In-progress study of microcell-stabilized lasers using dual-frequency sub-Doppler spectroscopy

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Summary

We report the in-progress development and frequency metrology characterization of two table-top Cs microcell-stabilized lasers (one DFB laser and one ECDL laser) using a dual-frequency sub-Doppler spectroscopy technique. The impact of key experimental parameters was studied to optimize the short-term stability. The current Allan deviation of the laser beatnote is 1.5 10^{-12} at 1 s. The latter is in good agreement with the systems' noise budget and is currently limited by the intermodulation effect from the DFB setup. The measurement of a relevant number of frequency shifts is also in progress to estimate main contributions to the lasers' mid-term frequency stability budget. Encouraging results of about 2 10^{-13} at 100 s and at the level of 10^{-12} at 10^4 s were obtained. Latest results will be presented at the conference.

Motivation

In recent years, significant efforts were pushed towards the development of new-generation microcell-based optical clocks. Recently, the photonic integration of a microcell-based optical clock using the 778 nm Rb two-photon transition was demonstrated with stability performances of 4 10^{-12} $\tau^{-1/2}$ until 1000 s [1] (with τ the integration time), later improved at 2.9 10^{-12} $\tau^{-1/2}$ using a 35 cm^3 micro-optics breadboard [2].
In this paper, we propose an alternative approach for laser frequency stabilization with a vapor microcell using the dual-frequency sub-Doppler spectroscopy (DFSDS) technique [3,4,5]. While our previous studies were focused onto the in-depth understanding of physics mechanisms involved in the DFSDS approach, no detailed frequency metrology characterization of such systems has been reported yet.

Results

Two table-top microcell-stabilized lasers were implemented (see figure 1). A beatnote of 30 MHz can be obtained between these two lasers by tuning AOMs embedded in each setup. Each setup (one with a DFB laser, one with an ECDL) uses a diode laser, an external fibered Mach-Zehnder electro-optic modulator (EOM) modulated at 4.596 GHz and an acousto-optic modulator (AOM) for total laser power stabilization. The output beam is sent into a buffer-gas free Cs vapor MEMS cell and reflected back at the cell output in order to create two orthogonally-polarized counter-propagating dual-frequency beams. The cell is temperature-stabilized at about 62.5°C and surrounded by a 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.
The short term stability of the laser beatnote is 1.5 10^{-12} at 1 s. The latter is currently limited by the intermodulation effect from the DFB setup. Allan deviation results of about 2 10^{-13} at 100 s and at the level of 10^{-12} at 10^4 s were obtained. Latest results will be presented at the conference.

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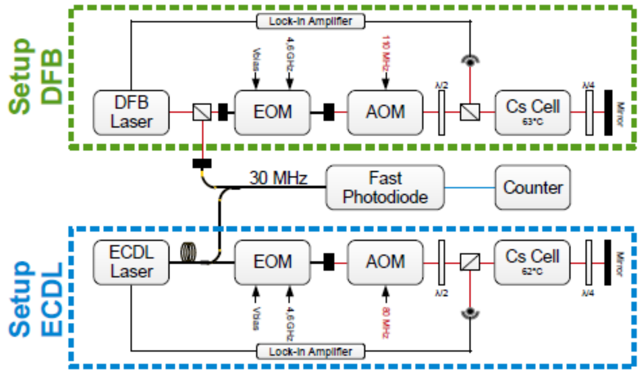

Fig. 1: (top) Experimental setup.