Evaluation of the frequency of H-maser 1401708 by primary frequency standard NPL-CsF2

National Physical Laboratory

4th January 2021

The primary frequency standard NPL-CsF2 was used to measure the frequency of hydrogen maser HM2, identified by clock code 1401708, over an evaluation period in November and December 2020. Maser 1401708 is a physical realisation of UTC(NPL). The evaluation was performed by measuring the mean frequency difference over the reporting period.

No changes to NPL-CsF2 or its associated operating protocols have been introduced since the evaluation report accompanying circular-T 394 (October 2020). A breakdown of the systematic uncertainties from this report is reproduced in Table 1. Note that the uncertainty contribution from cold collisions varies and the value listed here is purely indicative. A specific value for the given measurement period is presented together with the measurement results.

	uncertainty / 10^{-16}
Second order Zeeman	0.8
Blackbody radiation	1.0
AC Stark (lasers)	0.1
Microwave spectrum	0.1
Gravity	0.5
Cold collisions	0.4[†]
Background gas collisions	0.3
Rabi, Ramsey pulling	0.1
Cavity phase (distributed)	1.0
Cavity phase (dynamic)	0.1
Cavity pulling	0.6
Microwave leakage	0.6
Microwave lensing	0.3
2nd-order Doppler	0.1
Total u_B (1σ)	**2.0**

Table 1: Results of the most recent accuracy evaluation of NPL-CsF2.

[†] *The exemplary value here corresponds to the type B uncertainty contribution for a ratio of high to low atom density of 8 and a measured frequency difference between the two of below 2.5×10^{-15}.*

Measurement results

Results of the frequency measurement are listed in Table 2 below. Frequency biases are given for information only and represent the mean values of the biases over the measurement interval. The listed fractional frequency difference y(CsF2-HM2) is a value corrected for these biases. The total uncertainty u_{total} is defined as:

$$(u_{\text{total}})^2 = (u_{\text{A}})^2 + (u_{\text{B}})^2 + \left(u_{\text{A/lab}}\right)^2 + \left(u_{\text{B/lab}}\right)^2$$

Maser 1401708 is steered on a regular basis and the measurements listed are a weighted average of the measurements throughout each period.

		26 Nov 2020 – 31 Dec 2020
Period start	MJD	59179
Period end	MJD	59214
Duration	days	35
Measurement uptime	%	97.7
Biases:	$\times 10^{-15}$	
cold collisions		0.24
2$^{\text{nd}}$ order Zeeman		247.57
BBR shift		-16.32
gravity		1.30
microwave lensing		0.06
DCP		0.02
y(CsF2-HM2)	**$\times 10^{-15}$**	**-0.16**
u_{A}	$\times 10^{-15}$	0.13
u_{B}	$\times 10^{-15}$	0.20
$u_{\text{A/lab}}$	$\times 10^{-15}$	0.04
$u_{\text{B/lab}}$	$\times 10^{-15}$	0.00
u_{total}	**$\times 10^{-15}$**	**0.24**

Table 2: Results of the evaluation of the frequency of H-maser 1401708 by primary frequency standard NPL-CsF2.