# Long-Term Instability of a Pulsed Optically Pumped Micro-cell Rubidium Frequency Standard

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***Summary*—We report on the current status of our pulsed optically pumped (POP) Rubidium (Rb) double resonance (DR) micro-cell atomic frequency standard. An estimation of the limiting parameters to the short-term stability is given, including the relatively high relaxation rates in the microcell employed. The stability measured beyond $10^4$ seconds of integration time is $< 2 \cdot 10^{-12}$. In particular, in POP operation the light-shift effect is reduced by at least two order of magnitude compared to continuous mode.**

***Keywords*—miniature atomic clock, double-resonance, microfabricated cell, micro loop gap resonator, light-shift, POP**

## I. Motivation

Improved telecommunication networks and positioning accuracy are two examples of applications that benefit from the existence of portable or miniature frequency standards. Although miniaturization generally comes at the price of degraded frequency stability, efforts have been made to improve such standards, mainly in the Coherent Population Trapping (CPT) community.

Generally, the limiting factor to the long-term (one day) frequency stability of such standards is the light-shift. It is well-known that pulsed operation of frequency standards significantly lowers the light-shift coefficient without compromising too much on the clock's footprint [1]. This motivates our study on a pulsed optically pumped (POP) double-resonance (DR) clock based on a micro-fabricated Rb cell.

The setup features a 53 $mm^3$ microfabricated vapor cell containing natural Rb [2], enclosed in a sub-wavelength micro-loop-gap resonator [3]. Last year, we demonstrated the concept's feasibility of Ramsey operation in such physics' package [4].

Here, we demonstrate a significant improvement of the clock's mid- and long-term performances compared to the same clock setup operated in continuous wave (CW) mode. In particular, the light-shift is strongly reduced and is no more the dominant effect limiting the long-term stability.

## II. Results

One of the limiting factors of the POP scheme in small vapor cells are the relaxations rates $\gamma_1$ and $\gamma_2$. Their values are measured using the Franzen technique and found to be of the order of 5 kHz, imposing relatively short Ramsey times.

The clock's measured short-term stability is well-explained by the limit arising from the detected signal's relative intensity noise (RIN). However, given the short Ramsey times, both the Dick effect contribution and the RIN contribution have to be considered to fully understand and optimize the clock's short-term performances.

The long-term stability is dominated by the intrinsic frequency drift of the cell, around $2 \cdot 10^{-12}$ (relative) per day. The contribution of the main known instability sources, namely the microwave powershift, the frequency and intensity light-shifts and the temperature shift are evaluated. Thanks to the pulsed operation, the intensity and frequency light-shift contributions to the clock instability are of the order of or below $10^{-13}$ at one day, respectively.

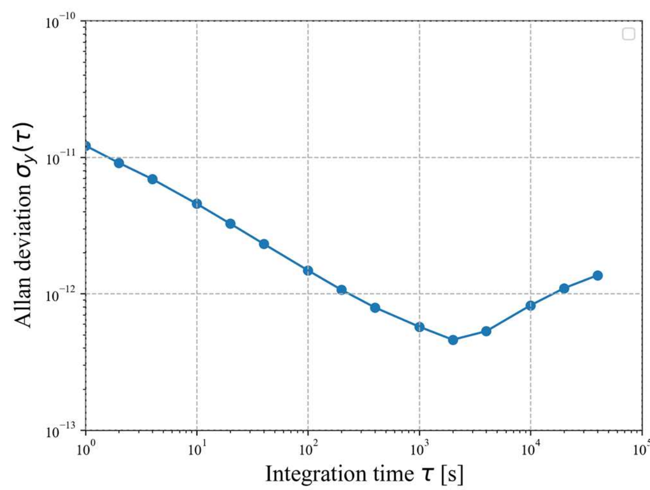


Figure 1 –Allan deviation (drift included) of our uPOP demonstrator.

## REFERENCES

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