Accurate determination of black-body radiation shift, magic and tune-out wavelengths for the $6S_{1/2} \rightarrow 5D_{3/2}$ clock transition in Yb$^+$

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Abstract

We present precise values of the dipole polarizabilities ($\alpha$) of the ground $[4f^{14}6s] \, ^3S_{1/2}$ and metastable $[4f^{14}5d] \, ^3D_{3/2}$ states of Yb$^+$, that are important in reducing systematics in the clock frequency of the $[4f^{14}6s] \, ^3S_{1/2} \rightarrow [4f^{14}5d] \, ^3D_{3/2}$ transition. The static values of $\alpha$ for the ground and metastable $[4f^{14}5d] \, ^3D_{3/2}$ states are estimated to be $9.8(1) \times 10^{-40} \text{ J m}^2 \text{ V}^{-2}$ and $17.6(5) \times 10^{-40} \text{ J m}^2 \text{ V}^{-2}$, respectively, while the tensor contribution to the metastable $[4f^{14}5d] \, ^3D_{3/2}$ state as $-1.2(3) \times 10^{-40} \text{ J m}^2 \text{ V}^{-2}$ compared to the experimental value $-13.6(22) \times 10^{-40} \text{ J m}^2 \text{ V}^{-2}$. This corresponds to the differential scalar polarizability value of the above transition as $-7.8(5) \times 10^{-40} \text{ J m}^2 \text{ V}^{-2}$ in contrast to the available experimental value $-6.9(1.4) \times 10^{-40} \text{ J m}^2 \text{ V}^{-2}$. This results in the black-body radiation shift of the clock transition as $-0.44(3) \text{ Hz}$ at the room temperature, which is large as compared to the previously estimated values. Using the dynamic $\alpha$ values, we report the tune-out and magic wavelengths that could be of interest to subdue systematics due to the Stark shifts and for constructing lattice optical clock using Yb$^+$.

Keywords: Yb$^+$ ion clocks, magic wavelengths, black body radiation shifts, dipole polarizabilities

(Some figures may appear in colour only in the online journal)