Optimal entrainment of the spikes emitted by a semiconductor laser with feedback

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The nonlinear dynamics of a semiconductor laser induced by optical feedback has been intensively studied in the last three decades, not only because these lasers are important practical devices, but also, because of the wide range of complex regimes that can be induced by optical feedback. The chaotic optical output generated has found various applications (secure communications, information processing, LIDAR, random number generation, etc.). In this contribution we focus on a dynamical regime known as *low frequency fluctuations* (LFFs), in which the laser emits an spiking output with dynamical properties that resemble the spike sequences of biological neurons. Operating in this dynamical regime, semiconductor lasers can be building blocks of ultra-fast information processing systems inspired in the way biological neurons process information. To use the laser as an information processing unit, it is crucial to understand how the information of a weak input signal is encoded in the output sequence of optical spikes.

In this contribution we consider the simplest situation of a weak periodic signal which is applied to the laser via direct current modulation. We present an experimental study of the role of the signal waveform and laser operation conditions in the entrainment of the output spikes to the periodic input. We propose several measures to quantify entrainment (inter-spike-interval distribution, spike success rate and ordinal spike correlations [1, 2]) and use them to analyze which waveform (at a given mean value and oscillation amplitude) produces optimal entrainment.

Figure 1 displays the ISI distributions for a semiconductor laser subject to an optical feedback and an external current modulation. Two periodic waveforms have been used. In Figure 1a we show the ISI distribution when a pulsed signal is applied while in Figure 1b illustrates the ISI distribution under a sinusoidal waveform. In both cases, four different modulation frequencies are choosen to show up the first four locking scenarios displayed by the dynamical system.

In the case of pulsed modulation, locking 1:1, 2:1, 3:1 and 4:1 (revealed by a high and narrow peak in the ISI distribution at $n \cdot T_{mod}$) are observed at modulation frequencies $f_{mod} = 7$, 14, 25 and 35 MHz respectively. On the other hand, for the sinusoidal test, a much broader ISI distributions are observed at low modulation frequencies which reveals an heterogeneous distribution of the power dropouts (i.e. poor entrainment). At higher frequencies the ISI distribution becomes narrower and the dynamical response of the system approches to the one observed with the pulsed modulation. Therefore, our results indicate that, for entraining the power droputs, the pulsed waveform is more efficient than the sinusoidal waveform..

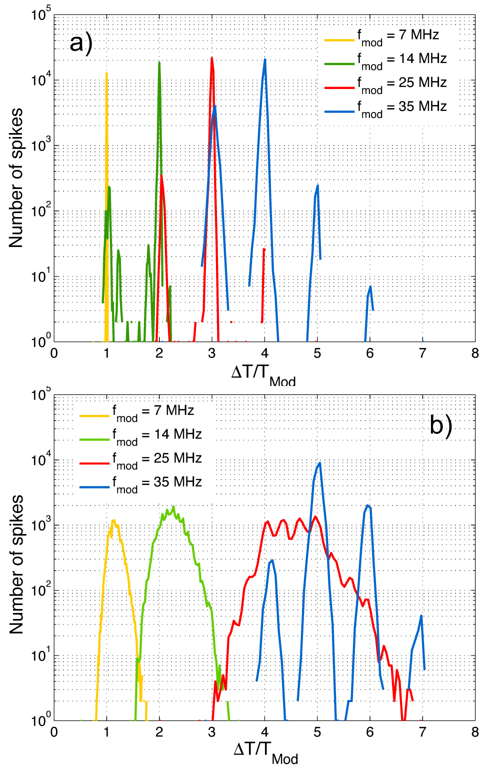

Figure 1: Experimental inter-spike-interval (ISI) distribution. The modulation amplitude is choosen to be 2.0% of I_{DC} and the modulation frequency is 7 MHz (yellow line); 14 MHz (green line); 25 MHz (red line); 35 MHz (blue line).

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