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Optical Lattice Clocks

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Since they were first proposed in 2003 [1], optical lattice clocks have become one of the leading technologies for the next generation of atomic clocks, which will be used for advanced timing applications and in tests of fundamental physics [2]. These clocks are based on stabilized lasers whose frequency is ultimately referenced to an ultra-narrow neutral atom transition (natural linewidths $<<$ 1 Hz). To suppress the effects of atomic motion/recoil, the atoms in the sample ($\sim 10^4$ atoms) are confined tightly in the potential wells of an optical standing wave (lattice). The wavelength of the lattice light is tuned to its "magic" value so as to yield a vanishing net AC Stark shift for the clock transition. As a result lattice clocks have demonstrated the capability of generating high stability clock signals with small absolute uncertainties ($\sim$ 1 part in 10^{16}). In this presentation I will first give an overview of the field, which now includes three different atomic species. I will then use experiments with Yb performed in our laboratory to illustrate the key features of a lattice clock. Our research has included the development of state-of-the-art optical cavities enabling ultra-high-resolution optical spectroscopy (1 Hz linewidth). Together with the large atom number in the optical lattice, we are able to achieve very low clock instability ($<$ 0.3 Hz in 1 s) [3]. Furthermore, I will show results from some of our recent investigations of key shifts for the Yb lattice clock, including high precision measurements of ultracold atom-atom interactions in the lattice and the dc Stark effect for the Yb clock transition (necessary for the evaluation of blackbody radiation shifts).

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