Complex Dynamics in Passively Mode-Locked Fibre Lasers

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Passively mode-locked fibre lasers have long been the focus of research efforts due to their ability to generate stable and regular trains of ultrashort pulses, which are useful for a broad range of applications. Away from these stationary regimes of operation, these sources also display myriads of puzzling dynamical behaviours, which constitute an ideal benchmark to study in detail the dispersive, nonlinear and dissipative effects at play in these systems and their complex interactions, and are also attracting interest for applications. These dynamics are broadly distributed on a scale of complexity, from gently vibrating soliton molecules to chaotic multiple soliton collective behaviours, to the formation of the enigmatic noise-like pulses (NLPs) and the onset extreme-intensity events (optical rogue waves). The extreme diversity of these regimes is also illustrated by the very diverse time scales over which the dynamics develop, which span 14 orders of magnitude, from a few tens of picoseconds to a fraction of an hour.

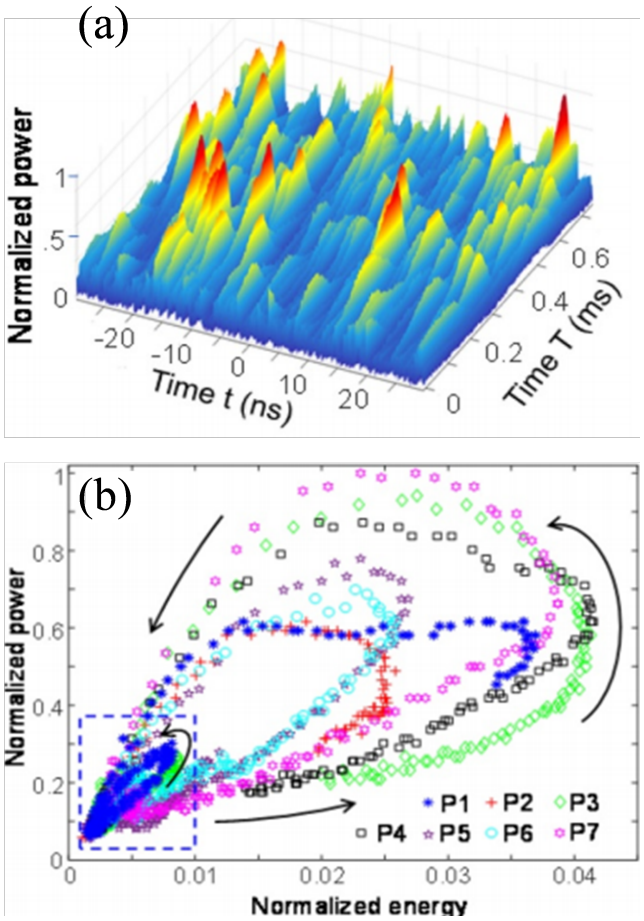

Figure 1: Incipient mode-locking dynamics in a ytterbium-doped fibre laser; (a) Temporal sequence showing emergence and decay of short-lived spikes; (b) Phase space diagram of several spikes

In this work, we browse a general overview of the main results reached by our group over the last years in the characterization and modelling of complex dynamics in passively mode-locked fibre lasers. Both experimental results (based mainly on the temporal and spectral mapping techniques) [1-4] and numerical simulations [5-7] are presented and discussed, leading in several cases to a better understanding of the underlying physical processes involved. The study covers different cavity architectures, dispersive regimes and operating wavelengths; the dynamics under study involve solitons, NLPs and their interactions, and also covers exotic behaviours such as the emergence of optical rogue waves. Finally, our study also shed light on regimes far away from mode-locking, in which pulsed components are short-lived and only constitute a few percent of total intracavity radiation, demonstrating in particular that the so-called "continuous-wave" regime of these sources should actually be thought of as a very complex dynamical mode of operation [4] (figure 1). We believe that our results gathered over the last 7 years contributed to set a few milestones in the extremely vast and still largely unexplored field of dynamical regimes of operation of passively mode-locked fibre lasers.

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