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Longitudinal Modes Distribution In DFB Laser Diodes With Different Reflector’s

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Abstract

Longitudinal mode distribution in distributed feedback laser diode structures are studied in the present work . The effect of external and internal reflectors are taken into account in solving the eigenvalues equation for propagation constant that derived and solved numerically . The results exhibit that the external and internal reflector’s affect the threshold lasers operation .

توزيع الانماط الطوليه في ليزرات ثنائية البلوره ذات التغذيه الاسترجاعيه لعواكس مختلفه

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الخلاصة

توزيع الانماط الطوليه في ليزرات الثنائية البلوره درست في البحث الحالي ان تأثير العواكس الخارجيه والداخليه قد اخذت بنظر الاعتبار عند اشتقاق وحل معادلة القيم الذاتيه لثابت الانتشار بالطرائق العدديه . لقد اظهرت النتائج ان العواكس الداخليه والخارجه تؤثر على توزيع الانماط الطوليه وعمل اليزات عند حد عتبة الليزر.

Introduction

Laser diodes are one of the important optical sources in the modern optical communication systems, for directly modulated, small structures and easy companied with other electronic circuits (Osowski et al 1998) .

The stability of these structures and its operation with narrow bands are the important features when used with communication .

The stability of longitudinal modes depend on many points . One of these are the reflector's inside the laser structure .The reflectors inside the distributed feedback (DFB) laser structures are obtained by :

i) A periodic DFB structure (corrugations) which is called the internal reflectors (Lo and Shiraz 1995) .

ii)The reflectors that produced by cleaving along a crystallographic planes to produce the parallel surfaces at the end facets and these called the external reflector's (Glinski and Makino 1987) .

The physical control of the relative reflectors-grating is very difficult because of the small period between the gratings for near IR and visible DFB lasers (Shiraz and Chu 1990) . In the present work the external reflector's position are contact with the complete grating at the end facets so a phase will added , i .e ., the mode propagate inside the cavity is due to the external reflector's and grating .

These reflector's play good role in selecting the modes that propagate inside the laser cavity and affected the gain threshold of the main and side longitudinal modes (Lee et al 2000) .

Theoretical model

The model used for our simulation is based on the traveling coupled-wave equations (Yu 1997)

$$\pm\frac{\partial}{\partial \mathbf{z}}\begin{bmatrix}\mathbf{A}\\\mathbf{B}\end{bmatrix}=(\alpha-\mathbf{j}\Delta).\begin{bmatrix}\mathbf{A}\\\mathbf{B}\end{bmatrix}+\mathbf{jke}^{\pm\mathbf{j}\Phi}\begin{bmatrix}\mathbf{A}\\\mathbf{B}\end{bmatrix} \qquad (1)$$

where A and B are the two fields propagate with opposite velocity inside the laser cavity . α is the amplitude gain coefficient and Δ is the mode frequency detuning from the Bragg condition where $\Delta=\beta-\beta_o$, β and β_o are the mode wave propagation constant and the wave number at the Bragg condition respectively and Φ is the optical phase. Equation 1 has best solution in the form

$$A(z)=a_1\exp(\eta z)+a_2\exp(-\eta z) \qquad (2)$$

$$B(z) = b_1 \exp(-\eta z) + b_2 \exp(\eta z) \qquad (3)$$

where $a_1, a_2, b_1 and, b_2$ are constants and can be determined by using the boundary conditions

$$A(0) = \rho_r B(L) \qquad (4)$$

$$B(L) = \rho_\ell A(0) \qquad (5)$$

where ρ_r and ρ_l are the right and left facets reflectivity of laser structure and L is the laser cavity length ..

Substituting eqs. (2- 5) into eqn.1 the threshold condition of the DFB laser can be determined

$$\begin{gathered}(1 + j\rho_\ell \gamma / k)(1 + j\rho_r \gamma / k)\exp(-\eta z) - \\ (\rho_\ell + \gamma / k)(\rho_r + \gamma / k)\exp(\eta z) = 0\end{gathered} \qquad (6)$$

where ,

$$\rho_i = \rho_i^- \exp(\pm j\Phi_i) \quad , \ (\text{i= r}, \ell) \qquad (7)$$

From the above analysis the complex wave constant η and the parameter γ are satisfying the following expressions

$$\eta^2 = (\alpha - j\Delta)^2 + k^2 \qquad (8)$$

$$\gamma = -\eta + \alpha - j\Delta \qquad (9)$$

Equation 6 can be solved numerically following the method outline (Duran etal 1990), then the normalized gain αL and detuning ΔL can be obtained .

Simulation results

The previous model has been tested for several types of DFB laser diodes where k, Φ, ρ_ℓ and ρ_r are varied . Figure 1 illustrates the normalized gain versus normalized detuning for three longitudinal modes (m = 1 , 2 and 3) with :

$\rho_\ell = \rho_r = .565\exp(j\pi)$. This figure shows that for small kL the three modes have high gain which decreases with increment of kL and the three modes propagate near $(\Delta L > kL, kL = 1{,}2)$ but for (kL > 3) the modes propagate within $\Delta L \cong kL$. Its clear that the reflector's are more important than the grating in determining the mode distribution inside the cavity , which mainly determine by the cavity dimensions .

Figure 2 shows same as in Fig.1 but for DFB laser with single reflector (i.e., $\rho_\ell = 0$ and $\rho_r = .565\exp(j\pi)$) . The results exhibit increase in mode gain with respect to that of DFB laser with two reflectors (Fig.1) , and this is because the grating affected the device behavior beside the single reflector in the right end and still the laser with small kL , propagate near $\Delta L > kL$ and those with kL>3 propagate near $\Delta L \cong kL$.

Distributed feedback laser without reflector's $\rho_\ell = \rho_r = 0$ are tested and the results are given in Fig.3 . The results show that the three modes propagate with high gain more than those given in Figs 1 and 2 and this is because the grating is more important than the reflector's in determining the laser behavior specially for small value of kL . For compression propose ,the mode m=1 for the previous cases under view was plotted in Fig. 4 .

The effect of the reflector's on the laser operation (i.e single mode or multimode operation) can be determined by calculating the gain margin : $\delta\alpha L = \alpha L_{m=2} - \alpha L_{m=1}$ where in the DFB laser the criteria for single mode operation is that $\delta\alpha L > 0.25$. the gain margin as a function of coupling coefficient is listed in Tables 1 , 2 and 3 and plotted in Fig .5 for three cases under view . The results show that DFB laser without reflector's (curve c) exhibits high gain margin than the other two cases ; curves a and b (two reflector's and single reflector , respectively) .

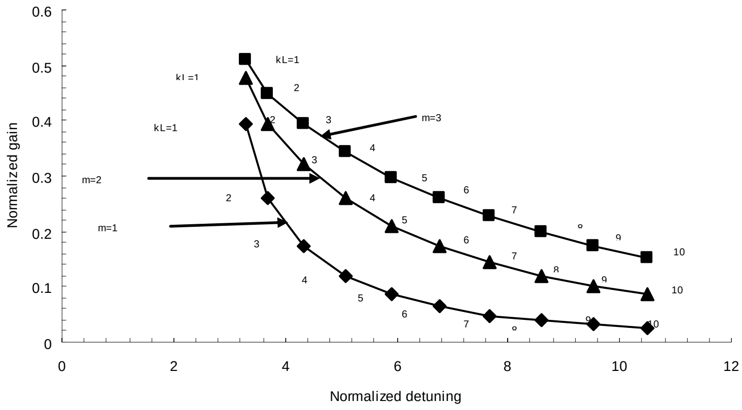

Fig.1 The normalized gain as a function of normalized detuning for different normalized coupling coefficient for three modes (m=1,m=2 and m=3) propagate inside the DFB laser cavity with two external reflectors.

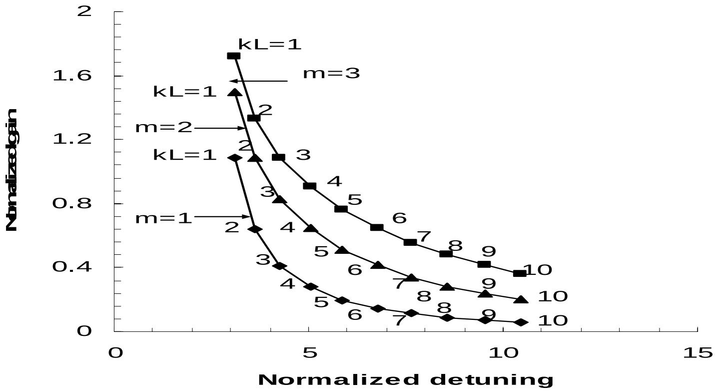

Fig.2 The normalized gain as a function of normalized detuning for different normalized coupling coefficient for three modes (m=1,m=2 and m=3) propagate inside the laser cavity with single external reflector.

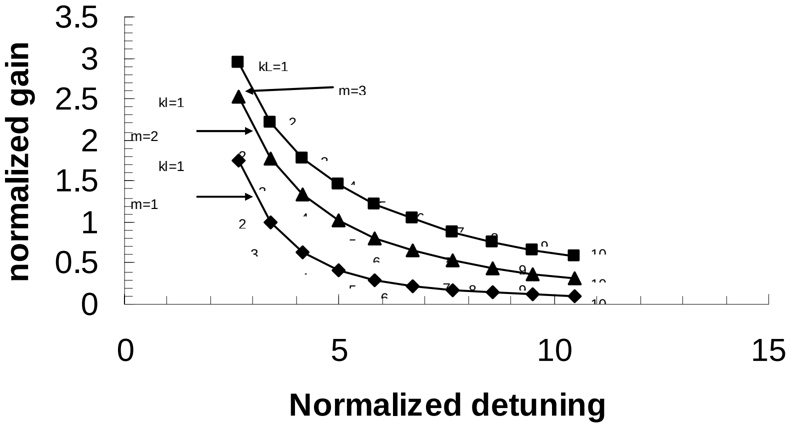

Fig.3 The normalzed gain as a function of normalized detuning for different normalized coupling coefficint for three modes (m=1,m=2 and m=3) propagate inside the DFB laser cavity without external reflectors

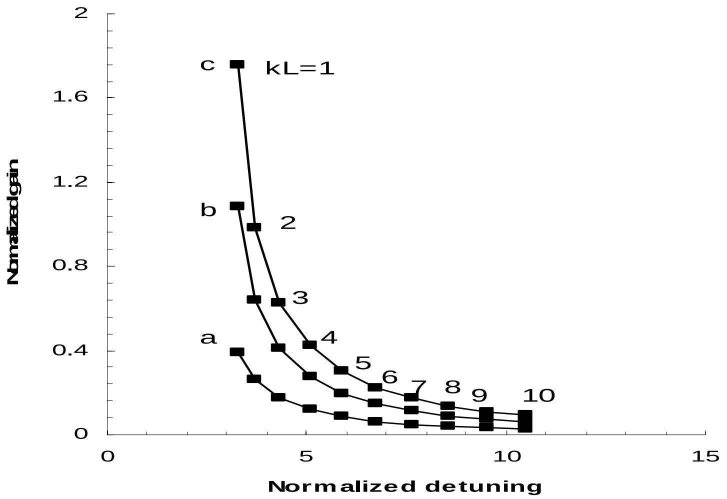

Fig.4 The normalized gain as a function of normalized detuning for different normalized coupling coefficient for m=1 propagate inside the laser cavity with a) 2 external reflectors b) single external reflector c) without external reflectors

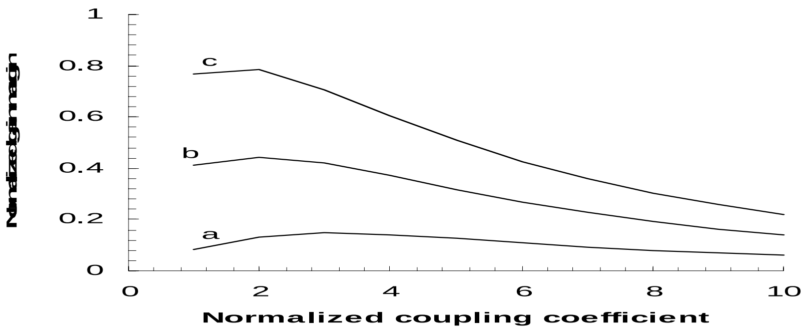

Fig.5 Normalized gain margin as a function of normalized coupling coefficient for DFB laser diode with a) 2 external reflectors b) 1 external reflector c) without external reflectors

Table 1: Mode gain margin values for DFB laser with two reflector's .

Coupling coefficient (normalized)	Main mode gain (normalized)	Side mode gain (normalized)	Gain margin (normalized)
1	.3938	.4779	.0841
2	.2593	.3930	.1337
3	.1723	.3197	.1474
4	.1187	.2593	.1406
5	.0851	.2109	.1258
6	.0633	.1727	.1094
7	.0486	.1426	.0940
8	.0384	.1190	.0806
9	.0310	.1002	.0692
10	.0255	.0853	.0598

Table 2: Mode gain margin values for DFB laser with single reflector .

Coupling coefficient (normalized)	Main mode gain (normalized)	Side mode gain (normalized)	Gain margin (normalized)
1	1.0852	1.4971	.4119
2	.6393	1.0839	.4446
3	.4082	.8280	.4198
4	.2766	.6473	.3707
5	.1970	.5144	.3174
6	.1461	.4148	.2687
7	.1121	.3391	.2270
8	.0882	.2808	.1926
9	.0713	.2354	.1641
10	.0587	.1995	.1408

Table 3 : Mode gain margin values for DFB laser without reflector’s .

Coupling coefficient (normalized)	Main mode gain (normalized)	Side mode gain (normalized)	Gain margin (normalized)
1	1.7545	2.5243	.7695
2	.9846	1.7692	.7846
3	.6226	1.3279	.7053
4	.4224	1.0273	.6041
5	.3019	.8113	.5094
6	.2247	.6518	.4271
7	.1729	.5316	.3587
8	.1367	.4397	.3030
9	.1105	.3682	.2577
10	.0911	.3120	.2209

References

Duran G.H , Gallion P. and Debarge G . ,"Analysis of the Phase Amplitude Coupling Factor and Spectral Linewidth of distributed Feedback and Composite-Cavity Semiconductor Lasers", IEEE , Q.Elec. , Vol.26 , No. 1 , 1990 .

Glinski J. and Makino T. ," Yield Analysis of Second-Order DSM DFB Lasers and Implication for Design ", Q.Elec .,Vol.23, No.6,1987 .

Lo B.S.K. and Shiraz H.G. , " Spectral Characteristics of Distributed Feedback Laser Diodes with Distributed Coupling Coefficient ", Lightwave Tech.,Vol.13,No.2,1995.

Lee H .S . , Kim H . K . , Kim B .G . and Lee B. , " Distributed Feedback Lasers with Refractive – Index - Modulated Upper Cladding Layer of the Grating for Reducing the Spatial Hole – Burning Effect ",Mic. and Op.Tech Letters,Vol. 26,No.3,2000 .

Osowski M .L ., Hughes J.S. and Coleman J. J. ," Effect of p-Contact Metallization on the Performance of Gain - Coupled DFB's with Oxide-Defined Surface Grating ", IEEE , Pho.Tech. Letters , Vol. 10,No.7,1998 .

Shiraz H . G and Chu C .Y. J . , " Effect of Phase Shift Position on Spectral Linewidth of the $\pi/2$ Distributed Feedback Laser Diode", Lightwave Tech.,Vol.8,No.7,1990 .

Yu S.F. ," Double - Tapered - Waveguide Distributed Feedback Lasers for High- Power Single-Mode Operation", IEEE, Q.Elec, Vol.33,No.1,1997 .