Applications of semiconductor lasers with optical feedback:
Novel concepts for tunable lasers and chaos control
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SHORT SUMMARY

Semiconductor lasers (SLs) are photonic devices used in many applications making our life more comfortable. Technology of manufacturing of SLs integrated on-chip is developing very rapidly. Unfortunately, optical feedback from the other components of the photonic circuit cannot be always avoided and may lead to laser in stabilities. Despite many attempts to understand how feedback influences behavior of SLs were made, some aspects are still not clear. Therefore in this thesis we focus on studying dynamics of SLs with optical feedback. We use the well-known Lang-Kobayashi rate equations that successfully model dynamics of semiconductor lasers subject to optical feedback. The first device studied in the thesis is a T-shaped Fabry-Pérot SL. We show numerically that the system, under certain conditions, is capable of generating a robust chaotic waveform appropriate for chaos-based optical communications. Two such chaotic devices can be synchronized uni-directionally. The main advantage of our scheme is short resynchronization time – time it takes to synchronize the lasers. Therefore message encryption can be successfully applied at a rate of hundreds of Mbit/s.

Another application of a T-shaped SL can be found in controlling the unstable emission, like periodic or chaotic oscillations. Filtered optical feedback is of particular interest because it allows re-injecting a specific range of frequencies and efficiently suppressing arising instabilities. In our model we use a second feedback branch with frequency selective mirror to stabilize periodic or chaotic oscillations induced by the first conventional branch. We give an overview of the analytical solution of the external filtered modes and show numerically that stabilization when filtered feedback branch is used is much more effective compared to conventional feedback.

Semiconductor ring laser is another interesting device to study optical feedback. They are promising components in photonic integrated circuits and can be used for instance to realize all-optical flip-flops. However, the potentially detrimental effect of optical feedback arising from the other optical components was not investigated yet. We find theoretically that when cross-feedback is symmetric the laser works in a bi-directional continuous wave or periodic regime for most parameter values. Only for some small parameter regions we obtain quasi-periodic behavior and anti-phase chaos. On the other hand, when the symmetry is broken complex dynamics such as quasi-periodicity or chaos emerge.

On-chip filtered optical feedback finds applications in tunable SLs for selecting the output wavelength. A novel integrated tunable laser was proposed and manufactured at the Technische Universiteit Eindhoven (TU/e), the Netherlands. Our numerical simulations show that the feedback-induced gain competition between longitudinal modes leads to switching speed of few nanoseconds. We find theoretically that the feedback phase is of the great importance in the tuning process and leads to direct or inverse switching. For some values of the feedback phase no switching is observed.