The Optical Clock with $^{176}Lu^+$

<u>Zhao Qi</u>[1], Qin Qichen[1], Zhang Zhao[1], Zhiqiang Zhang[1], K. J. Arnold[1], and M. D. Barrett[1]

1. Centre for Quantum Technologies, National University of Singapore, Singapore

email: e0593195@u.nus.edu

Singly ionized lutetium ($^{176}Lu^+$) is a unique clock candidate with several attractive features for clock applications [1-6]. It provides three independent clock transitions allowing consistency checks of error budgets through frequency comparisons within the one system [6]. Recently, the systematic uncertainties of two lutetium frequency references have been calibrated to the mid 10^{-19} fractionally on the 848-nm transition. Subsequent comparison via correlation spectroscopy, demonstrated inaccuracy to low 10^{-18} level limited by statistical uncertainty [1]. The absolute frequency measurement of 848-nm clock transition has been measured with a fractional uncertainty of 1.8×10^{-15} limited by our available realization of the second.

To realize the full potential lutetium has to offer requires an assessment of the 804-nm clock transition to a comparable level as the 848-nm transition. The two most challenging aspects of this are the blackbody radiation (BBR) shift and the residual quadrupole moment. The larger BBR shift of the 804-nm transition requires inaccuracy of the scalar differential polarizability at the 1% level. We plan to achieve this through comparison measurement with Ba+ as proposed in [7], for which the required measurements have been made [8]. The residual quadrupole moment arises from coupling between fine-structure levels resulting in imperfect cancellation via hyperfine averaging [9]. The effect is expected to give a shift at the low 10^{-19} as for the 848-nm transition and we plan to investigate this through high accuracy measurements of differential quadrupole moments and g-factors [9,10].

Absolute frequency accuracy requires an assessment of the system temperature, and this requires temperature calibration at the level of a few degrees for the 804-nm transition. However, for applications requiring only a comparison, such as height referencing, it is only a temperature difference that matters. For lutetium this can be assessed through measurement of the frequency ratio between the 804-nm and 848-nm transitions within each apparatus.

References

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