Ramsey-CPT spectroscopy for a microcell atomic clock

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Summary

We investigate the use of pulsed Ramsey-CPT spectroscopy in a coherent population trapping (CPT) atomic clock using a microfabricated buffer gas-filled Cs vapor cell. Tests are performed on a table-top setup with an external acousto-optical modulator (AOM) to produce the optical CPT pulse sequence. A relevant reduction of the clock frequency sensitivity to laser power variations by a factor of about 40 is observed, in comparison with the standard continuous-wave (CW) regime, with a free-evolution time T = 450 µs. The dependence to microwave power variations is also reduced in the Ramsey-CPT interrogation case. With the same cell physics package and similar environmental conditions, the clock Allan deviation is clearly improved for time scales higher than 100 s in the Ramsey-CPT case. These results suggest that the use of Ramsey spectroscopy might be an attractive approach in miniature clocks.

Motivation

CPT-based miniaturized atomic clocks have known a remarkable development progress, including their commercialization [1]. These clocks are extremely attractive candidates for numerous applications including secure communications, synchronization of sensor networks or navigation systems.
An important contribution to the mid-term and long-term stability of miniature atomic clocks is the dependence of the clock frequency to variations of the laser field. Different approaches have been proposed and demonstrated to mitigate light-shift effects in CW-regime CPT-based clocks [2-4].
In this paper, we investigate the application of Ramsey-CPT spectroscopy in a microcell atomic clock in order to evaluate how this approach might benefit, despite the application of short free evolution times, to the light-shift coefficients and to the clock fractional frequency stability performances for time scales higher than 100 s.

Results

A table-top microcell-based CPT clock experimental setup was implemented. The latter uses a 894 nm VCSEL laser modulated at 4.596 GHz, an external acousto-optical modulator (AOM) to produce the Ramsey-CPT sequence and a Cs-Ne vapor MEMS cell (see figure 1(a)). Figure 1(b) shows a Ramsey-CPT fringe detected in the cell for an input. For a dark time of 450 µs, we measured a reduction by a factor of about 40 of the clock frequency sensitivity to laser power variations, compared to the CW case. The sensitivity of the clock frequency to microwave power variations is also reduced in the Ramsey case. Allan deviation tests of the microcell-clock were performed in both interrogation schemes, in similar environmental conditions. A clear improvement of the clock Allan deviation is obtained for time scales higher than 100 s, at the expense of a possibly degraded short-term stability when the dark time is higher than the CPT coherence lifetime T_2 in the cell. At T = 450 µs, a short-term stability of about 10^{-10} at 1 s is obtained, reaching 4 10^{-12} at 10^4 s. Latest results will be presented at the conference.

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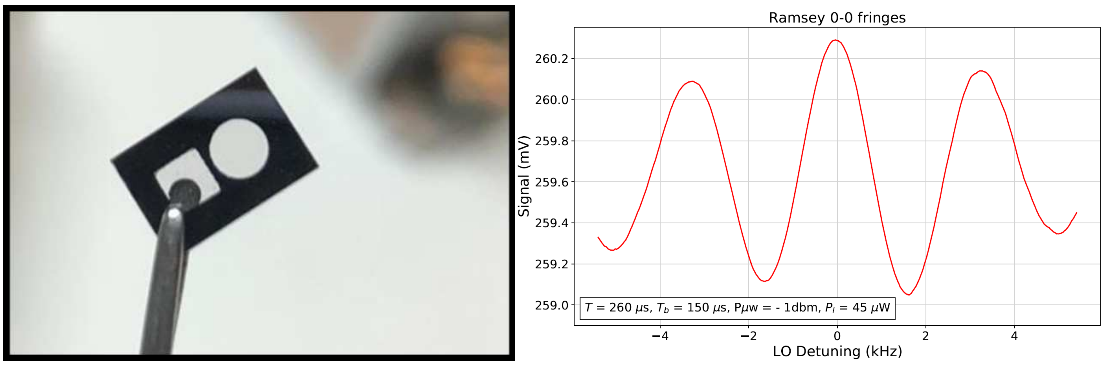

Fig. 1: (a) Cs-Ne microfabricated cell. (b) Averaged Ramsey-CPT fringe detected in the Cs-Ne microfabricated cell (laser power of 45 µW, a cell temperature of 70°C, a dark time of 260 µs and a pulse length of 150 µs).