Measurement of the absolute frequencies of two optical clock transitions in $^{171}Yb^+$

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Optical frequency standards have now demonstrated fractional systematic uncertainties below that of the best caesium primary standards, which are currently used to realize the SI second. Before a redefinition of the second in terms of an optical transition can occur, the frequency of the transition must be measured with an uncertainty limited by that of the caesium standard. This will prevent discontinuity at the point of redefinition and allow a smooth changeover to the new standard.

Uniquely amongst the many species under investigation as optical frequency standards, $^{171}Yb^+$ possesses two optical clock transitions that have both been accepted as secondary representations of the SI second. Previous absolute measurements of the two transition frequencies[1,2,3,4] have been in good agreement, and in particular the agreement between the measurements for the $^2S_{1/2} - {}^2F_{7/2}$ electric octupole (E3) transition at 467 nm represents the best international agreement between trapped ion optical frequency standards to date. We report new measurements of the absolute frequencies of these two optical clock transitions, referenced to the caesium fountain primary standard NPL-CsF2 via two optical frequency combs. The contributions to the total systematic uncertainty arising from the $^{171}Yb^+$ apparatus are substantially smaller than in our previously published work, which is mainly attributable to improved compensation for the ac Stark shift induced by the probe laser, better knowledge of the blackbody environment experienced by the ion, and a reduced uncertainty on the cancellation of the quadrupole shift.

In addition to measuring the values of the absolute frequencies, the ratio between the frequencies can be directly measured by the optical frequency combs. Due to the large and inverted fine structure of the ^2F state, the E3 transition has a particularly large sensitivity to any time-variation in the fine structure constant. Repeated measurements of this ratio[5] could therefore place a stringent limit on any variation at the level of 10^{-17} / year.

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