

# 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 two hydrogen masers during an evaluation period in December 2001 and January 2022 – maser HM5 for the first 7.5 days of the period and then maser HM6 for the remaining 22.5 days. The output of each of these masers 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 entire reported period.

In each case, the mean frequency of the maser was determined by fitting to the data a function consisting of a linear drift term and steps corresponding to any applied frequency steers.

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. The procedure for determining the frequency of UTC(NPL) from maser measurements, together with the corresponding contribution to the  $u_{A/lab}$  and  $u_{B/lab}$  uncertainties, was described in the report accompanying circular-T 399 (March 2021).

	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 <sup>†</sup>
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
2 <sup>nd</sup> -order Doppler	0.1
<b>Total <math>u_B</math> (1<math>\sigma</math>)</b>	<b>2.0</b>

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

<sup>†</sup> *The value presented here is exemplary. A specific value for the given measurement period has been computed and included in the measurement results.*

## 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  $y(\text{CsF2-UTC(NPL)})$  is a value corrected for these biases. The total uncertainty  $u_{\text{total}}$  is defined as:

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

		31 Dec 2021 – 30 Jan 2022
Period start	MJD	59579
Period end	MJD	59609
Duration	days	30
Measurement uptime	%	88.5
Biases:	$\times 10^{-15}$	
cold collisions		0.30
2 <sup>nd</sup> order Zeeman		247.51
BBR shift		-16.30
gravity		1.30
microwave lensing		0.06
DCP		0.02
<b><math>y(\text{CsF2-UTC(NPL)})</math></b>	<b><math>\times 10^{-15}</math></b>	<b>-1.36</b>
$u_A$	$\times 10^{-15}$	0.17
$u_B$	$\times 10^{-15}$	0.20
$u_{A/\text{lab}}$	$\times 10^{-15}$	0.19
$u_{B/\text{lab}}$	$\times 10^{-15}$	0.05
<b><math>u_{\text{total}}</math></b>	<b><math>\times 10^{-15}</math></b>	<b>0.33</b>

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