A CPT-based Cs cell self-sustained microwave oscillator

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***Summary*— We report the implementation of a CPT-based Cs cell microwave feedback oscillator. Here, a high-Q atomic resonance initiated through CPT in a buffer-gas filled Cs vapor cell is detected with a fast photodiode, amplified and sustained in a loop oscillator configuration, comparable to those of opto-electronic oscillators (OEOs). The Cs cell oscillator currently demonstrates at 9.192 GHz a phase noise of –24, –82 and –112 dBrad^2/Hz, for offset frequencies of 1, 100 and 10 kHz, respectively, in good agreement with the Leeson model. The AM noise was also measured, showing a comparable floor and 1/f dependence for offset frequencies lower than 200 Hz**

Keywords—microwave oscillator, phase noise, AM noise, vapor cell

I. INTRODUCTION

In a CPT-based vapor cell clock, the clock resonance signal is usually detected with a slow photodiode at the cell output as an increase of the light transmitted through the atomic medium. Alternatively, other studies in the early 2000s have demonstrated the possibility to directly detect optically-induced microwaves generated at the cell output with a fast photodiode and subsequently construct a self-oscillating atomic frequency reference [1-4].

Here, we aim to stimulate a renewed interest to the unusual latter concept with the demonstration of an all-optical microwave feedback oscillator using a Cs vapor cell resonator.

II. METHODS/RESULTS

Compared to previous studies [1-4], our experimental setup includes the use of a fibered Mach-Zehnder electro-optic modulator driven at 4.596 GHz that forces the request of a frequency divider in the loop. In addition, we report a simple and easy-to-understand phase noise characterization of the CPT-based feedback oscillator.

The phase noise of the Cs cell atomic oscillator, in good agreement with the Leeson model and shown in Fig. 1, is –24 dBrad^2/Hz at 1 Hz, with a flicker frequency noise compatible with a stability of 8×10^{-12} at 1 s, and currently degraded by the flicker phase noise of the EOM stage converted into frequency fluctuations of the oscillator loop. The noise floor of the oscillator is –112 dBrad^2/Hz and is limited by the low microwave power at the photodiode output.

We have also measured the AM noise of the oscillator, shown on Fig. 1, obtaining a spectrum well explained by the formalism developed in [7]. These results were submitted for publication [8].

Our analysis suggests that the reduction of the residual noise of the sustaining loop might pave the way to stability levels at 1 s in the 4×10^{-13} to 5×10^{-13} range, competitive with those of state-of-the-art vapor cell clocks [5-6]. In that sense, the exploration and test of noise reduction techniques to reduce phase fluctuations of the sustaining loop is under progress. Latest results will be presented at the conference

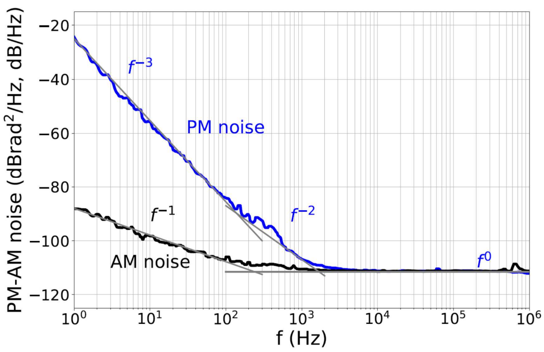

FIG. 1. PM AND AM NOISE, MEASURED AT 9.192 GHZ, OF THE CS CELL FEEDBACK OSCILLATOR

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