



NRC-FCs2 primary frequency standard at the National Research Council Canada

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The National Research Council of Canada is finalizing the first evaluation of a new primary frequency standard, the NRC-FCs2 cesium fountain clock. The physics package for NRC-FCs2 was designed and built in collaboration with the National Physical Laboratory (NPL) in the UK, based on the design of NPL fountains CsF2 and CsF3 [1]. The physics package has been successfully integrated with the optical, microwave, and electronics subsystems developed at the NRC [2].

The high signal-to-noise ratio NRC-FCs2 allows us to obtain a short term stability of $\sigma_y = 1 \times 10^{-13}$ at 1 second of averaging time, which is limited by our room temperature quartz crystal local oscillator. The fountain clock also demonstrates excellent robustness, as lasers maintain lock for months without intervention. This enables us to operate with an up-time of over 95%.

As shown in Table 1, we have nearly completed an evaluation of the expected biases of NRC-FCs2. We are currently evaluating the distributed cavity phase (DCP) shift, the last outstanding frequency bias to be characterized. We expect to complete the evaluation shortly, at which point NRC-FCs2 will serve as a primary frequency standard for Canada and contribute to the steering of UTC/TAI with a fractional systematic uncertainty of a few parts in 10^{16} .

Table 1. Preliminary error budget for NRC-FCs2. Italicized entries denote expected results.

Effect	Bias ($\times 10^{-16}$)	Uncertainty ($\times 10^{-16}$)
2 nd order Zeeman	724.0	0.4
Blackbody radiation	-162.7	0.7
Gravitational redshift	104.38	0.03
AC Stark	0	0.01
Cavity Pulling	0	0.2
<i>DCP</i>	<i>0.5</i>	<i>3.0</i>
Microwave lensing	0.8	0.2
Microwave leakage	1.0	1.2
Microwave spectral impurities	0	0.2
Cold collisions	10	0.5
Total	678.0	3.4

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1. R. J. Hendricks, F. Ozimek, K. Szymaniec, B. Nagorny, P. Dunst, J. Nawrocki, S. Beattie, B. Jian, K. Gibble, "Cs Fountain Clocks for Commercial Realisations --- an Improved and Robust Design," to appear in IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control, <https://doi.org/10.1109/TUFFC.2018.2874550>
2. S. Beattie, B. Jian, A. J. Alcock, J. Bernard, M. Gertsvolf, R. Hendricks, F. Ozimek, K. Szymaniec, K. Gibble, "Preliminary evaluation of NRC-FCs2 fountain clock at the National Research Council Canada," 2017 Joint Conference of the European Frequency and Time Forum and IEEE International Frequency Control Symposium, p. 640-641

