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Ultra high quality factor optoelectronic oscillator stabilized with acousto optic cells

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Abstract: TeO₂-crystal-based acousto-optic cells allows the stabilization of an optoelectronic oscillator (OEO). The system is operating for any resonator to be inserted into the OEO with a Q-factor from 2×10^7 to 10^{11} .

1. Introduction

In order to improve stability of an optoelectronic oscillator (OEO) [1,2] based on an optical resonator [2], it is necessary to stabilize optical frequency of the input laser at $1.55 \mu\text{m}$. Although Pound-Drever-Hall technique [3,4] can be used for the purpose, we use acousto-optic cells (AOC) based on a paratellurite TeO₂ crystal to stabilize the microwave signal generated by the OEO.

2. Operation of the stabilized optoelectronic oscillator

It is schematically presented in Figure 1. Pound-Drever-Hall technique can be used to properly stabilized the OEO [5,6]. However, to our knowledge, it is the first time that it was proposed the use of AOC pairs for OEO stabilization [7]. Bulk acoustic waves at two radio (RF) frequencies in the range 55–65 MHz are launched in the two identical cells providing a required locking of the microwave signal. For an optical resonator with quality factor of the order $2 \times 10^7 - 10^{11}$, the difference between the two RF signals should be varied from 2 kHz to 10 MHz: the 10 MHz maximal amplitude between those RF signals allows to work with a resonator with Q-factor no worse than 2×10^7 , and a upper value for an ultra high Q-factor at 10^{11} require a 2 kHz RF difference to drive the AOCs. An extraordinary polarized laser beam on the cells ultrasound is sent at Bragg angle of light incidence corresponding to a deflector regime of the cells operation [8]. It helped to perform a critical alignment of the two cells.

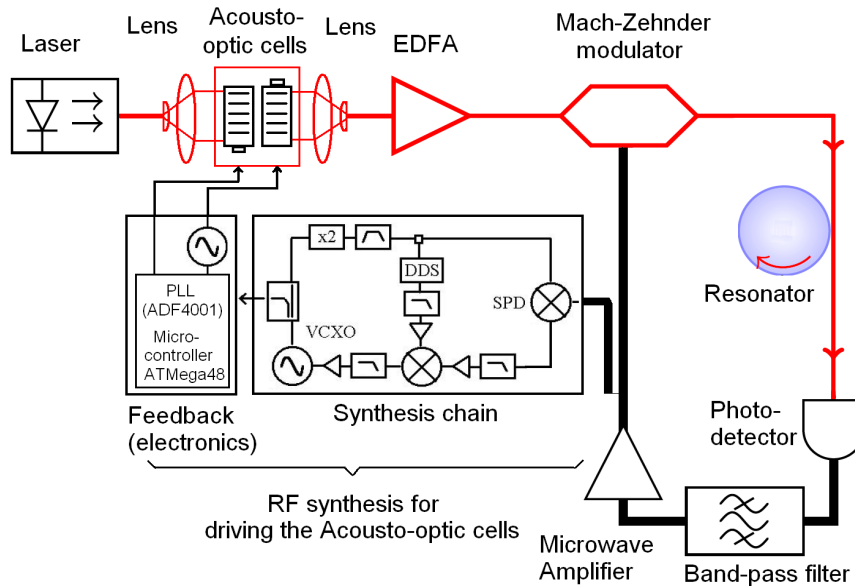


Fig. 1. Optoelectronic oscillator (OEO) stabilized by acousto-optic cells. EDFA = erbium doped fiber amplifier, PLL = phase lock loop, DDS = direct digital synthesis, VCXO = voltage controlled crystal oscillator, SPD = sampling phase detector, RF = radio frequency.

To generate radio frequency (RF) signals, a Voltage Controlled Oscillator (VCO) is locked to a micro-controller following the microwave frequency generated by the OEO. Although a pair of acousto-optic cells to stabilize a signal delivered by an optoelectronic oscillator (OEO) present some disadvantages in terms of alignment, the system operates in a proper manner only when the OEO is kept locked on the resonance.

3. Experimental application

As an experimental application of this study to lock a $Q = 1.3 \times 10^8$ Q-factor CaF_2 resonator based OEO, characterized by cavity ring down technique [9] as shown on Figure 2, two RF signals presenting a difference of 650 kHz were demonstrated to allow a significant better alignment of the two inserted AOC cells thanks to the +1e mode. We would like to underline the fact that the use of AOCs for locking an OEO is particularly interesting in case of testing various resonator with different Q factors between 2×10^7 and 10^{11} . The RF to be applied on the cells just need to be adjusted. To achieve spectral characterization of the signal delivered by the OEO, we use a dedicated optoelectronic phase noise measurement system [10].

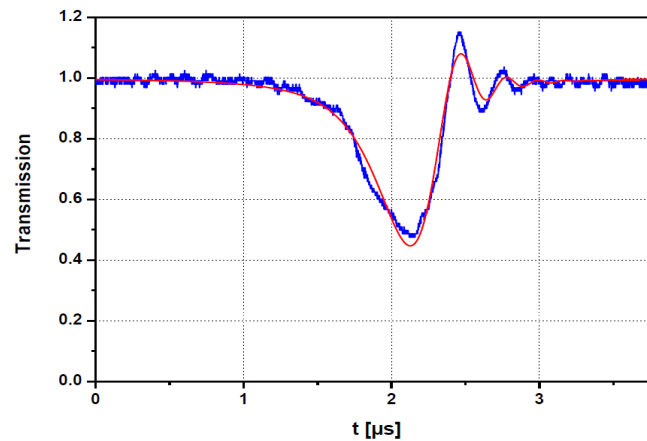


Fig. 2. Cavity ring-down characterization [6] during polishing process on a CaF_2 resonator. Transmission versus time (μs). Blue and red curves are respectively experimental transmission and its fit to determine the Q-factor of the cavity. Here, deduced Q is 1.3×10^8 .

4. Conclusion

OEO is successfully stabilized thanks to AOCs driven by two RF signals shifted by 650 kHz at 60 MHz. Preliminary phase noise measurement of the stabilized OEO at Fourier frequencies between 10 Hz and 100 kHz at 11 GHz are presented at the conference.

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