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Letter to the Editor

Simple method for an experimental determination of a coupling coefficient in arrays of diode lasers*

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A simple method for an experimental determination of coupling coefficient in arrays of diode lasers is proposed. The coupling coefficient is related to a difference of threshold current densities for a solitary laser and for a coupled laser. This difference may be easily determined experimentally.

1. Introduction

The coupled-mode theory [1] is a very powerful tool in analysing the operation of diode-laser arrays. The key parameter in this formalism is the coupling coefficient γ between coupled waveguides. Analytical expressions for this coefficient are well known for various waveguides (e.g., [2]–[8]). The purpose of this work is to propose a simple method for an experimental determination of the coupling coefficient between diode lasers composing an array. To some an extent, the approach presented in this work is similar to that reported by Kawaguchi and Matsumoto [9].

2. Threshold condition for a solitary laser

The threshold condition for a solitary diode laser (Fig. **a**) may be written as

$$R_F R_R \exp[2L(g_{TH}-\alpha_L)] = 1 \tag{1}$$

where the coefficient of internal losses may be expressed as the following sum:

$$\alpha_L = \Gamma\alpha_A + (1-\Gamma)\alpha_P + \alpha_S + \alpha_C, \tag{2}$$

and where the following notations are used: R_F and R_R – reflectivities from the front and the rear laser mirrors, respectively; L – length of a laser resonator, g_{TH} – threshold local gain, Γ – confinement factor, α_A – loss coefficient in the active layer, α_P – analogous coefficient in the passive confinement layers, α_S – coefficient of scattering losses, and α_C – coefficient of coupling losses (c.f. [10]).

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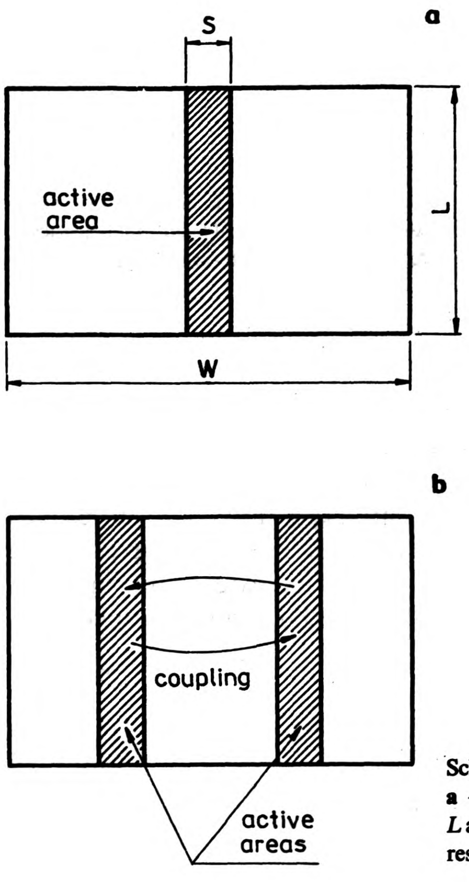
Radiation losses α_A within the active layer are caused mainly due to the free-carrier absorption [11]

$$\alpha_A[\mathrm{cm}^{-1}] = 3\times10^{-18}n+7\times10^{-18}p \quad (3)$$

where the electron concentration n and the hole concentration p should be expressed in cm^{-3}.



Schematic representation of a diode-laser resonator for: **a** – a solitary diode laser, **b** – two coupled diode lasers. L and W are the length and the width, respectively, of the resonator, S is the stripe width

3. Threshold condition for coupled lasers

For coupled diode lasers (Fig. **b**), the analogous to (1) threshold condition may be written in the following form:

$$R_F R_R(1+\gamma)\exp[2L(g_{TH,C}-\alpha_L)] = 1 \quad (4)$$

where γ is the coupling coefficient between both lasers. In this case, the threshold value of the local gain $g_{TH,C}$ is less than g_{TH} determined for a solitary diode laser

$$g_{TH,C} = g_{TH}-g_C, \quad (5)$$

because some part of the radiation which leaks out the active area being lost for a solitary laser, in the case of coupled diode lasers penetrates the second laser waveguide, lowering its threshold local gain.

4. Method for the determination of the coupling coefficient

The most important consequence of a decrease in the threshold gain from g_{TH} to $g_{TH,C}$ is an analogous decrease in a threshold current density from j_{TH} to $j_{TH,C}$. The threshold current density is usually related to the nominal current density j_{NOM} [10]

$$j_{TH} = j_{NOM}(d_A/a_i) \tag{6}$$

where d_A is the thickness of the active layer, and a_i is the internal quantum efficiency. The local gain is in turn dependent on the nominal current density in the following way [10]:

$$g = A(j_{NOM} - j_1) \tag{7}$$

where for GaAs/(AlGa)As diode lasers: $A = 0.050$ cm μm/A and $j_1 = 4500$ A/cm$^2\mu$m. Then the change g_C of the local threshold gain appears to be proportional to the change $j_{TH} = j_{TH,C}$ of the threshold current density

$$g_C = (a_i A/d_A)(j_{TH} - j_{TH,C}). \tag{8}$$

The coupling coefficient γ is in turn connected with the change g_C of the threshold gain in the following way:

$$\gamma = \exp(g_C L) - 1. \tag{9}$$

Thus, with the aid of Equations (8) and (9), the coupling coefficient γ is related to the change $j_{TH} = j_{TH,C}$ of the threshold current density, which follows a transition from a solitary diode laser to a coupled diode laser and which may be easily determined experimentally.

5. Conclusions

In the present work, a simple experimental method for the determination of the coupling coefficient is proposed for two diode lasers. In the case of an array of more numerous diode lasers, the same method gives an averaged coupling coefficient for the whole array.

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Простой метод экспериментального определения коэффициента связи в линейках лазерных диодов с усиленными волноводами

В настоящей работе предложен простой метод экспериментального определения коэффициента связи в линейках лазерных диодов с усиленными волноводами. Коэффициент связи связан с разницей плотностей порогового тока для отдельного лазера и для связанного лазера. Эту разницу можно легко определить экспериментально.