Self-Generation of Optical Frequency Combs in III-V/SiN External Cavity Laser with Frequency-Selective Mirror

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In recent years, laser sources based on hybrid integration have been attracting surging interest for their compatibility with silicon photonic (SiPh) platforms making them the key components for many applications in optical communication and sensing. Furthermore, this technology is appealing for the realization of optical frequency combs (OFC) [1] at chip scale [2]. In this contribution, we address the dynamics of III-V/SiN hybrid lasers with high-Q SiN rings (Fig. 1a), providing a narrowband effective reflectivity ($|r_{eff}|^2$ in Fig.1c). Our model makes use of time-delayed algebraic equations accounting for mirror frequency selectivity [4].

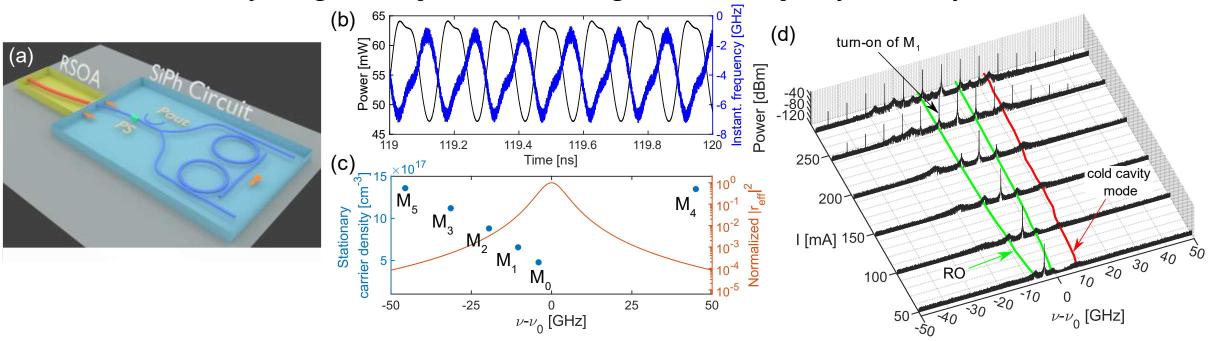

Fig. 1 (a) Schematics of the optical setup. (b) Temporal dynamics in output power (black) and instantaneous frequency (blue) in an OFC regime for bias current I_{bias}=240 mA and $|r_{eff}|^2$ FWHM=6 GHz (other parameters as in [4]). (c) Corresponding cavity modes (blue) and normalized SiPh mirror reflectivity profile (orange). (d) Optical spectra for increasing bias currents (RO: relaxation oscillations).

While this configuration has been proposed for the increased resilience of the laser to spurious back-reflections [3,4] and for the narrow emission linewidth [5], in [6] preliminary experimental results have also shown its potential in generating OFCs. Here, we investigate in detail (with the tools we presented in [4]) the mechanism that leads to the self-generation of the OFC. We highlight that the emergence of the comb relies on an unstable regime that is possible thanks to the very narrowband dispersive mirror feasible in this platform. In Fig. 1b we report an example of this regime, showing the temporal dynamics of both instantaneous frequency and optical power. Solving the oscillation condition, we plot in Fig.1c the cavity modes M_i in their frequencies (detuned with respect to the peak of effective reflection coefficient) and the corresponding carrier density that each mode would require to reach its threshold. Mode M_0 is detuned of $\Delta\nu$=-4 GHz with respect to the effective reflectivity peak by adjusting the phase shift of the phase control section (PS). The other modes are asymmetric with respect to M_0 because of the non-null α-parameter of the RSOA (set to α_H=3). To explain the mechanism leading to the self-starting of the OFC, we plot in Fig. 1d the optical spectra simulated at different currents above threshold (of about 20 mA). At low currents (50-100 mA) we have single mode lasing and the other bumps in the spectrum are (i) the sidebands of the laser relaxation oscillations (the green lines mark the trajectory of the RO for increasing current) and (ii) the cold cavity longitudinal modes (red line). Note that the cold cavity modes are different from M_i because of α_H=3. At 240 mA, relaxation oscillations can become undamped [4], due to the detuning of -4 GHz and the dispersive mirror, turning the laser phase noise into intensity noise that again enhances phase noise. Such oscillations generate a parametric gain capable of turning on M_1. Then, Four Wave Mixing of the RSOA can maintain locking of the modes. We conclude that narrowband mirrors, proper detuning of the lasing frequency, and a non-null α-parameter are essential ingredients for the self-generation of OFCs. For instance, we have checked that, forcing α_H=0, the laser remains single mode for most of the frequency detuning. Further analysis of the comb performance in terms of bandwidth, FM and AM component of the comb, and RF linewidth is currently ongoing.

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