Chaos Generation and Synchronization Using an Integrated Source With an Air Gap

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***Abstract*—We discuss experimentally and numerically the dynamical behavior of a novel integrated semiconductor laser subject to multiple optical feedback loops. The laser's structure consists of distributed feedback section coupled to a waveguide, an air gap section and two phase sections. It is found that the laser, due to the multiple feedback loops and under certain operating conditions, displays chaotic behaviors appropriate for chaos-based communications. The synchronization properties of two unidirectionally coupled (master-slave) systems are also studied. Finally, we find numerically the conditions for message encryption/extraction using the multiple-feedback lasers.**

***Index Terms*—Air gap, chaos-based communications, multiple feedback, semiconductor lasers.**

I. INTRODUCTION

THE PHENOMENON of synchronization has been the subject of numerous theoretical and experimental investigations in many research areas [1]. In particular, synchronized chaotic waveforms have found applications in chaos-based communication systems. Different setups for chaotic data transmission have been proposed in [2]–[7]. From the application point of view, chaos-based communications have become an option to improve privacy and security in data transmission, especially after the field demonstration over the metropolitan fiber network of Athens [8].

In optical chaos-based communications, the chaotic waveform is usually generated by semiconductor lasers subject to either all-optical [9]–[13] or electro-optical [14]–[16] feedback. Configurations using Fabry–Perot resonators providing the optical feedback, the so-called frequency selective feedback, have also been considered [17]–[20]. In this case the feedback can either destabilize the laser emission or improve the stability of the continuous wave (CW) emission allowing the control of the laser in a non-invasive way [17]. Recently, the chaos modulation technique [21] and the on/off phase shift keying encryption method [26] have been successfully applied to an integrated device composed of a semiconductor laser and a double cavity, which provides optical feedback.

It is now well accepted that secure all optical chaos-based communications rely on the closed loop scheme, after it has been shown that the open loop scheme requires a larger amplitude message, which could be detected by simple linear filtering techniques [22]. However, the closed loop scheme requires a precise matching between the emitter and receiver external cavities [24], [25]. Free space cavities are not sufficiently stable and integrated sources are required. Recently, a novel photonic monolithic integrated device consisting of a distributed feedback (DFB) laser, a passive resonator, and active elements that control the optical feedback properties, has been designed, fabricated, and evaluated as a compact potential chaotic emitter in optical communications [23]. Different operating regimes, including stable solutions, periodic states, and broadband chaotic dynamics have been identified.

It is our aim in this paper to further investigate the possibility of developing new integrated, mechanically stable, operating sources capable of generating chaotic light for its potential use in chaos based communication systems. To this end we propose, fabricate and test, both experimentally and numerically, an integrated optical source composed of a DFB laser, two passive sections, two phase sections, and a narrow air gap.

This paper is structured as follows. We start in Section II by describing the laser setup and the theoretical model. In Section III the experimental results are presented. Section IV presents a study of the dynamics of a laser under the influence of multiple feedback loops. The synchronization properties and the chaos modulation (CM) encryption method are also demonstrated. Finally, the summary and conclusions are given in Section V.

II. LASER STRUCTURE AND THEORETICAL MODEL

A sketch of the investigated integrated laser is shown in Fig. 1 and comprises a DFB section coupled to two phase sections, two optically transparent straight waveguides and an

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