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Measurement of the ^{88}Sr$^+$ $S_{1/2} \to D_{5/2}$ / ^{171}Yb$^+$ $S_{1/2} \to F_{7/2}$ frequency ratio with in-situ BBR shift evaluation

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A significant contribution to the uncertainty budgets of optical clocks based on the ^{171}Yb$^+$ $S_{1/2} \to F_{7/2}$ electric octupole (E3) transition results from the Stark shift induced by black-body radiation (BBR) of the environment of the trapped ion. Even if precise knowledge on the thermal environment is available, uncertainty in the sensitivity of the shift to thermal radiation, the differential polarizability $\Delta\alpha$ of the E3 transition, limits a shift evaluation to 2%. For the $S_{1/2} \to D_{5/2}$ electric quadrupole (E2) transition of ^{88}Sr$^+$ $\Delta\alpha$ is known to 0.15% [1]. By trapping both atomic species in a linear segmented ion trap and irradiating infrared laser light of the same intensity on both the ^{88}Sr$^+$ E2 and ^{171}Yb$^+$ E3 while monitoring their transition frequencies, permits a transfer of the relative uncertainty of $\Delta\alpha$ from ^{88}Sr$^+$ to ^{171}Yb$^+$.

In preparation to this experiment, the ratio of the unperturbed frequencies of the ^{88}Sr$^+$ E2 transition and the ^{171}Yb$^+$ E3 transition is measured. Since the ^{88}Sr$^+$ E2 is prone to BBR shifts, the thermal field at the position of the ion must be evaluated. While the ambient temperature of the vacuum chamber can be determined with low uncertainty, the effect of the temperature rise during operation needs to be evaluated independently. Under the assumption, that the heating of the trap results from Joule heating and a T^4-dependence of the BBR shift, the temperature can be inferred from measurements with different settings of the applied trap drive power. In this way, we determine the frequency of the ^{88}Sr$^+$ E2 transition for three different settings relative to an independent clock based on the ^{171}Yb$^+$ E3 transition. Within the statistical uncertainty, we find no significant change in the ratio and can determine its value with a fractional uncertainty of 8.0×10^{-17}. With the currently best-known frequency of the ^{171}Yb$^+$ E3 transition [2], the absolute ^{88}Sr$^+$ E2 frequency is evaluated to an uncertainty of 80 mHz.

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