Towards a high-stability Cs-microcell stabilized laser with dual-frequency sub-Doppler spectroscopy

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***Summary*—We report on the frequency stabilization of an external-cavity diode laser onto a Cs micro-fabricated cell using dual-frequency sub-Doppler spectroscopy (DFSDS). The Allan deviation of the laser, measured by creating a beat-note signal with an ultra-stable 895 nm signal extracted from a frequency comb phase locked to a cavity-stabilized laser, is $3x10^{-13}$ at 1 s and below $5x10^{-14}$ at 100 s. The stability level at 1 s is currently limited by the intermodulation effect due to the frequency noise (FM noise) of the laser. Studies are in progress to identify main limitations to the laser mid-term stability.**

Keywords—stabilized laser; microcell; frequency stability; sub-Doppler spectroscopy

I. Introduction

Significant efforts have been produced in recent years towards the development of new-generation microcell-based optical frequency references. In [1], a distributed-Bragg resonator (DBR) laser was locked to a Rb microcell using saturated absorption spectroscopy, achieving a frequency stability at the level of 10^{-11} up to 10^4 s. In [2], a fully-integrated Rb optical frequency reference, based on a glass-blown cell, demonstrated a stability level of $1.4x10^{-12}$ at 1 s. In [3-5], the Rb two-photon transition at 778 nm was adopted in a microcell-based optical frequency standard, demonstrating a frequency stability level up to $1.8x10^{-13}\ \tau^{-1/2}$ until less than 100 s (with τ the integration time), when use of a narrow-linewidth external-cavity diode laser (ECDL) to probe the atomic transition [5].

In this study, we report on laser frequency stabilization with a Cs vapor microcell, using the dual-frequency sub-Doppler spectroscopy (DFSDS) technique [6-7].

II. Methods/Results

The source of the Cs microcell-reference is an ECDL tuned at 895 nm, on the Cs D_1 line. A fibered electro-optic modulator (EOM), modulated at 4.596 GHz, is used to generate first-order optical sidebands separated by 9.192 GHz. An acousto-optic modulator (AOM) is implemented at the output of the EOM for laser power control. The laser beam is sent into a buffer-gas free Cs vapor MEMS cell [8] and reflected back at the cell output to produce counter-propagating dual-frequency beams. The cell is temperature-stabilized at about 60°C and surrounded by a single-layer mu-metal magnetic shield. The light is detected through a cube at the cell input with a photodiode. An error signal is extracted from the sub-Doppler resonance and is used to correct the laser frequency using a lock-in amplifier.

As shown on Fig. 1, a beat-note was obtained between the microcell-stabilized ECDL and an ultra-stable 895 nm signal extracted from a cavity-stabilized laser through a fiber-based optical frequency comb [9]. The stability of the cavity-stabilized laser is at the level of $2x10^{-15}$ at 1 s [10].

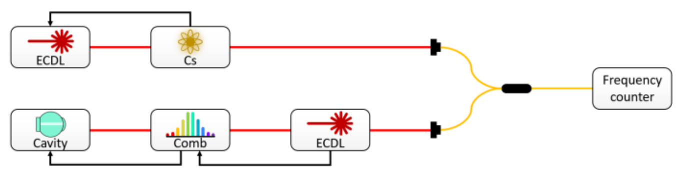

Fig. 1: Experimental setup

The short-term stability of the microcell-ECDL is measured to be $3x10^{-13}$ at 1 s. The latter is currently limited by the intermodulation effect [11] from the ECDL frequency (FM) noise. The Allan deviation of the microcell-ECDL is currently about $5x10^{-14}$ at 100 s. Frequency shift measurements are under progress in order to identify the main limitations to the microcell-laser mid-term stability.

III. Conclusions

We have demonstrated a laser frequency-stabilized to a Cs microcell using dual-frequency sub-Doppler spectroscopy with a stability level of $3x10^{-13}$ at 1 s and below $5x10^{-14}$ at 100 s. These results demonstrate the potential of the DFSDS approach for developing high-stability microcell optical frequency references. The main contribution to the laser short-term stability is the intermodulation effect. Efforts are under progress to improve these performances, both for short-term and mid-term stability. Latest results will be presented at the conference.

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