Motivating quantum-enhanced metrology with an ion-based optical atomic clock

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The extraordinary accuracy of optical atomic clocks is currently motivating the future redefinition of the SI second in terms of an optical frequency. The $^{171}\mathrm{Yb}^+$ ion is an excellent candidate due to its very low sensitivity to external field perturbations, and the presence of a strongly forbidden electric octupole transition with a natural linewidth at the nHz level [1]. The $^{171}\mathrm{Yb}^+$ ion is also particularly sensitive to variations in the fine structure constant, enabling tests of fundamental physics beyond the Standard Model [2, 3].

The ytterbium single-ion optical clock at the National Physical Laboratory has recently achieved a fractional systematic uncertainty of 2.2×10^{-18}. With its fractional instability of $2 \times 10^{-15}/\sqrt{\tau}$, it would take several weeks of measurement to reach the systematic floor. The quantum-projection-noise-dominated instability of ion-based optical clocks is proportional to $1/\sqrt{N}$ for N ions. While increasing the number of ions would improve the instability according to $\sqrt{N}$, entangling the ions could offer an instability proportional to $1/N$ [4], enabling metrology beyond the standard quantum limit. This poster will present an overview of the ytterbium ion optical clock at NPL for metrology and fundamental physics, and discuss possibilities for quantum-enhanced operation.

References

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