Evaluation of the frequency of UTC(NPL) by primary frequency standard NPL-CsF2

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The primary frequency standard NPL-CsF2 was used to measure the frequency of a hydrogen maser HM6 over an evaluation period in February and March 2021. The output of HM6 is linked to UTC(NPL) by a time interval logger, enabling us to obtain a measurement of the mean frequency of UTC(NPL) over the reported period.

Measurement configuration

Following a reconfiguration of the NPL timescale in January 2021, NPL-CsF2 no longer directly measures the physical source of UTC(NPL), but instead measures the frequency of a separate maser reference HM6. The time offset between HM6 and UTC(NPL) is continually measured by an SR620 time interval logger. By taking the difference in this time offset at the start and end of the measurement period we determine the mean frequency difference between the two signals. We combine this with the fountain measurements to obtain the frequency difference between NPL-CsF2 and UTC(NPL) that is reported in Table 2.

Deadtime in the maser frequency measurement is accounted for in a similar manner to previous reports, using a model based on a flicker floor of 1.7×10^{-15}. This value is derived from recent measurements of HM6 by NPL-CsF2.

HM6 was not steered during the reported measurement period.

HM6 - UTC(NPL) link uncertainties

The SR620 time interval logger that links HM6 to UTC(NPL) introduces some additional sources of uncertainty to the measurement. The type-A uncertainty in the time interval data is determined from the statistical spread of repeated measurements to be 64 ps. By averaging 10 samples we reduce this uncertainty to 20 ps. The corresponding frequency uncertainty is the ratio of this time to the reporting period multiplied by $\sqrt{2}$ and forms part of $u_{\mathrm{A/lab}}$.

The logger also exhibits a type-B error due to a measurement non-linearity that varies with the size of the time interval. We use the device's specified deviation of 50 ps. The resulting frequency uncertainty is the ratio of this time to the reporting period multiplied by $\sqrt{2}$ and is included as $u_{\mathrm{B/lab}}$.

NPL-CsF2

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-UTC(NPL)) is a value corrected for these biases. The total uncertainty u_{total} is defined as:

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

		24 Feb 2021 – 31 Mar 2021
Period start	MJD	59269
Period end	MJD	59304
Duration	days	35
Measurement uptime	%	99.2
Biases: cold collisions 2nd order Zeeman BBR shift gravity microwave lensing DCP	$\times 10^{-15}$	 -0.12 247.54 -16.33 1.30 0.06 0.02
***y*(CsF2-UTC(NPL))**	**$\times 10^{-15}$**	**0.23**
u_{A}	$\times 10^{-15}$	0.16
u_{B}	$\times 10^{-15}$	0.20
$u_{\text{A/lab}}$	$\times 10^{-15}$	0.01
$u_{\text{B/lab}}$	$\times 10^{-15}$	0.02
$\boldsymbol{u_{\text{total}}}$	**$\times 10^{-15}$**	**0.25**

Table 2: Results of the evaluation of the frequency of UTC(NPL) by primary frequency standard NPL-CsF2.