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Experimental study of nonlinear dynamics and chaos in a 1550nm-VCSEL subject to polarized optical injection

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Abstract: We report the experimental observation of nonlinear dynamics including chaos in a 1550nm-VCSEL subject to parallel- and orthogonally-polarized optical injection.

1. Introduction

Injection-locked 1550nm-vertical cavity surface emitting lasers (VCSELs) are very promising devices for use as optical sources in optical telecommunication systems [1]. However, stable locking is only attained in a small range of values in the plane of frequency detuning between the Master Laser (ML) and the Slave Laser (SL) versus the optical injected power. Outside this locking range a rich variety of nonlinear dynamics including chaos can be observed [2].

2. Experimental results

We have experimentally studied the nonlinear dynamics in a 1550nm-VCSEL subject to parallel and to orthogonal polarized injection into the two orthogonal polarizations of the fundamental transverse mode. For both polarization modes, different regions of nonlinear dynamics, including limit cycle, period doubling, bistability, polarization switching and also regions of chaotic dynamics have been observed.

Figs. 1(a) and 2(a) show, respectively, the optical and the electrical spectrum of the solitary 1550nm-VCSEL used in the experiments. The optical spectrum of the device exhibits two modes corresponding to the two orthogonal polarizations of the fundamental transverse mode. The emitting mode has parallel polarization and it is located at 1544.7 nm while the subsidiary mode has orthogonal polarization and is shifted approximately 0.5 nm to the long-wavelength side of the lasing mode. Figs. 1(b) and fig. 1(c) show respectively the optical spectra subject to parallel and orthogonal optical injection into the parallel and orthogonal polarization mode. The injected power and the initial frequency detuning, respectively, were equal to $P_{inj} = 1140 \mu\text{W}$; $f - f_{11\text{VCSEL}} = 1 \text{ GHz}$ and equal to $P_{inj\perp} = 20 \mu\text{W}$; $f - f_{\perp\text{VCSEL}} = -2.5 \text{ GHz}$ for the cases of parallel and orthogonally-polarized injection. Figs. 2(b) and 2(c) show the electrical spectra of the VCSEL for the same conditions as in figs. 1(b) and 1(c). For both cases of polarized injection, chaotic dynamics characterized by a multiple peak and wide optical spectrum, and by a wide electrical spectrum with an increase of the noise level, have been observed for both polarization modes. Fig. 1(c) also shows that polarization switching appears associated with the occurrence of chaotic dynamics for the case of orthogonal optical injection.

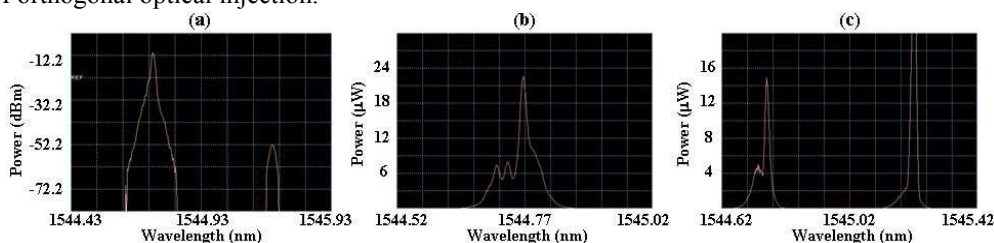


Fig. 1. Optical spectrum of the 1550nm-VCSEL (a) without optical injection and subject to (b) parallel and to (c) orthogonal polarized injection.

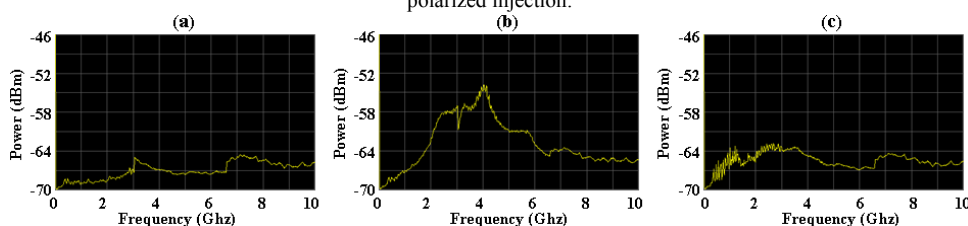


Fig. 2. Electrical spectrum of the 1550nm-VCSEL (a) without optical injection and subject to (b) parallel and to (c) orthogonal polarized injection.

3. Conclusions

We report the experimental observation of nonlinear dynamics including chaos in a 1550nm-VCSEL subject to parallel and orthogonally polarized injection into the two orthogonal polarizations of the fundamental mode.

4. References

- [1] C.-H. Hang et al, "Injection locking of VCSELs", J. Select. Topics Quantum Electron., **9**, 1386-1393 (2003).
- [2] J. Buesa et al, "Mapping of the dynamics induced by orthogonal optical injection in vertical-cavity surface-emitting lasers", J. Quantum Electron. **42**, 198-207 (2006).