Experimental Determination of Relaxation Rates in a Ramsey-mode Rubidium Cell Atomic Clock

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***Summary*—We describe a method to measure the relaxation rates in Rubidium (Rb) Pulsed Optically Pumped (POP) vapor cell frequency standards. By means of repeated spectroscopy measurements with varying Ramsey time, we show how to extract multiple estimations of the population and coherence relaxation rates of interest, which yields satisfying statistical error. The method can be applied using standard clock spectroscopy methods and equipment.**

Keywords—atomic clock, double-resonance, relaxation rates, short-term, Ramsey operation

I. Motivation

One of the main limitations in the use of Ramsey operation in vapor-cell Rb frequency standards are the high relaxation rates induced by collisions of the Rb atoms with the cell walls, the buffer gas and among each other. Indeed, higher relaxation rates imply lower lifetimes of the atomic ground state population inversion and coherence, which sets limits to the maximum Ramsey time and, in turn, to the achievable signal linewidth and amplitude. Currently, determination of relaxation rates from Ramsey spectra can be cumbersome and statistically more solid solutions are desirable [1].

Here we describe a method for measurement of population (γ_1) and coherence (γ_2) relaxation rates of the Rb ground-state clock transition that is easy to implement in an experimental Rb clock setup. The obtained results exhibit excellent statistics in terms of reproducibility and scattering.

II. Method

Measurement of relaxation rates by means of off-resonant microwave interrogation has been demonstrated [2], [3], notably for imaging applications. In these studies, a single, fixed microwave detuning was used.

In our present study we demonstrate a similar technique that exploits series of Ramsey fringe spectra, such as routinely produced in clock studies, taken for variable Ramsey time, T_R. Automated data analysis then treats the optical density signal for different selected microwave detuning as function of T_R that shows damped oscillations (see Figure 1) to which we fit (γ_1, γ_2) doublets. In this way, the technique operates at different detuning values at the same time, increasing statistics. However, care must be taken to distinguish results from relevant detuning against those from irrelevant detuning.

III. Setup

We apply the technique to our µPOP experiment [4] that uses a miniature vapor cell placed in a micro-loop-gap resonator.

IV. Results and Figures

For our microcell and with the data illustrated in Figures 1 and 2 we obtain $\gamma_1 \approx 5.8$ kHz and $\gamma_2 \approx 4.3$ kHz. We will discuss our experimental results and compare them to other methods and to the theoretical expectations.

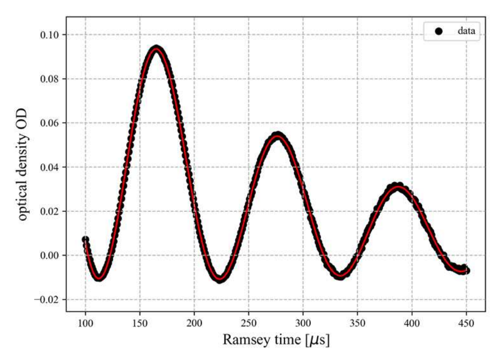

Figure 1 – Example of signal oscillation for 9 kHz microwave detuning. The red line is the fit function from which relaxation rates are extracted.

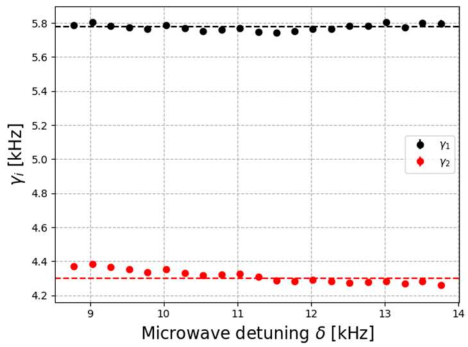

Figure 2 – Estimation of relaxation rates in the µPOP experiment [4] for various microwave detuning δ. The detuning values outside the range [8 kHz, 14 kHz] are not considered because they do not fulfill the requirements for good estimation of the relaxation rates.

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