Nonlinear Dynamics and Synchronization in Optoelectronic Feedback Loops

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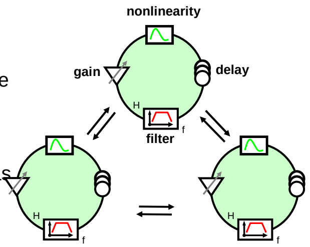
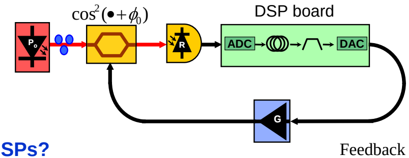
Introduction

Coupled chaotic oscillators exhibit interesting dynamical states depending on the mode and strength of coupling. We explore the synchronization of nonlinear optoelectronic feedback loops exhibiting high dimensional chaos. We will use these feedback loops as modular elements in our nonlinear photonic sensor network.



A single feedback loop



Feedback strength, $\beta = \frac{\pi}{2}\frac{P_0 R G}{V_\pi}$

Why DSPs?

✓Allows programmable filter design

✓Permits real-time control of filter, delay and feedback

Mathematical model

Here we consider a 2-pole bandpass digital filter which may be described as

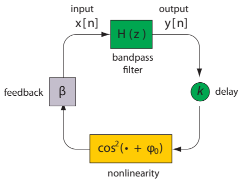
$$y[n] = b_0 x[n] + b_1 x[n-1] + b_2 x[n-2] - a_1 y[n-1] - a_2 y[n-2]$$

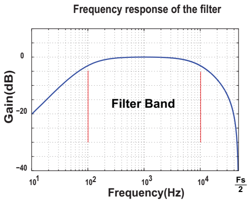
$$y[n] \equiv \text{output}$$

$$x[n] \equiv \text{input}$$

$$a_1, a_2, b_0, b_1, b_2 \equiv \text{filter coefficients}$$

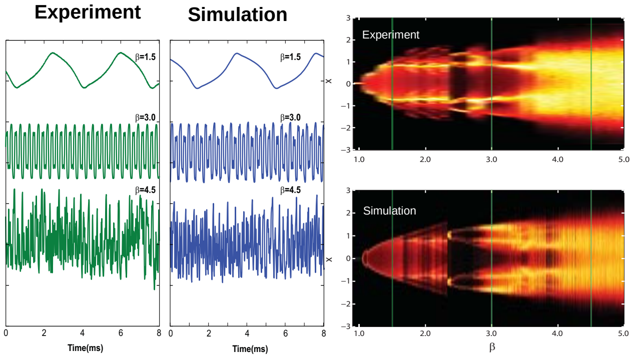
Here $x[n] = \beta \cos^2(y[n-m] + \phi_0)$ where *m* is the loop delay





Dynamical behavior of a feedback loop

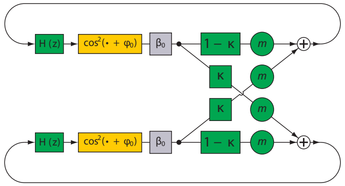
Dynamical behavior ranges from simple to complex, depending on β.

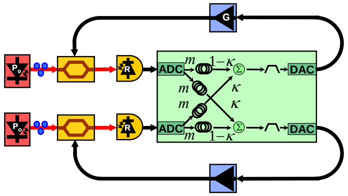


Mutually coupled systems

We consider mutually coupled feedback loops with identical loop parameters β and *m*. We explore the special case with the coupling delay being the same as the loop delay.

➢ Under these conditions, synchronization *can* occur depending on the strength of coupling, but is not *guaranteed.*

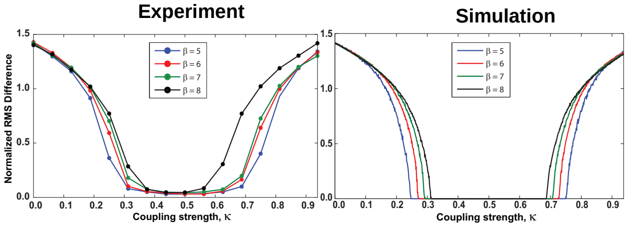




Q: Under what conditions can these systems synchronize?

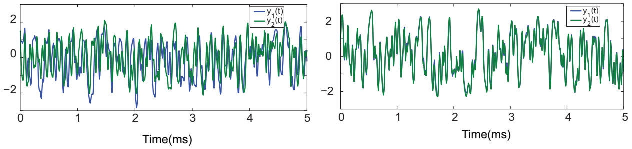
Synchronization of coupled systems

Regimes of Synchrony:



For $\beta = 5$:

Coupling strength, κ = 0.2	Coupling strength, κ = 0.3
⬇ Unsynchronized	⬇ Synchronized



Conclusions and future directions

- ➢ We experimentally explored the conditions under which coupled nonlinear optoelectronic systems synchronize.
- ➢ Digital signal processing allows flexible filter implementation, with possibility for future adaptive control.
- ➢ In the future, we intend to scale the network to incorporate many more oscillators with an emphasis on sensing applications.