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Extended Abstract

Manipulation of Light Through Inas Photonic Waveguide for Investigation of Pressure

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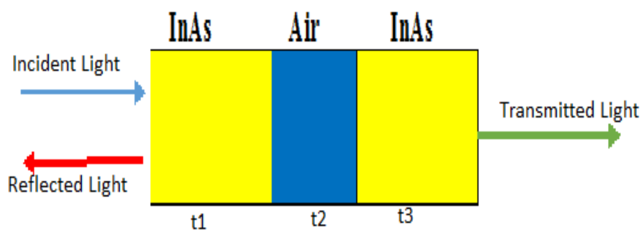
Abstract

The influence of pressure on a semiconductor (InAs) based 1-D photonic waveguide structure is thoroughly explored in the present communication at wavelength of 1550 nm. Here, effect of pressure is theoretically cogitated in reference to diffraction loss and reflected intensity for computation of transmitted intensity at the aforementioned waveguide. Reflectance from the said structure is computed through band gap analysis by employing finite difference time domain (FDTD) techniques, whereas diffraction loss is computed through numerical formulations. Simulation upshots revealed linear variation of diffraction efficiency as well as reflected intensity with respect to variation of pressure from 1GPa to 5Gpa. Apart from this, it is also revealed that transmitted intensity increases with increase in pressure, and nicely follows the linear trend line (R2=0.9951), which claims an excellent analysis of pressure in the proposed semiconductor based photonic waveguide.

Introduction

Over the last few decades group III-IV compound semiconductors have come up as excellent candidate in design of modern optoelectronic devices owing to their extraordinary optical properties like high mobility, low generation of noise and high breakdown voltage. Further, Indium Arsenide (InAs) that belongs to the above said group of materials, delivers some unique direct band gap characteristics, which finds wide spread applications in design of various efficient photonic devices such as high speed transistors, infrared detectors, photochemical sensors, solar cells etc. Furthermore, optical properties of such material leads to successful investigation of band gap.As far as literature survey is concerned, a healthy numbers on researches are already performed on semiconductor waveguide. In reference, authors demonstrated cascaded laser designed on InAs substrate under high current and low threshold voltage condition. Similarly, in referenc, author discloses transmission and reflected spectrum of both doped and undopedInAs grown on a GaAs substrate in infrared region, whereas in reference, authors have clearly elaborated the dependency of temperature on photoluminescence in InAs semiconductor grown on GaAs substrate. Again few papers deal with sensing applications by using photonic waveguide structure like reference, exposed the impurity concentration in chalcogenide glass by employing plane wave expansion technique, whereas reference includes the analysis of polymer based optical waveguide with respect to temperature. Again in reference, author represented numerous losses in semiconductor waveguide with respect to different sensing parameters like temperature, porosity, concentration etc. for realising efficient photonic integrated circuit. Moreover, pressure is a controlling parameter to uncover numerous optical properties of semiconductor material as these optical properties changes when the said compound semiconductor material is placed under pressure. Hence, keeping the importance of pressure on optical properties of photonic waveguide in mind, this communication deals with detail theoretical analysis of InAs based semiconductor waveguide under high pressure from 1GPa to 5GPa. Here, transmitted intensity at different pressure (1GPa to 5GPa) is computed through reflectance and diffraction loss by incorporating finite difference time domain technique, which can be efficiently used as pressure sensor in photonic integrated circuit.

Structural Analysis



To envisage the effect of pressure, we have considered a 1-D semiconductor (InAs) based waveguide structure, which is depicted in figure1. The aforementioned waveguide comprises two layers of InAs compound semiconductor layer having thickness of 700nm each and one layer of air having thickness of 300 nm. The principal reason for choosing the above said thicknesses is to mitigate different losses like diffraction and reflection loss which encounter serious problems during light transmission through the waveguide.Refractive index variation is obtained under different pressure from reference, which is depicted in table1.

Material	Pressure (GPa)	Refractive Index
InAs	0	4.61
	1	4.36
	2	4.18
	3	3.93
	4	3.82
	5	3.77

Table1: Refractive index information for different pressures.

Here, reflected intensity is computed through band gap analysis by deploying finite difference time domain approach. After calculation of reflectance, diffraction loss is anticipated as expressed below,

$$D_{loss} = 1-\sin^2(\pi dn/\lambda)$$

After that, transmitted intensity is figured out for wide range of pressure variation by considering diffraction loss, reflected intensity and absorption coefficient through simple numerical formulations, which is given as,

$$I_T = I_O\,(1-R)\,e^{-\beta t}$$

Where, I_T is transmitted intensity, I_0 is incident light intensity, R

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be the reflectance, β represents the absorption coefficient and t reflects the thickness of said waveguide.

Results Discussions

Simulation is carried out with the help of finite difference time domain (FDTD) technique for analysis of dispersion relation of the proposed waveguide structure to compute reflected intensity. The dispersion relation indicates the variation of frequency with respect to wave vector, which can be altered by controlling different parameters such as refractive index of the material, no. of grating layers, width and thickness of the photonic waveguide. From simulation point of view, thickness of odd layers (InAs) is taken to be 700 nm and thickness of even layer (air) is chosen to be 300 nm, whereas width is taken as 10nm. Aside this, refractive index of InAs semiconductor material for different pressure is acquired from reference[], and the same is enumerated in table1. Upon referring different data listed in table1, simulation is carried out for analysis of dispersion relation between frequency and wave vector with reference to different pressure (0 GPa to 5 GPa) by deploying FDTD technique. Simulation outcome for 0 GPa pressure is shown in figure 2, whereas simulation results for other values of pressure is not shown in this article.

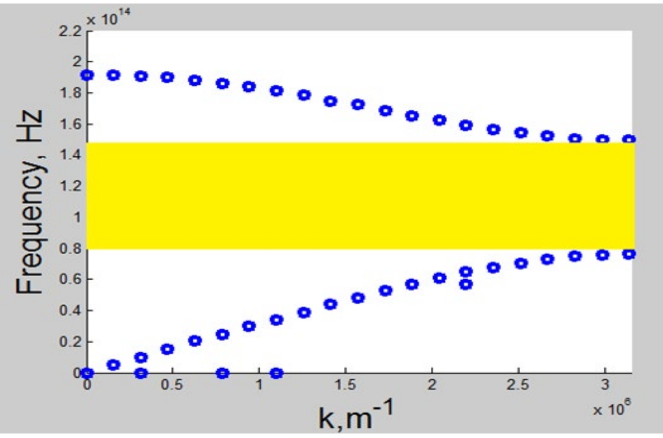

Figure 2: Dispersion relation of frequency with wave vector at zero GPa pressure.

In figure 2, frequency in Hz is plotted in the vertical axis whereas wave vector in m-1 is taken in the horizontal axis. The frequency gap highlighted with yellow colour in the figure, signifies the prohibited frequency range in the proposed photonic structure. By using this reflected frequency band, intensity of reflected light is calculated for different values of pressures which ranges from 0 GPa to 5 GPa. Again, it is also observed that, absorption in the proposed structure is zero as InAs has zero absorption coefficient.

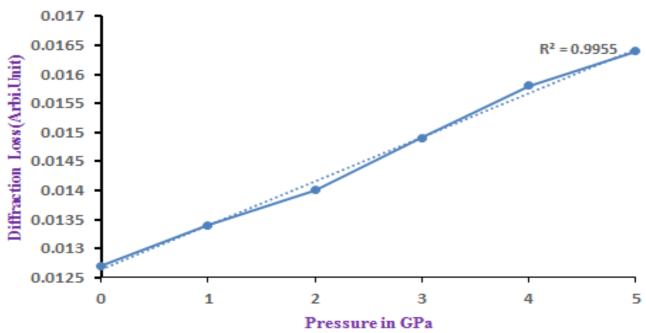

Figure 3: Variation of diffraction loss with respect to pressure

After calculating reflected intensity, we move on to compute diffraction loss and transmitted intensity for aforementioned pressures from the proposed structure by employing simple numerical equations. Figure 3, portrays the variation of diffraction loss with reference to different pressures at 1550 nm. Here, diffraction loss (Arbi.Unit) is plotted along vertical axis whereas pressure (GPa) is taken in horizontal axis. From the above figure, it is perceived that diffraction loss increases from 0.0127 to 0.0164 with increase in pressure from 0GPa to 5GPa. Also, it is seen that diffraction loss varies with pressure in excellent linearship (R2=0.9955) which leads to accurate analysis of pressure in the suggested structure.

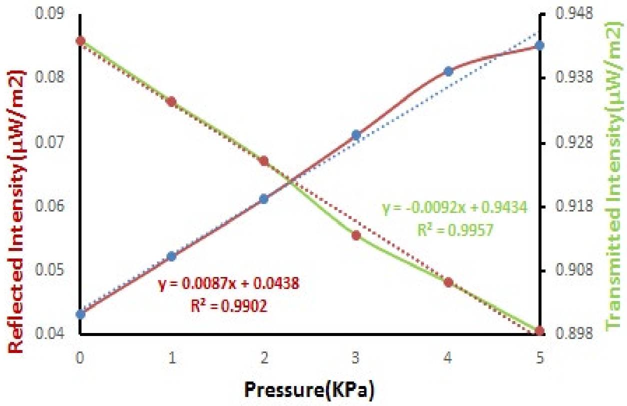

Figure 4: Variation of transmitted light intensity and reflected light intensity with Pressure

Furthermore, variation of reflected intensity as well as transmitted intensity with change in pressure is epitomized in figure 4. From this figure it can be clearly perceived that, reflected intensity rises from 0.0433µW/m2 to 0.0851 µW/m2whereas transmitted signal intensity falls from 0.9440µW/m2 to 0.8985µW/m2, upon variation of pressure from 0GPa to 5 GPa. From the above stated result, it is declared that the proposed photonic waveguide shows excellent upshot (i.e. minimum diffraction loss and minimum reflected intensity) at zero GPa pressure, hence delivers maximum transmitted intensity at the aforementioned pressure. Apart from this, it is also realised that variation of both reflected intensity as well as transmitted intensity follow the linear trend line (R2=0.9951for reflected intensity and R2=0.9949 for transmitted intensity), which infers precise sensing of pressure in the proposed InAs based photonic waveguide structure.

Conclusions

Present research deals with accurate realization of pressure in semiconductor (InAs) based photonic waveguide through FDTD approach. Here, transmitted intensity is cogitated by means of diffraction efficiency and reflected intensity under high pressure which ranges from 0 GPa to 5 GPa. Simulation outcomes infers that maximum transmitted intensity is achieved at zero GPa through the proposed waveguide. Again, it is divulged that variation of diffraction loss, reflected light intensity as well as transmitted light intensity follow the linear trend line, which claim the proposed structure as a suitable candidate for accurate pressure sensor in photonic integrated circuit.

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