REVIEW ON MODULATORS BASED ON III-V SEMICONDUCTORS
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ABSTRACT
Photonics is a field of science that focuses on understanding the basic properties of light, signal processing of light and understanding the concepts for generating and controlling the properties of light. An optical integrated circuit is a circuit containing a laser diode, functional components, interconnecting waveguides, and photodiode detectors on a single substrate to carry out a specific function. In this paper an effort has been made to review various existing papers related to various waveguides and materials which are suitable for modulator design which are existing and are in use.

KEYWORDS: Photonics, Waveguides, III-V Semiconductors, Modulators

I. INTRODUCTION
The role of light has a great impact in our lives today. Light is used everywhere and has a wide range of applications in various domains like telecommunication for data transmission, medical filed for image processing, transportation, entertainment, clothing, entertainment, etc. Light is nothing but a series of electromagnetic waves which behaves like a particle under certain circumstances. Photonics is a Greek word meaning light. Photonics is very closely related to optics and is similar to electronics. Photonics is said to advanced technology as it allows light to travel faster in an integrated chip than the electrons which are used in electronic chips. There is an exponential growth in the research activities in the field of photonics and optics over the years because of its wide range of applications and advantages in various domains. Integrated optics is a technology which aims at constructing an optical integrated circuit or photonic integrated circuits such as modulators, photo detectors, amplifiers, etc. An optical integrated circuit is a circuit containing a laser diode, functional components, interconnecting waveguides, and photodiode detectors on a single substrate to carry out a specific function. Optical integrated circuits were primarily used only for medical purposes, but later extended to other areas of applications. The waveguide is a structure that directs or guides the sound waves or electromagnetic waves with minimum loss in energy. Some of the common types of waveguides are rib, ridge, buried, slab waveguide, etc.

The selection of a proper waveguide structure and a proper material is important since it plays a prominent role in the circuit and it is also the main building block of an optical integrated circuit. Rib waveguide is the most commonly used waveguide for modulation purposes as it offers a higher bandwidth compared to other waveguides. A semiconductor is a material which has an electrical conductivity value between a conductor such as copper and an insulator such as glass. Silicon is the most widely used semiconductor and is cheaper compared to III-V semiconductors. A III-V semiconductor is an alloy which contains materials from groups III and V in periodic table. III-V semiconductors has advantages over silicon such as high speed switching at very low supply voltage and increased carrier mobility and are used for microwave and electro optic applications. Some of the common III-V semiconductors are gallium arsenide, indium nitride, gallium nitride, indium phosphide, indium arsenide, etc. Gallium Arsenide is currently the most widely used III-V semiconductor. Modulation is a process of varying properties of a periodic waveform which is called as carrier signal with a modulating signal which contains the information to be transmitted. A device which performs modulation is called as modulator. A Mach Zehnder interferometer is a device used to determine the relative phase shift variations between two beams derived by splitting light from a light source. It is sometimes called as Mach Zehnder modulator also. Typically a phase modulation is performed in a Mach Zehnder interferometer. A interferometer is made up of a particular waveguide through which light is passed.

II. LITERATURE SURVEY
Ali Cetin, Ercan Ucgun and M. Selami Kilickaya have proposed “Determining the refractive index of AIGaAs-GaAs slab waveguide based on Analytical and Finite Difference” [1]. In this paper effective refractive index of Aluminium Gallium Arsenide – Gallium Arsenide is calculated by using Finite difference method as well as theoretically. Appropriate effective refractive index values are also obtained with respect to number of matrix sizes.
and number of grid points. Finite Difference method allows the investigation of optical waveguides with their
dielectric cross sectional profiles without changing the geometries of the dielectric interfaces. They have considered
an optical slab waveguide. It was found that to propagate light effectively, the refractive index of the core layer
must be greater than substrate and top layer. Also it shows that finite difference method can be used as an
alternative method for symmetrical waveguide structures to calculate the effective refractive index.

R G Walker, M F O’Keefe, N Cameron, H Ereifej and T Brast have proposed “Gallium Arsenide Electro Optic
Modulators” [2]. In this paper effective refractive index of Aluminium Gallium Arsenide – Gallium Arsenide is
calculated by using Finite difference method as well as theoretically. Appropriate effective refractive index values
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finite difference method can be used as an alternative method for symmetrical waveguide structures to calculate the
effective refractive index.

Robert G Walker has proposed “High Speed III – V Semiconductor Intensity Modulators” [3]. This paper describes
about Gallium Arsenide – Aluminium Gallium Arsenide loaded line modulator. The bandwidth voltage figure is
increased in this method. An Aluminium Gallium Arsenide travelling wave design is explained which has the
highest figure of merit. In this design microwave and electro optic design considerations are largely decoupled and
evolution has been traced. Design Principles and capacitive loaded line has been explained. A review about progress
in the field of high efficiency and high speed using electro absorptive or electro optic effects. The design
principles of the capacitively loaded line approach have been explained.

M.M.Ismail, M.A.Meor Said, M.A.Othman, M.H.Misran, H.A.Sulaiman and F. A. Azmin have proposed “Buried
vs. Ridge Optical Waveguide Modeling For Light Trapping into Optical Fibre” [4]. This paper gives the
investigation on optical propagation characteristics of a straight waveguide on light intensity distribution within the
structure at 1.55 micrometer waveguide. In the integrated optical circuit, the design of ridge waveguide should
support low loss and strongly optical confinement for practical implementation. In Buried optical waveguide the
core width and the core thickness influence the value of effective index, normalized propagation constant and
electric field. The performance of Ridge waveguide will be affected by ridge width and core thickness. These
parameters will affect the effective refractive index and the normalized propagation constant. Buried type of
waveguide is suitable for integrated optical technologies like interferometers, switches, splitters and also as an optical
interconnects such as junction and bends. Ridge waveguide is widely used for modulators, switches, lasers and
semiconductor optical amplifiers.

Gnanakumar D and R K Jeyachitra have proposed “Design and Performance Analysis of Nonlinear Photonic
Crystal based THz Modulator for Ultra-High Speed Communication” [5]. This paper tells about Terahertz wireless
over fibre which is an emerging technology for ultra high speed communication. The Terahertz modulator is
designed and analyzed using Finite Difference Time Domain technique. Simulation results showed that Gallium
Arsenide material based Terahertz modulator has optimum results when compared to Polyaniline material based
Terahertz modulator. It showed high extinction ratio, low insertion loss and large modulation rate for Gallium
Arsenide material based Terahertz modulator when compared to Polyaniline material based Terahertz modulator.

Wei Liu, Richard S. Kim, Baolai Liang, Diana L. Huffaker and Harold R. Fetterman have proposed “High – Speed
InAs Quantum – Dot Electrooptic Phase Modulators” [6]. This paper reports the results of direct current and radio
frequency characteristics of self assembled Indium Arsenide quantum dot electrooptic modulators. Quantum dot
modulator wafers were by molecular beam epitaxy and phase modulator devices were fabricated with coplanar
travelling wave electrodes. Semiconductor quantum dot materials have gained a lot of interest for making of
electrooptic modulators because of their high electrooptic coefficient. High electrooptic coefficient capability can
lead to devices with high speed operations and low driving voltages. Results show that by making the device longer
with a pulse – pull drive, half wave voltage can be significantly reduced.

Hiroshi Nishihara, Masamitsu Haruna, Toshiaki Suhara have proposed “Chapter 26 – Optical Integrated Circuits”
[7]. This paper presents details on rib waveguide structure, its design and fabrication methods. Different types of
waveguides are studied to understand the structure, layering in waveguide with difference in refractive indices, light propagation and transmission. A broad classification is made between 2D and 3D waveguides. It also presents description on different waveguide materials and their fabrication. Periodic structures or gratings in waveguide are one of the most important elements for Optical Integrated Circuits, since they perform various passive functions and provide effective means of guided - wave control. 9 passive grating components for OICs are defined. Various coupling methods to achieve grating are mentioned and efficiency is given for each. Concept of Brillouin Diagrams is explained. The paper also presents brief description on passive optical devices. It also spreads light on functional waveguide devices.

Abu Sahmah Mohd. Supa‘at and Abu bakar Mohammad have proposed “Modelling Techniques For Rectangular Dielectric Waveguides – Ribs Waveguides” [8]. In this paper, analysis of optical propagation in dielectric waveguides using the semi analytical effective index method and a numerical method based on finite difference approach has been done. These methods are applied to the ribs waveguide. Rectangular waveguides has been known as a basic device structure in integrated optics. The results show that the effective index method is usually accurate particularly when the waveguide as an aspect ratio far from unity. Also near the cut off the effective index method will tend to give a slight overestimate for the value of the propagation constant. The mesh size determines the accuracy of the field and propagation constant. Larger the mesh size, the less valid is the approximation of the finite difference equation to the wave equation.

Robert G Walker, Nigel I Cameron, Yi Zhou and Stephen J Clements have proposed “Optimized Gallium Arsenide Modulators for Advanced Modulation Formats” [9]. A review of the guided wave subcomponents required in the design of high functionality modulators for advanced modulation formats using the Gallium Arsenide/Aluminium Gallium Arsenide material system. In these complex devices, small loss contributions increase rapidly and accumulate until the substructure are well optimised, not only for low loss but also for process tolerance. These modulation formats have benefits of environmental stability and ruggedness as well as excellent electro optic bandwidth and flatness with low drive power and compactness.

Balpreeth Singh Ahluwalia, Oystein Ivar Helle and Olav Gaute Helleso have proposed “Rib waveguides for trapping and transport of particles” [10]. This paper investigates the rib waveguides as an alternative to strip waveguides for planar trapping and transport of particles. Micro particles are successfully propelled along the surface of the rib waveguides and trapped in the gap between the opposing rib waveguides. Particles can be trapped in wider gaps formed by the opposing rib waveguides than with the strip waveguides. Rib waveguides were found out more efficient in trapping a collection of particles in the gap and these particles could be moved to different locations in the gap by changing the relative power in the two opposing rib waveguides. They did various numerical simulations to show that the trapping efficiency on the surface of the rib and the strip waveguides is comparable. The simulations performed also show the advantage of opposing rib waveguides for trapping particles in wide gaps.

A.D. Ferguson, A Kuver, J. M. Heaton, Y. Zhou, C.M. Snowden and S. Lezekiel have proposed “Low-loss, single mode GaAs/AlGaAs waveguides with large core thickness” [11]. This paper shows a design of a Low-loss, single-mode waveguides with a large core thickness in gallium arsenide/aluminium gallium arsenide waveguides. They have used detailed beam propagation method simulations to investigate the modal properties of the waveguides and have compared with measured results. It proved that it is very important that the waveguide should have as great an etch depth as possible before the guide becomes a multimode waveguide. This ensures that the mode is as tightly confined which improves the coupling efficiency to conical lensed fibre and to cleaved single-mode fibre. Also this work has demonstrated that the method used to achieve thick core Si/SiO2 single-mode waveguides is also valid for thick core GaAs/AlGaAs waveguides.

Feng Qiu and Shiyoshi Yokoyama have proposed “Electro-optic Modulators Further than 100 Gbps” [12]. This paper explains fact that the continuing explosive growth of the internet, wireless connection of many forms and digital storage technology is creating a growing need for compact, high performance, low power consumption and low cost electro-optic modulators. They have designed ultra high speed electro-optic modulators based on the self-deployed organic materials and unique designed optical waveguides. In order to enhance the EO activity, they have designed a nano meter dimensional high refractive index core and EO polymer cladding derived rib waveguide. The selected nano meter dimensional waveguide core is not only able to confine a large fraction of light into the relatively low refractive index EO polymer layer but also to increase the poling efficiency.

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III. CONCLUSION

In this paper an effort has been made to review various existing papers related to various waveguides, III-V semiconductors and its effect on various modulators which are existing and are in use. This preliminary work is useful and is necessary in order to continue any work on mach zehnder interferometer. Here an overview of papers related to what a waveguide is and their classification, advantages and disadvantages, various III-V semiconductors and how it plays a major role in modulation based on different applications is presented.

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IV. REFERENCES