Progress on Optical Clock Technology for Operational Timescales

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Dramatic progress on optical atomic clocks and frequency standards in recent years is having a significant impact on metrology and fundamental science. However, fully integrating optical technology into continuous operations for timing applications and timescale generation remains a significant challenge.

The U.S. Naval Observatory (USNO) produces one of the best realizations of Coordinated Universal Time (UTC) using a large ensemble of operational clocks and disseminates this time throughout the world via various methods, including GPS. The best clocks in the ensemble are rubidium fountains that were designed and built in house in order to meet requirements that could not be met with commercial clocks [1]. To prepare for emerging and future needs, efforts to improve the USNO clock ensemble and supporting technology are ongoing, including several avenues to incorporate optical technology.

While a lattice clock with an anticipated role similar to primary standards elsewhere is under development, we are experimenting with using the optical "front end" (telecom-wavelength-based local oscillator (LO)) as a continuously available clock signal; disciplined to a rubidium fountain, this offers an operational clock with optical-oscillator stability in the short term, with quantum-projection-noise-limited fountain performance in the long term. This may also serve as the basis of a future architecture in which the LO is steered by the optical lattice when online, and by a fountain (with white-frequency noise level of order 5×10^{-14}) at all other times.

Optical atomic clocks intended to run continuously are also under development. A system based on optical spectroscopy on a thermal beam of calcium is far less complicated than an optical lattice and is more compatible with 24/7 operation [2, 3]. Ramey-Borde spectroscopy at a resolution of ~3 kHz supports $<10^{-14}$ stability at 1 s, with the long-term stability achievable in a well regulated environment still being investigated. Laser-beam propagation reversal and optical ensembling of clocks are under consideration for optimizing long-term stability, as is slowing the atomic beam; recent demonstration of Ramsey-Borde spectroscopy on slowed calcium is enabling this avenue to be investigated.

References

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