Dual-polarization VCSEL-based optical frequency comb generation

E. Prior[1], C. de Dios[1], M. Ortsiefer[2], P. Meissner[3], P. Acedo[1], *Member*, IEEE
1. Electronics Technology Department, Universidad Carlos III de Madrid, Leganés, 28911 Spain
2. Vertilas GmbH. Garching, Germany
3. Technische Universität Darmstadt, Darmstadt, Germany

Optical Frequency Comb Generators (OFCG) based on Cost of the Shelf (COTS) laser diodes (LDs) are interesting systems for many applications as they offer compactness and cost efficiency. However, the optical frequency span and the coherence of the modes is still a limiting factor when comparing to combs based on other laser technologies. Among LDs, Vertical-Cavity Surface-Emitting Lasers (VCSELs) under Gain Switching (GS) regime [1] produce record combs in terms of energy efficiency and mode coherence. GS is a well-known nonlinear technique to directly generate OFCGs from LDs.

In this work we present new results on our on-going study of VCSEL-based GS-OFCGs. We have evaluated the dynamic behaviour of the two orthogonal modes of polarization present in a VCSEL output under GS for OFCG. We have observed that each mode generates a separate optical comb. The orthogonal mode, usually suppressed during fabrication, contributes to the total VCSEL-based OFCG obtaining a broader span.

Fig. 1b) shows that the VCSEL-based OFCG total output, P (blue), with an optical frequency comb with a 20dB span of 132GHz, is formed by two different combs: one associated to the main transversal mode, P_y (red) and the other one to the orthogonal mode, P_x (green). In order to evaluate the phase relation of these orthogonal polarized combs and how they combine to produce the total comb output, we compare the Phase Noise (PN) of the RF detected signal at $f_{comb} = \Delta f = f_{N+1} - f_N = f_{RF}$ = 5GHz, the frequency spacing of the lines of the combs, for the three cases of Fig 1 b (Fig. 1c). All the measurements show almost the same PN level. This means that the coherence of the optical modes associated to the combs for P_y and P_x are very similar and equal to the coherence of the total comb. These findings suggest that the modes in the overall comb share a stable phase relation independently of their state of polarization. Further work will be developed to understand if these observations are related to the fact that these two modes are degenerate states of the same spatial mode or this is a hint of a possible mutual injection locking mechanism between the P_x and P_y combs.

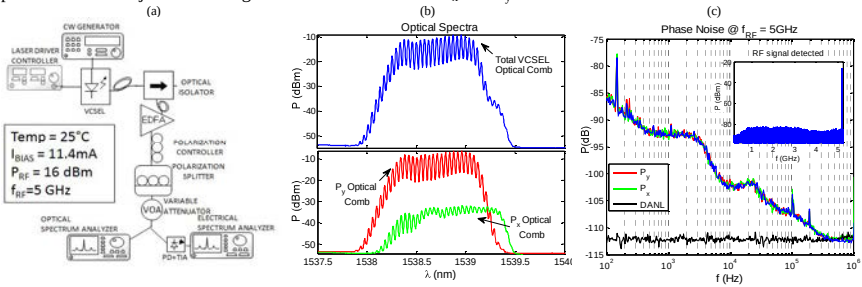

Fig. 1 a) Experimental set-up with a VCSEL test device provided by VERTILAS GmbH. b) OFCGs comparison: total OFCG (blue), OFCG generated by the main polarization mode Py (red) and OFCG generated by the orthogonal polarization mode Px (green). c) Phase Noise of the electrical signal detected with the total OFCG (blue), the main polarization comb Py (red) and the orthogonal polarization comb Px (green). The Noise Floor of the electrical spectrum analyzer (black) is also plotted. The inset shows the detected signal from DC to 5.4GHz where no other frequency components appear.

These results point out that VCSELs with the orthogonal mode not suppressed, would be able to generate a broader dual-polarization comb with a similar amount of energy injected and offering a very good phase relation between its modes. The availability of two coherent combs with separate polarization find applications in ultrafast laser dynamics studies [2] or in polarization-division multiplexing optical communication [3]. Our efforts continue in order to determine how each mode influences the total comb and how both combs are correlated with each other.

References

[1] E. Prior, C. de Dios, A. R. Criado, M. Ortsiefer, P. Meissner, and P. Acedo, *Photonics Technol. Lett.*, vol. PP, no. 99, pp. 1–1, 2014.
[2] M. Brunel, J. Thévenin, and M. Vallet, *CLEO: 2013*, 2013, p. CF1G.5.
[3] A. D. Shiner, M. Reimer, A. Borowiec, S. O. Gharan, J. Gaudette, P. Mehta, D. Charlton, K. Roberts, and M. O'Sullivan, *Opt. Express*, vol. 22, no. 17, pp. 20366–74, Aug. 2014.