Operation of the NPL-CsF2 primary frequency standard in 2020

The National Physical Laboratory in the UK currently operates one fully characterised and approved primary frequency standard, the caesium fountain NPL-CsF2. NPL-CsF2 was made operational and its accuracy evaluated for the first time in 2009. It was later reassessed in 2011, 2013 and 2015. Later, for a period of time, inconsistencies in both the short-term stability and accuracy of NPL-CsF2 were observed. After reconfiguring the grounding arrangement of the microwave synthesis chain, the physics package and associated devices, and removing a residual magnetisation of the magnetic shields near the cavity, this behaviour was no longer seen.

To regain confidence in the fountain's performance, it was operated for approximately a year starting in November 2019. The measurement data were initially only used internally for stability analysis of UTC(NPL). In October 2020, regular monthly submissions of data for TAI step interval measurements were reinstated. Including retrospective submissions, measurements were reported for 11 of the months in 2020.

The accuracy evaluation currently referenced in Circular-T was carried out in 2011, and an updated assessment was published in [1]. Following its reconfiguration in 2019, a revised accuracy evaluation of NPL-CsF2 was conducted in August 2020 and described in Circular-T 394. The table below summarises the results of this latest evaluation, which gives a total systematic uncertainty consistent with that in [1], together with typical values of the frequency biases that we now correct for.

	Typical bias / 10^{-16}	Uncertainty / 10^{-16}
Second order Zeeman	2475.0	0.8
Blackbody radiation	-164.0	1.0
AC Stark (lasers)		0.1
Microwave spectrum		0.1
Gravity	13.0	0.5
Cold collisions (typical)		0.4
Collisions with background gas		0.3
Rabi, Ramsey pulling		0.1
Cavity phase (distributed)	0.2	1.0
Cavity phase (dynamic)		0.1
Cavity pulling		0.6
Microwave leakage		0.6
Microwave lensing	0.6	0.3
Second-order Doppler		0.1
Total u_B (1σ)		**2.0**

A low noise microwave synthesiser referenced to an ultrastable laser, the stability of which is down-converted to the microwave domain via a frequency comb, has been implemented and routinely used as a local oscillator and microwave source. With this local oscillator, we can obtain short-term stabilities of 3.3×10^{-14} at 1 second. This new synthesiser is a shared resource and when it is unavailable a second synthesiser based on a BVA quartz crystal is used. With this system we obtain typical short-term stabilities of 1.2×10^{-13} at 1 second.

The temperature control of the fountain flight tube now relies on stabilisation of the room temperature rather than the active system with a water jacket that was previously used. We continually measure the flight tube temperature and compensate for the corresponding blackbody radiation shift. Thanks to the thermal insulation of the tube we do not observe any significant thermal gradients.

No other significant changes to the physics package of NPL-CsF2 or its control system have been introduced over the recent year.

[1] K. Szymaniec et al. J. Phys. Conf. Series 723 (2016) 012003.