Operation of IT-Yb1 in 2019

The frequency standard IT-Yb1 is a ^{171}Yb optical lattice clock operated at INRIM since 2016 [1]. The standard uses a clock laser at 578 nm generated from the second-harmonic of a laser at 1156 nm. The 578 nm laser is stabilized on an ultrastable cavity and probes the atoms trapped in an one-dimensional horizontal optical lattice at the magic frequency. The clock laser frequency is kept in resonance with the atoms by a digital control loop acting on an acousto-optic modulator. The fundamental 1156 nm laser is sent to a fibre frequency comb referenced to a local hydrogen maser. The frequency ratio between the maser and the ^{171}Yb transition is calculated from the comb measurement and from the corrections used for steering the acousto-optic modulator. Following this operation it was possible to calibrate the maser frequency from October 2018 to February 2019 in the periods MJD 58389 to 58419 (30 days), MJD 58419 to 58434 (15 days), MJD 58459 to 58469 (10 days), MJD 58489 to 58514 (25 days), MJD 58514 to 58539 (25 days). These calibrations were submitted to the BIPM and, after review, the results were published in Circular T 383 in November 2019. The calibration was based on the 2017 recommendation of the frequency for ^{171}Yb as a secondary representation of the second, $f(^{171}\text{Yb})$ = 518 295 836 590 863.6(3) Hz.

The instability of IT-Yb1 has been estimated to be about 2e-15 at 1 s from interleaved measurements [2] so that the statistical uncertainty is u_A<1e-17 after a few hours of measurement time. The most recent evaluation of the systematic uncertainty is u_B = 3e-17 [2] with an uncertainty budget reported in the table. This value corresponds to the uncertainty appeared in the Circular T. The uncertainty $u_{l/lab}$ of the link between the standard and the maser is dominated by the extrapolation uncertainty due to the intermittent operation of the standard [3], which had duty time ranging from 4% to 37% for each 5 days of measurements. Extrapolation uncertainty has been calculated from numerical simulation given the characteristic maser noise [2,4]. Moreover, a systematic uncertainty of 8e-17 has been assigned to $u_{l/lab}$ coming from the optical to microwave comparison at the comb.

Effect	Rel. Shift / 1e-17	Rel. Unc. /1e-17
Density shift	−5.9	0.2
Lattice shift	7.6	2
Zeeman shift	−0.693	0.014
Blackbody radiation	−235	1.2
Blackbody radiation oven	−1.7	0.8
Static Stark shift	−1.6	0.9
Background gas shift	−0.5	0.2
Probe light shift	0.09	0.05
Others	-	0.6
Gravitational redshift	2599.5	0.3
Total	2361.8	2.8

Table 1: typical systematic shift and uncertainties for IT-Yb1 between October 2018 and February 2019 (MJD 58389 to 58784).

References:

[1] M. Pizzocaro, P. Thoumany, B. Rauf, F. Bregolin, G. Milani, C. Clivati, G. A. Costanzo, F. Levi, and D. Calonico, "Absolute frequency measurement of the 1 S 0 – 3 P 0 transition of 171 Yb," Metrologia 54, 102 (2017).
[2] M. Pizzocaro, F. Bregolin, P. Barbieri, B. Rauf, F. Levi, and D. Calonico, "Absolute frequency measurement of the 1 S 0 – 3 P 0 transition of 171 Yb with a link to International Atomic Time," Metrologia (2019), not yet published in print
[3] D.-H. Yu, M. Weiss, and T. E. Parker, "Uncertainty of a frequency comparison with distributed dead time and measurement interval offset," Metrologia 44, 91 (2007).
[4] H. Hachisu and T. Ido, "Intermittent optical frequency measurements to reduce the dead time uncertainty of frequency link," Japanese Journal of Applied Physics 54, 112401 (2015).