FREQUENCY COMPARISON (H_MASER 140 0810) - (LNE-SYRTE-SrB)
For the period MJD 58454 to MJD 58464

The secondary frequency standard LNE-SYRTE-SrB has been compared to the hydrogen Maser 140 0810 of the laboratory, during a measurement campaign between MJD 58454 and 58464 (2nd December 2018 – 12th December 2018). The Sr clock operation covered 72.4 % of the period.

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

Period (MJD)	**Date of the estimation**	**y(HMaser$_{140\ 0810}$ – SrB)**	u_B	u_A	$u_{link/maser}$	u_{SecRep}
58454 – 58464	**58459**	**-6500.6**	**1.02**	**2.0**	**0.9**	**4**

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

The calibration is made using the recommended value for the ^{87}Sr secondary representation:
429 228 004 229 873.0 Hz (21st CCTF in 2017).
u_B is the ^{87}Sr optical lattice type B uncertainty.
u_{SecRep} is the recommended uncertainty of the secondary representation (21st CCTF in 2017).

The SrB optical lattice was operated in the same mode during all the period: a laser locked to 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 perform a linear unweighted fit to the average data points to determine the average frequency at the middle date of the period, as given in Table 1. The statistical uncertainty u_A is estimated using the Allan variance of the frequency residuals, after removing the drift. We estimate a conservative statistical uncertainty u_A of 2.0×10^{-16}.

We verified the result 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 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 duration. The results are in agreement with the values given in Table 1 within 1.8×10^{-16}, which is consistent with the estimation 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. During most of the calibration period, we observed a large systematic effect due to the presence of static charges. It was characterized through the sporadic comparison with the SYRTE-Sr2 clock, especially during the discharge event we triggered.

	Correction (10^{-18})	**Uncertainty (10^{-18})**
Black body radiation	*5143*	*10*
Quadratic Zeeman effect	*671*	*6*
Lattice light-shift	*-10*	*5*
Lattice spectrum	*0*	*1*
Density shift	*0*	*10*
Line pulling	*0*	*10*
Probe light shift	*0.4*	*0.4*
AOM phase chirp	*0*	*<1*
Servo error	*0*	*3*
Static charges	*200*	*100*
Blackbody radiation oven	*0*	*10*
Background gas collisions	*40*	*4*
Total	*6044.4*	*102*
Red shift	*-6114.6*	*10*
Total with red shift	***-70.2***	***102***

Table 2: Budget of systematic effects and uncertainties for SYRTE-SrB optical lattice clock for the MJD 58454-58464

$$\boxed{u_B = \mathbf{1.02 \times 10^{-16}}}$$

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 frequency standard to the maser. A new characterization of the signal distribution leads to a still conservative value of 0.5×10^{-16}.

-The uncertainty due to the dead times of the frequency comparison.

We have updated the estimation of this contribution, applying the method described in *Metrologia*, vol. 44, pp 91-96, 2007, as we did for the initial calibration reports of the LNE-SYRTE Strontium SFS. The maser noise model includes a white frequency noise component of 5×10^{-16} at 1 d and a flicker frequency noise component of 5×10^{-16} at 1 d, which is pessimistic especially for short averaging periods. We applied the method to the dead times longer than 600 s and obtained a stability degradation of 0.8×10^{-16}.