LEMAC: LTF-EPFL Miniature Atomic Clock: Demonstrator Performance Evaluation

C. Affolderbach[1], M. Pellaton[1], Y. Su[2], W. Moreno[1], E. Batori[1], M. Violetti[2,3], A. K. Skrivervik[2], G. Mileti[1]

[1]Laboratoire Temps-Fréquence, Université de Neuchâtel, Neuchâtel, Switzerland
[2]Microwave and Antennas Group, École Polytechnique Fédérale de Lausanne (EPFL), Lausanne, Switzerland
[3] Fondazione Toscana Life Sciences, Siena, Italy

Email: christoph.affolderbach@unine.ch

We report on the performance evaluation of the LEMAC miniature atomic clock, based on the optical-microwave Double-Resonance (DR) scheme, implementing a micro-fabricated Rb cell held inside a custom-designed micro-loop-gap microwave resonator (μ-LGR) and a low-power laser source[1]. Target specifications for this development, aiming beyond current miniature atomic clock performances, are a short-term stability of $1{\cdot}10^{-10}$ to $1{\cdot}10^{-11}$ $\tau^{-1/2}$ (τ=1 to 100 s) and a long-term frequency drift of $< 1{\cdot}10^{-11}$ to $1{\cdot}10^{-12}$ /day.

The highly simple DR scheme assures both a high signal contrast (thus superior short-term clock stability) as well as low light-shift effects, which can compromise long-term clock stability in alternative schemes such as CPT.

A key development of this work is the tuning-free μ-LGR implemented[2]. Based on a stack of micro-fabricated planar PCBs, this miniature microwave resonator (volume < 0.6 cm^3) assures operation at resonance as well as a highly uniform microwave field applied to the atoms in the Rb microcell, even in view of manufacturing tolerances, for better production yield.

The measured clock stability is $\approx 2{\cdot}10^{-11}$ $\tau^{-1/2}$ at 1 to 100 s and $4{\cdot}10^{-12}$ at 1 day, with a drift of $2{\cdot}10^{-13}$ /day. At the conference we will report on an analysis of the stability limitations, including instability budgets at both short-term and long-term timescales, and discuss prospects for future improvements.

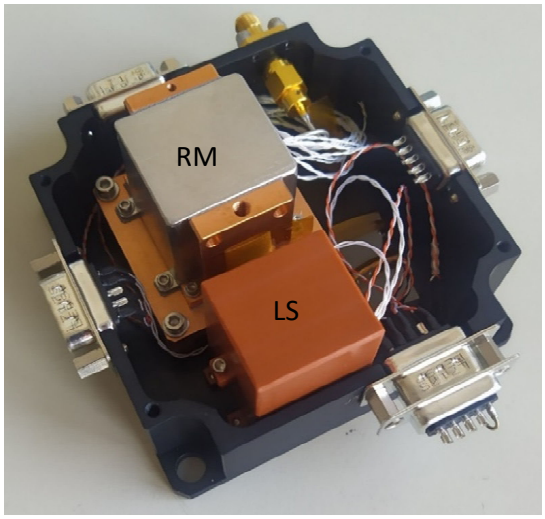

Fig. 1: Photo of the LEMAC clock demonstrator. The overall size of the black PP enclosure is 86 x 86 x 48 mm^3 (< 360 cm^3), with the Laser Source (LS) and atomic Resonator Module (RM) as main parts.

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[1] M. Pellaton et al., "LEMAC: LTF-EPFL Miniature Atomic Clock: current status", Proceedings of the joint EFTF and IFCS 2022, paper 5066, 2022.

[2] Y. Su et al., "Mode Suppression and Homogeneous Field Bandwidth Enhancement of a Tuning-Free Micro-Loop-Gap Resonator Using FR4 for Chip-Scale Rubidium Clock", IEEE TMTT 2023, doi :10.1109/TMTT.2023.3326482.