

Dr Bryan Kelleher

Projects in non-linear dynamics of lasers

Project 1/2/3: Control of excitable dynamics in an artificial neuron

(I call this Project 1/2/3 as it is possible to do it as a purely theoretical or computational project, as a purely experimental project or as a combination. Please indicate which version you'd like when choosing.)

For the theory and computational version, it will typically consist of analysing a rate equation model of a system of coupled oscillators. These could be lasers, phase oscillators or indeed just a generalised oscillator. The exact type can be pinned down in discussion with me. Direct **numerical simulation, bifurcation analysis and physical reasoning** will then be used to analyse the creation, propagation and destruction of excitable spike trains, mimicking the behaviour of biological neurons but in small networks.

For the experimental version, the work would be done in a lab in Tyndall and would consist of studying the optical injection system where one laser (the master) shines into another (the slave). The first step would be to map out the stability of the system for different control parameters (essentially the wavelength and power of the master laser), thereby finding the regions of excitability. The work would then consist of perturbing pulses deterministically using modulators and/or pulse generators. This would demonstrate spike creation. Spike destruction would then be investigated using the same techniques.

Project 4: Canard explosions with coupled lasers

This project would be theoretical or computational. Using rate equation models the phenomenon of canard explosions in the optical injection system would be investigated. This phenomenon arises when a small amplitude cycle in a system undergoes a rapid expansion leading to large amplitude cycles over a very small control parameter range. Such an explosion has very recently been observed in a laser system but only very preliminary results have been

obtained. Thus, the project represents a chance to discover some interesting physics in a novel system. The main tools would be **time series analysis**, **bifurcation analysis** and potentially some **analytical examination** of simplified models.

Project 5: Bespoke project

I am happy to discuss any ideas you may have regarding the nonlinear dynamics of coupled oscillators/lasers to see if we can design an interesting project together.