بهینه سازی پهنای باند به کمک مدولاسیون میدان نگهدارنده

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چکیده – مدولاسیون میدان نگهدارنده در *VCSEL*ها، توسط تنظیم فرکانس نوسانات واهلشی مربوط به لیزر نیمه هادی، بهینه سازی پهنای باند مدولاسیون را امکان پذیر می کند. مشخصه های بهبود یافته مدولاسیون همواره در کنار نرخ کاهش یافته میرایی قرار می گیرند. با انتخاب صحیح پارامترها رفتار دینامیکی سیستم و سالیتون ها تغییر می کند. مشخصه های متفاوتی از سالیتون کاواک، مانند شدت تقویت شده و افت و خیزهای فازی قابل مشاهده می باشند.

کلید واژه- میدان نگهدارنده، مدولاسیون، لیزر نیمه هادی.

Improved bandwidth in VCSEL with modulated Holding Beam

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Abstract- A modulated holding beam shining a VCSEL can improve modulation bandwidth by adjusting the semiconductor laser's relaxation oscillation frequency. The improved modulation characteristics are accompanied by reduced damping rate. By choosing correct parameters, dynamical behaviors of system and cavity soliton are changed. Different features of cavity soliton such as maximum amplified intensity and frequency fluctuations are observable.

Keywords: Holding Beam, Modulation, Semiconductor laser.

1- Introduction

Holding beam is an external coherent beam with uniform intensity driving the vertical cavity surface emitting laser (VCSEL). More specifically it relates to an essential element for generating cavity solitons and cavity acts just as a modulator or intensity amplifier for VCSEL. This paper is intended to satisfy temporally modulation on holding beam. During this new type of modulation, calculation of relaxation oscillation (RO) frequency is necessary. The relaxation oscillation frequency provides an indication of modulation speed in semiconductor lasers [1]-[3]. A semiconductor laser exhibits damped relaxation oscillations because of a time dependent energy exchange between laser field and carrier population. RO frequency for free-running semiconductor lasers typically ranges from 1 to 20 GHz [4],[5]. An interesting discovery is that the RO frequency of a semiconductor laser may be appreciably increased with injection locking [1],[6]. Improved modulation characteristics are accompanied by resonance condition which is easily obtained when modulation frequency is RO frequency of system. The invention relates generally to a process for large responses in resonance modulated semiconductor laser. It is predicted that the modulation bandwidth of strongly injection-locked semiconductor lasers can be significantly improved compared to free-running electrical modulation [4]. The modulation bandwidth can be 2–3 times of the free-running value. This is very attractive since it may allow one to achieve large modulation bandwidths with conventional semiconductor lasers at room temperature, avoiding the use of advanced devices and the need for complicated fabrication techniques.

2- Model

Following full set of effective Maxwell-Bloch equations describe system dynamical behavior. By introducing the quadratic fitting of the gain curve in the equations, the model will be more realistic with some unique features [7]. While quadratic fitting of the gain curve is functioning, characteristics for this kind of systems would modify and get close to a more realistic operation. In these equations, parameter $\beta = 0.125$, referred to carrier and gain quantity dependency. In this regime relation between carriers and gain are considered to be nonlinear (for more details see [8]). Equations (1), (2), (3):

$$\dot{E} = \sigma[P + E_i - (1 + i\theta)E + i\nabla_{\perp}{}^2 E] \tag{1}$$

$$\dot{D} = -b[\frac{1}{2}(E^* P + P^* E) + D - J - d\nabla^2 D] \tag{2}$$

$$\dot{P} = \Gamma(1 + i\Delta)[(1 - i\alpha)(1 - \beta D)DE - P] \tag{3}$$

where E and P are slowly varying envelops of electric filed and effective macroscopic polarization respectively. The parameter D is population variable proportional to the excess of carries with respect to transparency. The decay rates are defined as $\sigma = \frac{\tau_d}{\tau_p}$, $b = \frac{\tau_d}{\tau_c}$ where τ_p , τ_c and τ_d are the photon life time, carrier recombination time and dephasing rate of microscopic dipole respectively. Time is scald to dephasing rate τ_d of microscopic dipole. Detuning θ represents the frequency difference between cavity longitudinal mode and of the injected field multiplied by τ_p. However, we consider the specific case of small pump current, J, and sufficiently high injected amplitude, E_I, to ensure that the VCSEL operates beyond the injection locking point. The lower branch of the homogenous solution, which constitutes the background for CS, is stable [1].

In above equations that assume VCSEL with external injection, electric filed has been a homogeneous uniform DC like beam up to now. In this work its operation on system is changed to an AC, which its time dependent function can be expressed as Eq. (4):

$$|E_i|^2 = |E_0|^2 + |E_m|^2 \sin^2(2\pi \nu t) \tag{4}$$

where $|E_i|^2$ is holding beam intensity, $|E_0|^2$ is initial homogeneous holding beam value and $|E_m|^2$ is in small order of $|E_0|^2$. It should be mentioned here that second order s*in* function is used to avoid reducing the amount of holding beam from its initial value. This new modality of holding beam can change system's behavior. By introducing the term for injection, we will get various different behaviors from the system, depending on the injection strength and the detuning between the injection and the free running VCSEL. When their detuning has a value similar to the relaxation oscillation frequency of the laser, we often observe new behaviors.

3- Results and Discussions

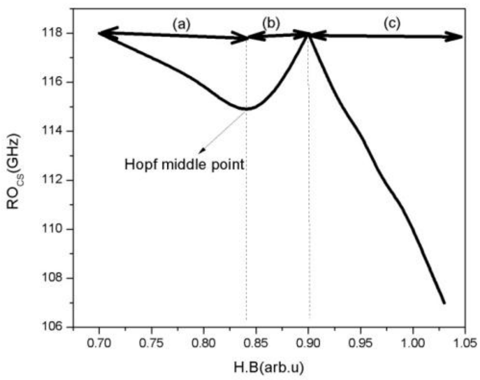

Fig. 1. relaxation oscillation frequencies as a function of laser holding beam in CS for nonlinear gain 20% above threshold. (a) and (b) Hopf bifurcation and (c) locking area zones.

Figure.1 shows the relation between RO frequencies of CS as a function of holding beam. When the system goes 20% upper than its threshold, partial branch of CSs in system is influenced by Hopf bifurcation. In the lower branch of bistable curve which is influenced by Hopf bifurcation, there is a detuning between injection and intra cavity field. This detuning is lead to beating force and in turn results to sustained RO in the output light. When the holding beam acts in Hopf bifurcation, RO frequency is reduced. There is a minimum point for RO in exactly middle point of limit cycle. After this occasion by approaching the locking point, there is ascending process in RO. In the zone, Where the Hopf bifurcation is ended there is a similar behavior to the relation between RO frequency and Holding beam. In which the cavity solitons are not affected by any Hopf bifurcation. It should be mentioned here that the same behavior in RO frequency is true for background of system.

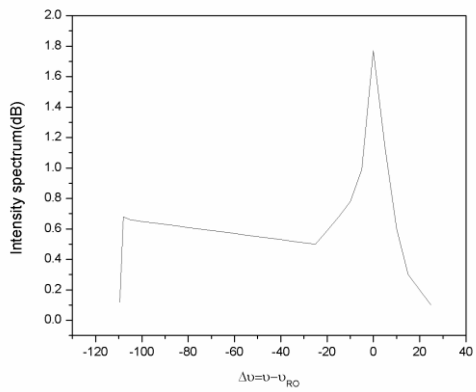

Fig. 2. CS intensity spectrum in nonlinear gain; Parameters are $|E_0|^2 = 0.58$, $|E_m|^2 = 0.05$ and $\upsilon_{RO} = 110GHz$.

In VCSEL with optical injection, enhancement of f_{RO} calculating beyond the injection-locking point is calculated, which is multiple fold compared with free running VCSEL. When frequency of modulation has a value similar to the relaxation oscillation frequency of the laser f_{RO}, interesting behaviors are observable that one of them is high amplification in cavity soliton peak. This opens a great possibility for developing high contrast between homogeneous background and cavity soliton intensity for small modulation amplitude $|E_m| = 0.05$.see Fig. 2.

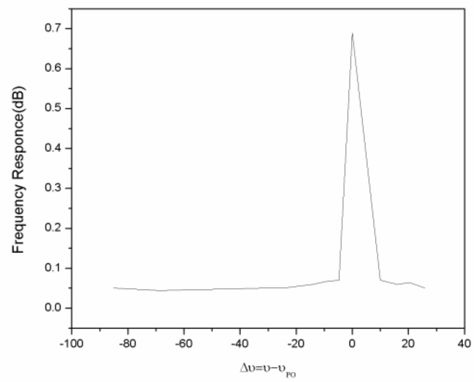

Fig. 3. Frequency response of CS in nonlinear gain; parameters are those of Fig. 2.

By choosing different frequency of modulation peak of soliton phase fluctuations is such that $\upsilon = \upsilon_{RO}$ corresponds to the maximum phase changes. Fig. 3 displays cavity soliton phase fluctuations in nonlinear gain regime. It can be determined by comparing curves that not only RO frequency of system has maximum phase. By tuning the modulation frequency of system within f_{RO} on nonlinear gain regime, system can have optimum condition for optical phase locking. As we know VCSELs utilization for high bit rate data transmission engenders the problems of frequency chirping which increases laser linewidth and limits the system performance severely. Optical injection locking is proposed as a solution to this problem. It enhances the intrinsic component bandwidth and reduces frequency chirp considerably. We show the improvement of 3dB modulation bandwidth of an injection-locked modulated laser, which is twice of its free-running value. The relaxation frequency is 25 times of its free-running value.

4- Conclusion

In this paper, we study the holding beam modulation effects on cavity solitons and system responses in nonlinear gain regime. We start from calculation of relaxation oscillation frequency and damping rate of system and use the results to improve the modulation bandwidth. In conclusion, we have demonstrated the optimum effect of modulated holding beam on soliton peak amplification and phase locking of CSs by considering the nonlinear gain.

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