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A theoretical study of the influence of barrier thickness variations on optical properties of a semiconductor multiple quantum well slow light device

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Abstract. **The influence of barrier thickness variations on the operation of GaAs/AlGaAs multiple quantum well (MQW) slow light devices based on coherence population oscillations (CPOs) is explained. The variations are shown to affect the slow down factor (SDF) and bandwidth of these devices. Bloch equations and the analytical model in fractional dimension are used to analyse and simulate the slow light device. It is shown that other physical parameters of MQW structures (QW width and barrier alloy concentration) affect significantly the optical properties of the device. The presented approaches make it possible to achieve suitable values of SDF and focal energy by adjusting the barrier thickness, QW width and aluminium content. The maximum range of the centre frequency tuning is estimated to be about 1 THz in our calculations, while the slow down factor can reach a high value of 8.5×10^4.**

Keywords: *barrier thickness, slow light, slow down factor, excitonic population oscillations, centre frequency.*

1. Introduction

Controlling the velocity of light has recently attracted much attention of researchers. Scientists have approved many ways to decrease and increase the speed of a light pulse [1]. Different applications of these effects in nonlinear and quantum optics have lead to attempts to implement the control of light pulses in various optical devices, including optical modulators, optical gates, bit level synchronisers and all-optical switches [2, 3].

The velocity of a light pulse can be decreased by using several methods, which differ according to the media and structures utilised [2, 3]. The choice of the method is based on the material properties, desired speed of light and output signal bandwidth. The mechanisms used include coherent population oscillations (CPOs), waveguides in photonic crystals, coupled resonator optical waveguides (CROWs), stimulated Brillouin scattering (SBS) and stimulated Raman scattering (SRS) [4].

CPOs are a mechanism that is utilised to implement slow light in semiconductors using a coherent pump–probe impact. One of the advantages of the CPO method is that it needs a long relaxation time [5]. Recently, much research has been performed to slow down the velocity of light in semiconductors [3]. The reasons for the wide employment of semiconductors in slow light devices are their advantages, including temperature dependence and compatibility with other optical devices [3, 6]. It should be noted that semiconductor structures in slow light systems should have a high material dispersion [3].

Excitons play a considerable role in the CPO method in order to reduce the speed of light [5]. There are many reports about the influence of excitons on the optical characteristics of slow light devices [7–9]. For example, making changes in exciton properties, such as exciton binding energy, lead to new optical characteristics and centre frequency in slow light devices. Some reports demonstrate the influence of physical parameters of the structures on the exciton binding energy and optical properties [8]. There are several physical parameters that modify the exciton characteristics in multiple quantum well (MQW) structures, including types of materials, well width and barrier alloy concentration. Moreover, the barrier thickness can also change important properties of excitons, such as binding energy, exciton oscillator strength (EOS) and fractional dimension in MQW structures. These variations cause in turn changes in the slow down factor (SDF) and a shift of the centre frequency of the slow light device. Structural parameters, such as radius and height of quantum dots (QDs), are also significant factors in determining optical characteristics of QD slow light devices [10, 11].

In this paper, we describe and simulate a MQW slow light device by the CPO method using optical Bloch equations and compare our theoretical results with experimental ones. We also describe the differences of Bloch equations from the analytical model in fractional dimension. In Section 3, we investigate the effect of the barrier thickness variation on the exciton binding energy, EOS and fractional dimension quantity. Meanwhile, using Bloch equations we illustrate the influence of the barrier thickness on the refractive index, SDF and centre frequency shift of the slow light device. Finally, based on the analytical model in fractional dimension we consider changes in slow light parameters including slow down factor and refractive index. These results of calculations show that SDF and centre frequency can be adjusted by varying the barrier thickness, barrier alloy concentration and well width.

2. Theory

This part describes theory and physical variables of MQW slow light devices based on the CPO mechanism, as well as investigates the impacts of the barrier thickness on the optical parameters of the slow light systems, such as binding energy, EOS and fractional dimension. MQW slow light structures based on the CPO effect are analysed using two approaches. One of them is based on Bloch equations for semiconductors

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and the other – on the analytical model in fractional dimension [8, 9].

2.1. Description of CPOs in slow light systems with a semiconductor MQW structure by Bloch equations

The goal of any slow light device is a decrease in the group velocity v_g. In order to reduce the group velocity, acute changes in the real part of the refractive index within a narrow frequency range are needed. This variation affects the optical parameters of slow light devices. The group velocity is determined by the real part of the refractive index $n(\omega)$ and its derivative $dn(\omega)/d\omega$ [1]:

$$v_g = \frac{c}{n_g} = \frac{c}{n(\omega) + \omega dn(\omega)/d\omega}. \tag{1}$$

In the CPO method, a dramatic change in the real part of the refractive index is created by two signals. These signals are the probe and pump that are applied to the structure. When the difference of pump and probe frequencies is near the exciton inverse lifetime, exciton population oscillations appear in two level systems. In semiconductors, two level systems include a heavy-hole QW exciton and a conduction band. These exciton population oscillations lead to a dip in the absorption spectrum. According to Kramers–Kronig relations, this dip provides a positive gradient in the real part of the refractive index that a slow light device requires due to a decrease in the speed of light. Bloch equations are utilised to investigate two level systems. Hence, we use these equations to analyse slow light devices based on two level systems. Effective total population difference and electric polarisation density in real space are expressed through the equations [12]:

$$\frac{\partial N_{ex\sigma}}{\partial t} = -\Gamma_1(N_{ex\sigma} - N_{ex\sigma}^{(0)}) - \Gamma_s(N_{ex\sigma} - N_{ex\bar{\sigma}}) + 4\,\mathrm{Im}\left[\frac{\mu_{12}\varepsilon(t)}{2\hbar} P_{ex\sigma}\right], \tag{2}$$

$$\frac{\partial P_{ex\sigma}}{\partial t} = -i[\omega_{ex} - i\Gamma_2(N_{ex\sigma})]P_{ex\sigma} - i\frac{\mu_{12}\varepsilon(t)}{2\hbar} N_{ex\sigma}, \tag{3}$$

where the subscript σ is the spin index of the system ($\sigma = \uparrow, \downarrow$); $\varepsilon(t)$ is the electric field strength; and $N_{ex\sigma}$ and $P_{ex\sigma}$ are the effective total population difference and the interband polarisation. Table 1 lists the parameters [5] that are utilised in equations (2) and (3).

These equations are valid in the low excitation regime and do not take into account the impact of electron hole plasma screening and phase space filling [5].

One of important parameters in Bloch equations is the linear permittivity tensor $\varepsilon_s(\omega_s)$ that is obtained by solving the relevant optical equation under steady state conditions [8].

Table 1.

Parameter	Value
Spin flip constant Γ_s	50 ps
Longitudinal relaxation rate Γ_1	2.5133 ns^{-1}
Transverse relaxation rate $\Gamma_2(N_{ex\sigma})$	0.4716 ps^{-1}
Exciton frequency ω_{ex}	2.333×10^{15} rad s^{-1}
Dipole momentum of the $\lvert 1\rangle \to \lvert 2\rangle$ μ_{12} transition	1.04×10^{-18} Å
Equilibrium population difference $N_{ex\sigma}^{(0)}$	−1

The refractive index, absorption and SDF are given by the expressions [8]:

$$n_s(\omega_s) = \sqrt{\varepsilon_s(\omega_s)}, \tag{4}$$

$$A_s(\omega_s) = 2\frac{\omega_s}{c}\mathrm{Im}[n_s(\omega_s)], \tag{5}$$

$$R_s(\omega_s) = \mathrm{Re}[n_s(\omega_s)] + \omega_s \frac{\partial\,\mathrm{Re}[n_s(\omega_s)]}{\partial \omega_s}. \tag{6}$$

Figure 1 shows the GaAs/AlGaAs MQW structure of a slow light device that is used in this paper for theoretical investigation and simulation based on coherence population oscillations. This structure contains 15 periods of $GaAs/Al_{0.3}Ga_{0.7}As$ QWs. As seen from Fig. 1, signal and pump light emit in perpendicular direction of QW growth.

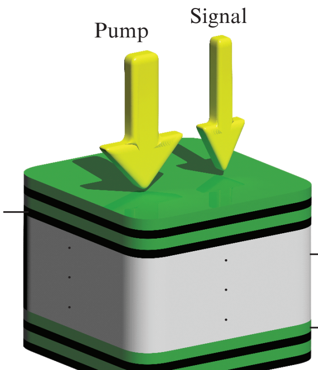

Figure 1. Experimental structure of a GaAs/AlGaAs MQW slow light device described in [5]; L_w is the QW width and L_b is the barrier width.

Figure 2 demonstrates the results of the simulations for absorbance, real part of the refractive index and SDF as a function of the signal–pump detuning frequency in the case of exciton population oscillations. It should be noted that the experimental results for a GaAs/AlGaAs MQW slow light device [5] are in very good agreement with the simulation results obtained in this paper. As can be seen from Fig. 2, the minimum absorbance, maximum value of SDF and sharp change in the real part of the refractive index occur at a zero value of the signal–pump detuning frequency. Thus, the lowest group velocity is achieved at a zero detuning where the pump and signal frequencies are set equal to the exciton frequency (exciton resonance energy). In the following, our purpose is the improvement of these experimental results that we attained theoretically.

2.2. Description of CPOs in slow light devices with a semiconductor MQW structure by the analytical model in fractional dimension

Some papers make use of the analytical model in fractional dimension for analysing slow light phenomena in a MQW structure [9]. In our paper [9] we investigated the influence of the well width on optical properties of devices corresponding to this model. Bloch equations do not take into account variations of the exciton oscillator strength and fractional dimension parameter in the simulation because these equations are valid in the down excitation regime and do not describe

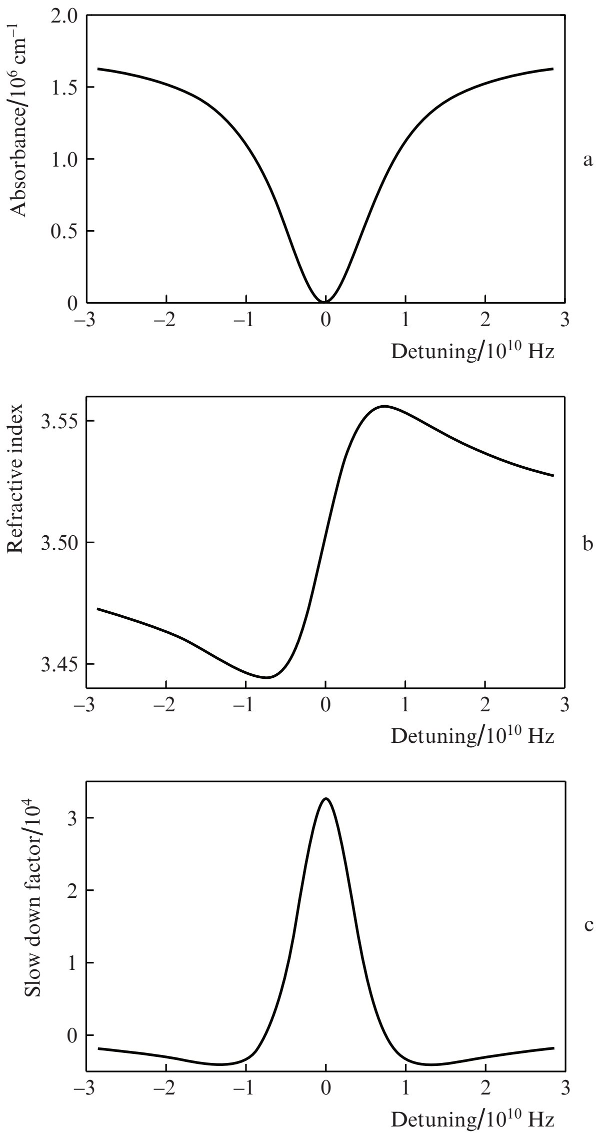

Figure 2. (a) Absorbance, (b) real part of the refractive index and (c) slow down factor as functions of frequency detuning according to the CPO method in a GaAs/AlGaAs MQW structure.

the influence of electron hole plasma screening and phase space filling. Therefore, variation of MQW structure parameters changes only the centre frequency and does not affect SDF. Nevertheless, we utilise Bloch equations to simulate the effect of the barrier thickness on the centre frequency. The analytical model in fractional dimension takes into account the exciton oscillator strength and fractional dimension quantity [13, 14]. Thus, within the presented model we can observe the influence of the barrier thickness on these variables. More details about this method are presented in [9, 15].

2.3. Influence of the barrier thickness

2.3.1. Dependence of the binding energy on the barrier thickness. The effect of the well width and barrier alloy concentration on the binding energy and optical parameters of slow light devices have been investigated in [16]. The binding energy of a GaAs/AlGaAs MQW is found by solving the Schrödinger equation for the exciton state and is expressed as [17]:

$$E_b(\gamma) = \begin{cases} (\gamma-1)^{-1}\ln^2[\gamma^{1/2}+(\gamma-1)^{1/2}], & \gamma > 1, \\ 1, & \gamma = 1, \\ (1-\gamma)^{-1}\arcsin^2[(1-\gamma)^{1/2}], & \gamma < 1, \end{cases} \tag{7}$$

where γ is the anisotropy parameter defined as [17]:

$$\gamma = \frac{\mu_{\parallel}}{\mu_{\perp}}; \tag{8}$$

and $\mu_{\parallel}$ and $\mu_{\perp}$ are the effective masses of the exciton in the plane of structure layers in two orthogonal directions [17]:

$$\frac{1}{\mu_{\parallel}} = \frac{1}{m_{e\parallel}} + \frac{1}{m_{h\parallel}}, \tag{9}$$

$$\mu_{\perp} = m_{e\perp} + m_{h\perp}. \tag{10}$$

Table 2 lists the parameters from equations (9) and (10) and the bandgap width [17]. The material parameters are given in the units of free electron mass m_0.

Table 2.

Parameter	Value	
	GaAs	AlAs
Effective electron mass in the plane of layers $m_{e\parallel}$	$0.06m_0$	$0.1m_0$
Effective hole mass in the plane of layer $m_{h\parallel}$	$0.11m_0$	$0.2m_0$
Effective electron mass in the direction perpendicular to the plane of layers $m_{e\perp}$	$0.06m_0$	$0.15m_0$
Effective electron hole in the direction perpendicular to the plane of layers $m_{h\perp}$	$0.34m_0$	$0.752m_0$
Bandgap energy E_g	1.514 eV	3.11 eV

To calculate the binding energy for a GaAs/$Al_xGa_{1-x}As$ MQW structure by equations (7)–(10), we first find from Table 2 the values of the effective mass and take into account the band offset equal to 0.67 eV [17]. Note that in all GaAs/$Al_xGa_{1-x}As$ MQW structures the effective masses depend on the well width, barrier thickness and barrier alloy concentration in the structure. Then, we obtain the anisotropy parameter based on equation (8). Changes in the effective masses result in different values of the anisotropy parameter [17]. Finally, the binding energy is calculated for the found values of the anisotropy parameter according to equation (7). In other words, we can obtain the values of the binding energy for heavy-hole excitons based on variations of the structure parameters including barrier width, well width and barrier alloy concentration [18].

To get an insight about the well width and barrier thickness, Fig. 3 demonstrates the spatial dependence of the band gap energy of a slow light device as well as the well width and barrier thickness in the structure.

Figure 4 presents the simulation results for the binding energy as a function of barrier thickness for a GaAs/$Al_{0.3}Ga_{0.7}As$ MQW structure with a 135-Å well width. One can see that the binding energy increases with increasing barrier thickness. This consequence is opposite to that which takes place when the binding energy decreases with increasing well width [8]. The obtained result shown in Fig. 4 has satisfactory agreement with the conclusions of paper [18].

2.3.2. Effect of the barrier thickness on fractional dimension. As far as we know, two important variables used to simulate a slow light system in a fractional dimension space

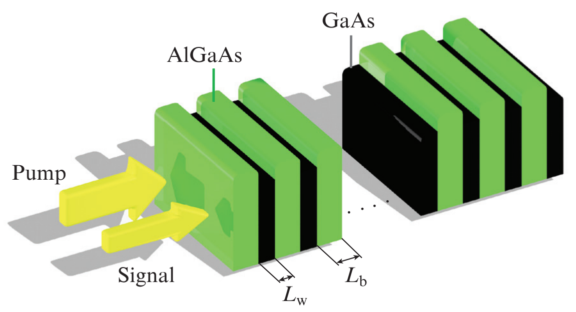

Figure 3. Spatial dependence of the bandgap energy (along the vertical), as well as the width and barrier thickness of a GaAs/AlGaAs MQW slow light device.

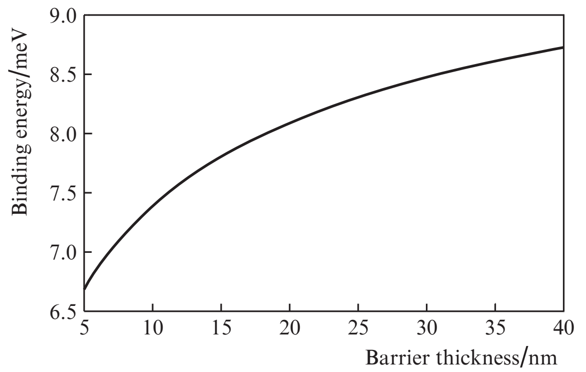

Figure 4. Dependence of the binding energy on the barrier thickness for a $GaAs/Al_{0.3}Ga_{0.7}As$ MQW structure with a QW width of 135 Å.

are the exciton oscillator strength and fractional dimension parameter. The fractional dimension parameter depends on the binding energy which was described in the previous section. Thus, fractional dimension changes with the barrier thickness. The correlation between these variables can be written as [19]:

$$E_b = \frac{4}{(D-1)^2} R^*, \tag{11}$$

where R^* is the effective Rydberg constant of the impurity, and D is the fractional dimension.

Figure 5 illustrates the calculation result of fractional dimension as a function of barrier thickness for a 135-Å well width in a $GaAs/Al_{0.3}Ga_{0.7}As$ MQW structure. One can see that an increase in the barrier thickness leads to a decrease in fractional dimension. It should be noted that further changes in this parameter occur for less than 5 nm of barrier thickness and are not considered in this paper. It follows from Fig. 5 that changes in fractional dimension are due to variations of the binding energy and therefore barrier thickness. The result agrees with the model reported in [19].

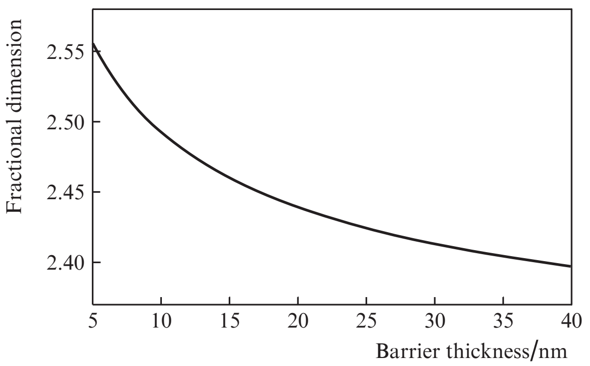

Figure 5. Fractional dimension as a function of barrier thickness in a $GaAs/Al_{0.3}Ga_{0.7}As$ MQW structure with a QW width of 135 Å.

2.3.3. Response of EOS to changes in the barrier thickness. As mentioned above, EOS plays a significant role in the simulation of a slow light device in the fractional dimension space. The exciton oscillator strength in a QW structure can be written as [20, 21]:

$$f = \frac{2K_s|Q|^2}{\pi m_0 E_s L_w |\phi_{eh}(0)|^2} \left| \int_{-\infty}^{\infty} \psi_e \psi_h \, dz \right|^2, \tag{12}$$

where ψ_h and ψ_e are the hole and electron envelope functions, respectively; L_w is the QW width; $K_s = 0.5$ for a heavy hole; Q is the matrix element between the valence and conduction band; E_s is the exciton transition energy [20, 21];

$$\phi_{eh}(0) = \frac{1}{\lambda}\sqrt{2/\pi} \tag{13}$$

is the exciton envelope function [20]; and λ is the variational parameter [20]. By simplifying equation (12) with substitution of defined quantities, EOS is approximated with $\exp(-2L_b\omega_s/c)$, where L_b is the barrier thickness [22].

Figure 6 shows the variations of EOS as a function of barrier thickness. One can see a decrease in EOS with increasing barrier thickness. According to the changes in EOS and fractional dimension, we can determine the slow light device parameters and consider the influence of the well width on these parameters by using the results of previous studies described in [23, 24].

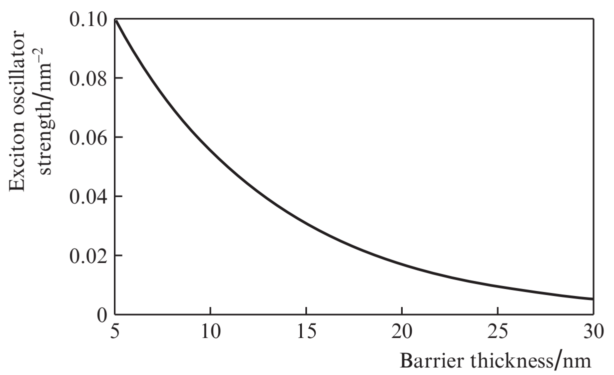

Figure 6. Barrier thickness as a function of exciton oscillator strength in a $GaAs/Al_{0.3}Ga_{0.7}As$ MQW structure with a well width of 135 Å.

3. Results and discussion

3.1. Estimate of the influence of the barrier thickness on optical parameters by Bloch equations

Exciton energy is an essential variable in Bloch equations that are used for slow light device simulation. The centre frequency of slow light devices is also related to the exciton energy E_{ex}.

The exciton energy is expressed through the bandgap energy and the binding energy:

$$E_{ex} = E_g - E_b. \quad (14)$$

As mentioned in Section 2.2, the binding energy depends on the barrier thickness of a MQW slow light device. Therefore, the barrier thickness has a direct impact on the exciton energy in Bloch equations.

Figure 7 shows the frequency dependence of the real part of the refractive index and SDF for three different values of the barrier thickness. One can see that changes in the barrier thickness lead to a shift of the centre frequency. The frequency shift is positive for a barrier thickness of less than 150 Å and is negative for a barrier thickness of more than 150 Å. Solid curves in the figure correspond to the experimental result for a GaAs/$Al_{0.3}Ga_{0.7}As$ MQW slow light device with a 150-Å barrier thickness [5]. Figure 7 is plotted for a fixed well width (135 Å) and aluminium content (0.3). It is obvious from Fig. 7 that changes in the barrier thickness simply shift the centre frequency of the device rather than affect the values of n_s and $\partial \mathrm{Re}\, n_s/\partial \omega_s$ (slope of refractive index). In addition, the peak value of the slow down factor is independent of the barrier thickness because the variations of EOS are not considered in Bloch equations.

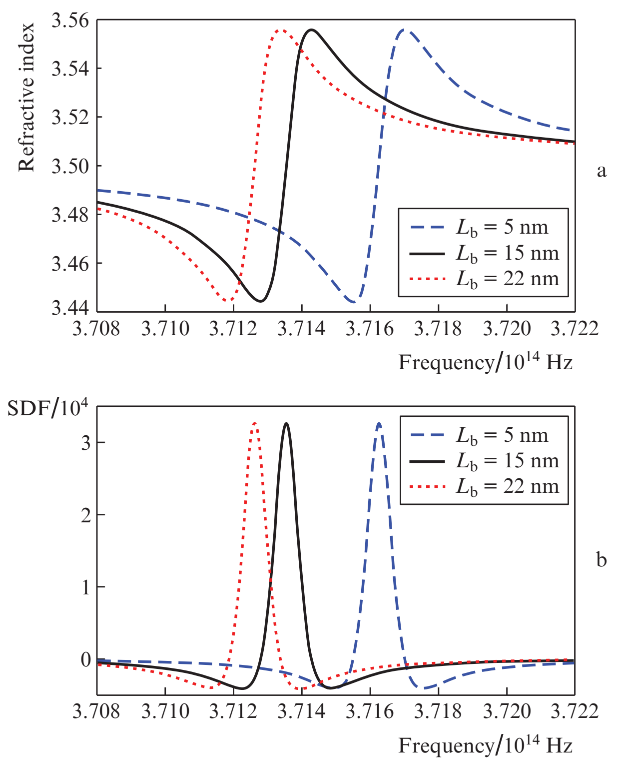

Figure 7. (a) Real part of the refractive index and (b) slow down factor of a GaAs/$Al_{0.3}Ga_{0.7}As$ MQW slow light device as functions of frequency for three different values of the barrier thickness with a QW width of 135 Å.

Physically, an increase in the barrier thickness increases the binding energy. As the binding energy goes up, the exciton energy decreases. Hence, the heavy-hole exciton band of the semiconductor moves down with increasing barrier thickness. It means that the difference between the conduction band energy and heavy-hole exciton state energy increases with increasing barrier thickness. Thus, a decrease in the heavy-hole exciton state energy with increasing barrier thickness leads to a shift of the centre frequency (or energy) of the system. The focal energy is equal to the pump energy of a photon that produces population oscillations and a hole in the absorption spectrum of a MQW slow light device. Therefore, the main reason for a centre frequency shift is the movement of the heavy-hole exciton band due to the barrier thickness variation.

Figure 8a shows the real part of the refractive index for simultaneous changes in the barrier thickness and frequency. One can see from Fig. 8a that changes in the barrier thickness lead to a shift of the centre frequency: an increase in the barrier thickness shifts the centre frequency to lower values.

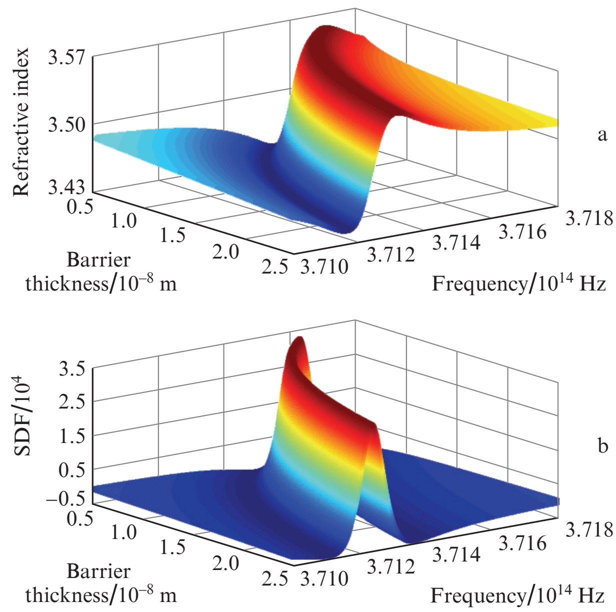

Figure 8. (a) Real part of the refractive index and (b) slow down factor as functions of barrier thickness and frequency for a fixed well width of 135 Å and a barrier alloy concentration of 0.3.

Figure 8b illustrates the dependence of the slow down factor on the barrier thickness and frequency. The QW width and alloy content are constant and equal to 135 Å and 0.3, respectively. One can see that the maximum value of SDF is independent of changes in the barrier thickness due to the fact that EOS is not taken into account in Bloch equations. Similar to Fig. 7, variations of the barrier thickness only lead to a shift of the centre frequency. As mentioned above, the change in the barrier thickness affects the binding energy, which causes a frequency shift in optical parameters of MQW slow light devices.

In our paper [16] we investigated the effect of simultaneous changes in the well width and barrier alloy concentration on the centre frequency of the MQW slow light device. Based on the simulation results described in [16], we can conclude that an increase in the well width reduces the binding energy, which shifts the centre frequency of a slow light device to higher frequencies. Also, an increase in the barrier alloy concentration leads to an increase in the binding energy, which causes a shift of the centre frequency to lower values. The physical sense of this phenomenon is as follows: as the well width is increased, the binding energy decreases and the heavy-hole exciton state energy moves up. Thus, the centre frequency (energy) increases with increasing well width. On the other hand, the exciton binding energy decreases with decreasing barrier alloy concentration and causes the heavy-hole exciton band energy to go up. This transition of the heavy-hole exciton state shifts the centre frequency to lower values.

Figure 9 illustrates changes in the centre frequency of the system as functions of physical parameters of a slow light device. As seen from Fig. 9a, the centre frequency shift depends on the barrier thickness and aluminium content. The well width is equal to 135 Å. A reduction of the barrier thickness leads to an increase in the centre frequency shift at constant values of the barrier alloy concentration. Also, in accordance with [16], an increase in the barrier alloy concentration is expected to decrease the frequency shift.

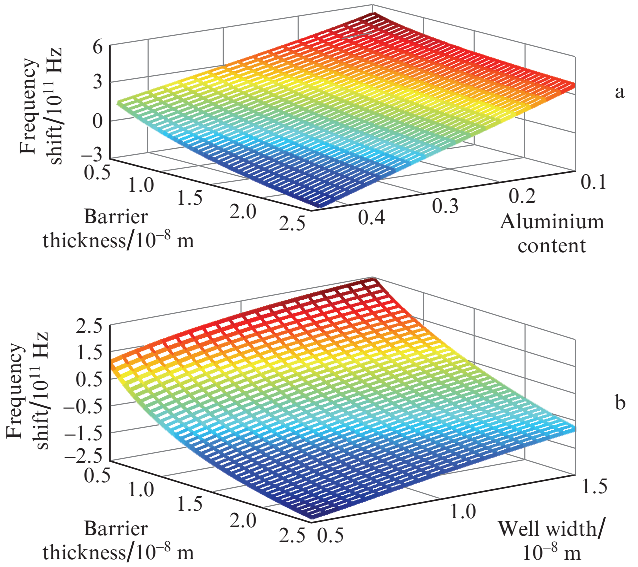

Figure 9. Dependence of the centre frequency shift on the simultaneous changes of (a) barrier thickness and aluminium content as well as (b) barrier thickness and well width.

Figure 9b demonstrates the effect of a simultaneous change in the well width and barrier thickness on the frequency shift. Figure 9b is plotted based on Bloch equations at a constant value of the aluminium content (0.3). One can see that the effect of the well width on the frequency shift is opposite to that of the barrier thickness effect. In this case, the influence of the barrier thickness on the frequency shift is stronger than that of the well width. Therefore, we can adjust the centre frequency of the device by choosing the physical parameters, such as barrier thickness, quantum well width and aluminium content.

3.2. Effect of the barrier thickness on optical parameters within the framework of the analytical model in the fractional dimension space

The results obtained in Section 3.1 show that variations in the barrier thickness lead to a shift of the centre frequency, while the SDF value and the slope of the refractive index are constant for all barrier thicknesses. In this section, the influence of the barrier thickness in slow light devices is studied within the framework of the analytical model in the fractional dimension space. Changes in the EOS and fractional dimension parameter play a fundamental role in this model.

Figure 10 shows the dependences of the refractive index and slow down factor on energy. The curves are plotted for three values of the barrier thickness. One can see that there is a focal energy for each barrier thickness. Actually, barrier thickness changes cause a shift of the focal energy. In addition, the value and slope of the real part of the refractive index are related to the barrier thickness. The variations of the refractive index are a result of changes in EOS and fractional dimension. On the other hand, an increase in the barrier thickness results in a decrease in the EOS and fractional dimension parameter so that a reduction of these parameters makes the slope of the refractive index steeper. A decrease in the refractive index slope with increasing barrier thickness reduces the peak value of SDF (see Fig. 10b).

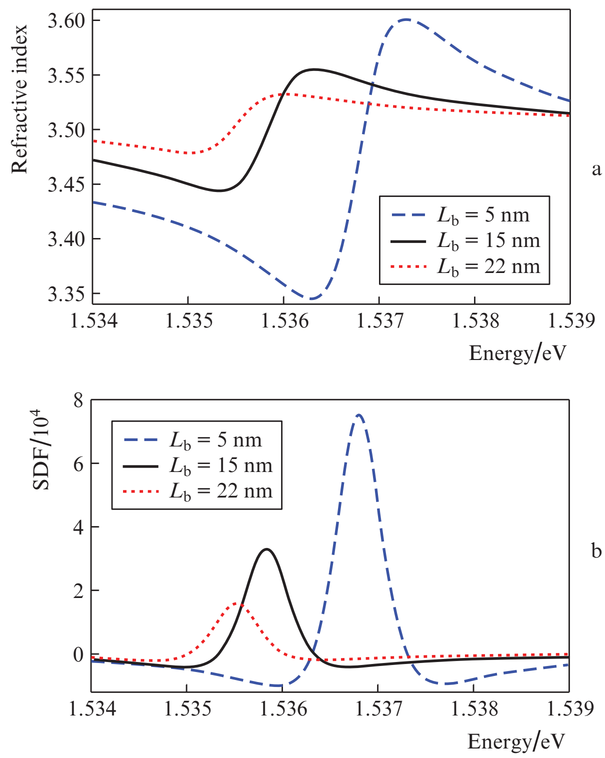

Figure 10. (a) Real part of the refractive index real part and (b) slow down factor of a MQW device as functions of energy for three different values of the barrier thickness with 135 Å well width and 0.3 aluminium content.

The reason for changes in the slope and refractive index is the absorbance variation. In other words, when the barrier thickness becomes larger, the depth of the dip in the absorption spectrum reduces. According to Kramers–Kronig relations, a reduction of the dip depth in absorption leads to a change in the slope and refractive index.

Figure 11a illustrates the real part of the refractive index as a function of simultaneous changes in the barrier thickness and energy.

Figure 11b shows the dependence of the slow down factor on energy and barrier thickness at a quantum well width of 135 Å in a $GaAs/Al_{0.3}Ga_{0.7}As$ structure. One can see that changes in the barrier thickness lead to an energy shift and variations in the SDF maximum value. By increasing the barrier thickness, the amount of the binding energy increases and consequently the focal energy will reach lower values. Moreover, with increasing barrier thickness, the values of the exciton oscillator strength and fractional dimension decrease and consequently the values of the refractive index slope and slow down factor will reduce. Thus, a decrease in the slope of the refractive index directly affects the peak value of SDF, which is clearly visible in Fig. 11b.

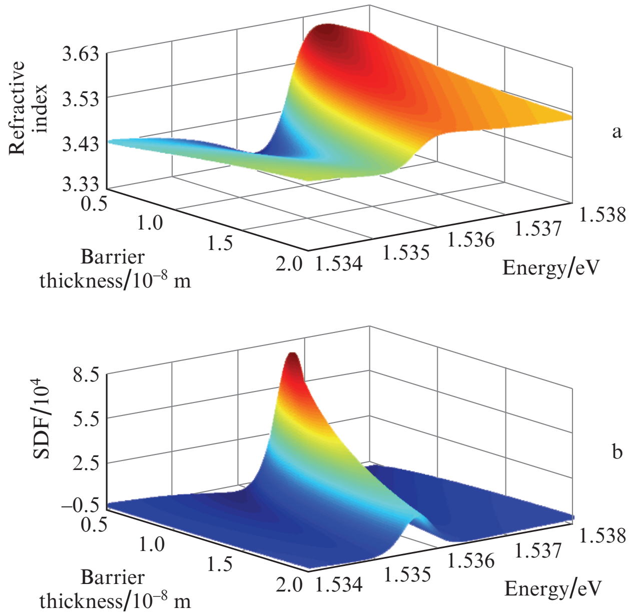

Figure 11. (a) Real part of the refractive index and (b) slow down factor as functions of the barrier thickness and energy for 135 Å well thickness and 0.3 barrier alloy concentration in a MQW GaAs/AlGaAs slow light system.

Figure 12 demonstrates a maximum value of SDF as a function of QW physical parameters including barrier thickness, aluminium content and well width. Figure 12a shows the dependence of the barrier alloy concentration and barrier thickness on the maximum value of SDF. It is well known that a reduction of the aluminium content decreases the EOS and increases the fractional dimension parameter. Thus, the maximum value of the slow down factor decreases with decreasing aluminium content. This plot is simulated for a constant value of the QW width equal to 135 Å. Figure 12b illustrates changes in the SDF maximum value due to simultaneous variations of the well width and barrier thickness at a fixed aluminium content of 0.3. Both the barrier thickness and well width reduction causes an increase in the maximum of SDF. On the other hand, a decrease in the well width causes an increase in SDF and a decrease in the fractional dimension parameter [9]. Also, a decrease in the barrier thickness leads to an increase in EOS and fractional dimension; these alterations of parameters result in an increase in SDF with decreasing barrier thickness. Based on the results obtained, we can adjust physical parameters such as barrier alloy concentration, barrier thickness and well width in order to achieve a suitable maximum value of SDF.

One can see from Fig. 12 that a simultaneous decrease in the barrier thickness and well width make a significant increase

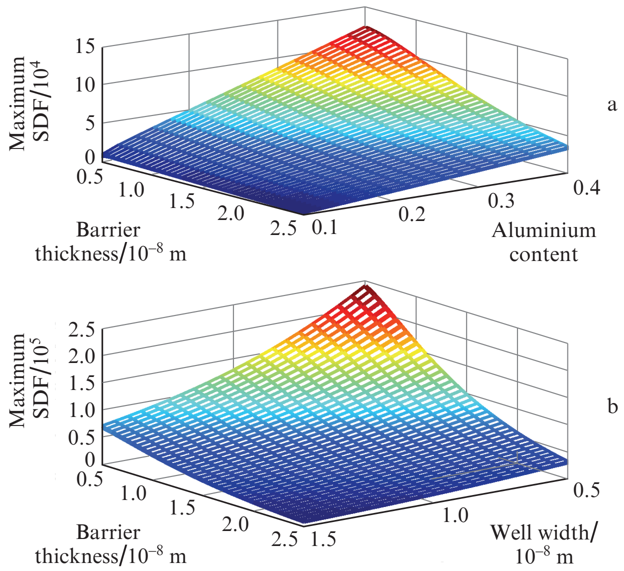

Figure 12. Dependence of the maximum value of SDF on (a) the barrier thickness and aluminium content, as well as on (b) the barrier thickness and well width.

in the peak value of SDF, which provides some advantages for slow light systems.

4. Conclusions

We have studied the effect of barrier thickness on main parameters of a GaAs/AlGaAs MQW slow light device. We use two different approaches in order to analyse and simulate the slow light structure based on the coherent population oscillation method. Variations of the binding energy are considered within the approach based on Bloch equations. We also use the analytical model in fractional dimension space in order to observe effects of EOS and factional dimension parameter changes on the optical properties of the device. Based on the obtained results, we can achieve a high value of the centre frequency shift with barrier thickness reduction. The maximum value of SDF can also be enhanced with decreasing barrier thickness.

It is shown that we can tune the slow down factor and substantially decrease the group velocity, which is the goal of any slow light system. Moreover, we can tune the centre frequency of the device in a range of ~1 THz.

Therefore, the barrier thickness, well width and barrier alloy concentration significantly affect the optical characteristics of GaAs/AlGaAs MQW slow light devices.

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