The NIST Al^+ Optical Clocks: Frequency Metrology at the 18th Digit

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Atomic clocks generate electromagnetic signals with extremely stable frequencies. In recent years, motivated by scientific and technological applications, atomic clocks that operate at optical frequencies (~ 1×10^{15} Hz) have pushed clock performance well above the level of their microwave predecessors. Two such clocks based on a narrow ultraviolet resonance in $^{27}Al^+$ have been built at NIST in Boulder, Colorado. These clocks are unique in that they rely on techniques developed in the context of trapped-ion quantum computing. I will describe the operation of the Al^+ optical clocks and review a series of experiments that demonstrate their performance. We characterize the accuracy of the clock at the level of 8.6×10^{-18} and measure a frequency stability of 2.8×10^{-15} at a one second averaging time. This performance allows for sensitive measurements of the gravitational redshift, which we demonstrate by observing the frequency shift due a height change of only 33 cm. Current and future work aims to improve the accuracy and stability of the clocks as well as simplify their operation.

*Work supported by ONR, IARPA, DARPA and AFOSR