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An ^{27}Al+ Quantum-logic Clock with Systematic Uncertainty below 10^{-18}

Samuel M. Brewer

National Institute of Standards and Technology

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Abstract

In 1973, Hans Dehmelt proposed a frequency standard based on a single trapped ion, dubbed the "mono-ion oscillator", based on the 1S0 ↔3P0 transition in Tl+. In 1982, the proposal was expanded to include B+, Al+, Ga+, and In+ and the possibility of a clock with a fractional frequency uncertainty of 10−18 was first discussed, setting the stage for a series of experiments that continue to push the limits of measurement science. For trapped-ion systems, the systematic uncertainty was predicted to be limited by uncertainty in second-order Doppler (time-dilation) shifts due to the ion motion. In this talk, I will describe an optical atomic clock based on quantum-logic spectroscopy of the 1S0 ↔ 3P0 transition in 27Al+ with a frequency stability of $1.2 \times 10^{-15}/\sqrt{\tau}$ and a fractional frequency uncertainty of 9.5 × 10−19, which is the lowest systematic uncertainty of any clock to date. A 25Mg+ ion is simultaneously stored with the 27Al+ ion in a linear Paul trap and used for

sympathetic cooling and state readout during clock operation. Improvements in a new trap have led to reduced secular motion heating, compared to previous 27Al+ clocks, enabling clock operation with ion motion near the three-dimensional motional ground state. Operating the clock with a lower trap drive frequency has reduced excess micromotion, compared to previous 27Al+ clocks, leading to a reduced time-dilation shift uncertainty. Other systematic uncertainties including those due to blackbody radiation and the second-order Zeeman effect have also been reduced.

Research Biography:

Samuel Brewer is a postdoctoral researcher in the Ion Storage Group at the National Institute of Standards and Technology in Boulder, Colorado. His research interests center on precision measurements in atomic systems for studies of fundamental physics. He received his Ph.D. from the University of Maryland in 2012, where he worked at NIST in Gaithersburg, Maryland on the first experiments to trap highly charged ions at low energy in compact Penning traps. During his time in Boulder, he has developed an improved quantum-logic clock based on a single trapped aluminum ion. With this newly developed clock, he and a joint team from NIST/JILA have performed frequency ratio measurements between the aluminum ion optical clock and the Yb and Sr optical lattice clocks in Boulder. These experiments represent the state-of-the art in optical frequency ratio measurements and are the first step towards establishing a timescale based on optical clocks and future tests of fundamental physics using atomic clocks.