High-Q Optical Resonators for Laser Stabilization in Microwave Photonics Oscillators

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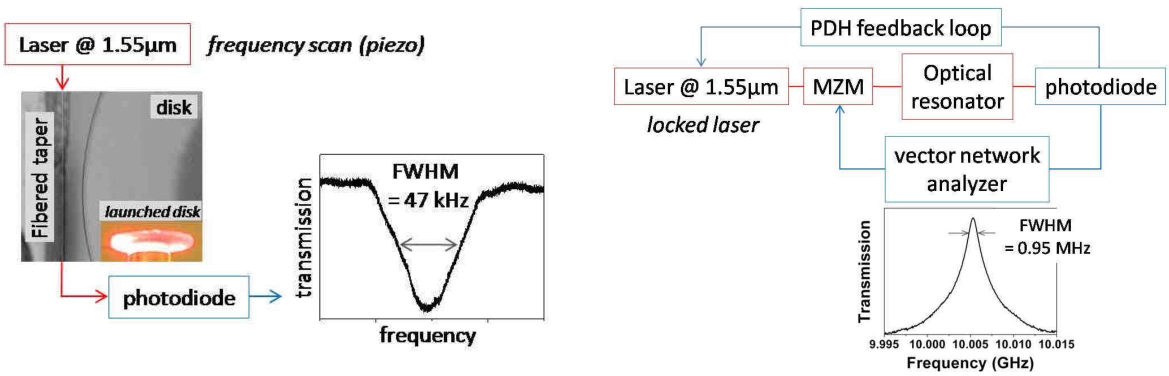
New resonators are investigated in order to design compact and high performances microwave oscillators. Because of long wavelengths in microwave range, dimensions of resonators are intrinsically large. Secondly, the quality factor of these resonators is now limited to about 2.10^5 at 10 GHz with whispering gallery modes (WGM) sapphire resonators. Nevertheless, it is possible to solve these difficulties if we use optical waves as a carrier for the RF frequencies, for example a 1.5 µm-laser. Resonators become optical ones, with low dimensions due to short wavelengths. The optical resonator creates an optical frequency comb with microwave spacing. Each mode of this comb is characterized by an optical Q factor (Q_{opt}) and an equivalent RF Q factor (Q_{RF}). Q_{RF} is the product of Q_{opt} and the RF to optical frequencies ratio. At 1.55 µm, this frequency ratio is about 10^4 at 20GHz and Q_{opt} must be at least equal to 10^8 to obtain a quality at 20 GHz better than the microwave resonators. We present different high-Q optical resonators and an application of one of them to microwave photonics oscillators.

Like for microwave resonators, WGM can be used in small bulk spheres or disks in silica or quartz, for example. With a scan method [1], using a 1.55-µm single-frequency tunable fibered laser to explore the frequency comb of the resonator, we have measured an optical Q factor of about 4.10^9 for a 3.3-mm-diameter quartz disk (Fig. 1(a)). The laser is launched in the resonator thanks to a tapered fibre. In spite of the really interesting Q_{opt} factor of these resonators, their optical transverse multimode behavior and the laser launching difficulties lead us to study another kind of resonators.

These resonators are resonant fibre loops, built with few-meter-long single-mode fibres and fibered couplers [2]. The laser is now directly launched in the resonator with low losses. Thermal effects due to power launching and external perturbations lead to frequency comb instabilities, because of the high Q factor of the cavity. The laser lock on a resonance loop is necessary, and a Pound-Drever-Hall feedback loop has been used. When the laser is locked, the RF modulation is applied with a Mach-Zehnder modulator (MZM). The optical Q factor is then measured with a vector network analyzer (Fig. 1(b)). We thus demonstrate a Q_{opt} of 3.10^9 in a 20 m-long loop, leading to a Q_{RF} of 3.10^5 at 20 GHz, better than for a WGM quartz resonator at this frequency.



(a) WGM resonator (b) Resonant fiber loop

Fig. 1 Optical Q factor measurement methods used with the WGM resonators (a) or the resonant fibre loop (b).

Despite this high Q factor, the optoelectronic oscillator (OEO) based on this resonator presents a high level of phase noise. We have developed another resonant loop (patent pending) to solve this problem, and obtained a phase noise level of -90.5 dBc/Hz at 10 kHz offset from a 10 GHz carrier for this new OEO. A lower Q_{RF} factor of $1.2x10^4$ ($Q_{opt} \sim 2.10^8$) is extracted from the frequency noise to phase noise transition. We are improving these results thanks to the design of a new resonator and the implementation of a noise model of the whole system.

These optical resonators have really high Q factors. WGM resonators are potentially performing for highly compact devices and fibered resonators are efficient and easily integrated in a complete system. They are really interesting for laser stabilization in photonics microwave applications, as shown with the performances of this OEO, and we are actually improving the efficiency of such optical resonators and oscillators.

References

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