NPL Primary Frequency Standards: current status

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The aim of the National Physical Laboratory's system of primary frequency standards (PFS), comprising two caesium fountains, is to perform regular calibrations of the international timescale TAI/UTC at the highest accuracy and to provide a stable reference for the construction and steering of UTC(NPL), the local representation of UTC. The PFS system can also be used for absolute frequency measurements of optical frequency standards under development at NPL. With both fountain standards fully operational, direct local comparisons of PFSs at the parts-in-10^{16} level in fractional frequency accuracy will be possible. The system will also possess the necessary redundancy to provide practically continuous frequency measurement for the local and international timescales.

The first fountain, NPL-CsF2, has been in use since 2009. Subsequent development and accuracy evaluations have enabled its type-B uncertainty to be reduced to 2.0×10^{-16}. Most recently, the frequency shift due to collisions with background gas has been evaluated, demonstrating that this effect contributes no more than 3×10^{-17} to the total error of the standard[1]. To date, 48 calibrations of the TAI step interval duration by NPL-CsF2 have been reported to BIPM. Using several years of data, the long term stability of NPL-CsF2 with respect to other PFSs and the time scale TT can be assessed with confidence. The residual instability is found to be consistent with the declared total type-B uncertainty.

Construction of the second fountain, NPL-CsF3, has recently been completed. The design of NPL-CsF3 is broadly similar to its predecessor: a simple single stage magneto-optical trap (MOT) with cooling beams in the (0,0,1) configuration serves as a cold atom source; an additional optical pumping stage accumulates the atomic population in the $m_F = 0$ clock state. The cold collisional shift is nearly zero owing to the low collision energy resulting from an expansion of the initially small atomic cloud released from the MOT[2]. The major novelty is a new microwave cavity (Ramsey cavity) designed to minimize the distributed cavity phase (DCP) frequency shift[3]. An early assessment of the DCP shift in NPL-CsF3 will be reported at the Forum.

The short-term stability of NPL-CsF2 is currently limited by the phase noise of the local oscillator, based on a room temperature quartz crystal. Looking forward, it is intended that this will be replaced by an optical local oscillator based on the down-conversion of an ultra-stable laser frequency by means of a femtosecond mode-locked laser frequency comb. For NPL-CsF2, it is anticipated that this will yield a three-fold reduction in the short-term noise.

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[3] K. Gibble, S. N. Lea, K. Szymaniec, "A microwave cavity designed to minimize distributed cavity phase errors in a primary cesium frequency standard", Conference on Precision Electromagnetic Measurements (2012) 700–701