

# Phase synchronization of monolithic dual DFB lasers for microwave photonics: experiment vs model

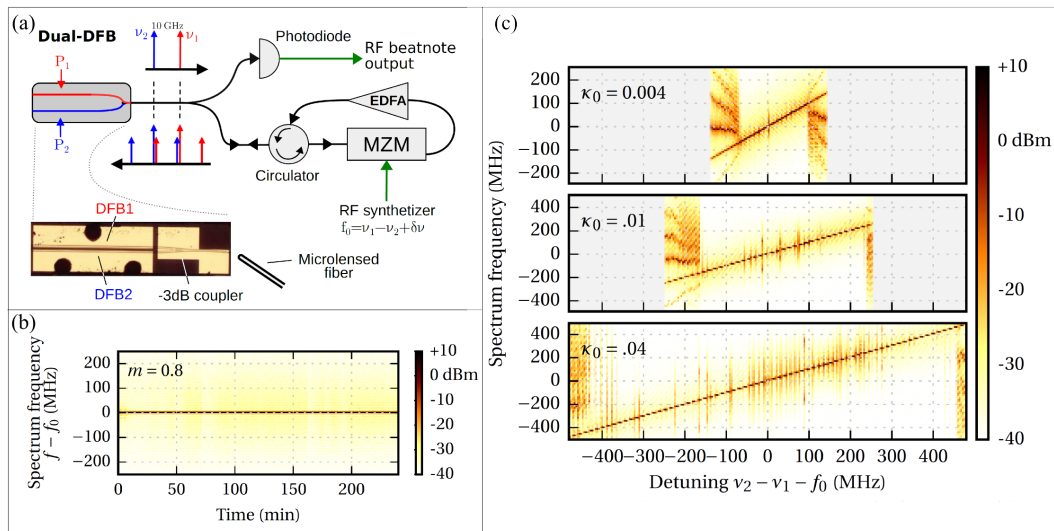
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The experimental implementation of optically carried RF signals, in the 1-100 GHz range and beyond, is fundamental for microwave photonics applications. The technique of heterodyning two laser waves provides an interesting alternative to direct modulation of light. Indeed, it allows generating directly a single-sideband signal over an optical carrier, that is inherently insensitive to dispersion in a fiber link. It also features a 100% modulation depth, a broad and continuous tunability. Phase-locking to electronic local oscillators results in optical beatings of very high spectral purity; furthermore, high microwave frequencies ( $\sim 100$  GHz) can be reached by suitable multiplication or downconversion techniques (at the expense of a degradation of the phase noise performances) [1].

In this work, we focus on an all-optical locking technique that relies on frequency-shifted optical feedback, and allows locking the beatnote of two monolithic dash-in-a-well DFB lasers [2] on an external electronic oscillator. The setup is sketched in Fig. 1(a) and involves a fibered optical feedback loop containing a Mach-Zehnder modulator (MZM) and an optical amplifier. This locking method is *passive*, i.e. it does not require any active control electronics. We have experimentally demonstrated that tunable, stable phase locking can be achieved over several hours (Fig. 1(b)).



**Fig. 1** (a) Experimental setup. Two monolithic DFB lasers are submitted to cross-injection, and unavoidable self-feedback, in order to lock their frequency difference on the RF synthesizer driving the in-loop Mach-Zehnder modulator (MZM). (b) Experimental spectrogram of the beatnote, showing the long term stability of the locking.  $m$  quantifies the ratio of cross-injection strength to the feedback strength ( $m = 1$  implies that only cross-injection is present). (c) Experimental spectrograms as the detuning is swept, for various feedback strengths  $k$ . It is seen that the locking range increases with  $k$ , and that inside the locking range stable locking regions alternate periodically with unstable regions. These features are reproduced by our model.

Furthermore, we have investigated experimentally the various dynamical regimes occurring in the system as some parameters, such as the injection strength or detuning between the free-running beatnote and the master oscillator frequency, are varied (Fig. 1(c)). We have built a rate-equation model and compared it carefully with the experimental findings. In particular, we have investigated the role of the unavoidable long delay introduced by the feedback loop, and the influence of the optical feedback phases, that cannot be controlled experimentally and are prone to drifts, on the stable locking regime [3].

## References

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