Figure-Eight Fibre Laser with Dynamically Varying Nonlinear Switching Characteristic

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Due to their low cost and flexibility, passively mode-locked fibre lasers are convenient sources of ultrashort pulses that can be used in a broad range of applications. Beyond their ability to produce stable trains of pulses, these complex systems also constitute ideal platforms to explore a broad spectrum of puzzling dynamics that arise as a consequence of the complex interaction between dispersive, nonlinear and dissipative effects, among others. Apart from different kinds of soliton instabilities, noise-like pulse (NLP) formation and the optical rogue wave (ORW) phenomenon are among the most emblematic regimes in this category.

Whereas NLPs are always characterized by a complex, chaotic evolution at fine inner scale, at coarser scale they can either behave quite regularly (with a stable envelope, yielding a pulse train suitable for applications) or display instabilities. One such instability that is quite common in the NLP regime consists in a slow quasi-periodic, "Q-switch-like" modulation, which we attributed to gain dynamics [1]. Although in general this kind of NLP dynamics may involve quite complex details, in particular spectral shifts, ORWs and soliton formation [2], the resulting modulation of the NLP energy is usually quite regular, either quasi-sinusoidal or forming bell-shaped envelopes that repeat with a nearly constant period (typically in the tens of μs range) [3,4].

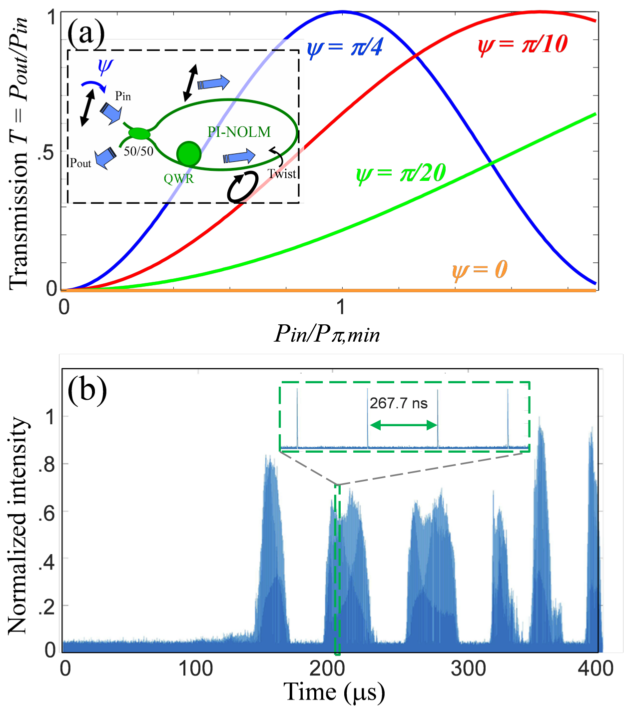

Figure 1: (a) Input-polarization-dependent PI-NOLM transmission (inset shows PI-NOLM scheme), ψ is the input polarization angle and $P_{\pi,min}$ is the minimal switching power; (b) scope trace of a train of NLPs displaying complex aperiodic oscillations (inset: close-up showing pulse train period)

In this work, we study NLP dynamics in a particular architecture of figure-eight fibre laser (F8L). In this scheme, a power-symmetric, polarization-imbalanced nonlinear optical loop mirror (PI-NOLM) [5] is used as saturable absorber, including a 50/50 coupler and a quarter-wave retarder (QWR) to break the polarization symmetry (Figure 1(a), inset). With this design, the nonlinear switching characteristic, in particular the switching power, is input polarization-dependent (Figure 1(a)) [6], so that in most F8L implementations a polarizer is inserted in the ring section of the laser in order to define the polarization state at the PI-NOLM input, and thus to determine the switching characteristic [7]. In this work, in contrast, no polarizer is used, so that the polarization incident to the PI-NOLM, and thus the switching characteristic, is free to vary dynamically. This peculiar feature of the proposed design adds to the complexity of the NLP dynamics compared to conventional schemes, as illustrated in figure 1(b), where highly irregular, aperiodic oscillations defining complex pulsating envelopes are observed, in striking contrast with the smooth oscillations observed with conventional schemes. In this work, we analyze this complex behavior at the light of a dynamically evolving switching characteristic. We believe that the present study adds a new entry into the vast catalog of nonstationary regimes of operation of passively mode-locked fibre lasers.

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