Resonator property of a neuromimetic excitable laser system

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A system is said to be excitable if it responds to an external perturbation by either producing an excitable response (e.g. a spike) if the perturbation is over the threshold, or otherwise relaxing to its stable state. It was already suggested several years ago [1] that a laser with an injected signal behaves as an excitable medium, whose phase dynamics can be basically described by the Adler equation, which also describes the motion of an overdamped pendulum forced with constant torque. After this theoretical prediction, observations of such excitable events in lasers systems were realized in [2] and [4], while a control of the generation of these events was obtained by [3]. Our aim is to better explore the conditions for the generation of these excitable responses depending on the shape of the perturbation.

In this work we use the setup of a laser with injection to probe the system with two consecutive under-threshold perturbations in the shape of pulses, and we record the number of excitable responses as we vary the delay between the two perturbations. What we unexpectedly find is that there is a particular delay where we have the maximum probability of generating a response (this is called a resonant feature). Another interesting property of our system is the existence of multipulse excitability, that is, the possibility of producing two or more responses for a single perturbation. This was already shown to be theoretically possible in a laser with optical injection in [5], and here we demonstrate that multipulse responses can be externally triggered. Both these properties cannot be explained by the simple adler equation.

Given the excitable nature of our system, it was almost natural to compare its behavior with that of neurons, which are the most typical example of excitable system. The most compelling analogy between these two systems comes from the similarities between the Adler equation and the Ermentrout-Kopell canonical model [6]. Even more, many neuronal model that are studied in the context of neuroscience already show some resonator or multipulse properties. To better define the connections between these two worlds (the laser world and the neuroscience world) we use tools from Geometric Singular Perturbation theory to study the dynamics of neuronal models that better fit our physical data. The long term goal is to exploit the neutron-like properties of our system for optical data processing and to provide possible insight about complex solitons interactions in forced oscillatory media [7].

Références

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