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Phase stability in next-generation atomic frequency standards

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Atomic clocks (or oscillators) form the basis of standard, everyday timekeeping. Separated, hi-accuracy clocks can maintain nanosecond-level autonomous synchronization for many days. The world's best Cs time standards are atomic fountains that use convenient RF quantum transition at 9,192,631,770 Hz and reach total frequency uncertainties of 2.7 – 4×10^{-16} with many days of averaging time. A new class of optical atomic standards with quantum transitions having $\pm1\times10^{-15}$ uncertainty drives an optical frequency-comb divider (OFD), thus providing exceptional phase stability, or ultra-low phase noise (ULPN), at convenient RF frequencies. In terms of time, this means that a 1 ns time difference wouldn't occur in a network of clocks for 15 days. I show how the combination of high atomic accuracy and low-phase noise coupled with reduced size, weight, and power usage pushes certain limits of physics to unlock a new paradigm – creating networks of separated oscillators that maintain extended phase coherence, or a virtual lock, with no means of synchronization whatsoever except at the start. This single property elevates their usage to a vast array of applications that extend far beyond everyday timekeeping. I show how accurate oscillators with low-phase noise dramatically improves: position, navigation, and timing; high-speed communications, private messaging and cryptology, and spectrum sharing. This talk outlines game-changing possibilities in these four areas to the degree that clock properties are sustained in application environments. I will show a summary of several ongoing US programs in which the commercial availability of such low-phase noise, atomic oscillators are now a real possibility.

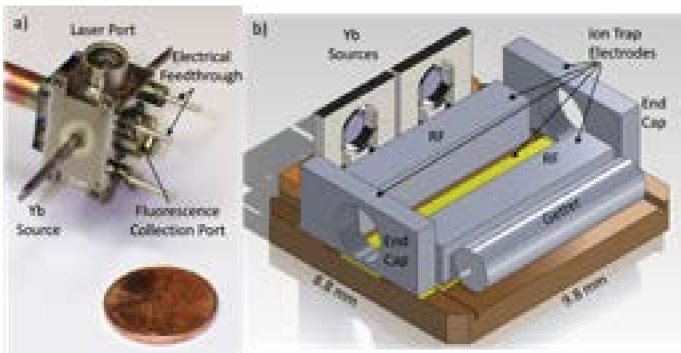

Figure 1. Miniature Trapped ^{171}Yb ion atomic physics package developed by Sandia National Lab, DARPA project - IMPACT.

Recent Publications

1. A Hatia, C W Nelson, and D A Howe (2016) Cross-spectrum measurement of thermal-noise limited oscillators (2016)Review of Scientific Instruments 87:034708.
2. Miniature Trapped-Ion Frequency Standard with 171 Yb+, Proc. 2015 Joint Mtg. IEEE Intl. Freq. Cont. Symp. and EFTF Conf.
3. Optical-to-RF Frequency Synthesis: Application Priorities for Ultra-Low Phase Noise, Frontiers in Optics 2015, 3 p., 2015.
4. Power Splitter Thermal Noise Correlations in Cross-spectrum Noise Measurements, Proc. 2016 IEEE Intl. Freq. Cont. Symp.
5. Attaining 10^{-15} Fractional-frequency Accuracy in Tenths of Seconds, Proc. Time in Space Symposium, National Reconnaissance Office Advanced Science and Technology, Chantilly, VA, Apr 10 – 12, 2017.

Biography

D A Howe is a Research Advisor to the Time and Frequency Division of the National Institute of Standards and Technology (NIST) and Colorado University Physics Department, Boulder, CO. His expertise includes time-series analysis, automated accuracy evaluation of primary cesium standards, reduction of oscillator acceleration sensitivity, and precision spectral analysis. He worked with David Wineland from 1973 to 1987 doing advanced research on NIST's primary cesium standard and compact hydrogen and ammonia standards. He developed and built the first operating compact hydrogen masers in 1979, led and implemented global high-accuracy satellite-based time-synchronization among national laboratories in the maintenance of Universal Coordinated Time (UTC).

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