# Controllable optical extreme events in the semiconductor laser output power


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***Abstract*—This work investigates the generation of controllable optical extreme events in an optically-injected semiconductor laser for disruptive RF transmission links.**



***Keywords—semiconductor lasers; extreme events; nonlinear dynamics.***


## I. INTRODUCTION

Rogue waves, extreme events or rare events can be visible in many nonlinear systems [1]. Nature is a prolific source of extreme events, which are seen as events of very high amplitude rising far above the mean level [1]. In this work, we study the features of optical extreme events in quantum well (QW) semiconductor lasers operating under optical injection. In particular, we propose a scheme for generation of controllable optical extreme events, which can be useful for possible applications in disruptive RF transmission links.

## II. EXPERIMENTAL RESULTS

Optical injection is a well-known technique for generation of RF oscillations in semiconductor lasers. [2] Fig. 1 presents a schematic view of the injection map showing the upper and lower boundaries of the injection-locking (IL) region. The two degrees of freedom are the injected power $P_{ML}$ as well as the frequency detuning i.e. the frequency difference between the master laser (ML) and the slave laser (SL).

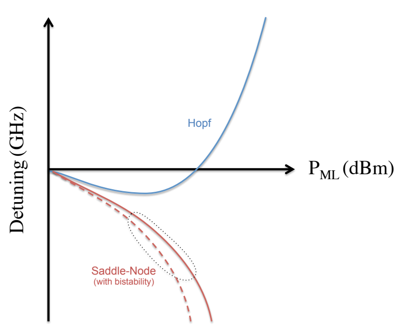


**Fig. 1:** Schematic view of the injection-locking map.

The blue line represents the Hopf bifurcation, corresponding to a gradual change from a periodic oscillatory behavior to stable IL operation, where the SL emits light only at the wavelength of the ML. The red line represents the Saddle-node bifurcation, characterized by a sudden change from usually chaotic oscillations to IL. The IL region is thus the area comprised between these two lines. In this work, the dot area is the region of interest namely nearby the SN bifurcation where bistability in the locking region can be observed [2]. Fig. 2 presents a time series measured in this region when the QW laser is operated closer to the IL boundary with PML power of 2.1 dBm.

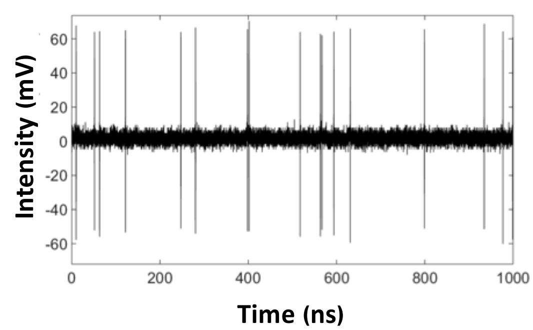


**Fig. 2:** Measured time series for a ML power of 2.1 dBm.

Only a few peaks are observed in the time series and they do not appear periodically. While IL should occur suddenly in this regime of the injection map, we believe that the noise of the system fades this boundary, and the SL laser in fact crosses it several times within the time series. When it crosses the boundary backwards, it comes back to the pulsation regime and emits one or several pulses before crossing again, back to IL. An interesting aspect of these pulsations is the fact that they keep a rather constant amplitude, the largest edge (the rising wave) having a height of roughly 120 mV. The time interval between pulses can be tuned with $P_{ML}$, which means that we have a full control over how rare the impulsions are within the time series. While this work is performed on a QW laser, it can be applied to any semiconductor lasers. Further work will investigate the fabrication of the extreme event generator onto a silicon chip.


[1] N. Akhmediev et al., Roadmap on optical rogue waves and extreme events, IoP J. of Optics, vol. 18, pp. 063001, 2016.

[2] D. Kane and A. Shore, Unlocking Dynamical Diversity, John Wiley & Sons, 2005.



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