Stability improvement of an aluminum ion optical clock

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As one of the most accurate measuring devices, optical frequency standards have demonstrated extensive research and application prospects in the fields of testing relativity effect, measuring fundamental physical constants, and satellite navigation. With the continuous improvement of the measurement accuracy in optical frequency standards developed by various laboratories, the discussion on redefinition of the "second" has been put on the agenda, and the corresponding requirements are stipulated.

In this report, we describe the evaluation of uncertainty and optimization of stability in an aluminum-ion optical clock system based on quantum logic spectroscopy. Compared with the previous result[1], the improvements mainly include the drift suppression of the biased magnetic field, the optimization of Raman sideband cooling, the signal-to-noise ratio of the quantum logic spectrum is improved, and the additional transmission noise compensation of the clock laser. Finally, the uncertainty evaluation of the current optical clock system is 2×10^{-18}. After a period of closed-loop locking operation, the stability of the system is obtained. The FWHM of the clock transition spectrum is observed to be 5.4(4) Hz within a detection time of 160 ms in the experiment. The frequency stability of a single system is improved from $3.9\times10^{-15}/\sqrt{\tau}$ to $2.6\times10^{-15}/\sqrt{\tau}$ by using the servo-controlled self-comparison locking method.

Contribution	Correction (10^{-18})	Uncertainty(10^{-18})
Excess micromotion	-7.4	0.8
Secular motion	-0.8	0.1
Quadratic Zeeman	-3285.1	1.2
Frist-order Doppler	0	0.9
AOM phase chirp	0	0.9
Blackbody radiation	-3.3	0.5
Laser Stack	0	<0.1
Background gas collisions	0	<0.1
Electric quadrupole	0	<0.1
Total	-3296.6	2.0

Table 1: Relative frequency shift and uncertainty evaluation of current $^{27}Al^{+}$ ion optical clock.

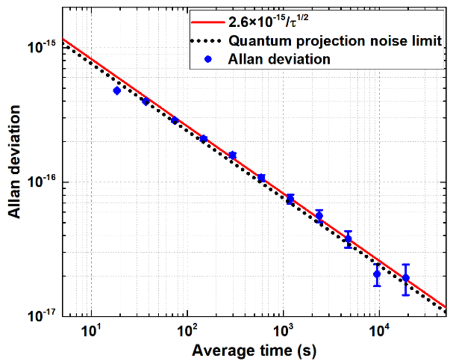

Fig. 2: Stability results of $^{27}Al^{+}$ ion optical clock system under closed loop locking.

[1] Z. Y. Ma, *et al*, "Investigation of experimental issues concerning successful operation of quantum logic based $^{27}Al^{+}$ ion optical clock", Appl. Phys. B, vol. 126, pp. 129, 2020.