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Influence of laser parameters on the stationary operation of a two-mode random micro laser

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Abstract. Solving the system of equations describing the stationary operation of a two-mode random microlaser we have found the transformation of saturated values of mode intensity when laser parameters as gain and loss coefficients as well as field coupling, photon hopping coefficients vary. From obtained results we determined which parameter takes the most important role for stationary operation of random microlasers.

Keywords: Random microlaser, field coupling.

1. Introduction

The study of random microlaser has been begun since three decades ago. Random lasing has been found in ZnO powder [1,2], in solution of TiO_2 nanoparticles, in Rhodamine dye in polymethy-methacrylate (PMMA) or in some polymer systems [3,4]. Recently, experiments showed random laser action with sharp lasing peak [5, 6]. The explanation of this has been not done yet.

There are many theoretical models that were established like John et al [7] combining the electron number equations of energy level with diffusion equation, Berger et al [8] using a Monter Carlo simulation and recently Kiang et al [9] combining a FDTD method with the semi classical laser theory [10]. However, at present the research on random laser is concentrated to the steady-state properties. Therefore, in this paper we examine the stationary operation of two-mode random microlaser. Starting from basic equations for two-mode random microlaser presented in [11], we have solved the basic equations in stationary regime by using numerical method.

The obtained results are shown in Section 2. In Section 3, we give the curves describing the influence of laser parameters on the saturated values of mode intensities and Section 4 devoted to discussion and conclusion.

2. Basic equations and solving method

In stationary regime, from [11] we have the system of equations:

$$\alpha_1 n_1 - \beta_1 n_1^2 - \theta_{12} n_1 n_2 + \gamma_{21} n_2 = 0 \tag{1}$$

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$$\alpha_2 n_2 - \beta_2 n_2^2 - \theta_{21} n_2 n_1 + \gamma_{12} n_1 = 0 \quad (2)$$

Where $\alpha_i, \gamma_i (i = 1, 2)$ denote gain and loss coefficients, θ_{12}, θ_{21} - field coupling coefficients, γ_{12}, γ_{21} - photon hopping coefficients, n_1, n_2- photon densities of mode 1 and 2.

These equations (1), (2) have been solved numerically by the Matlab language with chosen values of parameters shown in Table 1 (as seen in [12]).

Table 1.

$\alpha_1 = 1.1$	$\beta_1 = 0.4$	$\theta_{12} = 0.8$	$\gamma_{12} = 0.35$
$\alpha_2 = 0.9$	$\beta_2 = 0.3$	$\theta_{21} = 0.7$	$\gamma_{21} = 0.35$

For studying the influence of laser parameters on saturated values of mode photon densities, we vary one of parameters in table 1 and remain invariable all the rest of parameters. The obtained results are shown in Section 3.

3. Influences of laser parameters on saturated photon densities

3.1. Gain coefficients α_i

The curves presents in Fig.1 show the transformation of photon densities n_1, n_2 when α_1, α_2 vary.

We see that, when the gain coefficient α_1 augments, the mode photon density n_1 is increased and the one of mode 2 n_2 is diminished (see Fig 1a). However, when the gain coefficient α_2 augments, the transformation of photon densities is inverse (see in Fig 1b). This reveals that the increase of one mode photon density caused in the decrease of the other one.

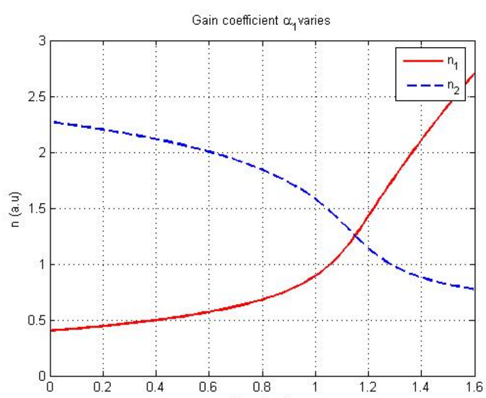

Fig. 1a. Gain coefficient α_1 varies.

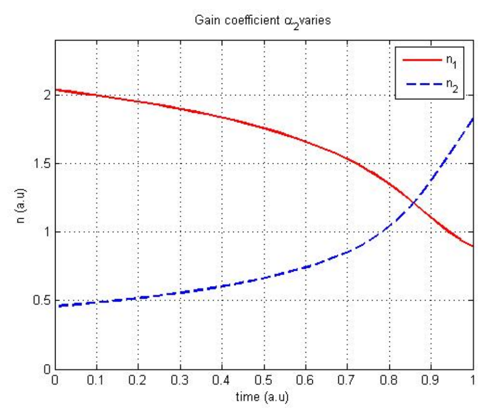

Fig. 1b. Gain coefficient α_2 varies.

3.2. Loss coefficients β_i

In this case, the augmentation of loss coefficient of one mode will decrease the photon density of this mode but increase the one of other mode as seen in Fig 2a, 2b.

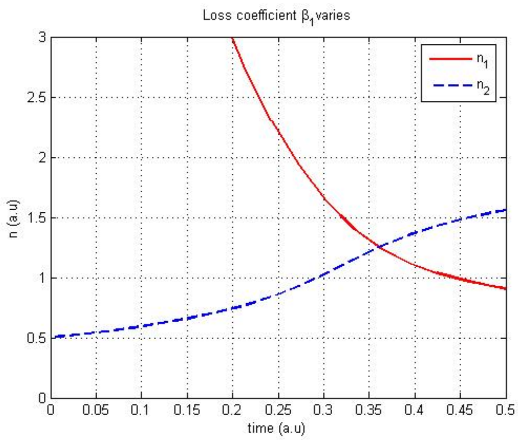

Fig. 2a. Loss coefficient β_1 varies.

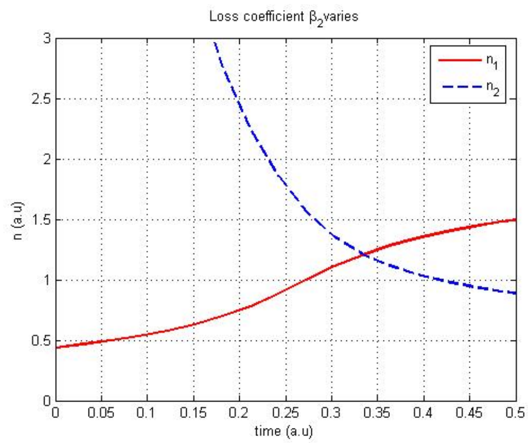

Fig. 2b. Loss coefficient β_2 varies.

3.3. Field coupling coefficients $\theta_{i,j}$

Analogously, the influence of field coupling coefficients θ_{12} and θ_{21} on the photon densities is inverse (see Fig 3a, 3b). This shows that in the process of interation between the fields of two modes, the increase of photon density of one mode always results in the decrease of photon density of other mode.

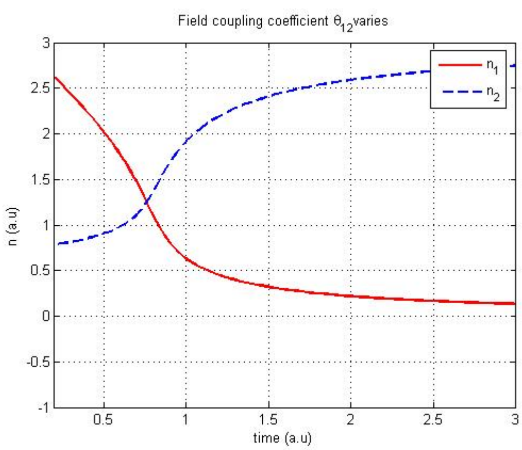

Fig. 3a. Field coupling coefficient θ_{12} varies.

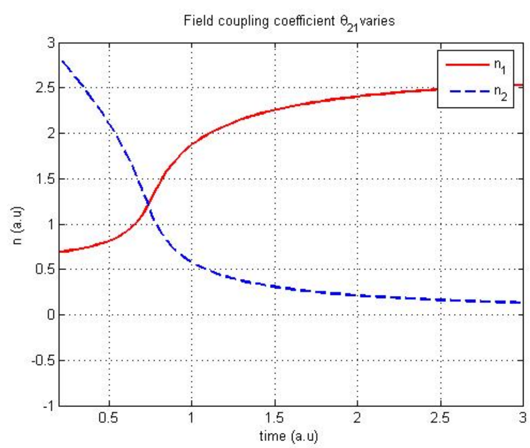

Fig. 3b. Field coupling coefficient θ_{21} varies.

4. Discussion and conclusion

In the stationary operation of two-mode random microlaser, the variation of laser parameters influences clearly on the transformation of mode photon densities. With each parameter, its influence on two modes almost is inverse. The increase of photon intensity of one mode makes the decrease of the one of other mode. The reason perhaps is due to the conservation of energy in the operation of two-mode random microlaser. However, this result reflects the energy transformation and the complex interaction process inside the laser powder that needs to be investigated thoroughly. We also note that with a small transformation of loss coefficient, the mode photon density varies clearly and quickly. Therefore, loss coefficient takes the important role in the process transformating the mode photon density in random laser that has been indicated in same experiments works (see [5]). At last, we hope this study method realized here will be extended to the case of multimode random microlaser afterwards.

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