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Metamaterial based photonic crystal fiber memory for optical computer

G. Palai[a,*], B. Nayak[a], Santosh Kumar Sahoo[b], Soumya Ranjan Nayak[c], S.K. Tripathy[d]

[a] Department of Electronics and Communication Engineering, Gandhi Institute for Technological Advancement (GITA), Bhubaneswar, 752054, India
[b] CVR college of Engineering, Hyderabad, India
[c] Department of CSE, K L University, Vaddeswaram, Guntur, Andhra Pradesh, 522502, India
[d] Department of Electronics and Communication Engineering, National Institute of Technology, Silchar, 788 010, India

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ABSTRACT

Photonic crystal fiber (PCF) based optical memory is discussed in this communication, which will be useful for optical computer. The proposed PCF is designed by using metamaterial structure, which bestows implausible upshot for envisaging optical memory in computer system. Present report uses two IR signals of 1300 nm and 1575 nm wavelengths to realize the aforementioned memory application, where 1300 nm acts as input signal and 1575 is used as excited signal. Moreover plane wave expansion technique is employed to study the modal analysis of electric-field distribution in the proposed photonic crystal fiber, where the variation of peak electricfield in the fiber is the basic operational principle of present discussion. Finally, this work avows that photonic crystal fiber with apt intrinsic parameters can be a suitable element for optical computer.

1. Introduction

The English proverb “slow and steady wins the race” is factual pertaining to tortoise and hare story from Aesop’s fable is going to be notional with respect to worldwide research in technology owing to the todays know-how is burgeoning as swift mode in such way that “fast and steady wins the race” [1]. The same can be acknowledged with respect to Moore’s law which vis-à-vis to ministration of optoelectronic devices [2]. Similarly research on information technology is hastily time to time with the help of nanotechnology. Furthermore the combination of information and nanotechnology bestows a fast communication using computer network. To achieve high speed computer network, each element or component of computer system should be emphasized for the same efficiency. To realize a speedily communication, researchers are speculating that light based computer would fetched an adequate efficiency as the desire of today’s generation as compared to current days electronic computer [3]. Moreover researchers are also considering that photonic based computer is an upcoming entrant to the world. However it takes delay to arrive in market due to fabrication feasibility and trapping of photons [4]. It is a device that uses photon in lieu of electron or electric current that performs a digital computation. As far as the limitation of today’s computer is concerned, electric current generates heat during digital computation in computer system [5]. Also the amount of heat increases due the increasing of speed of computer which leads to the generation of massive heat loss and as a result of which it damages the hardware component. However quantum of light (photon particle) creates insignificant amount of heat regardless of how much is used. Moreover with the help of the advantages of visible and infrared (IR) networks at the device or components of scale, this future computer could be pretended 10 or more times speed than that of a conventional electric

* Corresponding author. Tel.: +91 9439045946.
E-mail addresses: gpalai28@gmail.com, g_pallai@yahoo.co.uk (G. Palai).

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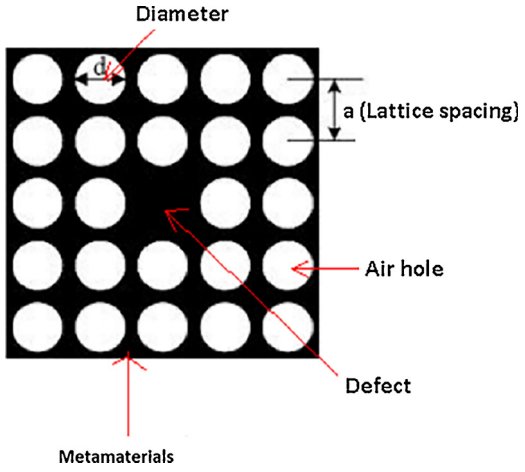

Fig. 1. Schematic diagram of metamaterial based photonic crystal fiber.

computer. Another, advantage of optical computer is due to non-effect of photon beams, but the interaction of electron beams creates predicament in the system.Therefore now a day's most research projects are being focused on the replacing of current computer components with optical elements. Resulting photonic digital computation system processing would be faster [6]. Though this paper states about the speed of the computer or optical computer,each component of the same plays vital role to make high speed computer.Out of different element of optical computer, optical memory is a key element of the same, which is discussed in this article using metamaterial structure. Again considering today's electric memory, semiconductor grating have widely been used now-a-days which relay on magnetic memory of molecular scale. Because of tiny molecules, it is '0′ when beam is magnetized and '1′ with respect to demagnetization which is equivalent to 0,1 bits. The principle of optical memory is similar to the same. However the intrinsic material is different from existing semiconducting magnetic materials. Because, this article uses metamaterial based photonic crystal fiber, that is the combination of PCF and metamaterial which belongs to the application of optical metamaterials. As far as literature survey on metamaterial isconcerned, though many works have been carrying out using the same, few works with respect to flabbergast upshot have been divulged in international journal of light and electron optics (OPTIK) [7–9].Also although few works related to sensing and communication have been realised using similar structure, the proposed structure in this paper discloses new type of application embedded with metamaterial structure [10,11].

This manuscript is organized as follows; Section 2 discusses the operational principle including the intrinsic structure of proposed PCF using metamaterial and results and simulation is discussed in Section 3. Finally conclusion is drawn in Section 4.

2. Structure and operational principle

Before going to discuss the principle of operation, lets us concentrate on metamaterial based photonic crystal fiber structure which is shown in Fig. 1 and it is represented as the cross sectional view of two dimensional square type photonic crystal fiber.

From Fig. 1, it is seen that 5 × 5 air holes are etched on metamaterial substrate in such way that defect is made at center (no etching of air hole). To get several memory applications, this article choose a specific values of lattice spacing and diameter of 10 nm and 8.4 nm respectively. The reason for selecting such structure and dimension is that to realize photonic based memory application. As far as operational principle of memory is concerned, it deals with the storing of signal and retrieving the same at the time of requirement. Since this work deals with optical memory, two different wavelengths are manipulated with aforementionedstructure, where first wavelength is represented as storing signals and second wavelength can be considered as retrieving the same input from the structure. Moreover the following schematic diagrams explain lucidly to envisage the same.

Fig. 2(a) represents, signal 1300 nm is incident to photonic crystal fiber (structure of Fig. 1), where Fig. 2(b) explains, the storing of signal 1300 nm with same and the storing of signal can be understood from R = 0, A = 1, T = 0 (zero reflection and transmission and 100% absorption). It indicates, the aforementioned photonic structure, does not reflect and transmit any signal, whereas all signals are absorbed by it.So it is affirmed that the applied signal is completely absorbed by said PCF. Similarly Fig. 2(c) shows the retrieves of same signal from same photonic crystal fiber. For example, the wavelength of 1575 nm acts as supply signal which is applied to metamaterial based PCF to retrieve of the signal1300 nm. The same can be realized by considering A = 0, R = 0 and T = 1. It indicates that absorbing or storing signal corresponding to the wavelength of 1300 nm is getting transmitted rather reflected or absorbed. Moreover an interestingly, it is revealed that the nature of the structure and dimension of PCF for step-1, 2 and 3 remains stationary.

The reason for above said interesting result is due to the nature of materials(metamaterial) along with structure diameter. Metamaterial is an extraordinary material which exhibits superior properties and bestows unbelievable application pertaining to current research scenario. Again, this interesting application of metamaterials lies with size of device with respect to incident signal (wavelength of signal). It is observed that size of the device is less than wavelength of signaland it is represented as metamaterial

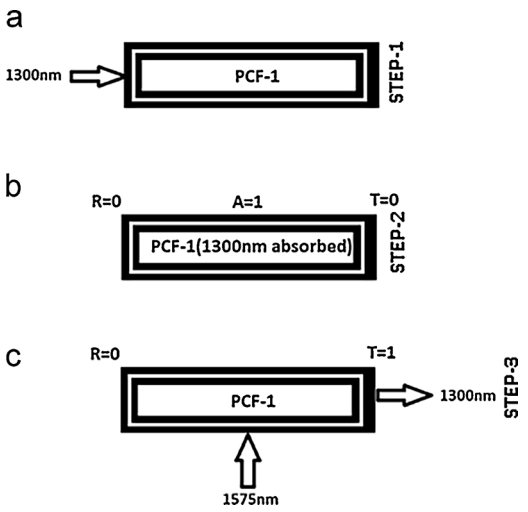

Fig. 2. (a); PCF with incident signal of 1300 nm (b); PCF with zero reflection and transmission and total absorption (c); PCF with excited signal of 1575 nm and emerging signal of 1300 nm.

device. Thereby metamaterial has lots of advantages as compared to bulk materials owing to it's abnormal properties. Since metamaterial is unique, the PCF based metamaterial would be a new type of application of optical memory and could be solved the recent hinderers of present computer by considering optical computer which is embedded with PCF based optical memory. Further the explanation of operational principle can be made validation through output upshot, discussed in next section.

3. Simulation result and discussion

Again, reminding the notion of operational principle of metamaterial based photonic crystal fiber, it is shown that three steps should be verified and validated through simulation result to realize optical memory application. As far as simulation result is concerned, plane wave expansion technique is employed to get electric field distribution through proposed photonic crystal fiber [12]. Aside this, two wavelengths such as 1300 nm and 1575 nm signal are manipulated with proposed structure, in such way that 1300 nm is represented as the storing signal, where 1575 nm is referred to retrieving signal. For example; 1300 nm wavelength of signal is incident to proposed structure and the structure is designed in such way that no signal would be escaped from it, i.e. 1300 nm signal will neither be reflected nor transmitted through it. All signals will be absorbed by the metamaterial structure. The same refers as storing of signal data. Further, signal 1575 nm is applied to the same PCF structure then and the signal 1300 nm escape from the structure. The same can be realized by analyzing the electric field distribution in the photonic crystal fiber. To accomplish the above said outcomes, the raw parameter for the same is refractive index of background material, number of air holes on the substrate, diameter of air holes and lattice spacing of the structure. Considering apposite values of the dimensions, the electric field distribution

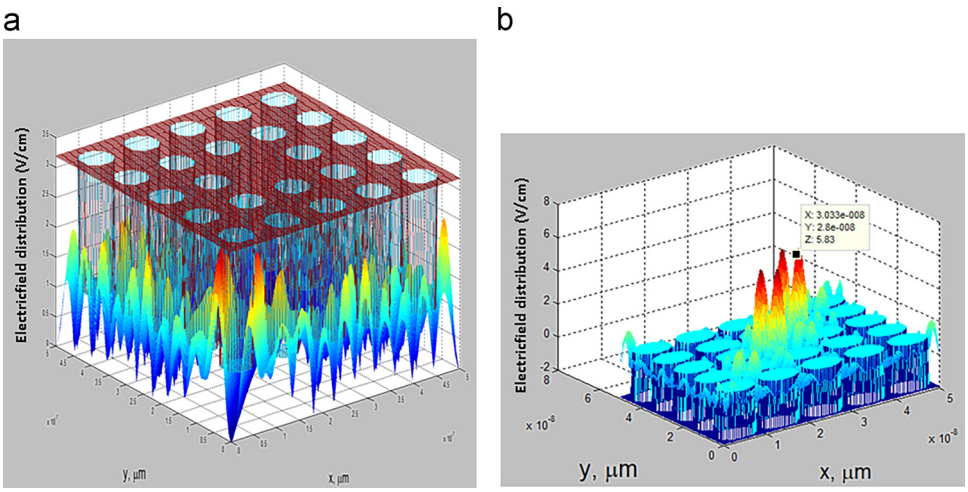

Fig. 3. 1: Electric field distribution corresponding to the wavelength of 1300 nm (r = 4.2 nm and a = 10 nm). 2: Electric field distribution corresponding to the wavelength of 1575 nm (r = 4.2 nm and a = 10 nm).

of photonic crystal fiber is shown in Fig.3(a).

Fig. 3(a) represents the variation of electric field distribution (V/cm) also z-axis with represent to length and breadth of optical fiber along x and y respectively. From Fig. 3(a), it is lucidly envisaged that no signal is coming out from fiber and also it is seen that all signal absorbed by it. Since the wavelength 1300 nm is incident on it. Therefore it is an unanimously confirmed that 1300 nm signal is stored by the structure, which explains in step-1 of operational principle. The above result is obtained at diameter of air holes of 8.4 nm and lattice spacing of 10 nm respectively. Further to retrieve the data or displaying the above signal, a wavelength of 1575 nm is used here. For example when wavelength of 1575 nm is applied to it, then same electric field are emerged through same PCF structure, which is shown in Fig. 3(b). In this case same electric field is coming out from the fiber out of these the peak value of it is 5.83 V/cm. Further using $\lambda = \frac{2hc}{\varepsilon o E 2}$ formula, an interestingly it is revealed that the wavelength of signal is 1300 nm corresponding to aforementioned electricfield, which confirms that the stored data, 1300 nm is retrieved by incident signal of 1575 nm.Though two signals (1300 nm and 1575 nm) have been used in this paper, other signals can be retrieved using different structures and dimensions using same principle.

4. Conclusion

An interesting application of metamaterial based photonic crystal fiber is disclosed in this communication, which would be useful for designing optical memory in optical computer. To sum up, it is summarised that signals of 1300 nm is stored by the metamaterial based photonic crystal fiber and the same data is retrieved with the help of 1575 nm signal, which is represented as memory application. This paper would help to researchers to design optical memory which will be useful for high speed computer and would be the need for coming generation.

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