# Self-Delayed Synchronization and analogies with long term memories

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## ABSTRACT

The chaotic spike train of a homoclinic dynamical system is self-synchronized by applying a time delayed correction proportional to the laser output intensity. Due to the sensitive nature of the homoclinic chaos to external perturbations, stabilization of very long periodic orbits is possible. On these orbits, the dynamics appears chaotic over a finite time, but then it repeats with a recurrence time that is slightly longer than the delay time. The effect, called delayed self-synchronization (DSS), displays analogies with neurodynamic events which occur in the build-up of long term memories.

## INTRODUCTION

We show that a delayed feedback can stabilize complex sequences of pulses from a laser undergoing homoclinic chaos; precisely the sequence repeats periodically after a fixed time and this stabilization of a complex periodic orbit is robust. Homoclinic chaos consists of a sequence of almost identical spikes repeating at erratic times because of the homoclinic scrambling at the saddle focus. Through a delay unit set at $T_d$, a small delayed fraction of the laser output intensity is added to the feedback signal.

This delayed feedback creates a sequence of spikes which is periodic with a period $T_r$ slightly larger than $T_d$. In this synchronization phenomenon, called Delayed Self Synchronization (DSS) [1], the overall dynamics reaches a stationary regime where the spikes of the delayed signal occur in correspondence of the region of largest susceptibility of the system, which occurs around $\tau = 150$ μs before the next large spike. Then the periodicity of the controlled signal is $T_r = T_d + \tau$. Evidence of this phenomenon is provided in Fig.1(a) where the laser output intensity is reported together with the control signal. In the expansion of Fig.1(b) the intrinsic refractory time $\tau$ is shown. A different way to illustrate DSS is by the space-time representation (STR)[2]. In this representation, the time series of the laser output intensity is split into pieces of length $T_r$, which then are stacked together as different "gray scale snapshots" of a one dimensional spatio-temporal system.

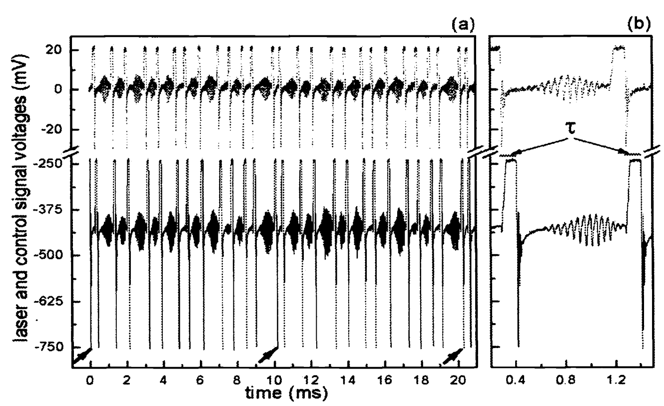


Figure1: (a) A sequence of homoclinic spikes in the output intensity of a CO2 laser in the DSS regime for delay of 10 ms. The upper trace is the delayed control signal applied to achieve the synchronized regime. The arrows denotes the periodicity $T_r$. (b) Expansion showing the refractory time $\tau$.



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Thus, every line of this representation is mapped onto the next line. Fig. 2 show the STR of the free running and of the DSS regime. We observe that the transition to the synchronized regime sharply occurs in one or two time delay units $T_r$. Moreover the synchronized patterns depend on the initial conditions of the system.

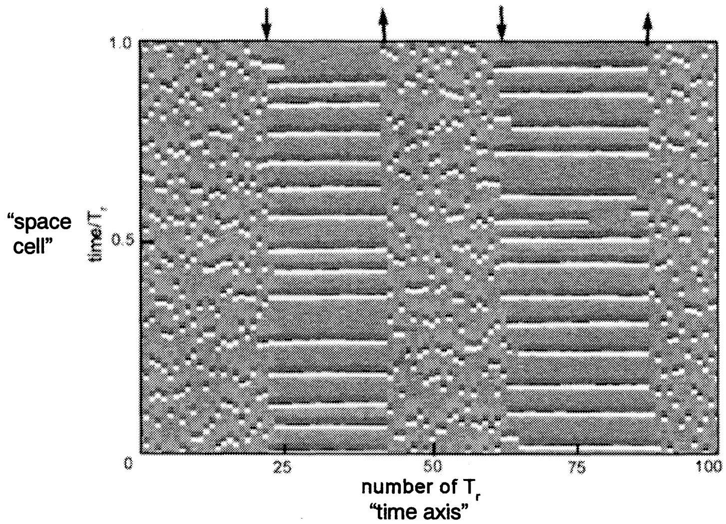


Figure 2: Space-time representation of the transition from free running to DSS regime with a delay time $T_d$ = 10 ms. The space cell corresponds to a single recurrence time $T_r$, the time coordinate is a sequence of integer values corresponding to the successive delay units. The downward and upward arrows denote respectively the time positions where the control is applied and removed. Notice that when the control is applied the sequence, even though chaotic along the vertical (space) axis, remains highly stable along the horizontal (time) axis.

## CONCLUSION

The ability to synchronize very long and complex periodic orbits is of particular interest in relation to the recent discovery of the neuronal mechanism of transformation of short-term memories into permanent (long-term) memories via so called synaptic reentry reinforcement (SRR) [3]. In those experiments, it has been demonstrated that neurons responsible for learning, repeatedly "replay" certain spiking patterns in order to establish permanent connections (synapses) among neurons.

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