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Optical / Microwave Comparisons at NICT

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The performance clocks based on optical atomic transition now exceeds that of clocks interrogating the microwave transition in atomic cesium that presently defines the SI second. A large amount of work is underway to employ the unprecedented stability and accuracy of such clocks in applications ranging from the implementation of stable time scales to the detection of dark matter.

Essentially all of these applications employ optical frequency combs either for direct optical-optical comparison, or for down-converting optical to microwave frequencies that are accessible to electronic frequency counting. Here I will report on the frequency comb system currently in use and in development at NICT. I will also present some of the measurements that it has recently been employed in, including:

Time-scale generation and TAI calibration with a strontium optical lattice clock

The optical frequency standard NICT-Sr1 at NICT [1] is operated regularly to determine the frequency of the local maser ensemble acting as flywheel for the generation of the Japanese national time scale UTC(NICT). Incorporating this information into the generation of the time scale provides stability comparable to what is achievable with cesium fountain clocks, even if the optical standard is only operated intermittently [2].

Sr-NICT1's measurements also provide information on the scale interval of the international atomic time scale TAI, to which NICT's maser ensemble is continuously compared by TWSTFT and GNSS measurements. The overall fractional frequency uncertainty for such a calibration is less than 6×10^{-16}, approaching the limit set by the 4×10^{-16} uncertainty now assigned to the Sr clock frequency as a secondary representation of the second. At the time of writing, NICT-Sr1 is under review for official recognition as a frequency standard contributing to TAI.

Absolute frequency measurement of the In+ clock transition

In addition to the strontium optical lattice clock, a new frequency standard based on the 237 nm clock transition in singly-ionized indium is in development at NICT [3]. Despite being at an early stage of its development, it already achieves a systematic uncertainty of less than 5×10^{-15}. Recent improvements to the operating methods enabled Zeeman-resolved spectroscopy with observed linewidths of less than 80 Hz.

We have performed the first ever measurement of an optical-optical frequency ratio involving the In+ clock transition. Such measurements play an important role in the demonstration and evaluation of optical clock performance, since they can surpass the limits otherwise set by even the best available implementation of the SI second. I will show that the performance of the frequency measurement system is not limited by the noise of the reference maser in such a direct comparison, which will significantly accelerate characterization measurements towards increased accuracy of the In+ clock.

References

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