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Modulation Properties of Quantum Dot Semiconductor Laser with Optical Feedback

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Abstract

This paper investigates the modulation properties of self-injected quantum-dot semiconductor lasers. Using a semi analytical approach, the modulation characteristic of a quantum-dot nanostructure laser operating under the influence of optical feedback is successfully modeled. This novel approach derives a feedback-induced modulation response model based on the incorporation of the specific quantum nanostructure carrier dynamics as well as the effects of nonlinear gain. a good behavior of periodic chaotic when $(\tau = 100\, ps, m = 0.6, F = 1*10^{12}\ Hz)$ and when time delay equal (300ps) as $(m = 0.1, m = 0.3, m = 0.7)$ similar behavior on photon density, scenarios between photon density and occupation probability and carrier density as a function of time.

Keyword: Modulation, semiconductor laser, quantum dot, optical feedback, , quantum dot laser.

INTRODUCTION

Quantum Dot Semiconductor lasers (QDSL) have already demonstrated many interesting properties such as high modulation bandwidths [1,2], strong resistance to optical feedback[3], high sensitive of optoelectronic feedback[4] and Stability of an Short External Cavity (SEC) of Quantum Dot Semiconductor lasers(QDSEL) dynamics with Optical Feedback is studied with two values of Linewidth enhancement factor (2,5) ,a good behavior of chaotic [6].

All of these features originate from the quantum confinement that usually characterizes atoms or molecules in contrast to semiconductor materials. Indeed bulk and quantum well semiconductor materials have a large density of states at high energy and, as a result, the maximum gain suffers a blue shift with increasing carrier density[4].

The output power of (QDSL) can be modulated directly by driving it to a signal superimposed on the dc injected current, and in general the signal amplitude is less than the injected current and must start after the steady state were reached[5].

This work presents a study of modulated QDSL dynamics, using the rate equations in the presence of the External cavity length effects on QDSL output power and the modulation response .

QUANTUM DOT RATE EQUATION

In QD semiconductor devices, the carriers are first injected into a wetting layer before being captured into a dot at a capture rate that depends strongly on the dot population. Thus, rate equations that commonly describe carrier dynamics of QD materials read [8, 9],

$$\frac{dE}{dt} = E\left(-\frac{1}{2t_s} + \frac{g_o \upsilon}{2}(2\rho - 1)\right) + \frac{\gamma}{2} E(t - \tau) + R_{sp} \qquad (1)$$

$$\frac{d\rho}{dt} = -t_n\, \rho - g_o(2\rho - 1)|E|^2 + cN^2(1 - \rho) \qquad (2)$$

$$\frac{dN}{dt} = J - \frac{N}{t_d} - 2n_d\, cN^2(1 - \rho) \qquad (3)$$

where N is the carrier density in the well, E is the complex amplitude of the electric field ρ is the occupation probability in a dot; t_s is the photon lifetime; t_n and td are the carrier lifetime in the well and the dot, respectively; N_d is the two-dimensional density of dots; and J is the pump. γ and τ describe the feedback level and delay time. c is Auger carrier capture rate. Modulation term [10]:

$$J(t) = J_m \sin(2\pi F(t)) \qquad (4)$$

Where $F = (\omega_m / 2\pi)$ is the modulation frequency, J_m is the amplitude of the part of the injection current and m modulation index. Equation (3) becomes after using modulation term:

$$\frac{dN}{dt} = J_m \sin(2\pi F(t)) - \frac{N}{t_d} - 2n_d\, cN^2(1 - \rho)$$

rate equation (1,2,5) are solved by using matlab.

RESULTS AND DISCUSSION

The dynamics of QDSL under the effect of time delay and modulation frequency on amplitude modulation Properties of Quantum Dot Semiconductor Laser with Optical Feedback are studied by solving the set of rate equations (1-5). The relation photon density, occupation probability and carrier number using the fourth-order Runge-Kutta numerical method and Matlab.

Fig (1-a,b) shows the photon density of (QDSL) as a function of time and photon density as a function of occupation probability when $(\tau = 100\,ps, m = 0.1, F = 1*10^{12}\ Hz)$, photon density reach to ($6.5*10^{20}\ m^{-2}$) and reduced to ($0.5*10^{20}\ m^{-2}$) at steady state and behavior not similar to Figure (2- a,b) when $(\tau = 100\,ps, m = 0.3, F = 1*10^{12}\ Hz)$. carrier density a chaotic behavior and scenarios between photon density and occupation probability is different from figure (1-b) . Fig (3-a,b) shows the photon density as function of time, carrier density as a function of time and a good chaotic results to application on chaos communication . when $(\tau = 300\,ps, m = 0.1, F = 1*10^{12}\ Hz)$ a simple change when (m=0.3,m=0.7), figures (4-a,b ,5-a,b,6-a,b) are similar behavior on photon density, scenarios between photon density and occupation probability and carrier density as a function of time.

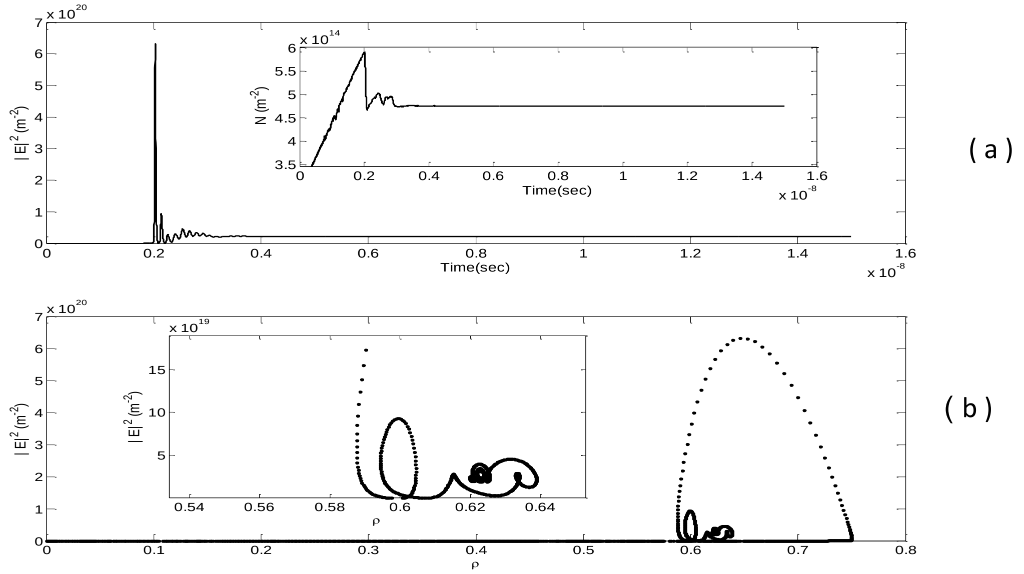

Figure 1: (a) photon density and carrier density as a Time, (b) scenarios between photon density and occupation probability when $(\tau = 100\,ps, m = 0.1, F = 1*10^{12}\ Hz)$.

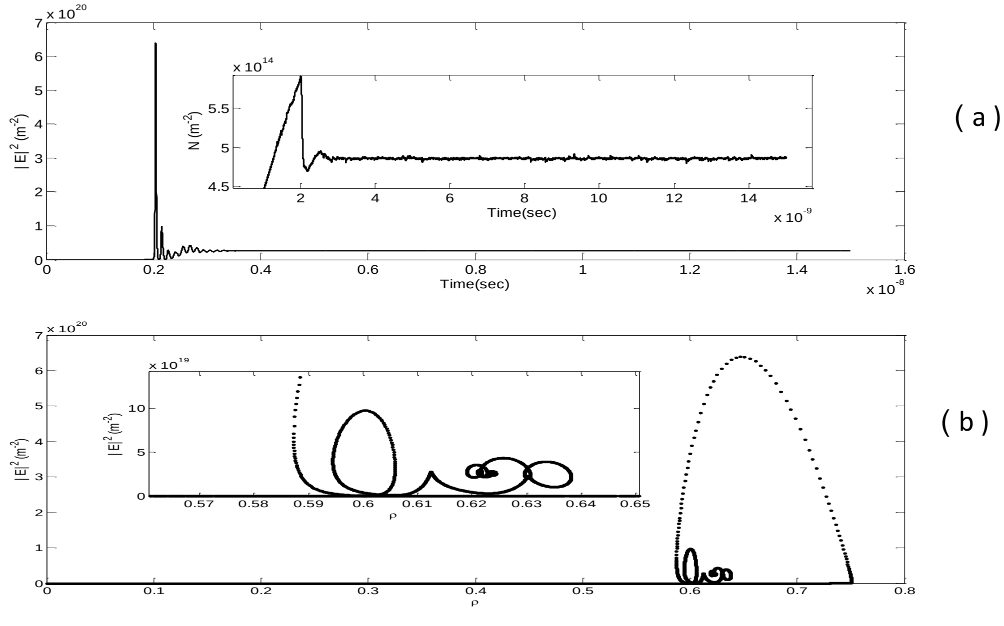

Figure 2: (a) photon density and carrier density as a Time, (b) scenarios between photon density and occupation probability when $(\tau = 100\,ps, m = 0.3, F = 1*10^{12}\ Hz)$.

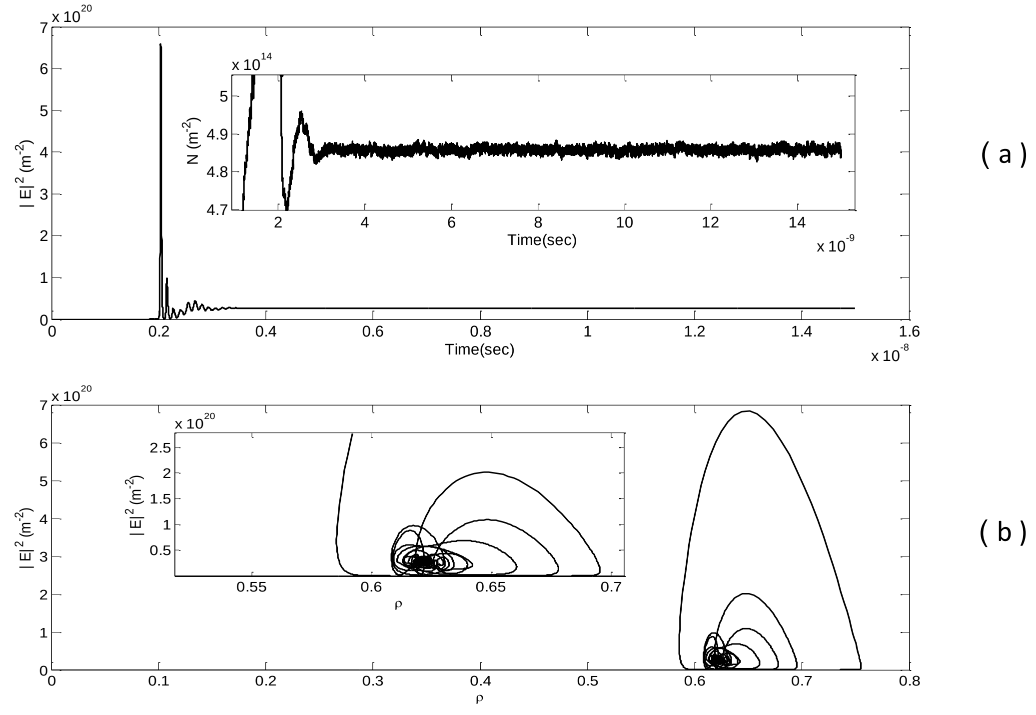

Figure 3: (a) photon density and carrier density as a Time, (b) scenarios between photon density and occupation probability when $(\tau = 100\,ps, m = 0.7, F = 1*10^{12}\ Hz)$.

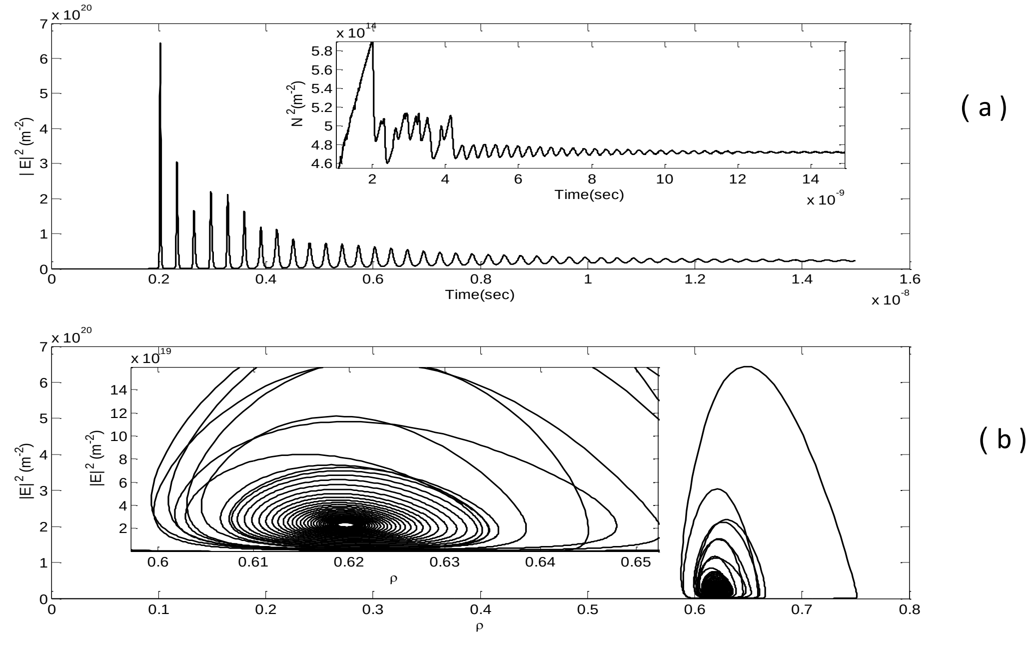

Figure 4: (a) photon density and carrier density as a Time, (b) scenarios between photon density and occupation probability when $(\tau = 300\,ps, m = 0.1, F = 1*10^{12}\ Hz)$.

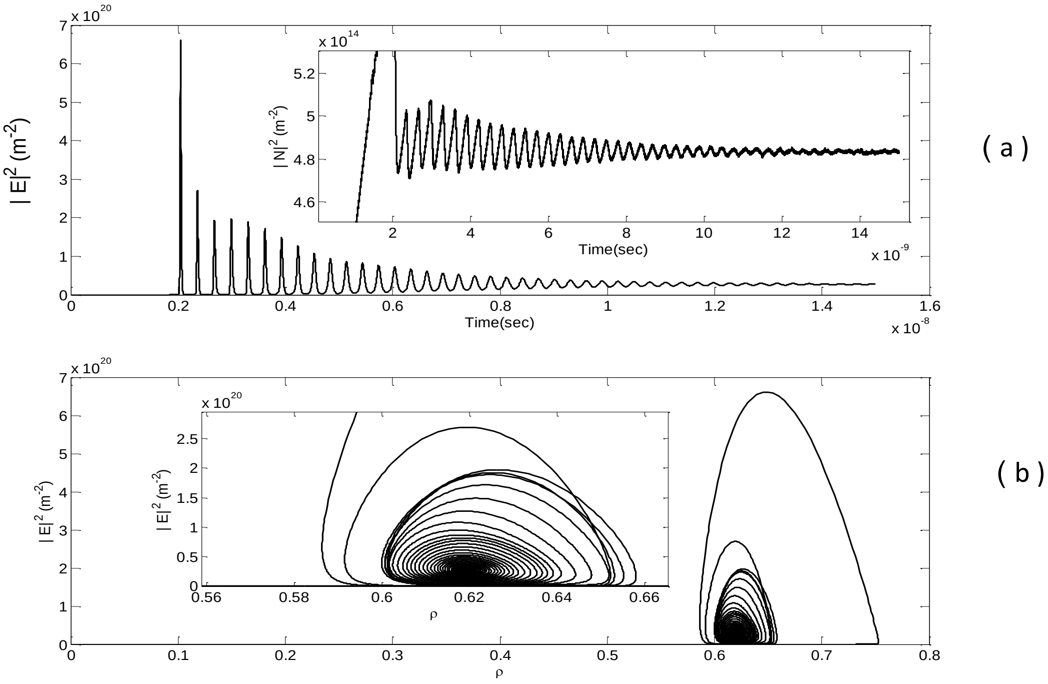

Figure 4: (a) photon density and carrier density as a Time, (b) scenarios between photon density and occupation probability when $(\tau = 300\,ps, m = 0.3, F = 1*10^{12}\ Hz)$.

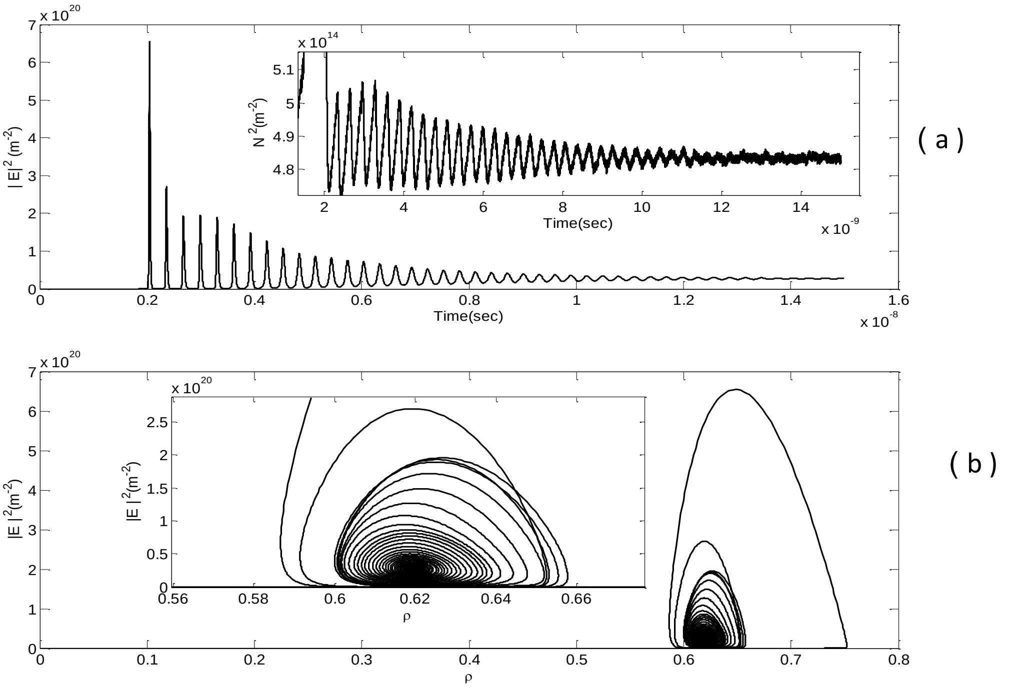

Figure 4: (a) photon density and carrier density as a Time, (b) scenarios between photon density and occupation probability when $(\tau = 300\,ps, m = 0.7, F = 1*10^{12}\ Hz)$.

CONCLUSIONS

The effect of modulation frequency on Quantum Dot Semiconductor lasers modulated dynamics with Optical Feedback are studied in this paper , a good behavior of periodic chaotic when $(\tau = 100\,ps, m = 0.6, F = 1*10^{12}\ Hz)$ and when time delay equal (300ps) as $(m = 0.1, m = 0.3, m = 0.7)$ similar behavior on photon density, scenarios between photon density and occupation probability and carrier density as a function of time.

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