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Opto-electronic delay device with two feedback loops

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Abstract

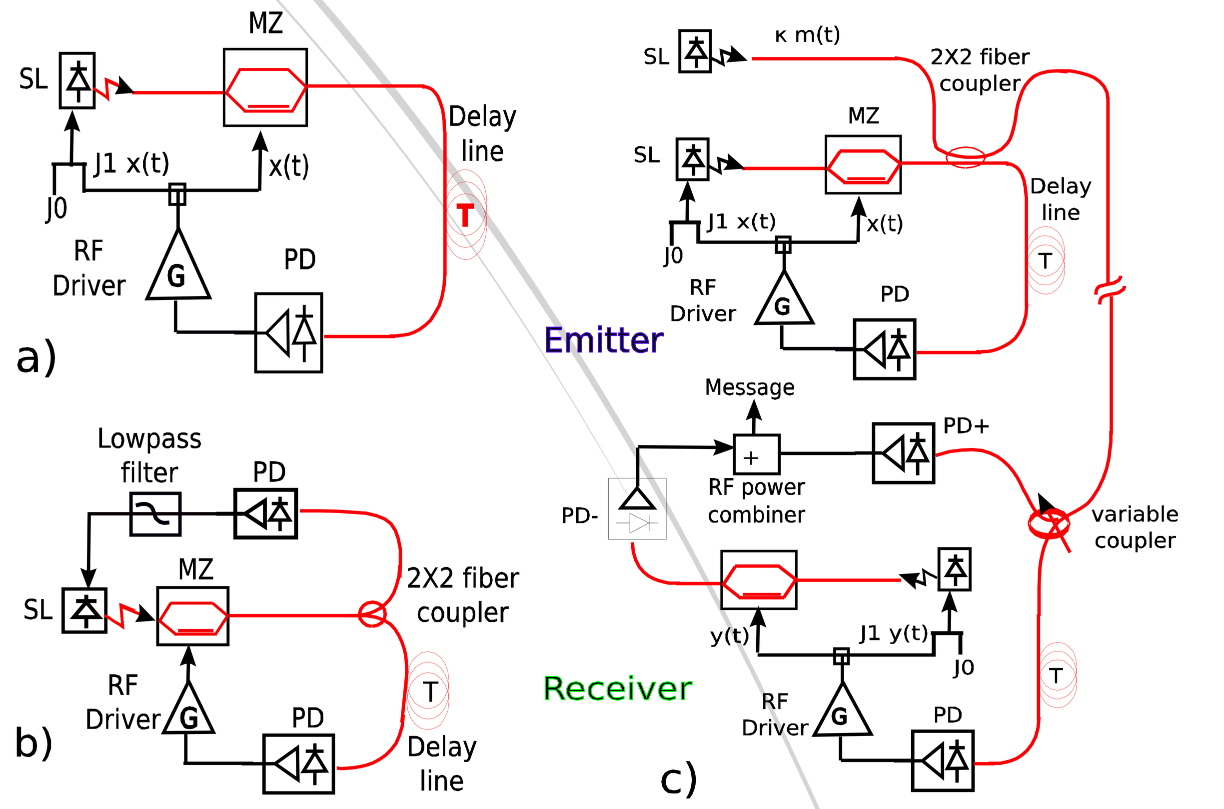
Previous research has shown that semiconductor lasers (SL) can be driven to chaotic regime by applying either optical injection or feedback process. Here we combine both, so that the feedback affects the SL, as well as, the electronic branch of the system. By the means of bifurcation diagram and correlation time, we numerically demonstrate from two different schemes how the chaos is induced for lower feedback levels or amplified for feedback strengths for which the system was already chaotic.

Introduction

Opto-electronic devices composed by a nonlinear interferometer (Mach-Zehnder) in which one of the arms is subject delay feedback modulation have been shown enough to provide rich variety of dynamics including a chaotic regime which is fruitful for chaos-based optical communications. In this context stronger chaos complexity is desirable. While chaos complexity increases with feedback strength there is a limitation imposed by the component bandwidths. Here we show that by combining feedback on the nonlinear interferometer and in the pump laser (previously under CW operation) we can achieve more complex dynamics.

Set-up and Model

setups



Equations

The model is described in terms of normalized RF voltage x(t) hereafter [1] and the photon number I [2].

$$X+\tau\frac{dX}{dt}+\frac{1}{\theta}\int_{t0}^{t}X(s)\,ds=\beta_1 I\cos^2[X(t-T)+\Phi]$$

$$\frac{dI}{dt}=(G_m-\gamma)I$$

$$\frac{dN}{dt}=J_0-\gamma_e N-G_m I+F[x] \qquad G_m=g_m\frac{N-N_0}{1+S_f I}$$

a) $F[x]=J_1x(t)$ b) $\frac{dF[x]}{dt}=-2\pi f_c\{F-J_1\beta_1 I\cos^2[x(t)+\Phi]\}$

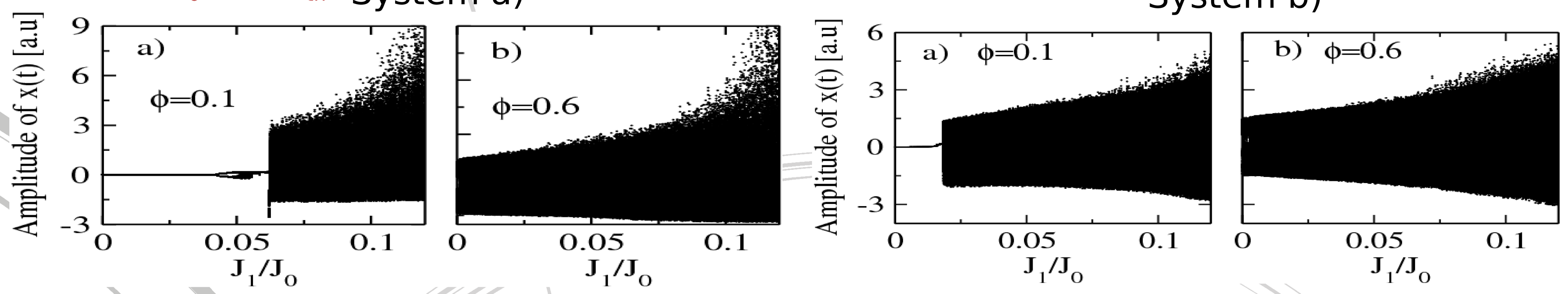
Parameters

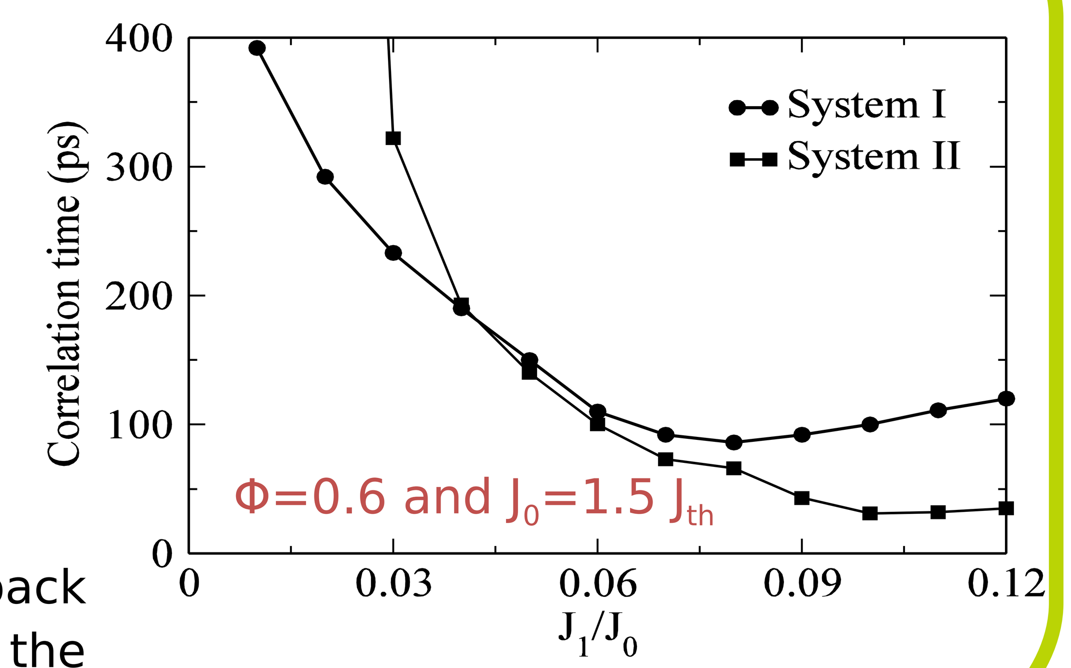
- high frequency cutoff $\tau=25$ ps
- low frequency cutoff $\theta=5\,\mu$s
- feedback coefficient $\beta_1=2.89\times10^{-5}$
- delay time $T=2.5$ ns
- gain parameter $g_m=1.5\times10^{-8}$ ps^{-1}
- gain saturation $S_f=2\times10^{-7}$
- carrier number at transparency $N_0=1.2\times10^{8}$
- inverse photon lifetime $\gamma=3.3\times10^{11}$ s^{-1}
- inverse carrier lifetime $\gamma_e=5\times10^{8}$ s^{-1}
- injected current threshold $J_{th}=7.1\times10^{16}$ s^{-1}
- Injected current J_0
- Laser feedback coefficient J_1
- offset phase Φ

We consider two new schemes in which the laser input current is composed of a DC component plus a feedback term F[x]. In a) F[x] comes from the output of the RF driver while in b) F[x] is taken at the output of the Mach-Zehnder and undergoes an optoelectronic conversion. Figure c) highlights upon the complete scheme to encode and decode the message using model displays in a). The similar can find out from model b)

Chaos generation

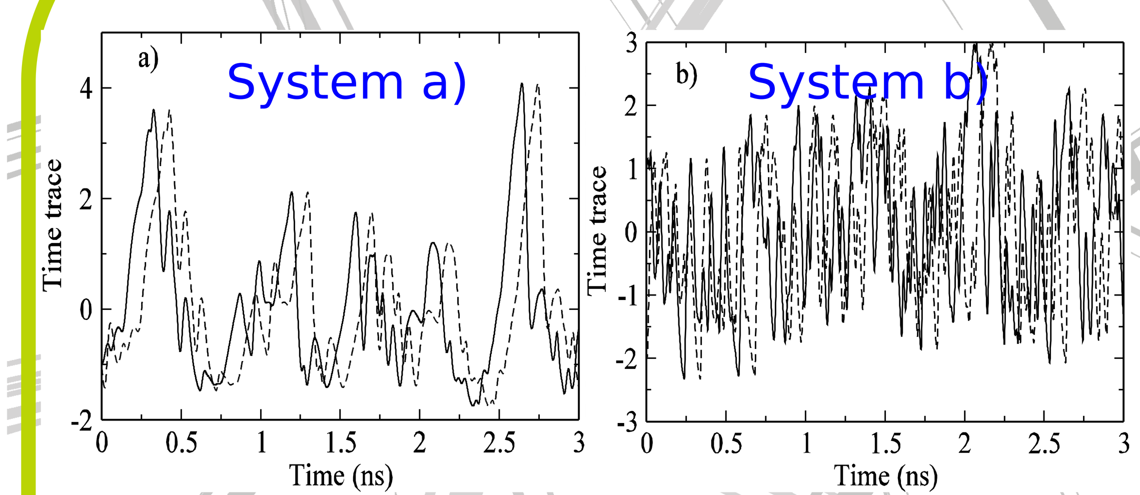
Bifurcation diagram as function of J_1 for different offset phases ϕ . $J_0=1.5\,J_{th}$

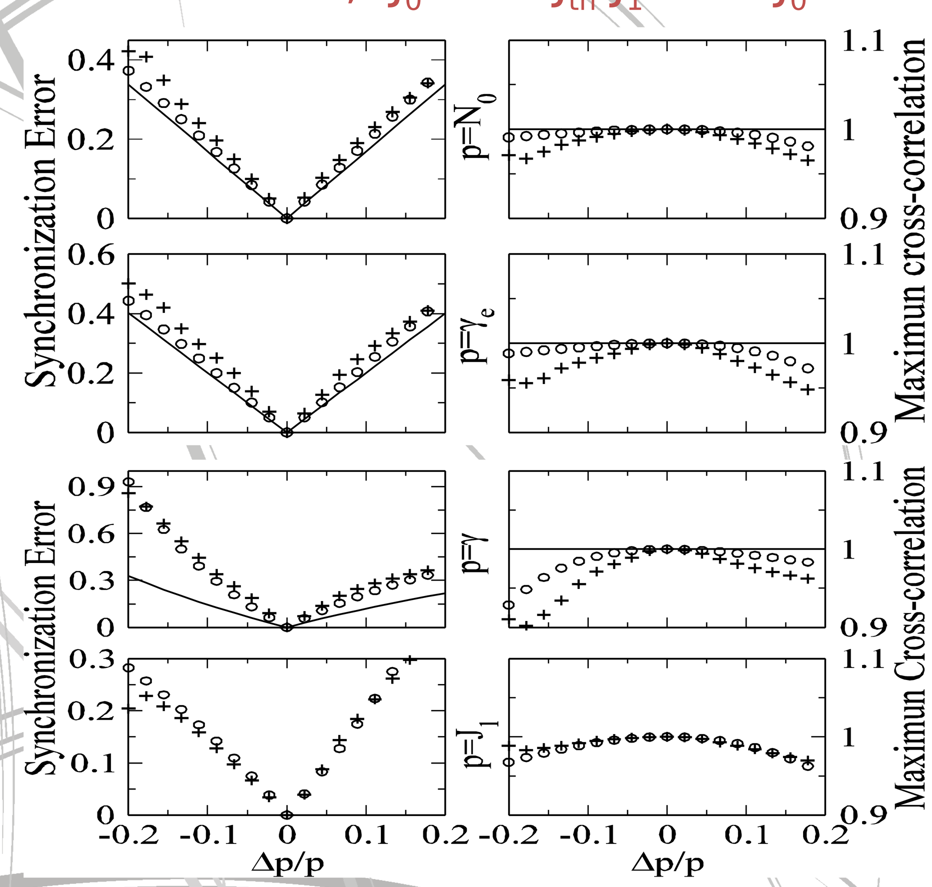




Increasing the laser feedback J_1 it is possible to generate chaos for parameters where the system with feedback only in the interferometer is not chaotic or induce more chaotic behavior. This can be quantified by the correlation time which decreases with J_1.

Synchronization and parameter mismatch





The emitter synchronizes (solid line) with the receiver (dashed line) with a time shift corresponding to the difference in time delays. Left figure shows the effect of mismatch in the synchronization. Solid line corresponds to J1=0 (no laser feedback), circles (o) to system a) and (+) to system b). Parameters γ and γ_e are more sensitive to mismatch while in other parameters the effect is similar to the case without laser feedback.

Summary

We have presented in this work an opto-electronic involving feedback both in the light source (laser) and the electronic branch. We have evidenced that this technique can be an alternative to induce further chaos in a system. The efficiency of the model has been tested by comparing the resulted effects due to mismatch to those intensively investigated in the system with single feedback.

References

1) L. Larger et al. Phys. Rev.E67, 6618 (1998)
2) G. P. Agrawal and N. K. Dutta, "Long Waves Semiconductor Lasers", *New York: Nostrand Reinhold*, 1986.

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