A compact laser-cooled atomic clock with a loop-gap cavity

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The miniaturization of laser-cooled microwave atomic clocks is necessary for more precise compact ground time-keeping instruments replacing bulky hydrogen masers, and ultra-precise navigation satellites. Currently, various laser-cooled atomic clocks are being developed [1, 2], and some have been commercialized [3, 4]. In this presentation, a compact laser-cooled atomic clock in a loop-gap microwave cavity will be introduced [5]. The loop-gap microwave cavity has the advantage of drastically reducing the volume and weight compared to the existing hollow cylinder type microwave resonator, which is advantageous for the miniaturization of laser-cooled atomic clocks, and further opens up the possibility of application as onboard atomic clocks for navigation satellite.

We fabricated a ten-hole loop-gap microwave cavity made of oxygen-free copper based on the FEM simulation results. Figure 1(a) and (b) show the top and side view of the cavity body, respectively. In the cavity body, eight holes with a diameter of 8 mm were symmetrically distributed around the central axis of the cavity. Four ports were for laser cooling and two were monitoring ports. The remaining two ports were used to feed the microwave symmetrically. The cavity occupies a volume eight times smaller than conventional cylindrical cavities. The measured linewidth of the Ramsey spectrum, which is limited by the free-fall distance of the atomic cloud in the cavity, was 19.6 Hz. Figure 1 (d) shows the relative frequency instability relative to that of a hydrogen maser. The frequency instability was measured to be $2.5\times10^{-12}\ \tau^{-1/2}$ [5]. After adopting a low phase noise local oscillator and increasing the number of atoms using an Rb-87 enriched atomic dispenser, the initial short-term stability is improved to $4.5\times10^{-13}\ \tau^{-1/2}$, which could be further improved by optimizing experimental parameters. We expect this type of physics package to be utilized for various portable applications of atomic clocks.

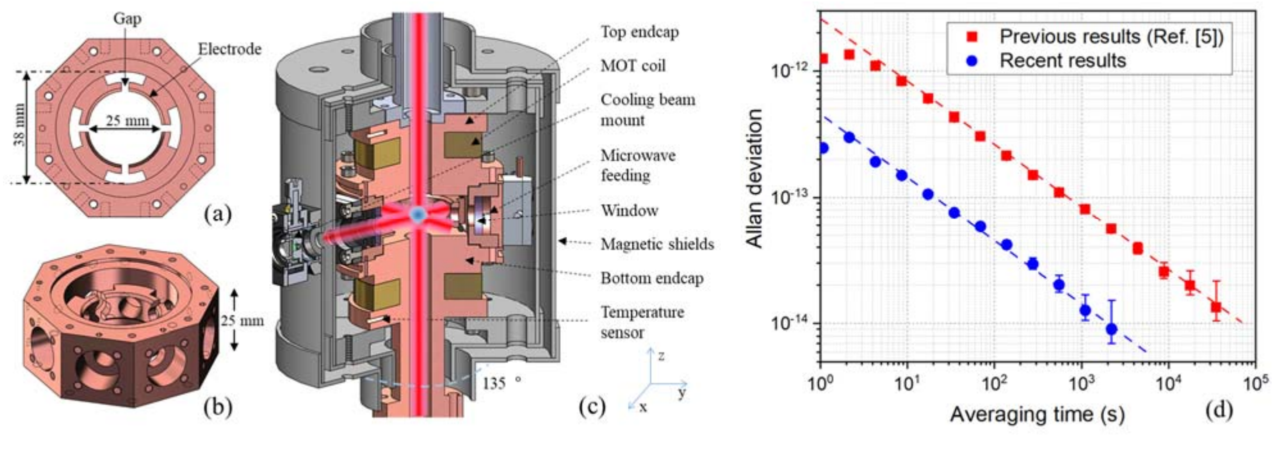

Fig. 1 . (a) Top view of the cavity body. (b) Side view of the cavity body. (c) Cutaway view of the assembled physics package. (d) Allan deviation of the compact cold-atom clock measured relative to a hydrogen maser. The red dashed line (previous results): $\sigma_y(\tau) = 2.5\times10^{-12}\ \tau^{-1/2}$, The blue dashed line (recent results): $\sigma_y(\tau) = 4.5\times10^{-13}\ \tau^{-1/2}$.

References

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