Controllable Rare Events in Optically-Injected Semiconductor Lasers

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Optical injection is a well-known technique for generation of RF oscillations in semiconductor lasers. Injecting the light of an external master laser of power P_{ML} into the slave laser cavity allows tuneable periodic, aperiodic and pulsing dynamics to be generated [1,2]. In the latter case, pulses are known to arise around the saddle-node (SN) bifurcation when the slave is temporarily driven away from locking by small perturbations [3].

Changes in locking boundaries when the laser is either entering or leaving the stable locking region have been studied extensively, and we concentrate here on bistability in the dynamics around the SN. The studied laser generates periodic oscillations before entering the injection-locking region, and a periodic train of pulses when leaving it. Using the system's noise around SN allows turning these trains of pulses into rare events with wave heights above the threshold for rogue waves (RW), their rareness being tuned with P_{ML}. We thus propose a scheme for generation of controllable RF rare events that could be integrated onto photonic integrated circuits.

Fig. 1 presents the hysteresis cycle observed in an optically-injected Quantum Well Fabry-Perot laser along with the evolution of the optical spectra in both branches of the cycle. In the forward branch, the laser exhibits weak periodic dynamics and locks for an injected power P_{ML} of 2.4 dBm. When decreasing P_{ML} from this point, the laser follows the backward branch and exhibits pulses when P_{ML} is below 2.1 dBm. It then goes back to the forward branch when P_{ML} passes below 1.5 dBm. Between 2 and 2.1 dBm in the backward branch, the system fades from the pulsing to the locking regime due to the noise of master and slave lasers, and is characterised in the time domain by an increasing timespan between pulses until they occur seemingly randomly.

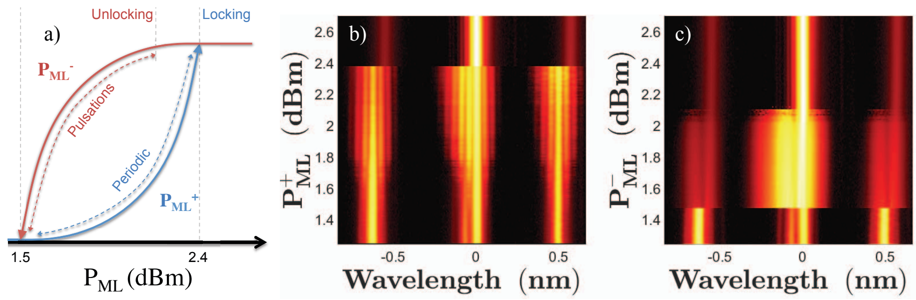

Fig. 1 a) Schematic view of the hysteresis cycle observed experimentally at the saddle-node bifurcation. b) Evolution of the optical spectrum on the forward (blue) branch of the cycle (increasing injection strength). c) Evolution of the optical spectrum on the backward (red) branch of the cycle (decreasing injection strength).

Fig. 2 a) presents an extract of real-time series of a periodic train of pulses, showing how regular their shape and amplitude are. The wave heights of the different portions of the pulses are presented in Fig. 2 b) with respects to P_{ML}, the threshold for RW being shown as a white line. While wave heights do not change significantly, as pulses become less frequent when the laser transitions towards injection locking the largest wave with a height of 120 mV is above the threshold for RW in a short window close to the locking boundary. Representing the times series as a succession of N_P waves of with the same height allows estimating accurately the maximum number of pulses in the time series allowing them to be considered as RW, as shown in Fig. 2 c).

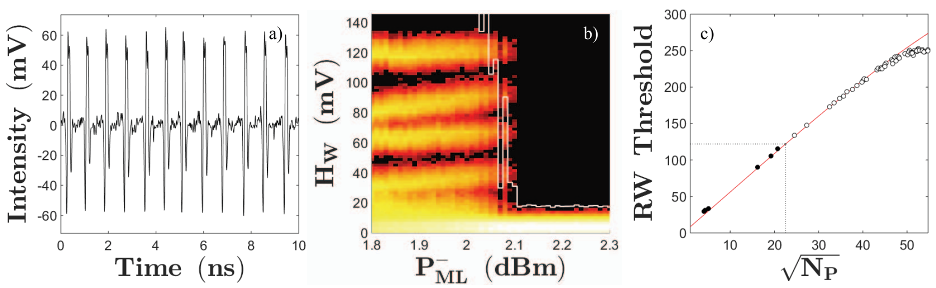

Fig. 2 a) Extract of real-time series of the pulses. b) Evolution of wave height H_w with backward injection power, the white line representing the evolution of the threshold for rogue waves. c) Experimental (dots) and estimated (red line) relationship between the threshold for rogue waves and the number of pulses in the time traces.

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References

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