Anticipated Synchronization of DFB Lasers with Passive Dispersive Section

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***Abstract* — We present a new model for the observation of phenomenon of anticipated synchronization in distributed feedback (DFB) lasers with passive dispersive reflector. The influence of parameters on anticipated synchronization in passive dispersive reflector lasers is discussed.**

***Keywords* — DFB laser, passive dispersive reflector, anticipated synchronization, optical feedback.**

I. Introduction

The effect of synchronization of various types of chaotic systems play an important role in physics due to its wide application in information security, communication and complex systems like biological sciences [1]. The first theoretical attempt of anticipated synchronization of two chaotic dissipative systems with time-delayed feedback was proposed by Voss [2]. This concept was explored for chaotic semiconductor "master-slave" lasers with optical feedback [3]. The anticipated synchronization was observed for the synchronized slave laser and delayed coupling time regime.

Since the anticipated synchronization represents an interesting phenomenon from theoretical and experimental point of view [4], various new models were proposed to enhance the anticipation time of the schemes [5]. Interesting implementation of this idea was done in chaotic semiconductor lasers [6], quantum dot lasers [7] and electronics circuits [8], where the estimation parameters of the chaotic system can be done.

In this paper, we present a model of anticipation in the synchronization of two DFB lasers with passive dispersive reflector. For some parameters of the system, we observe a transition from delayed synchronization to anticipated synchronization regime. A short description of the scheme setup and rate equations of the modes is presented in Section II. The Section III gives numerical results on the calculations and discussions. We finish with conclusions in Section IV.

II. Model Description

Our model consists of two DFB lasers with passive dispersive reflectors (master and slave) coupled in unidirectional configuration as shown in Fig. 1. It is considered that the slave laser is connected to an external optical circuit with a delay time τ. The injection current into the lasers scheme is notated by *I (t)*, while P_i, n_i for $i = 1, 2$ represent the output power of the lasers and currier density.

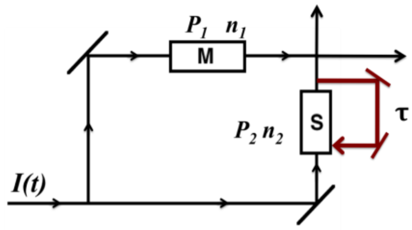

Fig. 1. Schematic setup of master (M) and slave (S) DFB laser with passive dispersive reflector connected in unidirectional configuration.

The rate equations that describe the dynamics of such type of system are [9]:

$$\begin{aligned} &\frac{dP_1}{dt} = TG(n)P_1 + I(t),\ \frac{dn_1}{dt} = J - n_1 - (1+n_1)\Gamma(n_1)P_1, \\ &\frac{dP_2}{dt} = TG(n)P_2 + I(t) + K(P_1(t) - P_2(t-\tau)), \\ &\frac{dn_2}{dt} = J - n_2 - (1+n_2)\Gamma(n_2)P_2, \end{aligned} \qquad (1)$$

where parameter *T* represents the ratio between the carrier and photon life times, and *J* is the relative excess injection rate.

The functions $\Gamma(n_i)$ and $G(n_i)$ from rate equations (1) have the form

$$\Gamma(n_i) = \Gamma_0 + \frac{AW^2}{4(n_i - n_0)^2 + W^2},\ G(n_i) = n_i + \alpha\Delta n \tanh\frac{n_i}{\Delta n}, \qquad (2)$$

where Γ_0, n_0, α and *W* coincide with those of [9].

III. Results and Discussions

In this section, we discuss the dynamics of master and slave lasers for various values of parameters. Figure 2 illustrates the evolution of laser power and currier density, in which a delayed of slave laser can be observed. In the Fig. 3 we can distinguish an interesting regime where the curve of master and slave lasers overlap. Thus, changing the shape and value of injection current in the system, we can reach the same evolution for master and slave lasers. An identical situation is observed also for the currier density.

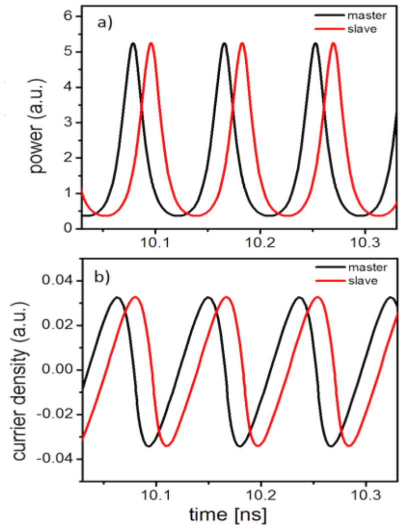

Fig. 2. Delayed synchronization. Time dependence of the a) output power and b) currier density for master (black) and slave (red) lasers. The next parameters are used: $I = 1$, $J = 2$, $T = 500$, $K = 1$, $\alpha = 5$, $\Delta n = 0.1$, $\Gamma_0 = 1$, $A = 0.5$, $W = 0.02$, $n_0 = -0.01$.

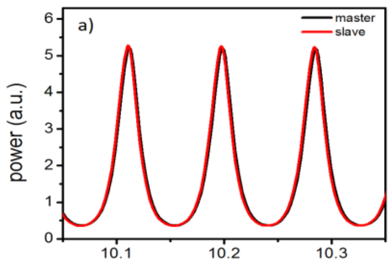

Fig. 3. Perfect synchronization. Parameters as in Fig. 2 except $I(t) = 1.25\sin(0.74t)$.

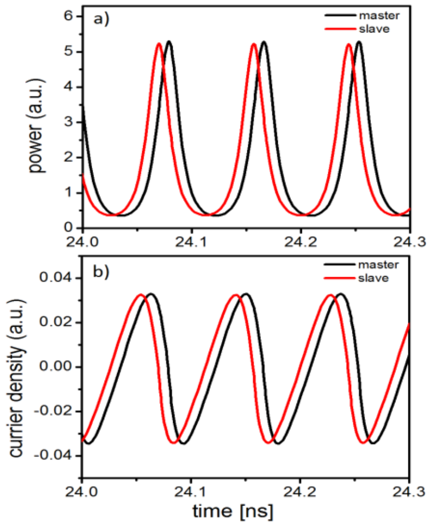

Fig. 4. Anticipation in synchronization. Parameters as in Fig. 2 except $I(t) = 0.95\sin(0.58t)$.

Finally, the anticipated synchronization of two lasers is shown in the Fig. 4. Here, we can observe anticipation in the pulse trace of slave laser due to change of injection current. We report an interesting transition from delayed to anticipated synchronization regimes via an intermediate situation for DFB lasers with passive dispersive reflector.

IV. Conclusions

Anticipated synchronization regime of two DFB lasers with passive dispersive reflector for is presented. We found the appropriate values of parameters for which this phenomenon can be observed.

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