AN ACCURATE OPTICAL LATTICE CLOCK WITH ^{87}Sr ATOMS

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The recent advent of optical lattice clocks opens a promising way towards frequency standards with improved accuracy [1]. With a large number of atoms probed in the Lamb-Dicke regime these clocks combine the advantages of traditional optical standards which use either a trapped single ion or a large number of free falling neutral atoms. A crucial concern however is the level of cancellation of the effects of the trapping potential on the clock transition. The first order perturbation is intrinsically cancelled by tuning the lattice to the "magic wavelength", but this is not the case for higher order terms. Theoretical predictions indicate that these effects should be compatible with a 10^{-18} accuracy goal [2], but do not properly account for two photon resonances at the vicinity of the magic wavelength. In Sr, the $5s5p\ ^3P_0 \rightarrow 5s7p^1P_1$ and $5s5p\ ^3P_0 \rightarrow 5s4f\ ^3F_2$ transitions lie respectively 7 x 10^{-2} nm and 5 nm away from the magic wavelength.

We report the observation of higher order effects in such a clock using strontium atoms. Non linear frequency shifts of several kHz are observed by operating the clock at a very high trapping intensity of 4 x 10^5W/cm^2 and by tuning the trap laser some 100MHz away from the $P \rightarrow F$ resonance. No effect of the $P \rightarrow P$ transition could be observed to within the present accuracy of our measurements. When tuning the laser at the magic wavelength, which we determine to be 813.428 (1) nm, higher order effects are compatible with zero to within a few Hz. This demonstrates that they will not constitute a limitation to the accuracy at the 10^{-18} level for a Sr optical lattice clock operated at a reasonable lattice depth in the range of 10^3W/cm^2[3].

We have also performed a full accuracy evaluation of the clock. The clock transition frequency is determined to be 429 228 004 229 879(5) Hz with a fractional uncertainty that is comparable to state-of-the-art optical clocks with neutral atoms in free fall. The two previous measurements of this transition [1,4] were found to disagree by about 2 x 10^{-13}, *i.e.* almost four times the combined error bar and 4 to 5 orders magnitude larger than the claimed ultimate accuracy of this new type of clocks. Our measurement is in perfect agreement with one of these two values and essentially solves this problem.

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