Optimization and evaluation of structural performance in the design of an all-optical nano-switch based on two-dimensional and alternating photon crystal structures used in all-optical circuits

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Abstract

Due to the special place of optical devices such as all-optical switches in next generation digital systems, in this paper, a new example of these structures has been designed and simulated using two-dimensional photon crystals. This proposed structure uses point nano-amplifiers to couple light to waveguides, and two input and output waveguides. In the design of this all-optical switch, the mechanism of interference effect in photon crystals has been used in order to make the structure simpler and smaller. This optical structure is based on silicon technology and is designed using dielectric rods in an air bed. In this structure, the constant value of the lattice is about 549 nm, the radius of the dielectric rods is about 100 nm and the radius of the nano-optical intensifiers is 30 nm. This structure was active at 1550 nm and by examining at 1559, its performance in switching mode was analyzed. The response rate of the structure was 0.75 ps. The rate of placement losses in the structure for different inputs according to the input power of 1 mW / 2m2 is about -13 dB and the rate of shutdown rate for this input is equal to 12.8 dB. In order to optimize the structure in terms of the effects of the parameters involved in it to examine various factors, including; The input power, wavelength and central frequency, the size of the radius of the nano-resonator rods, the size of the dielectric rods and the fixed network are discussed. In order to analyze the structure in terms of scattering and photon band gap range, PWE method has been used and to analyze and obtain the output spectrum of the structure, FDTD method has been used. Due to the size of 7.86 m2, flexibility and suitable simulation results, this proposed structure is very suitable for applications of optical integrated circuits.

Keywords: All-optical switch, Photon crystal, Photon band gap, Response speed, Optical intensifier

Introduction

Advances in new technologies and high speed of light are important and influential factors in the direction of optical integrated hardware. The result of this approach will be the gradual replacement of classical electronic systems with new generation optical systems. Due to the importance of this issue, fast transmission, reception, storage and processing of received information and most importantly all-optical computing in new generation optical devices is one of the most important programs in the realization of integrated photon technology and integrated optical circuits. In this regard, new photon materials with micron nanometer sizes such as graphene, plasmon and photon crystals with unique capabilities such as modulation of photon emission modes and control, emission and distribution of light in the structure, are very important for the development of these technologies. In this regard, new photon materials with micron nanometer sizes such as graphene, plasmon and photon crystals with unique capabilities such as modulation of photon emission modes and control, emission and distribution of light in the structure, are very important for the development of these technologies.

However, among the mentioned photon materials, the alternating structures of photon crystals are due to having a photon band gap range, which is the basic basis in controlling and directing light, as well as unique properties such as; Small size, ability to process and transfer information quickly, and on the other hand, their simpler and easier design and construction, and are among the basic needs in the design of the implementation of integrated circuits, have been highly considered. Due to this issue, photon crystals can be used in the design and implementation of various optical devices, including optical waveguides, optical filters, optical sensors, optical multiplexers, optical converters, lasers, optical power dividers, Nouri and ... pointed out. Among optical devices based on photon crystal structures, all-optical switches are one of the most important among them, which has attracted a lot of attention and interest among scientists and researchers in this field. Using photon crystal structures, the size of all-optical switches can be greatly reduced to micro-nanometer dimensions depending on the wavelengths used. Also, the structure of all-optical switches designed and manufactured using photon crystals consumes less energy and has a response time of less than a few picoseconds, which results in a high switching speed. Photon crystal-based all-optical switches are an all-optical structure that increases the possibility of creating integrated optical circuits. In these structures, digital information can be transmitted at the speed of light to an electronic processor by fiber optics. However, the maximum switching speed for switches All-electric light is equal to 50 ps for the average power of a switch, which

which is very low for future new systems due to its limitation between P-N semiconductor connectionsHowever, switching speed in all-optical switches is limited only by the speed at which light passes through

Overview of photon crystals:

Photon crystals are a new class of optical environments characterized by natural or artificial structures whose refractive index changes periodically. These environments have special properties according to which photon crystals can be used in various applications. Based on the geometric shape, the structure of photon crystals is divided into three main categories: one-dimensional, two-dimensional, and three-dimensional photon crystals.

In one-dimensional photon crystals, the alternating modulation of the dielectric coefficient occurs in only one dimension, while in the other two dimensions the structure is uniform. An example of this structure is the Bragg grid, which is used as a distributed reflector in VCSELs. In addition, one-dimensional photon crystals are widely used in the manufacture of anti-reflective coatings that allow a significant reduction in reflection from surfaces and are used to improve the quality of lenses, prisms and other optical devices. Their arrangement variation is relatively large compared to one-dimensional structures. A good example of this structure is perforated silicon with alternating holes. Another example of a two-dimensional photonic crystal is an alternating system of dielectric tubes with an air bed. Examples of these two-dimensional photon crystals can also be found in nature, such as the morpho butterfly wings, which are composed of alternating two-dimensional structures of natural photon crystals. In general, each photon crystal structure has special and unique properties that are used according to the conditions used. Some of the features of this type of structure are as follows:

1) 1) They have a 2D optical band gap in all directions of propagation in the rotation plane.

2) The rotation plane is uniformly and infinitely extended in the vertical direction.

3) There are two groups of waves with different polarities to propagate the flat wave in these structures.

4) The polarization of TE and TM is defined as a wave with an electric field and a magnetic field parallel to the axis of the air holes or insulation rods.

5) It is shown that a photon crystal with a square or triangular lattice can have a photon band gap for TE or TM polarization.

6) The electromagnetic equations describing the wave on the plane in these structures can be reduced to a scalar equation in terms of only one field component.

7) Numerical analysis of these relatively large structures with an average computer is possible in a reasonable time.

Photon crystal based all-optical switching mechanism:

Similar to electrical switching, in all-optical switching, the emission or non-emission of the probe is allowed, this time by the status of the optical pump. Photon crystal all-optical switching can actually modulate the emission modes of the probe based on the interactions of light and matter. Photon crystal all-optical switching, as an integrated photonic device, plays a very important and essential role in the fields of integrated photon circuits, optical interconnection networks and optical computing systems. In 1994, Escalo et al. Developed a conceptual design for switching all-optical photon crystals, which was designed in such a way that normally the probed light was completely reflected from the photon crystal and could not propagate in it. Then the optical switch is off. Only under the stimulation of the light pump, the probe signal can be propagated and the light switch will be on, so it can be stated that the light pump is in full control of the signal light emission modes. So far, various mechanisms have been proposed for switching all-optical photon crystals, including the photon band gap displacement mechanism, the defect mode displacement mechanism, and so on.

Design of optical switch based on nano-photon crystal intensifier

Today, with the advancement of technology, scientists are looking for solutions to make fully optical devices for use in integrated optical circuits. One of the options in this field is to use photon crystals to design and manufacture optical devices. Photon crystals are structures whose refractive index changes intermittently. The most important effect of rotation in photon crystals is the presence of frequency continuous regions in which it is not possible to propagate waves in the structure, which are called photon band gaps. This special feature of photon crystal structures is used to design photon crystal-based optical devices. To propagate light in the structures of photon crystals, defects in the structure are used, which can be divided into several categories, including: point defects, linear defects and annular intensifiers. Today, various optical devices use and design and fabricate these special properties of photon crystals. These devices include optical dimmers, optical filters, optical sensors, optical splitters, optical switches, optical logic gates, optical modulators and dimmulators, and optical converters. Optical switches are important devices designed by photon crystals and are widely used in other optical devices. In optical switches based on photon crystals, the resonator is usually placed between two waveguides, which are responsible for separating the light. The operation of the switch is such that light enters the structure from the inputs of the waveguides and is coupled to the resonator by the waveguide.

Depending on the specific design of the resonator, the light coupled into the resonator sends the desired wavelength into one of the waveguides and exits one of the outputs. So far, various amplifiers have been designed for use in these optical structures, and a photon crystal-based optical switch has been designed using a unique, newly modified nano-amplifier

In this design, first the structure parameters and the photon band gap extraction of the structure are presented and then the simulated optical structure based on the type of direct or inverse resonance is simulate. Parameters affecting the results of the structure such as the intensity of incoming light power, constant size of the network, the size of the radius of the dielectric rods and nano-amplifiers have been investigated to finally achieve the optimal structure for the intended applications.

In this design, PWE method is used to extract the photon band gap and FDTD method is used to simulate the structure, which are comprehensive methods for designing and simulating structures with this type of design [1].

Conclusion :

The need to increase data transmission speeds in telecommunication systems has dramatically increased the demand for signal processing using light. It is predicted that in the future, the current digital electronics will not be able to meet these demands. Therefore, in recent years, methods of processing and transmitting signals in all optical form has attracted the attention of many scientists. One of the most suitable structures to accomplish this is photon crystal-based optical devices, which have received much attention in recent years. Photon crystals can have a variety of applications, including optical waveguides, optical cavities and filaments, optical switches and gates, optical filters, and optical dimmers of photon crystals and photon crystal lasers, as they provide control over how light is emitted. One of the most important and interesting users of photon crystals is their use in optical communications, which uses the unique feature of photon crystals, ie full reflection of light when the frequency of light is in the range of the photon gap, and therefore the amount of losses in the fiber sheath is reduced. Findings and nonlinear effects are greatly reduced. In the construction of optical waveguides, which are one of the most important elements of optical devices, photon crystals are used, which will significantly reduce the reflection and loss of waveguides in extreme curvatures, especially when coupled to resonant cavities. Also, in the photonic gap, the density of states is zero, and naturally the rate of spontaneous emission will also be zero. This feature of photon crystals is used in the construction of semiconductor lasers with very low threshold currents. Thus, photon crystals provide the perfect basis for building integrated photon circuits, chips, and other photon devices.

In addition, research in the field of new optical phenomena and emerging devices based on photon crystals will lead to the construction and realization of optical systems, optical interconnection networks and ultra-fast processing systems in the future.

In addition to the above, referring to the use of photon crystals is one of the main applications of photon crystals in the design of logic gates and all-optical switching devices. These all-optical structures have unique features such as high speed, high security, low noise, compression and low power consumption compared to conventional devices. Due to the fact that in these devices, the movement of electrons is not used in data transmission and light is used for this purpose, the speed of information transfer and analysis of optical signals will be greatly increased. Hence, much attention has been paid to them in the field of optical computing and signal processing.

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