Optical Atomic Clocks

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An optical clock consists, like any other clock, of an oscillator that defines the ticks in time and a counter that is book keeping of these periods. For a long time a quartz oscillator locked to the ground state hyperfine splitting of cesium has been used for that purpose together with an electronic counter. Clocks as different as sun dials, pendulum clocks and quartz clocks have in common that their potential accuracy increases with more rapid oscillations that slices time into finer intervals.

Tremendous advances in laser spectroscopy in the 1970's ultimately resulted in trapped atom and ion standards in the 1980's. When it became possible to count these optical oscillations with harmonic frequency chains in the early 1970ies, optical transitions have been considered for running optical atomic clocks. However, working with these counters was so tedious that most of the frequency chains never reached the stage where they could operate continuously even for minutes.

With the femtosecond frequency combs reliable optical counters have been realized that can now be operated continuously for months. With this the prototypes of the optical clocks can operate long enough to calibrate against cesium fountain clocks with an accuracy that is limited by the latter. Optical clocks may not only prove to be useful for industrial applications such as satellite communication and network synchronization, but could certainly play an important role in basic research. The quest or setting limits for slow variations of fundamental constants and testing relativity are examples.

In addition frequency combs may be directly used for spectroscopy by employing their narrow band individual modes. Even though single mode lasers are better suited for this purpose, frequency combs can be converted to much shorter wavelengths by the process of high harmonic generation. This might allow to access the extreme ultraviolet region which is so far unexplored with high resolution spectroscopy. Since hydrogen like ions have their sharp transitions lines in this region, fundamental research can benefit from such a development. Eventually it might even become possible to construct an X-ray atomic clock.