Single longitudinal mode, symmetrical three-cavity GaInAsP/InP lasers

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Two ways of improving the mode-selection characteristics of diode lasers are analysed. The mode-selection mechanism and technological processes are presented for symmetrical three-cavity lasers, and the experimental results are in good agreement with theoretical results.

1. Introduction
In order to realize long-distance signal propagation with large capacity and high efficiency, it is necessary to use the single longitudinal mode InGaAsP/InP laser in an optical communication system. Three ways can be used to strengthen the single longitudinal mode operation: increasing the interval between two modes; raising the side-mode losses; and locking the modes by using external injection.

2. Mode-selection characteristics in symmetrical three-cavity lasers
The structure of the symmetrical three-cavity laser is shown in Fig. 1. Each of the two ends of the cavity $L_1$ is connected to a cavity $L_2$ in which some parameters are the same as in the cavity $L_1$. Considering the effective reflection of the cavity $L_2$ for the light wave in the cavity $L_1$, we can obtain the effective reflectivity in terms of the multiple reflection theory [1, 2]

$$r_e = \frac{\gamma_1 + \gamma_2 e^{x_{L2}}}{1 + \gamma_1 \gamma_2 e^{x_{L2}}} \tag{1}$$

Let

$$r_e = |\gamma_e| e^{i\delta_e}$$

When $g_2 = 0$ ($g_2$ is the gain in the short cavity $L_2$),

$$|r_e| = \left( \frac{-\gamma_1^2 + (\gamma_2 e^{x_{L2}})^2 + 2\gamma_1 \gamma_2 e^{x_{L2}} \cos 2\beta_2 L_2}{1 + (\gamma_1 \gamma_2 e^{x_{L2}})^2 + 2\gamma_1 \gamma_2 e^{x_{L2}} \cos 2\beta_2 L_2} \right)^{1/2} \tag{2}$$

$$|\delta_e| = \arccot \frac{\gamma_1 [1 + (\gamma_2 e^{x_{L2}})^2] + \gamma_2 e^{x_{L2}} (1 + \gamma_1^2) \cos 2\beta_2 L_2}{\gamma_2 e^{x_{L2}} (1 - \gamma_1^2) \sin 2\beta_2 L_2} \tag{3}$$

Using $r_e$, the symmetrical three-cavity laser, as shown in Fig. 1a, can be transformed into an equivalent single-cavity $L_2$ which is replaced by an equivalent interface $M_e$. It is obvious
that methods for and results from the usual single-cavity case can be used for this equivalent single cavity. The cavity loss, threshold and phase conditions are given by, respectively:

\[ \alpha_m(\lambda) = \frac{2}{L_1} \ln \left( \frac{1}{|r_1|} \right) \]  

\[ G = \alpha_m \]  

\[ 2\delta_c + 2\beta L_1 = 2m\pi \quad m = 1, 2, 3, \ldots \]  

Some questions are discussed as follows.

2.1. Cavity loss \( \alpha_m(\lambda) \)

In Equation 2 the expression for \( |r_1| \) can be changed into a simpler form when \( 2\beta L_2 = 2m_2\pi, (2m + \frac{1}{2})\pi, (2m + 1)\pi \), and three special values \( \alpha_m^1, \alpha_m^2 \) and \( \alpha_m^3 \) are obtained. Based on these above special values, the \( \alpha_m(\lambda) \) curve can be obtained roughly, as shown in Fig. 2 when \( \tilde{n}_1 > \tilde{n}_2 > n_0 \). It is shown that the variation of \( \alpha_m(\lambda) \) with \( \lambda \) possesses the appropriate relationship of \( \lambda_m \), where, \( \lambda_m \) is the mode spectrum when the cavity \( L_2 \) is thought of as a single cavity. The larger \( \Delta \alpha_m \) is of great advantage for strengthening the suppression of the side-mode oscillation. It can be proved that, when the parameters selected satisfy the condition

\[ (g_2 - \chi_1) L_2 = \ln \frac{(\tilde{n}_1 - \tilde{n}_2)/(\tilde{n}_1 + \tilde{n}_2)}{(\tilde{n}_2 - n_0)/(\tilde{n}_2 + n_0)} \]

\[ \tilde{n}_1 > \tilde{n}_2 > n_0 \]

\[ \Delta \lambda m = \lambda_m + \lambda_{m+1} \]

\[ \alpha_m(\lambda) \]