Long-Delay Self-Synchronization of a Chaotic Semiconductor Laser

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Abstract: We show theoretically and experimentally that a chaotic semiconductor laser (CSL) may be self-synchronized by re-injecting a delayed replica of its own output. The ensuing quasi-periodic dynamic is analyzed.

1. Introduction
Synchronization of CSLs subject to external optical injection has been widely studied in recent years [1]. When the external source is replaced by a delayed replica, from a distant mirror, of the same laser optical output, we expect the laser to synchronize upon itself [2]. In principle, a perfect self-synchronization would select in the chaotic attractor a periodic trajectory appearing, on a short time scale, indistinguishable from a genuine chaotic trajectory. In this paper, we investigate this regime both experimentally and by numerical simulations based on the Lang-Kobayashi model [3], finding that the CSL achieves imperfect synchronization, whose quality we quantify by observing how the output autocorrelation function peaks decay over the round-trips.

2. Self-synchronization experiment and numerical analysis
The experimental set-up is shown in the left part of Fig. 1. The light emitted by a DFB laser diode at 1550 nm is focused into one arm of a 50/50 coupler through a system of optics in a ~5 cm air-cavity, and is then back-reflected by a high-reflectivity mirror placed at the other arm, at the end of a 670 m single mode fiber. The laser is led to chaos by means of the Fresnel reflection of the straight-cut fiber tip, which acts as a first partial mirror. The backward delayed replica coming from the long fiber forces the laser to continuously synchronize upon itself (over the round-trip time $T \approx 6.7 \mu s$), giving rise to a quasi-periodic chaotic waveform. Indeed, as shown in the right side of Fig. 1, measurable autocorrelation peaks appear up to about 5-6 periods.

By computer simulations we have verified that the level of the correlation peaks, hence the quality of the self-synchronization, is independent of the period $T$, as long as this remains sufficiently larger than the typical timescales of the standalone laser dynamics (i.e., while working with incoherent injection), whereas it is very sensitive on the relative strength of the two optical injections, namely on the ratio $\kappa/\gamma$, where $\gamma$ is the short-cavity field reflection coefficient, and $\kappa$ is the injection coefficient of the delayed external field.

3. Conclusions
We have experimentally demonstrated that a chaotic semiconductor laser can be synchronized upon itself. Moreover, simulations reproducing the main features of the experiments have confirmed it. Applications simultaneously requiring the noise-like character of a chaotic signal and the regularity of a periodic source can be envisaged (e.g., target displacements measurements, chaotic cryptography).

4. References