Numerical Models of Semiconductor Lasers with Time Delayed Opto-Electronic Feedback

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Introduction

- We intend to use this system as a building block to understand a network of lasers which can be used in sensor applications.

- Time delayed semiconductor lasers systems can also be used while studying patterns on firing neurons and the dynamics of epidemics.

- We compare simulation results to experimental data.
Model Setup

- Derived equations for photon number, proportional to intensity, and carrier number from the electric field equations for a semiconductor laser.
- Experimental optical and electric time delays are treated as a total time delay sum.
- Our model allows us to verify experiment and explore a greater range of parameters more efficiently than experiment.
The nonlinearities of the laser combined with the delayed feedback creates complex and fascinating behavior.

Using MATLAB, we implemented a fourth order Runge-Kutta integration method for the delayed differential equations.

We apply the low and high pass filters in the time domain, using a first order differential equation to describe each one.

After matching parameters of the model to the characteristics of the laser, we vary the feedback strength and the time delay.
The relaxations are at the smallest timescale.

On the microsecond timescale, we see a pulsing behavior.

We also see modulated oscillations with a period of the total delay.
Results

- We measure the amplitude of oscillation of the time series by using $V_{\text{rms}}$.
- Oscillations begin for a self coupling strength above a specific threshold, as found in experiment.
Conclusions and Future Work

- Dynamics of the system depend greatly on the feedback strength and the time delay.
- We found a qualitative agreement between simulations and experiment.
- Further explore the physical cause of the pulsing on the microsecond timescale.
- Increase the order of the filters to better match experimental filters.
- Increase the number of lasers in the model.