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Dynamics of optically injected semiconductor and microchip solid-state lasers

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This contribution presents experimental and numerical methods used in the study of nonlinear dynamics in lasers with an injected optical field. Results for two different types of lasers are compared - the semiconductor laser and the Nd:YVO_4 microchip solid-state laser. In the experiments there are two controllable parameters; the frequency detuning of the injected light with respect to the free running laser frequency and the amount of light injected. By varying these two parameters, the injected lasers can be brought into locked, periodic and chaotic states.

¿ From an experimental point of view, these two types of lasers differ in one important aspect - the value of their relaxation oscillation frequency, which is a characteristic frequency of lasers. Whereas this frequency is several GHz in semiconductor lasers, it is only a few MHz in microchip solid-state devices. Therefore, experiments with semiconductor lasers have to mostly rely on spectral measurements, whereas with solid-state lasers the dynamics can be studied by recording intensity time series [2].

Results from the experiments are compared to a three dimensional nonlinear rate equation model by computation of the largest Lyapunov exponent [1] and by bifurcation analysis [3]. The largest Lyapunov exponent measures the stability of equilibria and the amount of chaos in chaotic orbits and allows periodic windows inside chaotic islands to be mapped. In bifurcation analysis, qualitative changes in laser behaviour, i.e. bifurcations, are sought and traced in the parameter plane, spanned by the frequency detuning between and the injected power.

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[1] T. Fordell, Å.M. Lindberg, "Numerical Stability Maps of an Optically Injected Semiconductor Laser", *Opt. Commun.*, **242**, 613–622 (2004)

[2] S. Valling, Fordell, T., Å.M. Lindberg, "Experimental and Numerical Intensity Time Series of an Optically Injected Solid-State Laser", *Opt. Commun.*, **254**, 282–289 (2005)

[3] S. Valling, Fordell, T., Å.M. Lindberg, "Maps of the Dynamics of an Optically Injected Solid-State Laser", *Phys. Rev. A.*, **72**, 033810 (2005)