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Herbert P. Broida Prize: Stable and Accurate Single-Atom Optical Clocks[1]

JAMES C. BERGQUIST, National Institute of Standards and Technology, Boulder, CO

Optical clocks based on narrow transitions of single ions have long promised unprecedented stability and accuracy, but only lately has this potential begun to be realized [1-3]. At NIST, two single-ion optical clocks are in operation. A $^{199}Hg^{+}$ clock uses a single laser-cooled ion held in a cryogenic rf Paul trap and is based on the $^{2}S_{1/2}$ $(F = 0) \leftrightarrow$ $^{2}D_{5/2}$ $(F = 2, m_F = 0)$ electric-quadrupole transition at 282 nm. An $^{27}Al^{+}$ clock uses a single ion held in a linear trap and is based on the $^{1}S_0 \leftrightarrow {}^{3}P_0$ intercombination line at 267 nm [4]. The burden of cooling, state preparation and state detection of the Al^{+} ion are borne by an auxiliary Be^{+} ion using quantum logic methods [5]. A recent comparison of these two standards achieved a relative fractional frequency instability of less than $7 \times 10^{-15}(\tau/s)^{-1/2}$, reaching 4×10^{-17} in 30 000. The absolute frequency of the Hg^{+} clock was measured against the cesium fountain standard NIST-F1, and we obtained fractional frequency inaccuracies below 10^{-15}. An evaluation of the systematic shifts of the Hg^{+} system in the latest of these measurements returns a total systematic uncertainty of about 3 x 10^{-17} and that of the Al^{+} standard, 2.6 x 10^{-17}. We will report the results of measurements conducted over the course of five years and discuss the implications of these results as a constraint to test for the constancy of the fundamental constants that determine atomic transition frequencies [6]. We will also describe the present limitations and planned improvements to the accuracy of the single ion clocks. 1. H.S. Margolis *et al.,* Science **306**, 1355 (2004). 2. T. Schneider, E. Peik, and Chr. Tamm, Phys. Rev. Lett. **94**, 230801 (2005). 3. W.H. Oskay *et al.*, Phys. Rev. Lett. **97**, 020801 (2006). 4. P.O. Schmidt *et al.,* Science **309**, 749 (2005). 5. D.J. Wineland *et al.*, *Proc. 6th Symposium on Frequency Standards and Metrology,* P. Gill, ed. (World Scientific, Singapore, 2002) pp. 361-368. 6. T. M. Fortier *et al.,* Phys. Rev. Lett. accepted for publication (2007).

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