Development of commercial fountain clocks in NIM

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While Cs fountain clocks have achieved a typical Type B uncertainties of a few parts in 10^{16}, and are employed as the primary frequency standards to realize the definition of the second [1-7], Rb fountain clock has also been studied. Due to its low collisional shift and more robust cooling lasers, a Rb fountain clock is easier to operate and more suitable be to a commercial clock. A new Rb fountain clock has been built in NIM aiming to operate semi-continuously and achieve an excellent long-term instability for time keeping. While the basic design is adopted from our Cs fountain clocks, some new features are included for a better performance. A double metal interrogation microwave cavity with a thermal expansion self-compensating mechanism is used to reduce the clock sensitivity to ambient temperature fluctuations. The cylindrical tube of the cavity is made from titanium (Ti), and two end caps are made from oxygen-free copper (OFC). A Thin layer of copper is coated inside the Ti- tube to ensure reaching a high *Q*-factor of about 10000. With an optimized design, the thermal-coefficient of the resonance frequency is reduced to less than 10 kHz/℃, more than an order improvement compared with a copper cavity. The optical system with two independent frequency stabilized laser sources with automatic re-locking system is located on a 400 × 600 mm optical breadboard with special designed optical mounts to ensure stable output light powers. All light powers are varied less than 10% with a environment temperature increasing 7℃. A similar design Cs fountain clock resume operating without any realignment of optical path after being transported to another lab 40 km away.

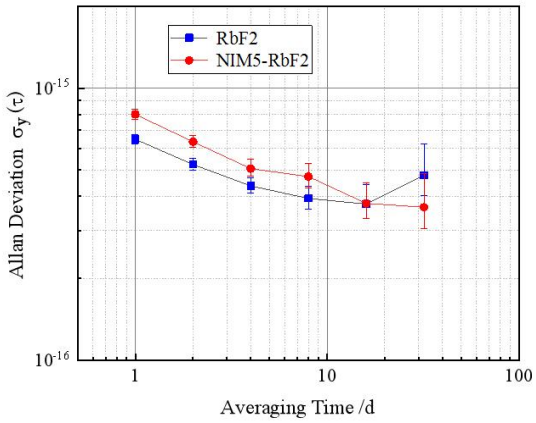

Fig.1.The measured instability of Rb fountain clock. The blue squares are compared to a H-maser, and its long term instability drifts up due to the H-maser. The red dots are compared with NIM5 fountain clock.

A short term instability of $1.49\times10^{-13}/\sqrt{\tau}$ was obtained for this Rb fountain clock. After optimization, the clock has been operated for more a year without any failure. A long term instability of 3.5×10^{-16} was obtained compared with NIM5 Cs fountain clock as shown in figure 1. The instability after 4 days didn't drop as $\tau^{-1/2}$ is under study.

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