J. Phys. B: At. Mol. Opt. Phys. **41** (2008) 155401 (8pp) doi:10.1088/0953-4075/41/15/155401

Chaos-based communications using semiconductor lasers subject to feedback from an integrated double cavity

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Received 17 March 2008, in final form 6 June 2008
Published 11 July 2008
Online at stacks.iop.org/JPhysB/41/155401

Abstract
We report the results of numerical investigations of the dynamical behaviour of an integrated device composed of a semiconductor laser and a double cavity that provides optical feedback. Due to the influence of the feedback, under the appropriate conditions, the system displays chaotic behaviour appropriate for chaos-based communications. The optimal conditions for chaos generation are identified. It is found that the double cavity feedback requires lower feedback strengths for developing high complexity chaos when compared with a single cavity. The synchronization of two unidirectional coupled (master–slave) systems and the influence of parameters mismatch on the synchronization quality are also studied. Finally, examples of message encoding and decoding are presented and discussed.

1. Introduction

The synchronization of chaotic oscillators has been the subject of significant studies in the last few years due to its fundamental and applied interests [1]. From the application point of view, chaos-based communications have become an option to improve privacy and security in date transmission, especially after the recent field demonstration of the metropolitan fibre networks of Athens [2]. In optical chaos-based communications, the chaotic waveform is generated by using semiconductor lasers with either all-optical [3–7] or electro-optical [8–10] feedback loops. In particular, semiconductor lasers subject to the influence of optical feedback from a distant mirror have been investigated extensively for the past two decades and different dynamical behaviours have been characterized, including periodic and quasi-periodic pulsations, low frequency fluctuations and coherent collapse (for more details, see [11]). In the conventional all-optical feedback case (COF), the set-up consists of a laser with an external mirror. Typically, to achieve chaotic behaviour in COF a delay roundtrip time of at least few hundreds of picoseconds is needed. So, in air the external cavity should be about few centimetres long, which is a drawback for the design of compact chaotic sources. In this context, multi-section lasers with an amplified feedback section could be suitable candidates for integrated chaotic emitters. Due to the continuing technological progress, multi-section lasers have reach stable and compact configurations which include integrated sections with common waveguides tunable phase shifts [12]. However, the simplest configuration, a two-section laser with one active section and one passive section acting as an external cavity, is not suitable since the length of the passive section is typically too short to achieve chaotic dynamics. Therefore, more complex designs have to be explored. A recent step in this direction was the consideration of integrated three section lasers with amplified feedback [13]. Here we consider a different configuration which includes feedback from an integrated double cavity.

Lasers subject to feedback from two cavities have been considered in several configurations [14–18]. In particular, feedback from a second cavity has been used to control the chaotic dynamics of semiconductor lasers with optical feedback. Control in the low frequency fluctuation regime has been achieved by properly adjusting both the length and the feedback strength of the second external cavity. Configurations using Fabry–Perot resonators to provide feedback have also been studied [19, 20]. In this

