Development of an industrial two-photon Rb atomic clock for timekeeping applications

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Optical atomic clocks based on hot atomic vapor cells have recently gained an increased attention due to their capacity to outperform traditional microwave atomic clocks in terms of frequency stability and accuracy while keeping a limited size, weight and power consumption budget. Among the possible atomic transitions, the Rb two-photon transition at 778 nm offers a particularly interesting combination of intrinsic stability, reduced complexity, and high reliability, which makes it a good candidate for the next generation of compact clocks with a large range of applications in metrology, telecommunication, radioastronomy, and navigation.

In the present contribution, we report on the performance of a 2-photon atomic clock currently developed at CSEM with an industrial partner. This clock, designed in view of its integration in a 19-inch rack-mount enclosure, is intended for 24/7 operation as a timescale master clock.

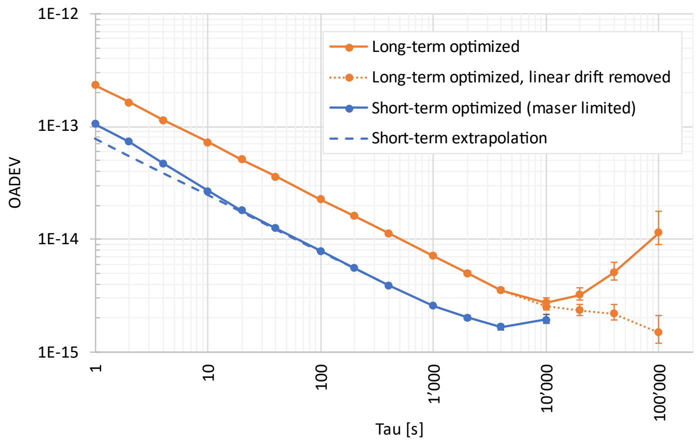

Fig. 1: Measured frequency stability of the system: orange: long-term optimized clock parameters (with and without linear drift removed); blue: short-term optimized clock parameters and clock short-term performance extrapolation.

The clock design, based on a standard architecture, takes advantage of the reliability and availability of fibred telecom C-band components. A 1556 nm narrow-linewidth laser is used as local oscillator. The laser light is amplified with an EDFA and frequency-doubled to address the $5^2S_{1/2} \rightarrow 5^2D_{5/2}$ two-photon transition of ^{87}Rb. This transition is probed in a Doppler-free configuration within an evacuated glass-blown cell. The wavelength of the laser is controlled by electro-optic modulation and synchronous detection with a PMT of the 420 nm fluorescence light arising from the atomic deexcitation. The stability of the locked optical reference is finally transferred to the RF domain using a 100 MHz repetition rate self-referenced fibred frequency comb. To ensure the frequency stability of the clock, the AC Stark shift is reduced by control of the incident light power, and the residual amplitude modulation is cancelled by feedback on the EOM DC offset. These functions are realized by a dedicated FPGA which also serves to frequency lock the CW laser to the atomic transition and could ultimately be used to control the frequency comb.

The system presented here demonstrates a long-term stability limited to a few 10^{-15} by the cell helium permeation drift. A drift-removed relative frequency stability in the 10^{-15} range at 10^5 s is moreover achieved, limited by the residual AC Stark-shift. Details of the clock architecture and an instability budget will be presented at the conference, detailing the contributions to the short- and long-term frequency instabilities. A development plan, ultimately targeting the declaration of this clock by METAS to the BIPM for the generation of UTC will also be described.