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

Contributing to International Atomic Time with an Ytterbium Optical Clock

Marco Pizzocaro*(1), Filippo Bregolin(1), Irene Goti(1)(2), Cecilia Clivati(1), Piero Barbieri(1), Filippo Levi(1), Davide Calonico(1),
(1) Istituto Nazionale di Ricerca Metrologica (INRIM), Torino, Italy
(2) Politecnico di Torino, Italy

International Atomic Time (TAI) is maintained by the International Bureau of Weights and Measures (BIPM) as a virtual timescale calculated from the comparison of frequency standards in about 80 laboratories. The agreement between TAI and the second of the International System of Units (SI) is assured from the contribution of caesium fountains clocks around the world. In the last years, optical frequency standards based on optical transitions of several atomic species demonstrated that they can outperform caesium fountains [1]. Their fast improvements prompted the discussion on a future redefinition of the SI second based on an optical transition and, provisionally, the International Committee for Weights and Measures (CIPM) recommended nine optical transitions as secondary representation of the second [2]. This means that optical clocks can be used to realize the SI second with an uncertainty similar to those of caesium fountains. The optical clocks at NICT [3], SYRTE [4], and NIST [1] were the first optical clocks to take this role, contributing to TAI as secondary representation of the second.

We have developed an ytterbium optical lattice clock and measured its absolute frequency with a link to TAI from several months of data with an uncertainty of 2.6×10^{-16} [5]. The link to TAI was used to provide traceability to the SI second as realized from the contribution of worldwide fountains, that contributed an uncertainty of 1.2×10^{-16} while the ytterbium clock had an uncertainty of 3×10^{-17}. Moreover, since the frequency of the ytterbium clock transition is among the nine optical secondary representation of the second, we also submitted this data to the BIPM and contributed to TAI with the ytterbium clock. At the conference we will present the latest measurements and improvement to the Yb clock, aiming to further reduce its uncertainty.

The regular incorporation into TAI of optical clocks, using different atomic species, is an important step toward the redefinition of the second and shows that optical standards have reached maturity.

References

[1] W. F. McGrew, X. Zhang, R. J. Fasano, S. A. Schäffer, K. Beloy, D. Nicolodi, R. C. Brown, N. Hinkley, G. Milani, M. Schioppo, T. H. Yoon, and A. D. Ludlow, “Atomic clock performance enabling geodesy below the centimetre level,” *Nature*, vol. 564, no. 7734, pp. 87–90, 2018.

[2] F. Riehle, P. Gill, F. Arias, and L. Robertsson, “The CIPM list of recommended frequency standard values: guidelines and procedures,” *Metrologia*, vol. 55, no. 2, pp. 188–200, 2018.

[3] H. Hachisu, F. Nakagawa, Y. Hanado, and T. Ido, “Months-long real-time generation of a time scale based on an optical clock,” *Scientific Reports*, vol. 8, no. 1, p. 4243, 2018.

[4] J. Lodewyck, S. Bilicki, E. Bookjans, J.-L. Robyr, C. Shi, G. Vallet, R. L. Targat, D. Nicolodi, Y. L. Coq, J. Guéna, M. Abgrall, P. Rosenbusch, and S. Bize, “Optical to microwave clock frequency ratios with a nearly continuous strontium optical lattice clock,” *Metrologia*, vol. 53, no. 4, p. 1123, 2016.

[5] M. Pizzocaro, F. Bregolin, P. Barbieri, B. Rauf, F. Levi, and D. Calonico, “Absolute frequency measurement of the $^1S_0 - {}^3P_0$ transition of ^{171}Yb with a link to international atomic time,” *Metrologia*, vol. 57, no. 3, p. 035007, may 2020.