URSI GASS 2021, Rome, Italy, 28 August - 4 September 2021

Contributions to TAI by evaluating its scale interval with an optical lattice clock

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Optical frequency standards have established superb stability and low systematic uncertainties that clearly surpass microwave standards. This urges the community of time and frequency metrology to discuss a possible redefinition of the SI second. At this time, the Consultative Committee of Time and Frequency (CCTF) has already established a task force toward the redefinition. In the discussion, one prerequisite requires optical clocks to contribute to International Atomic Time (TAI) by evaluating its scale interval. TAI is derived from a free atomic timescale (EAL, Échelle Atomique Libre) which is based on the weighted ensemble average of more than 400 atomic clocks. The scale interval, effectively implementing a "one second" tick, in EAL differs from the definition of the SI second at the level of fractional picoseconds due to the limitations of the contributing clocks. Cs fountain frequency standards have calibrated this difference for more than twenty years. If the definition of the second is to be changed, optical clocks will need to perform this calibration.

In this presentation, some examples of optical evaluation of the TAI scale interval will be presented. The first step is to obtain recognition as a secondary frequency standard (SFS) from the Working Group on Primary and Secondary Frequency Standards. The procedure will be briefly presented for the case of our strontium lattice clock (NICT-Sr1). This was accepted as an SFS in Nov. 2018 following the first acceptance of optical frequency standards SYRTE-Sr2 and SYRTE-SrB in 2016. Immediately after the acceptance of NICT-Sr1, we reported a TAI evaluation performed in Dec. 2018. This is the first "on-time" report without any latency that would allow confirming the agreement with the result of Primary Frequency Standards (PFS) beforehand. Such on-time reports are essential to an effective steering of TAI. As shown in Fig. 1, NICT-Sr1 reported four more times after Dec. 2018 [1], with uncertainties comparable with those of PFSs. Recently, NMIJ has also initiated on-time evaluation with a high up-time ratio above 90% [2]. NICT-Sr1 is not operated throughout the complete evaluation interval in this way, which requires careful evaluation of so-called "dead time uncertainties" resulting from the instability of the flywheel oscillator. The method of uncertainty estimation has made progress over the course of the evaluations and we will present details of the procedure.

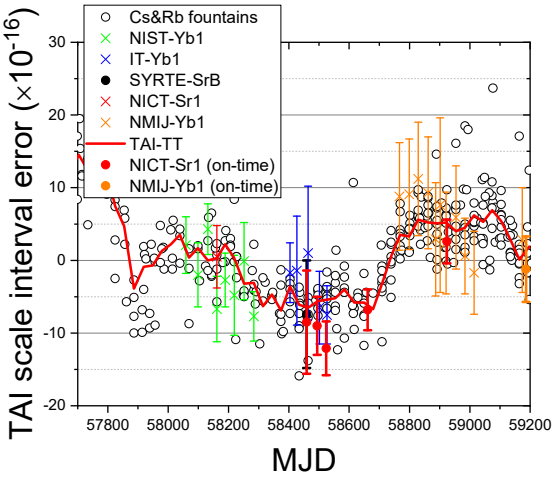

Figure 1. Evaluation of the TAI scale interval. Empty circles are the results from Cs and Rb fountains. Crosses (×) represent evaluations by four optical lattice clocks published only after the availability of the fountain results. Filled circles are on-time evaluations. BIPM estimates a monthly mean of the scale interval of TAI as shown by the red curve.

References

[1] Circular T No. 372
[2] Circular T No. 396
both https://www.bipm.org/en/bipm-services/timescales/time-ftp/Circular-T.html