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Opto-electronic devices with double feedback loop.

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Abstract: We study the dynamics of optoelectronic oscillators subject to delay feedback affecting both the interferometer and the pump laser current.

Opto-electronic oscillators (OEOs) provide a rich variety of dynamical behaviours. In particular they have been used a chaos generator for encoded optical communications. A typical OEO consist of a Mach-Zehnder (MZ) interferomete pump by a semiconductor laser (SL), a fibre delay line, a photo-detector and a gain amplifier. Chaos is induced by th delayed feedback on the refractive index of one of the arms of the MZ, while the SL itself operates in CW. However delayed optoelectronic feedback on the injection current of SL can induce chaos by itself. Here we combine both, s that feedback affects the MZ as well as the SL injection. We consider two set-ups shown in Fig. 1.

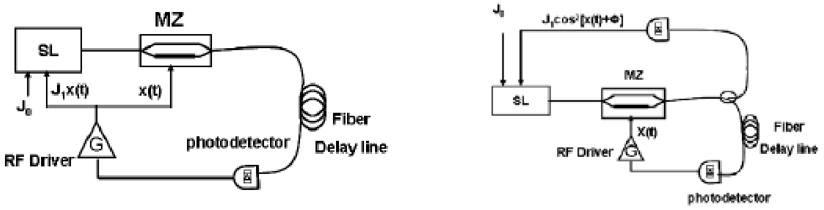

Fig. 1
Set ups considered in this work.

The dimensionless voltage applied to the MZ x, the number of photons I and carriers N are given by

$$\dot{I} = (G-\gamma)I$$
$$\dot{N} = J_0 - \gamma_e N - GI + J_1 f(x)$$
$$x + \tau\dot{x} + \theta^{-1}\int x = \beta_1 I \cos^2(x(t-T)+\phi)$$

Where T=2.5ns is the delay time, θ = 5 μs and τ=25 ps are the amplifier cut-off frequencies, $\beta'=2.89\ 10^{-5}$ is the proportionality coefficient for the MZ , ϕ is the delay phase, $\gamma=3.3\ 10^{11}\ s^{-1}$ is the inverse photon lifetime, $\gamma_e = 5\ 10^{8}\ s^{-1}$ i the inverse carrier lifetime, J_0 is the injection current, J_1 is the feedback laser coefficient and $G=g(N-N_0)/(1+sI)$ where $g=1.5\ 10^{-8}\ ps^{-1}$is the gain, $N_0=1.2\ 10^{8}$ the carriers at transparency and $s=2\ 10^{-7}$ the nonlinear saturation). For the set up on the left of Fig.1, $f(x(t))=x(t)$ while for the one on the right $f(x(t))=J_1 cos^2(x(t)+\phi)$.
Fig. 2 shows that J_1 can increase the chaos or induce chaos for parameters where it was not present.

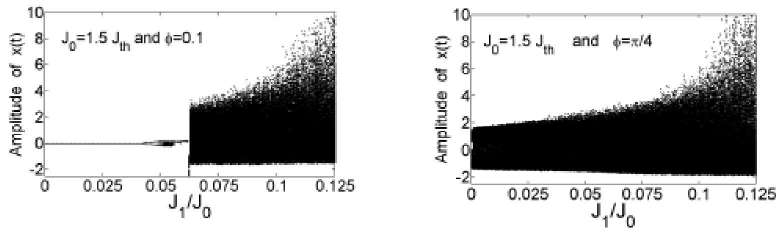

Fig. 2 Bifurcation diagram as increasing J_1 for two values of the feedback phase. We have considered the set-up shown in Fig. 1 left.

Fig. 3 shows how increasing J_1 the correlation time decreases. This effect is more noticeable in the sep-up corresponding to Fig 1 right.

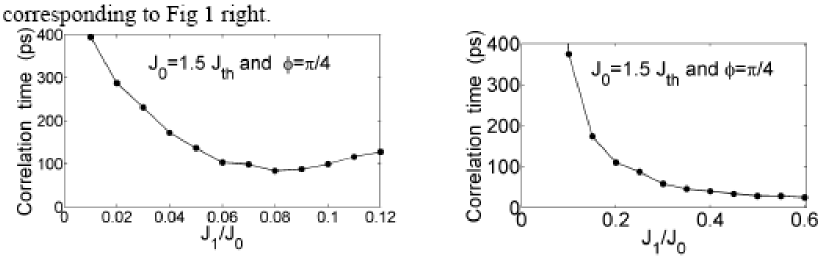

Fig. 3 Correlation time as function of J_1 for the two set-ups shown in Fig. 1.

We have also studied the synchronization between master and receiver systems as well as message encoding showing that this scheme provides a more chaotic carrier while synchronization is still good and message decoding can be done in a reliable manner.