Dynamical Methods for Studying Noise in Frequency Comb Sources

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Abstract

Frequency combs have revolutionized the measurement of time and frequency since their invention in 2000, and have a wide array of applications to applications that range from basic science applications, to a wide array of sensing applications, to commercial applications, to military applications, and the list goes on. Noise poses a fundamental limit to these systems, and calculating its impact play a critical role in system design. Frequency combs are created by modelocked laser systems that emit a periodic train of short pulses. Laser systems are complex nonlinear systems and the usual method for determining the impact of noise is to carry out computationally-expensive Monte Carlo methods. That limits the parameter range over which it is possible to study the noise impact. We have developed a new approach based on dynamical systems methods. In our approach, we determine a stationary state of the laser system as parameters vary solving a root-finding problem [Wang1]. Starting from a stationary state, we determine all the eigenvalues and eigenvalues of the linearized system. The variance of the amplitudes of the eigenvalues obey either random walk of Langevin equations [Menyuk]. Starting from that point, we can determine the power spectral density of the key laser parameters (amplitude jitter, timing jitter, frequency jitter, phase jitter) [Wang2]. We applied this approach to SESAM lasers and found that we were able to reproduce a computation that took 20 minutes on a cluster with 256 cores with a computation that took less than 4 minutes on a desktop computer.

References

[1] S. Wang, A. Docherty, B. S. Marks, and C. R. Menyuk, Boundary tracking algorithms for determining the stability of mode-locked pulses, *J. Opt. Soc. Am. B*, **31** (2014), 2914–2930.

[2] C. R. Menyuk and S. Wang, Spectral methods for determining the stability and noise performance of passively modelocked lasers, *Nanophotonics*, **5** (2016), 332–350.

[3] S. Wang, T. F. Carruthers, and C. R. Menyuk, Efficiently modeling the noise performance of short-pulse lasers with computational implementation of dynamical methods, *J. Opt. Soc. Am. B* **35** (2018), 2521–2531.