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Welcome to the New Age: Realization of an Ultra-Accurate, Single Ion Clock at the Quantum Mechanical Stability Limit

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There is now a revolution underway in ultra-accurate measurements of frequency and time using optical atomic transitions probed with highly coherent laser light. By suspending a single atomic ion using an electro-dynamic trapping field and reducing its velocity by laser cooling, we can approach, as close as possible, the ideal situation of an isolated and unperturbed quantum system. Laser sources that probe the atom can now be made so spectrally pure that they can be used as phase-stable sources of electro-magnetic radiation. In addition, the use of femtosecond laser technology now enables us to continuously measure the cycles of light from the reference and provide a working standard for time. Using such powerful methods, our team has realized an optical atomic frequency/time reference at 445-THz (674 nm) based on a single atomic ion of strontium. This talk will overview some of the exciting concepts making up such experiments and will include evaluated accuracies of this system (at 1.2×10^{-17} fractional uncertainty) that exceed by over a factor of ten the best current realizations of the definition of the SI second. Recently, we have demonstrated that such a single ion frequency standard can reach the level of stability limited by the principles of quantum mechanics. At this level of accuracy and stability, it is now possible to measure the distortion of local time due to Earth's gravitational field by changes of the clock height at the sub-meter level. Further refinement of the systematic shift evaluation promises to bring the evaluated uncertainty down into the 10^{-18} fractional uncertainty level. Some observations will be made as to what we expect these new generation optical clocks to yield in terms of the redefinition of the SI unit second, probing nature's weakest force (gravity), and other sensitive tests of Physics.

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