THE INFLUENCE OF MATERIAL PARAMETERS IN DFB LASER ON GENERATED IMPULSE

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1 Introduction

Distributed Feedback laser (DFB laser) is one of useful light sources generating laser radiation used widely in optical communication. This laser can generate longitudinal single mode and its wavelength is easily modulated. Especially, the DFB laser with two (or more) sections reveals a great convenience to optical communication and to all optical transformation. Therefore, to now this laser concentrates the attention of many researching groups on the world and many works related with this field are published [1-8]

In this paper, we would like to investigate the influence of semiconductor material used for construction of a DFB laser with two sections on the characteristics of generated impulse. Starting on the rate equation approximation, we have established a system of equations describing the changes of the carrier densities in the two sections and of the laser photon density versus time, as presented in section 2. For determining the influence of semiconductor material we notice the change of refraction index of material, and of confinement factors (Peterman coefficients) in each section. The received results are presented in section 3. Finally, the discussion and conclusions are given in section 4.

2. The basic equations

A modeling schema for a DFB laser with two sections is presented in Fig. 1.

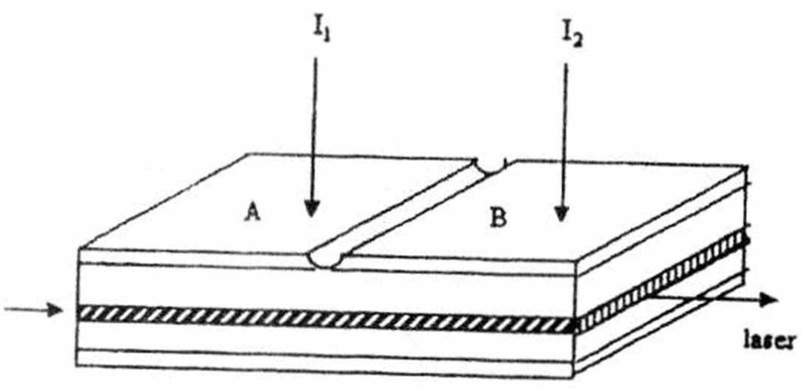

Fig.1

Here, cell A containing active medium designs active cell, but cell B having injection current I_2 smaller than I_1 in cell A takes a role as a saturable absorber cell. System of equations describing the transient operation of laser is, as in [7]:

$$\frac{dN_1}{dt} = \frac{I_1}{eV_1} - \eta_1 \frac{c_0}{n_{\text{eff}}} g(\omega_0 - \omega_j) n_j - \gamma_1 N_1, \quad (1)$$

$$\frac{dN_2}{dt} = \frac{I_2}{eV_2} - \eta_2 \frac{c_0}{n_{\text{eff}}} g(\omega_0 - \omega_j) n_j - \gamma_2 N_2, \quad (2)$$

$$\frac{dn_j}{dt} = (\Gamma_1\eta_1 + \Gamma_2\eta_2) \frac{c_0}{n_{\text{eff}}} g(\omega_0 - \omega_j)(n_j + 1) - \gamma n_j + \beta\sqrt{n_j} P(\omega). \quad (3)$$

Here N_1, N_2 - carrier density in cells A, B; n_j - photon density; c_0, e - velocity of light in vacuum and electric charge of electron; V_1, V_2 - volume of cells A, B; n_{eff} - refraction index of material is seen to be the same for two cells; η_i - amplification coefficient of each cell, depending which on carrier density in form:

$$\eta_i = \alpha_i N_i + \beta_i, \quad (4)$$

here α_i, β_i - material coefficients; γ_1, γ_2 - relaxation coefficients of carrier density also depending on carrier density as following function:

$$\gamma_1 = \frac{B_0 N_1}{1 + B_1 N_1}, \qquad \gamma_2 = \frac{\xi B_0 N_2}{1 + B_2 N_2}, \quad (5)$$

with B_0, B_1, B_2 - material coefficients; ξ - saturation coefficient designing the different relaxation of carrier density between two cells; Γ_1, Γ_2- confinement factors or Peterman coefficients of A, B cells, respectively. The relaxation coefficient of photon γ is determined by expression:

$$\gamma = \frac{c_0}{n_{\text{eff}}}(a\alpha_{\text{ac}} + b\alpha_{\text{ex}} + c\alpha_{\text{mirr}}). \quad (6)$$

Here a, b, c - material coefficients; $\alpha_{\text{ac}}, \alpha_{\text{ex}}, \alpha_{\text{mirr}}$- photon loss at active, absorber cell, and through mirrors, respectively. Function $g(\omega_0 - \omega_j)$ - characterizing the spectral broadening of laser radiation has form:

$$g(\omega_0 - \omega_j) = \frac{\Gamma^2}{\Gamma^2 + 4(\omega_0 - \omega_j)^2} = \frac{1}{1 + \left(\frac{\Delta_j}{\Gamma}\right)^2}, \quad (7)$$

with Γ- the line width; $\Delta_j = 2/\omega_0 - \omega_j/$ - detuning coefficient; ω_0, ω_j- angular frequency at center of line contour and at j^{th} mode. Moreover, unity in $(n_j + 1)$ designs the presence of spontaneous emission in laser operation. The last factor in equation (3) notices the interaction between external optical signal having power $P(\omega)$ with laser radiation, interaction coefficient β will be given unity in examination afterwards. System of equations (1) - (3) is solved numerically following Runge- Kutta method and the values of all parameters are taken following the experimental ones of Junichi Kinoshita on the basis of semiconductor material InGaAsP [9].

3. The influence of some material parameters

In our examination, we study only the resonance case in which the generating mode frequency ω_j coincides with ω_0. Therefore function $g(\omega_0 - \omega_j) = 1$. Other values of parameters will be taken as follows: $c_0 = 3.10^{10}$ cm/s, $e = 1,610^{-19}$C, $V_1 = V_2 = 8.4.10^{-9}$ cm^3, $B_0 = 10^{-10}$, $B_1 = B_2 = 10^{-8}$s, $\xi = 0.1$, $\beta_j = 0, \alpha_j = 4.10^{-16}, \Gamma_1 = 0.5, \Gamma_2 = 0.2, I_1 = 10^{-2}A, I_2 = 2.10^{-5}A, P(\omega) = 10^{10}$ (photons/cm^3.s), $a = 0.3, b = 0.7, c = 17, \alpha_{ac} = 100cm^{-1}, \alpha_{cr} = 200cm^{-1}, \alpha_{\text{mirr}} = 1.4cm^{-1}, n_{eff} = 3.4$ for two sections A and B. The received function $n_j(t)$,from solving method indicated above, is presented in fig.2a. By using the Fast Fourrier Transformation (FFT) method we also have function $n_j(\omega)$ given in Fig.2b.

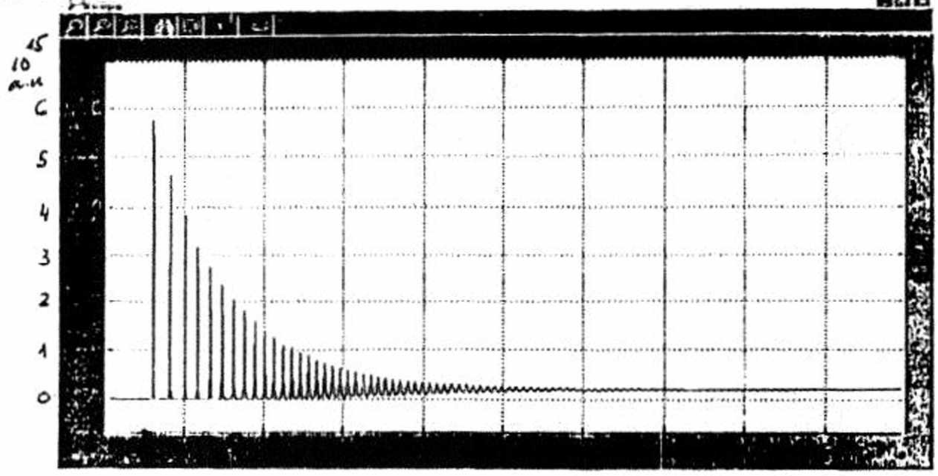

Fig.2a

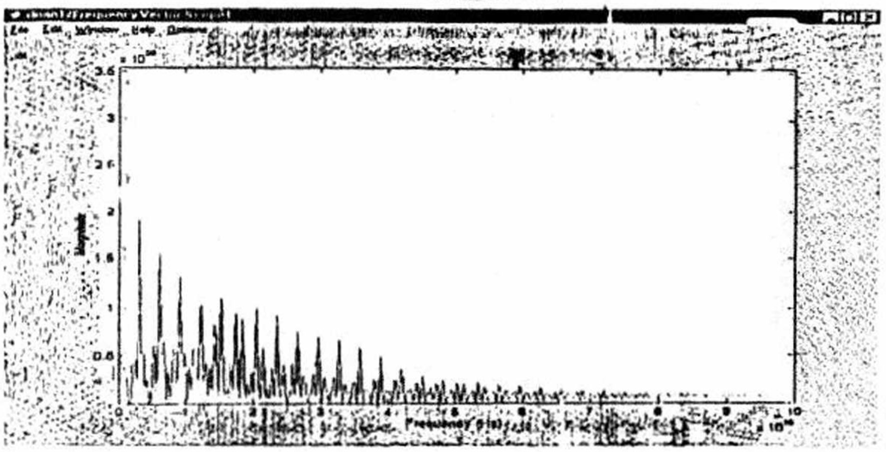

Fig.2b

All transformations of functions $n_j(t)$ or $n_j(\omega)$ will display clearly the change of pulse characteristics under the influence of diverse dynamical parameters .

1. The influence of refraction index n_{eff}

In order to examine the influence of refraction index in two cells, we choose three values of $n_{\text{eff}}(= 3; 3.4; 4)$ and remain constant all other values. By the same numerical method we have received different graphics of functions $n_j(t)$ and $n_j(\omega)$ which presented in Fig. 3 and Fig.4.

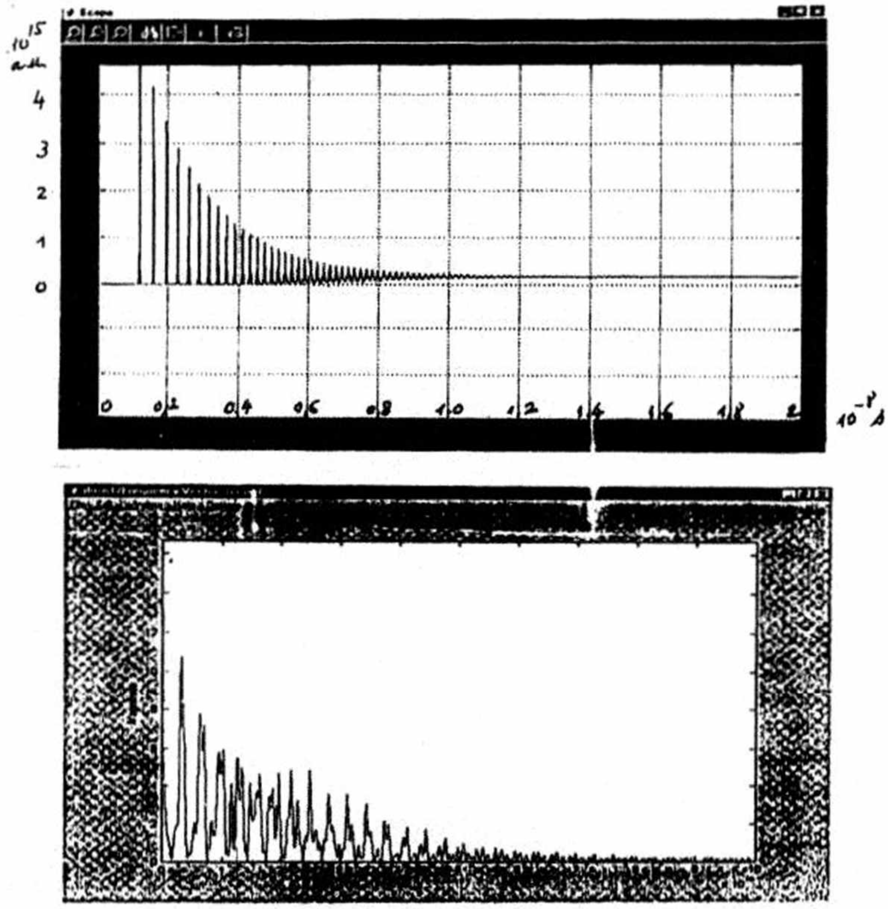
Scope
10^15 a.u.
4
3
2
1
0
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2
10^-8 s

Fig.3

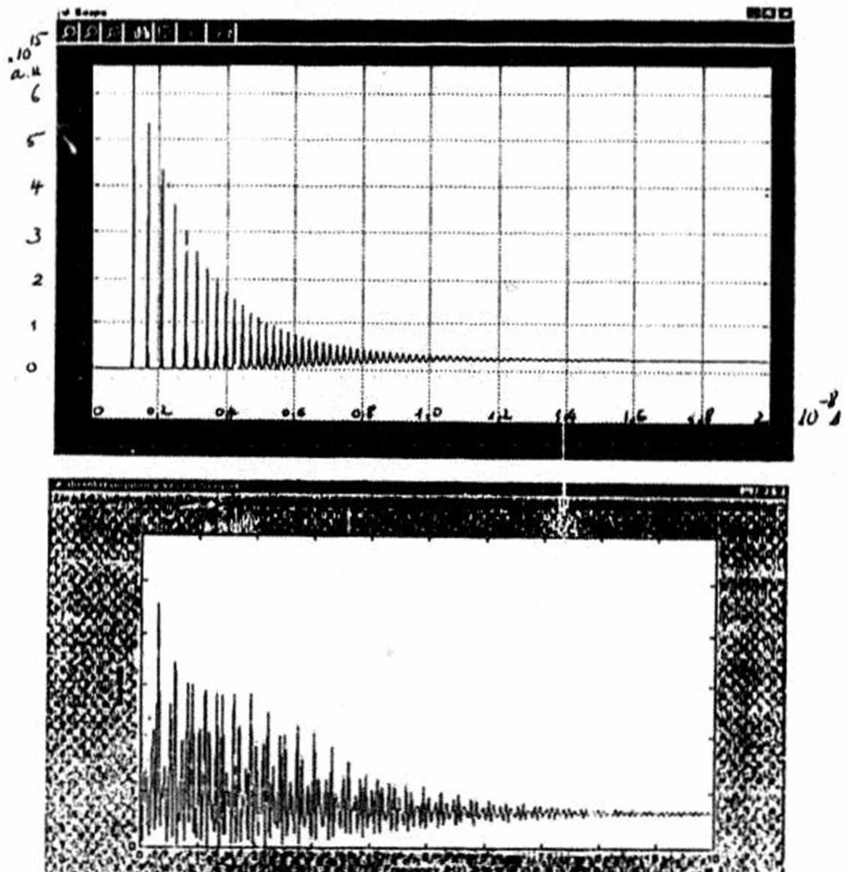
Scope
10^15 a.u.
6
5
4
3
2
1
0
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2
10^-8 s

Fig.4

From these figures we see that the pulse characteristics like the time interval of pulse generation Δt, the repetition rate of pulse frequency Δf and the maximum value of the first pulse intensity I_1 are transformed as seen in Table 1.

Table 1

n_{eff}	Δt	Δf	I_1 (in a.u.)
3.0	0.11×10^{-8}s	3.3GHz	1.8×10^{30}
3.4	0.12×10^{-8}s	3 GHz	1.9×10^{30}
4.0	0.16×10^{-8}s	2.2Hz	4.7×10^{30}

2. The influence of Peterman coefficient Γ_1 in cell A.

In this case we have taken three values of $\Gamma_1 (= 0.3; 0.5; 0.6)$. Repeating the analogous method of calculation, the obtained results about the change of pulse characters are presented in Table 2.

Table 2

Γ_1	Δt	Δf	I_1(in a.u.)
0.3	0.15×10^{-8}s	2.0GHz	0.85×10^{30}
0.5	0.12×10^{-8}s	3.0GHz	1.90×10^{30}
0.6	0.10×10^{-8}s	3.5GHz	2.10×10^{30}

3. The influence of Peterman coefficient Γ_2 in cell B.

We have given Γ_2 three values as $\Gamma_2 = 0.1; 0.2; 0.3$. The results, that are deduced from graphics of functions $n_j(t)$ and $n_j(\omega)$, also display the transformation of pulse characters as presented in Table 3.

Table 3

Γ_2	Δt	Δf	I_1 (in a.u.)
0.1	0.10×10^{-8}s	3.0GHz	2.6×10^{30}
0.2	0.11×10^{-8}s	3.0GHz	1.9×10^{30}
0.3	0.12×10^{-8}s	3.0GHz	1.4×10^{30}

4. Discussion and conclusions

From the changes of graphics of functions $n_j(t), n_j(\omega)$ like from the values in the Tables we can reveal some interesting remarks:

1. The augmentation of refraction index of semiconductor material in two sections results in the increase of pulse intensity I_1 like of time interval of pulse generation Δt, but frequency repetition rate Δf is decreased. This means that for each semiconductor material of constructing DFB laser, one need choose the suitable value of refraction index in order to benefit both the frequency repetition rate as well as the pulse intensity.

2. Peterman coefficients in two sections have contrary influence on pulse characters. The increase of this coefficient in section A (i.e. the increase of Γ_1) leads to the decrease of time interval of pulse generation and the increase of pulse intensity, while the augmentation of Γ_2 in section B leads to the increase and decrease of corresponding quantities cited above. In other words, the role of these Peterman coefficients is opposite. Therefore, choosing appropriate injection currents for two sections will be an important problem in the use of DFB laser with two sections in optical communication. This character of Peterman coefficients is also seen in the stationary operation of DFB laser [7].

3. It is necessary to notice that, all graphics of functions $n_j(t), n_j(\omega)$ received here is deduced from parameter values given above. Clearly, they don't display stable pulses for a long time (some ten ns). This also means that used parameter values are not preferable. However, the change of pulse characters indicated here still reveals the influence of material parameter in the use of DFB laser with two sections in all optical transformation.

References

1. H. Wenzel et al., *IEEE J.QE,* Vol. 32, **1**(1996), p 69.
2. B. Sartorius et al., *IEEE J. QE,* Vol. 33, **2**(1997), p 211.
3. G. Morthier., *IEEE J. QE,* Vol. 33, **2**(1997), p 231.
4. J.D. Freeze et al., *IEEE J.QE,* Vol 33, **8**(1977), p 1253.
5. K. Otsuka et al., *Phys. Rev. A* Vol. 60, **5**(1999), p 3389.
6. Siao-Lung Hwong et al., *Optics Letters,*Vol. 25, **9**(2000), p 646.
7. Dinh Van Hoang et al., *Modern Problems in Optics and Spectroscopy*. Tom. II, (2000) p 406.
9. Junichi Kinoshita., *IEEE J.QE,* Vol. 30, (1994), p 929.

TẠP CHÍ KHOA HỌC ĐHQGHN, Toán - Lý, T.XVIII, Số 2 - 2002

ẢNH HƯỞNG CỦA CÁC THAM SỐ VẬT LIỆU TRONG LAZE DFB LÊN XUNG PHÁT

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Trong bài báo này đã được tìm thấy ảnh hưởng của một số tham số vật liệu như hệ số Peterman, chiết xuất chất bán dẫn... lên các đặc trưng của xung phát, khi dựa vào lời giải bằng số theo phương pháp Runge - Kutta, của hệ phương trình mô tả sự hoạt động không dừng của một DFB laser 2 ngăn .