FREQUENCY COMPARISON (H_MASER 140 0889) - (LNE-SYRTE-Sr2)
For the period MJD 56954 to MJD 56964

The secondary frequency standard LNE-SYRTE-Sr2 has been compared to the hydrogen Maser 140 0889 of the laboratory, during a measurement campaign between MJD 56954 and 56964 (24^{th} October 2014 – 3^{rd} November 2014). The optical lattice clock operation covers ~ 94.0% of the total measurement duration.

The mean frequency difference at the middle date of each interval is given in the following table:

Period (MJD)	**Date of the estimation**	**y(HMaser$_{140\ 0889}$ – Sr2)**	u_B	u_A	$u_{link/maser}$	u_{SecRep}
56954 – 56964	**56959.0**	**-2557.5**	**0.42**	**2.0**	**1.0**	**5**

Table 1: Results of the comparison in 1×10^{-16}.

The calibration is made using the recommended value for the ^{87}Sr secondary representation: 429 228 004 229 873.2 Hz (20^{th} CCTF in 2015).
u_B is the ^{87}Sr optical lattice type B uncertainty.
u_{SecRep} is the recommended uncertainty of the secondary representation (20^{th} CCTF in 2015).

The Sr2 optical lattice was operated in the same mode during all the period: a laser locked on an ultra-stable cavity is frequency shifted by an acousto-optic modulator and probes an ensemble of ~10^4 ^{87}Sr atoms in an optical lattice at the magic wavelength. A digital feedback loop controls the frequency of the AOM. The frequency of the ultra-stable laser is simultaneously measured by a frequency comb against the microwave local oscillator. The outcome of this measurement is then combined with the frequency correction of the AOM.

Average value and statistical uncertainty

The frequency data are averaged over 0.2 day intervals. We then calculate with the average points, a linear unweighted fit to determine the average frequency given in Table 1. The statistical uncertainty is estimated with the Allan variance of the frequency residuals, after removing the drift. We estimate a conservative statistical uncertainty $u_A = 2.0 \times 10^{-16}$.

We verified the results by applying a second method. We calculated the accumulated phase by integrating the data points, assuming a constant frequency during each segment, and during the dead times of the optical lattice clock operation. The average frequency is then obtained by dividing the total accumulated phase by the calibration period duration. The processing has been performed with segments of 0.01, 0.1 and 1 day durations. The results are in agreement with the values given in Table 1 within 0.5×10^{-16}, which is consistent with the estimations of the statistical uncertainty u_A and the uncertainty due to the link.

Accuracy

The following table summarizes the budget of systematic effects and their associated uncertainties. The accuracy is the quadratic sum of all the systematic uncertainties.

	Correction (10^{-18})	**Uncertainty (10^{-18})**
Black body radiation	*5208*	*20*
Quadratic Zeeman effect	*1317*	*12*
Lattice light-shift	*-30*	*20*
Lattice spectrum	*0*	*1*
Density shift	*0*	*8*
Line pulling	*0*	*20*
Probe light shift	*0.4*	*0.4*
AOM phase chirp	*-8*	*8*
Servo error	*0*	*3*
Static charges	*0*	*1.5*
Blackbody radiation oven	*0*	*10*
Background gas collisions	*0*	*8*
Total	*6487.4*	*40*
Red shift	*-6086*	*10*
Total with red shift	***401.4***	***42***

Table 2: Budget of systematic effects and uncertainties for SYRTE-Sr2 optical lattice for the MJD 56954-56964

$$\boxed{u_B = \mathbf{0.42 \times 10^{-16}}}$$

Uncertainty of the link

The uncertainty of the link is the quadratic sum of 2 terms:
-A possible effect of phase fluctuations introduced by the cables that connect the optical lattice clock to the Maser. It is estimated to be 10^{-16}.
-The uncertainty due to the dead times of the frequency comparison.
To estimate this contribution, we use the comparison between the reference Maser and Maser 140 0809. We calculate the time deviation of the normalized phase differences with the linear frequency drift removed. The uncertainty is given by:

$$\sigma_{y_{Dead\ Time}} = \frac{\sqrt{\sum_i \sigma_{x_i}^2}}{T}$$

where σ_{xi} are the extrapolated TVar for each dead times. We applied the method to the dead times longer than 600 s and obtained stability degradations of 0.2×10^{-16}.