32nd URSI GASS, Montreal, 19–26 August 2017

Sr^+ single ion optical clock

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Extended Abstract

The development of modern optical atomic clocks was made possible by a number of important scientific milestones. Of particular importance are laser cooling, atom trapping, quantum state manipulation, and laser frequency stabilization. The development of self-referenced frequency combs based on femto-second lasers was another milestone, one that now provides a convenient method of comparing an optical frequency standard with microwave clocks that define the SI second, and with optical standards operated using different atomic systems. These advances have in turn motivated further developments in optical clocks, especially towards a better understanding and control of the systematic shifts. The current best optical clocks have evaluated uncertainties that are from one to two orders of magnitude lower than state-of-the-art cesium fountain clocks [1, 2].

The optical clock developed at the National Research Council of Canada (NRC) is based on the $5s^2S_{1/2}-4d^2D_{5/2}$ electric-quadrupole transition of a trapped and laser-cooled single ion of $^{88}Sr^+$. The current evaluated uncertainty is 1.2×10^{-17}, limited primarily by the evaluation of the blackbody radiation (BBR) field at the ion [3, 4]. Several improvements were made in recent years to reduce the systematic shifts uncertainties of $^{88}Sr^+$. The most significant ones were the development of a Zeeman averaging method of probing the clock transition that cancels the electric quadrupole shift and the tensor Stark shifts [5], and a high-accuracy experimental determination of the differential static scalar polarizability parameter, $\Delta\alpha_0$, of the clock transition [4]. The atomic parameter $\Delta\alpha_0$ determines the response of the clock transition frequency to the blackbody radiation field. The contribution of $\Delta\alpha_0$ to the BBR shift uncertainty has been reduced from 2×10^{-17} to below the 10^{-18} level with the high-accuracy measurement. For the *S–D* transition of $^{88}Sr^+$, the atomic parameter $\Delta\alpha_0$ is negative. As a consequence, the negative second-order Doppler shift and the positive scalar Stark shift caused by micromotion can be made to cancel each other by a proper choice of the trap drive frequency. This frequency is $f_0 = 14.408$ MHz for the *S–D* transition of $^{88}Sr^+$. We operate our trap at that frequency to suppress the micromotion shifts by an additional factor of more than 200, down to the 10^{-19} level. The uncertainty caused by thermal secular motion is also reduced by a factor of almost three by operating the trap at the frequency f_0. The $^{88}Sr^+$ ion has the potential for an uncertainty evaluation at the 10^{-18} level, the main challenge being the evaluation of the BBR field. The recent improvements to the $^{88}Sr^+$ ion clock will be discussed in more detail at the conference presentation.

We have recently made a new absolute frequency measurement of the $^{88}Sr^+$ ion clock transition using a GPS link to the SI second. These measurements will also be presented at the conference and compared to previous measurements made with GPS frequency transfer and with cesium fountain clocks.

References

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