Exploring frequency effects in chaotic semiconductor laser

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Abstract

The issue related to the chaos control in semiconductor laser has drew attention. The resonant perturbations have been of high importance with regard to the harnessing non-linear oscillators for different applications including inducing chaos as well as controlling chaos. Interesting results have been obtained regarding to the effect of the chaotic resonance by adding the frequency on the chaotic systems. The forcing frequency changes nonlinear dynamical system via critical value, there has been transition from periodic attractor to strange attractor. The experimental studying for the evaluation of chaos modulation behavior are considered in the case when frequency related to external perturbation has been changed, whereas the amplitude related to such perturbation has been fixed. This dynamic regarding laser output have been analyzed by time series, the FFT as well as the plot diagram as a result of this data.

Keywords: Chaos, Frequency, chaotic resonance.

Introduction

Chaos might be specified as a term applied for denoting irregular behavior that is associated to dynamical systems developing from strictly deterministic time evolutions with no sources related to the noise or external stochasticity [1]. Also, the dynamic chaos has been specified as extremely promising non-linear phenomenon that was thoroughly examined throughout the last forty years [2]. The dynamics that are related to the single mode class B semiconductor lasers has been judged through two linked variables (population inversion and the field density) due to the polarization term has been adiabatically eliminated, evolve with two extremely distinctive characteristic timescales. Furthermore, the application related to optoelectronic feedback establishing third degree of freedom as well as third timescale, result in 3D slow-fast system presenting chaotic oscillations as dc-pumping current regarding the semiconductor as well as the feedback strength has been fixed [3]. The feedback injection is suitable way to produce a chaotic semiconductor laser. Such chaotic systems utilizing the semiconductor lasers might be specified via three dynamic rate equations. The generation in addition to the control regarding the chaotic semiconductor laser accomplished via low level regarding the perturbation signal [4].

Control of chaos has been specified as the boundary field between the dynamic systems theory and the control theory examining how there is a possibility for control systems
showing irregular, chaotic behavior [5]. Furthermore, the output related to this system might be regular in the case when adequate amount of the noise has been added[4]. Today, it has been indicated that, in certain conditions, the response related to non-linear dynamical system to external forcing might be improved via the fluctuations [6]. Also, a resonance has been specified as the existence regarding maximum in the response related to the system as function of certain control parameter . Experiments, showing the striking similarities with electrical spike trains traveling on animal neuron’s axons [7].

The resonant perturbations were efficient approach to control the dynamics regarding non-linear oscillators in different applications[8–10]. Previous works concentrated on control of chaos; for instance, stabilize certain periodic motions from the chaos. It was indicated that with regard to periodically forced non-linear oscillator, the resonant perturbations with adequate strength might result in originally chaotic attractor being replaced via periodic attractor. Recently, it was indicated experimentally and theoretically that the resonant perturbations with the time-dependent phases might be utilized for continuously exciting stable periodic attractor in to hierarchy regarding the resonant states finally to the chaos with regard to Hamiltonian as well as dissipative systems[11-13].

With regard to this study, the experimental setup has been developed to examine the control of chaos in semi-conductor laser with the optoelectronic feedback. The impact related to frequency mismatch on attractors regarding non-linear oscillator within resonant perturbation has been examined. After that different values of amplitudes have been taken, examining the impact of frequency on chaotic behavior.

**Experimental work and discussions**

Schematic diagram regarding experimental setup can be seen in the fig(1), where it has been closed loop optical system, involves single semiconductor laser (hp/Agilent model 8150-A optical signal source) with the ac-coupled optoelectronic feedback. Also, output laser beam has been sent through optical fiber to photodetector, in which optical signal has been converted to the electrical signal. The produced electrical current has been proportional to optical intensity. After that, electrical signal passed via variable gain amplifier. Then, such electrical signal was feedback to injection current related to the semiconductor laser following being modulated with the use of function generator. Amplifier gain has been utilized to determine feedback strength. Also, the electrical signal in the narrow voltage pulses which has been emerging from high pass filter has been added to laser pumping current via a mixer. Furthermore, the laser providing emission with wavelength (850nm) as well as continuous output power (2mW). Then, electrical signal has been feedback to semi-conductor laser. External signal from the function generator modulate the laser output.
Figure 1: Experimental setup with optoelectronic feedback for investigating chaos modulation.

The experimental part included the following procedure: the net amplifier gain of the entire feedback loop and the dc-pumping current have been fixed, the output signal from the amplifier modulated by external perturbation which is sinusoidal signal that has two control parameter amplitude and frequency. The amplitude is fixed at 0.08 mV and the frequency is varied, after that the output signal is observed with digital oscilloscope. The result have been analyzed with origin program software. The dynamical sequence is demonstrated in Figure 2.
Figure 2: The time series as well as FFT regarding the dynamical model when frequency value is (a) 166 Hz (b) 170 Hz (c) 180 Hz (d) 185 Hz.

As shown in figure 2, the system is converted from chaos to periodic and then back to chaos. Now, adding fixed amplitude values (0.5, 0.16, 0.25) mV to the system’s dynamical state while frequency is changed. The magnitude of each frequency from FFT is calculated. Then the behavior of the system is plotted as shown in figure 3.
Figure 3: Frequency corresponding their magnitude at amplitude value (a) 0.08mV, (b) 0.16mV, (c) 0.25mV, (d) 0.50mV.

The output regarding this system might be regular in the case when sufficient amount of frequency has been added. The resonance happens in excitable system driven through the
frequency. The critical point position that is related to frequency lies on peak of the curve as shown in figure 3.

The active frequency at amplitude value (0.08 mV) is equal to 170 Hz (the peak of the Curve) as illustrated in figure 3(a). This value converted the system from chaos to periodic. Through gradual increase in amplitude regarding perturbation to 0.16 mV and varied frequency, the critical point is 175 Hz, which convert system from chaos to periodic as shown in Figure 3(b). Additional increasing in the amplitude of perturbation 0.25 mV shows that the position of critical point is shifted at 210 Hz as shown in Figure 3(c). Figure 3(d) shows increasing in value of critical point of frequency with increasing of amplitude value at 0.50 mV. That is mean, there is shifting in position of critical point from 170 to 175, 210 and then 240 Hz at different amplitude 0.08, 0.16, 0.25, and 0.50 mV. The different amplitude values refer to the different critical point position of frequency which convert system from chaos to periodic. The regularity of the chaotic in the intensity of semiconductor laser increases when adding some intermediate value of the frequency.

Conclusion

Chaotic behavior in a semiconductor laser with optoelectronic feedback can be controlled by adding perturbations. We have examined experimentally the impact of frequency on chaotic spiking systems. The results indicated that the frequency could be considered as a parameter which control the system’s dynamics. The different frequencies have been controlled the chaotic system. There is a critical point which is convert the system from chaos to periodic and then to chaos. The position of critical point for every value of amplitude are different, which is shifting depending on the value of the fixed amplitude. As the amplitude increased the critical position increased.

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