Tackling light-shifts in a microcell atomic clock with Symmetric Auto-Balanced Ramsey

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***Summary*— We demonstrate the implementation of a symmetric Auto-Balanced Ramsey (SABR) sequence in a CPT clock based on a microfabricated cell. For the demonstration, an external acousto-optical modulator (AOM) is used to generate the optical pulse sequence. The SABR method mitigates light shift effects by a factor higher than 100, in comparison with the CW-regime commonly used in CSACs. We also measure that SABR benefits to the clock Allan deviation for integration times between 10^2 and 10^5 s.**

Keywords—CSACs, light-shift, microfabricated cell, auto-balanced Ramsey

I. INTRODUCTION

CPT-based miniaturized atomic clocks present unrivaled size-power-stability budget and have known a remarkable development progress, including their commercialization [1]. They are now used in multiple navigation, positioning and timekeeping systems.

The mid-term fractional frequency stability of chip-scale atomic clocks (CSACs) can be limited by light-shift effects, induced by laser power, laser frequency or microwave power variations. Various methods have been then reported in the literature to mitigate these effects, for CPT clocks operating in the CW regime [2-4].

An alternative method to reduce light-shifts is to interrogate atoms with Ramsey spectroscopy [5]. This approach has been recently explored in microcell-based CPT clocks [6-7]. Nevertheless, Ramsey spectroscopy exhibits a residual sensitivity to light-shift effects. Sophisticated tailored interrogation sequences, demonstrated in various kinds of atomic clocks [8], have been then proposed to circumvent this issue. Among these approaches, the Auto-Balanced Ramsey (ABR) technique has met a significant success [9].

When applied in vapor cell clocks, it has been shown that the symmetry of the ABR interrogation sequence is of relevant importance to cancel a memory effect of the atoms [10]. In [10], this demonstration was performed on a compact clock setup using a 5-cm long glass-blown cell. While such techniques were implemented in high-performance CPT clocks, we have noted that they had never been explored in microfabricated cells.

The present study aims then to fill this gap. We consider that exploring SABR in microcells deserved specific attention for several reasons. With microcells, the limited relaxation time of the CPT coherence imposes a shorter light pulse pattern that might have increased the atomic memory effect. In addition, the reduction of the difference between both dark time values of the sequence might have degraded the light shift measurement sensitivity, and thus limiting the plus-value of the SABR on the clock stability. In addition, considering the significant market already represented by CSACs, we thought that demonstrating the benefit of the SABR method in microcells could interest the time and frequency community and stimulate the development of pulsed CSACs.

II. METHODS/RESULTS

A table-top CPT clock experimental setup was used. The latter combines a VCSEL laser tuned at 894 nm and modulated at 4.596 GHz, and a Cs-Ne vapor MEMS cell. The clock is piloted by a FPGA-based control electronics. An AOM is used to produce the pulsed optical sequence.

We probe the Cs clock transition in the MEMS cell with a symmetric ABR (SABR) sequence, using CPT spectroscopy, and study its impact for reducing the clock frequency sensitivity to variations of the laser field.

Figure 1 shows an example of the clock frequency sensitivity to laser power variations, in CW-regime, Ramsey-CPT, SABR and ABR (without symmetry) [11]. Compared to the CW case, the dependence of the clock frequency to laser power is reduced by a factor of about 465 with SABR. We also note the importance of the interrogation symmetry since simple ABR gives results comparable to the Ramsey-CPT case. Similar tests were also performed with the microwave power and the laser frequency, showing also a significant reduction of the clock frequency sensitivity in the SABR case.

By measuring successively a clock Allan deviation, in identical environmental conditions, with Ramsey-CPT or SABR, we have also observed that the use of SABR benefits to the clock Allan deviation for integration times between 10^2 and 10^5 s [11]. For time scales higher than 10^4 s, the clock stability remains limited to date by another mechanism which needs to be identified. Latest results will be presented at the conference.

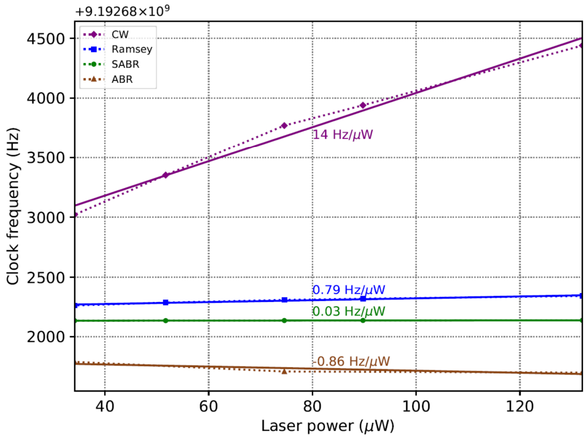

FIG. 1. FREQUENCY SHIFT OF THE CLOCK TRANSITION IN CW, RAMSEY-CPT, SABR AND ABR REGIMES

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