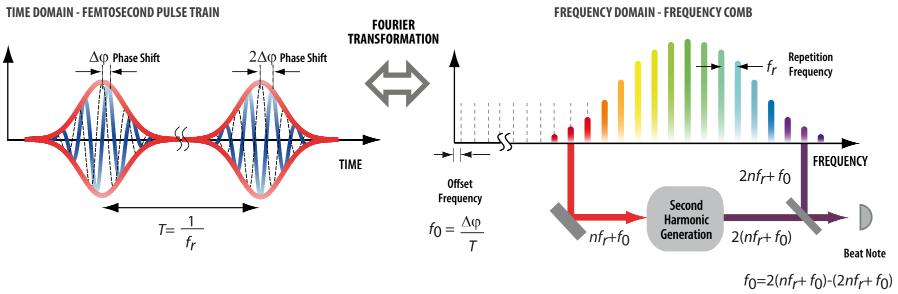
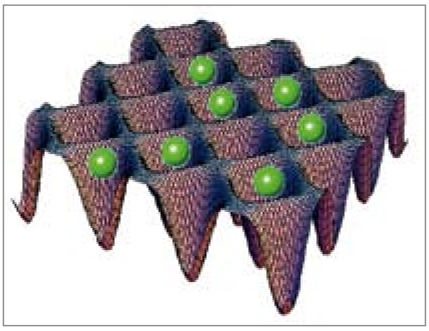
OPTICAL FREQUENCY COMBS





Spatial interference pattern of lasers can produce periodic trapping potentials for ultracold neutral atoms, called an optical lattice.

Image credit: Hidetoshi Katori/University of Tokyo

PRECISION MEASUREMENT AT THE HIGHEST LEVEL

The control of the broadband frequency comb emitted from a mode-locked femtosecond laser has permitted a wide range of scientific and technological advances – ranging from the counting of optical cycles in high-accuracy optical clocks to measurements of phase-sensitive high-field processes. A unique advantage of the stabilized frequency comb is that it provides, in a single laser beam, about hundreds of thousand optical modes with very narrow linewidths and very well-known absolute frequency positions.

Frequency combs are simple and compact systems that phase coherently connect the radio frequency domain (below 100 GHz) with the optical domain (above 140 THz). They greatly simplified high precision optical frequency measurements and provide the long awaited clockwork mechanism for an all-optical atomic clock.

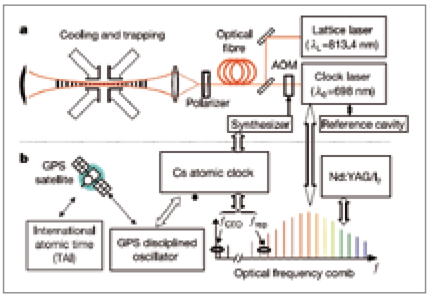
OPTICAL CLOCKS

The second is currently defined as the time taken to complete 9,192,631,770 oscillations between two energy levels in a cesium atom. The current generation of cesium clocks has an accuracy of 10^{-16} – equivalent to an error of less than one second in 30 million years. Scientists are looking for ways to create an even more accurate clock. One way of doing this is to increase the rate at which the clock ticks. This can be realized if optical transitions were used to measure time rather than microwave transitions in cesium. The main challenge when building an optical clock is to relate these optical frequencies to the much lower microwave frequencies that are used to define the second. Frequency combs are the indispensable tool providing the gear for this conversion.

The optical lattice clock proposed by Hidetoshi Katori from the University of Tokyo locates the atoms at lattice sites, thus minimizing mutual interaction without limiting the signal-to-noise ratio (in *Nature Vol. 435: 321-324, 2008*).

Other approaches focus on the enhancement of the detection scheme for single particle signals. Today, optical clocks reach accuracy beyond the 10^{-17} level and currently no limit is foreseen for what can be reached. Harald Schnatz, working on the frequency measurement of optical clocks based on a single Yb+ ion in a Paul trap or Sr atoms confined in an optical lattice at Physikalisch-Technische Bundesanstalt in Braunschweig, believes that "the time is ripe to prepare for secondary realizations of the second, which, later, could possibly lead to a new definition of the second."

State-of-the-art metrology system, the FC1500-250-WG Optical Frequency Synthesizer – seeded with the 250-MHz M-Comb Erbium-doped fiber oscillator.



Experimental configuration for the Sr lattice clock.
Image credit: Hidetoshi Katori/University of Tokyo

Klaus Hartinger from Menlo Systems in the Laboratory of Photonics and Quantum Measurements at the Swiss Federal Institute of Technology (EPFL) in Lausanne, Switzerland, working with an FC1500-250-WG Optical Frequency Synthesizer.

FIBER LASERS AT THE HEART OF THE MOST PRECISE CLOCKS

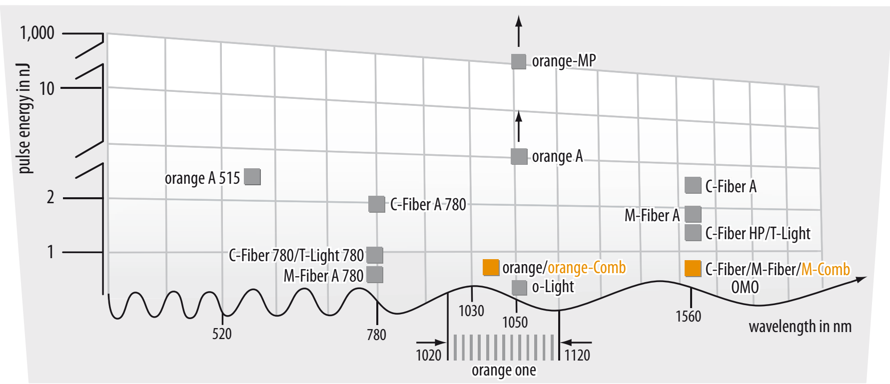
The accuracy of the frequency combs has reached a level that does not limit the overall accuracy of the optical clock when they are employed as an optical clockwork. Our laser systems have been engineered for the demanding metrology applications and have the following features:

- low phase noise Erbium- and Ytterbium-doped fiber oscillators
- high repetition rate of 250 MHz for wide spacing between the individual comb lines
- large tuning range of the cavity length and of the carrier envelope offset frequency for long-term stable operation
- electro-optic intracavity modulator – integrated in the oscillator for high-performance phase locking to an optical reference
- all-fiber-coupled f:2f interferometer for the offset frequency detection ensuring adjustment free and robust operation
- seeding up to five additional amplifiers for multiple measurement ports at user-defined frequencies and spectral ranges

The latest generation of our Erbium FC1500-250-WG and the recently released Ytterbium FC1000-250 Optical Frequency Synthesizer find applications in the following fields:

- high resolution spectroscopy
- optical clocks
- dimensional metrology
- low-noise microwave synthesis
- transfer of ultrastable timing signals and frequency standards

MENLO SYSTEMS' LASER SELECTOR



ORDERING INFORMATION

FC1500-250-WG
Erbium-based Optical Frequency Synthesizer

FC1000-250
Ytterbium-based Optical Frequency Synthesizer

FC8004
Ti:Sa-based Optical Frequency Synthesizer