Dynamics and applications of delay-coupled semiconductor lasers

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Summary

Semiconductor lasers are known to be highly sensitive to external perturbations and, as a result of the perturbations, can exhibit deterministic chaotic behavior. In particular, delayed optical feedback (see Figure 1, left) is a common way to induce and control chaotic laser emission. The complex dynamics of semiconductor lasers subject to optical feedback has led in turn to the development of novel applications ranging from chaos communications to random bit generation [1].

In this talk, I will first present recent advances in the experimental characterization of delay-coupled semiconductor lasers. These novel techniques allow e.g. for the acquisition of highly resolved optical spectra (see Figure 1, right) and for the real-time detection of the emitted intensity (with high sampling and long acquisition memory simultaneously) with sufficient detail of the relevant frequencies/time-scales involved in the complex laser emission.

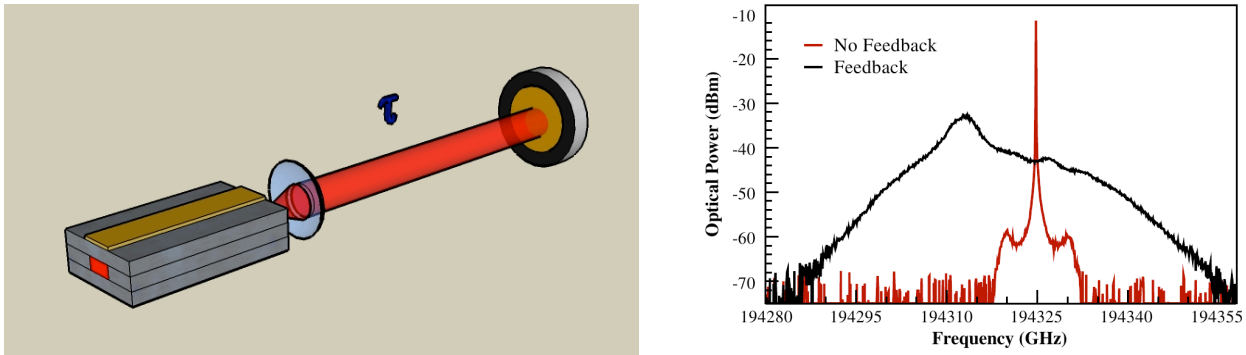

Fig. 1 (Left) Sketch of a semiconductor laser subject to delayed optical feedback from an external cavity. (Right) Highly resolved optical spectra for a solitary semiconductor laser (red) and a semiconductor laser subject to delayed optical feedback (black), displaying coherence collapse.

In the last part of the talk, I will cover two applications that benefit from the complex dynamical properties of semiconductor lasers. The first example will be the demonstration of a key exchange cryptosystem based on the phenomenon of identical chaos synchronization between two delay-coupled semiconductor lasers [2]. In this protocol, the two communicating lasers symmetrically generate a private key. This key is built up from the synchronized bits occurring between two current-modulated semiconductor lasers coupled with delay. I will briefly discuss the security of the exchanged key, demonstrating private key generation rates up to 11 Mbit⁄s over a public channel.

As a second application of delay-coupled semiconductor lasers, I will focus on an experimental demonstration of ultrafast optical information processing [3]. In this case, a semiconductor laser subject to delayed self-feedback and optical data injection is employed to solve computationally hard tasks. This simple photonic system demonstrates speech recognition and chaotic time-series prediction at data rates beyond 1 Gbyte/s, identifying spoken digits with very low classification errors and performing chaotic time-series prediction with 10% error.

Altogether, the availability of high-quality telecommunication components, advances in technology, and the cross-fertilization of photonics with other fields of science in which delay dynamics plays a role, offer qualitatively new chances. Novel applications have already been implemented, so far appearing rather as isolated solutions to particular problems. With these new perspectives, a whole infrastructure of applications can be developed that might contribute to solving major issues in today's communication systems, including privacy, computational efficiency, or power consumption.

References

[1] M. C. Soriano, J. García-Ojalvo, C. R. Mirasso, and I. Fischer, *Reviews of Modern Physics* **85**, 421-470 (2013).

[2] X. Porte, M. C. Soriano, D. Brunner, and I. Fischer, *Optics Letters* **41**, 2871-2874 (2016).

[3] D. Brunner, M. C. Soriano, C. R. Mirasso, and I. Fischer, *Nature Communications* **4,** 1364(2013).

Biography

Miguel Cornelles Soriano was born in Benicarlo, Spain, in 1979. He received the Telecommunications Engineering degree from the Polytechnic University of Catalonia, Spain, in 2002, and the Ph.D. degree in Applied Sciences from the Vrije Universiteit Brussel, Belgium, in 2006. He currently holds a tenure-track "Ramon y Cajal" research contract with the Institute for Cross-Disciplinary Physics and Complex Systems (IFISC), Spain, where he previously held an assistant professor position and a "Juan de la Cierva" post-doctoral contract. He has co-authored over 45 peer-reviewed publications, with more than 1000 citations and an h-index of 16 (Researcher ID: D-8480-2011). His research interests include synchronization and control of chaotic lasers and electronic circuits, applications of nonlinear dynamics, and neuro-inspired information processing. He is a Senior Member of the IEEE Photonics Society.