

Operation of NMIJ-Yb1 in 2020

During a period from October 2019 to April 2020, the ^{171}Yb optical lattice clock NMIJ-Yb1 [1,2] has calibrated the TAI frequency through comparison with UTC(NMIJ). Reports of these calibration results have been reviewed by the Working Group on PSFS, and then published in Circular T 392. In addition, the TAI frequencies measured in May, June, November, and December 2020 have been published in Circular T 396 and 398. The uptimes of NMIJ-Yb1 were 69.8 - 93.3 % for calibration periods ranging from 5 to 35 d.

u_A was estimated from the instability of NMIJ-Yb1 ($1 \times 10^{-14} / (\tau/\text{s})^{1/2}$) which was evaluated by our ^{87}Sr optical lattice clock [3]. u_B was estimated based on methods in Refs. [1,2]. For the reports in November and December 2020, u_B was improved to 2×10^{-16} as shown in Table 1 compared with an uncertainty of 4×10^{-16} in Ref. [2]. This improvement was made by reevaluation of the lattice light shift and density shift and operation of NMIJ-Yb1 with a smaller potential depth of the trap.

$u_{A/\text{Lab}}$ arose from the dead time in the comparison between NMIJ-Yb1 and UTC(NMIJ). This uncertainty was estimated with a method in Ref. [4]. $u_{A/\text{Lab}}$ also included the uncertainty of a frequency correction resulting from the dead time when the frequency steering of UTC(NMIJ) was carried out. $u_{A/\text{Lab}}$ varied from 8×10^{-17} to 4×10^{-16} .

$u_{B/\text{Lab}}$ arose from a microwave-optical link. For the reports in November and December 2020, $u_{B/\text{Lab}}$ was improved to 1.0×10^{-16} compared with an uncertainty of 2.2×10^{-16} in Ref. [2]. The previous uncertainty was mainly caused by frequency multiplication of a 10 MHz signal from UTC(NMIJ). Here we reduced this uncertainty by carefully stabilizing the temperature of a frequency multiplier.

Table 1. Up-to-date uncertainty budget of NMIJ-Yb1 in 1×10^{-17} for the report in December 2020

Effect	Shift	Uncertainty
Lattice light	5.9	4.5
Blackbody radiation	-267.0	20.6
Density	-1.1	0.7
Second order Zeeman	-5.1	0.3
Probe light	0.4	0.2
Servo error	-6.8	1.2
AOM switching	-	1
Line pulling	-	1
Total	-273.7	21.1
Gravitational redshift	229.4	6
Total (with gravitational redshift)	-44.3	22.0

[1] T. Kobayashi *et al.*, IEEE Trans. Ultrason., Ferroelectr., Freq. Control **65**, 2449-2458 (2018).

[2] T. Kobayashi *et al.*, Metrologia **57**, 065021 (2020).

[3] D. Akamatsu *et al.*, Appl. Phys. Express **7**, 012401 (2013).

[4] D.-H. Yu *et al.*, Metrologia **44**, 91-96 (2007).