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Photonic Crystal Based Structure for Enhanced Performance of Large Scale Optical Integrated Circuits

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***Abstract-* The photonic integrated circuits have emerged as one of the promising technologies to cope with the challenges in high performance of multi functional optical communication based telecommunication systems. The vital factor for performance of photonic integrated circuits is substrate material used for the design. In this paper we have analyzed the effect of the materials that may be exploited as substrate for designing both passive and active components for highly integrated optical circuits with enhanced performance.**

***Keywords* – Photonic crystal, optical IC, IC, Lithium Niobate, gallium arsenide**

I. INTRODUCTION

The evolution of optical fiber communication system to clinch the demand of higher bandwidth, speed and throughput in communication system, has witnessed several modification and evolution of many areas. The electrical system which existed was to cope up with the optical technology. The existing technology faced the speed constraints due to optical to electrical and electrical to optical conversion. The speed limitations due to conversion from one domain to another domain had always motivated researchers to think on the concept of all optical signal processing. The exponential changes in processing power, lower cost per device, improved reliability, reduced space and power requirements, and enabled countless new devices for a wide range of applications in microelectronic based devices offered their own advantage to be used with optical signal played a major role to motivate researchers to think in the direction.

The semiconductor based optical devices like lasers, light emitting diodes (LED's) and amplifiers were also attracting scientists to work in direction of optoelectronic devices. The very large scale integrated was offering enhanced performance and speed with reduced area and power requirement. The concept of photonic integrated circuits with all optical signal processing emerged as one of the promising technologies to cope with the existing challenges.

The photonic integrated circuits integrate multiple optical components such as lasers, modulators, detectors, attenuators, multiplexers/de-multiplexers and optical amplifiers whereas electronic integrated circuits integrate many transistors and resistors.

The high speed advancements in fabrication technologies extend the scope for integrating large number of optical devices on a single platform. The electronic integrated circuits are available both as hybrid and monolithic, similarly optical integrated circuits can include both hybrid and monolithic integration. The hybrid photonic integrated circuits include many single function optical devices assembled in a package, with the associated electronic integrated circuits.

II. CHOICE OF SUBSTRATE MATERIAL

The photonic integrated circuits demands compact, wavelength scale structures with high index contrast for high functionality and enhanced performance [1].The choice of substrate material used is one of the vital factors for enhanced performance of photonic integrated circuits [2].The few commonly used materials are Indium Phosphide (InP), Gallium Arsenide (GaAs), Lithium Niobate ($LiNbO_3$), Silicon (Si), and Silica-on-Silicon, each having its own advantages and performance to offer.

Lithium Niobate offers very less promise to practically implement active opto-electronic components like lasers and detector thus is not widely used for the photonic integrated circuits. Gallium Arsenide is one of another promising candidate for designing active opto-electronic components but limits its application due to its intrinsic band gap small window of telecom operation. Silicon when used as a substrate material for photonic integrated circuits offers a platform for large scale integration of passive optical devices like arrayed waveguide gratings, switches and others. The silicon is the first choice as it offers integration for both optical and electrical and can be build using standard CMOS processes. Indium Phosphide offers integration of both active and passive optical devices operating in telecom windows thus seems to be the most promising candidate for integrated devices.

The waveguides are the key component of all optical circuits. The photonic integrated circuits demands ultra compact wavelength scaled waveguides. The very important intrinsic property of photonic crystals to control and manipulate light has attracted researchers and industry to design devices based on photonic crystal for large scale integrated circuits [3-4]. The single defect in the photonic crystals helps creating cavity based devices. These cavity based structures can be employed to implement devices for different applications [5]. The waveguides are created with the line defects [6]. The bends in the waveguides structures for guiding and trapping signals can also be created in the photonic crystal based structures.

III. DEVICE DESIGN

The line defects in photonic crystals create waveguides. The dielectric rods and air hole in dielectrics are two most commonly employed two dimensional photonic crystal structures. The proposed work in this paper explores two types of waveguides, one designed with defects in solid rods and another designed in air holes type structures. The structures are further modified as square and hexagonal lattice structures.

IV. SIMULATIONS AND RESULTS

The complete work presented in the paper investigates the effect of substrate material for design of photonic crystal based waveguides. The first design under investigation is a waveguide designed in hexagonal lattice at a constant lattice constant with circular rods. The design was simulated with input signal as continuous wave at wavelength 1.55 μm for transverse electric polarization. The power values was recorded and then plotted at a fixed point with different values of refractive index of different materials. The materials considered for investigation includes silicon, lithium niobate, silicon nitride, gallium nitride, gallium arsenide and indium phosphide. The fig.1 shows the plot of power at a fixed distance with different materials.

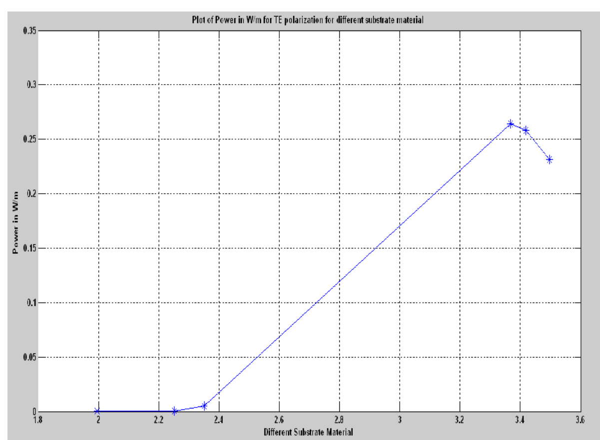

Fig.1 Plot of power for TE polarization for different material (rods type)

The second design under investigation is a waveguide designed in square lattice keeping lattice constant, radius and other parameters intact. The design was simulated with same input signal as continuous wave at wavelength 1.55 μm for transverse electric polarization. The fig.2 depicts the plot of power values at a fixed distance for different materials under investigation.

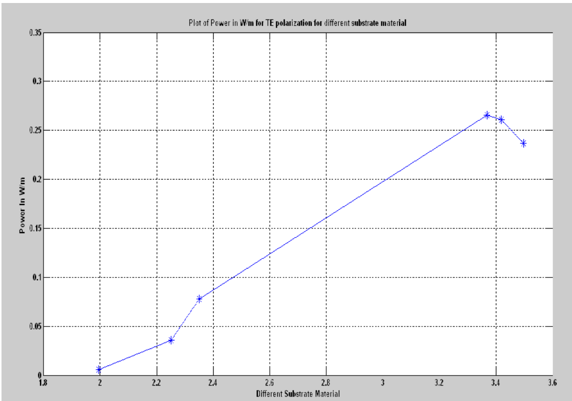

Fig.2 Plot of power for TE polarization for different material (rods type)

The waveguide designs with air holes with square and hexagonal lattice based structures were also investigated keeping all design and simulation parameters intact.

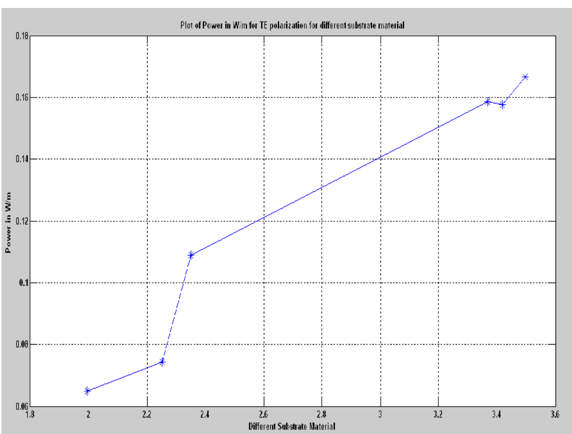

Fig.3 Plot of power for TE polarization for different material (air hole type)

The fig.3 depicts the plot of power for air hole type waveguides designed in hexagonal lattice type. Fig.4 below shows the plot of power for square lattice type design.

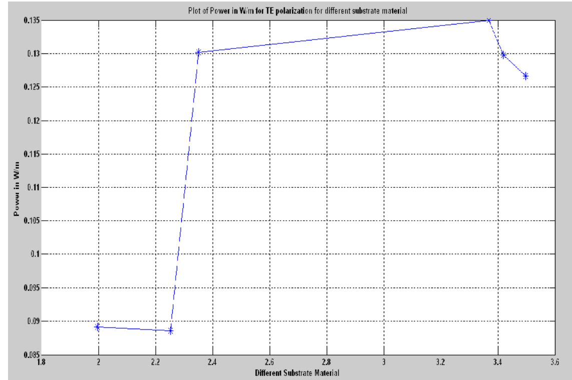

Fig.4 Plot of power for TE polarization for different material (air hole type)

V. CONCLUSION

The plots for the designs under investigation depicts that device designed with gallium arsenide and indium phosphide as materials results in better performance as compared to other materials under investigation.

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