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Experimental study of the nonlinear polarization dynamics induced by orthogonal optical injection in 1550 nm-Vertical-Cavity Surface-Emitting Lasers

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Optical injection in vertical-cavity surface-emitting lasers (VCSELs) is an attractive method to improve the characteristics of the injected laser or to obtain nonlinear transfer functions that can be used in all-optical signal processing. Optical injection is also a method that can induce rich nonlinear dynamics in the light emitted by the VCSEL. An example of those dynamics has been recently obtained when measuring the polarization of a 850 nm wavelength VCSEL subject to orthogonal optical injection [1]. In that experiment linearly polarized light from a tunable external laser source was injected orthogonally to the linear polarization of a free-running VCSEL that exhibited polarization switching (PS) between its two linear polarizations when increasing its applied current. In this work we perform an experimental study of the nonlinear dynamics of a 1550 nm wavelength single-mode linearly polarized VCSEL when subject to orthogonal optical injection. We have measured the mapping of the polarization resolved dynamics in the plane of detuning between the injection frequency and the free-running frequency of the VCSEL versus injected power. In contrast with previous results [1], our free-running VCSEL emits in a linearly-polarized fundamental transverse mode over the whole current range. This significatively affects the dynamics since our mapping shows qualitative differences with previously reported mappings [1].

Experimentally, the orthogonal optical injection from a tunable external-cavity laser diode in a commercial VCSEL (Raycan) is achieved by using an all-fiber setup. A bias current of 4 mA (approx. 2.5 x I_{th}) was applied to the device. The power of the dominant (parallel) polarization of the solitary VCSEL was 0.2 mW. The orthogonal polarization was suppressed 35 dB. We show in Fig. 1 (left) the mapping of the dynamics of the total power when the injected power is swept for different frequency detunings around the frequency of the orthogonal polarization of the fundamental transverse mode of the device. Fig. 1 also shows the injected power required for PS to the orthogonal polarization of the VCSEL. Different regions corresponding to different dynamical regimes are shown in the figure. Region SL represents the stable locking range and regions P1, P2 show periodic dynamics. The P1 region is characterized by the appearance of a strong peak near the frequency detuning in the RF spectrum. In region P2 situations can be found where several peaks appear in the RF spectrum at multiples of one half the relaxation oscillation frequency of the free-running VCSEL indicating period doubling dynamics. The CH region is characterized by wide RF spectra (see Fig. 1 right) that are the signature of irregular and possibly chaotic dynamics. In contrast with Ref. [1] the irregular behavior is obtained for negative values of the frequency detuning. In conclusion, avoiding complicated nonlinear dynamics in applications where the injection power is changed requires operation at positive frequency detunings.

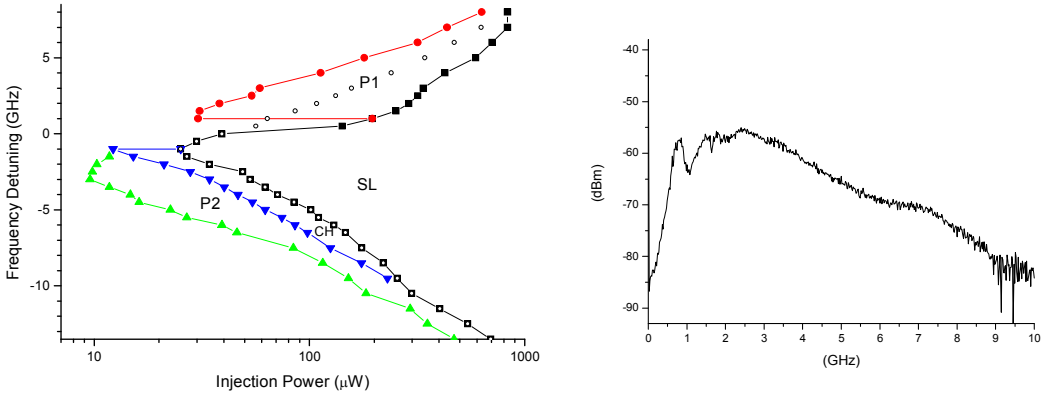

Fig. 1 Left: Mapping of the dynamics of the VCSEL subject to orthogonal optical injection. SL: stable locking region, P1,P2: periodic regions, CH: irregular dynamics. PS is also shown with open circles. Right: RF spectrum in the CH region (Injected power: 50 □W)

References

[1] J. Buesa, I. Gatare, K. Panajotov, H. Thienpont, and M. Sciamanna, “Mapping of the dynamics induced by orthogonal optical injection in vertical-cavity surface-emitting lasers”, IEEE J. Quantum Electron. 42, 2,198-207, 2006.