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TEMPERATURE DEPENDENCE OF DIFFERENTIAL GAIN CONSTANT AND CARRIER DENSITY AT TRANSPARENCY FOR InGaAsP/InP SEMICONDUCTOR LASER DIODES

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One of the most important parameters for the active layer of a laser diode is the differntial gain constant g_0(cm^3/sec) and the transparency carrier density N_T (cm^{-3}) at which the peak - gain coefficient $g=0$. The particular composition $In_{0.72}Ga_{0.28}As_{0.6}P_{0.4}$ of undoped active layer which lattice matches InP, is chosen because its bandgap ($E_g = 0.96$ eV at $\lambda = 1.3$ μm) is at a region of low - loss and minimum dispersion in optical fibers [1]. Based on the parabolic model of the peak - gain which relates the peak - gain coefficient, g, of the laser diode to the injected carrier density N [2], one can calculate the parameters g_0 , and N_T at different temperatures for undoped InGaAsP active layer.

The dependence of the laser diode peak-gain coefficient, g, of an undoped quaternary InGaAsP material with injected carrier density N at 1.3 μm band wavelength can be well-approximated by a parabolic model of the form [2]

$$g = \alpha N^2 + \beta N + \gamma \quad , \tag{1}$$

where N is the injected carrier density and α, β, and γ are the gain parameters and are functions of temperature, band wavelength and doping of the active layer. The solid curve in Fig.1 shows the superlinear relationship between the gain g and the injected carrier density N neglecting the low gain region. The commonly used linear approximation model is of the form [2]

$$g = A (N - N_T) \quad , \tag{2}$$

where A (= dg/dN) is the gain constant (cm^2) and N_T is the transparency value of carrier density illustrated by broken lines in Fig. 1.

Neglecting the low gain region, we can fit Eq.(2) with Eq.(1) to get the constants A and N_T in terms of α, β, and γ. We can express the relationship between the differential gain constant g_o and the constant A in the following form

$$g_o = v.A \quad , \tag{3}$$

where v is the speed of light in the active medium that is defined as

$$v = \frac{c}{n_r} \quad , \tag{4}$$

with c the light speed in vacuum and n_r the refractive index of the active medium given by [2]

$$n_r = 3.4 + 0.256\, y - 0.095\, y^2 \quad , \tag{5}$$

with y (= 0.6) the As composition in the active layer. The dependence of peak – gain coefficient on injected carrier density at different temperatures ranging from -10 °C to 50 °C is illustrated in Fig.2 for undoped InGaAsP material at a wavelength $\lambda = 1.3\,\mu m$.

Based on the data given in Ref.[2] and using a curve fitting computer program, we have obtained general forms for the temperature dependence of the three parameters α, β and γ as

$$\alpha = 4.29467 * 10^{-34} \exp (-0.00329828\, T) \quad , \tag{6}$$

$$\beta = -7.75887 * 10^{-16} \exp (0.002097630\, T) \quad , \tag{7}$$

$$\gamma = 347.373 \exp (0.00761227\, T) \quad . \tag{8}$$

Using these forms in Eq. (1) , one can get the temperature dependence of the peak gain coefficient g. Then using again the curve fitting computer program to approximate the gain g to a linear dependence on the injected carrier density N, as given in Eq. (2) , one can get N_T the carrier density at transparency and the constant A as functions of temperature. The transparency carrier density N_T has been obtained as

$$N_T = 10^{18} * (1.47369 + 0.00212129\, T + 8.43604 * 10^{-6}\, T^2 + 5.97474 * 10^{-8}\, T^3 + 1.74918 * 10^{-10}\, T^4) \; . \qquad (9)$$

From the obtained relation for the constant A, and using Eqs. 3 - 5, we have obtained the differential gain constant, g_o, as a function of temperature in the form

$$g_o = (8.93472 - 0.0651316\, T + 6.43553 * 10^{-5}\, T^2 + 1.00126 * 10^{-7}\, T^3 + 1.05953 * 10^{-9}\, T^4) * 10^{-6} \qquad (10)$$

Figures 3(a, b and c) show the variations of parameters α, β and γ with temperature ranging from -200°C up to 150°C.

Figure 4 displays the variation of both the differential gain constant g_o and the carrier density of transparency N_T with temperature. The results obtained have a good agreement with the experimental one [3] and show that the differential gain constant, Fig.4, increases with cooling the laser in consistence with that reported in Ref.4.

References

[1] N.K.Dutta, J.Appl.Phys., vol.51, P. 6095-6100, 1980.

[2] H.Ghafoori-Shiraz, J.Lightwave Tech., vol.LT-6, P.500-506, 1988.

[3] J.E.Bowers, IEEE J. Quantum Elec., vol.QE-22, P.833-843, 1986.

[4] J.E.Bowers, Electron.Letters, vol.21, P.1090-1091, 1985.

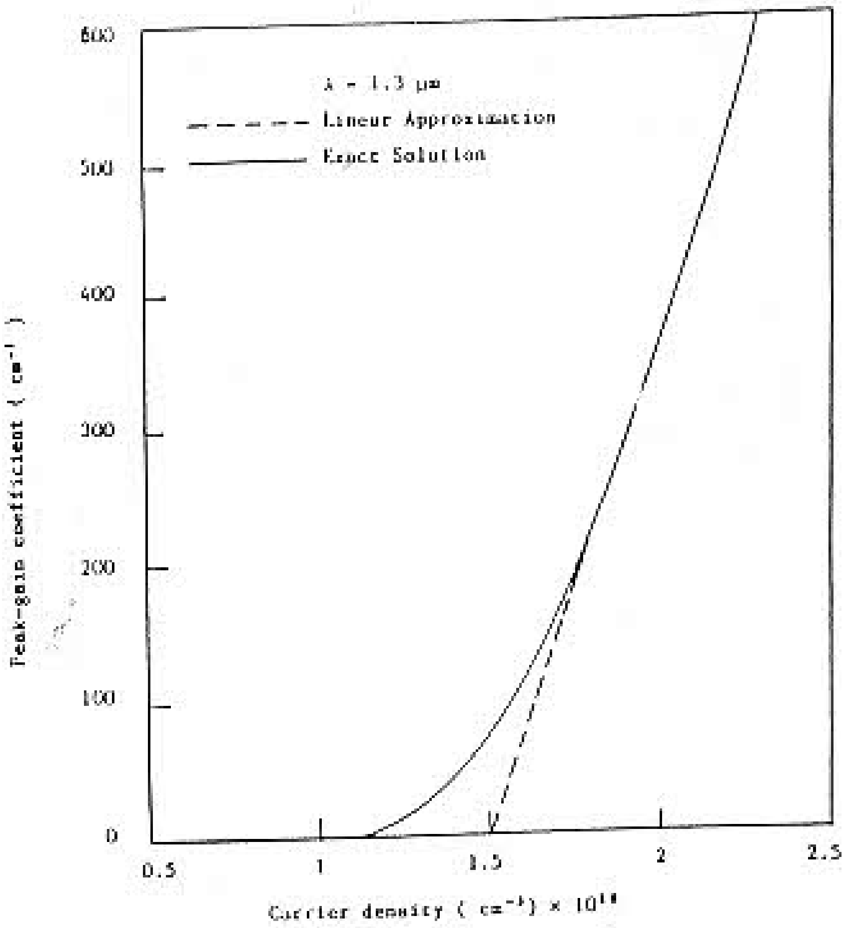

Fig.1. Variation of peak-gain coefficient with injected carrier density for undoped 1.3 μm band wavelength semiconductor laser diode .

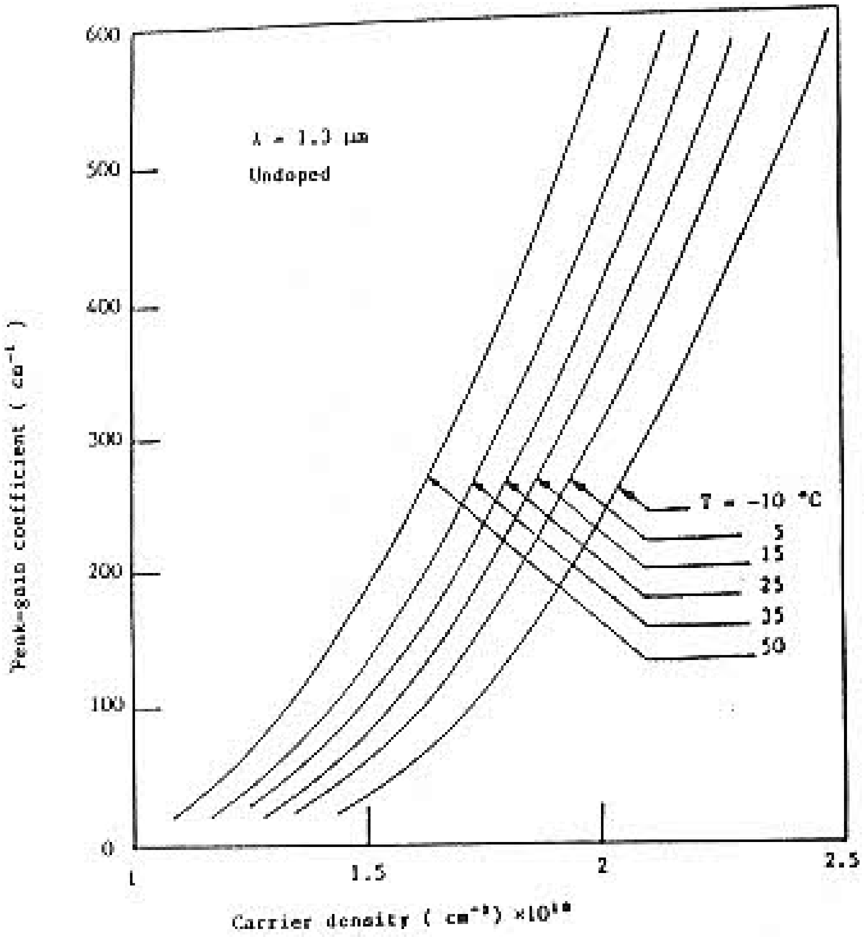

Fig.2. Variation of peak-gain coefficient with injected carrier density in an undoped InGaAsP quaternary alloy at different temperatures .

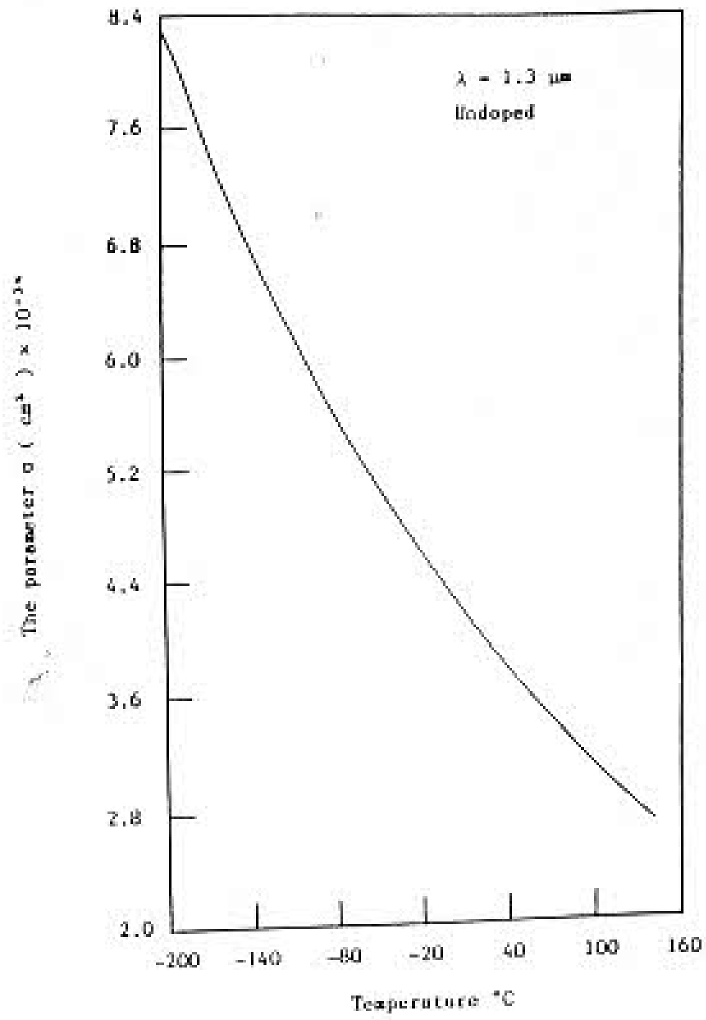

Fig.3-a. Variation of the parameter α with temperature .

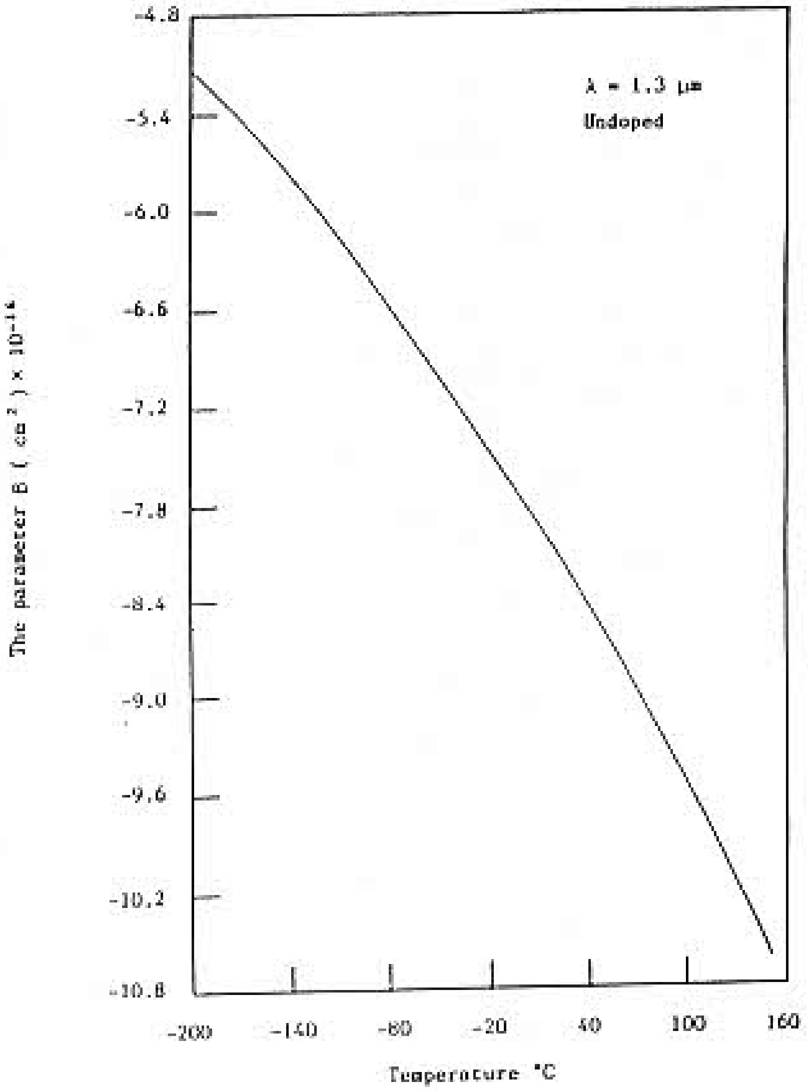

Fig.3-b. Variation of the parameter β with temperature.

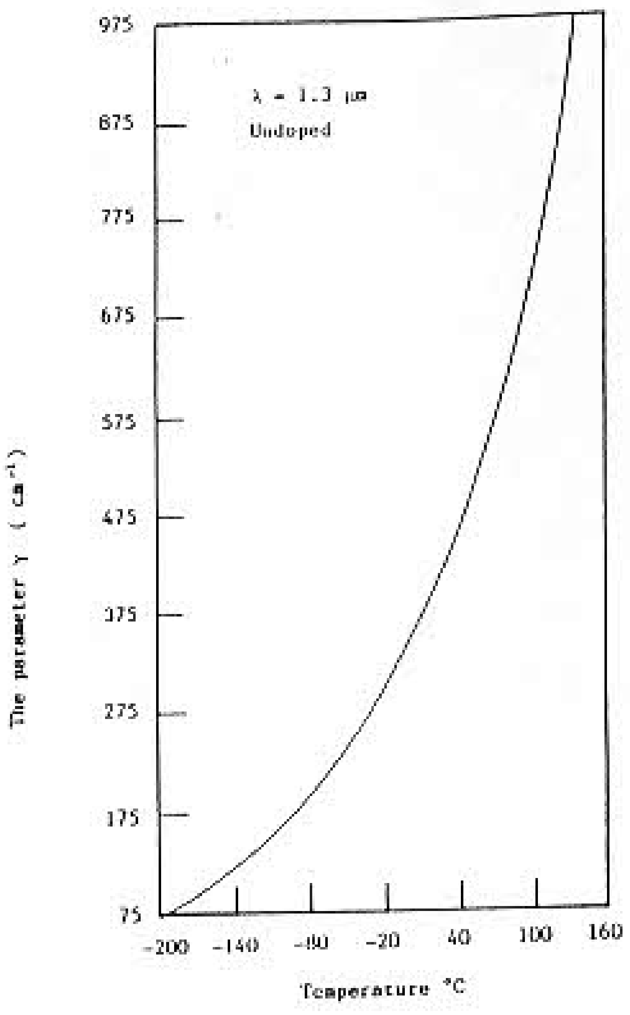

Fig.3-c. Variation of the parameter γ with temperature .

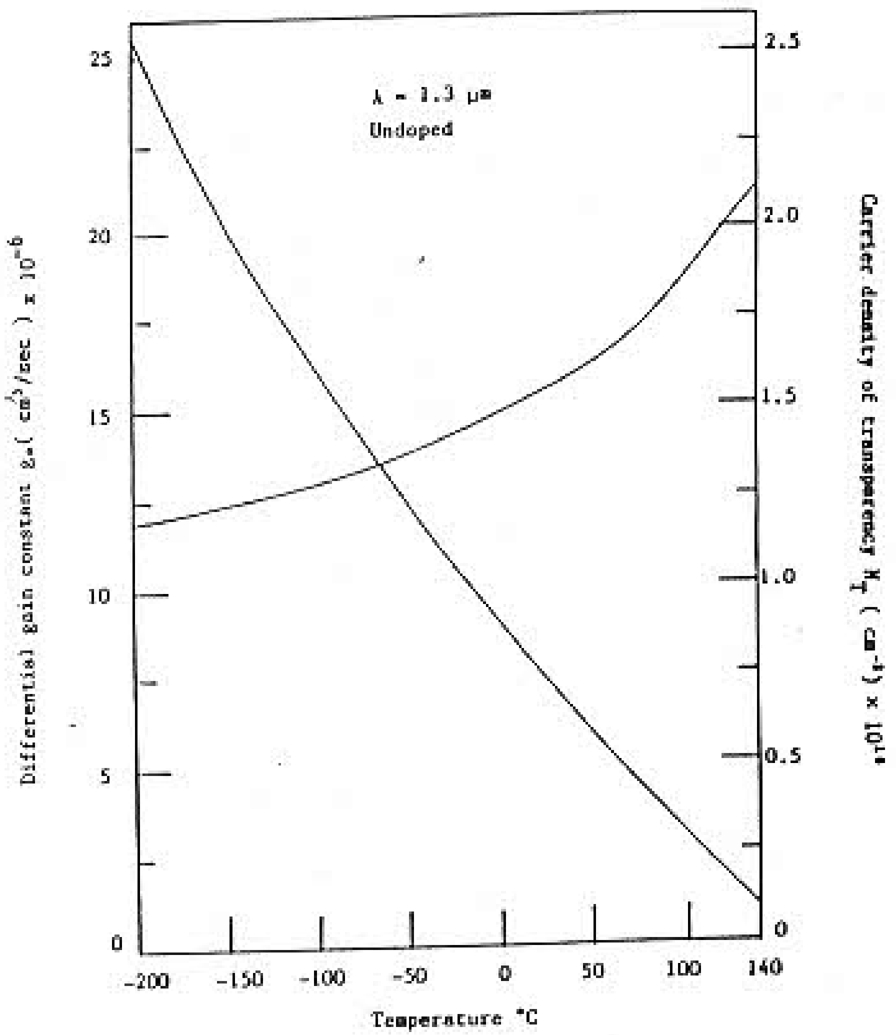

Fig.4. Variation of the differential gain constant g_* and the carrier density of transparency N_T with temperature .