Theoretical Aspects of Developing the Th-229 Nuclear Clock

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The low-energy isomer of ^{229}Th enables a fundamentally new class of quantum sensors: nuclear clocks with exceptional robustness and sensitivities to variation of fundamental constants far beyond existing atomic clocks. The concept was motivated in part by our proposal of a single-ion nuclear clock [1], which demonstrated that the nuclear transition's narrow linewidth and insensitivity to external fields could support metrology at the 10^{-19} level. Realizing this promise in practice requires understanding how the nuclear excitation behaves in realistic environments—especially in emerging solid-state platforms.

I will present our recent theoretical work that establishes the framework for engineering and interpreting solid-state ^{229}Th clocks. We developed a first-principles theory of internal conversion (IC) in insulating hosts [2,3], identifying the dominant electronic channels for nonradiative decay and providing predictive tools for selecting materials with suppressed quenching. IC can be used as a resource, *e.g.* opening photo-induced quenching pathways [4] that emerge under off-resonant laser excitation or using electric currents for clock readout [3].

I will also highlight predictions of host-dependent frequency offsets ("clockwork shifts") [5], essential for connecting solid-state spectroscopy to the free-ion transition envisioned in our 2012 proposal.

References

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