CHAOS 2009
2nd Chaotic Modeling and Simulation International Conference
June 1 - 5, 2009 Chania Crete Greece www.chaos2009.net

Computer-aided analysis of the Poincaré map for the characterisation of optically-injected semiconductor lasers

C. A. Stolz, D. Labukhin, N. Zakhleniuk, R. Loudon, M. J. Adams
School of Computer Science and Electronic Engineering, University of Essex, Wivenhoe Park, Colchester, CO4 3SQ, UK
cstolz@essex.ac.uk, dlabuk@essex.ac.uk, naz@essex.ac.uk, loudr@essex.ac.uk, adamm@essex.ac.uk

Abstract: A new automated analysis of the Poincaré map is suggested to perform a complete stability investigation of optically-injected lasers simulated with the travelling wave approach.

1. Introduction

The dynamics of optically-injected semiconductor lasers have been investigated for several years [1-6] and they can be simulated either using the rate equations (REs) [1] or the travelling wave (TW) [2] approach. In recent years the TW model has been used to find the dynamics of the system [4, 5]. The TW model can easily be used to find the locking bandwidth of the system but so far no distinction between regions of different instabilities has been made. In this paper a new method will be presented that uses the trajectory of the system to perform a complete stability analysis in which regions of different dynamics can be identified.

2. Method

The system is simulated using a commercial software program [7] and for each time moment the average carrier density and the absolute value and phase of the electric field are saved to create the trajectory of the system. It has been shown [3] that the trajectory depends on the state of the system. For the analysis a Poincaré section is taken through the carrier density – electric field space with a constant phase, and the intersection points of the trajectory with the plane are investigated to construct the so-called Poincaré map. To simplify the analysis the Poincaré map is divided into small sections and the intersection points per slice are counted. These numbers give a distribution which can be used for the analysis. For example, the wider the intersection points are spread the more chaotic the system is.

3. Results

Figure 1 shows an automatically-obtained stability map (shaded fields). White fields show the region where the system is stably locked. The darker the fields are shaded the more chaotic the system is. The dashed lines are the locking region boundaries obtained by manual analysis of the simulated laser spectra, as defined by a side-mode suppression ratio of 30 dB. As is seen from the figure, the agreement in the locking bandwidth, as well as the qualitative agreement with experimental results [6], is very good.

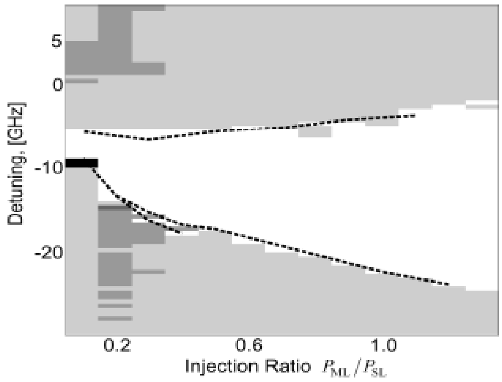

Fig.1. Stability map obtained automatically (shaded fields) and manually (dashed lines)

4. Conclusion

It was shown that the trajectory of the system strongly depends on the state of the system. This dependence in turn can be used for a complete stability analyses. The results obtained by the new method agree well with experimental data [6].

4. References

[1] R. Lang, "Injection locking properties of a semiconductor-laser," IEEE J. Quantum Electron. **18**, 976–983 (1982).
[2] G. R. Hadley, "Injection locking of diode-lasers," IEEE J. Quantum Electron. **22**, 419-426 (1986).
[3] S. Wieczorek, B. Krauskopf, , T. B. Simpson, and D. Lenstra, "The dynamical complexity of optically injected semiconductor lasers," Physics Reports-Review Section Of Physics Letters **416**, 1-128 (2005).
[4] R. Gordon, "Fabry-Perot semiconductor laser injection locking," IEEE J. Quantum Electron. **42**, 353-356 (2006).
[5] D. Labukhin, C. A. Stolz, N. Zakhleniuk, R. Loudon, and M. J. Adams, "Modified Fabry-Perot and rate-equation methods for the nonlinear dynamics of an optically injected semiconductor laser," IEEE J. Quantum Electron., to be published.
[6] N. M. Al-Hosiny, I. D. Henning, and M. J. Adams, "Tailoring enhanced chaos in optically injected semiconductor lasers," Optics Communications **269**, 166-173 (2007).
[7] VPIsystems (2009, March 18th) [Online]. Available: http://www.vpiphotonics.com.