WAVEGUIDE GRATING USING QUANTUM WELL INTERMIXING

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ABSTRACT

In this paper, a design of waveguide Bragg grating suitable for CWDM application is presented. The grating structure is generated by using fluorine ion implantation and anneal induced quantum well intermixing. Coupled mode theory and perturbation analysis has been used to model the grating and diffusion equations and Schrödinger wave equations are used to model the QW energy while interdiffusing thus giving the absorption coefficient to calculate the refractive index. The proposed device processing is similar to those used in nominal microelectronics processing. A channel bandwidth of 13nm and cross-talk in between -5dB to -10dB is obtained.

Keywords: Quantum well intermixing, ion implantation waveguide grating

1. INTRODUCTION

The semiconductor industry is currently interested in integrating various optoelectronic devices, such as lasers, modulators and detectors, within a single semiconductor structure. This initiative is motivated by the increasing demand of optoelectronic technology particularly in optical telecommunications. Integration of discrete passive and active optoelectronics devices on a single chip brings numerous benefits in terms of reduced packaging cost, low power consumption, improved thermal and mechanical stability, high component density, and high functionality. In recent years Quantum Well Intermixing (QWI) [1] is heavily investigated because it offers an important advantage of post-growth modification of refractive index through modification of the energy band structure, which makes it, a very attractive technique for optoelectronic integration. QWI uses a Rapid Thermal Annealing (RTA) process, to provide controlled diffusion of defects into the quantum well structure of an optoelectronic device. These defects are usually provided by a layer or layers of specially grown material that are grown above the quantum well structure. Under the influence of the RTA process, the defects diffuse down into the quantum well structure and introduce changes to the bandgap properties.

QWI can be achieved by different techniques like Impurity induced intermixing (III) [2], impurity free vacancy diffusion [3], laser induced intermixing [4], and photoabsorption induced disordering. Different QWI based devices have been proposed and demonstrated [5]. The impurity induced QWI (II-QWI) technique used here, involves impurity implantation and subsequent anneal, and is better suited for device design suitable for devices that are not close to the surface. Different dopant impurities such as Silicon (Si) and Zinc (Zn) give rise to free carrier losses in optical devices and hence they are not suitable. It is expected that the free carrier absorption will be small and can be neglected as F is a neutral impurity. This assumes the fact that the anneal process is done properly and at least 70% of the defects are annealed out. As the difference between the operation of 1550 and the bandedge is >500meV, thus the bandedge effects are neglected. Boron and fluorine (F) induced disordering of quantum well structures lattice matched to InP has also been investigated by Marsh et al. [6]. F implanted waveguides on InP lattice matched quantum well are also discussed in [7, 8]. It has also been observed that detrimental implantation damage can be cured under pulse anneal conditions [9].

QWI modifies the shape of Multi Quantum Wells (MQWs), which changes in the QW transition energies leading to a change in the MQW refractive index, and implanted F impurity is used for II-QWI and the resultant change in the refractive index leads to the formation of the waveguide gratings.

Periodic structures with index corruation along optical waveguides are widely used in fiber and integrated optic devices and circuits [10]. Contrapropagating wave are coupled by grating structures, and interference between the forward and backward waves leads to a variety of spectral and spatial patterns. The applications of Bragg gratings in integrated optics have been utilized in a wide range of structures such as input/output couplers [11], wavelength filtering [12], and external cavity laser and in switch structures [13]. The integration of a grating and a waveguide cannot normally be achieved by the same lithography steps. First order gratings which show larger wavelength discrimination, however are not realizable by simple photolithography is limited to e-beam or optical interference lithography, and processing steps are equally difficult owing to the need for a re-growth process for gratings embedded in a waveguide. Fourth order grating wavelength discrimination is not good enough for dense wavelength division multiplexing, however they could be useful for Coarse Wavelength Division Multiplexing (CWDM), where the wavelength discrimination is less stringent (20 nm). If the grating dimensions are realizable by simple
photolithography and ion implantation, which is compatible to those used in the microelectronics industry, one could use this technique to fabricate a grating using II-QWI, unlike the focused ion beam techniques [14]. This paper reports a design of a waveguide grating for four channels in CWDM range. Coupled mode theory for grating and the perturbation analysis is used to calculate the reflection coefficient produced by the QWI. This requires prior calculations of the refractive index of bulk layers and that of the impurity induced MQW layer for different values of operational wavelengths. For the impurity induced MQWs it includes first, a calculation of the interdiffusion profile of the In and Ga species, followed by solving both the diffusion equation and Schrödinger wave equation’s on a region containing quantum well. Finally, the dielectric constant is calculated to obtain the MQW refractive index at an operating wavelength. Atomic interdiffusion between the well and barrier atoms leads to changes in the shape of the quantum well. This modification in shape gives rise to changes in the absorption coefficient, refractive index and band gap.

2. DEVICE DESIGN AND CHARACTERIZATION

The proposed geometry as shown in Figure 1, consist of five layers structure on InP substrate, with a layer of n⁺ InP, a layer of undoped InP and a layer of n⁻ InP, a layer of undoped InP acting as upper and lower cladding layers respectively. The guiding layer is formed by (15 nm) In₀.₉₅Ga₀.₀₅As₀.₁P₀.₉/ (15nm) InP MQWs. In the design, the refractive index of the bulk materials is determined by using Sellmeier formula, followed by calculation of refractive index of the MQW layers with and without Fluorine implantation from the energy band structure in conduction and valance bands, including the effect of strain. Then the thickness of layers has been calculated in such a way that only fundamental mode is supported. Latter on grating parameters were optimized to obtain maximum reflectivity.

2.1 Refractive Index Calculation

The bulk refractive index of InP sample with doping level \( N = 5 \times 10^{16} \text{cm}^{-3} \) for wavelengths in the range 0.9-2\( \mu \)m has been obtained using Sellmeier formula (accuracy level ~ 7\( \times 10^{-3} \)) [15]

\[
n^2 = 7.255 + \frac{2.316 \lambda^2}{\lambda^2 - 0.392 \times 10^6} \tag{1}
\]

The refractive index of the substrate ( \( N = 2 \times 10^{18} \text{cm}^{-3} \) doped InP.) is given as

\[
n^2_s = 7.194 + \frac{2.282 \lambda^2}{\lambda^2 - 0.422 \times 10^6} \tag{2}
\]

The intrinsic InP refractive index \( n_g \) is given as

\[
n^2_g = 7.283 + \frac{2.333 \lambda^2}{\lambda^2 - 0.387 \times 10^6} \tag{3}
\]

where \( \lambda \) is in nm.
Using the equations from (1) to (3) the plot of the refractive indices of the bulk materials is shown in Figure 2. For MQW, the overall procedure is much more involved and the accuracy of this procedure is vital for device response which is very sensitive to variation in the refractive index of the guiding layer. Due to intermixing, the shape of quantum wells change. The Schrödinger equation has to be numerically solved to calculate the quantum well energies and from which the refractive index can be obtained through the dielectric constant calculation. The F-implantation enhances interdiffusion changes the shape of the QWs and their energy band-structure. As this is a limited source diffusion process and can be represented as Gaussian diffusion profile

$$N(z,t) = \frac{Q \exp\left(-\frac{z^2}{4Dt}\right)}{\sqrt{\pi Dt}}$$

(4)

where $D$ is the diffusion constant, $Q$ is the surface concentration of the species and $t$ is the anneal time. Since the diffusion occurs as a result of random motion of the particles and these are always thermally activated, the diffusion coefficient is therefore a very strong function of temperature ($T$) and time ($t$). The relation is given as

$$D = D_o \exp\left(\frac{-E_a}{kT}\right)$$

(5)

where, $D_o$ is a constant and $E_a$ is the activation energy. In F induced interdiffusion, the constant $D_{o,F}$ is somewhat dependent on F concentration whereas $D_{o,in}$ is constant as observed earlier by others.

Material parameters including lattice constants, effective masses of electrons and energy band gap is calculated using Vegard’s law [16]. The various material parameters used in the simulation are given in Table 1. The lattice mismatch between the different layers of the interdiffused structure is assumed to be accommodated by the built in elastic strain. The diffusion constants are assumed to be strain independent as their effects are small. However, the energy band modification due to strain has been considered. The complete QW structure is broken up into a number of slices for the analysis. The perturbation to the unstrained potential is calculated within each slice and hence the corresponding band potentials are modified accordingly. The energy eigen functions and the eigen values are obtained by solving the Schrödinger equation for the energy band profile obtained for the interdiffused QW. Finite difference method [17] is used to solve the Schrödinger equation and the boundary conditions are matched at the mesh boundaries. The one dimensional Schrödinger equation is given as

$$\frac{-\hbar^2}{2m^*} \frac{d^2}{dx^2} \psi(x) + V(x)\psi(x) = E\psi(x)$$

(6)

where $\psi$ is the wave function, $E$ is the energy, $V$ is the potential energy, $\hbar$ is the Planck’s constant and $m^*$ is the effective mass.

![Figure 3. Discretization of the potential using a non-uniform mesh](image)

In order to numerically solve the Schrödinger equation the structure has been discretized by using a three-point difference scheme as shown in Figure. 3.

$$\frac{-\hbar^2}{2} \left( \frac{1}{m^*} \frac{d^2}{dx^2} \right) \psi(x) + V(x)\psi(x) = E\psi(x)$$

(7)

The index $i$ identifies the grid point and the half integer index implies a point midway between the grid points on the one-dimensional mesh, $h_i$ being the mesh size between adjacent grid points $X_i$ and $X_{i+1}$. This may be cast in the form of a matrix equation as

$$\sum_{j=1}^{n} A_{ij} \psi_j = \lambda \psi_i$$

(8)
This gives a tri-diagonal matrix, which appears symmetrical only if the mesh spacing \( h_i \) is uniform. While the use of a non-uniform mesh size might be preferable for certain problems, this would destroy the symmetry of the matrix and hence obviate computational simplifications that result in the symmetry. Introducing a new parameter \( L_i \) where

\[
L_i = h_i + h_{i-1}/2
\]

the equation (8) becomes

\[
A_{ij} = \begin{cases} \frac{-h^2}{2m_{i+1/2}h_iL_i} & \text{if } j = i + 1, \\ \frac{-h^2}{2m_{i-1/2}h_iL_i} & \text{if } j = i - 1, \\ -A_{ii+1} - A_{ii-1} + V_i & \text{if } j = i, \\ 0 & \text{otherwise} \end{cases}
\]

and a new matrix \( B \) could be defined as \( B_{ij} = L_i^{-2}A_{ij} \), or in matrix notation,

\[
B = MA
\]

where \( M \) is a diagonal matrix whose elements are \( L_i^{-2} \). As matrix \( B \) is the product of a diagonal and tri-diagonal matrix, \( B \) is tri-diagonal. From (9) and (11) it can be shown that \( B \) is a symmetrical matrix \( B_{i,i+1} = B_{i+1,i} \). This provides the desired transformation that allow one to solve

\[
B\psi = MA\psi = \lambda M\psi
\]

The matrix \( M \) obtained from the above FDM method is diagonal may easily be expressed in the form

\[
M = LL
\]

where \( L \) is a diagonal matrix whose elements are \( L_i \). Using (11) it can be shown that

\[
L^{-1}BL^{-1}\psi = L^{-1}LL\psi = \lambda L^{-1}LL\psi
\]

Or

\[
H\Phi = \lambda \Phi
\]

where \( H = L^{-1}BL^{-1} \) and \( \psi = L^{-1}\Phi \)

The relations hold because \( B \) is symmetrical and \( L \) is diagonal. Therefore the matrix \( H \) is symmetrical and tri-diagonal. Eq. (14) is therefore the fundamental equation for finding the energy eigenvalues and wavefunctions (eigenfunctions) for electrons in conduction band, light holes and heavy holes in valance band respectively.

**Table 1. Material parameters used in the simulation**

<table>
<thead>
<tr>
<th>Parameters</th>
<th>GaAs</th>
<th>InAs</th>
<th>GaP</th>
<th>InP</th>
</tr>
</thead>
<tbody>
<tr>
<td>( E_g ) (eV)</td>
<td>1.4243</td>
<td>0.354</td>
<td>2.78</td>
<td>1.344</td>
</tr>
<tr>
<td>( a_0 ) (Å)</td>
<td>5.6533</td>
<td>6.0583</td>
<td>5.4512</td>
<td>5.8688</td>
</tr>
<tr>
<td>( m_0 )</td>
<td>0.067m_e</td>
<td>0.024m_e</td>
<td>0.0925m_e</td>
<td>0.079m_e</td>
</tr>
<tr>
<td>( m_{lh} )</td>
<td>0.076m_e</td>
<td>0.026m_e</td>
<td>0.14m_e</td>
<td>0.12m_e</td>
</tr>
<tr>
<td>( m_{hh} )</td>
<td>0.5m_0</td>
<td>0.35m_0</td>
<td>0.43m_0</td>
<td>0.56m_0</td>
</tr>
<tr>
<td>( C_{11} ) (dyne/cm²)</td>
<td>11.88 \times 10^{11}</td>
<td>8.329 \times 10^{11}</td>
<td>14.05 \times 10^{11}</td>
<td>10.11 \times 10^{11}</td>
</tr>
<tr>
<td>( C_{12} ) (dyne/cm²)</td>
<td>5.38</td>
<td>4.526</td>
<td>6.203</td>
<td>5.61</td>
</tr>
<tr>
<td>( a ) (eV)</td>
<td>2.7</td>
<td>2.5</td>
<td>3.0</td>
<td>2.9</td>
</tr>
<tr>
<td>( b ) (eV)</td>
<td>-1.7</td>
<td>-1.8</td>
<td>-1.4</td>
<td>-2.0</td>
</tr>
</tbody>
</table>
2.2 Calculation of Modal Profile and Reflection Coefficients

The Effective Index Method (EIM) is used to calculate the optical field profile of the proposed device structure. In EIM, Maxwell’s equations are solved in the multilayered structure, by making certain simplifying assumptions. The problem is reduced to an eigen value problem by using appropriate boundary conditions for magnetic and electric fields. Consider the following geometry of stacked multilayer structure. There are \( r \) layers along with substrate and cover, with thickness of \( i^{th} \) layer written as \( d_i \) and the refractive index as \( n_i \). The interface between layer \( i \) and \( i+1 \) layer is denoted as \( x_{i+1} \), as shown in Figure 4.

![Figure 4. A multilayer structure](image)

The method is presented here, is similar to Anemogainnis et al [18]. Here TE modes are only presented, but it can be easily extended to TM modes as well. Assuming a lossless propagation of a TE mode in \(+z\) direction, the electric field in the \( i^{th} \) layer is

\[
\hat{E}_i = \hat{y} E_i(x) \exp(j\omega t - j\beta z)
\]  

(15)

Similarly the magnetic field in the same layer is

\[
\hat{H}_i = \hat{x} H_{i0}(x) \exp(j\omega t - j\beta z)
\]  

(16)

where, the symbols have their usual meaning. The field components are related by Maxwell’s equations \( \nabla \times \hat{E}_i = -j\omega \mu \hat{H}_i \) and \( \nabla \times \hat{H}_i = j\omega \varepsilon_0 \hat{E}_i \) as

\[
\frac{d}{dx} \begin{pmatrix} E_{i0}(x) \\ \omega \mu H_{i0}(x) \end{pmatrix} = \begin{pmatrix} 0 & j \\ -jk_i^2 & 0 \end{pmatrix} \begin{pmatrix} E_{i0}(x) \\ \omega \mu H_{i0}(x) \end{pmatrix}
\]  

(17)

where \( \varepsilon_0 \) is the free space permittivity, \( \kappa_i = \pm \sqrt{k_0^2 n_i^2 - \beta^2} \) and \( k_0 = 2\pi / \lambda \) is the speed of light in freespace and \( \lambda_0 \) is the freespace wavelength. The solutions of (17) give the electric and magnetic fields within the \( i^{th} \) layer and as given by,

\[
E_{i0}(x) = A_i \exp[-j\kappa_i(x-x_i)] + B_i \exp[j\kappa_i(x-x_i)],
\]

and

\[
\omega \mu H_{i0}(x) = A_i \kappa_i \exp[-j\kappa_i(x-x_i)] - B_i \kappa_i \exp[j\kappa_i(x-x_i)]
\]

(18)

respectively.

Using the solutions of the above equations, the tangential fields at the bottom of the \( i^{th} \) layer \( (x = x_i) \) can be expressed as a function of the fields within that layer as

\[
\begin{pmatrix} E_{i0}(x) \\ \omega \mu H_{i0}(x) \end{pmatrix} = \begin{pmatrix} \cos[\kappa_i(x-x_i)] & \frac{j}{\kappa_i} \sin[\kappa_i(x-x_i)] \\ j\kappa_i \sin[\kappa_i(x-x_i)] & \cos[\kappa_i(x-x_i)] \end{pmatrix} \begin{pmatrix} E_{i0}(x) \\ \omega \mu H_{i0}(x) \end{pmatrix}
\]  

(19)
Using continuity of the tangential fields at any interface, the tangential fields in the cover layer and substrate layer are related via the matrix product

\[
\begin{pmatrix}
E_{s0} \\
o\mu_0 H_{s0}
\end{pmatrix} = M_1 M_2 \ldots M_r 
\begin{pmatrix}
E_{c0} \\
o\mu_0 H_{c0}
\end{pmatrix} = 
\begin{pmatrix}
m_{11} & m_{12} \\
m_{21} & m_{22}
\end{pmatrix} 
\begin{pmatrix}
E_{c0} \\
o\mu_0 H_{c0}
\end{pmatrix}
\]

where,

\[
M_i = \begin{pmatrix}
\cos(\kappa_i d) & j\sin(\kappa_i d) \\
j\kappa_i \sin(\kappa_i d) & \cos(\kappa_i d)
\end{pmatrix}
\]

for \( i = 1, \ldots, r \) \hspace{1cm} (20)

are the transfer matrices for \( r \)-layers. For propagating modes, the tangential fields at the boundaries must be exponentially decreasing,

\[
E_{s0}(x) = B_i \exp[-\beta_c (x-x_{si})] \quad \text{for } x > x_{si+1}
\]

\[
E_{s0}(x) = A_i \exp(\beta_i x) \quad \text{for } x < 0
\]

\[
o\mu_0 H_{c0}(x) = -j\beta_c B_i \exp[-\beta_c (x-x_{si})] \quad \text{for } x > x_{si+1}
\]

\[
o\mu_0 H_{s0}(x) = j\beta_i A_i \exp(\beta_i x) \quad \text{for } x < 0
\]

where \( \beta_i = \pm \sqrt{\beta_i^2 - k_y^2 n_s^2} \) and \( \beta_c = \pm \sqrt{\beta_c^2 - k_y^2 n_c^2} \).

Equation (19) with (21) gives the following dispersion equation

\[
F(\beta) = j(\beta, m_{11} + \beta, m_{22}) - m_{12} + j\beta, \beta, m_{12} = 0.
\]

(22)

Zeros of this equation gives the propagation constants \( \beta \). Back substituting these roots in (21) gives the modal profile. The electric field is then calculated with the expressions given in (21) taking into account the normalization of power.

The coupled mode theory [19] is used to calculate the coupling coefficient of the grating assisted interaction of the transverse and longitudinal field components. The two approximations being made here are, the electric field varies slowly over each layer and the optical wavelength is much larger than each layer’s thickness. The perturbation theory is used to derive the expression for the coupling coefficient (\( \kappa \)) of the guided wave grating device produced by \( F \)-ion implantation. The numerical value of \( \kappa \) depends on the shape, depth, and period of the grating. Moreover, the composition and the thickness of the active and upper cladding layers also affect it due to the transverse and lateral mode energy. The result of perturbation analysis, for TE modes is [19]

\[
\kappa = \frac{k_y}{2\beta N^2} \int A_n(x) E^2(x) dx
\]

(23)

where \( \kappa \) is the coupling coefficient , \( k_y = 2\pi/\lambda_y \) ( \( k_y \) is the free space wave vector), \( \beta \) is the TE-mode propagation constant, \( E^2 \) is the \( y \) component of the unperturbed electric field, \( A_n(x) \) is the \( m_{in} \) order Fourier coefficient of the refractive index perturbation which includes the lateral straggling due to \( F \) ion implantation and \( N^2 \) is the normalization constant given by

\[
N^2 = \int_{-\infty}^{\infty} E^2(x) dx.
\]

(24)

As the \( F \)-impurity is implanted from the external source, the diffusion process is a constant source diffusion process, which can be modeled by an error-function profile [20] as a good approximation. The exact diffusion parameters like lateral straggle etc. have to be calculated for the specific material and diffusion system by Monte Carlo simulations. These simulations were performed using TRIM software, which is based on the measured experimental data of various diffusion constants, and is a part of SRIM [21] (The Stopping and Range of Ions in Matter) software. The results of the Monte Carlo simulations have been plotted in Figure 5, for ion implantation energy of 125 KeV.
The coupling between the forward mode ($\beta_1$) and the reflected mode ($\beta_2$), neglecting interaction with any of the other modes, is described by the contradirectional coupled mode equations [18] which are given by

$$\frac{d}{dz} A_1 = -\kappa A_2 e^{i\Delta \beta z}$$  \hspace{1cm} (25)$$

$$\frac{d}{dz} A_2 = \kappa^* A_1 e^{-i\Delta \beta z}$$  \hspace{1cm} (26)$$

where $A_1$ and $A_2$ are the complex amplitudes of the normalized modes. Therefore, $|A_1|^2$ and $|A_2|^2$ represent the power flow in forward and reflected modes respectively. The net power flow in the $+z$ direction for the contradirectional case is $|A_1|^2 - |A_2|^2$. The coupled mode equations above need to be consistent with the conservation of energy, which requires that

$$\frac{d}{dz} \left( |A_1|^2 - |A_2|^2 \right) = 0$$  \hspace{1cm} (27)$$

Applying the boundary conditions for contradirectional coupling, $A_1 = A(0)$ at $z = 0$ and $A_2 = A_2(L)$ at $z = L$. We obtained the reflection coefficient as

$$R = \frac{|A_1|^2 \sinh^2 sL}{s^2 \cosh^2 sL + (\Delta \beta / 2)^2 \sinh^2 sL}$$  \hspace{1cm} (28)$$

where

$$s^2 = \kappa^* \kappa - \left( \frac{\Delta \beta}{2} \right)^2$$  \hspace{1cm} (29)$$

3. RESULTS AND DISCUSSION

In the design, first the refractive index of the bulk material is calculated followed by calculation of refractive index of MQW with and without F ion implantation, which is further used in designing the single mode waveguide using effective index method and then waveguide grating using coupled mode theory. The F implantation and dose is obtained from the SRIM simulations. For a chosen wavelength (CWDM Channel), 200 grating periods were assumed and the temperature varied till the grating reflection reaches 99% with the channel width of 13nm at the channel spacing of 20nm. The variation of Bragg reflection with respect to the anneal time at 800°C anneal temperature for wavelength of propagation 1610nm is given in Figure 6; other details of the technique are given in [22]. The electric field profile of the structure proposed is shown in Figure 7. The well-barrier widths and composition of the well for constant refractive index in the CWDM wavelength range (1270 nm to 1610 nm) is found after rigorous optimization which leads to the well width of 15 nm with a composition $In_{0.05}Ga_{0.95}As_{0.1}P_{0.9}$ is
good for the present structure. The various grating parameters i.e., duty cycle, number of grating periods, and perturbation in refractive index are optimized for the single mode waveguide grating. The parameter values $D_{a_{GaAs}} = 61 \times 10^{-4} \text{m}^2\text{s}^{-1}$, $D_{a_{InP}} = 1.8 \times 10^{-7} \text{m}^2\text{s}^{-1}$ [9] and $E_{a_{GaAs}} = 3.20 \text{eV}$, $E_{a_{InP}} = 2.38 \text{eV}$ [23] has been assumed. An F-impurity concentration of $10^{18} \text{cm}^{-3}$ suitable for a dose rate of $1 \times 10^{15} \text{cm}^{-2}$ at implantation energy ~125keV, has been used in this proposed structure for simulation. For ease of normal photolithography, the width of waveguide has been chosen to 2.0µm and rib height is 0.1 µm for single mode propagation only. The perturbation of 0.017 in the refractive index is achieved by annealing the implanted sample at 800°C for 15 seconds for the propagation of single mode only. The grating structure is simulated for four different wavelengths in the CWDM spectra from 1550 nm to 1610 nm at a space of 20 nm and the grating period obtained were 945 nm, 959 nm, 973 nm, and 985 nm at peak wavelengths of 1550 nm, 1570 nm, 1590 nm, and 1610 nm respectively keeping the number of grating periods constant and 50% duty cycle. The results were concatenated and shown in the Figure 8. A pass band of 13 nm has been achieved for CWDM. A -5dB to -10dB crosstalk is observed between the adjacent channels, the similar channel discrimination have been showed to work for DWDM [24].

4. CONCLUSIONS

An attempt has been made in this work to model a waveguide Bragg grating on InP, suitable for CWDM applications. The device design is based on the refractive index change due to F implanted impurity induced intermixing of a $\text{(15nm)} \text{In}_{0.95}\text{Ga}_{0.05}\text{As}_{0.1}\text{P}_{0.9} / \text{InP}$ nine period multi-quantum well waveguide. The refractive index change has been simulated starting from the basic QWI process and the respective changes in the band gap. Waveguide Bragg grating simulations have been done using the effective index methods. The required channel width for the spectra is obtained by optimizing the physical dimensions of the waveguide grating. A -5 dB to -10 dB crosstalk is observed between the adjacent channels. However this may not be detrimental for short haul networks where the power levels used are low.

Figure 6. The variation of Bragg reflection with anneal time at 800°C anneal temperature

Figure 7. The Electric Field profile of the proposed structure
Figure 8. Reflection Coefficient of Waveguide Bragg Gratings at various mask width in the range of 1550nm to 1610 nm

7. REFERENCES