Defining & Optimising Chaos Bandwidth - Semiconductor Laser Systems

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Achieving broad bandwidth chaotic output from semiconductor-laser-based nonlinear systems has been a research and development pursuit, in academia and beyond, for several decades. In addition to establishing fundamental understanding of these complex systems, this has been driven by applications in secure communication, random number generation, key distribution, LIDAR, and, more recently, photonics-based reservoir computing.

A plethora of such laser systems have been reported. They use different types of semiconductor laser (SL) (Fabry Perot lasers, distributed feedback lasers, vertical cavity surface emitting lasers (VCSELs), quantum dot lasers, quantum cascade lasers, semiconductor optical amplifiers in ring configurations), and, one or more of the standard approaches to destabilising the laser, such as optical feedback. Chaotic output is just one of the dynamical outputs from such systems. The rf bandwidth of the chaotic output, typically several to several-tens of GHz, has been a key characteristic that researchers have sought to define, maximise and optimise.

This presentation will critically review whether it is scientifically and technically sound to report a chaos bandwidth from such systems at all. It will also report new results on the rf spectrum of a free-space Fabry-Perot SL with delayed optical feedback system, as key SL parameters are varied systematically. These results, from numerical simulations of this system using a travelling wave model [1, 2], provide new insights into the impact of key device parameters affecting the chaos bandwidth and spectrum. Connections with prior experimental results are made [3, 4]. An improved fundamental understanding of chaos bandwidth is achieved.

[1] M. Radziunas, *Handbook of Optoelectronic Device Modeling and Simulation: Lasers, Modulators, Photodetectors, Solar Cells, and Numerical Methods*, J. Piprek, ed. (CRC Press, 2017), Vol. 2, chap. 31, pp. 153–182.

[2] M. Radziunas, D. J. Little and D. M. Kane, *Opt. Lett.* **44** (17), 4207-4210, (2019). https://doi.org/10.1364/OL.44.004207

[3] J.P. Toomey and D. M. Kane, *Opt. Express* **22** (2),1713-1725 (2014). https://doi.org/10.1364/OE.22.001713

[4] http://laser.portal.knowledgediscovery.org/dataset and at https://doi.org/10.6084/m9.figshare.c.3834916.