Frequency evaluation of UTC(NMIJ) by NMIJ-Yb1 for the period MJD 58784 to MJD 58814

The secondary frequency standard NMIJ-Yb1 has been compared to UTC(NMIJ), during a measurement campaign between MJD 58784 and MJD 58814 (28th Octorber 2019 – 27th November 2019). The Yb optical lattice clock operation covers 77.8 % of the total measurement period.

1. Results

Table 1. (a) Results of the comparison in 1×10^{-16}

Period (MJD)	**y(UTC(NMIJ) – NMIJ-Yb1)**	**Total u_A**	**Total u_B**	**$u_{A/Lab}$**	**$u_{B/Lab}$**	**u_{SecRep}**	**Uptime (%)**
58784 - 58814	4.5	0.07	3.97	3.0	2.2	5	77.8

(b) Budget of uncertainties in 1×10^{-16}

u_A : Type A uncertainty	
Yb statistics	0.07
Total	0.07
u_B : Type B uncertainty	
Yb systematics	3.93
Gravitational	0.6
Total	3.97
$u_{A/Lab}$: Type A uncertainty	
Dead time in UTC(NMIJ) – Yb	3.0
Total	3.0
$u_{B/Lab}$: Type B uncertainty	
Microwave frequency synthesis	2.2
Total	2.2

The calibration is made using the most recently recommended value for the $6s^2\ {}^1S_0 - 6s6p\ {}^3P_0$ unperturbed optical transition in the ^{171}Yb neutral atom: 518 295 836 590 863.6 Hz [1]. u_{SecRep} is the recommended uncertainty of the secondary representation [1].

2. Systematic effects and uncertainties

Table 2. Budget of systematic effects and uncertainties for NMIJ-Yb1 [2] in 1×10^{-17}

Effect	**Shift**	**Uncertainty**
Lattice light	3.4	33.1
Blackbody radiation	-263.8	20.8
Density	-4.9	3.4
Second order Zeeman	-5.2	0.3
Probe light	0.4	0.2
Servo error	-4.8	1.0
AOM switching	-	1
Line pulling	-	1
Total	-274.9	39.3
Gravitational redshift	229.4	6
Total (with gravitational redshift)	-45.5	39.7

3. Frequency comparison

The frequency comparison between NMIJ-Yb1 and UTC(NMIJ) was carried out using an optical frequency comb. The comb was phase locked to UTC(NMIJ). A beat frequency between a laser locked to an ultra-stable cavity and the comb was counted. The frequency of the ultra-stable laser was shifted by an acousto-optic modulator (AOM) and stabilized to the clock transition in ^{171}Yb atoms trapped in an optical lattice. The frequency of the AOM was then combined with the beat frequency to compute y(UTC(NMIJ) – NMIJ-Yb1).

A Type B $u_{B/Lab}$ uncertainty arose from microwave frequency synthesis of UTC(NMIJ) which includes frequency multiplication. This uncertainty was estimated by comparisons between two combs with independent setups for the microwave frequency synthesis.

A Type A $u_{A/Lab}$ uncertainty arose from the dead time in the comparison between NMIJ-Yb1 and UTC(NMIJ). This uncertainty was estimated using a method described in Ref. [3]. For this estimation, we derived a maser noise model from the measured stability of UTC(NMIJ) against NMIJ-Yb1. The model includes a white phase modulation of 1×10^{-12} / (τ /s), a white frequency modulation (FM) of 7×10^{-14} / (τ /s)$^{1/2}$, a flicker FM of 2×10^{-15}, a random walk FM of 4×10^{-24} (τ /s)$^{1/2}$. $u_{A/Lab}$ also includes the uncertainty of a frequency correction resulting from the dead time when the frequency steering of UTC(NMIJ) is carried out.

The gravitational redshift was calculated with respect to the conventionally adopted reference potential W_0 = 62 636 856.0 m^2/s^2.

References

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