Optical Lattice Clocks at NPL

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In the two decades since its inception, the optical lattice clock [1, 2] has been established as a leading platform for optical frequency metrology with multiple examples evaluated at close to 1×10^{-18} total systematic fractional frequency uncertainty [3-5]. Several high-uptime systems, including NPL-Sr1 [6], now regularly contribute to TAI, highlighting the progress of the technology for adoption in critical timing infrastructure and propelling the case for a redefinition of the SI second. Exploiting the low quantum projection noise offered by the many-atom system has relied heavily on a complementary effort to develop ultrastable lasers [7-10], mitigating to an extent the problematic Dick-effect and enabling record single clock instabilities approaching $1 \times 10^{-16}\tau^{-1/2}$ [3, 11, 12]. Through synchronous comparisons of clocks sharing the same local oscillator, relative clock instabilities approaching one order of magnitude below this figure have been observed, both between distinct clocks at NPL and others [12], and across neighbouring ensembles that share a similar environment. This has allowed for measurements of gravity at the mm-scale [13, 14] and highlights the promise of a new realm of precision space-time measurement.

We present our contribution to the state-of-the-art including the evaluation of NPL-Sr1 targeting $< 5 \times 10^{-18}$ total systematic uncertainty, and the systems in place to achieve high-uptime near-autonomous operation and validation for contribution to timescale steering, both locally synthesised and in on-time contributions to the BIPM for determination of TAI. Framed by the goal of improving the precision of the NPL $^{171}Yb^{+}$(E3)/^{87}Sr frequency ratio which offers a favourable sensitivity to variations in the fine structure constant, we will present composite clock schemes similar to ref. [15] to extend local oscillator coherence for reduced Yb^{+} QPN-limited instability. The schemes entail both dynamical decoupling [16] in near zero-deadtime operation of two Sr clocks, where 50% duty cycle [17] cannot be trivially reached, and the exploitation of quantum non-demolition readout schemes for repeated successive measurement of laser phase [18]. Finally, progress of a new Yb optical lattice clock with focus on low measurement deadtime, and fully autonomous operation will be presented.

References

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