Vibrational Molecular Lattice Clock

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The techniques of manipulating laser-cooled atoms can be successfully applied to create samples of ultracold molecules. These samples can be held in optical traps and be fully state-controlled.

Moreover, molecules provide physical degrees of freedom that atoms lack. For example, diatomic molecules feature vibrational dynamics, and vibrational quantum states are typically separated by terahertz frequencies. They possess very long natural lifetimes in nonpolar molecules as well as very low sensitivities to external fields.

We have fully evaluated the systematic shifts of a clock based on the largest vibrational interval in ground-state Sr_2 molecules, reaching a total systematic uncertainty $<5\times10^{-14}$ that is limited by two-photon interactions with the trapping light (Fig. 1) [1]. We have also evaluated the absolute frequency of this 32 THz transition.

Paths forward include reducing decoherence and nonlinear frequency shifts induced by the lattice environment, and applying the clock to a novel set of vibrational isotope shifts measurements for fundamental tests of mass-dependent physical forces.

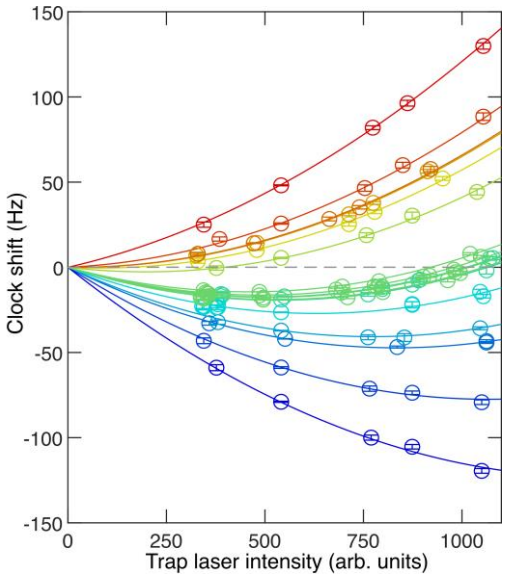

Fig.1. Hertz-level shifts of the Sr_2 vibrational clock for a range of nearby optical lattice wavelengths near 1005 nm, exhibiting scalar polarizabilities and hyperpolarizabilities.

References

[1] KH Leung, B Iritani, E Tiberi, I Majewska, M Borkowski, R Moszynski, T Zelevinsky, Terahertz Vibrational Molecular Clock with Systematic Uncertainty at the 10^{-18} Level, Phys. Rev. X, vol. 13, 011047, 2023.