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# Optical system design for $^{171}Yb^{+}$ optical clock

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With the development of optical frequency comb [1] and ultra-stable laser systems [2], the performance of optical frequency standards has been improved significantly over the past 20 years. The optical clocks based on neutral atom lattice hold excellent stability due to the large signal-to-noise ratio, while those based on trapped ions occupy great uncertainties. The state-of-the-art optical clocks achieve unprecedented stability, reproduction, and accuracy, surpassing the primary Cs clocks [3][4]. And numerous potential applications have stimulated the development of optical clocks, such as redefining SI seconds, navigation, and relativistic geodesy, and finding new physics that has stimulated higher performance.

Single charged Yb ions have an alkali-like atomic structure and have ultra-long storage time (even one month). The ytterbium single-ion optical frequency standards have two clock transitions (E2 & E3). The ultra-narrow electric octupole (E3) transition with nHz natural linewidth has achieved 3E−18 systematic uncertainty [5], while the electric quadrupole (E2) transition with 3.1 Hz linewidth has achieved systematic uncertainty of 5.9E−16[6]. The dominant contribution to the systematic uncertainty of E2 arises from the second-order Stark shift-induced by the ambient blackbody radiation. It could be significantly improved to the mid-to-low 1E-18[8]. With two frequency standards on the E3 transition, direct optical frequency comparison within their combined systematic uncertainty of 3.6E−18 has obtained more stringent limits on violations of Lorentz symmetry [7]. And the performance of the system still has a large potential to be improved. First, a perturbation-immune version of Ramsey's method (Auto-balanced Ramsey Spectroscopy) [9] opens up frequency accuracy perspectives below the 10E-18 level for the Yb ion clock. And the state-of-the-art vibration-insensitive single-crystal silicon cryogenic cavity [2] can generate a clock laser with mHz-linewidth, it will be possible to interrogate the clock transition with Ramsey times of many seconds to improve the clock's stability.

The apparatus of the optical ytterbium ion clock includes the physics package and the optical system. Due to the single ion's weak fluorescence signal and its influence on the signal-to-noise ratio (SNR), the clock's short-term stability is limited by the quantum limit noise. Therefore, the effective uncertainty evaluation needs the optical clock to operate for a long time, which requires high stability of the optical system. In this paper, the long-term stabilization of the laser system is realized by locking the cooling and re-pumping lasers to the optical frequency comb.

## References

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