Experimental Evidence of Optical Dynamics in Chaotic Semiconductor Laser by Optical Feedback

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Abstract: ***Examination of confusion and nonlinear elements of a semiconductor laser in light of nonlinear optical circle reflect (optical input OFB) utilizing Ott, Grebogi and Yorke (OGY) technique tentatively was exhibited in this work. What's more, we got the bifurcation chart through the variety in estimation of criticism quality by methods for lessening worth and variety in estimation of inclination current. Is get the steadiness of the framework was tried, which ended up to being monostability.***

Keywords: Semiconductor**,** Nonlinear dynamics, Chaos, Optoelectronic feedback, Optical feedback

1. Introduction

Nonlinear factors of semiconductor lasers have been generally examined because of the vital parts semiconductor lasers play in regular and riotous optical correspondence frameworks.Beneath outer discomfort, for example, optical feedback[1], optical infusion [2], and optoelectronic feedback[3], different nonlinear progression and courses to confusion have been watched and examined in semiconductor laser[4].The chaotic regime[5]is the notable conduct of a substantial class of nonlinear frameworks and comprises of pseudorandom motions, which are reproducible just when beginning from indistinguishable starting conditions and parameter esteems. Numerous riotous frameworks have been exhibited in the field of optics. For instance, it has been broadly demonstrated that a semiconductor laser might be steered to disorder by infusion from another source [6] or basically by backreflection from an outside mirror [7]. As of late, mayhem has been proposed for various applications in the media communications field. Among them, cryptographic correspondence is particularly appealing since it completely misuses the normal for disarray of being deterministic, appearing, in the meantime, a solid reliance on even insignificant varieties of beginning conditions and parameter esteems.

Optical input is conductedby re-infusing laser emanation in outer hole or by ring-pit geometries. Consequently, various hypothetical and exploratory examinations on dynamical administrations in semiconductor lasers with optical criticism by re-infusing laserradiation [8,9] and couple of numerical investigations with ring pit have been accounted for [10,11]. Chaos, a random phenomenon, is generated by a deterministic nonlinear system. As chaos is a pseudo-random signal with wide bandwidth and it is unpredictable for a long term, it can be used as carrier to securely hide the confidential message [12]. Chaos is not a state of randomness or disorder, but rather a state whereby phenomena that appear to be unrelated actually follow an unknown or hidden pattern [13 - 15]. This hidden pattern is called an attractor and it can be visually observed through the plotting of data in phase space. Furthermore, the relationships among the variables in a chaotic system are existent, but arerather vague and at best, difficult to discern [16]. Chaotic systems possess two characteristics, sensitive dependence to initial conditions and unpredictability in the long run.

Semiconductors laser subject to the outside bother can produce disorganized waveforms. The annoyance can be outside optical infusion by another laser, optical input, or optoelectronic criticism. Semiconductor lasers are invaluable for disorganized communications [17]. Semiconductor lasers actuated by an optical input are extremely fascinating not just from the perspective of principal material science yet additionally for commonsense applications because of their capacity to produce very confused signs utilized as a part of optical correspondence, optical information stockpiles, and optical measurements [18]. The sporadic motions that incited by the flow associated with laser known as disarray portrayed by nonlinear postpone differential equations [19]. The likelihood of disorganized conduct in lasers was first foreshadowed by Haken in 1975[20], Haken demonstrated that the progression of some ring-laser gadgets could be portrayed by a Lorenz-like arrangement of normal differential conditions. From that point forward, confusion has been hypothetically and tentatively experienced in a wide range of lasers (strong state, gas, semiconductor, etc...)[21].

You will discover two necessary conditions to create chaos in semiconductor lasers the nonlinearity and threefold dimensionality [22]. Hence, when the nonlinearity of the laser is not adequately strong, an external nonlinear component can be launched along the same range, when the dimensionality of the laser strategy is not high enough, it can be increased by deferred feedback loops[23]. Simply because far as semiconductor lasers are concerned, there are two delayed systems that are usually used to obtain chaos by optical responses. The first one was proposed by Ikeda, and it consists in a continuous-wave laser whose outcome light propagates in a nonlinear ring-cavity [24]. The other, study in detail by Lang and Kobayashi [25], compares to the situation where a fraction of the delayed output light of a semiconductor laser beam is feedback in to theenergeticregion layer. In both case, hyper chaos can be generated, that is, the delay plays a destabilizing role as it drastically broadens the laser beam light line width. Semiconductor lasers are mostly innately stable devices when operate as an isolated device.

However, it is well known they can exhibit complicated instabilities and chaos when additional perturbations, such as optical feedback. It has been observed that even small amount of optic feedback could affect the laserlight behavior dramatically [26, 27].

There are two style of feedback to consider, negative and positive. Negative feedback seeks to respond a system to its original or typical state. For example, when one is dictation into a mike, the speaker may find themselves adapt their precept, either speaking softer or louder in order to find the perpendicular roll. Other stamp of negative Larsen effect would be if the speaker stirs the microphone finisher or further a vaunt; or if the unbroken experts suit the volume on the sound plank. Positive feedback on the other agency amplifies the deviations in the system and pushes it further away from its fresh or normal estate [28], nut a elegance of peremptory audio feedback that would occur if the speaker were to spot the mic near the speaker.

This kind of event would cause requirements to distort and improve itself throughout the system. The outcome from the speaker becomes input to the microphone, creating iterations which become louder and louder. Hence, a positive review distorts and amplifies the deviations in the system. In a chaotic system, positive feedback moves the deviceaway from its original state to a new state. It is necessary to take note that the process of iteration is necessary for the system to develop into its new form. Hence, the use of time series data is necessary when the specialist is studying chaotic systems.

The optoelectronic feedback is the best way toobtain incoherent feedback by the injection current of the laser and it is an energetic method for extremely control the fantasy characteristics of semiconductor lasers [29]. The use of a semiconductor laser with an applied delayed optoelectronic feedback loop is also an efficient way ofwide band chaos generation. The disturbance to the injections current is an extra level of freedom. Consequently, the disturbance to the injections current generates Instabilities in the semiconductor lasers and chaotic behaviors are observed [30]. Optical feedback is introduced into a diode laser by inserting some portion of the optic output back into the device. A semiconductor laser beam with optical feedback is a very good model for creating chaos in the laser output ability [31]. Optical feedback firstly emerges as a perturbing effect scheduled to undesirable reflections by using an optical channel. However, researchers quickly realized that a diode laser subject to a controllable amount of optical feedback could be a great test bed for the study of dynamical instabilities leading to high dimensional chaos and it also be used as a flexible source of optical chaos for physical layer secure communications. The prelude of such opinions has been found to have dramatic and various effects on the functioning characteristics of the simple diode laser [32]. Optical feedback can be achieved by two ways, 1) free space exterior cavity [33]. 2) Optic fiber coupler as a loop mirror. In this work it is used the second choice, which used optical fiber coupler as an external cavity to generate chaotic output in the semiconductor laser.

2. Experimental Work

The experimental constitute of nonlinear dynamics based on optic feedback is seen in figure (1). In this set up the optic loop mirror feedback, has been used a semiconductor laser which based uponthe same model distributed feedback laser beam devices (DFB), with standard specifications, Noyes OLS 2-Dual Optical Source with an output power of -10dBm. Laser active medium is (InGaAs), emitting Continuous trend (CW) with wavelengths around 1310nm and 1550nm (1310nm was used in our work). The original source| operates on disposable batteries or AIR CONDITIONING UNIT. The optical output is via a top-panel FC connector. The output power of the laser radiation is linked to the first input part of (2 x 2) (FC connector) optical fibers splitters (50/50) model. The two outcomeelements of the optical fibers coupler are linked collectively by (MN924C) variable optic attenuator (VOA) (0-65dB).The reflected light from coupler is split in 2 different ways, one aimed toward the cavity of semiconductor laser as feedback, the another is find out by a fast (InGaAs) photo detector (PD)model 1811-125MHz from New Focus, typical bandwidth is 125 MHz with a current gain of 40 V/mA. The wavelength range that can detect is from 900nm to 1700nm. used to convert the optical signal to electric signal and this (PD) is observed with a four channels Digital Storage Oscilloscope (DSO) of model “Tektronix TDS2024B” is used to analyzing the time series with the possibility of direct Fast Fourier transformation (FFT). The oscilloscope is connected with a personal computer (PC), in order to exchange data with a variety of computer applications such as Origin Lab software. The controllable parameters of this optical feedback suit are form of the feedback strength (using an optical attenuator). By regulating thesefactors, the system could be operated in different dynamical levels .

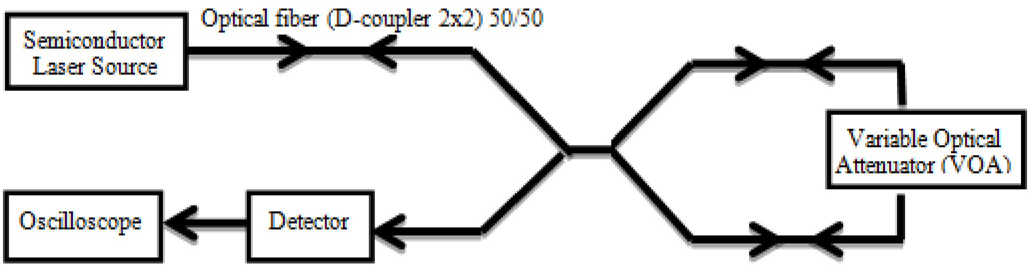


Figure 1: Experimental setup of a semiconductor laser with an Optical feedback using 2x2 optical fiber coupler (feedback strength as parameter)

In this configuration figure (2) the HP 8150A semiconductor laser source with 850 nm wavelength was used. The Laser modulation can either be done by an internal function generator (DC up to 50MHz) or externally with any modulating signal up to 250MHz. It produces optical power over a range of 1 nW to 2 mW, a dynamic range of 63 dB.The outcome power from the laser is linked to the first input part of two x 2 (FC connector) optical fiberscouplers 50/50 model. The two output regions of coupler are linked together by adapter.The reflected light from coupler is be divided in 2 different ways, one directed toward the chamber of semiconductor laser as feedback, the another is detected bya fast InGaAs photo detector with Rise/Fall time 0.1ns and bandwidth 1GHz, The spectral response of the utilized detector range from 800nm to 1800nm. The detected signal is amplified by GOS-652G (50 MHz) oscilloscope used as variable gain amplifier. The output signal from amplifier is observed with a four channels Digital Storage Oscilloscope (DSO) of model "Tektronix TDS2024B" is used to analyzing the time series with the possibility of direct Fast Fourier transformation FFT.oscilloscope is connected with a personal computer (PC), in order to exchange data with a variety of computer applications such as Origin Lab software. The controllable parameters of this optical feedback suite are controlled of the bias current. By regulating these factors, the system could be operated in variables dynamical states.

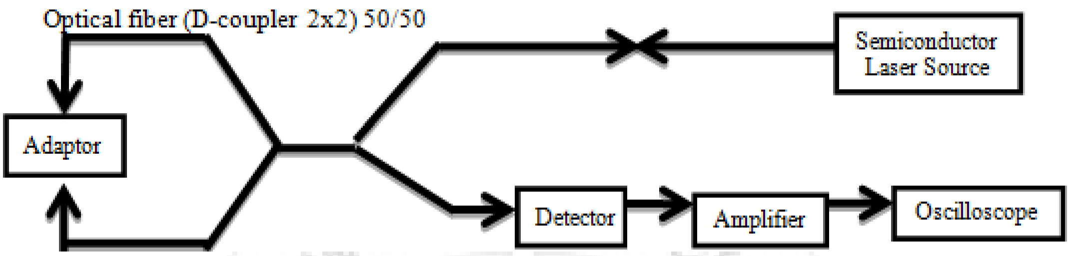
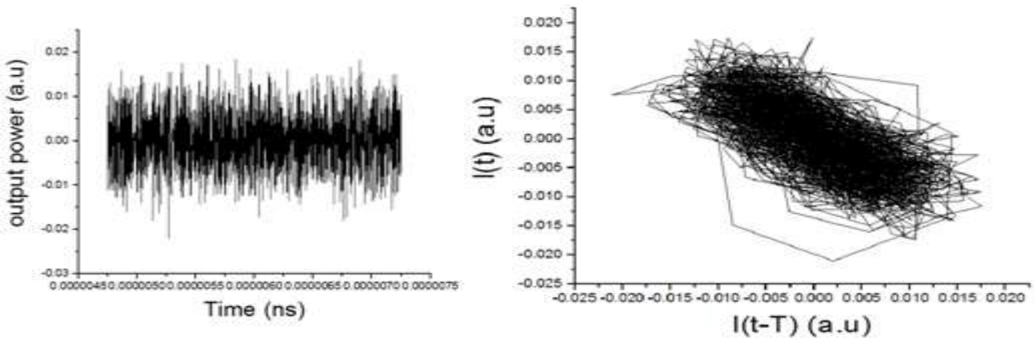


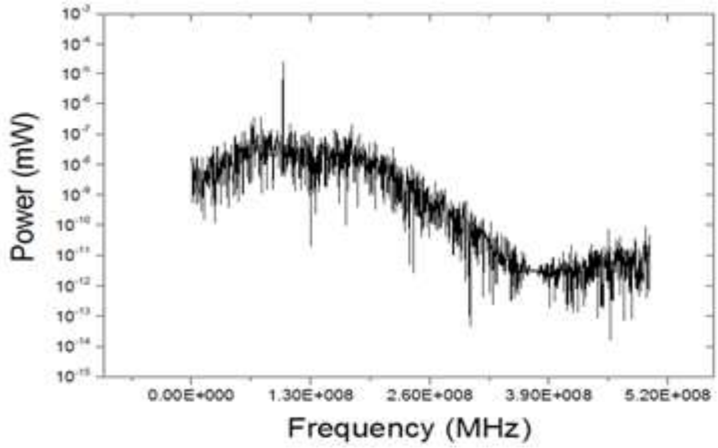
Figure 2: Experimental setup of a semiconductor laser with an Optical feedback using 2x2 optical fiber coupler (bias current as parameter)

3. Result & Discussion

The optical feedback (OFB) after test instability in optic loop mirror it can be foundmono-stability by use semiconductor laser have wavelength (1550-1310) nm. According to figure 1 semiconductor laser light beam has been feedback full optically and the chaotic behavior of semiconductor laser beam light output under the result of the reviews power as control variables is discussed analytically, including time series, Fast Fourier Modification, and the hybridation diagram due to offering a complete description of the devicebehavior under the influence of a certain parameter. Figures 3, 4, 5, 6, 7 and 8 show the end result of variance optical reviews strength on chaotic spiking in semiconductor laser. In these characters, Laser demonstrated chaotic patterns with high intensity in figure 3a, the power of disorderly behavior lower with the increasing of optical damping as in figures 4a, 5a, 6a, 7a and 8a. Figures 3b, 4b, 5b, 6b, 7b, and 8b symbolize the related attractors. It has unusual varieties, Figures 3c, 4c, 5c, 6c, 7c, and eight degree centigrade symbolize the related (FFT), they show the personal unguaranteed of chaotic behavior, where the distribution is decaya ways exponentially including spiking.. Figure 9 shows the bifurcation diagram which symbolizes the peak-to-peak laser outcome intensity against the damping in feedback strength as a control parameter. This kind of diagram is constructed by a slow increase of the control parameter. The bifurcation diagram is frequently used to check disorderly routes and evolutions of the output in nonlinear systems by varying the control parameter.The interpretation of the coupure diagram shows, for optic attenuation value from (0dB -8dB) (i. e. indicate high feedback strength) the dynamics of the oscillator is chaotic with power. For more increase in optical attenuation (8. 5dB-13dB) (i. e. mean low feedback strength) the mechanics of the oscillator is chaotic with low enormousness. Figure 10 shows the bifurcation stability diagram which was (mono-stability) by change the attenuation value in optical feedback strength from (0dB-13dB) and back from (13dB-0dB) without interruption to gratify the stability condition. Figure 11 shows the bifurcation stability diagram which was (mono-stability) by change the bias current value in power from (2nA-999nA) and back from (999nA-2nA) without interruption to meet the stability state.

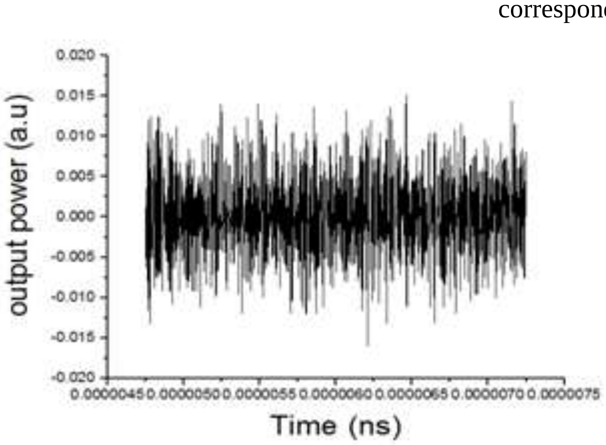


(a) (b)



(c)

Figure 3. (a)Experimental time series of system when attenuator value is 0 dB, (b)the correspondingattractor, (c)the correspond FFT



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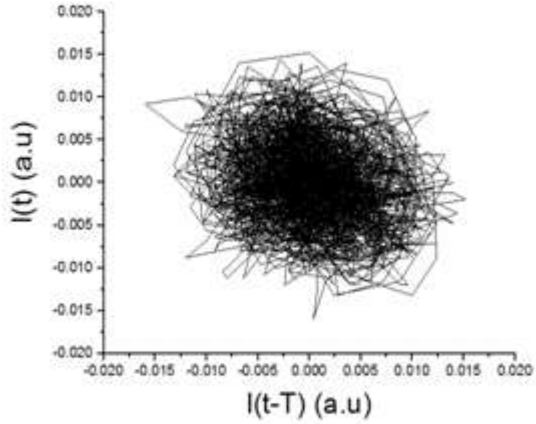

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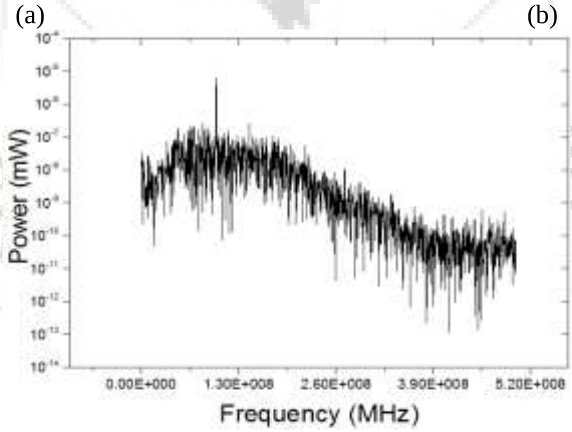

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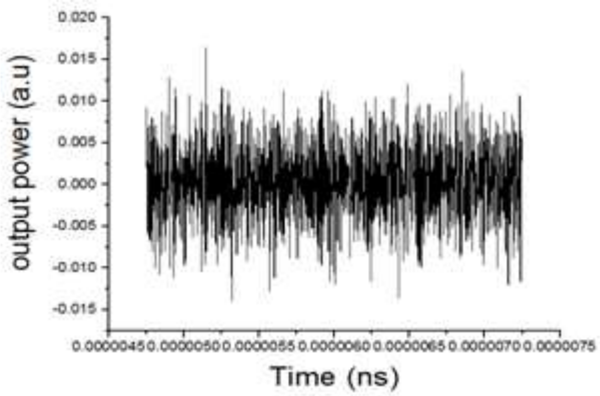
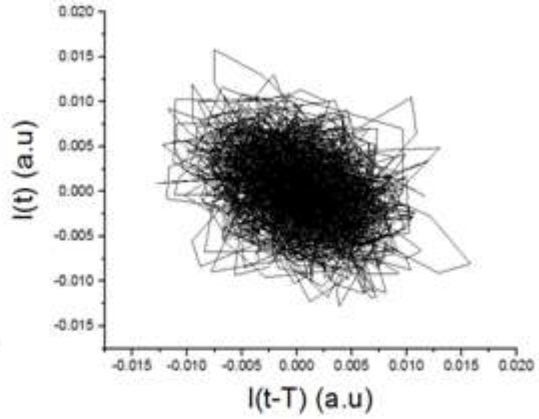
Figure 4: (a)Experimental time series of system when attenuator value is 3 dB, (b)the correspondingattractor, (c)the corresponding FFT



(a)



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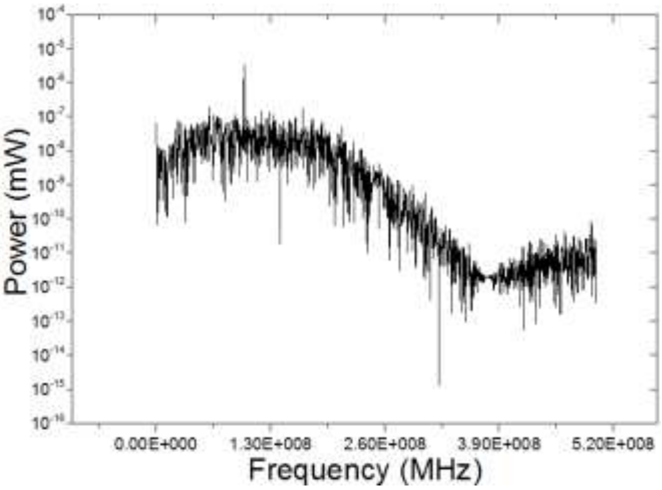
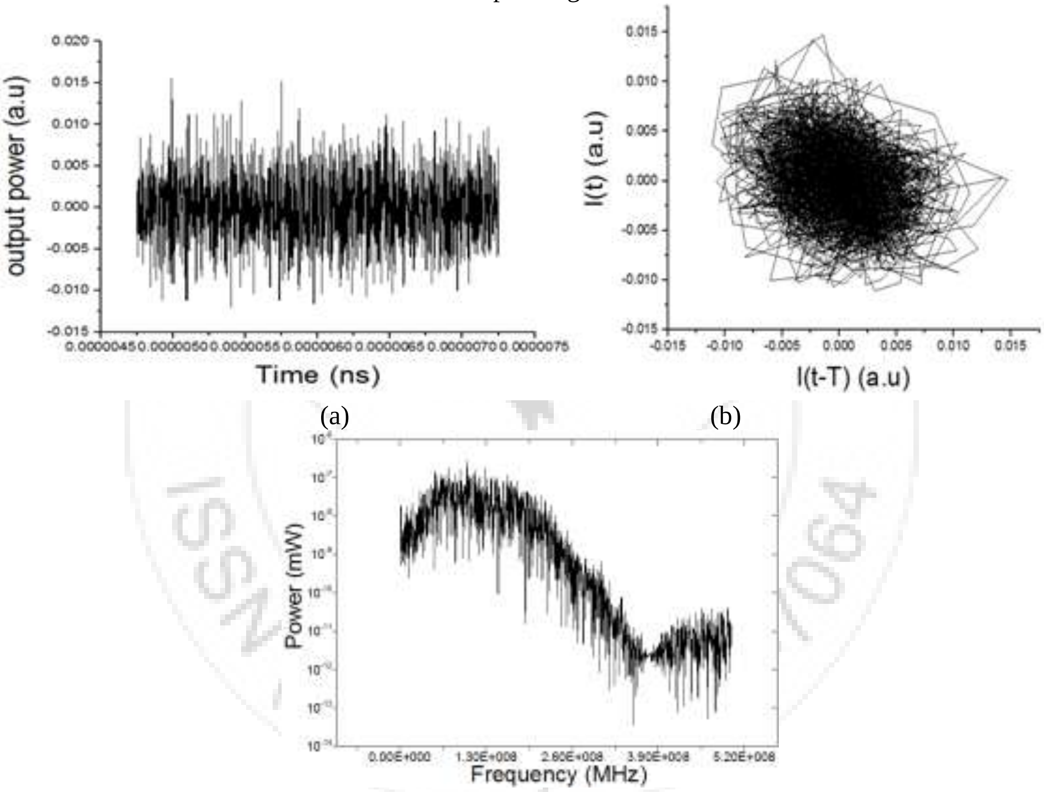


(c)

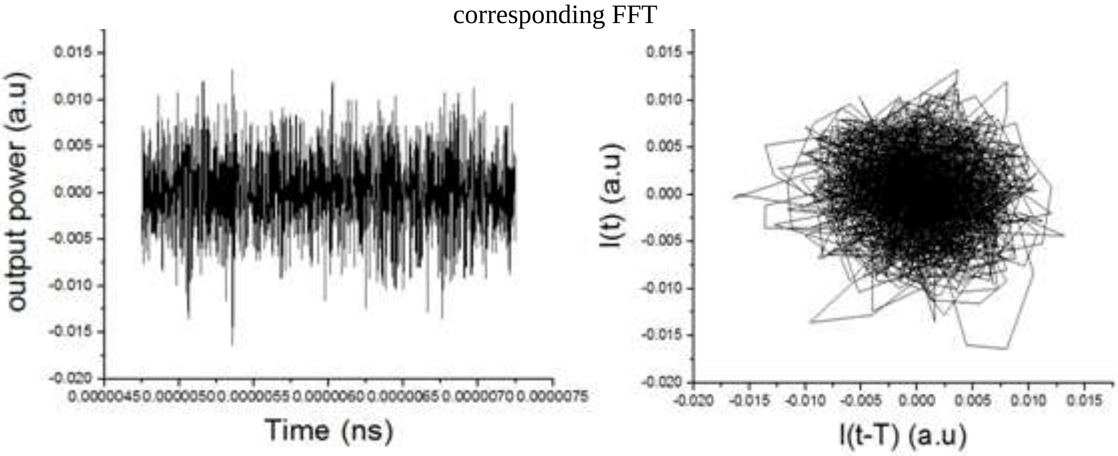
Figure 5: (a)Experimental time series of system when attenuator value is 5 dB, (b)the correspondingattractor, (c)the corresponding FFT



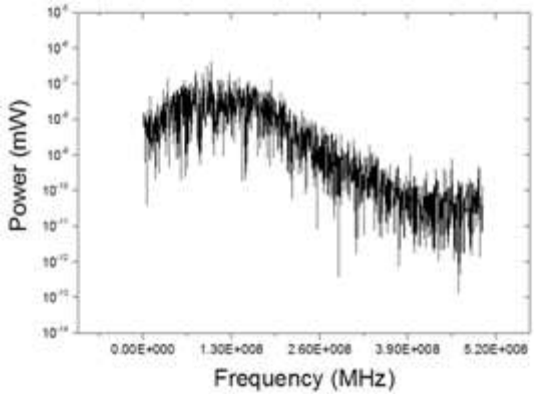
(a) (b)

(c)

Figure 6: (a)Experimental time series of system when attenuator value is 8 dB, (b)the correspondingattractor, (c)the corresponding FFT

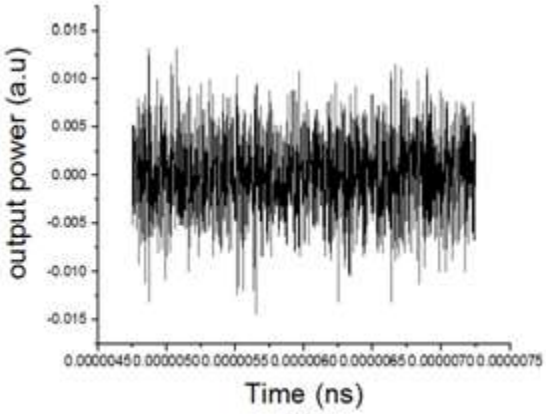


(a) (b)

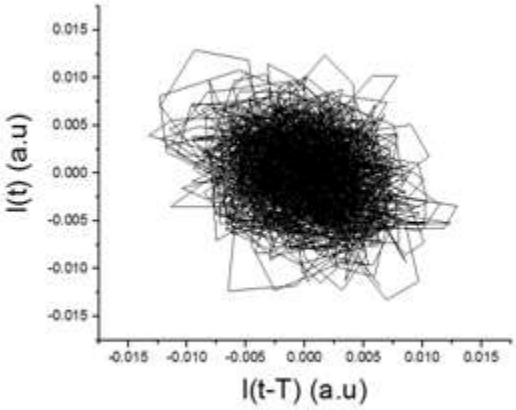


(c)

Figure 7: (a)Experimental time series of system when attenuator value is 10 dB, (b)the correspondingattractor, (c)the corresponding FFT



(a)



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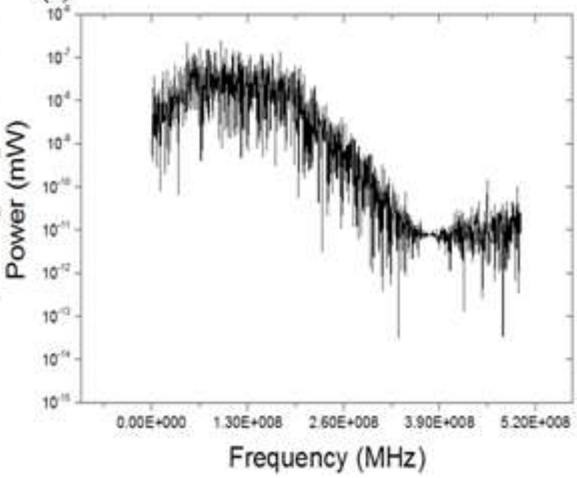

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Figure 8: (a) Experimental time series of system when attenuator value is 13 dB, (b)the correspondingattractor, (c)the corresponding FFT

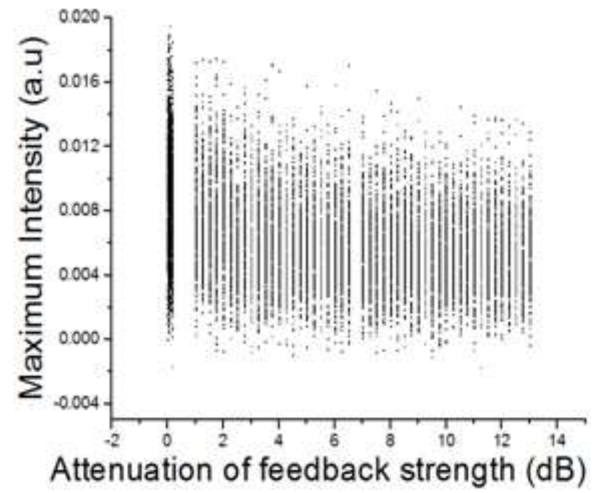

Figure 9: Bifurcation diagrams (maxima of photon densities Vs attenuation of feedback strength as a control parameter).

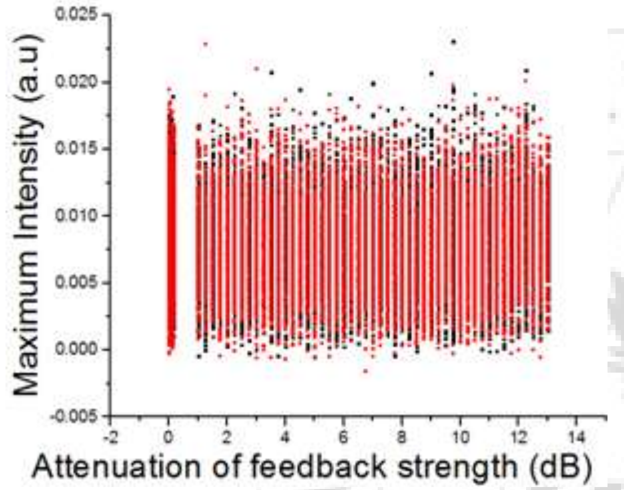

Figure 10: Bifurcation stability diagram (mono-stability)(maxima of photon densities Vs attenuation of feedback strength as a control parameter)

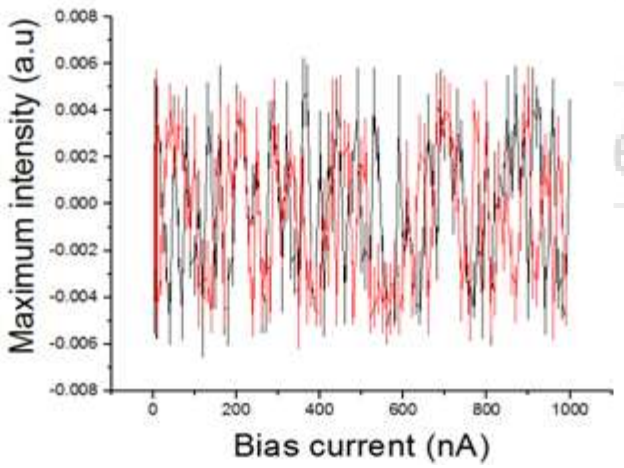

Figure 11: Bifurcation stability diagram (mono-stability)(maxima of photon densities Vs bias current as a control parameter)

4. Conclusions

Disorganized spiking in semiconductor laser with an optical input is tentatively illustrated, in conclusions. It has been demonstrated that the time size of these elements is completely controlled by the criticism circle and their whimsical however deterministic. A few parts of the dynamic reaction of volatile frameworks to various estimations of criticism quality are contemplated, the optical input quality impact on disordered conduct, when the criticism quality is high the confused flag has expansive sufficiency and it diminish with the diminishing of the criticism quality. The bifurcation graph demonstrates that the lessening quality could controlled the confused plentifulness (i.e. increment the lessening esteem, diminish the confused sufficiency). The soundness of the mayhem framework with change input quality which was mono-steadiness. Concerning the part on changing the inclination current, it was observed to be mono-steadiness too.

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