only to the amplification of optical signals but is also used as an oscillator thereby eliminating the use of external laser source.

SOA Characteristics

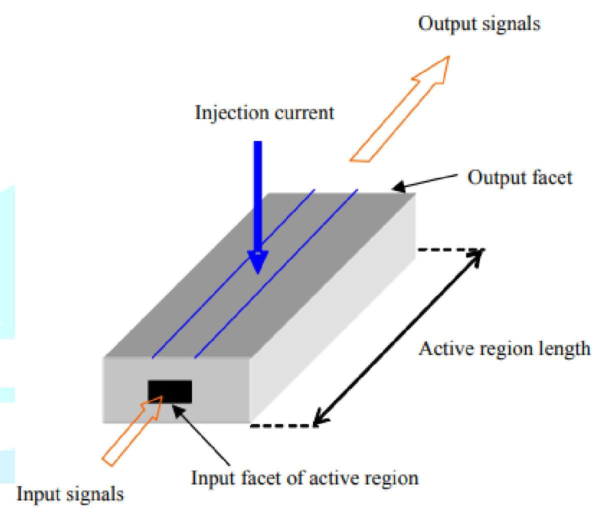

Fig. 1. Schematic diagram of the SOA.

When light is injected into the SOA, changes occur in the carrier and photon densities within the active region of the SOA. These changes can be described using the rate equations. The gain medium of the amplifier is described by the material gain coefficient, g (per unit length) which is dependent on the carrier density N and is given by:

$$g = \alpha_g (N - N_0), \qquad (1)$$

where N_0 is the carrier density at transparency point and αg is the differential gain parameter. The net gain coefficient g_T is defined by:

$$g_T = \Gamma \cdot g - \alpha , \qquad (2)$$

where αs is the internal waveguide scattering loss, and Γ is the confinement factor which is the ratio between the cross -sectional area of the active medium and the transverse area of the optical waveguide.

The total gain G of an optical wave experienced at the location z of an SOA can be calculated according to

$$G = e^{gT.Z}, \qquad (3)$$

assuming a constant carrier density at any given location z within the active region of the SOA. Therefore, the average output power P_{av} over the length of the SOA becomes:

$$P_{av} = \frac{1}{L}\int_0^L P_{in}\,G dz \qquad (4)$$

where L is the length of the SOA and P_{in} is the input signal power. The average output power can be rewritten as:

$$P_{av} = P_{in}\,\frac{e^{gT.L}-1}{gT.L} \qquad (5)$$

The dynamic equation for the change in the carrier density within the active region of the device is given by:

$$\frac{dN}{DT} = \frac{I\,dc}{q.V} - R(N) - \frac{\Gamma.G.Pav.L}{V.h.f} \qquad (6)$$

where I dc is the dc current injected to the SOA, q is the electron charge and V is the active volume of the SOA,

$$V = L.W.H\,, \qquad (7)$$

where W and H denote the width and the thickness of the active region, respectively.

Experimental Setup

The proposed model consists of bidirectional isolator, semiconductor optical amplifier, bidirectional filter, bidirectional coupler, and optical spectrum analyzer. Two arms of the semiconductor optical amplifier are connected to the pump coupler and bidirectional coupler. To optimize the wideband travelling wave SOA, it is made to operate at 1550 nm, keeping injection current of 225 mA. Other parameters of SOA are listed in Table 1.

Table 1. Optimized SOA parameters.

PARAMETER	VALUE
Power	0 dBm
Wavelength	1550 nm
SOA injection current	225 mA
Input facet reflectivity	5*e-005
Output facet reflectivity	5*e-005
Optical Confinement Factor	0.6
Group Velocity	75000000 m/s
Active length	500 µm
Active refractive index	3.2

The optimized SOA is then connected to the simulation setup as shown. The optical delay is used to hold the signal. The bidirectional coupler is a cross coupler for combining or splitting the optical signal. The bidirectional isolator is used for the propagation of signal without insertion and coupling losses. The isolator connected to the bidirectional filter acts as the FBG which in turn acts as a reflective mirror that reflects only the signal at particular wavelength i.e., 1550 nm. Other wavelengths will be isolated by the isolator. The bidirectional filter is then connected to the coupler which forms the loop necessary as per the Barkhausen criteria for oscillation. Thus, the SOA now acts as the laser source without applying any external signal and it generates a power of 20 microwatts at this condition.

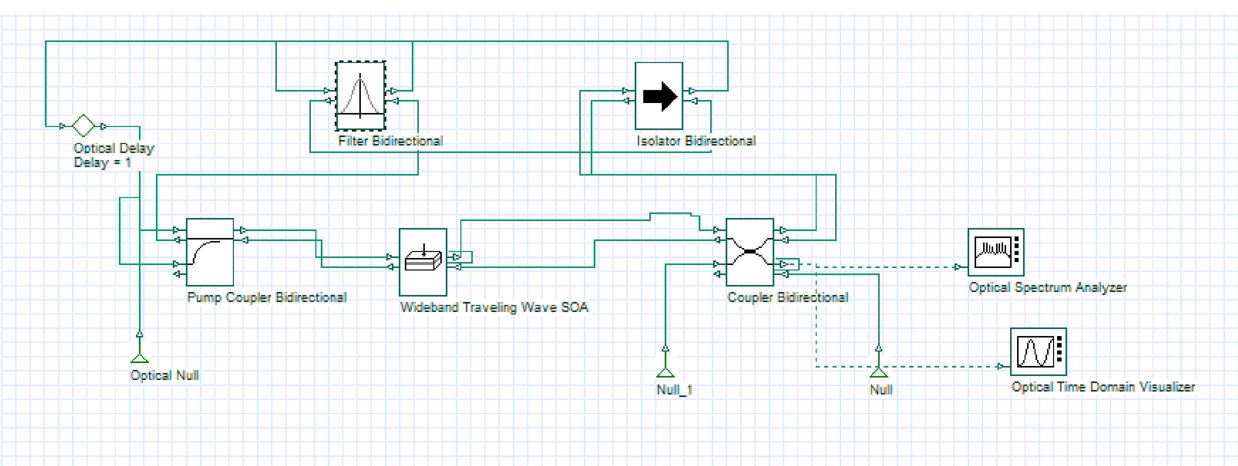

Fig. 2. Proposed SOA based Oscillator system simulation set up using Optisystem

Results and Discussion

In this work, optimization of SOA parameters such as input power and injection current as in Table 1 are carried out to start with. Then this optimized SOA is converted as a Laser source to generate ultra-short pulse as in Fig.1 and connected to the simulation setup which acts as an oscillator. After running the layout using Optisystem V.16.1 simulation software, the output signal obtained in the Optical spectrum analyzer as shown in Fig 3.

Optical Spectrum Analyzer

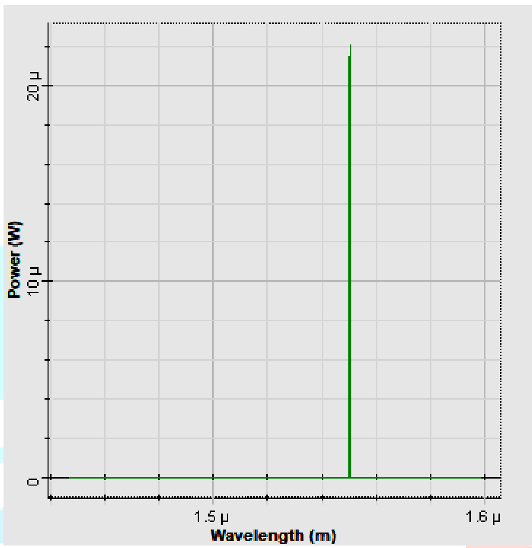

Fig. 3. Gain and versus Wavelength of the SOA

Conclusion

From the simulation results, it is noted that the proposed system can be used to convert SOA into an Oscillator which oscillates at an operating wavelength of 1550 nm with an output power of 20 µw. This work can be extended to improve the output power by applying the concepts such as Mode-locking, Q-switching and exploitation of other nonlinearities of SOA.

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