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Al^+ optical clocks for fundamental physics, geodesy, and quantum metrology[1]

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Laser-cooled trapped atoms have long been recognized as potentially very accurate frequency standards for clocks. Ultimate accuracies of 10^{-18} to 10^{-19} appear possible, limited by the time-dilation of trapped ions that move at laser-cooled velocities. The Al^+ ion is an attractive candidate for high accuracy, owing to its narrow electronic transition in the optical regime and low sensitivity to ambient field perturbations. Precision spectroscopy on Al^+ is enabled by quantum information techniques. With Al^+ "quantum-logic" clocks, the current accuracy of 8.6×10^{-18} has enabled a geo-potential-difference measurement that detected a height change of 37 ± 17 cm due to the gravitational red-shift. We have also observed quantum coherence between two Al^+ ions with a record Q-factor of 3.4×10^{16}, and compared the Al^+ resonance frequency to that of a single Hg^+ ion to place limits on the temporal variation of the fine-structure constant. This work is done in collaboration with D. B. Hume, M. J. Thorpe, D. J. Wineland, and T. Rosenband.

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