Active Rejection at the Level of 10^{-7} of the Residual Amplitude Modulation

J. Gillot, S. F. Tetsing-Talla, S. Denis, G. Goavec Merou, J. Millo, C. Lacroûte, Y. Kersalé
FEMTO-ST
ENSMM, Univ. de Bourgogne – Franche-Comté, CNRS
26, rue de l'Epitaphe, 25000 Besançon, France

***Summary*— The stability of lasers locked on ultra-stable cavities suffer of the residual amplitude modulation (RAM). We manage to improve the level of RAM fluctuations in the 10^{-7} decade for more than one hour integration time, which equals a fractional frequency instability of $\sigma_y(\tau) \approx 10^{-18}$ for a typical ultra-stable cavity at 1.5 µm. This represents an improvement of the state of the art of about one order of magnitude.**

***Keywords*— RAM, cavity, Pound-Drever-Hall, stability.**

I INTRODUCTION

We report an improvement of the state of the art on the cancellation of the residual amplitude modulation (RAM) [1].

The RAM is one of the most common problem in the time and frequency community when using an electro-optic modulator (EOM), since the RAM deteriorates the relative frequency stability of optical references. The Pound-Drever-Hall method [2] is the most often technique used for locking a laser on a Fabry-Perot cavity, but it requires the use of an EOM for the phase modulation of the laser beam. The RAM is inherent to this method, finding its origin in a polarization mismatch between the axis of the crystal and the polarization [1], or etalon effect in optics [3].

Up to now, the best level of cancellation reached 10^{-6} [4] or about 10^{-7} for only five minutes in fibered EOM [5]. In this work, we manage to get a level of 10^{-7} in a free space and non-wedged EOM for at least one hour.

II METHODS/RESULTS

We apply a RF modulation of 23 MHz on a free-space $LiNbO_3$ EOM crystal to modulate in phase the light. The active scheme implemented for the cancellation of the RAM is based on an accurate temperature stabilization of the EOM (within ± 20 mK), a control of the DC voltage applied on the EOM and a laser power stabilization. The RAM is reduced by adjusting the temperature at a null RAM point, and the DC voltage loop performs quick corrections. Furthermore, the electronic is entirely digital, as every servo loop is driven by a RedPitaya. The digital control allows to finely tune the servo loop parameters, provide repeatability and avoid hysteresis and non-linearity.

III DISCUSSION/INTERPRETATION

For our ultra-stable cavity [6] with a typical finesse of 250 000, we expect a RAM induced fractional frequency instability of $\sigma_y(\tau)=2.5\times10^{-18}$, far under the thermal noise floor estimated to 4 $\times10^{-17}$.

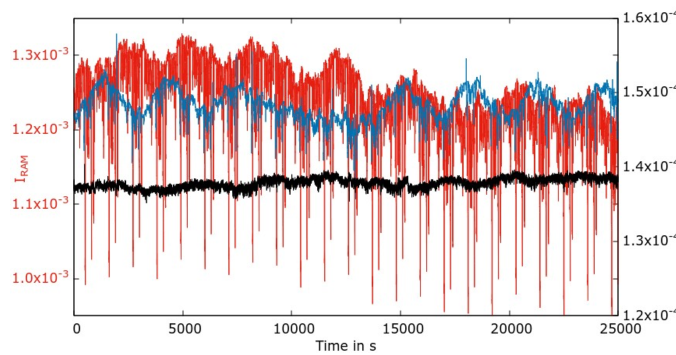

Fig. 1 - Temporal evolution of the RAM signal when the temperature regulation of the EOM is activated. In red and blue (left scale), the servo loop to control the RAM is off, respectively without and with optical power stabilization. In black (right scale), the RAM control is activated.

IV CONCLUSIONS

We enhanced the state of the art by improving the rejection of RAM fluctuations over a few thousands of seconds and thus reject this technical limitation for cavity stabilized laser with fractional frequency stability in the $\sigma_y(\tau)\approx10^{-18}$ decade.

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