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Control of instability in a semiconductor laser using a functional pump current generator with a dynamical parameter

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ABSTRACT

In this paper, an electric circuit to control the dynamic output of a semiconductor laser is introduced. The circuit controls chaos and instability of the laser output by changing its pumping current. The change of the current is also introduced by a nonlinear map. The most important element of this nonlinear map is a dynamical variable parameter. We have studied the dynamic behavior of the laser before and after applying the control using bifurcation curves and time series. We have shown that the laser output, in the intervals of the feedback phase and strength where it is chaotic, can be totally inverted to the quasi periodic (QP) and period one (P1) oscillation modes, by control method.

1. Introduction

Chaotic optical communication has attracted much attention because of its potential applications in secure communications [1,2]. Semiconductor lasers are the most important source generators in secure optical communications, coherent light sources for technological optical transition, and ultra fast optical processing [3–5]. Nonlinear dynamics of semiconductor lasers have been widely studied because of the important roles they play in conventional optical communications and in chaotic optical communications. Under external perturbations, such as optical feedback, optical injection, or optoelectronic feedback, various nonlinear dynamics and routes to chaos have been observed and investigated [6]. External cavity semiconductor lasers (ECSLs) are an integral part of high speed chaos based communication systems [7]. Different studies have been conducted to characterize long external cavity [8] and short external cavity [9]. Where, the short cavity regime has more advantages as described in [10]. One of the remarkable discoveries of the recent decade is related to the pervasive presence of chaos in multidynamical systems that has led to a new field of research for control of chaos. The Ott, Grebogi, and Yorke method [11] has been successfully demonstrated to convert a chaotic motion to a periodic regular motion [12] in emerging applications such as encoded communications and design of high quality optical communication systems [13]. Chaos control in the lasers has been extensively used in recent years in applications, such as bulk cavity ring oscillator [14], single-mode CO_2 lasers with an electro-optic feedback on the cavity losses [15], and modulating and variation of the pump current [16,17]. The control of multistability using periodic perturbation has been investigated in different theoretical models such as the Henon map [18], laser models [19], coupled Duffing oscillators [20] and a delayed logistic map [21]. In this paper, we have investigated stability of the laser output by controlling parameter 'ε' and pump current dynamically. Dynamical control parameter and pump current have been selected as implementation tools of control method. This method is simple and easy to implement experimentally. The method involves the continuous generation of an error signal from the difference between the output intensity, $|E^2|$, signal and its value at an earlier time. It is called continuous time-delay feedback. This method was useful in fast system applications to control a chaotic nonlinear circuit [22], where a basic role is played by an electrical circuit. The output of laser, after conversion to the photodiode voltage, is sent to a comparator. The comparator injects a suitable pumping current is to the laser via the switches 1 and 2 of the electrical circuit. This current, which is used to stabilize the output of the laser, is generated by the chaotic map. It is noted that the value of the ε can be changed manually by operators. An important advantage of this method is that it is enough to have information only for one variable. The experimental setup is shown in Fig. 1. We have studied the dynamical behavior of the laser as a function of feedback phase and strength, before and after applying the control method, as it is described in this section, using bifurcation curves and time series. It has been shown that in some

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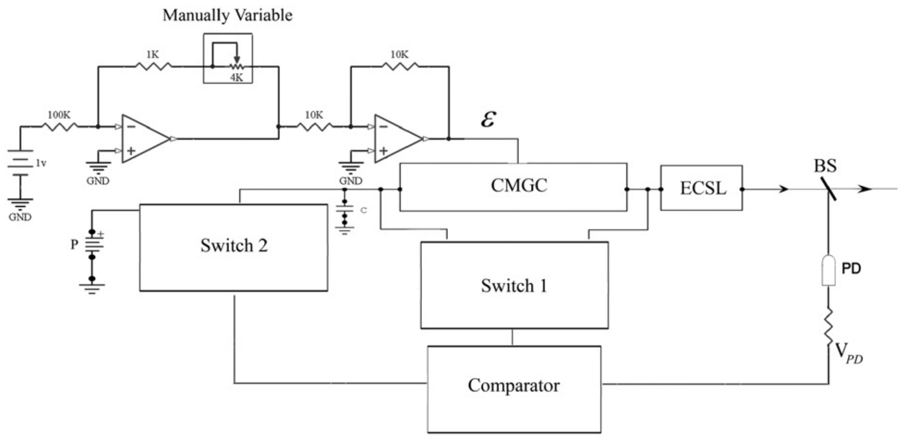

Fig. 1. Optical setup based on semiconductor laser with controller electrical circuit.

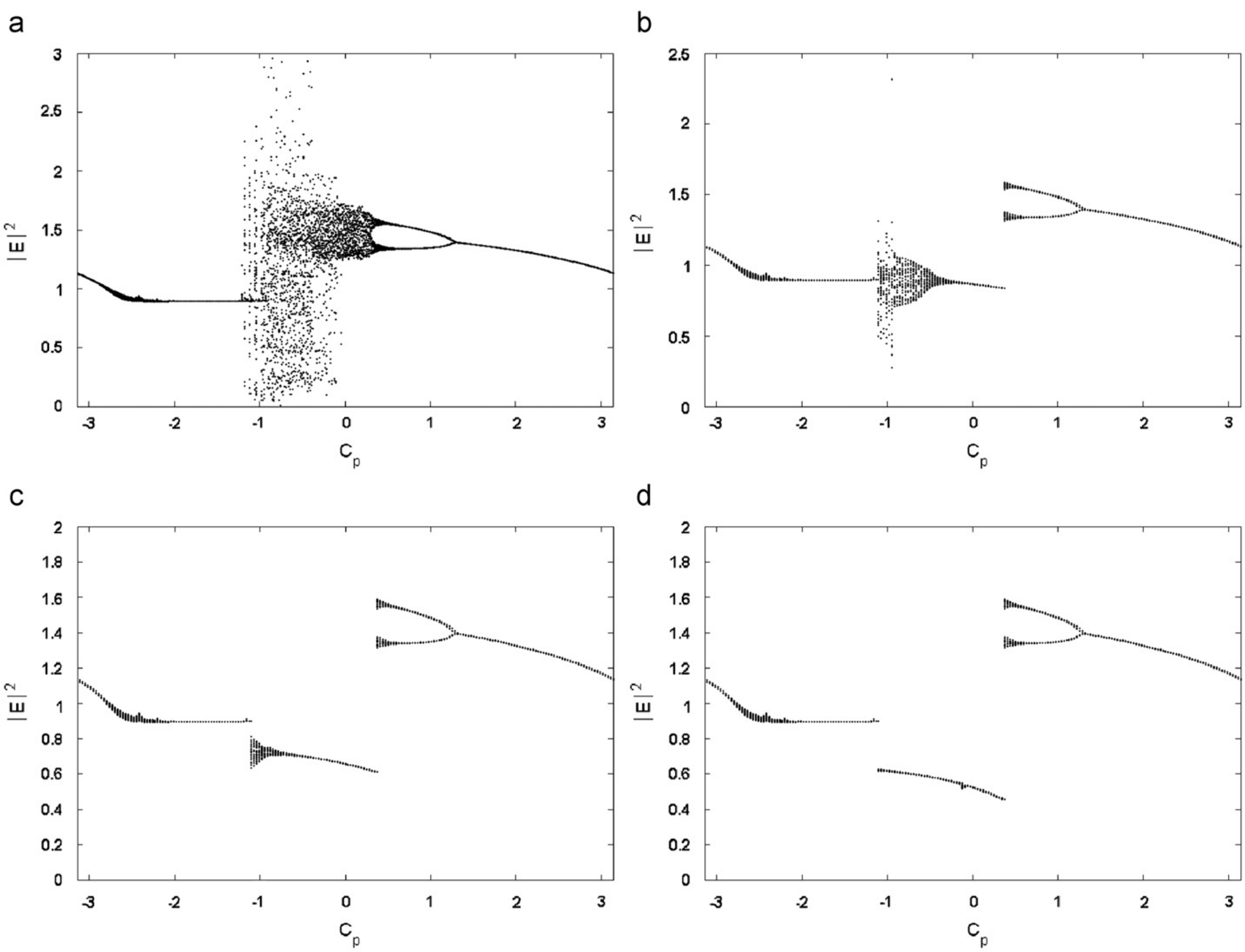

Fig. 2. Bifurcation of $|E^2|$ versus C_p with η=0.036 and P=0.8, before applying control method (a), after applying control method with ε=0.01 (b), ε=0.02 (c), and ε=0.03 (d).

ranges of the feedback phase and strength, the laser output may be chaotic. We showed that the dynamics of the laser output, in these ranges, could be controlled to a stable state by applying the control method. Our studies are theoretical, and for implementation of the control feedback loop experimentally, it is attempted to introduce an optical setup containing electrical circuits.