Characterization of $4f^{13}({}^2F^o_{5/2})5d6s({}^1D)^1[5/2]_{5/2}$ state for Metastable Qubit Operations in Yb+ ions

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Trapped ions offer a pristine platform for quantum simulation and computation using hyperfine, optical, and metastable qubits. Yb^+ ions have a complex atomic structure due to transitions involving electrons from the f orbital closed inner shell. This allows for the existence of highly excited states that can be useful for repumping, detection, and state preparation in the metastable qubits encoded in the $4f^{14}5d$ ${}^2D_{3/2}$, ${}^2D_{5/2}$, and $4f^{13}6s^2$ ${}^2F_{7/2}$ states. We report spectroscopic and time-resolved data to characterize the atomic state $4f^{13}({}^2F^o_{5/2})5d6s({}^1D)^1[5/2]_{5/2}$. We observed an unexpectedly narrow transition from the metastable $4f^{14}5d$ ${}^2D_{3/2}$ and ${}^2D_{5/2}$ states, with a measured lifetime of τ = 38.4(9) μs that allows visible Rabi oscillations and sideband resolved spectroscopy. We also report measurements of the branching ratios to ${}^2D_{3/2}$ (0.36) and ${}^2D_{5/2}$ (0.64) states. By observing the steady state population at long timescales, we place an upper bound of 0.002 on the branching ratio between ${}^1[5/2]_{5/2}$ state and the $4f^{13}6s^2$ ${}^2F_{7/2}$ state. Our measurements contribute to a better understanding of the atomic structure of Yb^+ ions, which still lacks accurate numerical methods to predict atomic properties.

Keywords: Trapped ions, Ytterbium, Metastable states

Acknowledgements: This work is supported by the National Science Foundation (NSF CAREER award No. PHY-2144910), the Army Research Office (Grant No. W911NF22C0012), the Army Research Laboratory (Grant No. W911QX21C0031), Welch Foundation Grant No. C-2154, and the Office of Naval Research (Grants No. N00014-23-12665 and the Young Investigator Program N00014-22-1-2282). We acknowledge that this material is based upon work supported by the U.S. Department of Energy, Office of Science, Office of Nuclear Physics under the Early Career Award No. DE-SC0023806.