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Phase Noise Reduction of Narrow Linewidth Optical Fibre-Ring Based Microwave Oscillators : Modelling and Experimental Results

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The utilisation of optical carriers is of strong interest for microwave applications such as microwave generation [1]. For example, optical resonators can replace microwave resonators and allow to overcome the performance of traditional microwave oscillators in terms of compactness and quality factor, which will strongly reduce the phase noise of the overall microwave oscillator. Whispering gallery modes resonators have been studied and used in this aim [2, 3]. Whereas they exhibit very interesting characteristics in terms of quality factor, the long-term stability of the resulting microwave oscillator is reduced because of the mechanical instability induced by the fibre-to-resonator coupling systems. An interesting alternative consists in using optical fibres based ring resonators [4]. This kind of set-up presents easily a high stability in time in terms of light coupling, while having great potential for exhibiting high-Q values. It is composed of a single-mode fibre with a length between 10 and 20 m, and two low losses fibered couplers. The choice of the fibre length and the couplers ratios are critical for the optical quality factor of the resonator. A first study of an optoelectronic oscillator (OEO) based on this fibre ring (Fig. 1) has shown that, despite a very high Q-factor of the resonator (about 2.10^8 at $1.55 \mu\text{m}$ for a length of 10 m), the phase noise of the OEO can be high (Fig. 2) and has to be decreased [4]. We have thus based our optimisation of resonant fibre rings on a theoretical study of the OEO phase noise to understand the influence of the resonator on the noise of the oscillator. This study concerns mainly the phase noise due to the white frequency noise induced by our resonators and is comparable to the one proposed for purely microwave oscillators by J. Everard [5].

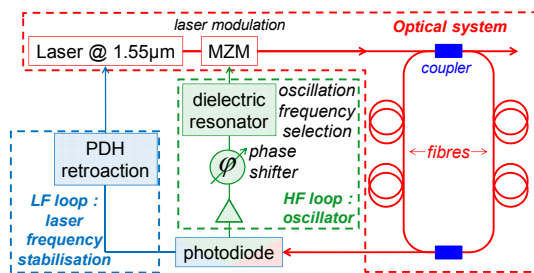


Fig. 1 Set-up of the OEO.

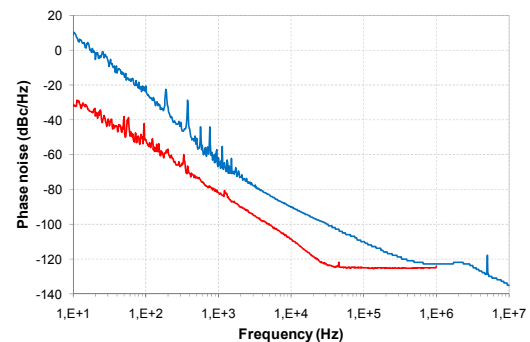


Fig. 2 Phase noise of the OEO with the non optimized fibre ring (in blue) and with the optimized fibre ring (in red).

Comparisons between modelling and experiments, performed on both the resonator and oscillator noise, have allowed us to determine with accuracy the physical parameters of our first fibre ring, mainly the transmission and losses of its couplers and the intrinsic losses of the ring. An in-depth study of the influence of the couplers and ring losses on the noise performance allowed to conclude that the best performance in terms of optical quality factor does not lead automatically to the lowest phase noise. A global optimum has thus to be found. In the frame of this work, we thus have proposed a new resonant fibre ring design thanks to this analysis. Its quality factor is 5.10^9 at $1.55 \mu\text{m}$, for a length of 20 m. We have thus built a new OEO with it. Its phase noise has considerably been improved (Fig. 2). We can observe on this spectrum that the main component of the OEO phase noise is the flicker-like noise. The next step of this study is to understand the origin of this noise in this case and how to reduce it.

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