Optically Steered Time Scale Generation at OP and NPL and Remote Comparisons

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Optical frequency standards (OFS) under development in many institutions worldwide have demonstrated impressive progress in terms of accuracy and stability [1-5], surpassing the performances of atomic fountain microwave frequency standards by two orders of magnitude. In the frame of the redefinition of the second in the international system of units (SI) [6], several OFS currently considered as secondary representations of the SI second already contribute to the steering of International Atomic Time (TAI), calculated monthly by the Bureau International des Poids et Mesures (BIPM). Local time scales maintained by National Metrology Institutes will also benefit in the near future from the accuracy and stability of OFS with an expected time offset from Coordinated Universal Time (UTC) maintained in the 100 ps range or lower [7-10].

In this paper, we will present real-time optically steered timescales generated at the same time at OP and NPL. In this experiment, performed during the Robust Optical Clocks for International Timescales (ROCIT) project funded by the European Metrology Programme For Innovation and Research (EMPIR), independent experimental time scales UTCx(k) were generated for one month in both laboratories in parallel to the local UTC(k) time scales. The UTCx(k) time scales were based on hydrogen masers whose frequency was calibrated by the local OFS (SYRTE-SrB and SYRTE-Sr2 optical lattice clocks [11] at OP, NPL-Sr1 [12] and NPL-Yb^+E3 [13] OFS at NPL) via frequency combs. From these frequency calibrations, steering corrections were updated hourly via frequency offset generators fed by the hydrogen masers, to better compensate for the real time maser frequency fluctuations. After a detailed description of the experimental chains, we will present the implemented algorithms for outlier filtering and frequency steering estimations. We will then analyse the performance of the experimental timescales based on local comparison against the local UTC(k) and remote comparisons performed via UTC and using the GPS Precise Point Positioning (PPP) technique, before presenting strategies for improvement. We will show that the two optically steered time scales remained less than 4 ns away one from each other, which is better than the corresponding UTC(k) over the same period. To our knowledge, this is the first-ever comparison of two independent 'optical time scale' prototypes, and the results demonstrate the capacity of optical clocks to produce operational timescales.

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