Dynamics of Dual-polarization VCSEL-based Optical Frequency Combs including Optical Injection Locking

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Our Vertical-Cavity Surface-Emitting Laser (VCSEL) Optical Frequency Combs (OFC) generated using a large signal modulation technique called Gain Switching (GS) are interesting systems for many applications: they produce record combs in terms of energy efficiency and mode coherence and offer compactness, integrability and cost efficiency [1]. In this work we present new results on our on-going study of VCSEL-based GS-OFCs. Firstly, we have evaluated the dynamic behaviour of the two orthogonal modes of polarization present in a VCSEL output under GS. We have observed that each mode generates a separate optical comb and the orthogonal mode, usually suppressed during fabrication, contributes to the total VCSEL-OFC [2]. Secondly, we have included Optical Injection Locking (OIL) to modify and adjust both polarization contributions. We have observed that the control of the polarization of the injected light clearly influences the overall optical comb and the sub-combs it is formed of. We have been able to balance and equalize the power associated to those sub-combs obtaining an enhanced dual-polarization OFC. Besides, we have also tuned the injected polarization to cancel one of these sub-combs maintaining the other one in similar power levels inducing a polarization switching along all the modes of the overall comb. This means that we can control the polarization state of the final comb as we prefer, which is quite a remarkable result.

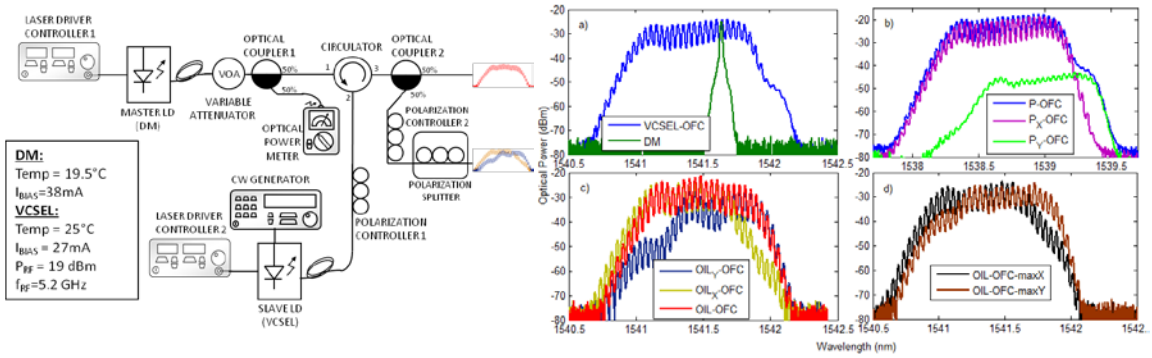

Fig. 1 (left) Experimental set-up. The comb is generated inside the VCSEL (25ºC, 27mA, 5.2GHz, 19dBm) which is at the same time optically injected by the DM laser (19.5ºC, 38mA) through a circulator. The injection ratio is -6.6dB. The optical output is first power divided and then one arm is split in two orthogonally polarized sub-combs with a polarization splitter. (right) a) VCSEL-OFC (blue trace) with 25 teeth in the 20dB span which corresponds to 130GHz. DM output (green trace), master light being injected into the VCSEL at 1541.63nm. b) VCSEL-OFC (blue trace) and its polarization components: Px-OFC (purple trace) and Py-OFC (green trace). c) OIL-OFC (red trace) output signal with OIL adjusting the polarization to equalize both sub-combs. The resulting comb has 27teeth in the 20dB span, which corresponds to 140GHz. The polarization components of the OIL-OFC are OIL_X-OFC (yellow trace) and OIL_Y-OFC (dark blue trace). This means that with the injection both sub-combs maintain their orthogonal states of polarization. d) OIL-OFCs adjusting the master polarization to maximize either the P_X-OFC (OIL-OFC-maxX or black trace) or the P_Y-OFC (OIL-OFC-maxY or brown trace).

The availability of two coherent combs with separate polarization find applications in ultrafast laser dynamics studies [3] or in polarization-division multiplexing optical communication [4]. Our efforts continue to implement the OIL using a VCSEL as master. Future work will also be oriented to a deeper understanding in the OIL technique for VCSEL-based OFCs facing these results with theory.

References

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