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# TITLE : DYNAMICS AND SYNCHRONIZATION OF VCSELS AND SRLS SUBJECT TO CURRENT MODULATION AND OPTICAL/OPTOELECTRONIC FEEDBACK

## Abstract

This thesis is concerned with the study of the dynamics and synchronization of VCSELs and SRLs driven by sinusoidally modulated current, self-sustained oscillators, coherent or incoherent optical and optoelectronic feedback with an application to optical cryptography. The following main results are obtained:

- VCSELs subject to sinusoidally modulated current emit single pulse or package of pulses for a few-hundred MHz of modulation frequency;
- Sinusoidally modulated current is shown to reduce the width of the bistability hysteresis loop and, hence, suppress the bistability which is replaced by smooth single or multiple switching;
- For a few GHz of modulation frequency, the polarization modes of VCSELs exhibit a period-doubling transition to chaotic behavior;
- The new set of three first-order autonomous system used to modulate VCSELs and SRLs pump currents displayed different dynamical behaviors including periodic behaviors, bursting oscillations, dissipative and horseshoe chaos;
- By modulating the VCSELs pump current by one of the outputs of a new self-sustained electronic oscillator proposed in this work, we generate dynamical behaviors found in VCSELs subject to sinusoidally modulated current but the chaotic dynamics is more complex and is therefore more suitable for chaos encryption techniques;

- The numerical investigation of unidirectional coupling VCSELs driven by one of the chaotic outputs of the self-sustained electronic oscillator shown that high-quality synchronization and transmission of messages using chaos shift keying methods can be realized for suitable system parameters;
- SRLs subject to sinusoidally modulated current exhibit a period-doubling route to in-phase chaos similar to single mode semiconductor lasers at modulation frequencies of the same order or higher than the relaxation oscillation frequency;
- At lower modulation frequency, the counter-propagating modes of SRL displayed a period-doubling transition to anti-phase chaotic regime without the involvement of any carrier dynamics;
- A two-dimensional asymptotic model of SRL at lower modulation frequency which reproduces the observed dynamical behavior is derived and by further simplification, we can link this reduced set of equations to Duffing-type oscillators;
- By modulating the pump current of SRL by one of the outputs of a new self-sustained electronic oscillator, we demonstrated that by varying, the coupling strength between the SRL and the new autonomous system at a fixed bias current, the counter-propagating modes display
an intermittency route to anti-phase chaos;
- For fixed value of the coupling strength between the SRL and the new self-sustained electronic oscillator, the bifurcation diagrams of counter-propagating modes versus one of the parameters of new autonomous system revealed that the counter-propagating modes intensities of SRL depict anti-phase chaos for small parameter value followed by a period-doubling route to out-of-phase and anti-phase chaos;
- The theoretical investigation reported on synchronisation of two unidirectionally coupled chaotic SRLs subject to asymmetric coherent

optical feedback has established that the SRLs in combination with ON/OFF phase shift keying scheme are promising candidates for the security of the encoded message;

- By varying the feedback strength and delay time, the intensities of counter-propagating modes of SRLs under negative optoelectronic and incoherent optical feedback exhibit continuous wave operation and period-doubling route to chaos for delay time of same order or high than the period of relaxation oscillations, they exhibit in-phase chaos similar to chaos found in single mode semiconductors lasers to single mode semiconductors lasers while for delay time significantly large than the period of relaxation oscillations, they exhibit out-of-phase chaotic behavior;
- Thanks to the asymptotic methods, the delay differential equations used to describe SRLs under negative optoelectronic and incoherent optical feedback is reduced to two delay differential equations and one map valid for delay time significantly large than the period of relaxation oscillations then by performing the stability analysis of this reduced system, we have obtained the analytical expressions of the local bifurcations.