Projects in nonlinear laser dynamics

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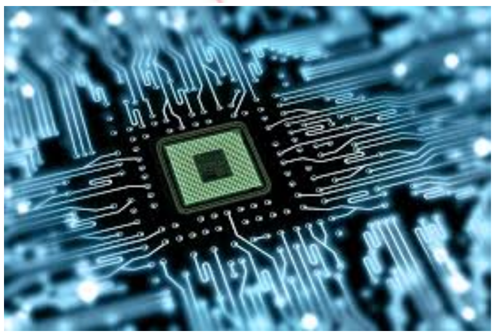
University College Cork

Motivation



Who cares about lasers?

Motivation

Who cares about lasers?

Everyone – they are everywhere in modern life

Motivation

Enabled improvements in existing devices

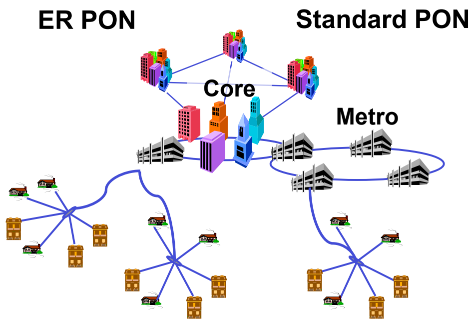
Enabled creation of many new devices

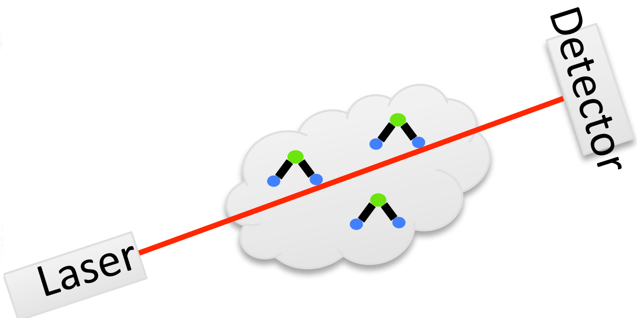
Applications:

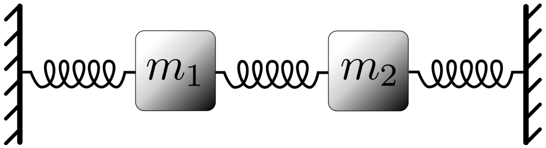
- Bar codes
- Printers
- Sensors
- Telecommunications
- Material testing
- Spectroscopy
- Military
- Medicine

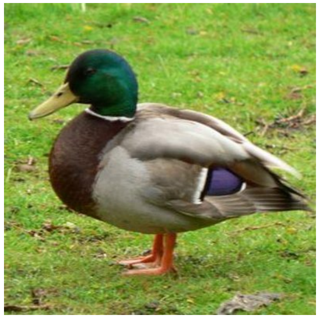
Locations:

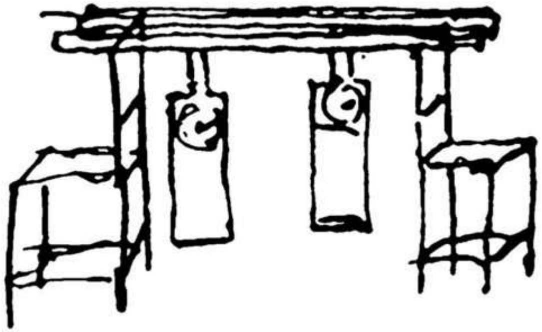
- Homes
- Shops
- Ocean
- Space
- Factories
- Hospitals
- Education
- Research

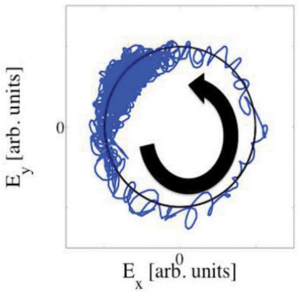

ER PON
Standard PON
Core
Metro

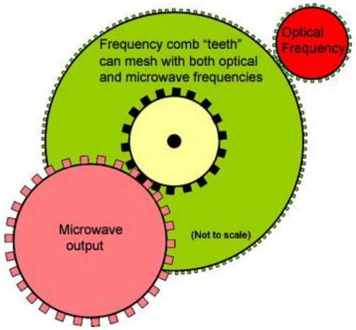

Detector
Laser


m_1
m_2






E_y [arb. units]
0
E_x [arb. units]
0

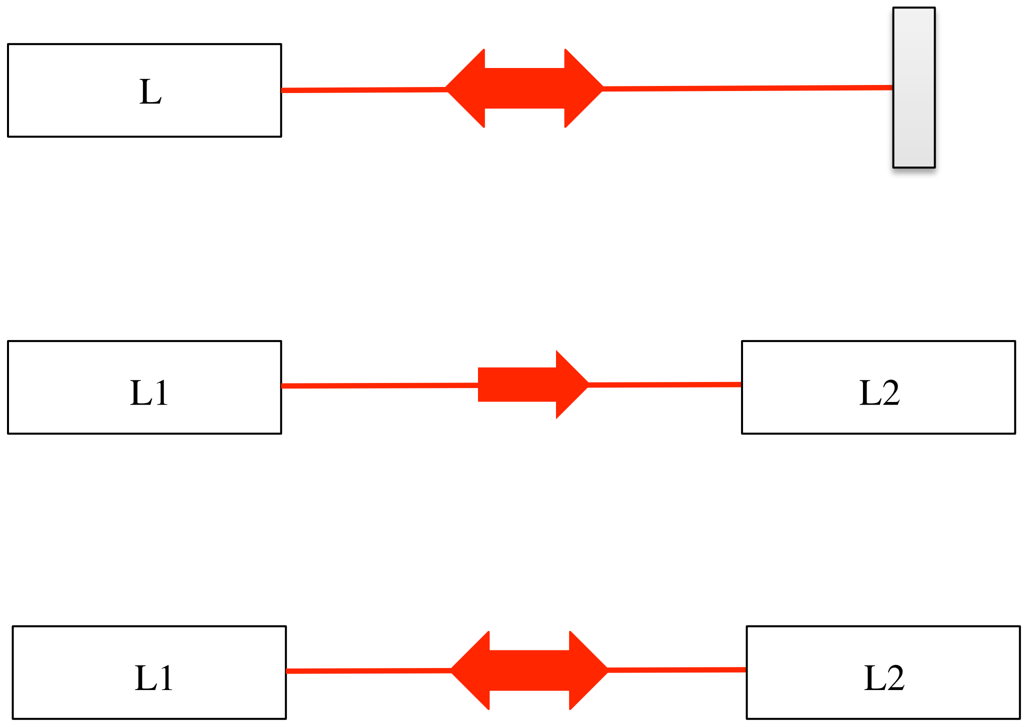

Frequency comb "teeth" can mesh with both optical and microwave frequencies
Optical Frequency
Microwave output
(Not to scale)

General theme of projects: Coupled lasers

Optical Feedback

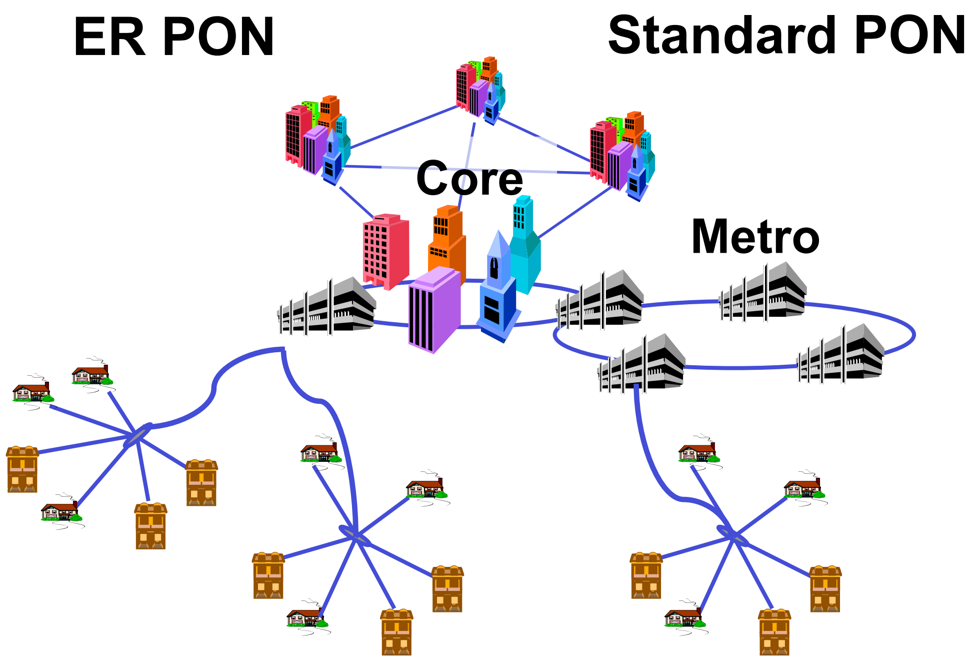
Optical Injection

Mutual Coupling



Non linear dynamics of lasers

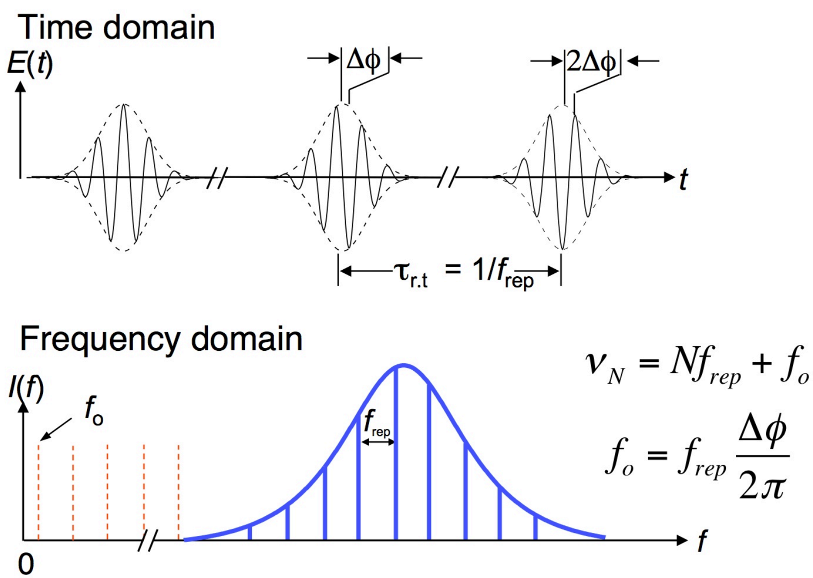
- For applications: communications

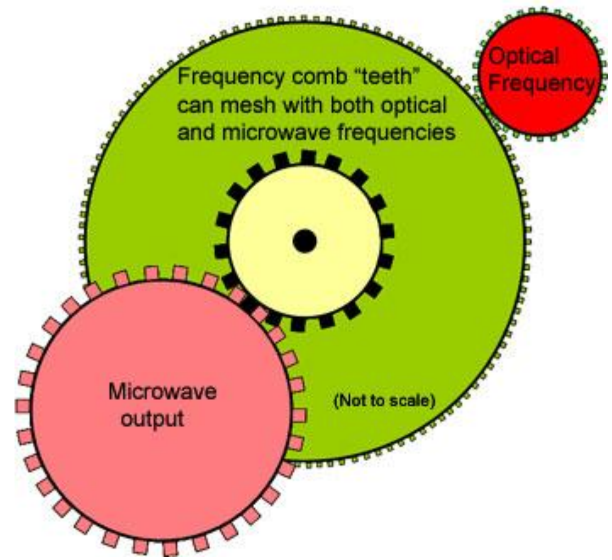


Metrology

Non linear dynamics of lasers

- For applications: communications, metrology and precision timing

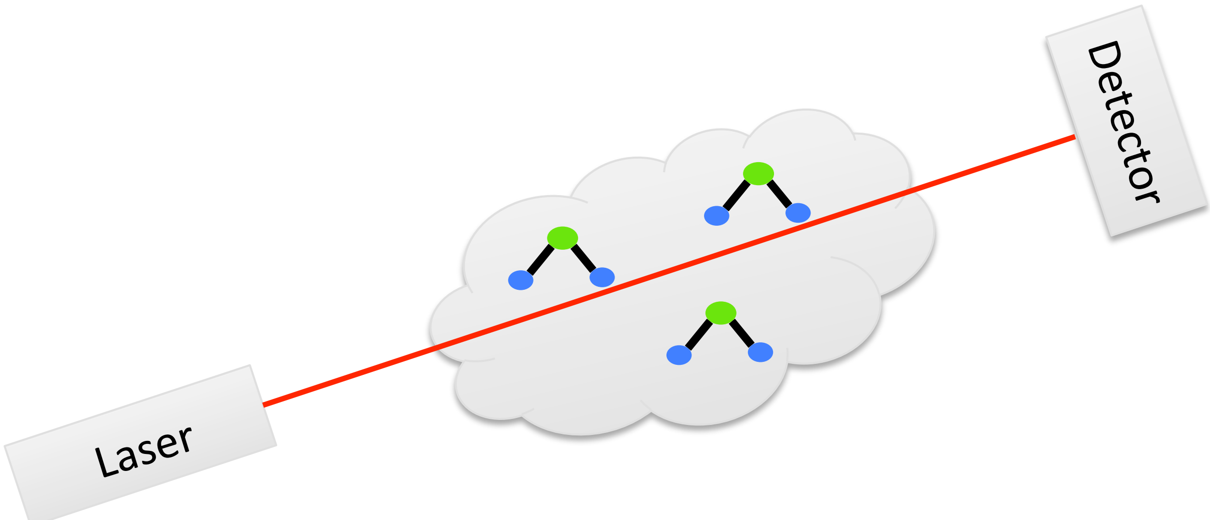




https://www.nist.gov/pba/optical-frequency-combs

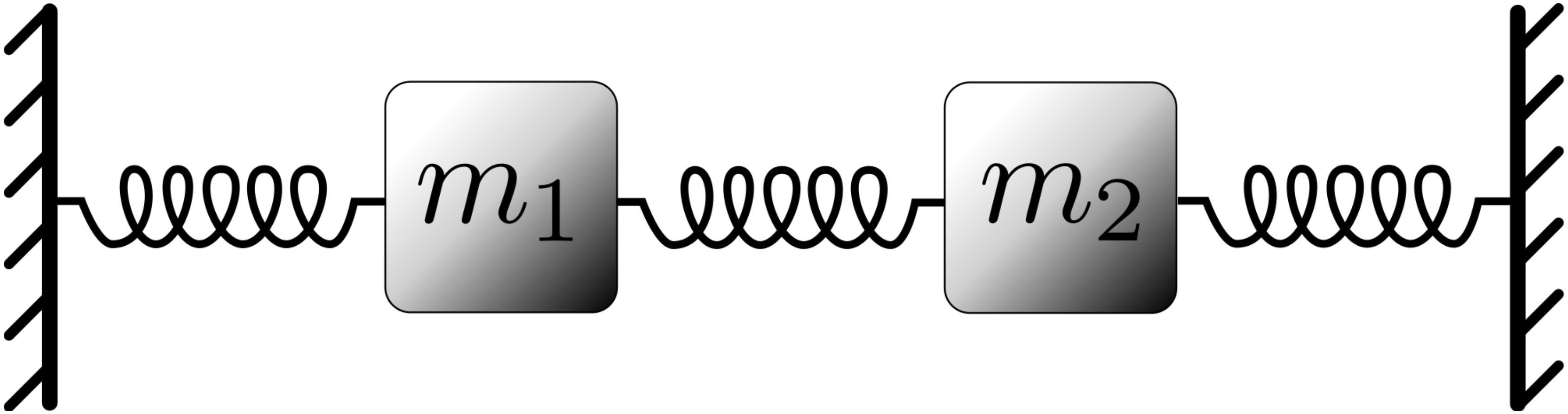
Non linear dynamics of lasers

- For applications: communications, metrology and precision timing, sensing…



Non linear dynamics of lasers

- For fundamental science: coupled oscillators



Synchronisation

Non linear dynamics of lasers

- For fundamental science: coupled oscillators, fireflies

Synchronisation

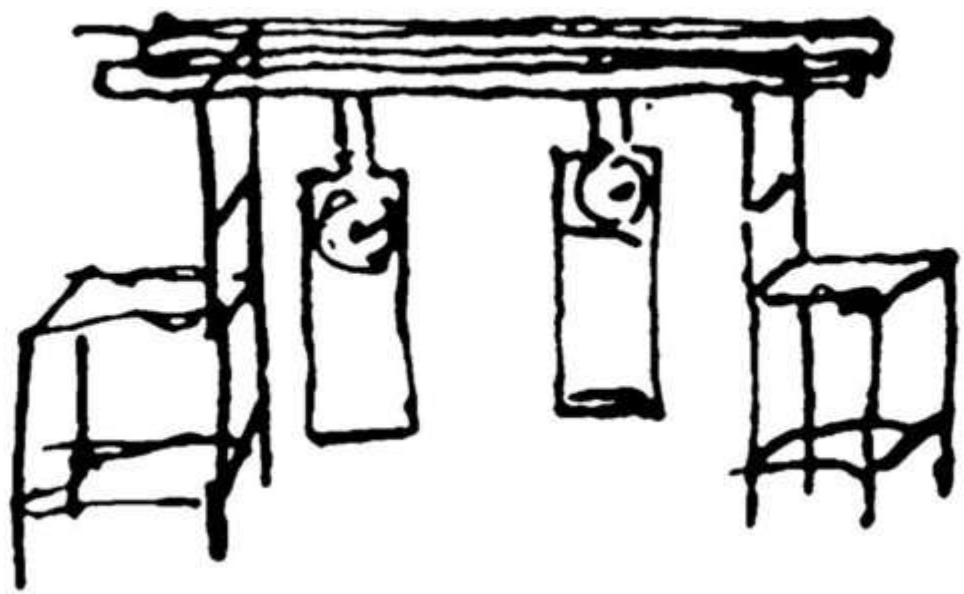
Non linear dynamics of lasers

- For fundamental science: coupled oscillators, fireflies

Synchronisation

Non linear dynamics of lasers

- For fundamental science: coupled oscillators, fireflies, coupled clocks



C. Huygens (1665)

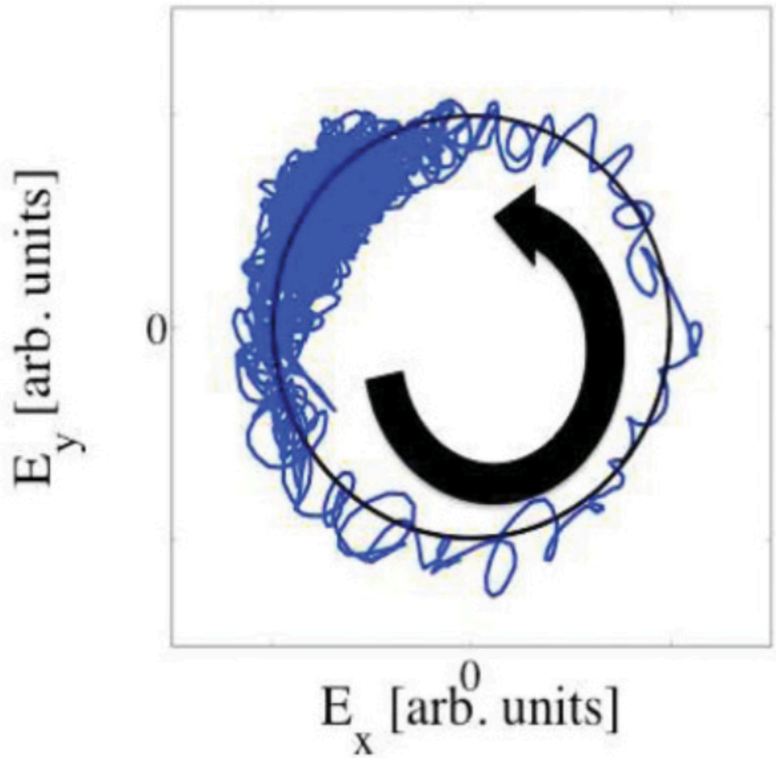
Non linear dynamics of lasers

- For fundamental science: coupled oscillators, fireflies, coupled clocks, chimeras

Trajectories

Non linear dynamics of lasers

- For fundamental science: coupled oscillators, fireflies, coupled clocks, chimeras, noise induced phenomena and phase space determination



Trajectories

Non linear dynamics of lasers

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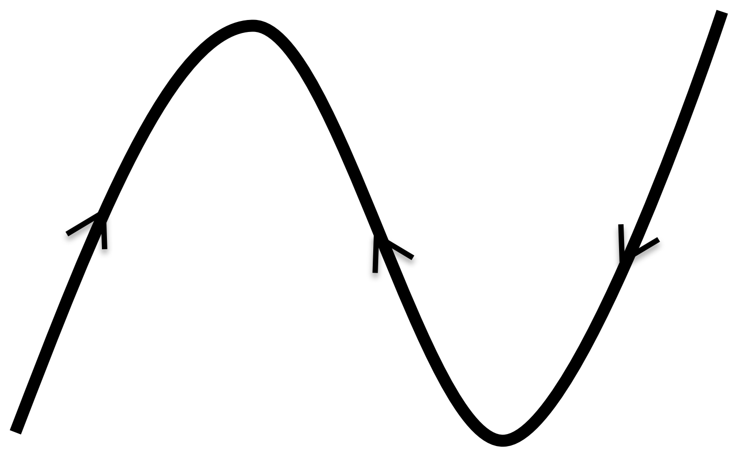

Trajectories

Non linear dynamics of lasers

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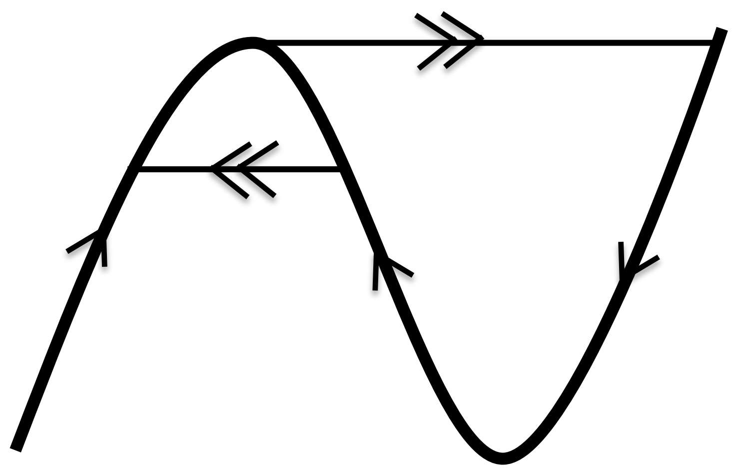
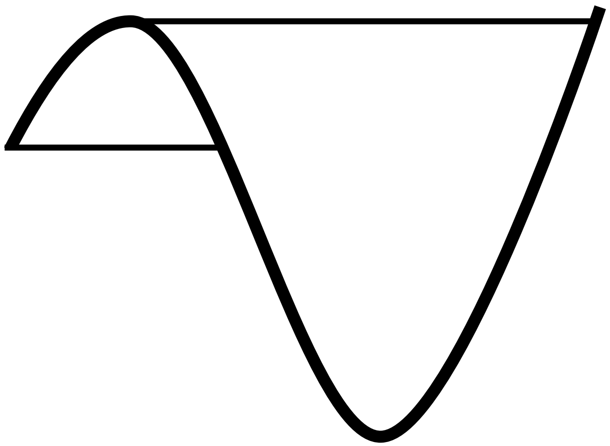


Trajectories

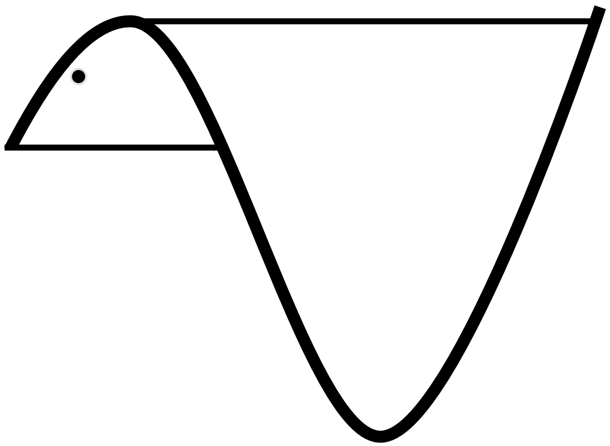
Non linear dynamics of lasers

- For fundamental science: coupled oscillators, fireflies, coupled clocks, chimeras, noise induced phenomena and phase space determination



Non linear dynamics of lasers

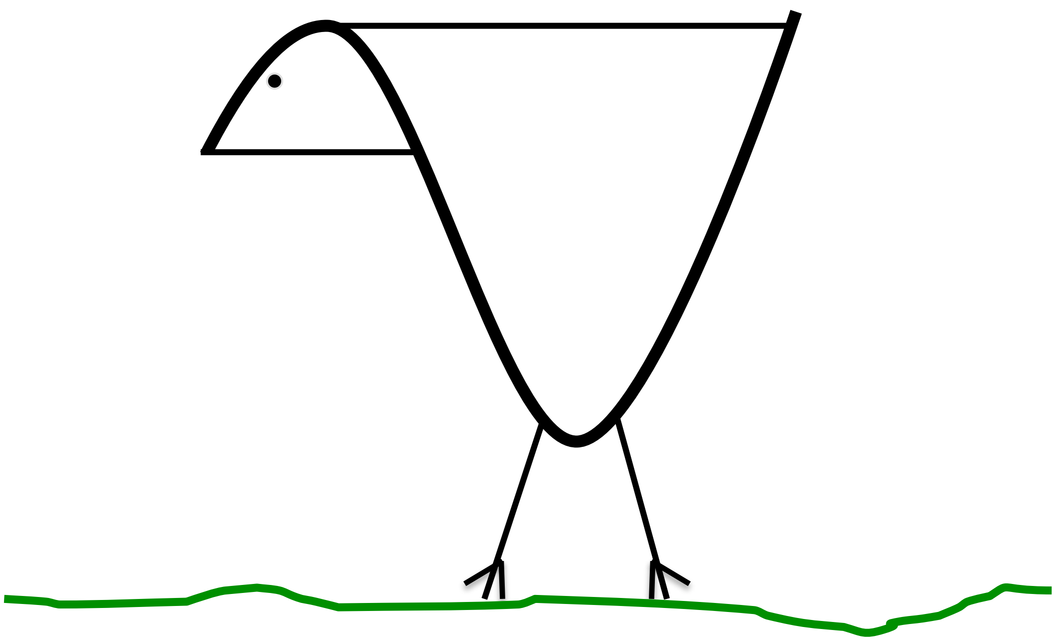
- For fundamental science: coupled oscillators, fireflies, coupled clocks, chimeras, noise induced phenomena and phase space determination



Trajectories

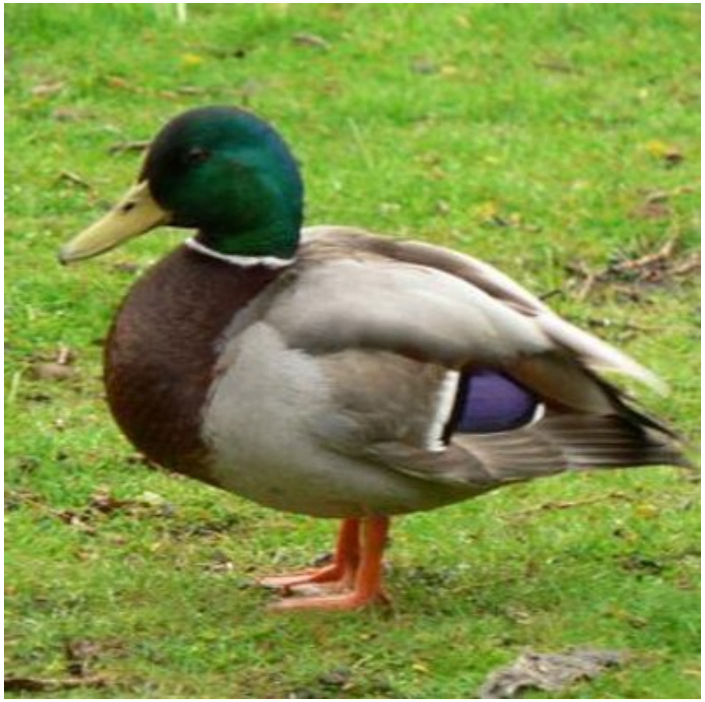
Non linear dynamics of lasers

- For fundamental science: coupled oscillators, fireflies, coupled clocks, chimeras, noise induced phenomena and phase space determination



Non linear dynamics of lasers

- For fundamental science: coupled oscillators, fireflies, coupled clocks, chimeras, noise induced phenomena and phase space determination, canards



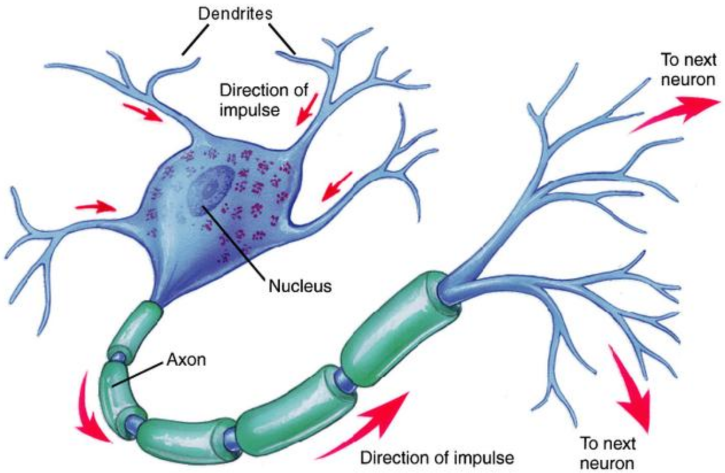
Most important

Non linear dynamics of lasers

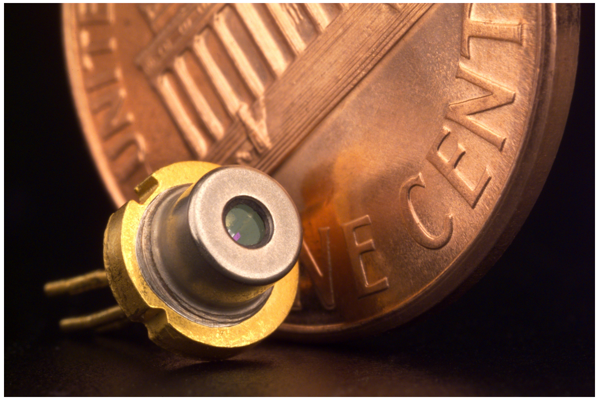
- For fun: The pleasure of finding things out

Projects

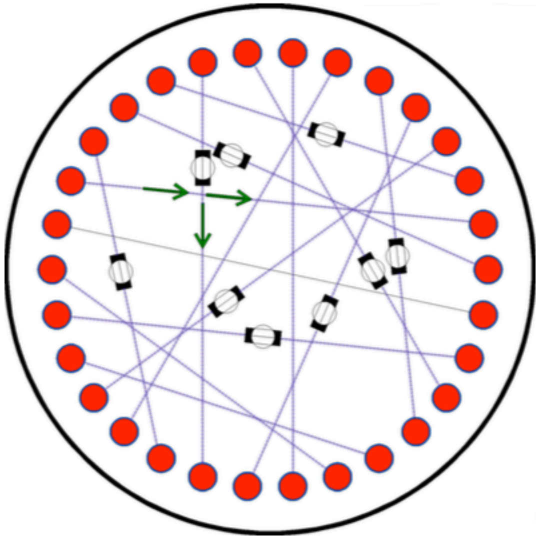
Neurons



Semiconductor Lasers

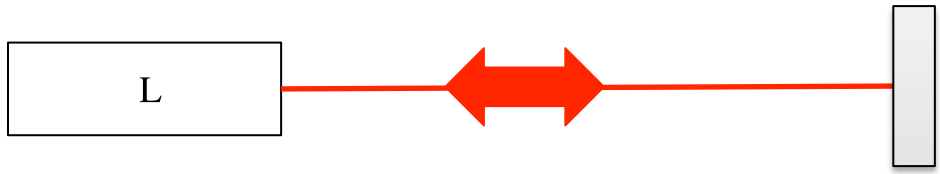


Networks of neurons are brilliant computers

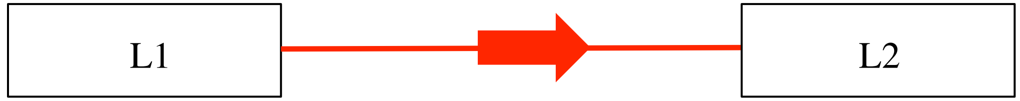


General theme of projects: Coupled lasers

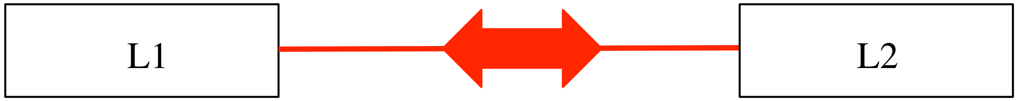
Optical Feedback



Optical Injection

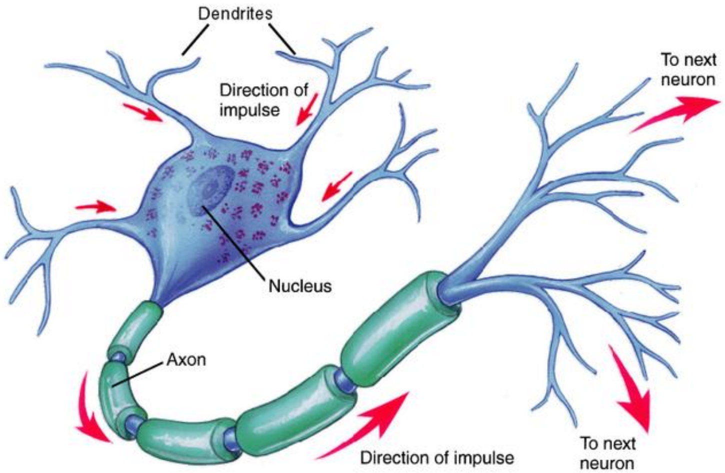


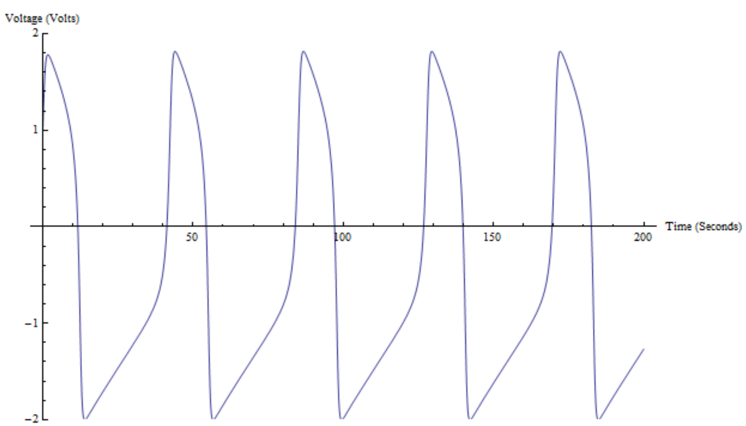
Mutual Coupling



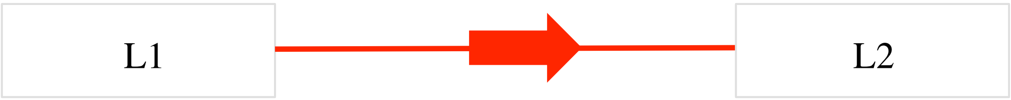
Projects

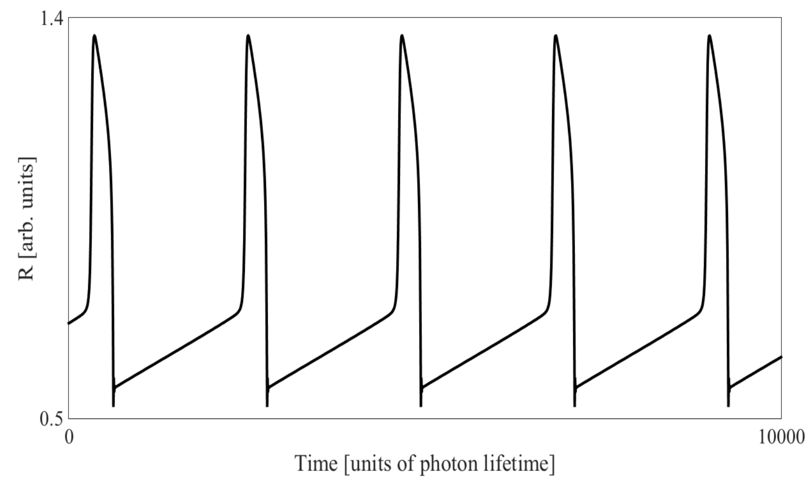
Neurons





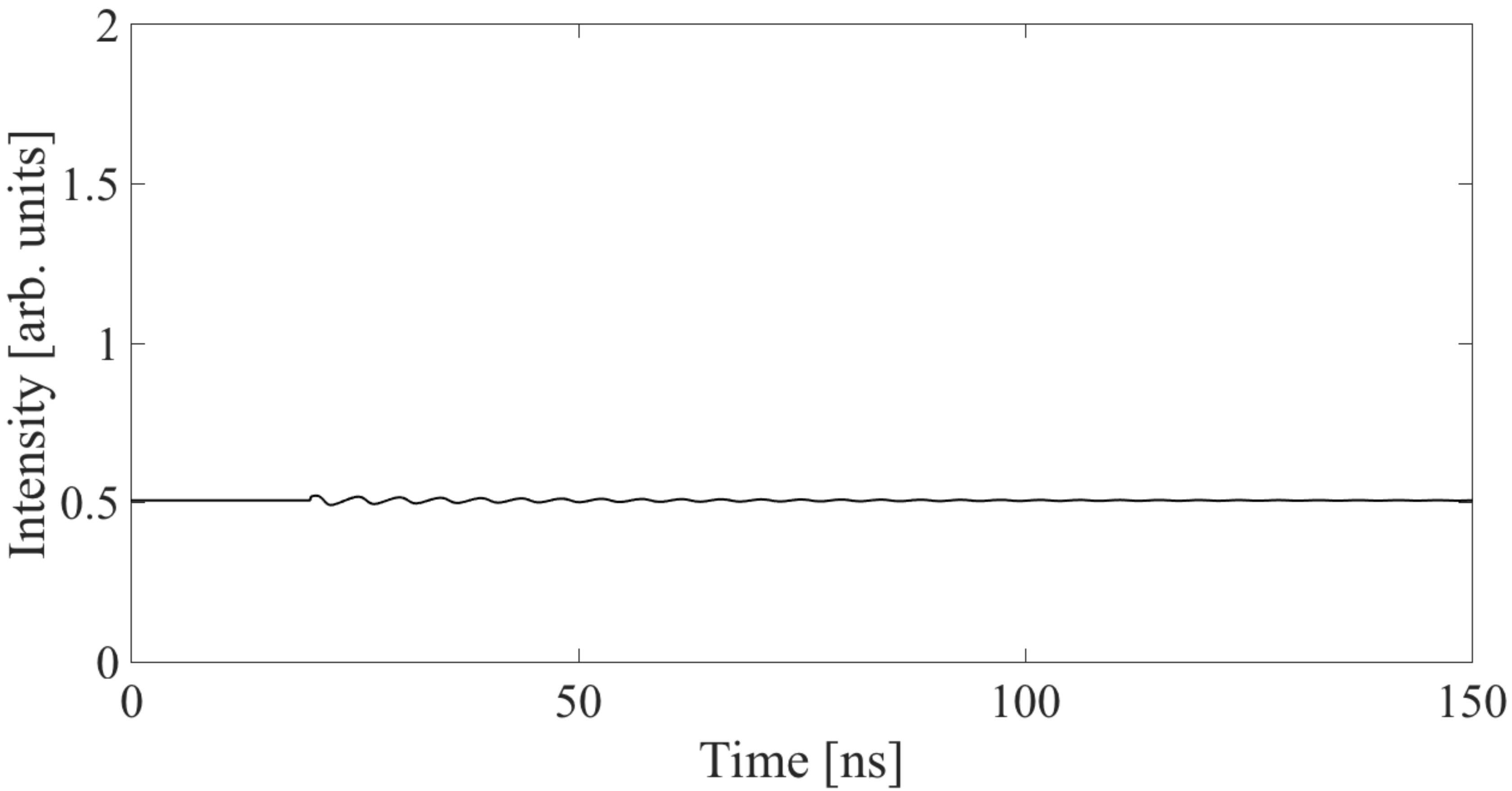
Semiconductor Lasers





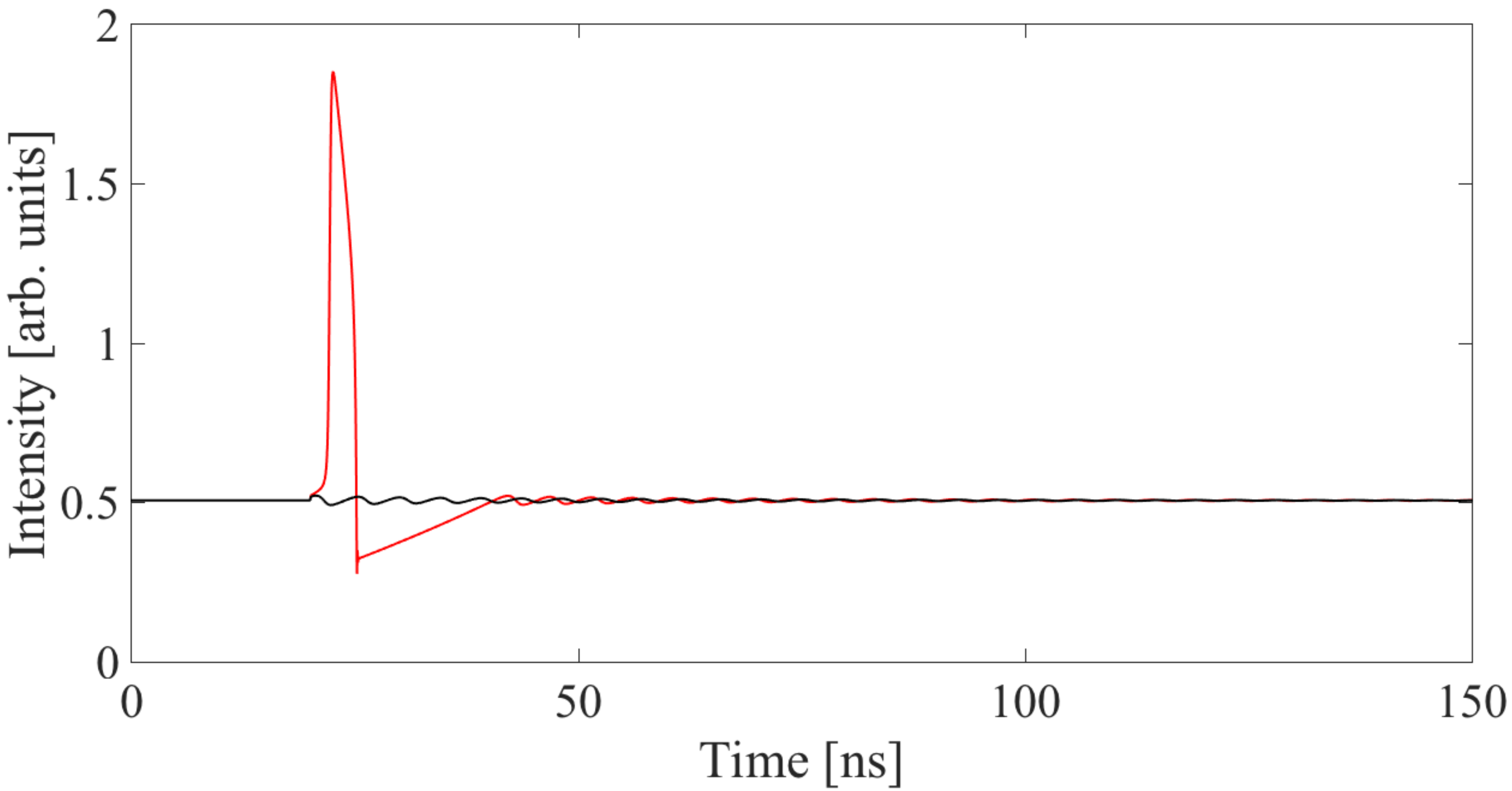
Excitability

Give the system a small kick and nothing happens:

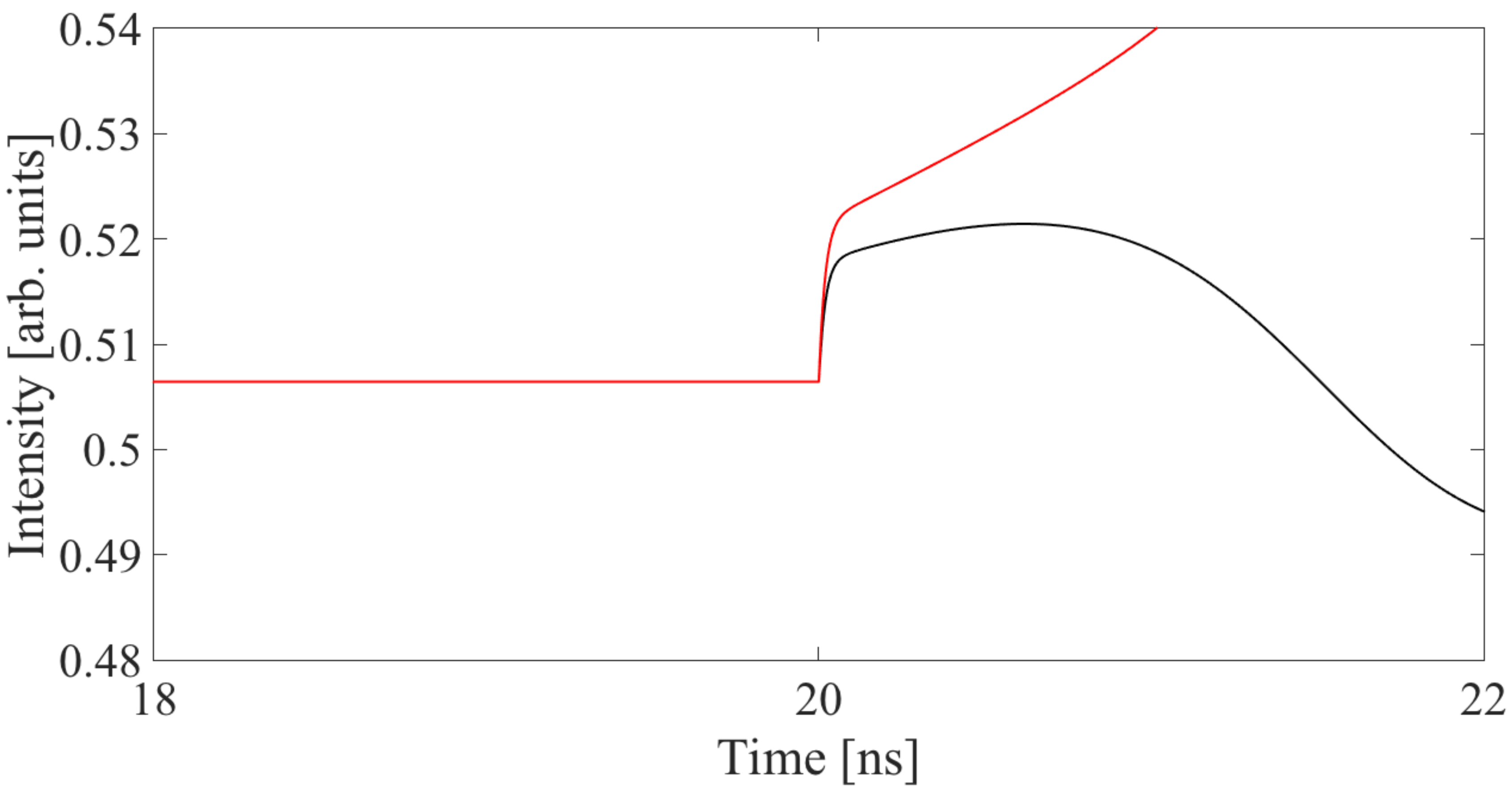


Excitability

Give the system a big (enough) kick and it excites a pulse:

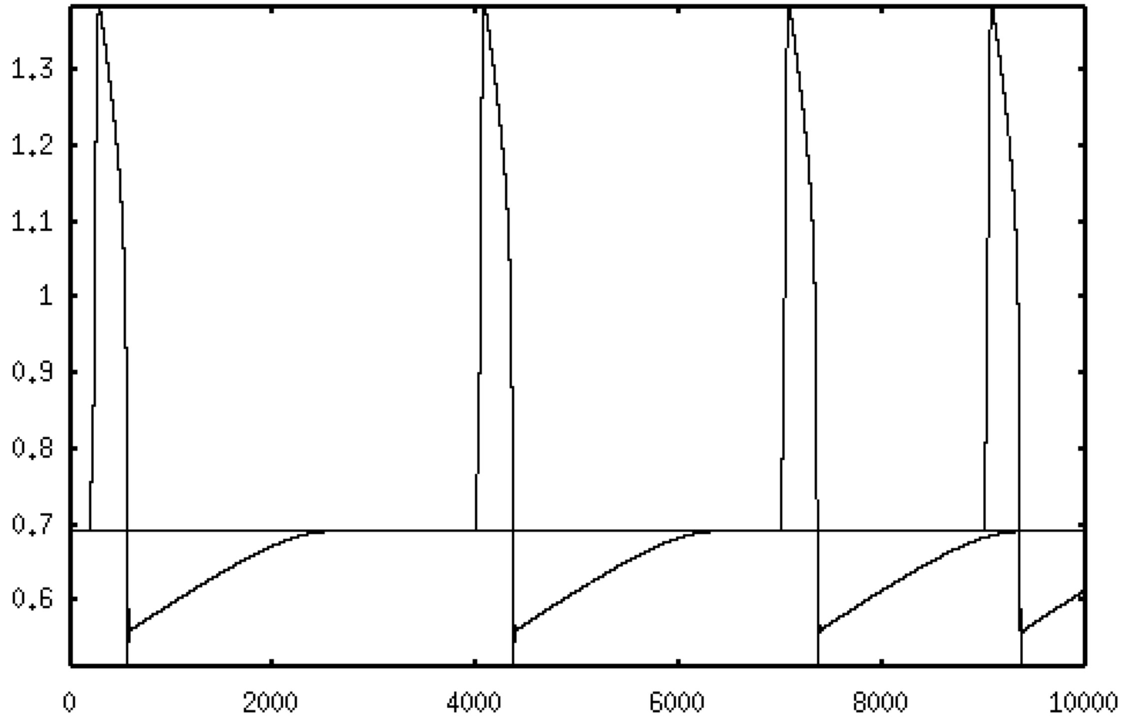


What is “big enough”?



Project:

Create a pattern in a pulse train: “write” pulses



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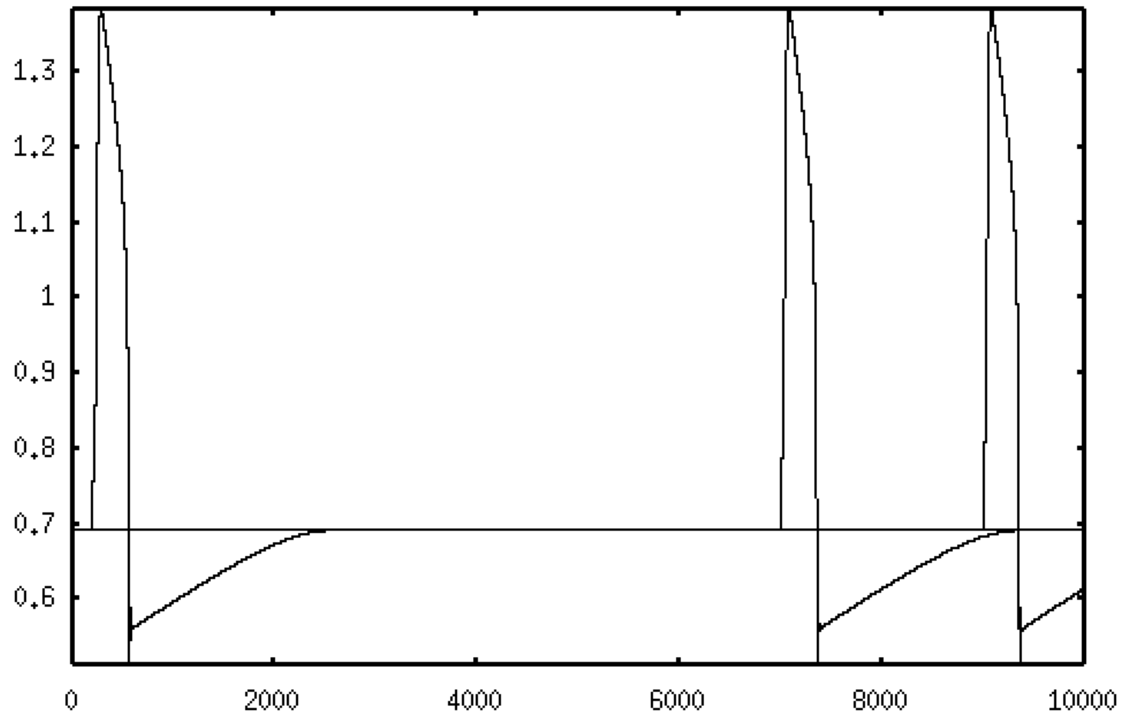
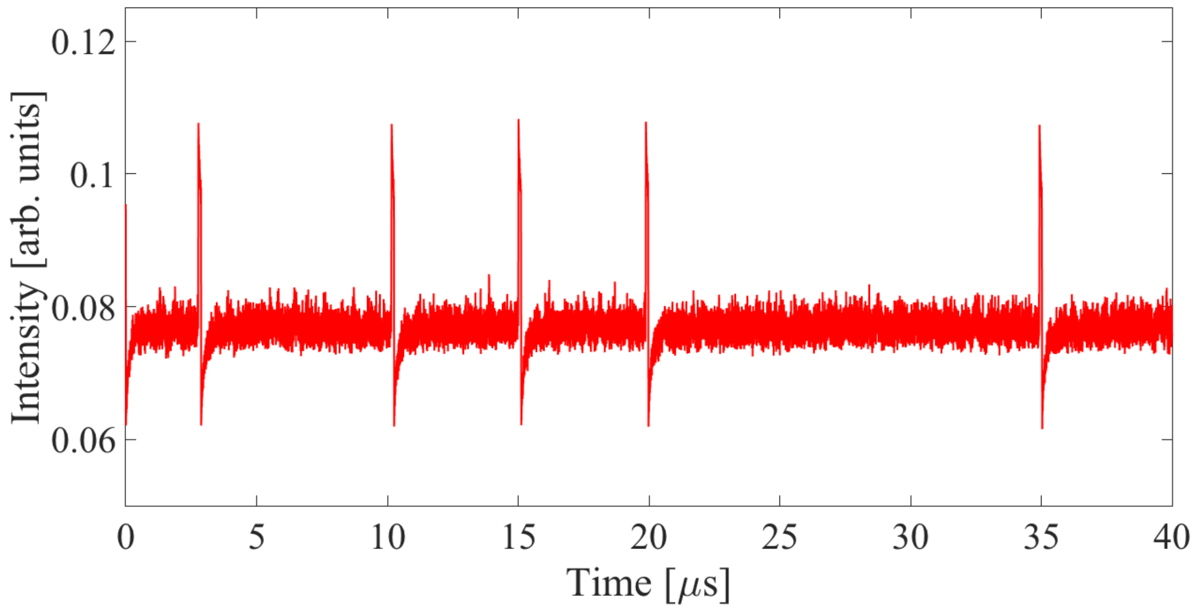
Project:

Create a pattern in a pulse train: “erase” pulses



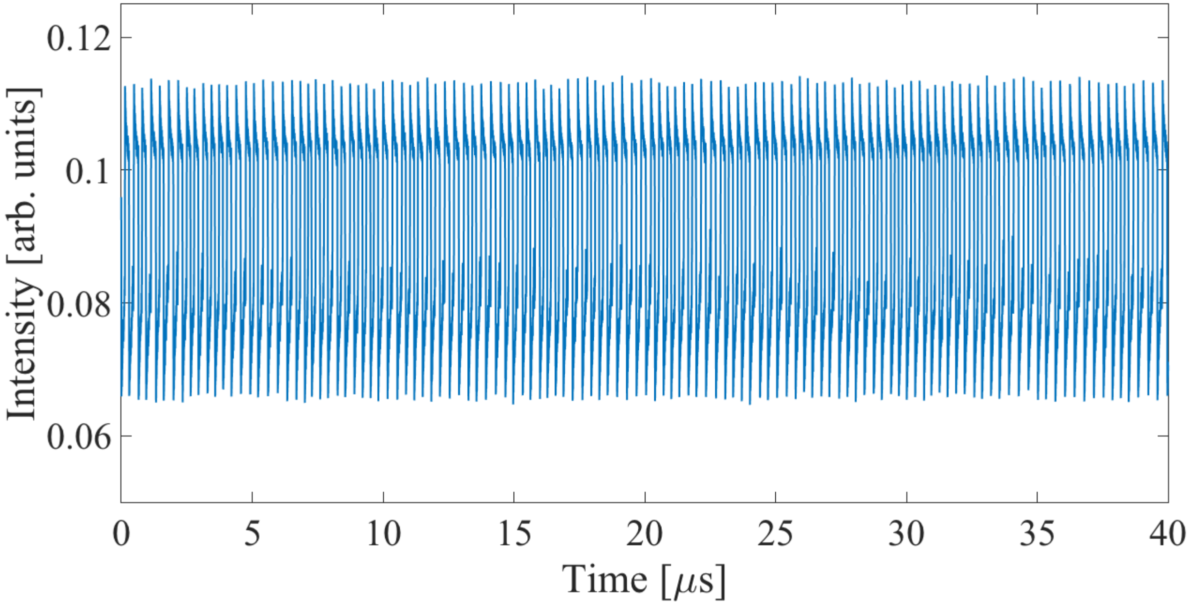
Project:

Presence of noise → create pulses randomly



Project:

Add the ***right amount*** of noise → create "periodic" train



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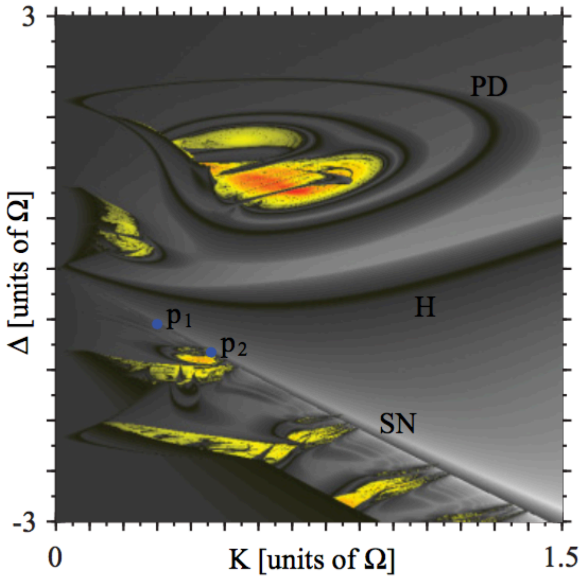
Theoretical version

Necessary attributes:

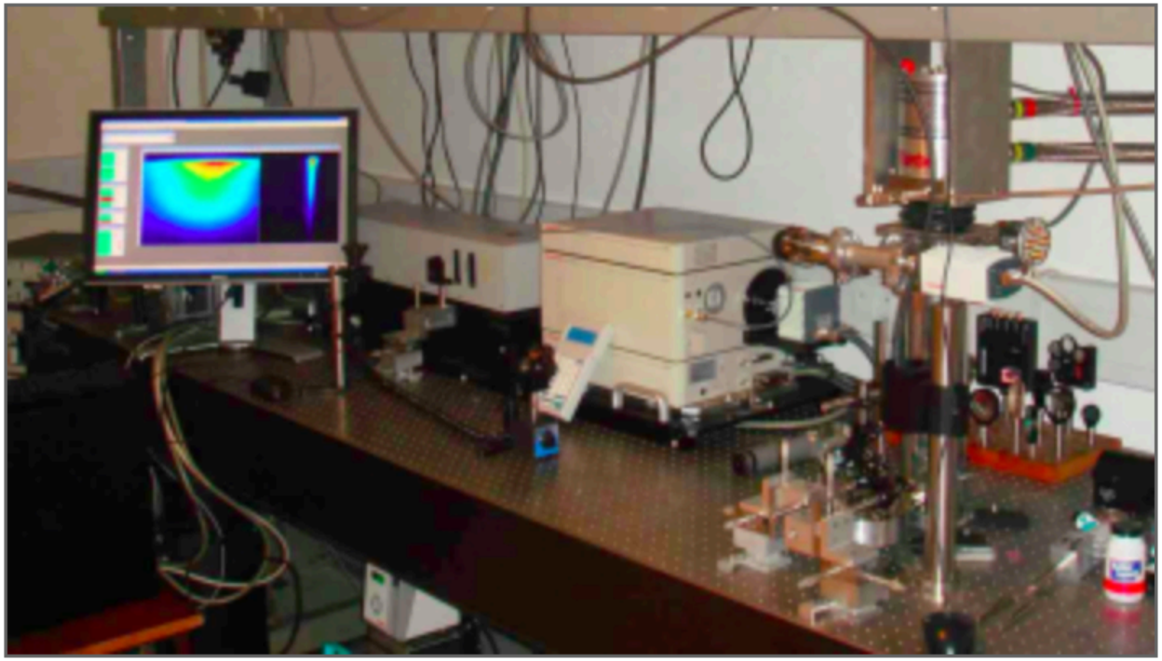
- Must like equations
- Computer Literacy
- Enthusiasm

$$\dot{R} = R\frac{(P-R^2)}{1+2R^2} + K\cos\phi$$
$$\dot{\phi} = \alpha\frac{(P-R^2)}{1+2R^2} - (\Delta-\omega) - \frac{K}{R}\sin\phi$$
$$\dot{\omega} = -\gamma\left(\omega - c\left(R^2-P\right)\right)$$

Bifurcation analysis



Tyndall National Institute



Experimental version

Necessary attributes:

- Must like hands on work
- Patience
- Enthusiasm

Sample Projects

Project 1: Control of excitable dynamics in an artificial neuron (Theoretical/Computational)

Project 2: Control of excitable dynamics in an artificial neuron (Experimental)

Project 4: Canard explosions with coupled lasers (Theoretical/Computational)

Project 5: Bespoke project – just come and chat to me and we can tailor a project

Plenty of alternative possibilities

Contact me to discuss if interested

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Questions?