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Enhancing Accuracy of Photonic Structure of Photonic Crystal Fiber Using ANN

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Abstract

There are several methods introduced to refining the accuracy of Photonic structures. No one has as yet studied the effect of Neural Networks in refining the accuracy of the photonic structure of the Photonic Crystal Fibers. In this paper we use the simulation that will be conducted using artificial neural networks to refining the accuracy of the photonic crystal fibers. Artificial neural network will be further optimized by varying the number of layers and number of neurons to enhance the accuracy of the photonic structure of the photonic crystal fibers.

Keywords: *Hollow core-Photonic crystal fiber, Numerical Aperture, Dispersion, holes, neurons & layers, ANN (Artificial Neural Network).*

1. Introduction

Photonic-crystal fiber (PCF) is a new class of optical fiber based on the properties of photonic crystals. Because of its ability to confine light in hollow cores or with confinement characteristics not possible in conventional optical fiber, PCF is now finding applications in fiber-optic communications, fiber lasers, nonlinear devices, high-power transmission, highly sensitive gas sensors, and other areas.

Photonic Crystal Fiber (PCF) can provide characteristics that ordinary optical fiber do not exhibit, such as: single mode operation from the UV to IR with large mode-field diameters, highly nonlinear performance for super continuum generation, numerical aperture (NA) values ranging from very low to about 0.9, optimized dispersion properties, and air core guidance, among others. Applications for photonic crystal fibers include spectroscopy, metrology, biomedicine, imaging, telecommunication, industrial machining, and military, and the list keeps growing as the technology becomes a mainstream. Photonic crystal fibers are generally divided into two main categories: Index Guiding fibers that have a solid core, and Photonic Band gap or air guiding fibers that have periodic micro-structured elements and a core of low index material (e.g. hollow core). Structured optical fibers are also called micro structured optical fibers and sometimes photonic crystal fiber in case the arrays of holes are periodic. PCF (Photonic Crystal Fiber) is a type of optical fiber using the properties of photonic crystals. Its advantages against a

conventional optical fiber are possibility to control optical properties and confinement characteristics of material. The conventional optical fibers simple guide light and they have started revolution in telecommunication. The principle of total internal reflection has been used for guiding of light in the fiber. Nowadays, we almost have reached the maximum of its the best properties, which are limited by the optical properties of their solid cores (attenuation 0.2 dB/km, zero dispersion shifted to the minimum loss window at 1550 nm on used wavelength with fiber.

Low-loss dielectric periodic material with sufficiently different dielectric constants in crystals can control flow of the light. Crystals with photonic band gaps can be design. We can design such structure which can prevent the light from propagation in certain directions with specified range of wavelengths. Hollow Core Photonic Crystal Fibers (HC-PCF) is also called holey fiber. It enables the guidance of the light in the hollow core with lower attenuation than in the solid silica core. The core can be filled by air or gas. There are many advantages of using PCF against a conventional optical fiber. The biggest ones are possibility to control optical properties and confinement characteristics of material. Since these fibers allow for guidance through hollow fibers (air holes).there is smaller attenuation than with fiber with solid core. PCFs with larger cores may carry more power than conventional fibers. Larger contrast is available for effective-index guidance. Attenuation effects are not worse than for conventional fibers. Control over dispersion: size of air holes may be tuned to shift of zero dispersion into visible range of the light.

2. Design methodology

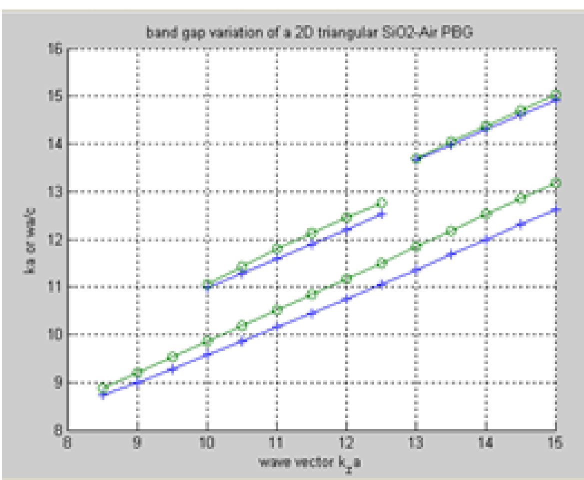
Matlab will be used as the simulation tool. Attempt will be made to enhance the Accuracy of Photonic Structure of Photonic Crystal Fiber using Artificial Neural Networks.

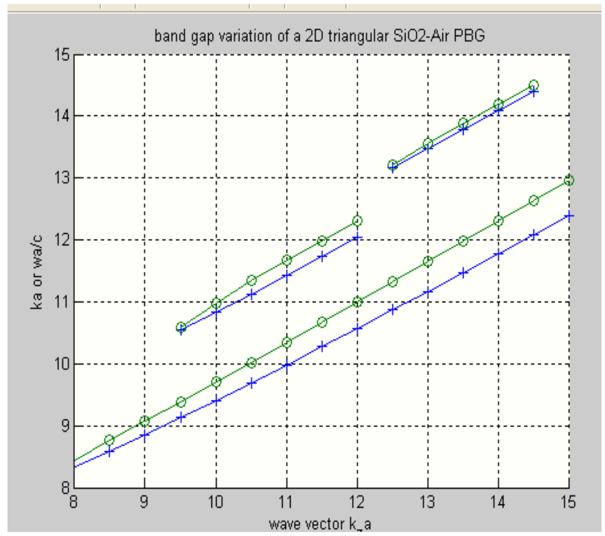
First The Parameters of the photonic structure will be considered. Neural networks have proved themselves as proficient classifiers and are particularly well suited for addressing non-linear Problems. Given the non-linear nature of real world phenomena, like Enhancing the Accuracy of Photonic Structure of Photonic Crystal Fiber, neural networks is certainly a good candidate for solving the problem. The Parameters as shown in Table I will act as inputs to a neural network and the enhancement of accuracy of the photonic structure will be the target.

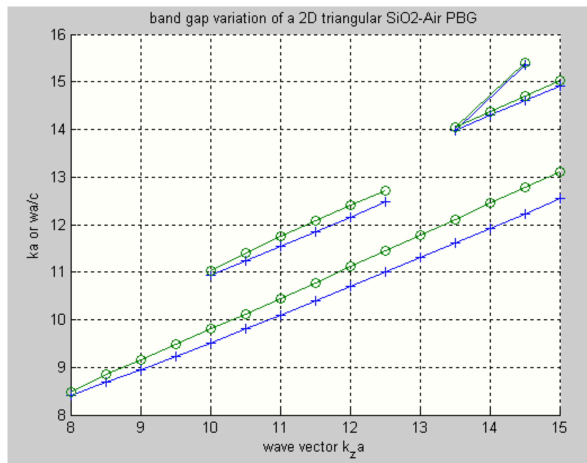
Table I- Input Parameters of Photonic Structure

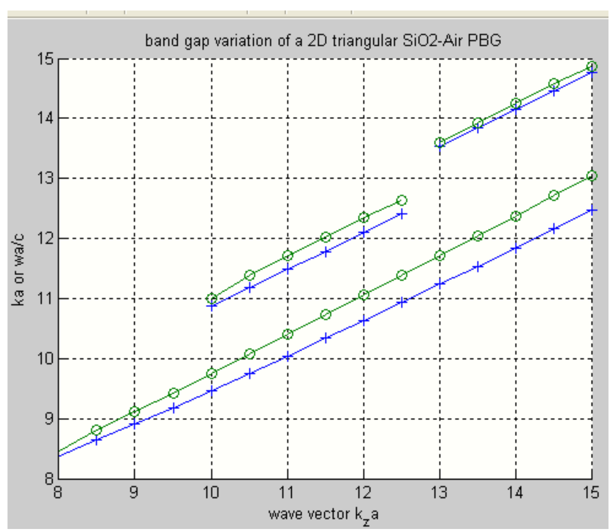
Input	SAMPLE 1	SAMPLE 2	SAMPLE 3
epsa	1	1	1
epsb	1.42+(iter/100)^2	1.46^2	1.46^2
a	1.0	1.0	1.0+(iter*0.01)
f	0.7	0.7-(iter*.01)	0.7

Calculate the photonic band gaps for various input parameters by using plane wave method. Find the unit cells which are perpendicular to the x-y plane, then form the equation matrix of 2N by 2N. For this case, there have no TE & TM decoupling. Find the band gap & save these values into its appropriate band, then plotting the variation of band gap between sio2-air PBG. Similarly repeat all of these for three samples unless you get desired PBG (as shown in fig 1a, 1b, 1c, 1d).









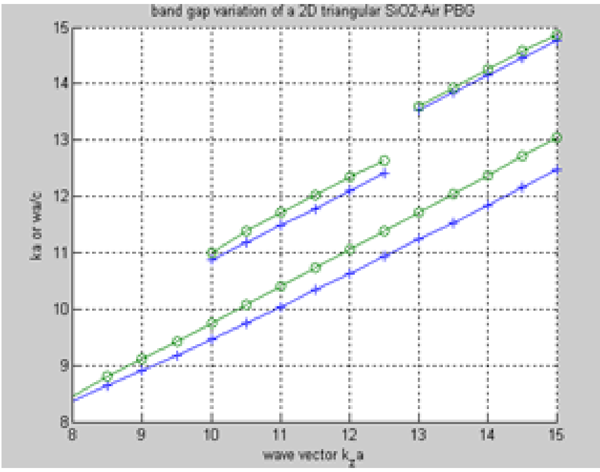


Figure 1 (a, b, c, d, e) Photonic band gap variation for input parameter of Sample 1

These figures show the photonic band gap variation in 2-d triangular lattice of sio2-air PBG. For figures 1(a, b, c, d), epsa is the dielectric constant of air, epsb is the dielectric constant of sio2, a is the diameter & f is the spacing between holes. At last in the photonic band gap graphs if the region width < .574, then it guides the value else leaky the value. Further given an input, which constitutes the measured values for the parameters of the photonic structure, the neural network is expected to identify if the accuracy has been achieved or not. This is achieved by presenting previously recorded parameters to a neural network and then tuning it to produce the desired target outputs. This process is called neural network training. The samples will be divided into training, validation and test sets. The training set is used to teach the network. Training continues as long as the network continues improving on the validation set. The test set provides a completely independent measure of network accuracy. The trained neural network will be tested with the testing samples. The network response will be compared against the desired target response to build the classification matrix which will provide a comprehensive picture of a system performance.

3. Training Data

The training data set includes a number of cases, each containing values for a range of input and output variables. The first decisions you will need to make are: which variables to use, and how many and which cases to gather. The choice of variables (at least initially) is guided by intuition. Expertise in the problem domain will give you some idea of which input variables are likely to be influential. As a first pass, you should include any variables that you could have an influence - part of the design process will be to reduce this set down. Neural networks process numeric data in a fairly limited range. This presents a problem if data is in an unusual range, or there is missing data, or if data is non- numeric. Fortunately, there are methods to deal with each of these problems. Numeric data is scaled into an appropriate range for the network, and missing values can be substituted for using the mean value (or other statistic) of that variable across the other available training cases.

4. Simulation Results

In this, we used unary encoding in this simulation to perform symbol translation. The first six columns of data will represent the Cloud characteristics. The 7th column represents whether the job is to be transferred or not. This data will be randomly generated. The next step will be to preprocess the data into a form that can be used with a neural network. The next step is to create a neural network that will learn to identify if the accuracy has been achieved or not. The assumed samples will be automatically divided into training, validation and test sets. The training set will be used to teach the network. Training will continue as long as the network continues improving on the validation set as shown in figure 2.

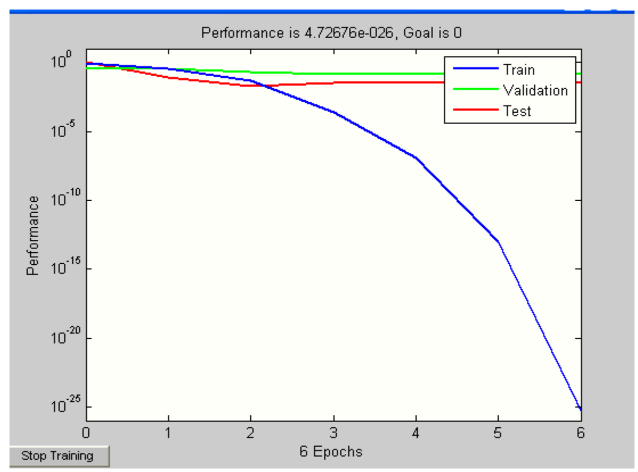


Figure 2. Performance of neural networks

The test set will provide a completely independent measure of neural network accuracy to detect accuracy. The trained neural network will be tested with the testing samples. This will give a sense of how well the network will do when applied to data from the real world. The overall architecture of your neural network is store in the variable net. The simulation of network returned output in matrix or structure format. The performance evaluation involves comparison between target and network's output in testing set (generalization ability) & comparison between target and network's output in training set (Memorization ability).

Design a function to measure the distance/similarity of the target and output.

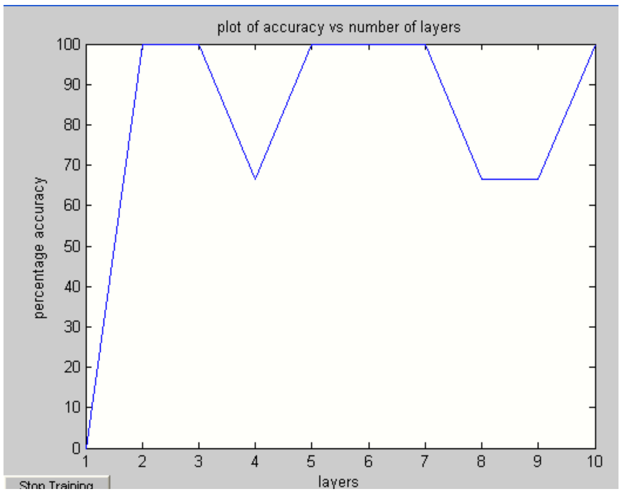


Figure 3. Plot of number of layers vs. percentage accuracy

The result shows the graphical representation of percentage accuracy versus number of layers as shown in Figure 3.

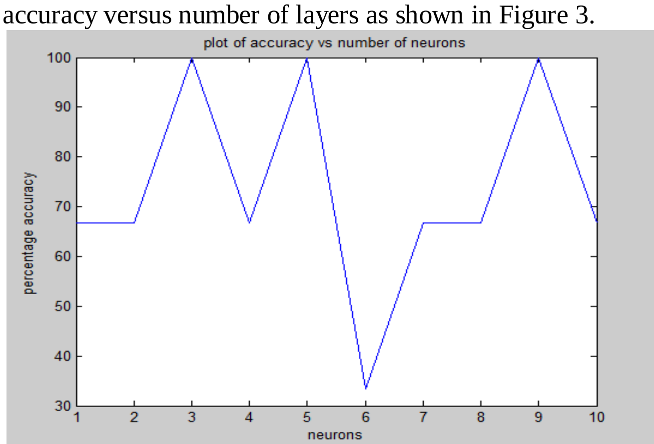


Figure 4. Plot of number of neurons vs. percentage accuracy

The result shows the graphical representation of percentage accuracy versus number of neurons as shown in Figure 4. From this it is clear that number of two layers and three neurons are sufficient to achieve the 100% accuracy.

5. Conclusion

Neural networks have proved themselves as proficient classifiers and are particularly well suited for addressing non-linear problems. Given the non-linear nature of real world phenomena, like Enhancing the Accuracy of Photonic Structure of Photonic Crystal Fiber, neural networks is certainly a good candidate for solving the problem. From the figure 3 it is clear that only number of two layers and three neurons are sufficient to achieve the accuracy of 100%.

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