Polarization-Insensitive Electroabsorptive Modulation Using Interdiffused InGaAs(P)–InP Quantum Wells

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***Abstract*—This is a theoretical study to demonstrate the use of interdiffusion in the realization of polarization insensitivity at the band-edge. Two InGaAs–InP quantum well as-grown structures have been investigated: one with lattice-matched condition and the other with small as-grown tensile strain (0.15%). The interdiffusion is considered to take place on the Group V (As and P) sublattice only. As a result, a tensile strain is produced which merges the heavy- and light-hole states in order to achieve polarization insensitivity. Criteria to develop polarization-insensitive quantum wells (QW's) using interdiffusion are presented here. When the two-phase interdiffusion mechanism is modeled, the results show that the well barrier interfaces of the QW maintain an abrupt profile while the well width remains constant after interdiffusion. The two interdiffused QW structures considered here can produce polarization insensitive electroabsorption at operation wavelengths around 1.55 μm. The one with lattice-matched condition is particularly attractive since it only requires an easy (high-yield) fabrication process with a simple postprocessing thermal annealing to achieve polarization insensitivity.**

***Index Terms*—Diffusion process, electrooptic modulation, optical polarization, quantum-confined Stark effect, quantum-well interdiffusion, quantum-well intermixing, quantum wells, strain layered material.**

I. Introduction

In THE realization of monolithic photonic integration, quantum wells (QW's) can provide a large absorption change for use in optical switching and modulation [1] and yet be able to integrate with lasers and detectors. However, these QW structures exhibit various drawbacks including a strong polarization dependence of the incoming optical fields (transverse electric (TE) and transverse magnetic (TM) polarization) [2]. Optical signals traveling a relatively long distance in optical fibers usually do not preserve the polarization of light, so that in an electroabsorption modulator, polarization dependence is undesirable. In order to remove this barrier, several polarization-independent or polarization-insensitive QW material systems have been proposed for electroabsorptive devices [3]–[8]. Among these QW's, there are basically three types of structures: quasi-parabolic QW structures [6], tensile strain QW structures [3]–[5], [8], and a combination of these two [7]. All of them can produce similar electroabsorptive changes for both TE and TM optical polarization of light. In this paper, we propose a fourth type which depends on the interdiffusion-induced tensile strain in the QW's.

Conventional polarization-insensitive InGaAs(P)–InP QW structures which operate at photon wavelengths of $\sim$1.55 μm, normally have as-grown well widths between 11 and 12 nm, with the as-grown tensile strains being $\sim$0.3% [4], [9]. We propose here the use of QW interdiffusion [10], in order to generate the tensile strain in an InGaAs(P)–InP QW structure required for obtaining polarization insensitivity. Since a large portion of the tensile strain is produced by interdiffusion, only a small strain is required in an as-grown QW with well width of 11 nm. More interestingly, the lattice-matched condition is sufficient for an as-grown QW with a well width of 12 nm prior to interdiffusion. The difficulties in growing highly strained as-grown QW's can thus be bypassed. In addition, by using such a simple and controllable interdiffusion technology, the operation wavelength of the modulator can be adjusted because of the modifiable QW bandgap energy through interdiffusion [11], [12]. All the above features make the interdiffused QW (DFQW) an attractive structure for developing polarization-insensitive modulators. It should be noted that the interdiffused InGaAs–InP QW material has already been studied in some detail [11], [13], [14] and it has been successfully realized in various optical devices, such as waveguides [12] and lasers [15].

In this paper, we will theoretically study the effects of interdiffusion of two InGaAs(P)–InP DFQW's on the electroabsorptive polarization insensitivity: one QW structure having a well width of 11 nm and 0.15% as-grown tensile strain, and the other one grown lattice-matched, with a 12-nm well width. In Section II, the model in obtaining the DFQW absorption coefficient is discussed. In Section III, the criteria and steps to achieve electroabsorptive polarization insensitivity are presented. Section IV presents the results which include discussions on the advantage of Group V only interdiffusion for the development of polarization insensitivity; proposals of the polarization insensitive electroabsorptive change of DFQW's with and without as-grown tensile strain in the well layer are also presented. In Section VI, conclusions will be drawn.

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II. Model of the DFQW Optical Parameters

In this section, the effect of interdiffusion on the subbands of the QW's are briefly discussed, which is followed by their corresponding absorption coefficient, $\alpha(\omega)$, and their change of absorption coefficient, $\Delta\alpha(\omega)$, induced by an externally applied electric field.

There are three types of interdiffusion processes in InGaAs–InP QWs: 1) Group III (In, Ga atoms) only interdiffusion [16]–[18]; 2) Group V (As, P) only interdiffusion [19], [20]; and 3) interdiffusion on both Group III and V sublattices [18], [21]. Only Group III interdiffusion induces compressive strain in the well and tensile strain in the barriers, while only Group V interdiffusion induces tensile strain in the well and compressive strain in the barriers. Interdiffusion on the two sublattices can induce either tensile or compressive strains in the well or it can maintain a lattice-matched structure. In order to induce a tensile strain large enough to realize polarization insensitivity, interdiffusion on the Group V sublattice only is used here. During the interdiffusion, not only is strain induced in the DFQW, but the fundamental transition energy also increases. This implies that the operation wavelength can be adjusted. One model which has been proposed for Group V only interdiffusion is a two-phase interdiffusion mechanism with different diffusion coefficients in the barrier and the well layers [20], [22]. This implies a "discontinuity" of the Group V concentration profile at the interface across the QW structure after interdiffusion. For a QW heterostructure, where the InGaAs well is sandwiched between two InP barriers, the interdiffusion process can be represented by a set of diffusion equations, respectively, for different species. This is defined as follows:

$$\frac{\partial C_i(z,t)}{\partial t} = D_i \frac{\partial^2 C_i(z,t)}{\partial z^2} \tag{1}$$

where z is the growth direction, t is the annealing time, the i subscript denotes the barrier for $|z| \geq L$ or the well for $|z| < L$. L is the position of the QW interface from the well center ($z = 0$); C and D are the concentration of the diffusion species, and their diffusion coefficients, respectively. In solving this partial differential equation, two continuity conditions must be satisfied at the well/barrier interfaces (i.e., $z = \pm L$), namely

$$C_{\text{barrier}}(t)\big|_{z=\pm L} = kC_{\text{well}}(t)\big|_{z=\pm L} \tag{2}$$

$$D_{\text{barrier}} \left.\frac{\partial C_{barrier}(t)}{\partial z}\right|_{z=\pm L} = D_{\text{well}} \left.\frac{\partial C_{\text{well}}(t)}{\partial z}\right|_{z=\pm L}. \tag{3}$$

Equation (2) models the discontinuous ($k \neq 1$) concentration at the interface while (3) expresses the flux continuity. Further details have been thoroughly discussed in [22]. Equation (1) is solved by using a finite difference method to obtain the concentration distribution of the diffused species after an annealing time t. This concentration ratio gives the spatial molar fraction (composition) of the interdiffused As concentration $\tilde{y}$ in the $\text{In}_{x_o}\text{Ga}_{1-x_o}\text{As}_{\tilde{y}}\text{P}_{1-\tilde{y}}$–InP QW structure. The notation x_o is the concentration of the In atoms (Group III composition) and since the interdiffusion only involves Group V composition, x_0 is a fixed constant. The induced tensile strain strongly depends on the extent of interdiffusion. It should be noted that in order to use an as-grown lattice-matched $\text{In}_x\text{Ga}_{1-x}\text{As}_y\text{P}_{1-y}$-InP system as a candidate to achieve polarization insensitivity, the relation $y = 2.2(1 - x)$ should be used for the as-grown condition [23]. The various stages of interdiffusion can be obtained by varying the annealing time and temperature, where the latter affects the diffusion coefficients.

The interdiffusion-induced quantum-confinement profiles and the electron and hole subband edges are calculated numerically [24]. The field effect is calculated according to a scheme developed by Bloss [25]. The subband envelope functions for the conduction band χ_C, valence band χ_V, and their transition energy E_{CV} are first calculated. These subbands are then used to calculate the heavy-hole (HH) and light-hole (LH) related $1S$ exciton bound states (binding energies and wavefunctions) by a perturbation variation method [26].

The bound states absorption coefficient is given as

$$\alpha_{\text{bound}}(\omega) = \frac{e^2 \mu_{\|}^* \omega}{6\varepsilon_0 c_0 n_r m_C^* E_{CV}^2 L_z} \cdot M_o \sum_{C,V} |\langle \chi_C | \chi_V \rangle|^2 I_{CV}(\hbar\omega) \tag{4a}$$

where

$$M_0 = \frac{E_g(E_g + \Delta_0)}{E_g + \frac{2}{3}\Delta_0} \tag{4b}$$

$$I_{CV}(\hbar\omega) = \int_0^\infty \wp(E) S(E) L(E)\, dE \tag{4c}$$

$|\langle \chi_C | \chi_V \rangle|^2$ is the probability of the wavefunction overlapping between the χ_C and the χ_V, ε_0 is the permittivity in free space, c_0 is the velocity of light in free space, n_r is the refractive index, e is electronic charge, m_c^* is the effective electron mass, and $\mu_{//}^*$ is the electron-hole reduced effective mass. In (4b), E_g is the interdiffusion modified bandgap at $z = 0$ and Δ_o is the diffused spin-orbit splitting gap. In (4c)

$$L(E) = \frac{\Gamma_B}{\pi\{[E_{CV} + E - \hbar\omega)^2 + \Gamma_B^2\}} \tag{4d}$$

$S(E)$ is the Sommerfield enhancement factor and is assumed to be unity, $L(E)$ is the Lorentzian broadening factor, and $\wp(E)$ is the polarization factor. For light propagating along the quantum layer, both the TE and TM polarizations exist and the polarization factors are given by $\wp^{\text{TE}} = \frac{3}{4}(1 + E_R)$ for HH, $\frac{5}{4}[1 - \frac{3}{5}E_R]$ for LH, $\wp^{\text{TM}} = \frac{3}{2}(1 - E_R)$ for HH, and $\frac{1}{2}(1+3E_R)$ for LH where $E_R = (E_C+E_H)/(E_C+E_H+E)$. In (4d), Γ_B is the bound state linewidth (half-width half-maximum) broadening factor, $E_{CV} = E_g + E_C + E_H$. The exciton absorption coefficient, $\alpha_{\text{exc}}(\omega)$, is given by

$$\alpha_{\text{exc}}(\omega) = \frac{A\omega}{c_0 n_r} |\chi(\rho = 0)|^2 \frac{\Gamma_{XB}}{\pi\{(E_{\text{exc}} - \hbar\omega)^2 + \Gamma_{XB}^2\}} \tag{5}$$

where

$$A = \frac{e^2\hbar^2}{3\varepsilon_0 m_C^* E_{CV}^2 L_z} M_0 |\langle \chi_{C1} | \chi_{V1} \rangle|^2 \wp$$

$$E_{\text{exc}} = E_{C1} + E_{H1} + E_g + E_b$$

is the excitonic transition energy and Γ_{XB} is the exciton linewidth (half-width half-maximum) broadening factor. For the $1S$ exciton, only $\rho = 0$ is allowed and hence $\wp^{\mathrm{TE}} = \frac{3}{2}$ (HH), $\frac{1}{2}$ (LH), and $\wp^{\mathrm{TM}} = 0$ (HH), 2 (LH). The total absorption coefficient $\alpha(\omega)$ is given by $\alpha(\omega) = \alpha_{\mathrm{bound}}(\omega) + \alpha_{\mathrm{exc}}(\omega)$. The change of absorption coefficient $\Delta\alpha(\omega)$ is obtained using

$$\Delta\alpha(\omega) = \alpha_{F\neq 0}(\omega) - \alpha_{F=0}(\omega). \tag{6}$$

The contrast ratio (CR) for an electroabsorptive modulator is defined as the relative optical intensity modulation and is given as

$$\mathrm{CR\ (dB)} = 10\log\left[\frac{\exp(-\alpha_{\mathrm{ON}}l)}{\exp(-\alpha_{\mathrm{OFF}}l)}\right], \tag{7}$$

where α_{ON} and α_{OFF} are the absorption in the on and off state, respectively, and l is the modulation length. Here, the optical confinement factor is assumed to be unity.

III. Criterion and Steps to Develop DFQW Polarization Insensitivity

The absorption coefficient of a conventional rectangular QW is polarization dependent. One of the reasons for this dependence is the splitting of HH and LH states at the band edge. In the following, we will present the criteria and develop the design steps to achieve polarization insensitivity by using Group V interdiffusion in InGaAs–InP QW's. To achieve the electroabsorptive polarization insensitivity, the first criterion is to generate an adequate amount of shear strain which can at least counterbalance the splitting of HH and LH states due to the quantum confinement [8], i.e.,

$$2E_s \leq E_{\mathrm{LH}} - E_{\mathrm{HH}} \tag{8}$$

where E_s is the shear deformation potential, and E_{LH} and E_{HH} are the heavy-hole and light-hole energy levels, respectively. E_s is multiplied by 2 because an approximately equivalent amount of shear strain influences both HH and LH while under the assumption that the spin-orbit splitting has a relatively small influence on the LH-related strain. Instead of using an as-grown InGaAs–InP QW with 0.3%–0.7% tensile strain [8], [9], we propose to use Group V interdiffusion to produce enough tensile strain such that (8) can be satisfied.

To maintain the DFQW active cavity under a coherent pseudomorphic condition is a crucial criterion in developing the polarization-insensitive modulators. During interdiffusion, the effective critical layer thickness of the DFQW continues to vary since the induced strain and the Group V compositions vary in the DFQW system. The QW may therefore degrade into a structure with dislocations. From our results, the maximum induced strain in the two DFQW structures considered here with well widths of 11 and 12 nm are 0.45% (after 0.4 h of 750°C annealing) and 0.32% (after 1 h of 750°C annealing), respectively. These DFQW's should be experimentally achievable without any dislocations since wider DFQW's with an as-grown well width of 20 nm (exceeding the critical thickness) and at longer annealing time (2 h) under the same annealing temperature have been produced [22].

There are various parameters that can modify the tensile strain in the InGaAs(P)–InP DFQW. The as-grown composition itself can generate tensile strain in the well layer. A reduction of the as-grown indium concentration from the $y = 2.2(1-x)$ condition in the well layer introduces tensile strain. After interdiffusion, the alloy concentration, the well width, diffusion temperature, and time all contribute to the resulting strain in the QW system. This tensile strain can merge the HH and LH states and result in polarization insensitivity. The higher the diffusion temperature and the longer the diffusion time producing the interdiffusion on the Group V sublattice, the larger is the tensile strain that results in the well.

The amount of as-grown P content in the well layer is crucial to the development of polarization-insensitive DFQW's. When an amount $(1-y)$ of P is added to the as-grown lattice-matched $In_xGa_{1-x}As_yP_{1-y}$–InP QW, the C–HH (first electron and first heavy hole) and C–LH (first electron and first light hole) transition energies increase (blue shift), and the splitting between the LH and HH also increases. Taking an as-grown lattice-matched QW with $L_z = 11$ nm as an example, when the P content in the well increases from 0–0.1 under lattice-matched conditions, C–HH (C–LH) blue shifts from 0.7958 (0.8166) to 0.8238 eV (0.8490 eV). At the same time, the energy difference between HH and LH states increases from 0.0209 to 0.0252 eV (difference of 4 meV). In Group V interdiffusion, since P diffuses from barrier to well and As diffuses from well to barrier, the transition energies increase as shown in Fig. 1. The longer the annealing time, the larger the transition energies. Since tensile strain in the well increases with annealing time, the difference of the transition energies (splitting of HH and LH) reduces. As annealing time reaches 0.4 h, HH and LH transition energies merge, hence polarization insensitivity is obtained. However, starting with an as-grown quaternary well (i.e., InGaAsP) creates two disadvantages for the interdiffusion to produce polarization insensitivity. The first one is that with the P content, the splitting between HH and LH increases, implying that larger tensile strains are required to bring back the LH and HH states together. Thus longer annealing time is required to generate stronger tensile strain. However, if a low initial as-grown tensile strain is introduced in an as-grown rectangular QW structure, only a small tensile strain is required to be produced from interdiffusion. The second disadvantage is that the increase of as-grown P content in the well will increase the transition energy of the as-grown QW structure, thereby reducing the adjustable range of transition energy by interdiffusion. This reduces the tuning ability of the DFQW to reach the target wavelength of 1.55 μm. Therefore, a material system with a small as-grown tensile strain in the InGaAs–InP QW without any as-grown P in the well is also considered here in addition to the lattice-matched QW.

Chronological design steps for achieving electroabsorptive polarization insensitivity can now be drawn. The first step is to remove the effect of splitting between the LH and HH states. This implies that appropriate diffusion temperature and diffusion time should be selected. The second step is to select

the concentration of indium and the well width of the as-grown QW structure in order to produce the operation wavelength within the range of 1.52–1.56 μm, which is of interest for current optical erbium-doped fiber amplifier technology. As a final step, it should be ensured that the DFQW structure remains coherently strained. These three steps are mutually related because the interdiffusion will reduce the operation wavelength while the concentration of indium will affect the splitting of HH and LH states. The resulting DFQW's may not satisfy the coherent pseudomorphic condition and results would have to be checked experimentally.

IV. Results and Discussions

The two DFQW structures studied here are an undoped $In_{0.51}Ga_{0.49}As$–InP QW with well width of 11 nm and 0.15% as-grown tensile strain, as well as a lattice-matched undoped $In_{0.53}Ga_{0.47}As$–InP QW with well width of 12 nm. Both of them are considered to be annealed under the same diffusion temperature of 750°C. The diffusion coefficient of the well and that of the barrier, as well as the concentration ratio are taken from a typical structure [22]. The exciton broadening factors of HH and LH are considered to be the same and with a value of $\Gamma_{XB} = 10$ meV. The electroabsorptive modulation operates at $F = 0$ and 100 kV/cm. The ON state is designed at $F = 0$. The operation wavelength is selected at the dip of the biased exciton absorption at which $\Delta\alpha_{\mathrm{TE}}$ equals $\Delta\alpha_{\mathrm{TM}}$ in order to obtain polarization insensitivity. Before discussing the absorption change of the DFQW's, the implications of using the two-phase model are discussed.

A. Implications of Using the Two-Phase Model for Group V Interdiffusion

Applying the two-phase interdiffusion model, the potential profile of the DFQW, shown in Fig. 2(a) (dotted line), exhibits approximately the same shape as the as-grown profile (solid line) with only a slight deviation at the bottom of the well. The diffused well width equals the as-grown well width because the model entails a discontinuous interface for the Group V composition even after interdiffusion. This is defined by (1) and (2), and thus, as shown in Fig. 2(b), the P profile after interdiffusion (dotted line) remains similar to its as-grown profile (solid line). As a consequence, a confinement potential profile Fig. 2(a) (dotted line) with an abrupt interface is obtained and its width equals that of the as-grown QW. It should be noted that when the compositional profile after interdiffusion in InGaAs–InP is modeled by an error function distribution both an abrupt confinement profile (in the case of interdiffusion on the Group III sublattice only) [24] and a graded confinement profile (in the case of interdiffusion on the two sublattices) [27] can result. In the latter case, shown in Fig. 2(a) (dashed line), it is clearly difficult to determine the effective well width.

A constant well width with interdiffusion would simplify the development of a polarization-insensitive modulator; a graded profile makes it difficult to determine parameters in (4) and (5) such as the effective well width L_z and the broadening factors Γ_B, Γ_{XB}. Interdiffusion as a result of the two-phase mechanism would maintain the same well width, so that the effect of well-width variation would be reduced, thus improving the potential for the tailoring of the polarization insensitivity. Suitable tensile strain in InGaAs–InP can also be produced in the well, in the case of interdiffusion at different rates on the two sublattices, resulting in the merging of the HH and LH transition energies [28]. In this case, the confinement energy exhibits a graded profile with the consequent complications in determining parameters such as width $L_z, \Gamma_B, \Gamma_{XB}$.

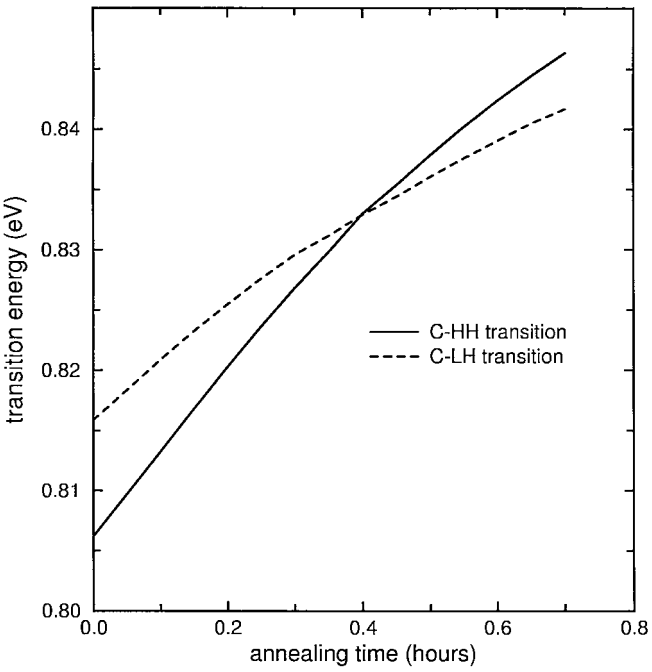
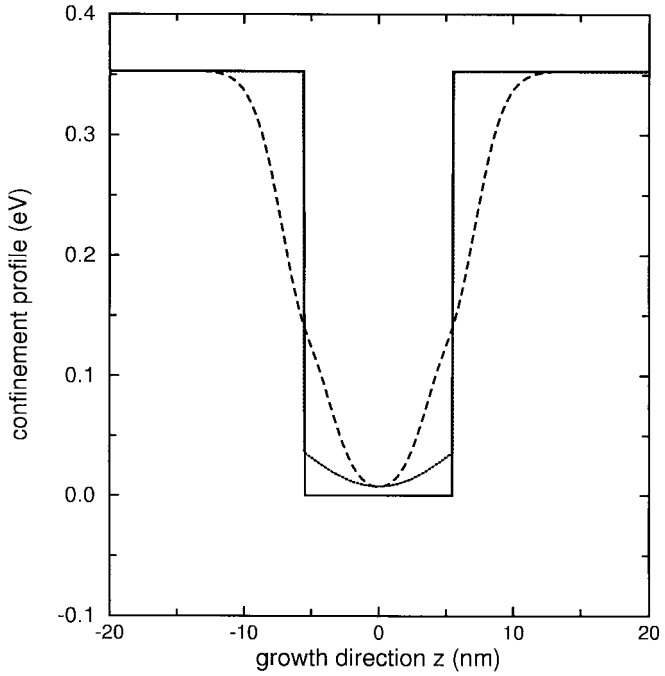


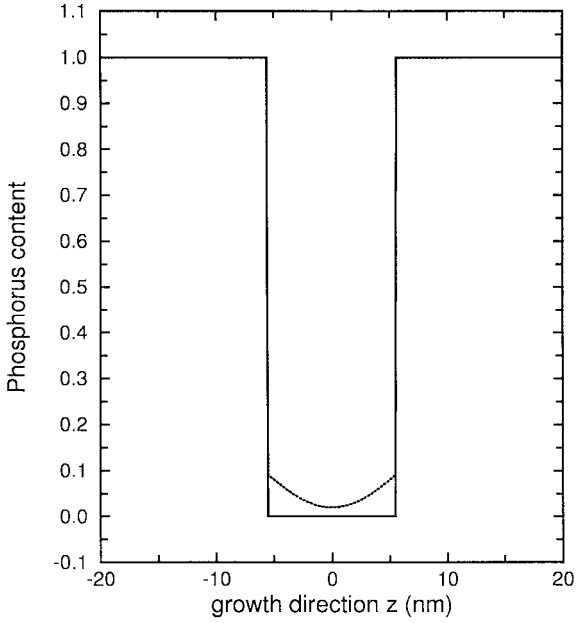
Fig. 1. The change of C–HH (solid line) and C–LH (dash line) transition energies of DFQW (with In content of 0.51, well width 11 nm) with increasing annealing time.

B. Polarization-Insensitive Electroabsorption Change

For the case of $x = 0.51$, the C–HH and C–LH exciton transition energies can successfully merge together when annealing time increases to 0.4 h, as shown in Fig. 1. The TE and TM absorption coefficient spectra of the DFQW with this annealing time are shown in Fig. 3. The C–HH and C–LH exciton absorption edges in the TE polarization overlap at $F = 0$, verifying the merging of HH and LH states. It can be seen that the TE and TM absorption spectra overlap over a range of photon wavelengths for both $F = 0$ and 100 kV/cm, showing that polarization-insensitive electroabsorption is possible. The operation region can be found from the absorption change spectra, as shown in Fig. 4, from which it can be observed that the operation wavelength locates between 1.54 and 1.56 μm with a maximum polarization-insensitive absorption change of $\sim$1200 cm^{-1}. Fig. 5 shows the CR in dB of the DFQW electroabsorptive modulator with modulation interaction length of 50 μm. For this DFQW cavity, assuming the optical confinement is unity, a maximum CR of 18 dB is obtained at photon wavelength of 1.542 μm. The attractive feature here is that the amount of tensile strain is increased



(a)



(b)

Fig. 2. (a) Electron potential profile of InGaAs–InP QW with well width of 11 nm and In content of 0.51: 1) square QW (solid line), 2) DFQW after Group V two phase interdiffusion with annealing time 0.4 h (dotted line), and 3) DFQW after interdiffusion on both Group III and Group V sublattices (dashed line). (b) Phosphorus profile of as-grown QW (solid line) and DFQW after Group V interdiffusion (dotted line).

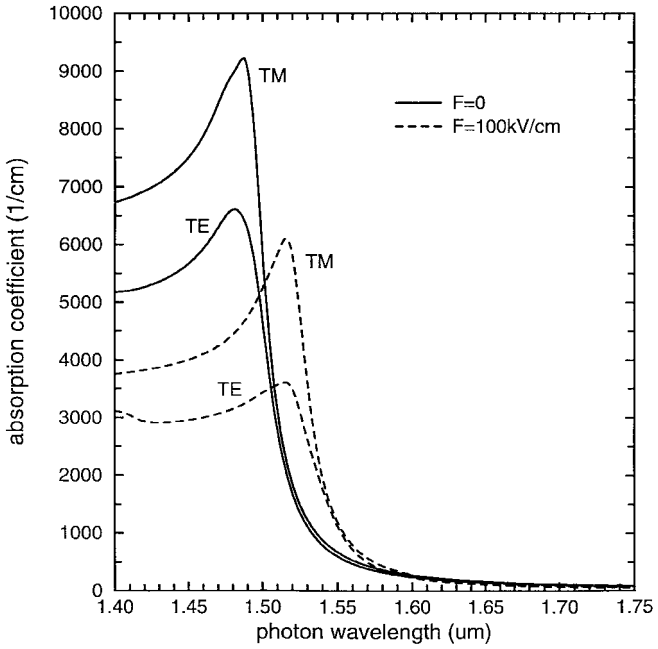


Fig. 3. The TE and TM absorption coefficient spectra of DFQW with In content of 0.51, well width 11 nm, and annealing of 0.4 h: (a) applied field $F = 0$ (solid line) and (b) $F = 100$ kV/cm (dashed line).

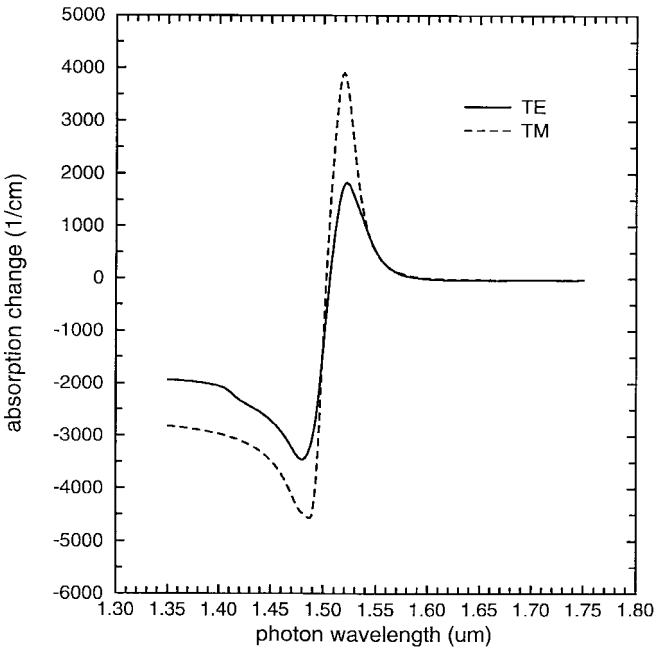


Fig. 4. The TE and TM absorption change spectra of DFQW with In content of 0.51, well width 11 nm, and annealing of 0.4 h with $F = 100$ kV/cm.

by more than 200% in the DFQW (as shown in Fig. 6) as compared with its as-grown tensile strain. The average tensile strain is 0.36% and the maximum tensile strain positions at the interfaces with a value of 0.46% when the as-grown tensile strain is only 0.15%. This means that a smaller as-grown tensile strain (0.15%) QW can produce polarization insensitivity after interdiffusion and thus ease the material growth and the device fabrication.

In another structure with lattice-matched condition ($x = 0.53$), electroabsorptive polarization insensitivity can be achieved after one hour of annealing. The TE and TM absorption spectra are shown in Fig. 7. The maximum absorption change of $\sim$1000 cm^{-1} (CR of $\sim$16 dB) can be obtained at photon wavelength of 1.55 μm as shown in Fig. 8. In this structure, the maximum strain at interfaces is 0.32% and the average strain is 0.27%. As compared to the experimental structure with the same well width (12 nm) [4],

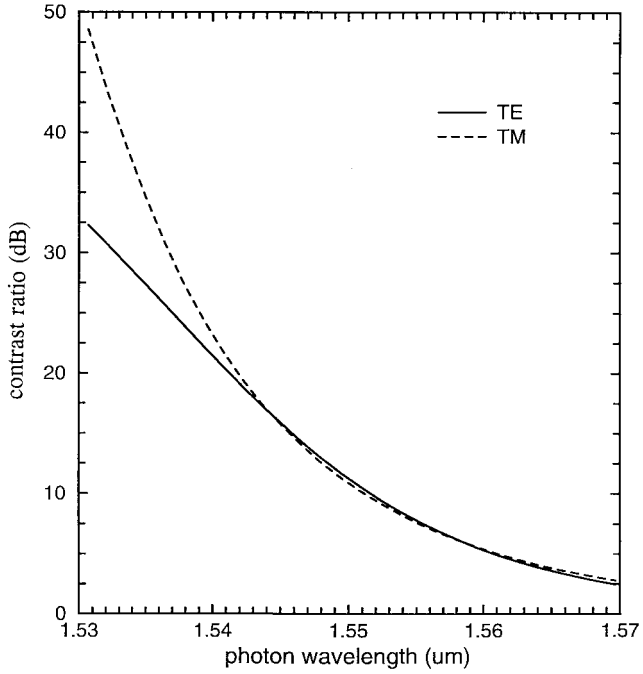


Fig. 5. The CR in dB of a full DFQW (the one with $x = 0.51$) electroabsorptive modulator with length 50 μm.

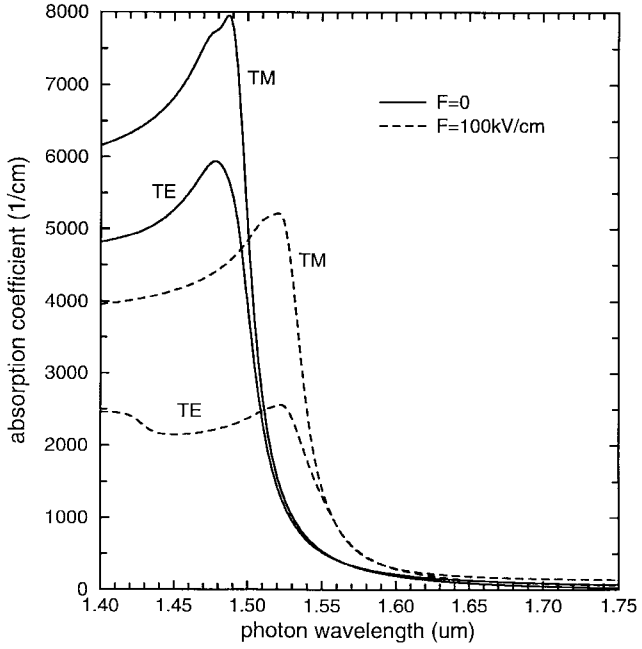


Fig. 7. The TE and TM absorption coefficient spectra of DFQW with In content of 0.53, well width 12 nm, and annealing of 1 h: (a) applied field $F = 0$ (solid line) and (b) $F = 100$ kV/cm (dash line).

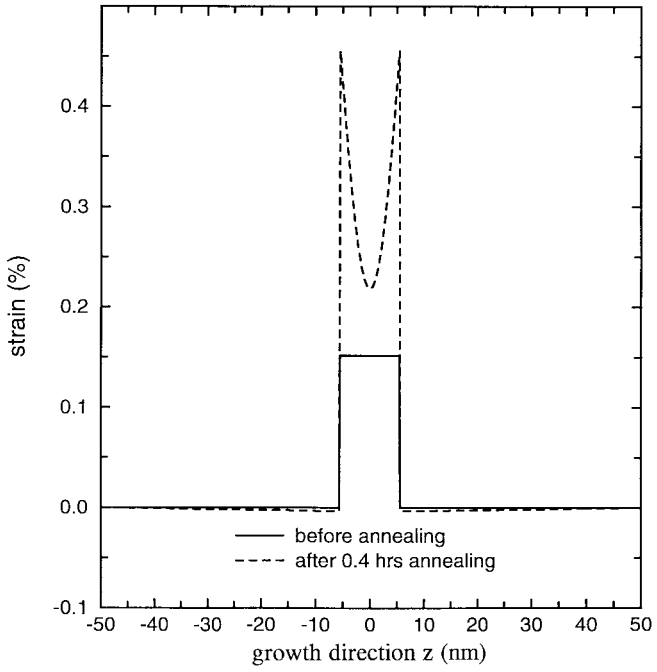


Fig. 6. The strain profile of InGaAs–InP QW with well width of 11 nm and In content of 0.51: (a) square QW (solid line) and (b) DFQW after annealing time of 0.4 h (dashed line).

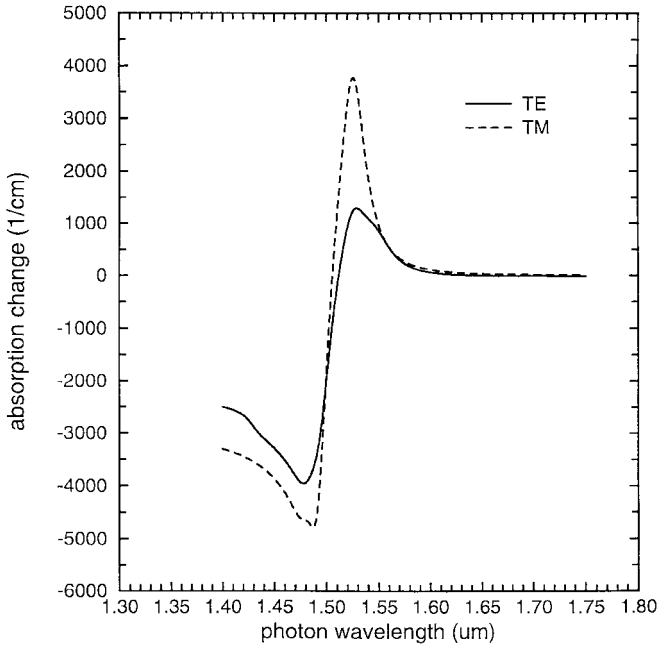


Fig. 8. The TE and TM absorption change spectra of DFQW with In content of 0.53, well width 12 nm, and annealing of 1 h with $F = 100$ kV/cm.

where a 0.3% as-grown strained $In_{0.49}Ga_{0.51}As$–InP square QW was fabricated, we here start with a lattice-matched as-grown QW, and polarization insensitivity can be obtained at around the 1.55-μm wavelength.

V. Conclusion

We have investigated the effect of interdiffusion on the electroabsorptive polarization insensitivity in InGaAs(P)–InP QW's. Interdiffusion on Group V sublattice only is proposed to develop polarization-insensitive QW's. The two-phase interdiffusion model entails similar well widths for both the as-grown and the interdiffused QW's, thus reducing the difficulty in determining parameters such as effective well width and broadening factors after interdiffusion. The criteria and steps which can serve as guidelines to develop DFQW's with electroabsorptive polarization insensitivity are also discussed. In order to optimize the adjustable wavelength range

of interdiffusion in producing the polarization insensitivity, the as-grown wells should preferably contain no phosphorus content. Our results show that the two DFQW structures, $In_{0.51}Ga_{0.49}As$–InP as-grown QW with well width 11 nm and 0.15% as-grown tensile strain, as well as lattice-matched $In_{0.53}Ga_{0.47}As$–InP as-grown QW with a well width 12 nm, can achieve electroabsorptive polarization insensitivity at the photon wavelength of $\sim$1.55 μm. It is thus interesting to note that an as-grown lattice-matched rectangular QW, an easily fabricated QW structure, can produce polarization insensitivity by using QW interdiffusion, which should be attractive from a device application point of view.

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