Investigations on the mid-term frequency stability of the Double-Modulation CPT clock

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***Abstract*—Atomic clocks based on coherent population trapping and constructive polarization modulation are promising for high performance and compact devices. We present a cw mode CPT clock with a short-term fractional frequency stability at the level of $3.2 \times 10^{-13}/\sqrt{\tau}$ for a few 100 s integration time. Thanks to the linear architecture, this Double-Modulation CPT technology could be reduced to a miniature and robust setup for future applications.**

Keywords*— *coherent population trapping, atomic clock, frequency stability

I. Introduction

The constructive polarization modulation coherent population trapping (CPT) [1] is a promising way to implement a high performance compact CPT clock [2,3]. Here we report on investigations about mid-term frequency stability of our high performance Dual-Modulation CPT clock. This clock could find applications in industry, telecommunications, instrumentation, or global navigation satellite systems.

II. DM-CPT Setup Properties

In this setup, the CPT resonance is driven by sidebands generated at 4.6 GHz with a fast pigtailed Electro-Optic Phase Modulator (EOPM), as represented in Fig. 1.

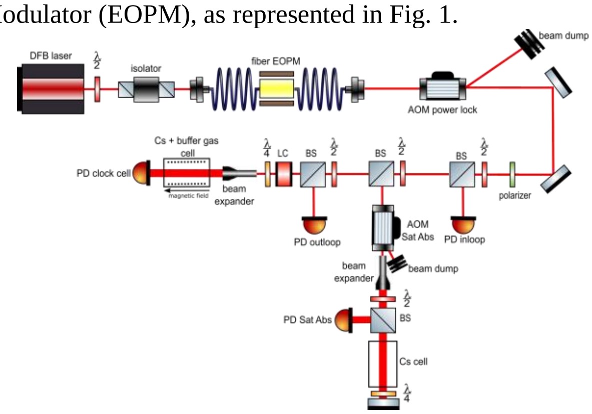

Fig. 1. Main setup for double-modulation CPT including the laser AOM power lock and additionnal saturated absorption frequency lock.

Since the DFB diode laser is very sensitive to back-reflections, a 60 dB isolator is used to reduce the light feedback from the EOPM fiber input reflection. To reach the clock stability performance, the laser power and the laser frequency are stabilized with two separate lock systems, shown in Fig. 1 and more detailed in [5], as well as the polarization modulation technique. The laser beam is adjusted for free propagation with a diameter expanded before the Cs vapor cell. The cylindrical vapor cell, 25 mm diameter and 50 mm long, is filled with 15 Torr of mixed buffer gas (argon and nitrogen). The cell temperature is stabilized at about 35°C. In our experiment, a uniform magnetic field of 3.43 µT along the direction of cell axis is applied to remove the Zeeman degeneracy.

III. Short-Term and Mid-Term Effects

With the DM-CPT setup, we get a relatively high contrast and narrow linewidth CPT resonance. When the local oscillator frequency is locked to the atomic clock signal, and compared to a hydrogen maser frequency standard, we record a very promising result presented in Fig. 2, which shows the frequency stability averages as $3.2 \times 10^{-13}/\sqrt{\tau}$ up to the 100 seconds integration time [6].

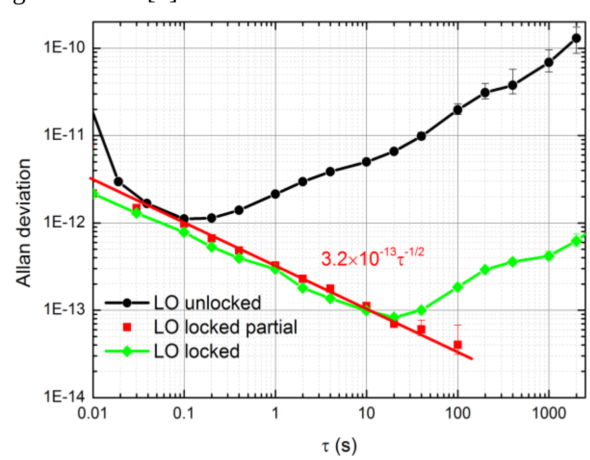

Fig. 2. Allan deviation of our DM CPT clock.

This short-term frequency stability performance is very close to the best CPT clocks. The limitations at 1 s are the microwave power, LO phase noise, laser frequency noise and laser intensity noise. At 1000 s, the main limitations are the microwave power, laser frequency and laser intensity. Further study will focus on the improvement of mid- and long-term frequency stability.

IV. CONCLUSIONS

A cw CPT clock with polarization modulation has demonstrated a short-term frequency stability of $3.2 \times 10^{-13}/\sqrt{\tau}$ up to 100 second. This results clearly shows the technological feasibility to implement a high performance and compact CPT clock based on polarization modulation. The mid-term investigations will be presented at the conference.

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