I. SUMMARY

The primary frequency standard NIM5 was used to measure the average fractional frequency difference of the H-maser, identified by the clock code 1404857, during an evaluation campaign over 10 days in Nov. 2021. The results are given in table 1, together with the total uncertainties in relating NIM5 to maser 57.

Table 1 Summary of the frequency measurements of H-maser 57 (1404857)

Period	MJD 59534.0 to 59544.0
$y_{(H57\text{-}NIM5)}$ [$\times 10^{-15}$]	68.58
Duty cycle [%]	99.7%
u_A [$\times 10^{-15}$]	0.67
u_B [$\times 10^{-15}$]	0.90
$u_{link/lab}$ [$\times 10^{-15}$]	0.10
u_{total} [$\times 10^{-15}$]	1.13

The combined total uncertainty u_{total} is the square sum of the three uncertainties as following:

$$u_{total} = \sqrt{(u_A)^2 + (u_B)^2 + (u_{link/lab})^2} \quad (1)$$

Type A uncertainty u_A is the statistical uncertainty on the frequency measurement, u_B is the Type B uncertainty from bias evaluations, and $u_{link/lab}$ is the uncertainty induced by the link between NIM5 fountain clock and the H-maser 57, which includes the dead time and the phase noise of the link between NIM5 and H-57. All the above uncertainties are calculated at 1σ.

II. Measurement methods

The whole optical system has been replaced by a new one with a Toptica laser (DLC TA PRO 850) for cooling and detection, and a DBR laser for repumping. This new system is a compact one with an optical bench of a dimension of 900 mm × 600 mm. The light shift due to each beam has been evaluated by the operating under two different conditions alternately. One is the routine sequence, the other is turning up the light power during the

interrogation time by AOM control. The fractional frequency difference are always less than 5E-15. Since the light powers can be lowered down to 3 orders of magnitude, the light shift will be negligible. The other parts of the fountain remain the same. A summary of the systematic frequency shift evaluations for NIM5 is listed in Table 2. The combined relative Type B uncertainty is approximately 0.9×10^{-15}.

Table 2 Uncertainty budget of NIM5 in these evaluations.

Physical Effect	Bias [$\times10^{-15}$]	Uncertainty [$\times10^{-15}$]
2nd order Zeeman	73.21	0.2
Collisional shift	-1.60*	0.1
Microwave interferometric Switch	0.0	0.6
Microwave leakage	0	<0.1
DCP	0.0	0.6
Microwave spectral impurities	0.0	0.1
Blackbody radiation	-16.23	0.1
Gravitational red shift	11.8	0.1
Majorana transition	0. 0	0.1
Light shift	0.0	<0.1
Rabi and Ramsey pulling	0.0	<0.1
Cavity pulling	0.0	<0.1
Collision with background gases	0.0	<0.1
Total	67.16*	0.9*

* The collision shift is calculated at low density.

The dead time distribution during the report period is shown in the figure 1:

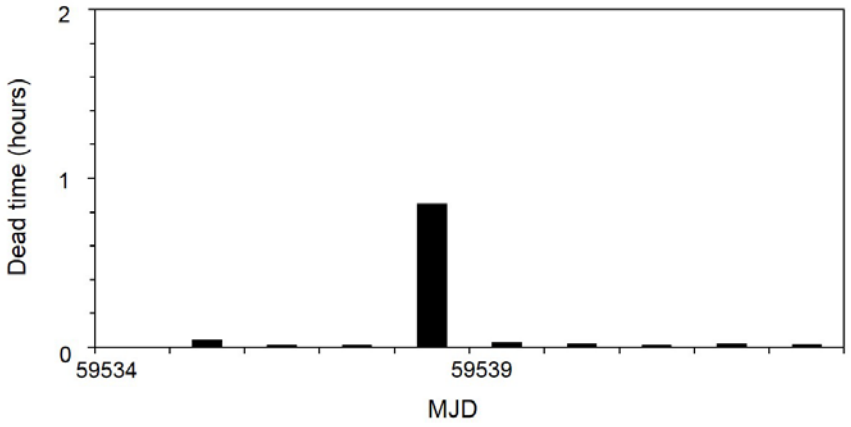

Figure 1 Dead time distributions in Nov., 2021 report period.