Ramsey Spectroscopy in a Micro-Fabricated Rb Vapor Cell for Miniature Atomic Clocks

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***Abstract*— We present a prospective experimental study on double-resonance Ramsey spectroscopy in a micro fabricated Rb vapor cell, in view of future miniature atomic clocks with improved stability performance. Ramsey signals with a narrow central fringe width of 1.5 kHz combined with a competitive contrast of > 5 % are observed, resulting in a clock short-term stability of $\approx 1{\times}10^{-11}\ \tau^{-1/2}$. The employed pulsed optical pumping (POP) scheme bears promise for reduced light-shift effects and thus for improved clock stability on medium- to long-term timescales.**

Keywords— atomic clock, Ramsey interrogation, pulsed optical pumping, double resonance, Rubidium, microfabrication, vapor cell.

I. Motivation

Light shifts are a well-known limitation to the long-term stability of atomic clocks operating in the continuous-wave regime. The POP Ramsey scheme [1] can significantly reduce this effect and thus improve on the clock stability. Here we apply this scheme to Ramsey spectroscopy in a micro-fabricated Rb vapor cell [2]. Microwave radiation is applied via a sub-wavelength size micro-loop-gap resonator [3] of only 1 cm^3 volume. Frequency-stabilized light is provided by a compact stabilized laser head [4] including an acousto-optical modulator as optical switch. The experimental setup is sketched in Fig. 1.

II. Results

The Ramsey pattern's pulse sequence used in our study is shown in Fig. 2. From measurements of the intrinsic linewidth in continuous-wave double-resonance, we estimate the relaxation rate in our cell to $\gamma_2 \approx 2400\ s^{-1}$, which limits the useful Ramsey time to $T_R \approx 0.2$ ms. The observed Ramsey signals (see Fig. 3) show a narrow linewidth of ≈ 1.5 kHz, in agreement with theoretical expectations and about one order of magnitude smaller than for optimum continuous-wave double-resonance operation. Simultaneously, competitive high signal contrasts of 5 % are observed.

With this signal, we measure a preliminary short-term clock stability of $\approx 1{\times}10^{-11}\ \tau^{-1/2}$, close to the signal-to-noise limit estimated at $8{\times}10^{-12}\ \tau^{-1/2}$ under these operating conditions. The shot-noise limit is $< 3{\times}10^{-12}\ \tau^{-1/2}$.

III. Figures

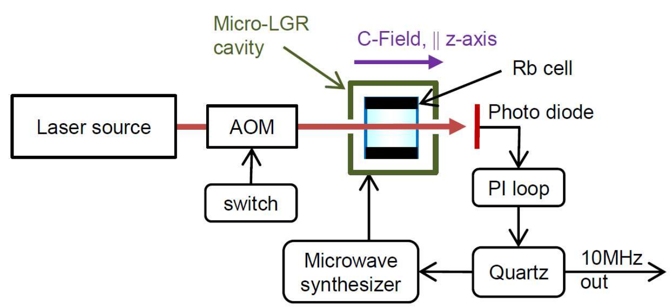

Fig. 1. Experimental setup.

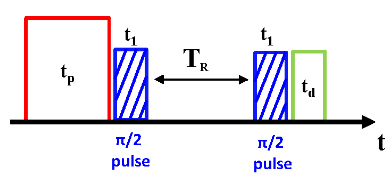

Fig. 2. Ramsey pulse sequence used for the study. Red: optical pump pulse. Blue: microwave pulses separated by Ramsey time. Green: optical detection pulse.

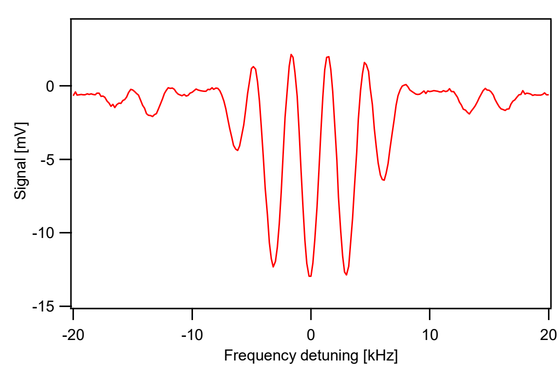

Fig. 3. Example of Ramsey fringes observed in the microfabricated Rb cell.

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