Micro-Loop-Gap Microwave Resonator Development for the LEMAC LTF-EPFL Miniature Atomic Clock

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Two different microwave resonator schemes have been investigated to develop the LEMAC miniature atomic clock based on the optical-microwave double-resonance, aiming for short-term and long-term stabilities in the order of $1{\cdot}10^{-11}\ \tau^{-1/2}$ and $1{\cdot}10^{-12}$ /day, respectively. Both microwave resonators derive from the basic micro-loop-gap resonator (µ-LGR)[1]. Their performance is superior in terms of size reduction and magnetic field homogeneity for the miniature atomic clock.

The first design is a wide-frequency tunable µ-LGR[2]. The tuning scheme combines printed strip lines and metallic pins to increase the equivalent capacitance. The loop-gap architecture is re-designed and its symmetry is improved, hence reducing the number of stacked PCB layers and yielding a higher inner magnetic field homogeneity. The total volume is decreased by 40%, compared to the benchmark µ-LGR[1].

The second scheme is a tuning-free µ-LGR[3]. The side mode suppression method allows the TE_{011}-like mode to operate over an enhanced homogeneous field bandwidth. In addition to the appropriate dielectric loading, the higher symmetry can provide µ-LGR with sufficient magnetic field strength to excite the atom transition between the microwave hyperfine levels. The frequency shift due to the fabrication tolerance and the assembling errors thus can be compensated.

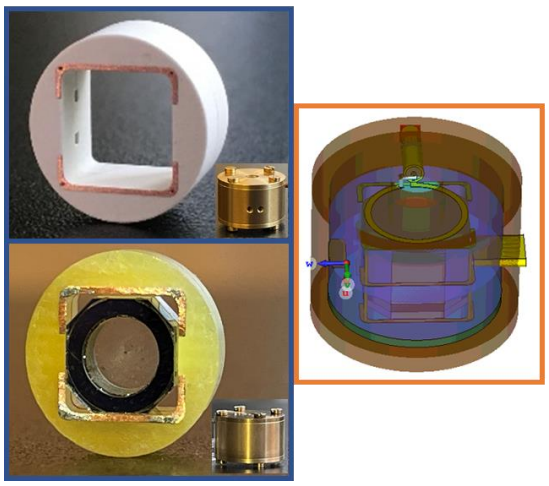

Fig. 1: Photos of the proposed tunable (top left, right) and tuning-free (bottom left) µ-LGRs. Total volumes are 572 mm^3 and 648 mm^3, respectively.

At the conference, we will present a comparison between these two schemes and discuss the suitable working scenario for each scheme. Besides, more examples for further improved designs as shown in Fig. 1 will be provided and the results will be reported.

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[1] M. Violetti et al., "The micro-loop-gap resonator: A novel miniaturized microwave cavity for double-resonance Rubidium atomic clocks," *IEEE Sensors J.*, vol. 14, no. 9, pp. 3193–3200, Sep. 2014.

[2] Y. Su et al., "A wide-frequency-tuning micro-loop-gap resonator for miniature rubidium vapor-cell atomic frequency standards," *IEEE Trans. Microw. Theory Techn.*, vol. 71, no. 12, pp. 5135–5146, Dec. 2023.

[3] 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 Trans. Microw. Theory Techn.*, 2023, doi :10.1109/TMTT.2023.3326482.