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The Strontium Optical Lattice Clock: Optical Spectroscopy with Sub-Hertz Accuracy

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Atomic clocks find significant roles in a number of scientific and technological settings. One interesting approach to a next-generation clock based on an optical transition uses atomic strontium confined in an optical lattice. The tight atomic confinement eliminates motional effects which otherwise trouble the atomic interrogation. At the same time, the optical lattice is equally perturbs the two electronic clock states so that the confinement introduces a net zero shift of the natural transition frequency. Here I describe the design and realization of an optical frequency standard using ^{87}Sr confined in a 1-D optical lattice. With an ultra-stable laser light source, atomic spectral linewidths of the optical clock transition are observed below 2 Hz. High accuracy spectroscopy of the clock transition is carried out utilizing a frequency comb referenced to the NIST-F1 Cs fountain. To explore the performance of an improved, spin-polarized Sr standard, a coherent optical phase transfer link is established between JILA and NIST. This enables remote comparison of the Sr standard against optical standards at NIST. The high frequency stability of a Sr-Ca comparison ($3\text{x}10^{-16}$ at 200 s) is used to make measurements of Sr transition frequency shifts at the fractional frequency level below 10^{-16}. These systematic shifts are discussed in detail, resulting in a total uncertainty of the Sr clock frequency at $1.5\text{x}10^{-16}$, the smallest for a neutral atom system.