Results in Physics 6 (2016) 401–406

Contents lists available at ScienceDirect

Results in Physics

journal homepage: www.journals.elsevier.com/results-in-physics

High chaotic spiking rate in a closed loop semiconductor laser with optical feedback

Banaz O. Rasheed [a,b], Parekhan M. Aljaff [a], Kais A. Al Naimee [a,c,*], Mahdi H. Al Hasani [c], Riccardo Meucci [a]

[a] Istituto Nazionale di Ottica, Largo E. Fermi 6, 50125 Firenze, Italy
[b] Department of Physics, School of Science, Faculty of Science and Science Education, Sulaimani University, Sulaimani, Iraq
[c] Department of Physics, College of Science, Baghdad, Iraq

ARTICLE INFO

Article history:
Received 29 April 2016
Accepted 15 July 2016
Available online 25 July 2016

Keywords:
Chaos
Spiking
Optical feedback

ABSTRACT

We investigate experimentally and numerically the existence of fast chaotic spiking in the dynamics of a semiconductor laser with ac-coupled optical feedback. The observed dynamics is chaotic in the explored range of both bias current optical feedback strength. The effects of a modulation applied to the bias current are also investigated. We eventually indicate that the observed chaotic dynamics is a good candidate to hide information to satisfy secure communications.

Introduction

Semiconductor lasers with optical feedback have proven to be very useful devices in practical applications such as chaos based communication encryption systems and chaotic lidars [1–3]. Two aspects turned out to be essential for the observation of chaos in these systems, that is, the delay in the round trip of the light in the cavity and the nonlinearity in the interaction of the light with the semiconductor medium [4,5]. A semiconductor laser can be stabilized by introducing an external perturbation such as an external optical feedback [6], or optoelectronic feedback [7]. The dynamical behaviour of semiconductor lasers with external optical disturbance was broadly studied [8–10]. Lang and Kobayashi examined feedback-induced instabilities and chaos in semiconductor lasers [11]. The collapse of coherence by increasing the degrees of freedom of the laser from two to three degrees using a delayed optical feedback was investigated by Tromborg and Mork [12]. Many critical parameters, comprising feedback strength, feedback delay, pump current, feedback type and laser nonlinearities affect the dynamics of semiconductor lasers with external cavities [13].

In this work, we investigate the effects of an optical feedback using an optical fibre coupler as a loop mirror. The timescale of the observed dynamics (few ns) is entirely determined by the delay introduced by the optical feedback. In our investigation, we considered the impact of different control parameters such as the bias current and the optical feedback strength and the effect of a modulation applied to the bias current.

Experimental setup

We generated chaotic dynamics in our semiconductor laser by introducing a coupled optical feedback. The experimental setup consists of a single-mode semiconductor laser (1550 nm wavelength) with the optical feedback provided by an optical fibre closed loop (Fig. 1). The pigtailed laser output is connected to Variable Optical Attenuator (VOA) which in turn is connected to two 1×2 directional couplers (1×2 DC, 90%:10% and 1X2YC, 50%:50%) to form a fibre loop mirror. We realize the loop by connecting the two output branches of the Y-coupler. The reflected light from coupler is split into two parts; the first one provides the optical feedback to the cavity of the semiconductor laser whilst the other is connected to a high-speed InGaAs photodetector with response time <1 ns. The photodetector is connected to a sampling digital storage scope (LeCroy 500 MHz). In our experimental configuration, it is possible to introduce a modulation of the driving current of the semiconductor laser by means of an external sinusoidal function generator.

Experimental results and discussion

The influence of the bias current

After closing the optical feedback loop, the laser output intensity is observed and recorded on a high-speed digital oscilloscope. We performed the temporal and spectral analysis of the chaotic spiking evolution of the laser intensity using the bias current as a control parameter (see Figs. 2–5). We observe that the laser intensity is chaotic in the whole range of the control parameter. Both the

---

* Corresponding author at: Istituto Nazionale di Ottica, Largo E. Fermi 6, 50125 Firenze, Italy.

http://dx.doi.org/10.1016/j.rinp.2016.07.006
2211-3797/© 2016 The Authors. Published by Elsevier B.V.

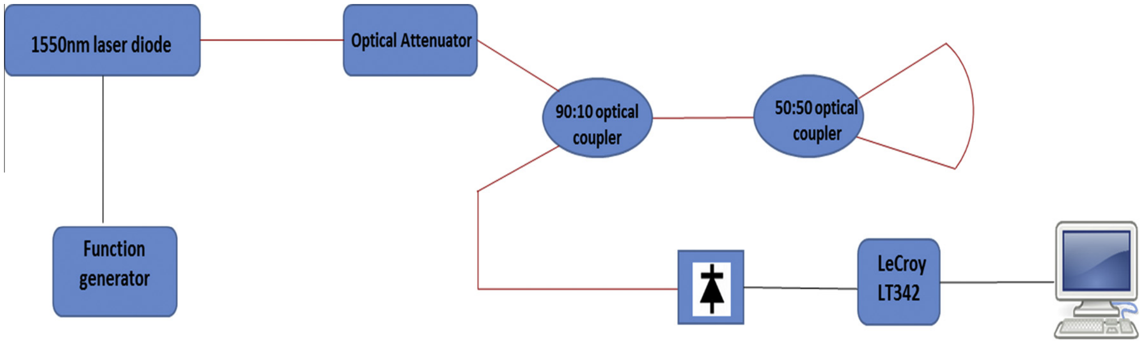

Fig. 1. Experimental setup of a semiconductor laser with optical feedback using two 1×2 directional couplers. Red lines indicate the optical path, the black lines indicate the electrical connections. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

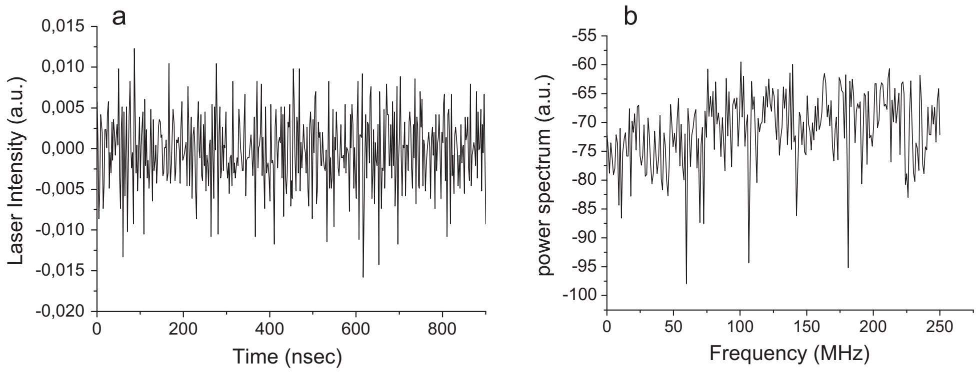

Fig. 2. Experimental time series of the laser intensity (a) and its corresponding FFT spectrum, (b) when the bias current of laser is 10 mA.

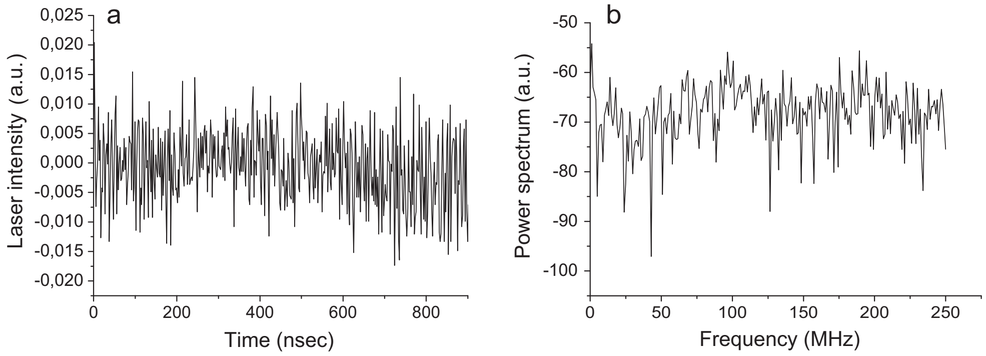

Fig. 3. Experimental time series of laser intensity (a) and its corresponding FFT spectrum, (b) when the bias current of the laser is 15 mA.

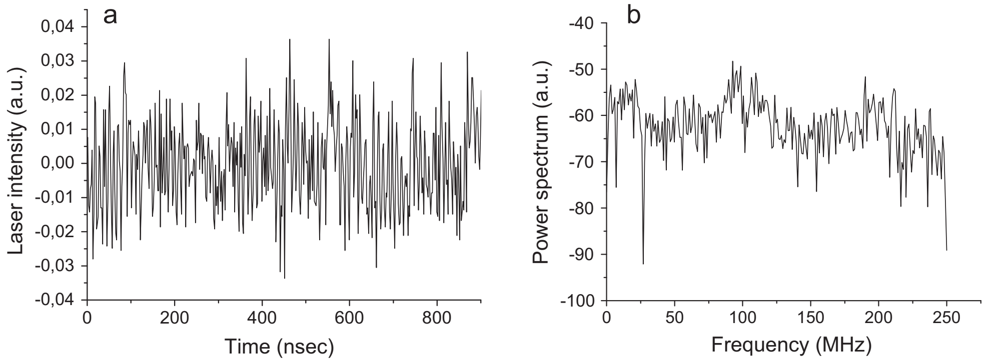

Fig. 4. Experimental time series of the laser intensity (a) and its corresponding FFT spectrum, (b) when the bias current of the laser is 20 mA.