Short-term stability improvement of a compact cold-atom clock with a loop-gap cavity

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Atomic clocks serve as the backbone of modern timekeeping and navigation systems. However, traditional atomic clocks, such as hydrogen masers, are bulky and power-hungry, hindering their integration into portable applications. To address this challenge, various laser-cooled atomic clocks are being developed, and some have been commercialized[1,2,3,4]. Here we present a miniaturized laser-cooled atomic clock based on a loop-gap microwave cavity[5]. The loop-gap microwave cavity offers a significant reduction in size and weight compared to conventional cylindrical cavities.

Figure 1(a) shows a picture of the physics package surrounded by magnetic shields. In the cavity body, eight symmetrically distributed holes are positioned around the central axis. These holes are used for the laser cooling beams, fluorescence observation, and symmetric microwave feeding. This cavity occupies a volume eight times smaller than conventional microwave cavities. The measured linewidth of the Ramsey spectrum is 19.6 Hz, limited by the free-fall distance of the atomic cloud in the cavity. The frequency stability measured relative to a hydrogen maser is improved by reducing the local oscillator noise and increasing the trapped atom number. The best short-term stability achieved so far is $4.5\times10^{-13}\ \tau^{-1/2}$, as shown in Fig. 1(b). The miniaturized design and competitive performance make this technology suitable for various mobile applications, such as navigation satellites, portable ground-based timekeeping instruments, and other devices requiring high-precision timekeeping.

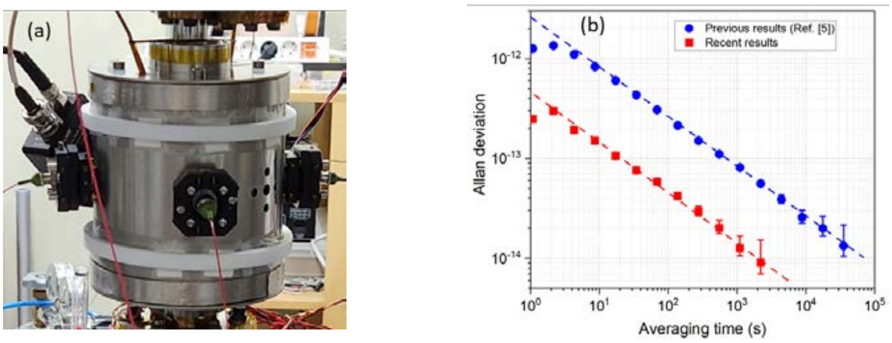

Fig. 1: (a) Physics package of compact cold atom clock. (b) Frequency stability of the compact cold-atom clock measured relative to a hydrogen maser. The red dashed line: $\sigma_y(\tau) = 4.5\times10^{-13}\ \tau^{-1/2}$.

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