American Journal of Materials Research
2018; 5(1): 14-18
http://www.aascit.org/journal/ajmr
ISSN: 2375-3919

American Association for Science and Technology

ANN Modeling for Gain of the Irradiated Semiconductor Optical Amplifier

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Citation

Taymour A. Hamdalla. ANN Modeling for Gain of the Irradiated Semiconductor Optical Amplifier. *American Journal of Materials Research.* Vol. 5, No. 1, 2018, pp. 14-18.

Received: January 1, 2018; **Accepted**: January 16, 2018; **Published**: February 27, 2018

Abstract: Artificial intelligent are powerful data treatment that used in different field of science. Artificial Neural Network modeling (ANN) is considered the most important type of artificial intelligent. Here, the gain of irradiated semiconductor optical amplifier (SOA) used in signal amplification within the core of the optical fibers system has been studied. An experimental studies for the gain of irradiated SOA followed by a simulation network using ANN model has been investigated. The ANN of SOA is consist of two hidden layer, two inputs and one output. The ANN shows a high compatibility with the performance of irradiated SOP with an error of about 10^{-5}. These results candidates the examined model to act as a computational physics program within the fiber optics amplifier system.

Keywords: SOA, Optical Amplifier, Gain

1. Introduction

Semiconductor optical amplifier (SOA) technology has matured to the point where commercial devices are available for use in optical communication systems [1, 2]. In 1980s, it was the beginning of SOA as a linear amplifier. Challenges included the realization of low-facet reflectivity and high fiber-to-fiber gains by also reducing the coupling losses almost out-competed as linear amplifiers [3]. In 1990s, EDFAs begin to be used due to lower noise levels and with better crosstalk properties for amplification. Because of its longer recombination times for the excited states in Erbium compared to the very fast carrier dynamics in semiconductor material [4]. The semiconductor optical amplifier is considered one of the most important source of signal amplifying. Into the access networks, the SOAs still mush useful than EDFAs due to its potential price and its powered directly inside the system. Moreover, they can provide solutions outside the 1500-nm band where fiber-based amplifiers are more difficult to realize. The SOA is instrumental in this context due to its compactness, inerrability and rich nonlinear functionality [5, 6].

So, it is necessary to develop some techniques to calculated the change in the gain (G) due to the change in the amount of dose, such as the artificial neural network model. The neuron is the simplest part of the ANN, every neuron is joined by another to create this network. These ANN are trained, so the target could be obtained (estimated output result) from a certain input result. Trained ANN are able to perform complex functions in various fields of application including pattern recognition, modeling, identification, classification, speech, vision and control systems [7]. Making use of the capability of ANN, the present work uses ANN to model the gain of the SOP under the effect of the radiation.

2. Experimental Setup and ANN Modeling

2.1. Experimental Setup

The effect of the neutron doses on the gain of the SOP are measured with the experimental setup shown in Figure 1. It is explained in detail in [8]. The SOP is exposed to a neutron beam emitted from Am-241/Be-9 neutron source of 5 Ci activity for 24 hrs. the system consists of tunable laser source, the pump laser connected to optical isolator. Artificial neural networks may either be used to gain an understanding of biological neural networks, or for solving artificial intelligence problems without necessarily creating a model of a real biological system. The real, biological nervous system is highly complex: artificial neural network algorithms attempt to abstract this complexity. The SOA is inserted inside the radiation chamber. finally, it is joined to the optical spectrum analyzer. Using the optical analyzer by which the gain (g) could be measured and also the noise figure (NF).

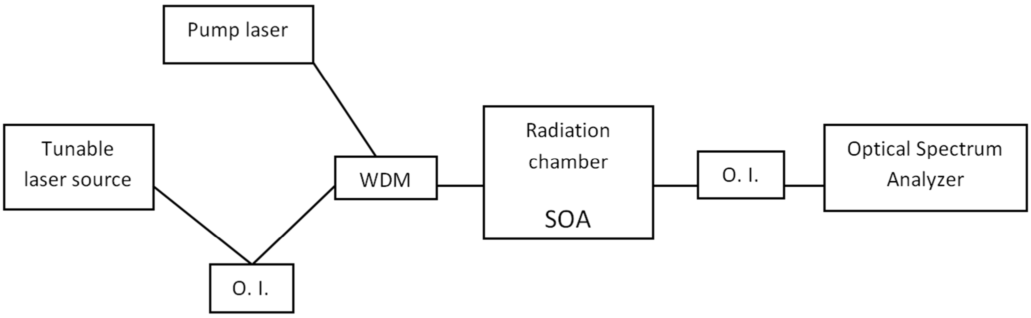

Figure 1. *TDFA experimental setup. (O. I. optical isolator).*

The SOA model is 1013S from Thro company has the following features: center wavelength of 1500 nm, SM or PM Fiber Pigtails (1.5 m) with FC/APC Connector, saturated output power 14 dB Typical, typical NF is 8.0 dB Typical Inline Amplifier, Detector Pre-Amp, and Fast Optical Switch.

2.2. ANN Modeling

For each ANN, there is a simple unit called neuron or node [9]. Its function is to receive one or more input signals and provide an output. The output received depends on the processing function of the node [10]. This is a simple processing unit and is known as an elementary perceptron. Each input X_i is weighted by a factor W_i and the whole sum of inputs is calculated ($\sum_{all\ inputs} W_i X_i$) then an activation function f is applied to the result a. The neural output is taken to be f(a):

$$output = activiation\ function(\sum_{all\ inputs} WX = F(a) \quad (1)$$

Also provides a numerical solution to the problem of minimizing a function [8], generally nonlinear, over a space of parameters of the function Levenberg-Marquardt algorithm LMA has been used, also known as damped least squares.

The neuron transfer function, f, is typically step or sigmoid function that produces a scalar output (n) as in Eq. (1):

$$n = f\ (\sum_i w_i I_i + b) \quad (2)$$

Where, I_i, w_i and b are the ith input, the ith weight and the bias (b) respectively.

There is an interconnection strength, weight, associated with each connection as in figure 2. When the weighted sum of the inputs to the neurons exceeds a certain threshold, specified by threshold function with bias, the neuron is field and output signal is produced. The network can recognized input-output relation once the weights are tuned via some kind of learning process [5, 6]. The essential features for a feed forward NN are reviewed below employing a two layer NN. However, the results generally hold for any multiple layers NN (see figure 3).

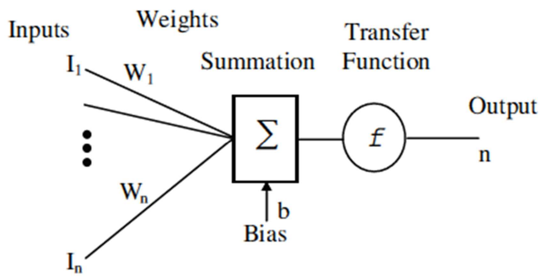

Figure 2. *Simple neuron model.*

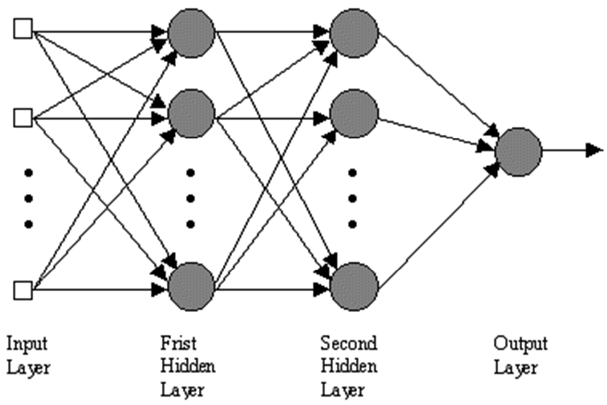

Figure 3. *Complete neural network.*

The Levenberg-Marquardt updates the network using the following rule:

$$\Delta W = (J^T J + \mu I)^{-1} J^T e \quad (3)$$

where J is the Jacobean matrix of derivatives of each error with respect to each weight. J^T is the transposed matrix of J; I is the identity matrix that has the same dimensions of J^T J. μ is a scalar; changed adaptively by the algorithm and e is an error vector. The Levenberg-Marquardt updates the network using the following rule [10, 11]. J^T is the transposed matrix of J; I is the identity matrix that has the same dimensions of J^T J. μ is a scalar; changed adaptively by the algorithm and e is an error vector.

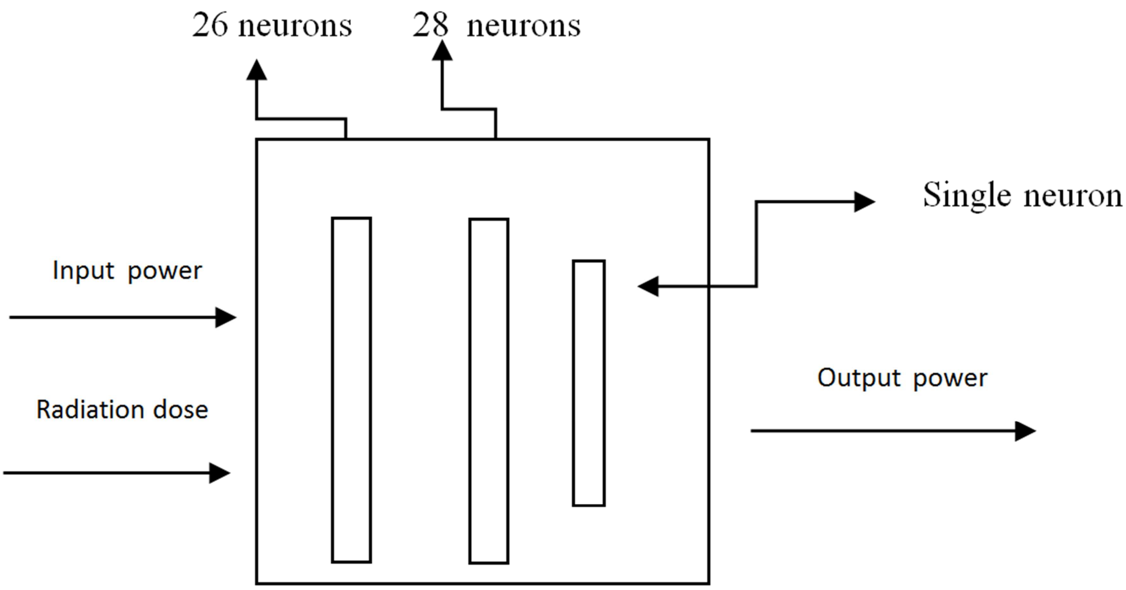

Figure 4. *A block diagram of the output power using ANN modelling.*

Figure 4 shows a block diagram for our designed network containing the estimated inputs and outputs.

3. Result and Discussion

The proposed ANN model of the gain of irradiated SOA can be viewed as an two –input one output model. The inputs are: the input power.(P_{in}) and the Dose in m (D), while the output is the G and NF.

Using this input-output arrangement, the network configuration was tried to achieve good mean sum square and good performance for the network. There are two hidden layers of 13 neurons, 11 in each. The transfer function is the tan sigmoid. Also provides a numerical solution to the problem of minimizing a function, generally nonlinear, over a space of parameters of the function Levenberg-Marquardt algorithm LMA has been used, also known as damped least squares.

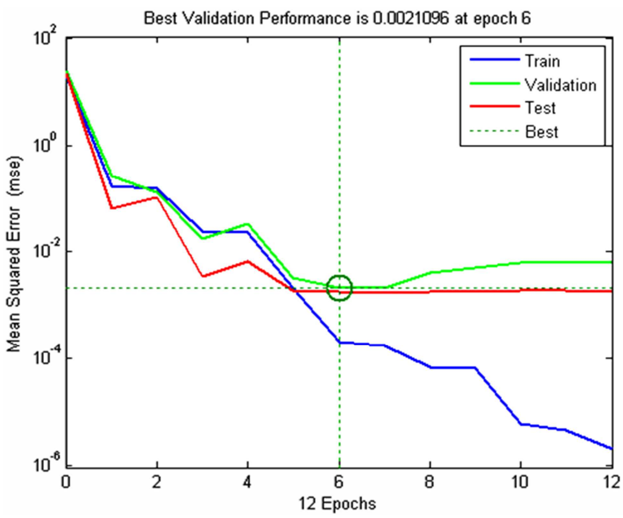

Figure 5. *The relation between the mean square error with the number of Epochs in ANN simulation.*

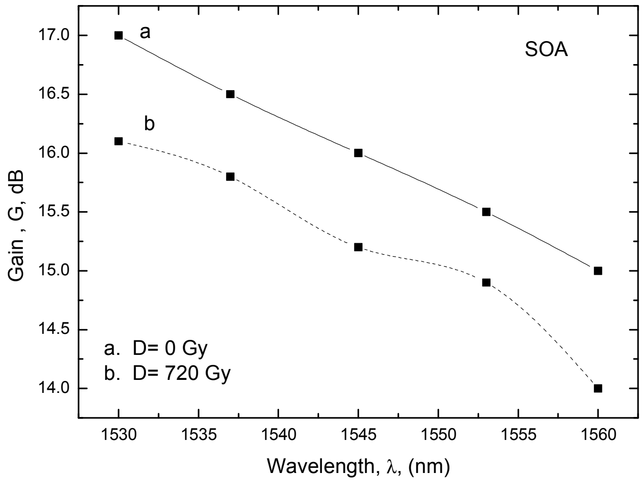

Figure 6. *The gain of Irradiated SOA versus the input wavelength in nm for a dose up to 720 Gy, Symbols represented the training by ANN model.*

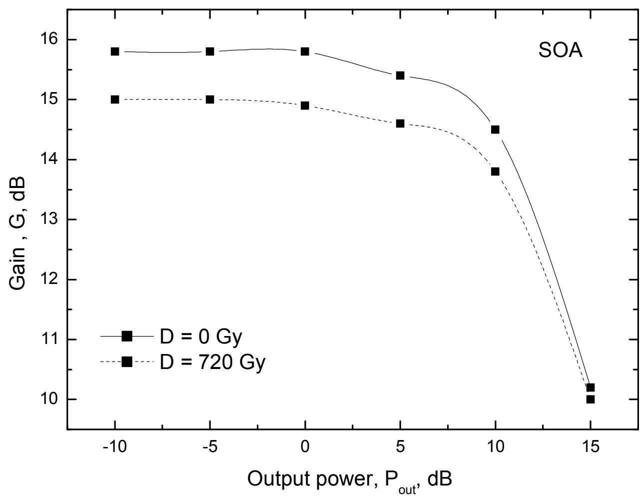

Figure 7. *The gain of Irradiated SOA versus the out power in dB for a dose up to 720 Gy, Symbols represented the training by ANN model.*

Figure. 5 shows the variation of the mean square error of the ANN network after simulating the SOA performance. It is clear from the figure. that the error is 1.4×10^{-5}. This low value give us indication that the network design is suitable for simulation of the gain values. The small values of error shows the program has the ability to simulate the semiconductor amplification within the optical fiber. Figure 6 The gain of Irradiated SOA versus the input wavelength in nm for a dose up to 720 Gy, Symbols represented the training by ANN model. The gain of the signal amplified by irradiated SOA decreased by about 0.8 dB for a dose of 720 Gy. The effect of irradiation on the optical fibers will creates a color centers throughout the whole fibers. These color centers will decreased the optical amplifying signals. The gain of Irradiated SOA versus the out power in dB for a dose up to 720 Gy, displayed in Figure 7. The Symbols represented the training by ANN model. In the Figure the gain is decreased due to the irradiation increases. The high energy absorbed inside the material will lead to a complete change in the material structure. The match is still good, indicating that the designed NN is robust. The weights, biases and the obtained equation for the designed network are provided in the appendix This changing will cause a direct change in the refractive index which is responsible to do a change in the gain of the SOA.

4. Conclusion

The gain of the SOA has been investigating the varying effects of input power, radiation dose and wavelength. Thus, many tries are done to find the best ANN used low numbers of epochs, number of hidden layer and number of neurons. Simulation results of temperature sensor using ANN are tested with experimental data which showed a perfect fitting. Thus, many tries are done to find the best ANN used low numbers of epochs, number of hidden layer and number of neurons. Also, prediction results of the ANN is checked with the experimental data not used in the training giving good performance. The obtained results that have been reported will give designers much knowledge of the potential of using the SOA in their system. The ANN model stimulate experimental results with very small error 1.6×10^{-6}.

Appendix

Our obtained function is generated using the obtained control NN parameters as follows:

The structure of the network is 2-13 -11-1. The obtained equation which describes the temperature sensor of the sea water with respect to the time for different depth is given by:

$$G = pureline[\{net.LW(3,2).\tan sigmoid.\{net.LW(2,1).\tan sigmoid\{net.IW(1,1).P + net.b(1)\} \\ + net.b(2)\} + net.b(3)\}]$$

Where, Pure line is linear transfer function, tan sigmoid is hyperbolic tangent sigmoid transfer function as shown in the following figure,

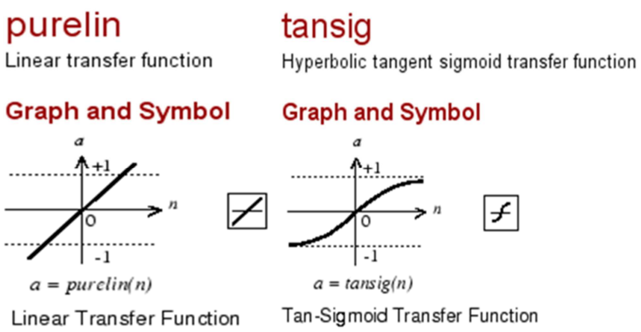

Figure 8. The functions used in the ANN designing.

P is the input which is (t, D).

$net.LW(3,2)$ linked weight between the second hidden layer and the output.

$net.LW(2,1)$ linked weights between the first and the second hidden layer.

$net.IW(1,1)$ linked weights between the input layer and the first hidden layer.

$net.b(1)$ is the bias of the first hidden layer.

$net.b(2)$ is the bias of the second hidden layer.

$net.b(3)$ is the bias of the output layer

Acknowledgements

The author acknowledges prof. Mahmoud Yassin Elbakry for his guidance and support throughout the work in these thesis.

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