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Closed-loop synchronization in photonic-integrated chaos emitters

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Abstract: The synchronization of closed-loop receiver architecture to a chaotic signal emitted by a photonic integrated chaotic oscillator is studied. A phase matching condition and precise temperature control are prerequisites for stable synchronized operation.

1. Introduction

Photonic integrated devices that employ semiconductor lasers with additional controllable sections that perturb the solitary laser operation prove to be efficient in terms of their potential to generate non-linear dynamics [39-42]. The device presented very recently in [43] exhibits a fully-controllable rich dynamical behavior, providing a broad chaotic spectrum under specific operating conditions. In the present work a matched pair of such devices is evaluated in terms of their ability to synchronize in a closed-loop receiver configuration, which means that the receiver is an identical device to the emitter, operating in optimized conditions.

2. Results and discussion

Closed-loop synchronization can be achieved with very precise matching of the external cavity lengths between the emitter and the receiver. The monolithic fabrication process can guarantee identical cavity lengths for all devices; nevertheless, even if a small fine tuning in the round trip time of the electric field is needed within a cavity for accomplishing the optimal synchronization conditions, the appropriate biasing of the active phase section that is included in the device will provide that.

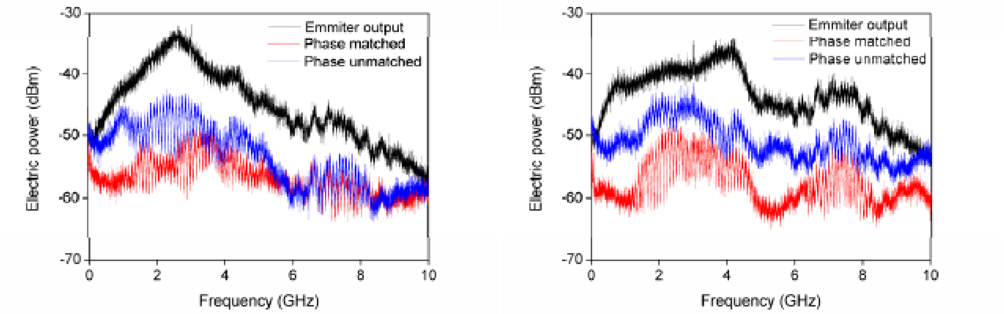

Fig. 1: Experimental microwave spectra of the monolithic integrated emitter optical output (black) and the subtraction signal between the hybrid emitter and the synchronized closed-loop receiver for phase-matched (red) and phase-unmatched (blue) conditions, for a feedback strength k_f of ~3.3% (left) and ~5% (right).

The dependence of the phase matching condition in the synchronization process of short-cavity devices is presented, after considering two different feedback conditions for both emitter and receiver devices, which are determined by accordingly biasing a gain/absorption section (G/As) that is also integrated in the device. When G/As is positively connected but biased with 0mA, the feedback strength lays in adequate levels to generate powerful chaotic dynamics gathered around the laser's relaxation frequency (fig. 1, left). Cancellation maximum reaches up to 20dB in the most powerful spectral regions, when a phase matched condition is applied. On the contrary, unmatched phase conditions will result in severe synchronization efficiency deterioration. When feedback is increased (fig. 1, right) the spectral distribution of the chaotic carrier is changed as a result of the much different dynamics that prevail in the device. Under appropriate phase matching, a good synchronization performance is recorded, with a cancellation maximum over 20 dB. As it can be also observed, the cancellation error is some spectral regions emerges from intense fringes. These fringes are attributed to the local reflection of the emitter's injected field at the receiver's laser-fiber interface and are caused by the correlation that exists between the emitter's output and the same delayed chaotic signal reflected at the receiver's laser. A better performance should be expected in terms of synchronization if minimization of this back-reflection could be achieved.

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