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Quantum-based optical clocks for improved frequency standards and tests of fundamental physics

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For decades, atomic clocks based on trapped ions and ensembles of trapped neutral atoms have been at the forefront of precision frequency metrology and tabletop experiments to search for physics beyond the standard model. Simultaneously, advances in trapped-ion quantum information science have led to exquisite control of quantum systems. In recent years, a new field of quantum metrology has emerged, which seeks to harness quantum information science techniques for use in the development of high-performance frequency standards and tests of fundamental physics. In this talk, I will describe an Al^+ quantum-logic clock, developed at NIST, which is a prime experimental example of this new field of quantum metrology. This system has recently demonstrated a fractional frequency uncertainty of $\Delta\nu/\nu = 9.4 \times 10^{-19}$. I will give an overview of the systematic uncertainty evaluation of the Al^+ clock, recent optical clock comparisons for tests of fundamental physics, and discuss future work on quantum-enabled spectroscopy of highly charged ions.